Modelling the spread of bluetongue virus in Great Britain

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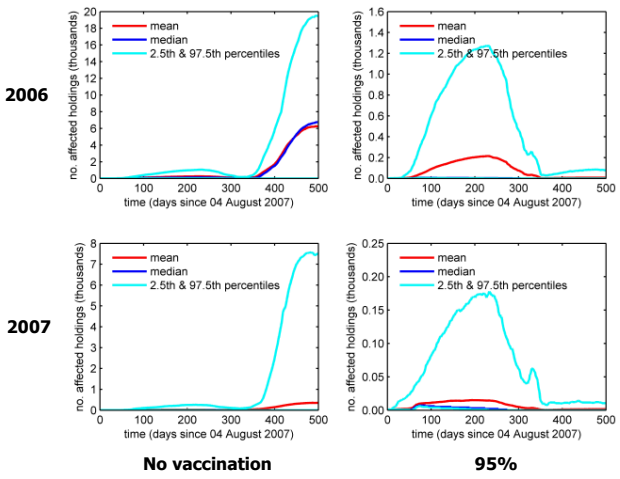
Introduction

- Since its arrival in northern Europe in summer 2006, bluetongue virus serotype 8 (BTV-8) has caused thousands of livestock deaths and spread across much of the continent
- BTV-8 arrived in Great Britain in August 2007 and by the end of the year, it had spread to 125 holdings in southern and eastern England
- A voluntary vaccination scheme was launched in England and Wales in May 2008 to control the spread of the virus
- In contrast with other European countries, no cases of bluetongue (BT) were reported in GB during 2008
- Using mathematical models, we explored why this may have been the case and investigated the key factors influencing the apparent success of vaccination in order to assess the risk of future outbreaks

Results 1: Time course of the epidemics



The model

- We developed a stochastic, spatially-explicit farm-level model, with a daily time step based on the following probability for a susceptible farm to acquire infection:

$$\psi_j(t) = p_j^{(A)}\left[1 - \prod_{k \in I(t-1)} \left(1 - p_k^{(T)}\kappa(x_{jk})\right)\right],$$

and

$$\log\left(\frac{p_j^{(i)}}{1-p_j^{(i)}}\right) = \gamma_0^{(i)} + \sum_k \gamma_k^{(i)} D_{kj},$$

- Transmission between farms was described by a Gaussian transmission kernel

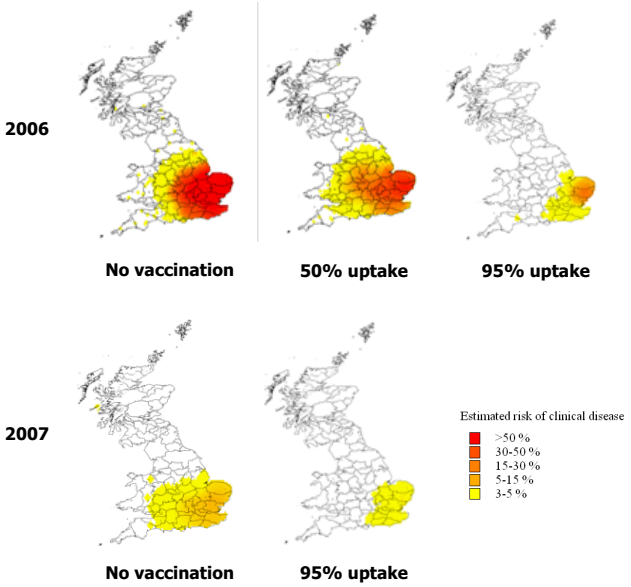
$$\kappa(x) = \frac{\alpha}{\sqrt{\pi}}\exp\left(-\alpha^2 x^2\right), \qquad \text{with } \alpha = 0.034$$

- The probabilities of acquisition and transmission ($p_j^{(Z)}$) and the kernel parameter (α) were estimated from the 2006-outbreak dataset from Northern Europe
- Once a farm acquired infection, the within-farm dynamics (Gubbins et al 2008) were simulated based on the number of cattle and sheep on the farm and local temperatures for either 2006 (a warmer year) or 2007 (a cooler year)

Simulation assumptions

- The model was initialised with a single infected farm on the 4th of August 2007, with six further long range transmission events
- Vaccination was assumed to reduce the probability of transmission between vectors and hosts, with 100% efficiency
- Vaccine uptake gave the probability that a farmer in a county decides to vaccinate his or her stock
- Vaccination was implemented from May 2008 (day 250) following the Defra roll-out plan, which progressively extended the protection zone (i.e. where vaccine could be used)

Results 2: Spatial Spread



Conclusions

- Temperatures significantly affect the probability that an outbreak will take off
- The size of the outbreaks which do take off is significantly reduced by a high level (>70%) of vaccine coverage
- The absence of reported cases in Great Britain during 2008 can be attributed to high levels of vaccine coverage coupled with cooler temperatures
- Low-levels of vaccine uptake combined with warmer temperatures could lead to recrudescence of outbreaks in 2009
- Introduction of new serotypes, which are spreading on the near continent, could constitute a very serious threat

Reference
Gubbins et al. (2008). "Assessing the risk of bluetongue to UK livestock: uncertainty and sensitivity analyses of a temperature-dependent model for the basic reproduction number". J. R. Soc. Interface **5**, 363-71

Acknowledgements
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