Preventive Veterinary Medicine xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Preventive Veterinary Medicine

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

Assessing the impact of a cattle risk-based trading scheme on the movement of bovine tuberculosis infected animals in England and Wales

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ARTICLE INFO

Article history:
Received 6 March 2015
Received in revised form
18 November 2015
Accepted 30 November 2015

Keywords:
Risk factors
Risk-based trading
Bovine tuberculosis
Risk scores

ABSTRACT

The adoption of bovine tuberculosis (bTB) risk-based trading (RBT) schemes has the potential to reduce the risk of bTB spread. However, any scheme will have cost implications that need to be balanced against its likely success in reducing bTB. This paper describes the first stochastic quantitative model assessing the impact of the implementation of a cattle risk-based trading scheme to inform policy makers and contribute to cost–benefit analyses. A risk assessment for England and Wales was developed to estimate the number of infected cattle traded using historic movement data recorded between July 2010 and June 2011. Three scenarios were implemented: cattle traded with no RBT scheme in place, voluntary provision of the score and a compulsory, statutory scheme applying a bTB risk score to each farm. For each scenario, changes in trade were estimated due to provision of the risk score to potential purchasers. An estimated mean of 3981 bTB infected animals were sold to purchasers with no RBT scheme in place in one year, with 90% confidence the true value was between 2775 and 5288. This result is dependent on the estimated between herd prevalence used in the risk assessment which is uncertain. With the voluntary provision of the risk score by farmers, on average, 17% of movements was affected (purchaser did not wish to buy once the risk score was available), with a reduction of 23% in infected animals being purchased initially. The compulsory provision of the risk score in a statutory scheme resulted in an estimated mean change to 26% of movements, with a reduction of 37% in infected animals being purchased initially, increasing to a 53% reduction in infected movements from higher risk sellers (score 4 and 5). The estimated mean reduction in infected animals being purchased could be improved to 45% given a 10% reduction in risky purchase behaviour by farmers which may be achieved through education programmes, or to an estimated mean of 49% if a rule was implemented preventing farmers from the purchase of animals of higher risk than their own herd.

Given voluntary trials currently taking place of a trading scheme, recommendations for future work include the monitoring of initial uptake and changes in the purchase patterns of farmers. Such data could be used to update the risk assessment to reduce uncertainty associated with model estimates.

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1. Introduction

Bovine tuberculosis (bTB) is an infectious disease of cattle caused by the bacterium *Mycobacterium bovis* and is one of the biggest challenges facing the cattle farming industry in England and Wales. The cost of controlling bTB is the largest single component of animal health related expenditure in these countries paid by the tax payer, amounting to nearly €100 million in 2014 (Defra, 2014). The adoption of risk-based trading (RBT) has the potential to aid the management of livestock diseases by providing those participating within schemes more accurate information when purchasing animals (Defra, 2013). However, the performance of such schemes in reducing the movement of infected cattle between farms is dependent on how well schemes are implemented and the specific rules established to permit or prevent trade. Risk scores can be implemented within assurance schemes or certification standards that are managed by industry organisations with a voluntary

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http://dx.doi.org/10.1016/j.prevetmed.2015.11.021
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Please cite this article in press as: Adkin, A., et al., Assessing the impact of a cattle risk-based trading scheme on the movement of bovine tuberculosis infected animals in England and Wales. PREVET (2015), http://dx.doi.org/10.1016/j.prevetmed.2015.11.021

Table 1
Baseline risk score, with 1 denoting the lowest risk for farms and a maximum score of 5 for the highest risk.

	Risk score
Initial value for all farms	+1
+Risk factor	
Years since bTB breakdown (0–2 years)	+3
Years since bTB breakdown (3–5 years)	+2
Years since bTB breakdown (6–10 years)	+1
Cattle movements from high risk areas in last 5 years	+1

disclosure of the score, or assisted by government with statutory controls whereby disclosure is compulsory in order for the legal sale of cattle. Scheme rules can dictate whether or not certain batches are permitted to move between herds or zones of different risk scores, and whether a herd score is affected by the purchase of animals of a lower risk status.

Discussions were facilitated with representatives from the farming community (farmers, auctioneers, private veterinarians, government officials involved in monitoring facilities, and farmer association representatives) at seven meetings during 2012–2013 in England and Wales to evaluate how informed cattle trading may vary within different schemes that could be adopted. Understanding the basis of the decisions made by farmers is crucial to the success of any functioning RBT scheme.

In order to parameterise the model, estimates on the expected level of RBT scheme participation by farmers with the voluntary provision of the risk score was discussed with stakeholders, alongside compliance levels that may be achieved within a statutory scheme based on the compulsory provision of the risk score prior to purchase. From 25 interested stakeholders (farmers, valuers, and representatives from non-government organisations) when asked whether cattle farmers would prefer a voluntary or statutory RBT scheme, 76% (19/25) expressed a preference for a voluntary provision of the risk score, with all Welsh respondents opting for an initial voluntary scheme. However, concerns were frequently raised that without a statutory scheme the system may not be effectively carried out and that there may be differences in its application in different regions. It was felt that for farmers in clean areas, or those that have not experienced a recent breakdown that a statutory system may be favoured. However, for those farms that had experienced a recent breakdown, several stakeholders expressed the view that such farmers would not want to participate in any scheme that reduced the price of their animals or where they had to declare their bTB status. The engagement of farmers in RBT schemes by geographic location, and the purchasing choices given different schemes, were explored and quantitative estimates gained through a follow up questionnaire.

The aim of this research was to estimate the impact of farmers using risk scores to make more informed choices when buying cattle. The reduction in movements of infected cattle between farms over one year in England and Wales was estimated under three key scenarios: (1) cattle traded with no RBT scheme, (2) voluntary provision of the risk score, and (3) compulsory provision of the risk score in a statutory RBT scheme. Additionally, the impact of changes in calculating the risk score was evaluated together with an investigating into areas of significant uncertainty in input parameters.

2. Methods

A stochastic model implemented in Excel with the add on @Risk (version 6.1) was used to estimate the number of infected movements under each of the three scenarios. The final risk score developed using a method described in the accompanying paper, that could be practically applied, is presented in Table 1.

In this risk assessment each iteration in the model represents a random year with convergence to 4% of the mean value of each output parameter achieved with 5000 iterations using Latin Hypercube sampling. Each individual trading farm was included in the model and separately simulated for the probability of being infected (between herd infection), and if infected, the within herd prevalence was sampled for that herd size. All historical trading events in England and Wales recorded on the Cattle Tracing System (CTS) have been used (July 2010–June 2011) to estimate the number of total movements and infected movements in one year with no RBT scheme in place. Movements to slaughter have not been included as such movements would not spread infection to new herds. It is assumed that all remaining movements involve a trade between a selling farm and a purchasing farm. The risk assessment uses distributions for certain parameters to describe any known uncertainty or variability associated with input parameters. Where uncertainty could not be quantified within a distribution, separate scenario simulations were carried out to investigate the impact on model results of the level of participation by farmers, bTB between herd prevalence and purchase behaviour by farmers as detailed in the sensitivity analysis.

2.1. Estimating the number of infected movements per year

The number of infected movements per year is dependent on (1) the probability each farm which is selling cattle is bTB infected but the infection is undetected (farm either not under restriction or with specific movement license), (2) the within herd infection prevalence on that farm, (3) the proportion of animals moved from that farm in batches to other farms, and (4) the sensitivity of the pre-movement test where applied. The risk pathway for the movement of infected animals off farm is provided in Fig. 1. Numerous parameter values were extracted from the National database SAM RADAR bTB reception database, herein referred to as SAM.

2.1.1. Probability farm infected with bTB, P_{inf}

For each farm in the dataset the probability of the herd being bTB infected, P_{inf} was estimated using a modified freedom from infection (FFI) model (AHVLA, 2011). This model has been previously developed to estimate the probability that a given herd was free of infection given its test and disease history, $P(\text{free})$ (Martin et al., 2007) and is described in the accompanying paper. There is considerable uncertainty associated with the probability of a herd being infected with bTB which is investigated in the sensitivity analysis. For each iteration, each selling farm is either infected or not, modelled as a Bernoulli random variable, based on the probability of infection per year estimated for that farm.

$$P_{\text{inf}} \sim \text{Binomial}\,(1, 1 - P(\text{free}))$$

2.1.2. Number of animals infected, N_{Inf}

The number of infected animals in a herd is dependent on the within herd bTB prevalence and the number of animals within that herd. From a review of the literature, the within herd bTB prevalence applicable to undetected infected herds of varying herd size in England and Wales was not available. To calculate, we first estimated the annual number of infected animals in herds, Inf_{year}, where routine whole herd testing had been carried out in 2011. Where disease is not suspected, whole herd tests are conducted with the single intradermal comparative cervical tuberculin test (SICCT) test. Given the mean sensitivity of the SICCT test, Se_{mean}, together with the total number of test positive reactors identified in whole herd tests S_{year} (SAM) in England and Wales, the negative

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