BADGERS & BOVINE TUBERCULOSIS

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The first record of tuberculosis in *Meles meles* came from Switzerland during the mid-1950s. In 1971, a dead badger recovered from the Cotswold Hills in Gloucestershire (UK) was found to be infected with *Mycobacterium bovis*, the bacteria known to cause tuberculosis in cattle (that is to say, bovine tuberculosis, or bTb for short). This specimen represents the first case of a badger infected with bTb from Britain.

In humans, Tb is typically caused by *M. tuberculosis.* However, *M. bovis* is a close relative of *M. tuberculosis* and can be equally problematic for humans. During the 1930s, the incidence of *M. bovis* in children (and cats) was high; the bacterium was contracted through the consumption of unpasteurised milk. The implementation of milk sterilization and pasteurising lead to a dramatic decline in human bTb cases, although people in prolonged contact with cattle or their meat (i.e. slaughter houses) have been known to contract *M. bovis* infections – according to the Institute of Animal Health in Berkshire (UK), around 2000 people currently die of bTb each year, globally. Today, Tb as a complex is the world's biggest bacterial killer, estimated to kill three million people annually.

At the bottom of this summary, I have provided several links to the Department for Environment, Food and Rural Affairs (DEFRA, which superseded the Ministry for Agriculture, Fisheries and Food, or MAFF, in 2001) reports, which will give you a much more comprehensive view of the problem than I intend to provide here. Anyhow, for the uninitiated, here are the basics.

Just how big of a problem is bTb in Britain?

Following a dramatic reduction of infections post-1930s, incidences appear to be on the increase. According to DEFRA's figures, bTb is now "*endemic in some parts of Great Britain and increasing at a rate of 18% a year*", with about 20,000 infected cows dispatched in the UK per annum (roughly 0.2% of the UK's cattle population). This is unfortunate not only for farmers (for whom bTb can represent the end of a livelihood) but also for one of Britain's best-loved mammals because, as DEFRA go on to state: "*The main wildlife reservoir for the disease in Britain is in badgers*." Indeed, most authorities now consider that there are two main bTb reservoirs in the UK: one in the badger population and the other in the cattle population.

How is bTb spread?

Unfortunately, despite many years of fairly intensive research into bTb, there are still many areas of its epidemiology that we can only speculate upon; perhaps the most significant of these is its transmission. We know that *M. bovis* primarily infects the lungs' and kidneys' of badgers, suggesting that Tb can be spread on the badgers' breath and in their excreta. Indeed, a summary of bTb cases published in *Research in Veterinary Science* during 2000 reported that of the 146 tuberculous (i.e. infected with bTb) badgers studied, 51% had lesions in the lungs, 25% in the kidneys, 40% on the lymph nodes and 14% in bite abscesses (implying territorial disputes may spread infection). Lesions to the brain, spleen and gut were infrequent (0.7%, 0.7% and 2%, respectively).

At the badger-to-badger level, *M. bovis* is probably transmitted as an aerosol (i.e. badgers breathe it in). However, the situation is less clear at the badger-to-cattle level. Currently, the primary route of transmission is considered to be through scent marks, especially urine. Indeed, studies have found that while badger faeces can contain up to 75,000 tuberculosis bacilli per cubic gram and badger pus up to 200,000 per millilitre, urine may contain up to 300,000 per ml. Considering the ranging behaviour of badgers, this implies that cows feeding on grass along the periphery of fields (where badgers are more prone to scent) are at a higher risk of picking up the disease than those grazing more centrally. Moreover, badgers take very precise routes, frequently re-marking the same areas and it is not unwarranted to think that a build up of the bacteria (which can survive on the ground or in faeces for days or months, depending on the conditions, while spores may survive for decades) could occur in these areas and may persist even after badgers have been removed. Consequently, several studies have tried to assess how different parts of a field system might present different levels of infection potential. Overall, it was found that urination was more prolific at "crossing points" (i.e. the points where badgers cross a linear feature like a fence or hedge) than other parts of a pasture. Pastures with lots of linear features were, therefore, found to have increased contamination with badger urine. It is perhaps mildly reassuring, therefore, that field observations suggest direct contact between badgers and cattle in the wild is rare and studies looking at where cattle choose to feed have demonstrated that cows generally avoid areas of grass contaminated with badger excreta. However, this situation might be different when feeding from a trough and it is not difficult to see how, in typically oligotrophic (low nutrient) pastures, the added fertilization provided by nutrient-rich faeces and urine may cause grass to grow lusher than in other areas of the field.

One study recently published in the *Journal of Dairy Science* reports that the type of grazing plan a farmer implements may affect how likely his/her cattle are to come into contact with contaminated pasture. The biologists write:

"*If investigation is a major route of tuberculosis transmission, the risk to cattle is greatest in extensive rotation-grazing* [access to whole field for up to 7 days at a time] *systems. However if ingestion of fresh urine is the primary method of transmission, strip-grazing management* [field subdivided for grazing for periods of less than 24 hours] *may pose a greater threat.*"

One might be forgiven for thinking that, in this case, a simple double fence to keep the cattle away from this grass is the obvious solution. However, this link has yet to be firmly established, let alone ratified as the principle route of infection and *M. bovis* transmission may occur by three main routes: urination or other scent marking (including latrines); aerial; or through direct contact with either the badgers themselves or ground they use (e.g. digging for worms). Unfortunately, each of these contact routes would involve a different control methodology. It is also important to remember that the process of

transmission is not a unilateral one; it is highly probable that cattle can pass the disease to badgers just as easily as *vice versa*.

Are badgers the only transmitter of bTb?
No. To further complicate the issue, although badgers seem to have a considerable tolerance to the infection, they are not the only species capable of transmitting the bacterium. However, while badgers may not be the sole route of wild-domestic transmission, they are one of the few species that can act as effective vectors, because the disease is rarely fatal to them. Despite the observation that, even in the most susceptible species, bTb infection can persist for many months (even years) before it becomes fatal, not all species that can become infected with the bacterium are effective carriers (most die fairly soon after contracting the bacilli). Badgers seem to have a remarkable tolerance to the bacterium and generally between 50% and 80% of tuberculous individuals have no observable lesions. Moreover, a paper published in *The Veterinary Record* during 1998 reports that infected badgers generally have few sites of infection and small numbers of the bacilli in their tissues. In the UK, badgers are the only known maintenance host for *M. bovis,* although there are some "spill-over hosts" (i.e. populations in which infection will persist where a maintenance host is present in the ecosystem), including ferrets and Red foxes.

A recent review of *M. bovis* infection in wild mammals from the UK, headed by Central Science Laboratory (CSL) biologist Richard Delahay, lists ten species (excluding the badger) from which this bacterium has been isolated. Included in this list are Fallow deer (*Dama dama*), Red fox (*Vulpes vulpes*), Mink (*Mustela vision*), Mole (*Talpa europaea*), Brown Rat (*Rattus norvegicus*), Ferret (*Mustela furo*) and Domestic cats (*Felis domesticus*). A recent study of 1,307 Bank Voles (*Clethrionomys glareolus*) found that only one yielded positive results for *M. bovis*, leading the authors to suggest that this species is relatively unimportant as a reservoir for bTb. Similar studies have shown that rabbits and mice can be experimentally infected with bTb, although no records are known from the wild.

Some evidence suggests that sex and age may affect susceptibility to *M. bovis*, while the stage of disease progression seems to influence mortality. In a paper to the *Journal of Zoology* in 2000, a group of scientists fronted by David Wilkinson (CSL) report that, while ELISA-Positive badgers (i.e. incubating bTb, but not excreting the bacilli) at Woodchester Park did not have a substantially higher death-rate than uninfected individuals, infected badgers that were excreting *M. bovis* did. The study also found that the progression of the disease is considerably more rapid in males than it was in females; females ultimately seemed to cope with the disease better than the males. Similarly, the susceptibility of badgers to *M. bovis* infection may be related to age, although studies to date have yielded mixed results. One 1991 paper found that infection rate was slightly higher in cubs than in adults (46% and 39%, respectively), while another paper from 1998 found the opposite (13% of cubs and 20% of adults).

There are also data from Ireland to suggest a connection between irregular bacula development and incidences of bTb infection.

How does bTb manifest itself?
Regardless of how or from which species the infection arrives, upon entering cattle the bacterium targets the lungs, manifesting as a severe pulmonary infection. Overall, the symptoms of Tb typically include loss of appetite, weakness, weight loss, fever and caseous (looking cheese-like) lesions in the lungs, on the bronchomediastinal lymph nodes (little 'filters' in the neck near the thymus) and other organs. Swelling of the lymph nodes can lead to lameness (especially if it leads to skeletal and synovial lesions).

How do you test for bTb?
Testing for bTb *post mortem* (which is the only way bTb can be confirmed in badgers) can be done histopathologically (looking at tissue sections under the microscope, culturing of bacteria etc.). Testing live animals can be achieved through a variety of methods. In the UK, the most common test is the Tuberculin -- or Delayed Hypersensitivity -- Skin Test, which is typically used in conjunction with the Gamma Interferon Blood Test (for details on these tests, see the links below). It should be noted that the Gamma Interferon test is only viable for bovine livestock and that research is continually underway looking for more accurate (one problem with using a vaccine is that vaccinated cattle will show positive for bTb infection) and more rapid testing procedures. One such blood test is the Enzyme-Linked Immunosorbent Assay (ELISA), which shows promise not only in its wide species application, but also in its ability to test badger faeces for *M. bovis*.

Is the UK alone in its battle against bTb?
No, bovine TB is not just a UK problem; it is also prevalent in North America, Africa, New Zealand and Australia. In the USA, deer and elk are considered to be the primary reservoirs, while buffalo are the main reservoir in Southern Africa, Brushtail possums and ferrets in New Zealand and feral pigs and feral Water Buffalo in Australia. Additionally, sporadic reports of *M. bovis* isolates from free-ranging wildlife are known from other countries (e.g. Red foxes in Spain).

What can be done to reduce/eradicate bTb?
Until quite recently, culling was considered the main answer to the bTb epidemic. Badgers were culled using cyanide gas between 1975 and 1981 -- when gassing was outlawed -- although research indicated that not only was gassing inhumane, but it was also ineffective at combating TB transmission. It also cost more to gas the badgers than the government saved with any resulting decline in bTb. Since 1975, some 30,000 badgers have been killed in a bid to eradicate and research bovine TB, even though only 20% of them had any sign of the disease.

It has been widely implied that culling badgers is still the most obvious and practical way to

control bTb infections in cattle. Although it may seem inherently logical that reducing the wild reservoir would lead to a reduction in infection rate, the reality is considerably more complex. Recently, the National Farmers Union (NFU) has thrown its support behind DEFRA's culling trial, in which they plan to instigate a substantial cull of badgers in southwest England so as to assess its impact on reducing cattle infection. This action was deemed worthwhile largely on the results of a study from Ireland, frequently referred to as the "Four Counties Trial" (FCT). The FCT, found that culling badgers did indeed lead to an decrease in the incidence of bTb in the Irish herd. However, one of the main findings of this -- highly controversial -- study was that bTb infections can only reduced significantly if you cull 100% (or very close to) of badgers. In other words, you can only solve the problem this way if you kill **all** the badgers! As such, the authors of the FCT paper state that culling is **not** the way forward in combating bTb!

Several studies from the UK confirm the idea that culling is not a plausible alternative to other strategies, including vaccination and better biosecurity. Two papers to the journal *Nature* (one in 2003 and the other in 2005) have demonstrated that far from helping the situation, anything less than a wide-scale, blanket (i.e. as close to total eradication as possible) cull will only make the situation worse. The data, collected and analysed by a team of 14 scientists from across the country, show that not only did culling have a negligible impact on bTb incidence within the study areas (roughly 19% decline), it actually lead to a **29% increase** in cases of bTb in peripheral areas. The biologists suggest that culling badgers causes a breakdown in the clan's social cohesion; badgers leave the clan and move into neighbouring areas, taking any infection with them. Indeed, a paper to *Biological Conservation* by Linda Sadlier and Ian Montgomery of The Queen's University of Belfast, found a significant negative relationship between the severity of disturbance and sett size in Northern Ireland's badger clans. In other words, as the disturbance got worse, the number of adult badgers in the clan declined. The authors consider that this migration from the main sett was a result of a disturbance-induced disruption in territorial behaviour. Unfortunately, it seems that the results of these studies, which cost some £30 million over six years and have the findings published in perhaps the world's foremost peer-reviewed natural sciences journal, have been largely ignored by DEFRA and the NFU, who are going ahead with their cull as planned.

Another proposal has been to impose restrictions on cattle movements. In fact, a recent paper to the journal *Nature* reported that, although the current distribution of bTb infection in cattle most closely mirrors the areas of highest badger density, the current spread of the disease most closely mirrors the patterns of cattle movement across the UK. Indeed, this paper notes that the disease has spread more rapidly than the badger population itself. Consequently, this means tighter restrictions on nationwide cattle movements as well as more rigorous bio-security measures, regulating movement between farms and how cattle are handled at market, will be required.

It is worth pointing out that there is evidence that bTb infection can induce behavioural changes in badgers. Studies looking at the ranging behaviour of infected badgers have found that these individuals range further than their uninfected conspecifics. In their 1981 paper to the *Journal of Zoology*, CSL biologists Chris Cheeseman and Peter Mallinson report that badgers infected with *M. bovis* became solitary, often taking up residence in outlier setts and ranging more widely than was usual (similar results have been found in primates infected with this pathogen). More recent work has found that infected badgers can have home ranges as much as 50% larger than uninfected individuals; they also range over a greater proportion of the territory than healthy clan members, foraging, on average, 65% further away from the main sett. Consequently, infected badgers may be more likely to stray onto neighbouring farmland and potentially into barns and farmyards, which would put them in direct contact with cattle.

The discovery that badgers infected with bTb move around more than uninfected individuals coupled with the potential for disease transmission through direct personal contact has lead to the suggestion that bTb could be significantly reduced (if not actually eliminated) by excluding badgers from cowsheds (with better fencing) and feeding troughs (with better designs). Indeed, visits to farms by badgers can be common, especially in periods of low rainfall, when the soil is dry and digging for earthworms is all but impossible. For example, in a 2002 paper to the *Proceedings of the Royal Society of London*, Ben Garnett and Richard Delahay of the CSL and Tim Roper Sussex University in Brighton report on the use of cattle farm resources by badgers in Gloucestershire. The biologists found that during 449 hours of observation (59 half-nights and 17 full nights), at least 26 individually identifiable badgers from two clans made 139 separate visits to farm buildings, using cowsheds, feedsheds, barns, haystacks, slurry pits, cattle troughs and farmyards. In some instances the badgers were seen to approach to within 2m (6ft) of penned cattle as well as consume cattle feed, silage and defecate in cattle troughs. Moreover, tests on the clan found three of the visiting badgers to be tuberculous and excreting *M. bovis*.

Based on Garnett *et al* results, it may intuitively seem like the best solution would be to take precautions to exclude badgers from farms. However, subsequent work by the same scientists has found that this is easier said than done. For example, in their 2003 paper to *Applied Animal Behaviour Science,* Garnett and his colleagues report that the maximum height to which badgers in their clan at Woodchester Park (Gloucestershire) would climb to gain access to a trough was 115 cm (almost 4 ft). Unfortunately, according to Garnett *et al*. research, raising a trough to this height would place it out of the reach of calves, young heifers and bullocks. If the data presented by Garnett *et al* are representative -- and offhand, climbing height may vary in relation to how hungry a badger is when it comes across the trough -- it seems that if exclusion of badgers is going to be a workable alternative to culling, new designs for feeding troughs and cattle sheds are going to be necessary. Garnett *et al*. make a few suggestions as to how a trough may be designed to deter badgers, including rolling bar to the rim or placing a pressure plate on the floor; ultimately these require experimentation.

The fact that bTb is a global problem might hold the key to its resolution here in the UK. Currently, many authorities consider that the only way to eliminate *M. bovis* from the British herd is to vaccinate the reservoirs (i.e. the badger and cattle). Although vaccination of badgers is fraught with complications, work in New Zealand has shown some promise of an attenuated *M. bovis* bacillus Calmette-Guerin (BCG) vaccination for cattle. Experiments by virologists at the Wallaceville Animal Research Centre in New Zealand and the UK's National Institute for Medical Research and Veterinary Laboratory Agency have demonstrated that a BCG booster vaccination can induce protection (a 70% reduction in pathology) against bTb. However, even in humans (where it is the most widely-used vaccine in the world), the results are highly variable and given that in excess of 75% of the cattle reservoir would require inoculation, it is clear that there is much work still to be done. Although a marketable vaccine may still be a way off, in June 2005 the British Farming Minister announced to the House of Commons that a three-year vaccine field trial is due to commence in an area of southwest Britain later this year (2006).

So, what's the upshot of all this?
Ultimately, it seems that vaccination in conjunction with tighter (nationwide) movement restrictions and overall biosecurity measures is the only positive way forward. The alternative is to eradicate badgers over large parts of southern England – a proposal that is not only in conflict with the majority of public opinion, but also very expensive and difficult to coordinate. One thing that's certain is that a piecemeal or reactive culls will simply make the situation worse.

External Links

- DEFRA Animal Health
- DEFRA Consultation on badger culling
- DEFRA Tuberculosis in cattle
- Gamma Interferon Blood Test
- Impact of localized badger culling on tuberculosis incidence in British cattle (*Nature* abstract)
- International Study Group report on Bovine TB (PDF Document – Requires Acrobat Reader)
- National Farmer's Union Bovine Tuberculosis
- Positive and negative effects of widespread badger culling on tuberculosis in cattle (*Nature* abstract)
- Randomised Badger Culling Trial (DEFRA)
- Tuberculin Skin Test
- Tuberculosis Vaccine Trial (BBC News)