Does reactive badger culling lead to an increase in tuberculosis in cattle?

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BADGERS play an important role in the epidemiology of bovine tuberculosis (TB) in Ireland and the UK. A range of control measures are in place or have been under consideration, including badger culling. In the UK, there is a concern that reactive badger culling may be counterproductive, leading to increased TB incidence in associated cattle and the residual badger population. Although these concerns had been raised previously (Swinton and others 1997, Krebs and others 1998, Rogers and others 1998), results from the randomised badger culling trial (RBCT) provide the first detailed data with which to test this hypothesis. In the RBCT, an increased TB incidence associated with localised reactive culling was reported in cattle (Donnelly and others 2003, Le Fevre and others 2005). A similar finding was reported in herds in areas adjoining proactive culling areas (Donnelly and others 2006, 2007). Further, proactive culling was associated with an increased prevalence of TB infection in the residual badger population (Woodroffe and others 2006). A cascade of adverse events following badger culling has been proposed (Macdonald and others 2006), whereby badger culling results in substantial changes to the spatial and social organisation and the territorial behaviour of badger populations (these steps are collectively termed 'perturbation'), which in turn lead to increased contact and transmission of infection between badgers, increased contact between cattle and the disturbed badger population, and increased infection risk in associated cattle.

The proposed cascade is theoretically valid. Further, the first steps in the cascade, that is, perturbation following badger removal, are well documented in both Ireland (O'Corry-Crowe and others 1996, Costello and others 2006) and the UK (Tuyttens and others 2000a, 2000b). However, we question the evidence from the published RBCT results in support of the latter stages of the hypothesised cascade, that is, perturbation leading to increased risk of cattle TB breakdowns. Two aspects of the RBCT are relevant to this cascade: the effects of reactive culling inside RBCT areas and effects of proactive culling adjoining RBCT areas. In this article, we raise concerns about specific aspects of the interpretation of these data, in particular the biological plausibility of measured effects, the precision of these effects and the timing of biological processes, and of the accuracy of spatial data.

THE RBCT RESULTS

In keeping with the fundamental principle of causality, the effect of reactive badger culling can only be examined during periods when such effects are biologically plausible, in a setting where all factors are controlled apart from the issue under study, and after sufficient time has elapsed to allow an effect to be detected. These issues will be considered in turn.

In their analyses, Donnelly and others (2003) and Le Fevre and others (2005) attribute the effects of reactive culling during periods when we consider such effects are biologically implausible. To illustrate, the Independent Scientific Group on Cattle TB (ISG) (2007) concludes that 'reactive badger culling induced an estimated increase of 22 per cent in the incidence of confirmed cattle herd breakdowns (95 per cent confidence interval [CI] 2·5 to 45) (P=0·025)'. However, this analysis encompasses two adjoining observation periods: from the completion of the proactive cull until the first reactive culling operation in each triplet (42 per cent of the total observation period), and from the first reactive culling operation in each triplet until November 4, 2003 (58 per cent), when the reactive cull ceased. A measured effect during the latter of these two periods could potentially be related to reactive culling; however, a similar effect during the former could only result from factors not related to reactive culling. This former period represents a substantial proportion (42 per cent) of the total period under observation (Fig 1). Furthermore, in the analysis, data are included from triplets A to I before the start of the reactive cull, and all data from triplet J, where reactive culling was never implemented.

An increase in TB incidence in cattle in association with reactive culling has been presented on several occasions (Donnelly and others 2003, Le Fevre and others 2005, ISG 2007). During the period from the first reactive culling operation in each triplet until November 4, 2003 (that is, while the reactive culling was being conducted), an 18·9 per cent increase (95 per cent CI -5·4 to 49·5) (P=0.14) was reported (ISG 2007). However, the ISG (2007) also reported a very similar, and also imprecise and non-significant, increase (23·7 per cent; 95 per cent CI -10·7 to 71·5) (P=0·20) during the period immediately preceding the start of the reactive cull. This raises several noteworthy points. The imprecision and lack of significance of the results do not justify the conclusion that 'localised badger culling not only fails to control but also seems to increase TB incidence in cattle' (Donnelly and others 2003). It can reasonably be argued that the observed increase was a consequence of pre-existing area differences in TB incidence that were not controlled with randomisation, and was not the result of any effect of reactive culling. These data do not provide sufficient evidence to rule out alternative hypotheses, including the possibilities that reactive culling had either no adverse impact, or indeed was protective.

The hypothesised cascade is a chain of consecutive events, which collectively will take time to complete. Therefore, there will be a time lag between its start (badger removal) and end (increased detection of confirmed TB in associated cattle) (Godfray and others 2004, Griffin and others 2005). Although the duration of this time lag cannot be defined with certainty, it must be sufficiently long to enable completion of each of the key events within the cascade; namely, disruption in badger social organisation leading to increased transmission of TB among badgers, dispersal of badgers infected with Mycobacterium bovis, contact between cattle and the disturbed badger population leading to cattle exposure, the establishment of infection in cattle, the development of responsiveness to tuberculin following establishment of infection, and the completion of the annual herd test. Although the timing of several of these steps has been estimated by Le Fevre and others (2005), much of this is based on data from experimental infections and holds limited relevance to events occurring under conditions of natural transmission. The RBCT analyses considered change in cattle herd incidence during a range of time periods (as discussed previously), but none allowed for any delay to enable all elements of the cascade to take place. For example, the ISG (2007) reported the effects of reactive culling inside RBCT areas from the start of the reactive cull, and the effects of proactive culling outside RBCT areas from the end of the initial proactive cull. In addition, the effects of proactive culling outside RBCT areas were only significant (P=0·052) between the initial and first follow-up cull, an average of 1·26 years. Following this period there was no significant effect (P=0·22).

Spatial accuracy is of particular importance in the interpretation of the RBCT results, given that key findings, for example, adverse effects in association with proactive badger culling (Donnelly and others 2006, 2007) were observed within defined geographic areas. These authors have suggested that expanded badger movement patterns (the first steps in the hypothesised cascade) will be observed in reactive culling areas, and also on farms neighbouring proactive trial areas. Two different data sets (VETNET and RBCT) were used to conduct this spatial analysis. Although both data sets are a representation of the same land, there is evidence of substantial inconsistencies between them, as reflected in the reported results.

Using equivalent analyses, the number of herds in reactive culling areas with confirmed breakdowns compared with no-cull areas was reported as either 28·2 per cent (if the RBCT data set was used) or 17·8 per cent (VETNET) (Le Fevre and others 2005). Similar differences were observed when analysing data from the proactive trial areas (Donnelly and others 2006, 2007, ISG 2007). In addition, farms were represented as a single point in space based on 'the centre of the largest land parcel' (Donnelly and others 2006), without account being taken of the potential impact of farm fragmentation (Ferguson and others 2001). Errors in farm location and allocation will affect the interpretation of results concerning TB in cattle (Donnelly and others 2003, 2006, 2007, Le Fevre and others 2005), but not in badgers (Woodroffe and others 2006)"

CONCLUSION

Bovine TB remains a very serious concern for government and industry in both Ireland and the UK, and it is essential that all policy options are considered as part of a broad control and eradication programme. We raise a number of questions relevant to the current interpretations of the RBCT results. It is important that interested policymakers and the general public are aware of varying perspectives surrounding this topic.

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