Evaluating selective culling with vaccination to control wildlife disease: badgers and bovine tuberculosis (bTB)

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Abstract

Emerging infectious diseases often originate in wildlife, but the complex dynamics of wild animal populations mean that disease control is a major scientific and policy challenge. Culling and vaccination can be effective but the ecological characteristics of wild animals may confound the outcomes of simple management programs. In Britain, badgers *Meles meles* are a recognized reservoir of *Mycobacterium bovis*, the causative agent of bovine tuberculosis (bTB), and are involved in its transmission to cattle. Experiments have shown that culling badgers can increase bTB incidence in badgers and cattle, by perturbing the social structure of badger populations, and increasing contact rates. Selectively removal of infected badgers and vaccination of the remainder has recently been advocated as a potential solution. Simulation modelling suggests that this intuitively appealing policy could at best deliver only a minor advantage over thoroughly applying either vaccination or culling, but carries a risk of making the disease problem much worse. We suggest this counterintuitive outcome arises because: 1, not all animals can be caught and tested 2, some genuinely infected animals will be test negative 3, selective culling leaves a larger population of susceptible hosts than non-selective culling 4, some susceptible hosts will not respond to vaccination and 5, perturbation increases contact and transmission rates among a relatively high density population of infectious and susceptible animals.

Keywords: cattle, combined control strategies, *Mycobacterium bovis*, perturbation, spatial model

Introduction

The selective culling of infected wild animals has been proposed as a more acceptable alternative to large-scale culling, and when combined with vaccination of the non-infected susceptible individuals, can be seen as a viable strategy for disease management. Here, we examine the case for selective culling of badgers to reduce bTB, by using an established simulation model, and taking account of the possible role of social perturbation that can occur with group living animals. Social perturbation, as a result of culling, in the badger has been responsible for negative consequences for bTB in cattle (Donnelly et al., 2003; 2006).

Materials and methods

A spatially explicit, stochastic mechanistic simulation model of bTB dynamics in badgers and cattle was utilized. This comprises a farm landscape, with cattle herds subject to normal cattle management practices (movement, slaughter, skin testing and pre-movement testing) overlaid onto a badger population consisting of contiguous social group territories (Wilkinson et al., 2009). Following culling the badger population becomes perturbed, allowing individuals to move more widely, spreading infection and increasing disease prevalence. The level of perturbation in the model (Wilkinson et al., 2009) has previously been validated against results from a large-scale field experiment (Donnelly et al., 2007; Jenkins et al., 2008). Since it is not known how much culling triggers social perturbation, we tested the sensitivity of the model to a range of perturbation trigger points. We also simulated an optimum control strategy, where we used best-case management parameter values (trapping efficacy, bTB test-performance and vaccine efficacy). Selective badger culling was simulated once each year, when every captured badger was tested for bTB and either culled (test positive animals) or vaccinated (test negative animals). Badger perturbation was either switched on for any level of cull, or low level culling was assumed to avoid perturbation, and these were compared to culling or vaccination on its own. Vaccination on its own was assumed to avoid any perturbation effect.

Results

Before any intervention in badger populations was applied in the model, the mean output parameters stabilized at: 7.5 adult badgers per social group, 1.3 infected badgers per social group, and 0.05 herd breakdowns per farm per year.

Comparing strategies involving culling or vaccination only, the effect of perturbation after culling resulted in a greater reduction in the number of infected badgers during the 5 years of vaccination. However, after 10 years, the culling strategy had resulted in fewer infected badgers than vaccination.

With a combined targeted strategy, the effect on the number of infected badgers was strongly dependent on the point at which perturbation was assumed to be invoked. When perturbation was triggered by one or more animals being culled, the number of infected badgers initially increased higher than that observed for the cull-only strategy, and remained worse than doing nothing for almost twice as long as culling. When perturbation was triggered by three or more culled badgers, a similar number of infected badgers remained as for the vaccination-only strategy, in both the short and the long term.

By limiting the number of badgers culled annually in any one group to below the threshold required to invoke perturbation all these targeted cull and vaccinate strategies resulted in fewer infected badgers than the vaccination-only strategy, but the mean difference was very small.

Discussion

Modelling vaccination-only and culling-only strategies on *M. bovis* infection rates in badgers, show that vaccination-only is a more successful strategy in the short-term than culling, because of the adverse effects of social perturbation. In the longer term (beginning a few years after control ceases), badger culling appears more successful at reducing badger infection.

The intuitive appeal of combining badger vaccination with selective culling is that by removing fewer animals from each social group, perturbation effects are minimized. However, such a strategy would not necessarily prevent perturbation. It is not known how many badgers can be removed before perturbation occurs as it could be a response to mortality by any means. Triggering social perturbation during selective culling (with vaccination of test-negative, i.e. healthy animals) could produce the negative social effects, but with a higher density population. This leads us to the non-intuitive conclusion that selective culling is likely to be a higher risk strategy than vaccination-only or culling-only. Even a combined cull and vaccinate strategy in which the number of badgers removed was limited to below the threshold for inducing perturbation was only marginally more successful at reducing *M. bovis* infection in the badger population than a vaccination-only strategy. We suggest that these results are tested for generality in other species disease systems.

References

Donnelly CA, Wei G, Johnston WT, Cox DR, Woodroffe R, Bourne FJ, Cheeseman CL, Clifton-Hadley RS, Gettinby G, Gilks P, Jenkins HE, Le Fevre AM, McInerney JP, Morrison WI 2007 Impacts of widespread badger culling on cattle tuberculosis: concluding analyses from a large-scale field trial. International Journal of Infectious Diseases 11: 300-308

Donnelly CA, Woodroffe R, Cox DR, Bourne FJ, Cheeseman CL, Clifton-Hadley RS, Wei G, Gettinby G, Gilks P, Jenkins H, Johnston WT, Le Fevre AM, McInerney JP, Morrison WI 2006 Positive and negative effects of widespread badger culling on tuberculosis in cattle. Nature 439: 843-846

Donnelly CA, Woodroffe R, Cox DR, Bourne J, Gettinby G, Le Fevre AM, McInerney JP Morrison WI 2003 Impact of localized badger culling on tuberculosis incidence in British cattle. Nature 426: 834-837

Jenkins HE, Woodroffe R, Donnelly CA 2008 The effects of annual widespread badger culls on cattle tuberculosis following the cessation of culling. International Journal of Infectious Diseases 12: 457-465

Wilkinson D, Bennett R, McFarlane I, Rushton S, Shirley M, Smith GC 2009 Cost-benefit analysis model of badger (*Meles meles*) culling to reduce cattle herd tuberculosis breakdowns in Britain, with particular reference to badger perturbation. Journal of Wildlife Diseases 45: 1062-1088