The risk of badger to cattle transmission of *Mycobacterium bovis*: the effect of control strategies and the identification of crucial gaps in our knowledge.

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Summary

A Quantitative Risk Assessment (QRA) model which estimates the risk of badger to cattle transmission of *Mycobacterium bovis* (*M.bovis*) via badger urine was developed. Using the model, crucial areas of data deficiency in our understanding of this transmission were identified and the effects of uncertainty on the estimates of risk were investigated. In particular, the quantity of *M. bovis* excreted and the dose-response relationship were found to be important .

Various transmission control strategies were also investigated to determine their effect on the risk estimates. It was found that, restricting cattle access to badger latrines and reducing badger prevalence leads to a reduction in the number of cattle infected per year.

Introduction

In 1997, as part of an independent government commissioned review, “Tuberculosis in cattle and badgers” (Krebs, 1997), recommendations to focus on investigating the badger to cattle transmission hypothesis were made. In response to these recommendations, a QRA model has been developed in order to estimate the risk of transmission of *M.bovis* from badgers to cattle.

Objectives

The primary objective was to identify crucial areas of data deficiency in our understanding of badger to cattle transmission of *M.bovis*. A second objective was to estimate the risk of transmission and its associated uncertainty. The final objective was to determine the effects of control strategies on the risk of transmission.

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Materials and Methods

Transmission of bovine TB from badger urine to cattle requires three sequential events: badgers present in the area must be infected and capable of excreting *M. bovis* in their urine, cattle present in the area must be exposed to *M. bovis* excreted by badgers and at least one cow in the herd must become infected following exposure.

To describe these events, a lattice simulation model was developed. The model describes a simplified field, spatially represented by two linked co-planar lattices. The first lattice is defined as a “grazing lattice” and represents an area that the cattle herd will graze. The first lattice represents a grazing area, the size of which represents the average field size in the south west of England and the number of “meals” consumed by a dairy cow per day. The average field size is estimated as 39 hectares and the number of meals per cow per day is taken to be 5 meals each resulting in the consumption of 79.2m^2 of area grazed field per meal per cow. Each cell within the lattice represents one cow meal. The second lattice is defined as a badger "latrine lattice". It is assumed that cattle will not graze in the badger latrine but may make investigatory contact with the latrine area (Hutchings and Harris, 1999). The latrine lattice consists of 5,184 cells each representing the area of latrine contacted during a investigation (0.016m^2). The lattices are joined to represent a field boundary.

The model was run in 24-hour time steps, over a period of 1 year. It was assumed that there are 2 infected badgers capable of excretion present on the field (b=2). During each time step, the infected badgers enter the field and excrete *M. bovis* in their urine with a probability of 0.5 on any given day, thus simulating the intermittent nature of *M.bovis* excretion. If excretion occurs, 1.25 mls of urine containing 1000 *M.bovis*/ml are excreted (=u). These parameter estimates were obtained by expert opinion. The number of urination events per badger per time step is varied depending on the season to represent the differences in badger urinary behaviour that have been observed (Brown, 1993). It was assumed that urination is equally likely to occur on either the latrine lattice or the grazing lattice with equal probability . Once a given lattice is selected, the location of the excretion is assumed to be equally likely to occur on any cell.

Following excretion, the population of *M. bovis* is assumed to decline as a result of environmental factors. This decline is described by an exponential decay the parameter of which (s) is derived from published data (Gallagher, 1998). Therefore, the number of *M.bovis* on cell (i,j) of the lattice at the end of day t is given by

$$x_{ij}(t) = [x_{ij}(t-1) + \alpha_{ij}(t)]e^{-s} \qquad i, j = 1..n$$

Where α_{ij} = number of *M.bovis* excreted onto cell ij and s = 1.0027.

A herd of 74 cattle (h=74) is assumed graze the field lattice and investigate the latrine lattice. Latrine lattice investigation is assumed to occur with a probability of p=0.3 during each meal the cow consumes. When cattle graze, it is assumed that they are exposed to a proportion of organisms on the cell and they may or may not become infected according to a dose-response relationship, the parameter of which (r) is derived from unpublished data (Vordermeier pers com, 2002). The probability of infection (P_{inf}) is given by:

$$P_{\text{inf}} = 1 - e^{-rx_{ij}(t)}$$

Where r= 0.0002

To represent the randomness associated with events such as excretion of *M. bovis*, movement of animals around the field and infection following exposure, the model is stochastic Coding of the model was undertaken using Visual Basic for Applications (© Microsoft Corp.) and for each run of the model, 2,000 iterations were performed in @RISK (Palisade Corp.).

For 3 model parameters there was very limited quantitative data: the number of organisms excreted and the parameters of the survival and dose-response models. To investigate the effects of this uncertainty, these parameters were individually lowered and increased from their "baseline" values and the model rerun, with all

other parameters held at their baseline values. The particular values for which results were obtained are; number of *M. bovis*/ml of urine: *u*=100 and *u*=300,000 (*u*=1,000 in baseline model), the parameter of survival model: *s*=0.9 and *s*=1.1 (*s*=1.0027 in baseline model) and the parameter of dose-response model: *r*=0.00002 and *r*=0.002 (*r*=0.0002 in baseline model)

The model was also used to investigate three methods of control: reducing the number of infected and excreting badgers (from *b*=2 to *b*=1), reducing the herd size (from *h*=74 to *h*=60) and restricting cattle access to latrines (from *p*=0.3 to *p*=0).

Results

Table 1: Probability distributions for the number of cattle infected via urine: the effect of uncertainty on model predictions

Scenario	**5th %tile**	**50th %tile**	**95th %tile**
Baseline (*u*=1,000, *s*=1.0027, *r*=0.0002)	1	2	5
Number of *M. bovis* per ml/urine reduced (*u*=100)	1	1	2
Number of *M. bovis* per ml/urine increased (*u*=300,000)	3	7	12
M. bovis more likely to survive (*s*=0.9)	1	2	5
M. bovis less likely to survive (*s*=1.1)	1	2	4
M. bovis less infectious (*r*=0.00002)	1	1	2
M. bovis more infectious (*r*=0.002)	1	4	8

Table 2: Probability distributions for the number of cattle infected via urine: comparison of the baseline model with three control methods

Control option (parameter)	**5th Percentile**	**50th Percentile**	**95th Percentile**
Baseline (*h*=60, *b*=2, *p*=0.3)	1	2	5
Herd size reduced (*h*=60)	1	2	4
Badger prevalence reduced (*b*=1)	1	1	3
Access to latrine limited (*p*=0)	1	1	3

Discussion

The baseline model predictions rely on a number of assumptions and have a fairly large associated uncertainty. However, cattle testing data from Great Britain between 1969 - 2002 indicate that the mean number of cattle infected per herd breakdown is 3.4 (Mitchell, pers. comm., 2002) and although this data includes other modes of cattle infection, for example, cattle to cattle transmission and direct contact between badgers and cattle, it does suggests that the model estimates are plausible.

Several parameters were identified as lacking in data and three were selected to investigate the effects of this uncertainty. The quantity of *M. bovis* excreted and the dose-response parameter (*s*) had a substantial effect on model predictions, whereas for the range considered in the analysis, the *M.bovis* survival parameter (*r*) had a very limited effect.

The control options investigated here indicate that the restriction of cattle access to badger latrines and reducing the number of excreting badgers present both demonstrate a reduction in the number of cattle infected. However, reducing cattle density appears to have a very limited effect on the number of cattle infected.

References

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