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Bovine Tuberculosis

The issue of bovine tuberculosis (TB) has become more urgent recently as the UK moves ever closer to losing its status of TB-free. The increasing number of cases detected within the UK herd, and the geographical spread of cases has caused concern and a demand for an explanation.

It has been proposed that the methods used to bring down the incidence of tuberculosis in cattle has been hampered by the existence of a reservoir for the disease within the UK badger population. Culling of badgers is one proposal for dealing with the rise of bovine TB but it is an emotive issue.

A government report (MAFF) has suggested that a five year study should be carried out to determine once and for all whether badgers are responsible and whether culling would be an effective strategy for dealing with the disease. This has pleased no-one. The badger groups do not believe in the strategy and some organisations will refuse permission for culling to be carried out on their land. The farmers are displeased with the fact that the proposed compensation is not sufficient. The scientific community is not pleased because it is felt that the study will not be rigorous enough to truly determine the role of badgers in the transmission of bovine TB.

Stephen McGinness

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I Introduction

The relationship between badgers and bovine tuberculosis may not be immediately obvious. Badgers to many people represent a beloved species of animal resident in the countryside, close in levels of affection to the hedgehog. Indeed, the badger is one of the country's most protected species of mammal with regulations in place to make the killing of these creatures against the law. It comes as a surprise to many to find that many farmers do not hold badgers in quite the same level of respect. This is because there has been an accumulation of evidence which suggests that badgers may be carriers of bovine tuberculosis and therefore responsible for the failure of disease control measures in parts of the country where the badger population is most dense. In this paper I hope to investigate the conflict that has arisen in the countryside between conservationists who aim to protect the badger and farmers who want to rid themselves of what they perceive as a pest.

A. Badgers in Britain

The badger has been a resident of the UK for a long time and has been variously treated as entertainment (through baiting with dogs); as food and, most recently, as evidence of countryside credentials.

Badgers are protected by a number of laws. Badgers may not be deliberately killed, persecuted or trapped except under licence. Badger baiting (using dogs to fight a badger) has been outlawed since 1835, and digging for them was made illegal by the Badgers Act 1973. The Protection of Badgers Act 1992 consolidates past badger legislation and, in addition to protecting the badger itself, makes it an offence to damage, destroy or obstruct badger setts.

This protection means that badger rights often over-ride those of people, e.g., when badgers colonise common land or allotments then the badgers take priority under the law. In the press badgers are often presented as the victims of baiting (or lamping as it is sometimes called). In Tony Banks' speech when introducing the Protection of Badger Setts Bill to the House in 1990[1] He mentioned that out of a population of 250,000 an estimated 9,000 to 10,000 are killed every year due to badger baiting activities. His comments reflect the perception by which many view badgers,

> …the badger symbolises the countryside and we have, rightly, protected that wonderful and mysterious creature.

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1 HC Deb, Protection of Badger Setts, 23rd January 1990, col. 747-748.

The affection which these creatures are held has meant that those opposing measures to protect badgers have attracted physical threats. Whilst the Protection of Badger Setts Bill was passing through the House it was temporarily blocked by fox hunting supporters as they wanted to protect the right of huntsmen to block setts to prevent foxes escaping by this means led to sensationalist headlines in the press[2].

The public desire to protect the badger has resulted even in the construction of badger runs under busy roads to help prevent road deaths, the cost not an issue when it was directed at badger preservation[3]. In 1991 it was even claimed that modern farming methods and countryside development threatened the existence of the badger[4], and badger protection culminated with the Protection of Badgers Act in 1992 which consolidated all previous legislation into a coherent policy.

In the mid 1980's and early 1990's there were substantial increases in the incidence of bovine TB noted amongst cattle; in the Southwest of England in particular. It was noted that the incidence of TB coincided closely with the density of the badger population and that badgers were capable of acting as carriers of the disease. In 1997 the headline *"Badger numbers have hit pest level says union"* [5] were not uncommon in the rural press, and the farming community was certain that badgers were to blame for the incidence of TB. MAFF were by this time carrying out a policy of culling badgers in areas where TB outbreaks were noted but their methods were objected to by badger protection groups.

Eventually the badger groups began to reject the fact that badgers were responsible for the incidence of TB and the lack of real scientific evidence became a point of contention. There was no way to reconcile both interest groups without firm evidence of badger complicity and potential strategies to relieve the situation.

It was, and is, a conflict of interests between two countryside concerns.

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2 Death threats sent to senior Tory who blocked badger Bill, Independent, 7th July 1990.
3 Badgers: too set in their ways, Sunday Times, 18th February 1973.
4 Badgers put at risk by farming, Times, 24th June 1991.
5 The Western Mail, Farming Section, 28th January 1997.

II Bovine Tuberculosis[6]

Tuberculosis (TB) is a contagious disease of both animals and humans. It is caused by three specific types of bacteria that are part of the Mycobacterium group: *Mycobacterium bovis*, *M. tuberculosis*, and *M. avium.*

Bovine TB, caused by *M. bovis*, can be transmitted from livestock to humans and other animals. No other TB organism has as great a host range as bovine TB, which can infect all warm-blooded vertebrates (animals with a backbone). *M. avium* can affect all species of birds, as well as hogs and cattle. *M. tuberculosis* primarily affects humans but can also be transmitted to hogs, cattle, and dogs.

Bovine TB has affected animal and human health since antiquity. Once the most prevalent infectious disease of cattle and swine in the United States, bovine TB caused more losses among U.S. farm animals in the early part of this century than all other infectious diseases combined[7]. This disease's presence in humans has been reduced as a result of the eradication programme, advances in sanitation and hygiene, the discovery of effective drugs, and pasteurisation of milk.

A. The Disease

In general, disease-causing mycobacteria live only a few weeks outside a host's body because they cannot tolerate prolonged exposure to heat, direct sunlight, or dry conditions. Under cold, dark, and moist conditions, the organisms can survive longer.

Mycobacteria do not grow outside of a host except in cultured media, where they multiply approximately once every 20 hours. Because of this relatively slow rate of growth (*E. coli* under similarly good conditions may multiply once every 20 minutes), the disease usually takes many months to develop. In some instances, the organisms lie dormant within the host's body for its lifetime, both in animals and in humans, without causing progressive disease.

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6 Bovine Tuberculosis (factsheet), Animal and Plant Health Inspection Service U.S. Department of Agriculture

7 *ibid*

Bovine TB is a chronic disease, seldom becoming apparent until it has reached an advanced stage in cattle, captive deer, and swine. Some infected livestock seem to be in prime condition, showing no evidence of infection until they are slaughtered, yet they may be found so seriously infected during slaughter inspection that their carcasses must be condemned.

B. TB Transmission

Bovine TB can be transmitted from animals to humans and vice versa. Although young animals, and humans, can contract the disease by drinking raw milk from infected dams (mothers), the most common means of transmission is through the respiratory system. Invisible droplets (aerosols) containing TB bacteria may be exhaled or coughed out by infected animals and then inhaled by susceptible animals or humans. The risk of exposure is greatest in enclosed areas, such as barns. Inhalation of aerosols is the most common route of infection for farm and ranch workers and veterinarians who work with diseased livestock. Livestock also are more likely to infect each other when they share a common watering place contaminated with saliva and other discharges from infected animals. Calves, hogs, and humans can contract bovine TB when they drink unpasteurised milk from infected cows.

C. Diagnosis

TB lesions may be found in any organ or body cavity of diseased animals. In early stages of the disease, these lesions are difficult to find, even during post-mortem examination. But in later stages, the nodules or lumps caused by bovine TB become very evident in the lungs and associated lymph nodes and in the lymph nodes of the head and intestinal tract. Lesions may also appear in the abdominal organs, reproductive organs, nervous system, superficial body lymph nodes, and bones.

Humans and animals with TB develop an immune response, which can be detected by the tuberculin skin test. Tuberculin is a sterile laboratory product made by growing TB bacteria, killing them with heat, removing them from the substance on which they were grown, and properly diluting and preserving the remaining mixture. About 72 hours after tuberculin is injected into animals affected with TB, a characteristic swelling reaction appears at the point of injection. This reaction is a positive test result, indicating exposure to one type of mycobacteria.

Further diagnostic methods are necessary to confirm the presence of bovine TB. In humans, these tests include chest x-rays and sputum cultures. For animals, the comparative cervical tuberculin test, serological tests, post-mortem examinations, and other laboratory procedures are used. There has been some effort in developing a test for TB in badgers, as currently the

only way to be sure of infection is through post-mortem examination. The current “live-test” regularly gives false positives and negatives, so that effectively no decisions can be made on the basis of this test.

The course of treatment for humans with bovine TB takes 6 to 9 months, and the success rate following treatment is more than 95 percent. In livestock, bovine TB can be controlled within an affected herd through regular testing and slaughter of any single animal that tests positive until the entire herd tests negative for this disease.

III Wildlife and Bovine TB

The fact that Mycobacteria are capable of infecting a wide range of hosts there exists the possibility that there may be sources of infection within the environment that are outwith the immediate control of farmers or veterinarians.

The potential host range for the disease comprises any of the free-ranging mammal species that share space with cattle but the host status of these species is variable. Some are too restricted in numbers or distribution to have any significant role in disease dynamics. Others exhibit limited susceptibility or are dead-end hosts that become infected but not infectious. Controversy has arisen over the distinction between two categories of infectious host: spill-over hosts that require an external source of re-infection to maintain the disease within their population; and reservoir hosts where the disease persists by cycling within the population. In the UK the main reservoir host identified has been the badger (*Meles meles*) though in other countries other animals such as Possums (*Trichosurus vulpecula*) and wild deer (*Cervus elaphus* and other species) are generally accepted as reservoirs, but the status of scavenging species such as ferrets (*Mustela furo*) and feral pigs (*Sus scrofa*) is still under debate.

A. Ecology of wildlife reservoirs

Most individuals in a mammal population remain close to the area where they were born, but a small proportion travel long distances. Habitat preferences of feral mammals may also bring them into contact with farmed cattle and deer.

Social interactions are likely to facilitate intra-specific disease transmission. One study in New Zealand found that 32 possums have been observed feeding at a single site over a 3-week period, with frequent biting and scratching and possum den sharing is common in some habitats[8]. Fighting among male ferrets is common during the mating season[9] and preliminary studies indicates that den-sharing occurs. Red deer are sociable animals and in the wild form groups ranging from two or three up to 50-150 individuals. The distribution of most wildlife species is aggregated, which favours disease spread. For example, bovine TB is about twice as prevalent among possums at crowded capture sites as at less crowded sites.

Behavioural interactions also facilitate wildlife/livestock disease transmission and may explain, in part, differences in disease spread by different wildlife hosts. For example, farmed

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8 Ecology of Wildlife reservoirs of bovine TB: A brief review

9 King, C.M. (1990). The handbook of New Zealand mammals. Oxford University Press, Auckland.

cattle and deer actively investigate possums that have been partially sedated (to mimic the terminal stages of tuberculosis) but show relatively little interest in sedated ferrets[10]. This has importance because it shows the importance of how cattle behaviour may differ when presented by similar behaviour by different species. If the cattle do investigate then there is a much greater chance of transfer of TB. Hunting pressure has displaced wild deer away from grasslands and forest/pasture margins so that interactions with farmed cattle and deer are rare.

B. Management of wildlife reservoirs

The management of wildlife reservoirs is an issue not only in the UK but in other countries such as New Zealand where the possum is the reservoir[11]. This situation may be likened to that which exists in the UK only in that the management of the ecology would be similar. Possums however do not have the same legal protection in New Zealand, nor is there a similar level of public antipathy toward their control as there is to the control of badgers in the UK. It is useful however to compare management strategies in order to establish what has been found to work, or not to work.

Successful pest management distinguishes control strategies (e.g. eradication, one-off control, sustained control) from tactics (e.g. toxins, sterilants, vaccines). Eradication of wildlife reservoirs is often advocated, however, no widespread vertebrate pest has ever been successfully eradicated from mainland habitat. For eradication to succeed, three conditions must be met[12]:

(1) All individuals must be susceptible to the control work;
(2) The pests must be killed faster than they can replace their losses;
(3) The probability of reinvasion must be zero. Some island eradication campaigns have been successful. However, at even the highest feasible expenditure on control work, none of these conditions can be met on the New Zealand mainland.

Experts in epidemiology (the distribution of disease within a group or population) predict that there is a threshold density below which a disease, such as bovine tuberculosis, cannot be sustained in the host population. That is, if there are not enough individuals of an animal species within a set area then the disease will effectively burn itself out.

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[10] Sauter, C.M. & Morris, R.S. (1995) N.Z. Veterinary Journal.

[11] Wildlife reservoirs of bovine tuberculosis in New Zealand, Graham J. Hickling, http://www.lincoln.ac.nz/ento/wild/reserv.htm

[12] Parkes, J.P. (1993). N.Z. Journal of Zoology 20: 223-230.

Intensive but relatively infrequent control operations represented the main strategy for controlling tuberculous possums in the 1970s and early 1980s. Modern control methods (e.g., aerial distribution of possum baits) can achieve greater than 90% kills and such operations can be highly cost-effective in reducing cattle reactor rates (numbers of cattle testing positive to tuberculin skin tests). However, they have generally failed to eradicate the disease from either possums or livestock in New Zealand.

By studying the animals in the wild and using epidemiological models the strategies to deal with TB changed around the mid 1980s to attempting to keep the numbers of possums below the TB threshold[13]. This control strategy had some success[14], the possum population was held at 22% of its original density for a six year period and the average incidence of bovine tuberculosis in cattle was reduced by 74%. The complicity of possums in the transfer of the TB was strengthened as the population density of ferrets, the alternate wildlife reservoir for the disease, remained unchanged over this period. There remained after this control period however two centres of tuberculous possums, which would tend to suggest that the threshold hypothesis does not hold strictly true under all conditions. Repeat surveys on populations, which were not subject to control measures, have shown that such centres of tuberculosis may remain for decades[15]. It is these persistent centres of disease that may require novel techniques and strategies if tuberculosis control is to be successful in the near future.

Future prospects to eradicate tuberculosis from wildlife reservoirs may prove more difficult than current epidemiological models predict[16]. Current control methods may prove difficult to maintain through adaptation of animals to control methods or through unpopularity of control methods within the general public. One threat is that behavioural resistance (e.g. bait aversion, *neophobia*) may develop if the pest populations are controlled repeatedly. Another is the potential for increasing public opposition to controversial control tactics such as leg-hold traps.

Research should concentrate upon developing new control tactics such as alternative vaccines and biocontrol agents. However, without being underpinned by ecological and epidemiological expertise this research is likely to remain inadequate and ultimately unsuccessful. Finally, it is clear that livestock and farm management are critical for tuberculosis control[17]; these need to be fully integrated with any management of wildlife reservoirs.

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[13] Barlow, N.D. (1991). Jornal of Applied Ecology 28: 794-809.

[14] Caley, P., Hickling, G.J. & Cowan, P.E. (1995). Proc. 10th Austral. Vert. Pest Contr. Conf. Hobart, pp. 276-281.

[15] Hickling, G.J. (1991). Massey Univ. Cont. Ed. Publ. 132: 67-71.

[16] Hickling, G.J. (1995) Tuberculosis in wild and domestic animals. University of Otago, pp.174-177.

[17] Morris, R.S. & Pfeiffer, D.U. (1991). Massey Univ. Vet. Cont. Educ. Publ. 132: 1-8.

IV Bovine TB in the UK

The issue of bovine TB in the UK is a complicated issue due to the special status accorded to badgers both in legislation and in the minds of the general populace. It is difficult to control animals that people are fond of. Bovine TB is, however, a major issue as the incidence of TB in the country has been rising and may soon result in the UK losing its TB free status and further impacting upon the meat industry.

The disease is notifiable, and farmers are paid 75% of the average market value of an animal slaughtered by the Government in the case of a reactor (an animal which tests positive for TB). In the case of an animal slaughtered which does not have TB, but which the Government considers needs to be slaughtered because it has come into contact with the disease, the compensation payable is 100% of market value, with no ceiling[18]. Nevertheless, if several TB reactors are slaughtered in a herd, and if a dairy cow is worth, say, £500, a farmer could still stand to lose some thousands of pounds if the return is only 75%.

A. Bovine TB in the UK herd

The incidence of bovine TB had been falling steadily from the time of 1962 when measures were taken to eradicate it, as far as possible, from the UK herd. In 1934 at least 40% of British cows were infected with TB and in the 1930s and 40s there were 50,000 cases of human TB each year[19], though there is no evidence to suggest that these were strongly related. In 1950 the present eradication process began, and by 1960 all herds had been tested twice for TB and all animals which had tested positive, or 'reactors', were slaughtered. The incidence of reactor herds was then about 1 in 50. The incidence of reactor herds in Britain continued to fall over the next ten years, except in South West England, where the situation remained static. The only explanation was that there was another source of infection which was not being treated, and that source underlay the rise. In 1995, 316 new cattle herds in the South-West were confirmed as having TB, an increase of 15% from 1994. Worryingly, 32 new cases were recorded in Hereford (compared to 11 in 1994), 26 of which have so far been attributed to infection by badgers[20]. In 1996 the TB had returned to being present in over 0.5% of herds in the UK and at the level where it triggers action from the international community and Britain is in danger of losing official status as TB-free.

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[18] source: MAFF 20 June 1997

[19] Andrew Turnbull, Disease Control Division of MAFF speaking at the All Party Parliamentary Group for Animal Welfare meeting, 21 May 1996

[20] *Bovine Tuberculosis in Badgers* Nineteenth report by MAFF, July 1996

The Krebs report[21] provides evidence for the transmission of bovine TB from badgers to cattle. The evidence is, however, mainly of a circumstantial nature, proving that infected badgers *can* cause infection of cattle, that infected badgers *can* shed significant amounts of infectious material, that cattle *may* interact with badgers in real situations.

B. Bovine TB and Badgers

As badgers have been identified[22] as, potentially, the main wildlife reservoir for bovine TB there have been sustained efforts to contain the disease within badger populations and a range of methodologies have been used to this end. It was controversy over the extent of badger transmission of bovine TB that led to the Government commissioning the Krebs Report[23],

> 'There is a great deal of circumstantial evidence that badgers are implicated in the transmission of bovine tuberculosis to cattle. Professor Krebs is looking at the incidence of tuberculosis in cattle and badgers and assessing the scientific evidence for the links between them. I expect him to report later this year. We will consider any recommendations Professor Krebs makes very carefully'.

The circumstantial evidence referred to is most compelling when it is realised that approximately 4% of badgers are infected with bovine TB compared to 1.2% of moles, 1.2% of rats and 1% of deer. There has been some evidence that if badgers are culled extensively the incidence of TB in cattle decreases but such evidence is often anecdotal and not supported by proper scientific studies.

1. Badger culling

A 1970-72 study by MAFF vets in Cornwall recommended that wildlife be examined in case any species constituted a reservoir of infection for cattle. In 1973 investigations led the Ministry to conclude that badgers constituted such a reservoir, and that action was required where infected badgers posed a threat to cattle. Badger culling began in 1975 and at the same time the *Consultative Panel on Badgers and Tuberculosis* was established, to provide independent advice to MAFF on the evidence regarding bovine TB and badgers, to recommend appropriate research and to advise on operations undertaken by MAFF to limit the transmission of TB from badgers to cattle. The present members include independent professional zoologists (from universities rather than Ministry scientists), and, among others, representatives of the British Veterinary Association, the Mammal Society, the National Federation of Badger Groups, the Flora and

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[21] Bovine Tuberculosis in Cattle and Badgers, MAFF, 1997.

[22] *Badgers and Bovine Tuberculosis*, Dunnet *et al.*, 1986 and Lord Zuckerman's report, *Badgers, Cattle and Tuberculosis*, 1980

[23] HC Deb 11 June 1997 c506W

Fauna Preservation Society, the National Farmers Union, the Universities Federation for Animal Welfare and the RSPCA.

In 1979-80 gassing was suspended to review[24] whether badger control was still necessary, and could be performed more humanely. The review recommended that control operations should be resumed as soon as possible, but recommended trapping and killing rather than gassing. Today badgers are no longer gassed but lured by using bait into traps, and shot. MAFF currently removes around 2,000 badgers each year compared to around 40,000 killed by cars, out of a total population of around a quarter of a million[25]; the animal is of course highly protected by law.

2. The interim strategy

The Dunnet report in 1986[26] called for the urgent development of a live serological TB test for badgers, so that badgers could be tested for TB without having to kill them. In the meantime, it recommended that culling should be scaled down so that only badgers in the area where cattle breakdowns (proven infections of cattle by TB) had occurred should be removed - previously, badger removal operations might have involved several farms. This is the so-called 'interim strategy'.

3. Present situation and Staffordshire/Derbyshire outbreak

Farmers blame the interim strategy for the increase in TB breakdowns. Because of the poor results with the live test, the worrying rise in cattle breakdowns in Hereford last year and little prospect of vaccines being developed in the near future, the NFU has called for the interim strategy to be abandoned and for a large badger cull to take place, of 10% in areas with the highest population densities[27].

The British Veterinary Association and Royal College of Veterinary Surgeons have in the past expressed support for the policy of restricted culling (i.e. the interim strategy), but saw the need for more vigorous control of those badgers implicated in cattle TB breakdowns[28]. Following the latest developments (the spread of the disease outside the main area of infection in the South West and no prospect of a reliable cattle vaccine for another ten years) the BVA has come under pressure from farmers to take a stronger line. It has now called for an effective return to the pre-Dunnet strategy, i.e., the abandonment of the interim strategy; it believes TB is spreading rapidly

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[24] Lord Zuckerman's report, *Badgers, Cattle and Tuberculosis*, 1980

[25] Andrew Turnbull, Disease Control Division of MAFF speaking at the All Party Parliamentary Group for Animal Welfare meeting, 21 May 1996

[26] *Badgers and Bovine Tuberculosis*, Dunnet *et al.*, 1986

[27] *Independent* 22 June 1996 p.7 'Badgers facing threat of holocaust'

[28] HC Deb 22 May 1997 c169W

and causing farmers unsustainable losses. The BVA wants extensive culling in places where TB in cattle coincides with a high level of infection among the badger population[29];

> 'Until a more effective way of controlling the disease can be found, extended and rigorous culling of badgers in new areas offers the best available control ... Any culling operation must include lactating sows.'

The RSPCA, Mammal Society, The Wildlife Trusts and the National Federation of Badger Groups jointly proposed to MAFF in December 1995 a different solution[30];

- The "interim strategy" was not resulting in a decrease in the incidence of TB - this should be recognised.
- There should be a halt to the culling of badgers - the effect should be monitored.
- There should be improved compensation for farmers and
- Research into the transmission of the disease should be undertaken and recommendations on farming practice should be promoted.
- Research into a vaccine should be continued to provide a long-term solution.

4. The Krebs Report

The report was commissioned by the Ministry of Agriculture Fisheries and Food on the 23rd of July 1996 and announced in a press release[31],

> The Minister of Agriculture, Fisheries and Food, Douglas Hogg, today announced that GB Agriculture Ministers had decided to set up an independent review into the Government's policy on bovine tuberculosis in cattle and badgers.
>
> Replying to a written Question in the House of Commons from Sir James Spicer MP, Mr Hogg said,
>
> "I am pleased to tell my hon friend and the House that, following consultations with interested parties, the Secretaries of State for Scotland and Wales and I have decided to set up an independent scientific review into the policy on TB and badgers. Professor John Krebs, who is Chief Executive of the Natural Environment Research Council has kindly agreed to chair the review, which is expected to report in the early summer next year. The membership of the review team will be announced later, together with the date when the review will commence. The current control policy for bovine tuberculosis will continue for the duration of the review.
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> "The terms of reference for the review will be:

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29 *Times* 6 May 1997 'Vets back demand for badger cull to save cattle from TB'

30 HC Deb 22 May 1997 c167W

31 Independent Review on TB in Cattle Announced (269/96), MAFF, 23rd July 1996.

> 'To review the incidence of tuberculosis in cattle and badgers and assess the scientific evidence for the links between them; to take account of EU policies on reducing and eliminating the incidence of tuberculosis in cattle; to take account of any risk to the human population; and accordingly to review, in the light of scientific evidence, present Government policy on badgers and tuberculosis and to make recommendations.'"
>
> The Minister's announcement coincides with the publication of the 19th report on Bovine Tuberculosis in Badgers. This report describes the work carried out to eradicate sources of TB infection in cattle during the year. It also includes statistics detailing the outbreaks of TB in cattle, the numbers of badgers and other wildlife examined for the disease, and a summary of recent research.

The recommendations are too extensive to replicate here but a series of extracts it is felt necessary to include in this document are presented in Appendix A, the Government's response is provided in Appendix B.

In summary however the report did not make any firm conclusions on how the problem of bovine tuberculosis was to be addressed. The report has recommended a five year programme of experimentation to prove conclusively whether badgers are responsible for the spread of tuberculosis in cattle and whether badger-culling strategies will be effective in reducing the incidence of tuberculosis within cattle.

5. Other Analyses of the Situation

There has been interest in the issue of bovine tuberculosis and the spread of the disease from badgers to cattle from the academic community. One of the major scientific contributions has arisen from Professor Stephen Harris of Bristol University. He has written several scientific papers which address the issue of bovine TB in badgers and analyses the dynamics of the disease within the badger population.

Professor Harris believes[32] that it is necessary to understand the dynamics of the disease within the wildlife reservoir before it can be possible to determine where the blame may lie for the spread of bovine TB or how to effectively tackle the problem without the complete extermination of badgers from areas where cattle are farmed. The simulation models in this experimental work showed that the transmission of bovine TB between such badgers is so difficult that the disease is not self-sustaining within the badger population unless there is a higher density of badgers, i.e., high numbers within a family group and numerous groups whose territories were in contact with other badger groups.

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[32] Bovine tuberculosis in badger (*Meles meles*) populations in south-west England: the use of a spatial stochastic simulation model to understand the dynamics of the disease (1995) Phil. Trans. R. Soc. Lond. B **349** 391-413. PCL White and S Harris.

Transfer of infection between badgers is most likely to occur when there is conflict between badgers of different family groups, such as might occur when there is pressure from cull operations. This is due to the increased number of cuts and abrasions that would be present within both family group members and the spread of infectious bacteria onto grass etc from the infected cuts. Professor Harris has utilised the models of disease transmission constructed in his laboratory to assess the control methodologies that have been utilised in attempts to control bovine TB in the UK[33]. In this Professor Harris makes several recommendations about the control of badger mediated bovine TB including,

- The live test strategy will not lead to significant improvements in the overall disease situation in the south-west. It will result in more badgers being killed each year which will increase disruption to the badger population. This may possibly lead to local increases in the spread of infection following the cessation of control as conflicts spread the disease within family groups and these groups then increase in number after controls are lifted. Control efforts will be targeted less accurately rather than more accurately as was the original intention.
- No reactive strategy based on responsive action to control localised incidences of infection in badgers will provide a long-term solution to the problem of bovine tuberculosis in badgers, whether it is based on culling or vaccination. A pro-active strategy directed in those areas with a recent history of bovine tuberculosis in badgers has a far greater potential for success.
- The most effective strategy for the long-term eradication of bovine tuberculosis from the badger population in south-west England would involve repeated vaccination directed proactively in those areas with a history of bovine tuberculosis infection in badgers.

He also makes a case for better cost benefit analysis of various strategies both in terms of wildlife conservation and farming interests, considering long term requirements in terms of control and compensation.

The effects of farm management are investigated in another research paper[34] where there is a closer investigation of how the bacteria are transmitted from badgers to cattle. Badgers mark their territories in much the same way as many animals, by urination. The urine of infected badgers contains large quantities of *Mycobacterium bovis*, which have been shown to be present in soil for up to two years after marking ceases. This is an obvious route for transmission to cattle, i.e., by grazing from grass contaminated by such urine. A study by Benham and Broom[35] suggested that there is little contact between cattle and badgers, cows

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[33] Bovine tuberculosis in badger (*Meles meles*) populations in south-west England: an assessment of past, present and possible future control strategies using simulation modelling. (1995) Phil. Trans. R. Soc. Lond. B **349** 415-432. PCL White and S Harris.

[34] Effects of farm management practices on cattle grazing behaviour and the potential for transmission of bovine tuberculosis from badgers to cattle (1997) The Veterinary Journal **153:**149-162, MR Hutchings and S Harris.

[35] Responses of dairy cows to badger urine and faeces on pasture with reference to bovine tuberculosis transmission (1991) British Veterinary Journal **147:**517-532, PFJ Benham and DM Broom.

even avoiding areas of pasture contaminated by badger urine and faeces. Professor Harris supplements this data by referring to the facts that such contaminated pasture may be more lush than grazed areas and that cattle may eventually be drawn to more lush pasture despite the evidence of badger excreta. In an experiment conducted under field conditions he showed that there is evidence that there is indeed a considerable contact between grazing cattle and badger excreta, even if such contact was investigative (i.e., nose to sward contact) or cursory grazing.

Professor Harris also concludes from this study that farm management practices had a definite effect on grazing of contaminated sites. Adding an extra field to the grazing field system reduced contact with contaminated sites, though ungrazed sites were often grazed earlier when rotated back to that field (more lush pasture). It is advised that on farms where there are repeated breakdowns that farming practice should be observed to identify high risk grazing and management practices.

The National Federation of Badger Groups, The Mammal Society, The Wildlife Trusts, and the RSPCA replied to the Krebs Report by raising a series of points:

They pointed out the experimental evidence for the effectiveness of culling does not exist, and that after 20 years of culling the situation has not improved. In fact some experiments show culling to exacerbate the incidence of disease and disruption through culling may increase the contact of badger excreta and cattle. Whilst some studies show that cattle avoid badger latrines this is only true for latrines that are being used currently. If badgers subsequently cease using latrines then the scents which discourage grazing will wane despite there remaining a significant risk of infection from bacteria in the soil. Management strategies should be based on clear scientific goals and sound research criteria.

It was also mentioned that compensation to farmers should be full compensation of losses, and should be linked to the take-up of good management practices.

Finally it was stated that there were other factors related to herd breakdown, such as climatic conditions and habitat features, should be taken into account. Climatic conditions have already been claimed to explain the inter-annual variation of herd breakdowns in the south-west of England.

The NFBG endorsed the view expressed both by Professor Krebs and Professor Harris that vaccination of cattle is the only long term solution to the problem, though in the interim the incidence of TB may be decreased through improved husbandry. Husbandry may be improved immediately by the enforced use of passports for cattle which have to contain their TB status and contact.

The Wildlife Trusts have rejected the recommendations of the Krebs Report and have refused to allow culling of badgers on the land they own. They do not believe the proposed experiment will be worth carrying out as there is little chance that either farmers or badger protection groups will allow the experiments to proceed without interference.

Due to the increase in numbers of cattle infected with TB it has been accepted that the disease is spreading from areas where it is has been endemic over the recent past. It is possible that the disease is not spreading but recurring in areas where it has lain dormant for some period due to favourable current conditions. This is a theory which may be easily tested utilising modern molecular technology. If a disease is spreading then it will have a specific "genetic fingerprint" and all infected cattle will have bacteria which posses the same fingerprint. If the rise in cases is due to sporadic outbreaks then the fingerprints will be different in various areas of the country.

The National Farmers Union made the point that if we move to using a vaccine then we will have made the step of accepting that TB is endemic within the UK herd. Obviously if that is what is required to eradicate the damage in both animal welfare and economic terms then perhaps that is a step that must be taken. The bottom line for farmers must be the economic consequences of whatever strategy. If a strategy results in farmers going out of business then it would be unacceptable.

One of the major economic consequences will be the issue of compensation. The NFU believes that there should be a better compensation regime for farmers who are impacted by an outbreak of TB, a call supported by wildlife and badger groups. Some of the issues which are not covered by the recompense of market value are:

- restrictions in stock movement from farm;
- requirement for extra housing when unable to market stock;
- difficulties associated with milk quotas;
- need for additional feed and bedding;
- additional veterinary costs beyond TB concerns;
- arrangements for moving infected cattle from farm.

MAFF has received a number of responses to its consultation which will be made available to public scrutiny in the near future.

V Important Points

1. The incidence of TB in the UK herd is increasing after decades of falling.

2. The cost of compensation is greater than that of researching an effective vaccine or cure.

3. The link between badgers and TB in cattle has not been proven but there is circumstantial evidence that would suggest a link of some kind.

4. It is important that any solution considers all the potential factors: disease transmission, disease vectors, husbandry practices, environmental, and economic.

5. The present spread of the disease may be due to increased cattle movements, or through spontaneous re-occurrence of the disease through climatic change. This needs to be tested by looking at serotypes of the disease present in various parts of the country.

6. Farmers are unlikely to follow scientific procedures unless it makes economic sense to them in the short to medium term. Experiments therefore must take the likely actions of farmers into consideration.

7. Badger culling may be as likely to worsen the spread of TB as to remedy it. Any culling schemes must ensure that culling procedures do not stimulate increased movement of infected badgers outside of their normal ranges.

1. Appendix A

Recommendations from the Krebs Report
(extracts produced verbatim from report)

The link with badgers and other wildlife

We therefore recommend that attribution of the cause of breakdowns should be classified according to the presence or absence of badgers in the area. Information on whether or not infection has been detected (including the severity of any infection) in any badgers present should also be recorded where this information is available, for example from road traffic accident data.

Badgers are not the only wildlife species to carry *M. bovis*. Previous estimates suggest that the prevalence is higher in badgers than in other species. The possibility of other wildlife species acting as reservoirs of infection should be kept under scrutiny. We recommend that the risk to cattle from other species should be assessed in the areas of high herd breakdown risk taking account of four factors:

(i) prevalence of the disease;
(ii) the severity of the disease and its effect on infectivity;
(iii) abundance of the species; and
(iv) the extent of contact with cattle including movement range of the wildlife.

Field studies of badgers

We recommend that future research on badgers should include three priorities:

(i) Extensive surveys that will contribute to how variation between local areas in the risk of herd breakdown is connected with badger presence or absence and variations in the prevalence and severity of the disease in badgers
(ii) Using molecular epidemiology to understand more about the badger to cattle transmission dynamics within intensively studied areas; and
(iii) Estimation of recolonisation times at sites subject to the proactive and reactive culling strategies referred to [later]

Epidemiology of the disease in badgers and cattle

Testing of road traffic accident badgers offers an important source of data on the underlying disease prevalence. We recommend a limited reintroduction of the road traffic accident survey targeting areas with a high or increasing herd breakdown rates and nearby areas with low breakdown rates. Data gathered this way on the prevalence and severity of the disease will allow a more rigorous analysis of the link between herd breakdowns and the prevalence of TB in badgers over time and space.

We recommend that an analysis is carried out to determine the correlates of local variation in risk. Relevant data will include presence/absence of badgers, prevalence and severity of TB in badgers, husbandry, climate and landscape variables. Data should be collected for low and high risk locations. Sources of information would include the data from rigorous attribution of the cause of herd breakdowns (some sampling of badgers would be necessary in low risk areas), the recommended road traffic accident survey and other newly collected information.

Establishing transmission routes is highly desirable, partly because of the implications for husbandry and partly because of the contribution this would make to understanding local variation in risk. We recommend that further consideration should be given to whether appropriate techniques can be developed to research this area.

Molecular typing of the infective agent

We recommend extending the use of these tools to analyse the spatial and temporal dynamics of the disease in badgers and other wildlife as well as cattle. This should be a carefully designed, intensive study over restricted areas. The optimal procedure would involve a combination of two or more methods of molecular typing.

Modelling

The integrative modelling approach is common practice in medical epidemiology and has been used in the analysis for this review. We recommend that its use should be extended to future modelling studies. MAFF should harness external expertise to extend its capacity in this area. We further recommend that there should be better liaison between modellers and MAFF to ensure that the data gathered are better able to meet research needs.

Badger management and control strategies

We recommend a randomised block experiment of three strategies: a reactive culling strategy, a proactive culling strategy, and a no culling strategy.

Ideally recolonisation of setts should be prevented for a period under the reactive strategy. This would be costly. We therefore consider that the costs be balanced against the potential benefits in deciding whether this should be included in the detailed experimental design. In any event, given the lack of data on recolonisation times, we recommend that further research should be done on this in areas subject to both the reactive and proactive control strategies.

Such an experiment would have two key results. First it would provide unambiguous evidence on the role of the badger in cattle TB. Secondly it would provide quantitative data on the cost-benefit analysis of different control strategies, including 'no culling'. Through appropriate modelling, and taking account of the results of the multi-variate analysis of local variations in risk recommended earlier it would provide a basis for determining appropriate policies for both 'hot-spots' and other areas. It is important that MAFF does not delay the start of this experiment. We recommend that it is initiated within four months (by spring 1998).

We recommend that the following measures should be taken to enhance the efficacy of badger removal operations.

(i) The average 41 week delay from the herd breakdown to completion of the badger removal operation is undesirable: targets for reduced delays should be set and monitored for removal operations.

(ii) The use of stop-snaring should be explored as an alternative to trapping where badgers are to be culled, taking account of efficacy, cost and welfare considerations.

We also recommend that further consideration should be given to what farmers themselves can contribute. This is important to secure their ownership of the experimental approach. It is in their interests to ensure that the experiment is properly implemented and not undermined in any way. Farmers might be involved in a number of ways: with MAFF carrying out appropriate training and supervision they could perform a substantial element of the operation (e.g., mapping setts, pre-baiting traps). They might also be involved in identifying and recording badger activity. In addition they could also contribute to the costs.

We recommend that an independent Expert Group, including statisticians and mathematical epidemiologists, should be established to oversee the final detailed experimental design, including the final determination of the areas to be included in the experiment.

On balance we recommend that no culling should be carried out outside the hot-spot areas. Given the low risk of TB breakdown and the even lower risk of repeated breakdown, areas outside the highest risk hot-spots are not best suited for testing culling strategies. The costs of extending the area of the experiment to lower risk areas therefore have to be balanced against the limited value this would add. However, TB incidence in cattle and prevalence in badgers in these areas should be kept under review. We recommend that the Expert Group should keep under review whether there is sufficient evidence that any new herd breakdown areas which are not picked up by the analysis of historical data, might justify inclusion in the experiment.

We recommend the possibility of testing various proactive husbandry strategies should be explored with the farming industry.

Diagnostic tests

The live test for badgers, the so-called BROCK test, detects only about 40% of infected badgers. Development of improved diagnostic techniques could have be an important tool for epidemiological surveillance. In particular a blood based immunological test would be essential to monitor any badger vaccination programme. We recommend that work on development of improved tests for badgers should be pursued in the context of the vaccination programme. This would have a lower priority than development of the vaccine related diagnostic test for cattle.

We also recommend that the scope for using modern DNA amplification techniques, such as the polymerase chain reaction (PCR), for diagnosis should be further explored. The PCR is quicker than microbial culture and can detect the remnants of dead bacteria in addition to living organisms. If sufficiently sensitive, we see two applications for such a test.

(i) It could provide rapid screening of samples from badger carcasses. We suggest MAFF should consider whether this might be an alternative to culture. We estimate that existing assays could be optimised within one to two years.

(ii) MAFF could monitor the presence and distribution of infection by environmental sampling of areas used by badgers.

Vaccines

We recommend that the best prospect for control of TB in the British herd is to develop a cattle vaccine. This is a long term policy and success cannot be guaranteed. But the potential benefits are substantial and we consider this should be a high priority. Currently no money is targeted at this specific area although 26% of MAFF's total TB research budget is spent on the related area of badger vaccines.

The time is ripe to build on the major world-wide current research on human vaccine development: the similarity between *M. bovis* and M. tuberculosis means that results from genome sequencing and identification of antigenic properties are likely to have substantial read-across. We recommend that vaccine development work should be co-ordinated with analogous programmes for human TB and that MAFF should give further consideration on how this might most effectively be achieved, including through the involvement of independent experts. Note should be taken of cattle vaccine work being carried out in other countries, especially New Zealand.

Vaccine development would fall into three phases, each of about five years: identification of candidate vaccines; experimental investigation of vaccination protocols; and field trials. We recommend that the first stage should include research on the immune responses of cattle to *M. bovis* with the aim of identifying antigens which may be useful in vaccination or diagnosis. We also recommend that MAFF should consider how best to ensure effective co-ordination between those responsible for the initial laboratory stage and those responsible for the later stages so that logistical requirements of the implementation are fully taken into account in the early stages.

Our current estimate is that a vaccine for field trials could be available within ten years, if the best groups in the UK were harnessed to work on the problem. However, achieving this timetable will require considerably more resources than the £0.4 million a year currently spent by MAFF. We recommend that progress should be formally reviewed after five years, taking account of developments in wider related areas (including the results of the culling experiments).

If MAFF were to bear the full costs of delivering the vaccination to cattle. Although there could be significant savings in the long term, it would be likely to cost more than the current testing regime in the first few years. Alternatively farmers could bear the cost of vaccination. Once the properties of an effective vaccine are known, a cost-benefit analysis would have to be performed. We recommend that better epidemiological models should be developed to evaluate the level of protection required of a vaccine to obtain significant savings.

Use of a cattle vaccine is effectively prohibited by the current EU legislation because it would compromise the tuberculin skin test. It will be crucial to develop a specific diagnostic test which can detect and differentiate between infected animals, including those that have become infected even after vaccination, and vaccinated animals. A vaccine such as BCG, for example, could result in false positive reactions using the current

tuberculin test. We recommend that such a test should be developed alongside the vaccine. In due course further consideration should also be given to including some form of molecular tag in the vaccine to enable identification of vaccinated animals.

Vaccine requirements for badgers are less demanding than those for cattle. A badger vaccine would require merely reduction of bacterial excretion, whereas a cattle vaccine would require prevention of the establishment of infection. A badger vaccine would also have useful effect in reducing the likelihood of badger to cattle transfer, even if only a proportion of the badger population were vaccinated. We therefore recommend that the option of a badger vaccine, using the information gained in cattle work, should be retained as a fall back position if the cattle vaccine requirements cannot be met.

We further recommend that some work essential to the development of a badger vaccine is pursued in parallel with the cattle vaccine work. In particular it will be essential

(i) to have susceptible badgers and appropriate containment facilities to test candidate vaccines; and

(ii) to develop a blood-based immunological test which would have an important role in monitoring any vaccination programme. As for cattle, such a test would be required to differentiate between naturally infected and vaccinated animals.

There could be commercial interest in developing a cattle vaccine. We recommend that MAFF should explore the possibility of partnership with industry in developing a vaccine.

Biological control

The risk of transmission of human TB is reduced partly by vaccination and partly by the treatment of infections. We recommend that further consideration should be given to developing techniques for reducing TB infection in badgers through biological control, for example using bacteriophages to destroy *M. bovis* in the environment.

Data availability

Key data have not always in the past been readily available to researchers in this area. We have seen welcome signs of a change of approach but recommend that there should be a clear commitment by Government to ensuring data are made available at the earliest possible opportunity. This will ensure that important research opportunities are not lost or postponed and make optimum use of the inevitability limited public resources available for research in this area.

Research

Only 5% of MAFF's £1.7 million TB research budget is currently contracted out. We recommend that MAFF should ensure in future that research is commissioned from those with the best expertise from throughout the UK research community. We also recommend that MAFF should look at partnerships with industry, universities and other funding agencies to develop a more co-ordinated approach.

Over nine times as much money is spent on TB control (£16 million a year) as is spent on TB research in Great Britain. This contrasts with the position in New Zealand where the absolute amount spent on research by the Government is nearly three times as high (£5 million) as in Britain and the amount spent on control is just under twice that spent on research. The money spent on research in Britain is very small given the economic cost of the disease and the uncertainties that surround many key issues. Given the need for substantial continuing research in this area we recommend that the Government should review the amount spent on research in absolute terms and consider whether allocation of resources between research and control is correct and the extent to which it would be reasonable for the main beneficiaries (the farmers) to contribute to the control costs from which they benefit directly.

2. Appendix B

Government Response To The Krebs Report

(reproduced verbatim)

Introduction

1. In November 1996, Professor John Krebs FRS began a scientific review on behalf of the Government into the links between bovine tuberculosis and badgers. His terms of reference were:

> " To review the incidence of tuberculosis in cattle and badgers and assess the scientific evidence for links between them; to take account of EU policies on reducing and eliminating the incidence of tuberculosis in cattle; to take account of any risk to the human population; and accordingly to review, in the light of the scientific evidence, present Government policy on badgers and tuberculosis and to make recommendations".

2. Professor Krebs was assisted in his review by Professor Roy Anderson FRS, Professor Ivan Morrison, Professor Douglas Young, Professor Tim Clutton-Brock FRS, and Dr Christl Donnelly, as well as by two research assistants.

3. The Government is most grateful for the vigour, and rigour with which Professor Krebs and his Team have tackled their remit. It believes that their report represents the best available scientific advice across this area. It follows that the Government is disposed to accept their recommendations in principle, subject to further consideration of the public expenditure, legal and practical implications. Further details of the Government's response to individual recommendations are set out below.

4. The Government also recognises that the subjects covered by the report are of profound concern both to those in badger conservation groups, and to livestock farmers. Account also needs to be taken of the fact that bovine tuberculosis can be transmitted to humans, although the number of cases is very low because of measures such as milk pasteurisation. The Government is therefore setting a period of two months for comments on how the recommendations should be implemented.

5. Comments should be sent to:

Miss G Wahalatantri Ministry of Agriculture, Fisheries and Food, Hook Rise South, Tolworth, Surbiton Surrey KT6 7NF (for recipients in England) or emailed to G.Wahalatantri@AHDC.maff.gov.uk

Mr A J Streeter Welsh Office Agriculture Department Cathays Park Cardiff CF1 3NQ (for recipients in Wales)

Mrs M Bradley Scottish Office Agriculture, Environment and Fisheries Department Pentland House 47 Robb's Loan Edinburgh EH14 1TY (for recipients in Scotland)

by Friday 27 February 1998.

Background

6. The belief that badgers are the main cause of bovine TB is widespread in farming circles, although not universally shared elsewhere. There have been a succession of policies for culling badgers in order to control bovine TB. However, Professor Krebs' review was initiated because:

(a) the link between badgers and bovine TB remained unproven

(b) the only reliable method for showing badgers have bovine TB involved killing them first: the blood test on live badgers was insufficiently sensitive

(c) there was still little sign of a successful vaccine against bovine TB in badgers which had long been seen as the solution

(d) the effectiveness of badger culling remained doubtful
(e) bovine TB was spreading

7. The current policy, known as the "interim strategy", involves the removal and culling of badgers from certain farms. These are farms where there are cases of bovine TB, and where, following an investigation, it is presumed that there is no other cause of the disease than infection from badgers. Notwithstanding the limited badger culling under the "interim strategy", the annual incidence of bovine TB has been increasing in South West England since the late 1980s. In addition, the disease has been spreading to areas where there is no recent history of infection in the West Midlands and South Wales. The number of herds with outbreaks in Great Britain increased from 125 in 1991 to 471 in 1996.

8. Professor Krebs is not the first chairman of a committee which has looked into the links between bovine tuberculosis and badgers. He was preceded by Lord Zuckerman (1980) and Professor Dunnet (1986). This is evidence of the intractability of the problem.

Culling of badgers

9. Professor Krebs' Team points out that although there is substantial evidence for an association between TB infection in badgers and cattle, the evidence that badgers transmit TB to cattle in the natural situation is all indirect. Moreover, even though the sum of evidence strongly supports the view that badgers are a cause of bovine TB outbreaks, there has been no proper experimental study to enable firm conclusions to be drawn about the effectiveness of badger culling. The report therefore recommends that such a trial should be carried out (Chapter 7, Section 14, Recommendation B(i).

10. Outside the areas subject to the trial, it recommends that no badger culling should be undertaken (Recommendation B(ii)), because this is unlikely to add to the information gained from the experiment. The Government accepts this recommendation, pending the results of the culling trial (see paragraphs 12-15 below). The "interim strategy" will therefore be replaced with a "no culling strategy" outside the areas subject to the experiment. However, there will also be further work on improved husbandry in these areas, provided this can be agreed with the farming industry (see paragraphs 16-17 below).

11. This "no culling" policy will apply from now on. However, there are a number of badger removal operations which have already begun under the existing "interim strategy". The Government will, resources permitting, take through to a conclusion those operations which have already been started.

Culling trial

12. The Team recommends that a randomised block experiment be put in place to determine the effectiveness of culling in reducing TB breakdowns in cattle herds (Recommendation B(i)). A minimum of 30 10km by 10km squares would be selected from areas which are bovine TB ‘hot-spots’ ie where there have been large numbers of outbreaks in the recent past. 10 of these would be randomly assigned to a "proactive" strategy of culling of all badgers. A further 10 areas would be randomly assigned to a "reactive" strategy of culling of badgers if there have been cattle TB cases which appear to be associated with badgers. This "reactive" strategy would be an enhanced version of the current "interim" strategy: all of the social groups of badgers with access to the farm where there had been cattle TB would be removed. A final 10 areas would be randomly assigned to a "no culling" strategy.

13. The Government agrees that unless a policy trial of this sort is undertaken, it will not be established with certainty whether culling of badgers influences bovine TB cases; nor, even if it does, whether badger culling is cost effective, and which culling strategy is the more effective. It is therefore favourably disposed to Recommendation B(i), subject to examining in more detail the public expenditure, legal and practical implications of the form of trial recommended. It would expect staff in the MAFF Wildlife Unit currently involved in badger culling to be redeployed to assist with the trial if this goes ahead in the form envisaged.

14. The Government also agrees with Professor Krebs that such a trial should start as soon as is practicable, subject to culling beginning at times of year when the number of lactating sow badgers is minimised (see paragraph 15(c) below).

15. The Team make a number of more detailed recommendations with regard to the trial:

(a) B(i)a that an independent Expert Group be formed to oversee the trial. The Government accepts this recommendation, and will form this Group as soon as possible. The Expert Group will press on with work on detailed design of the trial, but the trial will not begin until after the end of the consultation referred to in paragraph 4.

(b) B(i)b that there should be an estimate of recolonisation times for setts in areas subject to the "reactive" and "proactive" strategies. The Government agrees that better information on recolonisation times would be useful and will consider how this might be done with the expert group.

(c) B(i)c that lactating sow badgers should be culled in the "reactive" and "proactive" trial areas. Under the "interim strategy", such sow badgers are spared, because culling such badgers will also inevitably lead to the death of their cubs. The Team has concluded that the effectiveness of the interim strategy is undermined by failure to remove lactating sows. The Government accepts that culling of such badgers across the country as a whole would be undesirable on welfare grounds. However, it agrees that not culling such badgers in the "reactive" and "proactive" trial areas would reduce the power of the experiment. On these grounds, the Government is inclined to accept the report's recommendation here, but will seek as far as is possible to undertake culling at times of year when the number of lactating sow badgers is minimised.

(d) B(i)d that further measures should be taken to enhance the efficiency of badger removal operations. The Government agrees on the need to avoid delays in carrying out such operations, and will consider whether more can be done within resource constraints. It will also examine how farmers might take a greater part in monitoring badgers and preparing for culling, without compromising badger welfare.

Improved husbandry

16. The Team suggests that improved husbandry methods by cattle farmers may play an important role in reducing bovine TB outbreaks. In particular, it recommends (B(iii)) that MAFF should work with the farming industry to evaluate the effect of different husbandry methods, with the industry taking the lead and primary responsibility for implementation, and MAFF providing advice and determining any incentives that might be provided.

17. The Government has for some time been issuing advice to farmers on keeping badgers and cattle apart. It agrees with Professor Krebs that this advice has not always been heeded, and that farmers should be encouraged to take ownership of this issue. The Government will pursue discussions with the farming industry on establishing an experimental comparison of different husbandry methods. Such an experimental comparison is likely to have to take place outside the areas selected for the culling experiment, to avoid compromising the latter. It will be important for the industry to take the lead here, but the Government will make available advice from MAFF and the independent Expert Group which will be established to oversee the culling policy trial.

Research strategy

18. In addition to the culling experiment, the Team recommends a number of other major initiatives in the field of research into bovine TB. These are set around two main themes: achieving a better understanding of the causes of outbreaks of bovine TB, and developing improved strategies to reduce outbreaks (in particular, through seeking to develop a vaccine to protect cattle against TB). The specific recommendations include:

(a) statistical analysis and epidemiological modelling to assess local variation in risk (recommendation A(i))
(b) application of molecular strain typing techniques (recommendation A(ii))
(c) development of improved tests for detection of *M. Bovis* in badger carcasses and in environmental samples (recommendation A(iii))
(d) development of appropriate techniques for research into bovine TB transmission routes (recommendation A(iv))
(e) analysis of the risk to cattle from wildlife species other than badgers (recommendation A(v))
(f) development of a vaccine to protect cattle against TB (recommendation C(i))
(g) retaining the option of developing a vaccine to protect badgers against TB (recommendation C(ii))

(h) further consideration of reducing TB infection in badgers through biological control (recommendation C(iii))

19. The Team recommends extending the use of integrative modelling in this area (recommendation D(i)).

20. This is a carefully thought through research programme. Some elements are present now in existing MAFF funded research (for example, there is already work on developing a vaccine in badgers), but some are entirely new (for example, work on developing a vaccine in cattle).

21. The Government believes the report's recommendations here provide some very helpful suggestions for the research strategy in this area in the future. This is of course subject to the public expenditure implications, which will have to be looked at carefully. In addition, it will be important for the research programme to remain closely linked with policy. For example, as the Team recognises, development of a cattle vaccine, which could take 15 years, will need to be complemented by further work to enable infected animals to be distinguished from vaccinated animals. This is not possible using the currently available bovine tuberculosis skin test. If an effective vaccine is developed, there would also need to be discussions with the European Commission to seek amendments to current EU legislation so that properly vaccinated cattle would not be subject to trade restrictions.

22. The Government will take forward the recommendations for a bovine TB research strategy as follows:

(a) MAFF will move significantly in the direction of open competition for research in this area, to meet Professor Krebs' recommendation that research should be commissioned from those with best expertise from throughout the research community (D(iii)). In Spring 1998, MAFF will publish a Research Requirements Document including work on TB, which will take account of the Team's recommendations in the TB area. Responses to this document will be evaluated over the Summer of 1998: and the new research programme will begin in April 1999;
(b) the Government will in the meantime discuss with existing contractors how their research in the year April 1998 - March 1999 can take account of the Krebs Report. These discussions with contractors will begin urgently.

23. The Team recommends that MAFF should review the amount spent on research both in absolute terms and as a proportion of the total MAFF TB budget (recommendation D(v)). The Government will undertake such a review as part of the work leading to the putting in place of a new research programme by April 1999. The Government can make no commitments on future levels of expenditure on TB research in advance of that review.

24. The Krebs report draws attention to the mechanisms in New Zealand for contribution by the farming community to the costs of both bovine TB research and bovine TB control (again, recommendation D(v)). The Government is interested by the New Zealand example, and is sympathetic towards the principle of farmers being asked to make a financial contribution to control of a disease when the control programme exists primarily for their benefit. However the practical implications would have to be assessed carefully before such an approach could be adopted in this country.

25. The Team recommends there should be a better co-ordinated approach to research through partnerships with industry, universities and other funding agencies (recommendation D(iv)). There is already regular liaison between MAFF and other UK funders, but the Government will look to build closer links on to the existing arrangements and also to create closer links with international bovine TB research, notably that in New Zealand and the Republic of Ireland.

Other recommendations

26. The Committee notes that in the past data collected by Government on bovine TB have not always been made available to researchers outside Government. It recognises that there have been welcome signs of a change of approach but seeks a clear commitment to accessibility of data in this area (recommendation D(ii)).

27. The Government is happy to give that commitment. It agrees with the principle that data collected using public money should be made available to facilitate research. There will of course be a need to respect legal requirements for example those on data protection and those relating to intellectual property rights, and to take account of resource constraints, but the Government believes this is possible within a general policy of accessibility of data.

28. Finally, the Team recommends that the incidence of bovine tuberculosis in humans should be kept under review in the light of the increasing incidence in cattle (recommendation D(vi)). The Government recognises this is a prudent measure even through the current incidence of bovine TB in humans is very low (only 32 confirmed cases in the UK in 1995, the majority of which were probably the result of reactivation of infection acquired in the past before current control measures such as milk pasteurisation had been introduced). The Government will continue to monitor *M. Bovis* infections in humans as part of the routine surveillance of tuberculosis.

Related issues

29. There are two related issues to be considered in the light of the report.

30. The first is the level of compensation for farmers. At the moment farmers whose cattle are slaughtered because they have bovine TB receive compensation equivalent to either 75% of the animal's market value, or 125% of the average monthly market price two months before valuation, whichever is the less. Cattle slaughtered because they have been in contact with affected animals are compensated at their full market value.

31. The Government recognises that like other diseases, bovine TB is liable to lead to disruption and economic losses. In the light of its provisional conclusions on the Team's report, the Government has considered requests for increasing compensation to farmers. It does not however see grounds for asking taxpayers to meet a larger share of farmers' losses. As the report points out, there are other means in place for ensuring that bovine TB does not pose a threat to public health. In the longer term, the Government will consider whether compensation should be maintained at the same level for those farmers whose husbandry practices take no account of the risk of bovine TB in their herds.

32. The second issue is the future of the Consultative Panel on Badgers and Tuberculosis, commonly known as the Badger Panel. The Panel brings together farming, conservation and animal welfare groups with an interest in badgers and bovine TB. It offers advice to Government. The Panel has not met since Professor Krebs began his work.

33. The Government does not believe that there will continue to be a role for the Badger Panel under the new arrangements. The only areas where badger culling takes place will be subject to the supervision of the Expert Group (paragraph 15(a)). The Government will, of course, continue to consult as necessary on policy on badgers and bovine TB as it does on other policies where there is a wide public interest.

Conclusion

34. The Government believes that the Krebs Team's report provides a good basis for the further work needed to understand the links between badgers and bovine TB and to underpin policies in the longer term. It considers that in the meantime, there will be benefits both from abandoning the "interim strategy" and from a better focussed research programme which offers the prospect of a substantial reduction in disease. It accepts the Team's recommendations in principle, subject to further consideration of the public expenditure, legal and practical implications. The Government also believes that it is in the long term interests of both farmers and those concerned about badger conservation for this further work to be carried out: and in particular, for the proposed trial on the effects of badger culling to proceed as rapidly as possible.

35. It recognises that policy in this area has to proceed through a partnership of Government, farmers and conservation interests. It therefore looks forward to receiving comments by 27 February 1998 on how Professor Krebs' recommendations should be implemented.