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Development of risk-based trading farm scoring system to assist with the control of bovine tuberculosis in cattle in England and Wales

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ABSTRACT

Identifying and ranking cattle herds with a higher risk of being or becoming infected on known risk factors can help target farm biosecurity, surveillance schemes and reduce spread through animal trading. This paper describes a quantitative approach to develop risk scores, based on the probability of infection in a herd with bovine tuberculosis (bTB), to be used in a risk-based trading (RBT) scheme in England and Wales. To produce a practical scoring system the risk factors included need to be simple and quick to understand, sufficiently informative and derived from centralised national databases to enable verification and assess compliance. A logistic regression identified herd history of bTB, local bTB prevalence, herd size and movements of animals onto farms in batches from high risk areas as being significantly associated with the probability of bTB infection on farm. Risk factors were assigned points using the estimated odds ratios to weight them. The farm risk score was defined as the sum of these individual points yielding a range from 1 to 5 and was calculated for each cattle farm that was trading animals in England and Wales at the start of a year. Within 12 months, of those farms tested, 30.3% of score 5 farms had a breakdown (sensitivity). Of farms scoring 1–4 only 5.4% incurred a breakdown (1-specificity). The use of this risk scoring system within RBT has the potential to reduce infected cattle movements; however, there are cost implications in ensuring that the information underpinning any system is accurate and up to date.

1. Introduction

Bovine tuberculosis (bTB) is an infectious disease of cattle caused by the bacterium *Mycobacterium bovis* (*M. bovis*). The disease has proved expensive and difficult to eradicate in livestock once the disease has been introduced into a new area. This is due to long incubation periods, moderate sensitivity of diagnostic tests, presence of spatially dependent disease transmission factors including infected wildlife reservoirs in certain areas, and the further complication of undetected infected cattle being traded between farms. One method of targeting resources in animal health eradication programmes is to apply risk-based concepts which may include risk-based surveillance or risk-based trading (RBT) with the categorisation or risk scoring of farms most likely to be affected.

Risk-based surveillance enables higher efficiency (benefit-cost) than traditional systems from the application of exposure and risk assessment methods (Stärk et al., 2006). Risk-based surveillance systems for bTB have been developed for Minnesota US, Scotland and Ireland using a variety of methods to target herds according to risk, taking into account the most likely transmission pathways present in those territories (Ribeiro-Lima et al., 2015; Bessell et al., 2013; Wolfe et al., 2010). There is normally a small group or individual risk manager, in industry or government, who is responsible for the implementation of surveillance schemes and identifying those premises or animals to be tested. The level of resources and training of the risk manager may permit development of complex methodologies and ranking systems, using a broad range of risk factors including spatial factors (climate and population density), host factors, and management factors (biosecurity and risk practices) (Oidtmann et al., 2013). With unrestricted risk-based trading schemes there may be as many risk managers as there are batches of cattle being sold, where a rapid view of the information, consideration and subsequent decision needs to be made by cattle

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purchasers. Due to these requirements such schemes need to be (1) practical: risk categories need to be presented in a simple, standardised and unambiguous way enabling rapid identification of different risk levels, (2) transparent: farmers need to be able to understand how risk scores are estimated and be able to gain sufficient information from those scores to make an informed choice at purchase, and (3) based on accurate and available data: in order for any scheme to work the information used must be robust, with categories and the relative rankings reflecting the risk that animals originating from that herd are infected (Defra, 2013; Kennedy, 2003).

Approaches taken to ranking herds may be based on subjective judgement or more quantitative methods including risk factor analysis, based on within-herd prevalence, or other risk assessment activities. There are significant variations in national approaches that have been applied to classify herds within current animal health RBT schemes, even within programmes focused on the control of the same disease. For example, there are multiple herd scoring systems for Johne's disease (*Mycobacterium avium* subspecies *paratuberculosis*) including prevalence based systems, categorisations derived from quantitative risk assessment, and expert judgement classifications (Geraghty et al., 2014). For bTB several eradication programmes have implemented RBT schemes based on the number of years that a herd tests clear of disease. The Australian scheme coupled this herd classification with a ban on the movement of cattle from high risk farms/zones to low risk farms/zones, where zones were classified by a maximum permissible between herd prevalence (Cousins, 2001). In New Zealand, trade can occur between farms of differing bTB risk; however, the farm status is based on the lowest of all animals in the herd, deterring the purchase of lower status cattle.

The aim of this research was to develop a quantitative approach for England and Wales to classify cattle herds on the probability of being infected with bovine tuberculosis (bTB), which could be used within a risk-based trading scheme. A final aim to estimate the impact of selected scoring systems on infected movements is presented in the accompanying paper.

2. Material and methods

There were five key stages in developing the risk-based trading scoring system:

(1) Estimation of the probability of bTB infection for each farm in England and Wales.
(2) Identification and inclusion of risk factors (that could be practically applied in a scoring system) significantly associated with the probability of bTB infection using a generalised linear model.
(3) Selection of a method to present the risk scoring system.
(4) Calculation of the points contributing to the risk score using the mean odds ratios; and,
(5) Assessment of the performance of the scoring system in the sensitivity analysis.

The results of the sensitivity analysis were then used to optimise the selection of risk factors to be retained in a risk scoring system.

2.1. Study population and data sources

The study population was active cattle herds in England and Wales recorded on cattle surveillance databases (SAM RADAR bTB reception database (SAM)) between July 2009 and June 2010, which amounted to 60,233 herds. Surveillance data for each herd was downloaded on the 1st April 2013 of all bTB tests undertaken between July 2005 and June 2010. The single intradermal comparative cervical tuberculin test (SICCT) is used for all routine surveillance. The test frequency varies with annual herd testing in high incidence areas in England and throughout Wales and quaternal in low incidence areas of England. Data extracted from external data sources included cattle movements to slaughter and movements on/off herd by year by County Parish Holding (CPH) identifier from Cattle Tracing System (CTS) (BCMS, 2013). Herds were not separated at holding level due to limitations in extracting movement data to that strata.

2.2. Estimated probability of bTB infection per herd, P(Inf)

The estimated probability of bTB infection per farm in England and Wales was generated by modifying a freedom from infection (FFI) model (AHVLA, 2011). This Bayesian model was previously developed to estimate the probability that a given herd was free of infection given its test and disease history and the probability of introduction of infection (Martin et al., 2007; Cameron and Baldock, 1998a,b). This model framework has been adapted and described in full for estimating the probability of cattle herd bTB incidents using Scottish bTB surveillance data (Bessell et al., 2012). The underlying premise of the model is that the probability of infection on farm can be estimated based on the farms testing history and on the probability of introduction since that time. The model inputs required are herd size, the frequency and number of animals in the herd historically tested together with test results, animal-level sensitivity of the diagnostic test performance (Downs et al., 2011), an initial prior infection status of farm and the probability of introduction of bTB infection into herd during each time period. The probability that a herd is infected with bTB at time t, $P(\text{Inf})$, was estimated using this approach which is presented with the relevant formula in Supplementary materials. Several modifications using English and Welsh surveillance were made and are detailed as follows.

The probability of bTB infection in herd at the starting time point (time = 0) for each farm was estimated by the bTB incidence rate at that time point. The probability of introduction of bTB infection into the herd during each subsequent time period was based on observed bTB incidence rate updated annually from June 2005.

The bTB incidence rate was defined as the rate of new herd bTB incidents in the period of interest relative to the sum of the time the herds (time at risk or TAR) were at risk of infection (and officially tuberculosis free). New herd bTB incidents may occur as a result of herd tests (tests conducted on the majority of animals in the herd) and individual animal tests during the time period of interest. The TAR is the sum of time the herd was at risk of infection from the last negative herd test up to the most recent negative herd test in the period of interest. It excludes periods of time the herd was restricted as result of a bTB incident (see Appendix to Downs et al., 2013). The background incidence rate calculated for this study was each herd was the overall incidence rate for the 200 herds that were geographically closest.

When an infection was detected in a herd due to a positive bTB test either during field surveillance, or through post-mortem inspection in the abattoir, the probability of freedom from infection, 1-$P(\text{Inf})$, was reduced to zero. At this point, the farm was subject to cattle movement restrictions until the confirmed cases were removed and at least one (although usually two) successive short interval skin tests were undertaken with negative test results. During this entire period the probability that the herd was free from infection remained at zero to indicate the herd remained infected. When movement restrictions were lifted, the probability that the herd was free from infection was reset to the original prior but limited to a maximum value of 62% for the following 24 months using evidence for the probability of bTB recurrence of infection (Karolemeas et al., 2011).