POLICY: BIOMEDICINE

Badgers and Bovine TB: Conflicts Between Conservation and Health

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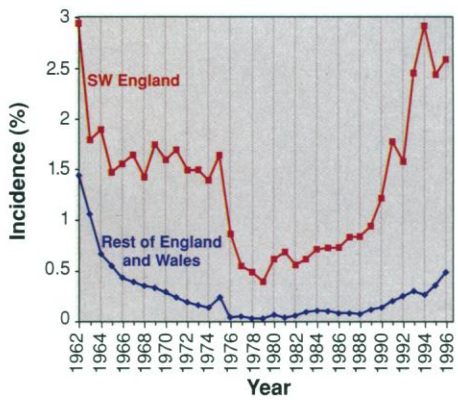
Many important pathogens of humans and livestock have mammalian hosts in the wild that act as reservoirs of infection, seeding epidemics of disease in both agricultural and human communities. Well-known examples include viruses such as rabies and rinderpest, and bacterial infections such as Lyme disease, which is carried by ticks. In some cases, domestic livestock are the major or only reservoir that induces infection in human populations. An important recent example in Europe is bovine spongiform encephalopathy (BSE), which may be the origin of a new variant of Creutzfeldt-Jakob disease in humans (*1*). BSE has had a major impact on the agricultural industry in the European Union (EU) (*2*). Other infectious diseases transmitted from cattle to humans also threaten the livelihood of cattle farmers in Europe. At present, one of the most important of these is bovine tuberculosis (TB), which is thought to be maintained as an endemic infection in a variety of wild mammals. These reservoirs are believed to trigger epidemics of bovine TB in cattle herds, with an associated threat to humans unless infected animals are rapidly detected and destroyed. There are also important commercial reasons for controlling bovine TB in EU countries, because the export of cattle could be restricted if the incidence of disease is too high in a given country.

Over the past 10 years, Great Britain has experienced a rising incidence of TB in cattle herds (see the graph), especially in the southwest of England and in South Wales. Although a range of species including moles (*Talpa europaea*), foxes (*Vulpes vulpes*), rats (*Rattus norvegicus*), and wild deer (various species) can be infected with bovine TB, current evidence suggests that the likeliest source of infection of cattle is the badger (*Meles meles*), whose natural habitat often lies near or within cattle pasture areas.



Increasing incidence of tuberculin-positive cattle. The proportion of total herds with individuals responding to the tuberculin skin test from 1962 to 1996. It is not possible to draw firm conclusions about the effectiveness of intervention strategies during the late 1980s and early 1990s. At this time, other factors also changed; for example, the badger population increased and the climate became warmer.

Here lies the source of a long-running battle for the hearts and minds of the public and policymakers—among the conservation lobby, which wants to protect the badger; the farming industry, which generally wants to kill badgers in TB-affected cattle farming areas; and public health workers who seek to protect humans from a potentially very serious infectious disease. Faced with the increasing incidence of herds infected with bovine TB (herd breakdowns), the Ministry of Agriculture, Fisheries and Food (MAFF) set up a review committee [the third such review since 1979 (*3*, *4*)] in 1996, which has recently published its findings (*5*). Here the members of the review team summarize the key scientific conclusions and highlight the complexities of policy formulation in an area in which scientific uncertainties hinder the development of precise guidelines to protect animal and human health.

Mycobacterium bovis, the etiological agent of bovine TB, is closely related to *M. tuberculosis*, the principal cause of TB in humans. A 1934 inquiry reported that 40% of cows in dairy herds in the United Kingdom were infected with bovine TB, and *M. bovis* was estimated to cause about 2000 human deaths annually in the United Kingdom (about 6% of the total deaths from TB at that time). Since the 1930s, two measures have been introduced that have had a dramatic effect on human and cattle health: pasteurization of milk and regular tuberculin testing of cattle, followed by compulsory slaughter of infected animals. In 1995, less than 0.5% of UK cattle had TB, and only 32 cases of human TB in the United Kingdom were attributed to *M. bovis*. Most of these were older patients probably experiencing a reactivation of infection acquired before the current control measures were introduced. In technologically advanced countries, TB has been declining in incidence and prevalence for at least 100 years. In the developed world, it has become a disease of the urban poor, with most clinical cases occurring in the elderly. However, in immunocompromised patients, such as those infected with human immunodeficiency virus, TB (particularly the drug-resistant strains) continues to present a serious threat to human health (*6*).

TB is a difficult disease to study. Many species of *Mycobacterium* present in soil and water share antigenic properties; the disease develops slowly and only in a small proportion of infected individuals; and in these individuals, excretion of the bacterium may be intermittent. These two latter features facilitate endemic persistence of the disease in badger populations (*7*). The persistent nature of the infection, combined with the capacity of culled badger populations to bounce back within a few years, has apparently hampered the success of control efforts.

Transmission

Much of the controversy surrounding this disease centers on the question of whether badgers really transmit TB to cattle. Experimental studies show that badgers can transmit the infection to cattle in enclosures (*8*), and they forage for earthworms on cattle pasture where infected individuals can shed large quantities of *M. bovis* via urination and sputum. Moreover, the regional distribution of bovine TB in cattle correlates loosely with both badger density and with the prevalence of TB in badgers (estimated from somewhat limited surveillance). Where badgers have been removed from cattle farming areas, the incidence of TB has declined, but such studies have not been conducted as experiments with control and intervention treatments. To date, the evidence, although strongly sug-

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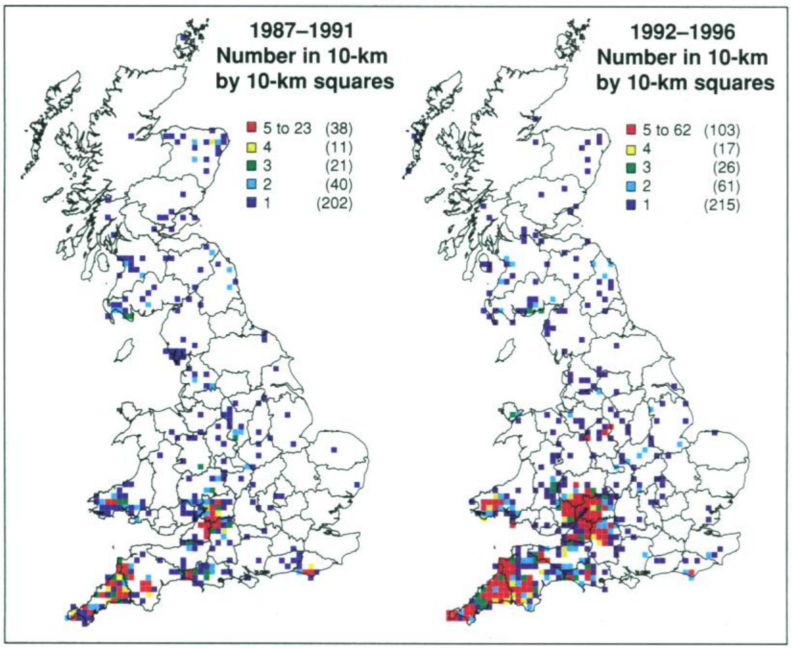
gestive, does not formally demonstrate causation.

During the past 20 years, four different strategies for killing badgers have been implemented to control TB in the belief that the badger is the major source of cattle infection. Because the strategies were largely implemented in succession rather than in parallel, and because there were no appropriate controls, it is not possible to compare their effectiveness. However, the indications are that severe culling of badgers is most effective in reducing the incidence of TB in cattle. The current policy, which requires incomplete removal of badger social groups and prohibits complete removal of badgers from a locality where infection of cattle is recorded, appears to have been unsuccessful in preventing the increase in incidence of bovine TB during the past 11 years. It could actually have exacerbated the problem by disrupting the badger's territorial system and causing remaining group members to range more widely, spreading TB to other localities (9).



Infected herds before and after 1992.

Recommendations

We recommend both long- and short-term objectives, to be achieved with a more rigorous and extensive research template. Four short-term research priorities were identified: (i) analysis of why some localities are at higher risk than others (in southwest England, southern Wales, and the Welsh Borders there are "hot spots" of high risk, the reasons for which are not clear), (ii) assessment of the importance of simple husbandry practices in reducing risk, (iii) implementation of a carefully designed experiment to assess the effectiveness of badger culling, and (iv) use of molecular epidemiological tools to resolve the question of who gets infected from whom. Determining the reasons for local variation in the incidence of disease involves further data collection and the analysis of existing data with multivariate statistical techniques to investigate the relative importance of different factors (the presence of badgers; the presence of infection in badgers and other wildlife species; ecological, climatic, and landscape variables; and agricultural practices). Assessing the importance of husbandry practices requires the cooperation of the farming industry, with the help of MAFF, in evaluating the effectiveness of simple measures such as keeping badgers away from cattle feeding troughs and restricting cattle access to areas where badgers urinate and defecate. Although husbandry guidelines are already emphasized by MAFF, they are not generally followed by the industry.

The third recommendation is the major one, suggesting the design and implementation of an experiment to compare the effects of three different control strategies—no culling at all, removing badgers from a substantial area, and removing badgers in response to herd breakdown (a strategy designed to prevent the recurrence of TB). We suggest that the experimental area be restricted to areas of high incidence, the so-called hot spots. The top 31 hot-spot squares (10 by 10 km) would encompass two-thirds of all repeat and contiguous breakdown areas. The treatments should be assigned randomly and the experiment be supervised by an independent group of experts, as is often the case in clinical trials of different intervention strategies to control disease in human populations. In 5 years, the experiment will provide a quantitative estimate of impact that can then form the basis for a detailed cost-benefit analysis. The total number of badgers killed in the experiment would not differ greatly from the number killed under the current control policy and would probably be far fewer than are killed in road traffic accidents.

The best long-term goal is research aimed at developing a vaccine for cattle, with an associated diagnostic test to distinguish infected from vaccinated cattle and perhaps a molecular tag to allow the positive identification of vaccinated animals. This goal may not be achieved in the foreseeable future, given past difficulties encountered in developing an efficacious vaccine for human TB. However, recent progress in understanding the natural history of TB and the development of immunity to infection, combined with the recent availability of the complete sequence of the *M. tuberculosis* genome, provide hope for progress in this area.

There are a number of general lessons to be learned from the history of bovine TB control in the United Kingdom. First, in the past, control measures have been implemented without adequate scientific evaluation of their impact and cost-effectiveness. In order to rigorously evaluate the impact of any strategy for controlling TB, the experimental design must compare treatments, and include replication and randomization. Second, central to assessing the magnitude of the problem are effective epidemiological surveillance and measurement of variables that facilitate the assessment of heterogeneity in risk, on both local and national scales. Linked to these is the need to enhance the interpretation of observed trends through the use of mathematical models of host demography, bacterial transmission, and disease pathogenesis. Third, it is important that MAFF make use of existing expertise in nongovernmental research institutes and universities, paying particular attention to disciplines outside the traditional boundaries of veterinary medicine, such as molecular and medical epidemiology and population biology. The fourth point is that MAFF spends nine times as much on tuberculin testing and badger culling as it does on research. Because research may, in the long run, provide a solution that will save these costs, MAFF should review the balance of its spending. In doing so, note should be taken of the fact that the farmers, who benefit from TB control, do not make any contribution themselves.

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