Policy statement

British Veterinary Association

BVA policy position on the control and eradication of bovine TB

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Executive summary

Bovine Tuberculosis (bTB) is one of the UK's most challenging animal health and welfare issues. Consequently, the UK veterinary profession has given considerable thought to this issue.

In this paper we have set out 35 recommendations across each aspect on the control and eradication of bTB.

Recommendations

Introduction

1) **The four governments of the United Kingdom should establish structures to ensure ongoing cooperation and collaboration on bTB post EU exit.**

Farmers, vets and behavioural science

2) **Behavioural science should be central to the control, eradication and research of bTB. There should be consideration of the effect on behaviours within the monitoring and evaluation of government programmes. Research into bTB should prioritise interdisciplinary working between vets and social scientists, with research institutions, including funders, developing and embedding structures that enhance interdisciplinary thinking and research.**
3) **To support partnership working, there should be a specific mechanism for direct contact between a named government and named private vet so they can engage more fully and provide joined-up and long-term support to farmers. To facilitate this, government should explore how to introduce systems to allow greater data sharing between government vets and private vets.**
4) **bTB advisor training should be developed in line with the BCVA BVD Free[1] and National Johne's Management Plan[2] initiatives. This should complement the existing programmes and learn from their experiences, e.g. holding practical training workshops which proved beneficial to Cymorth TB training.[3]**
5) **bTB data should routinely be collated, analysed and published showing local parameters such as incidence, average number of reactors and typical duration of restrictions in that area. Private vets should become adept at using these data sources to provide the best advice to their clients and maintain their role as key advisors.**
6) **Knowledge-based trading should be accepted as standard practice with provision made for this to become mandatory. To facilitate this the provision of information must be user-friendly and provided in a timely manner. The expansion of government traceability IT systems should incorporate animal health data at the point of sale.**

[1] British Cattle Veterinary Association, BVDV and BVDFree Scheme Training.

[2] British Cattle Veterinary Association, Johne's Veterinary Advisor Training.

[3] Improve International, OCQ(V) - Cymorth – TB.

7) **Government should secure the long-term funding for dedicated bTB advisory services, providing permanence and assurance for service users and incorporating lessons from social scientists into the wider design.**

8) **Government, in collaboration with industry, should develop a framework of earned recognition based on past performance, implementation of biosecurity measures and local risk factors. It is imperative that the veterinary profession is involved in the development and use of such a programme. The framework should include a practical and accessible scoring system derived from centralised national databases to enable verification and assess compliance. This could build on the lessons of the CHeCS (Cattle Health Certification Standards) TB Herd Accreditation Scheme.[4]**

Bovine Tuberculosis controls in cattle

9) **Farmers should agree and implement a herd policy for introducing any new animals and isolation with their private vet as part of their herd health plan.**

10) **Communication with farmers regarding 'TB confirmed or non-confirmed' should be simplified, to remove unnecessary industry confusion, particularly on the value of different tests. To support this, policy should be aligned with the true value of the Single Intradermal Comparative Cervical Test SICCT by applying the same controls to breakdowns regardless of post-mortem examination or culture results in moderate or high prevalence areas.**

11) **Government should fund, and continue to roll-out, the IFNγ test as a more sensitive supplement to the SICCT and explore the potential for wider use of IFNγ as part of the testing regime, including pre- and post-movement testing and between short interval tests.**

12) **Government should build on the success of the roll-out of IFNγ and encourage research and trials to assess the potential for additional tests or combinations of tests.**

13) **Where possible the results from bTB testing should be automatically shared with a farmer's private vet, to allow a swift, coordinated response between all parties. This would bolster the ability of a farmer's private vet to advise appropriately.**

14) **Government should no longer use the Officially TB Free suspended (OTFS) status for moderate and high bTB prevalence areas and instead use a single status of OFTW.**

15) **Government should evaluate if animals moved off-farm shortly after receiving OTF status pose an increased risk. To support this, the Welsh Government should provide an evaluation of its policy requiring chronic breakdown herds to produce two clear SIT tests and a pre-movement test before movements off farm are permitted.**

16) **Where appropriate, and subject to appropriate partnership working, government should encourage and facilitate the use of private IFNγ testing by farmers and their vets.**

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[4] CHeCS (Cattle Health Certification Standards), bTB Herd Accreditation Scheme.

17) **The relevant authority should permit the exceptional private use of non-approved tests for bTB on cattle under certain conditions, with reactors statutorily notified and the herd remaining OTFW until the usual two tests.**

18) **Government should thoroughly evaluate the effect of the introduction of pre- and post-movement test requirements. This should consider any reduction in new cases of bTB in lower prevalence regions as well as any behavioural changes that may arise from slowing the movement process.**

19) **Government should monitor finishing units to determine if there is an increased risk of infection to both cattle and wildlife and evaluate the policy based on these findings. Government should support research into the effects of approved finishing units on farmer attitudes to risk and behaviours as part of a wider programme of social science research.**

20) **Government should continue to prioritise the development of a cattle vaccine and DIVA test (a test that can differentiate between infected and vaccinated cattle). In the longer term, vaccination of cattle, could play an important role in any bTB eradication policy, alongside other disease control measures.**

Bovine Tuberculosis controls in the badger population

21) **Licences to cull badgers should not be issued until the respective farmers are able to demonstrate appropriate implementation of biosecurity best practice and risk-based trading as part of a wider earned recognition programme.**

22) **Badger culling should be deployed in a targeted, effective and humane manner only where cull design is based on the best available evidence and mitigates against the "perturbation effect". Efforts to further reduce any pain and distress experienced by badgers through cage trapping and shooting should be a priority for government.**

23) **Control activities should be appropriately monitored in order to ensure the effectiveness and humaneness of operations can be assessed during culling operations, and to inform continuous improvement. The appropriate body should put in place the necessary capacity to monitor an adequate proportion of all badger culls.**

24) **Government should prioritise research to evaluate the impact of badger vaccination on bTB incidence in cattle. This evidence should provide a greater understanding of this control method as part of any 'exit strategy' or as a firebreak to stop the spread of the disease into new areas.**

25) **Longer term, research budgets should seek to encourage the development of improved diagnostics for bTB in badgers which could open additional possibilities for control methods.**

26) **The veterinary profession and farming unions should work in partnership to communicate the potential adverse effects of illegal badger culling, highlighting the potential for local increase in the incidence of bTB in cattle.**

Bovine Tuberculosis in species other than cattle and badgers

27) **Government should seek to evaluate and validate existing bTB tests for susceptible non-bovine farmed species. Government should also seek to develop new validated tests for bTB diagnosis in live animals.**

28) Government, industry and the veterinary profession should tailor messages to the farmers of non-bovine farmed species. There should be exploration of providing information to non-bovine farmers through the TB Hub website.

29) Government should enact clear and consistent protocols for bTB in pig herds. Where there is suspicion of bTB in a pig herd, the application of restrictions should be based on an appropriate veterinary risk assessment. Furthermore, government should develop improved and rapid methods to confirm the presence or absence of *M. bovis* in pig carcasses.

30) For farmed and park deer, Government should consider changing the requirement for two clear consecutive bTB tests at 120-day intervals. We recommend that government undertake an appraisal of following the example from New Zealand where 80 days is considered preferable and has proved highly effective.

31) Government should consider the rationale behind the current dispensation from routine SICCT testing afforded to the Chillingham wild white cattle herd and seek to apply it elsewhere following appropriate risk assessment. There is potential merit to applying dispensation for both farmed wild animals, wild deer and zoological collections where the SICCT poses risks for animal welfare and the personal safety of the tester. This should be considered alongside other obligations such as food safety regulations or international trading obligations on animal and public health.

32) Government should evaluate the safeguards in place (including training, qualifications and declarations) to ensure infected wild deer meat does not pose a public health risk through entering the human or pet food chains.

33) Where authorities declare potential bTB hotspots for enhanced surveillance, this should be actively communicated to the deerstalking community to ensure they are vigilant to the signs of bTB in deer.

34) Vets who work with cats and dogs should be vigilant to the risk posed by bTB in these species and be aware of the appropriate reporting process if they suspect the disease.

Research

35) Government should undertake to continue their research and develop a plan which ensures the inclusion of all relevant stakeholders and disciplines in setting priorities.

Research Priorities

This policy position identifies many areas where additional research or evidence would be beneficial. However, it is imperative that the limited resources available for research are directed to those areas which would have the greatest impact. We believe the five key research priorities for the next five years are:

- The development and validation of a cattle vaccine and DIVA test
- Better understanding of the effects of badger vaccination on the incidence of bTB in cattle.
- Evidence to establish the role of cattle faeces in the transmission of bTB
- Better understanding of the causes of repeat breakdowns
- Estimate of the true costs of bTB breakdowns to farms

Introduction

Bovine tuberculosis (bTB) is one of the UK's most challenging animal health and welfare issues, with control measures costing the livestock industry and government millions of pounds a year. Consequently, the UK veterinary profession has given considerable thought to this issue over a number of years. BVA specialist divisions, including the British Cattle Veterinary Association[5] and British Veterinary Zoological Association,[6] have developed considered positions on the control of the disease which have informed this position.

bTB is a devastating chronic disease of cattle and a major challenge facing large parts of the UK cattle farming industry today. bTB is caused by the bacterium, *Mycobacterium bovis (M. bovis*), and advanced infections in cattle result in deterioration in condition, milk yield, and meat quality.

In the UK, the European badger (*Meles meles*) is the principal wildlife reservoir for the bacterium and is implicated in its transmission to cattle. *M. bovis* can also infect a wide range of other mammalian hosts including sheep, goats, pigs, deer, camelids (alpacas & llamas), bison, buffalo, zoo collections and other UK wildlife.

1.1 The human impact of bTB

bTB is a zoonotic disease, which means that it can be transmitted from animals to humans under certain conditions. Before milk pasteurisation became standard practice, bTB was a significant public health problem in the United Kingdom. Today, only a few human infections occur annually in the UK. Between 2009 and 2018 the annual number of new diagnoses of human tuberculosis associated with M. bovis in the UK fluctuated between 25 and 41, with no obvious upward or downward trend. This accounts for approximately 1% of human tuberculosis cases confirmed each year. M. tuberculosis accounts for around 97%.[7] However, a public health risk exists for farmers, vets, vet nurses, meat hygiene inspectors and others working closely with cattle and other susceptible species. There is also a public health risk for those consuming raw milk and raw milk products from infected animals.

There is a wider consequence for human welfare, with a recognised impact on the mental health and well-being of farmers.[8,9] The socio-psychological impacts of bTB are felt in various ways:

- Farmers will feel anxious about a forthcoming inspection and stressed about the increased workload that comes with testing.

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[5] British Cattle Veterinary Association, BCVA bTB Policy Report. 2019 Oct 18.

[6] British Veterinary Zoological Association, BVZS Position Statement on the necessity of wildlife interventions for the control of bovine tuberculosis (*M. bovis* infection) in cattle in the United Kingdom. 2019 Apr.

[7] Public Health England, Tuberculosis caused by Mycobacterium bovis: notification data. 2019.

[8] Crimes D, Enticott G. Assessing the Social and Psychological Impacts of Endemic Animal Disease Amongst Farmers. Frontiers in veterinary science. 2019;6:342. doi: 10.3389/fvets.2019.00342

[9] Bartram DJ, Yadegarfar G, Baldwin DS. A cross-sectional study of mental health and well-being and their associations in the UK veterinary profession. Social psychiatry and psychiatric epidemiology. 2009 Dec 1;44(12):1075. doi: 10.1007/s00127-009-0030-8

- The confirmation of a positive bTB test and seeing their livestock being culled can have emotional impacts on a farmer.
- The incident may also lead to economic pressures as trade is restricted. While compensation is provided for slaughtered cattle, this is unlikely to cover the full cost of replacement or the indirect costs.
- An incident of bTB may also lead to a perceived stigma particularly for those farmers who rely on breeding and showing pedigree animals.
- This can even lead to a breakdown in family relationships and poor mental wellbeing amongst family members.

There is little published academic research into the effect of bTB on farmers' well-being or their ability to work. Some research has highlighted how farmers have become fatalistic, believing there is nothing they can do to prevent a bTB outbreak.[10] Other qualitative research by farming charities concerned with farmers' welfare suggests that bTB is associated with increased levels of anxiety.[11]

There are also effects on the wellbeing of vets who work closely with affected animals[9,12] and can feel trapped "between a rock and a hard place."[13] Additionally, bTB may affect vets' commitment to their profession.[14] As with farmers, understanding how vets manage with the stresses of bTB control is important for the continued management of the disease and provision of veterinary services.

There is also a health and safety risk of physical injury for vets involved in bTB testing. BVA Voice of the Profession statistics[15] show 65% (using a representative sample of the profession) of vets working in clinical practice have been injured by animals in the course of their work over the previous 12 months, with 53% having been injured more than once. Qualitative data from the survey indicated that some vets have received injuries during the bTB testing process.

1.2 The current UK bTB programmes

The UK administrations work to eradicate bTB within a framework specified by the European Union (EU). Deviations from this framework are at present illegal and would impact the UK's ability to trade with other countries in the EU. Trade is impacted because countries protect their national herds from infection by import restrictions on live animals

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[10] Enticott G. The ecological paradox: social and natural consequences of the geographies of animal health promotion. Transactions of the Institute of British geographers. 2008 Oct;33(4):433-46.

doi: 10.1111/j.1475-5661.2008.00321.x

[11] Farm Crisis Network, Stress and Loss: A Report on the Impact of Bovine TB on Farming Families. 2009.

[12] Bartram DJ, Yadegarfar G, Baldwin DS. Psychosocial working conditions and work-related stressors among UK veterinary surgeons. Occupational medicine. 2009 Aug 1;59(5):334-41.

doi: 10.1093/occmed/kqp072

[13] Association of Government Veterinarians, Government Veterinarians Wellbeing Survey. 2019.

[14] Enticott G. International migration by rural professionals: professional subjectivity, disease ecology and veterinary migration from the United Kingdom to New Zealand. Journal of Rural Studies. 2018 Mar 3;59:118-26. doi: 10.1016/j.jrurstud.2018.02.006

[15] British Veterinary Association, BVA News, "Majority of farm animal vets report being injured at work, BVA survey finds". 2019 Jul 19.

and animal products from countries or regions that are not officially tuberculosis free (OTF), and statutory or government measures are required to maintain freedom of trade.

> In the UK, the devolved administrations have responsibility for bTB policy and the variable prevalence of bTB across the UK means that achieving eradication in different regions will be realistic within different timeframes.

The disease is particularly prevalent in the west of England, Wales and Northern Ireland. Scotland has been Officially Tuberculosis Free (OTF) since September 2009. This unique position within the UK is a recognition of the relatively low and stable incidence of bTB found in Scottish herds. This has provided Scotland with the flexibility to better target resources and adopt a risk-based approach to surveillance, providing a model which the rest of the UK could learn from.

Statutory surveillance and testing programmes are in place across the UK in accordance with (and in some cases exceeding) European and international legislation. This approach is based on the use of the comparative skin test, supplemented by the interferon gamma (IFNγ) blood test, to detect infected cattle which are then slaughtered. This is combined with routine post-mortem meat inspection of carcases in slaughterhouses.

Cattle to cattle is the primary transmission route, but the disease can also pass from cattle to badgers and badgers to cattle, through direct or indirect contact.[16] Consequently, there have been attempts to control bTB in the badger population. These efforts have proven to be amongst the most controversial aspects of bTB eradication policy, often overshadowing the extensive efforts of vets and animal keepers to tackle infection in cattle.

1.3 Biosecurity is key

Central to the prevention and management of any infection is good biosecurity, the series of measures that protect against the entry and spread of pests and diseases. Biosecurity practices on livestock farms include sanitation, animal management, feed management, facility maintenance, manure handling, wildlife-proof fencing, and disposal of dead animals.

In order to improve biosecurity on the ground, policies, innovations, and best practices, must be implemented on-farm. Improving understanding, achieving buy-in, and changing the farming practices must form an integral part of improving biosecurity. Vets are the trusted advisors of the farming community and play a vital role in raising the importance of biosecurity.

1.4 The influence of EU exit

EU membership has provided a common framework for bTB control across the UK.

Leaving the European Union (EU) will affect the way bTB is controlled in the UK. Leaving the regulatory framework of the EU can offer new freedoms in how the UK manages infection. However, the freedom to diverge may be limited in practice because, as with all trade, exporters will be expected to meet the requirements of the importing market. While there is uncertainty about the future relationship between the UK and EU, the UK may lose

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[16] Crispell J, Benton CH, Balaz D, et al. Combining genomics and epidemiology to analyse bi-directional transmission of Mycobacterium bovis in a multi-host system. Elife. 2019 Dec 17;8:e45833. [doi: 10.7554/eLife.45833](https://doi.org/10.7554/eLife.45833)

or have limited access to a range of EU systems and organisations that are central to safeguarding public and animal health.

There will be changes to the funding of bTB programmes as the UK leaves the Common Agricultural Policy (CAP) and this presents opportunities for new bespoke funding to support animal health and welfare outcomes in England, Scotland, Wales and Northern Ireland, including the eradication of bTB.

Trade and animal movements within the regions and nations of the UK will remain hugely important for the whole UK economy. Diseases do not respect political borders, meaning that collaboration and shared approaches will continue to be a priority.

Recommendation 1: The four governments of the United Kingdom should establish structures to ensure ongoing cooperation and collaboration on bTB post EU exit.

1.5 An end to blame culture

When something goes wrong, the first question that is often posed is, “Whose fault is it?” Assigning blame seems to be a natural reflex and this has been the case with bTB, where blame is directed either towards farmers or badgers. Where there is blame, open minds close, inquiry tends to cease, and the desire to understand the whole system diminishes. Blame rarely enhances understanding and often hampers effective problem-solving.

Instead, a focus on accountability is needed, which recognises that everyone involved may make mistakes or fall short of commitments. Becoming aware of shortfalls and viewing them as opportunities for learning and growth enables us to be more successful in the future. A culture of accountability therefore creates conditions for ongoing, constructive evaluation and open dialogue in which all stakeholders work together to seek root causes, understand the system better, and identify systemic improvements.

Farmers, vets and behavioural science

1.1 A behavioural approach

Behavioural science can improve understanding of why people act as they do. It can be used to create more effective policy, bringing novel and effective approaches to complex challenges such as the eradication of bTB. A large volume of research, from a range of disciplines, is available on factors influencing attitudes and behaviours. Social science is increasingly seen as an essential tool to tackle challenges such as antimicrobial resistance[17] and climate change.[18] There is growing social science literature on behaviour change within agriculture from researchers based in the UK and worldwide.

Interventions aimed at changing behaviour can play an important role but making permanent changes to long-established habits can be challenging, even when change is perceived as necessary. Outcomes of interventions are difficult to predict, and responses vary by target groups.[18] Behavioural science can be complex but at a basic level the EAST (Easy, Attractive, Social and Timely) framework,[19] developed by the Behavioural Insights Team, can be useful.

Research studies have shown that farmers' actions and choices play a substantial role in determining how livestock diseases spread within and between farms.[20,21,22,23] For example, farmers' livestock trading activities can be responsible for the geographical spread of disease.[24,25] Consequently, influencing the actions of farmers must be considered as an integral part of any programme to limit the spread of infection. More needs to be done to understand the barriers and incentives impacting on farmer behaviour.

The literature on livestock trading regularly addresses farmer behaviour from a biosecurity perspective, which is appropriate as livestock trading is one of the primary means of

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[17] Reyher KK, Barrett DC, Tisdall DA. Achieving responsible antimicrobial use: communicating with farmers. In Practice. 2017 Feb 1;39(2):63-71. doi: 10.1136/inp.j341

[18] Scottish Government, Agriculture and Climate Change: Evidence on Influencing Farmer Behaviours. 2012 Oct 29.

[19] Behavioural Insights Team, EAST: Four simple ways to apply behavioural insights. 2012.

[20] Fournié G, Guitian J, Desvaux S, et al. Interventions for avian influenza A (H5N1) risk management in live bird market networks. Proceedings of the National Academy of Sciences. 2013 May 28;110(22):9177-82. doi: 10.1073/pnas.12208151103

[21] Manabe T, Hanh TT, Lam DM, et al. Knowledge, attitudes, practices and emotional reactions among residents of avian influenza (H5N1) hit communities in Vietnam. PLoS One. 2012;7(10). doi: 10.1371/journal.pone.0047560

[22] Paul M, Baritaux V, Wongnarkpet S, et al. Practices associated with highly pathogenic avian influenza spread in traditional poultry marketing chains: social and economic perspectives. Acta tropica. 2013 Apr 1;126(1):43-53. doi: 10.1016/j.actatropica.2013.01.008

[23] Vernon MC, Keeling MJ. Impact of regulatory perturbations to disease spread through cattle movements in Great Britain. Preventive veterinary medicine. 2012 Jun 1;105(1-2):110-7. doi: 10.1016/j.prevetmed.2011.12.016

[24] Gilbert M, Mitchell A, Bourn D, et al. Cattle movements and bovine tuberculosis in Great Britain. Nature. 2005 May;435(7041):491-6. doi: 10.1038/nature03548

[25] Carrique-Mas JJ, Medley GF, Green LE. Risks for bovine tuberculosis in British cattle farms restocked after the foot and mouth disease epidemic of 2001. Preventive veterinary medicine. 2008 Apr 17;84(1-2):85-93. doi: 10.1016/j.prevetmed.2007.11.001

introducing infection onto a farm. Various practices associated with livestock trading have been previously studied including maintaining a closed herd,[26,27] verifying the disease status of purchased animals,[28,29,30] and considering the disease risk status of source farms and regions[31,32]. Other studies have suggested that farmers perceive these practices as being effective, but often impractical,[33] which may partially explain why farmers may not implement these measures.

Despite this growing literature, there are still few examples where the findings of research have been implemented into practical behaviour change models within agriculture. Consequently, there are few cases where behaviour change policies or programmes have been evaluated.

Farmers, vets and others need to change their actions and choices. Policy needs to enable this by better reflecting the findings of research in order to empower farmers. Three components are needed for a shift to a more behaviour-centred approach, all of which are underpinned by the involvement of the veterinary profession:

- The best advice from trusted sources
- Reliable and accessible local data
- Positive messaging that rewards best practice, including a compensation regime that incentivises behaviour change.

It is important to note that factors other than farmers' attitudes toward biosecurity can contribute to livestock trading behaviours. Studies indicate that wider environmental,

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[26] Sayers RG, Sayers GP, Mee JF, et al. Implementing biosecurity measures on dairy farms in Ireland. The Veterinary Journal. 2013 Aug 1;197(2):259-67.

doi: 10.1016/j.tvjl.2012.11.017

[27] Broughan JM, Maye D, Carmody P, et al. Farm characteristics and farmer perceptions associated with bovine tuberculosis incidents in areas of emerging endemic spread. Preventive veterinary medicine. 2016 Jul 1;129:88-98. doi: 10.1016/j.prevetmed.2016.05.007

[28] Benjamin LA, Fosgate GT, Ward MP, et al. Attitudes towards biosecurity practices relevant to Johne's disease control on beef cattle farms. Preventive veterinary medicine. 2010 May 1;94(3-4):222-30. doi: 10.1016/j.prevetmed.2010.01.001

[29] Ritter C, Jansen J, Roche S, et al. Invited review: Determinants of farmers' adoption of management-based strategies for infectious disease prevention and control. Journal of Dairy Science. 2017 May 1;100(5):3329-47. doi: 10.3168/jds.2016-11977

[30] Young I, Rajić A, Hendrick S, et al. Attitudes towards the Canadian quality milk program and use of good production practices among Canadian dairy producers. Preventive veterinary medicine. 2010 Apr 1;94(1-2):43-53. doi: 10.1016/j.prevetmed.2009.11.018

[31] Hidano A, Carpenter TE, Stevenson MA, Gates MC. Evaluating the efficacy of regionalisation in limiting high-risk livestock trade movements. Preventive Veterinary Medicine. 2016 Oct 1;133:31-41. doi: 10.1016/j.prevetmed.2016.09.015

[32] Little R, Wheeler K, Edge S. Developing a risk-based trading scheme for cattle in England: farmer perspectives on managing trading risk for bovine tuberculosis. Veterinary Record. 2017 Jan 11. doi: 10.1136/vr.103522

[33] McAloon CG, Macken-Walsh Á, Moran L, et al. Johne’s disease in the eyes of Irish cattle farmers: a qualitative narrative research approach to understanding implications for disease management. Preventive veterinary medicine. 2017 Jun 1;141:7-13. doi: 10.1016/j.prevetmed.2017.04.001

social, and cultural factors collectively influence farmers' behaviour.[34] Considering culture is also essential. Hidano et al. (2019) consider farmers' behaviours as influenced by various factors including their identity as farmers, farm environments, and farmer-animal relationships.[35]

Recommendation 2: Behavioural science should be central to the control, eradication and research of bTB. There should be consideration of the effect on behaviours within the monitoring and evaluation of government programmes. Research into bTB should prioritise interdisciplinary working between vets and social scientists, with research institutions, including funders, developing and embedding structures that enhance interdisciplinary thinking and research.

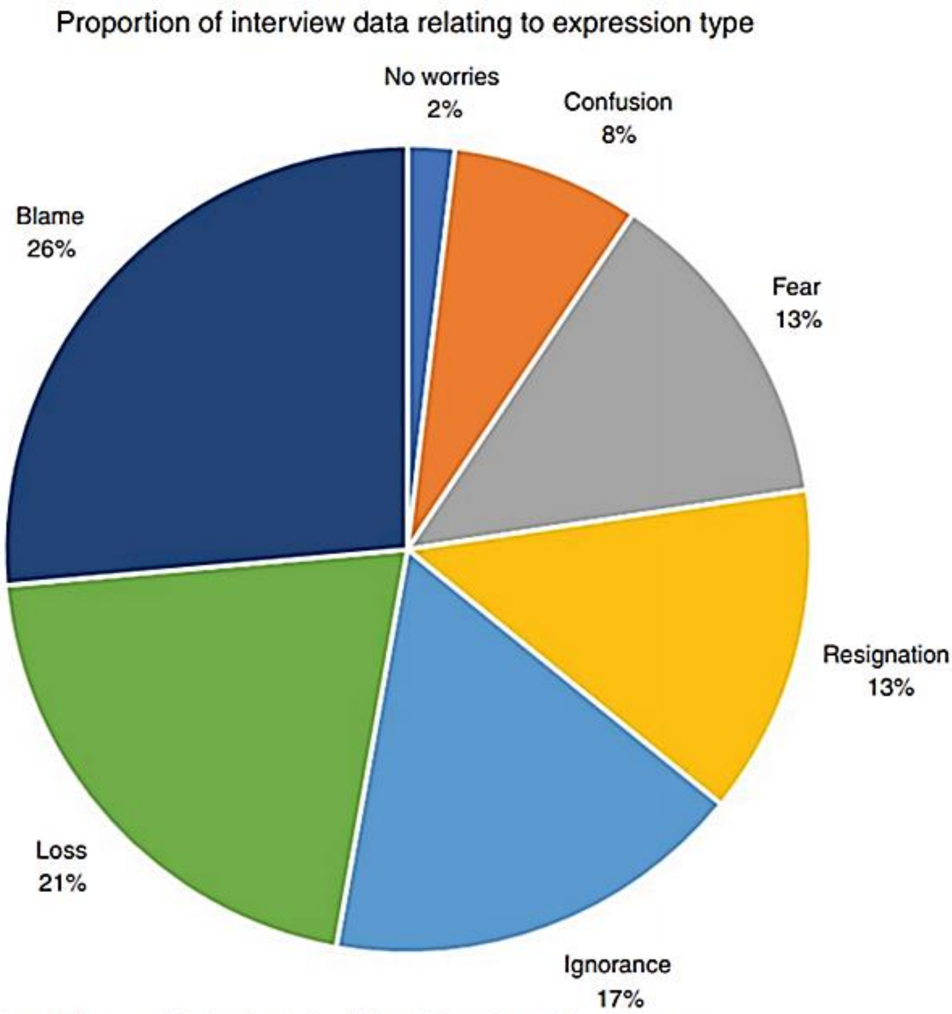
2.2 Farmers' and vets' feelings of negativity towards bTB

The inescapable fact when trying to address bTB is that cattle farmers (and vets) have become discouraged by the lack of progress in tackling the disease. XL Farmcare UK research analysed the feeling of farmers in England towards bTB[36] by interviewing approximately 54 farmers at agricultural shows in Telford, Somerset, Shrewsbury and Stoneleigh. The frequency of words in use was measured to produce a set of common themes, providing an illustration of farmer feelings about bTB.

[34] Burton RJ, Peoples S, Cooper MH. Building 'cowshed cultures': A cultural perspective on the promotion of stockmanship and animal welfare on dairy farms. Journal of Rural Studies. 2012 Apr 1;28(2):174-87. doi: 10.1016/j.jrurstud.2011.12.003

[35] Hidano A, Gates MC, Enticott G. Farmers' decision making on livestock trading practices: cowshed culture and behavioural triggers amongst New Zealand dairy farmers. Frontiers in Veterinary Science. 2019;6:320. doi: 10.3389/fvets.2019.00320

[36] Hamilton L, Evans N, Allcock J. " I don't go to Meetings": understanding farmer perspectives on bovine TB and biosecurity training. The Veterinary Record. 2019;184(13). doi: 10.1136/vr.104995



The typology of feelings towards bovine tuberculosis coded from the interview material and sticky notes.

There is a particularly clear expression of blame, loss, confusion, ignorance, resignation and fear. These findings[36] have identified two key reasons why so many farmers have disengaged from efforts to tackle bTB:

- A plethora of feelings of negativity and powerlessness are set against a sense of personal responsibility and agency. The high level of negativity associated with biosecurity and bTB make it difficult to stimulate positive action, including learning and innovation.
- It is not merely the breadth of negative feeling that exists, but the length of time that the farming community has lived with such negativity that has resulted in 'concern fatigue'. This 'fatigue' has become encultured through repetition in the ways that UK farmers talk about bTB control, prevention and eradication and is exacerbated by the multifactorial nature of biosecurity.[37,38] Also noteworthy is how farmers are spoken to about bTB, including by vets. Language can often be distanced, impersonal or accusatory.

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[37] Lahuerta-Marin A, Brennan ML, Finney G, et al. Key actors in driving behavioural change in relation to on-farm biosecurity; a Northern Ireland perspective. Irish veterinary journal. 2018 Dec 1;71(1):14. doi: 10.1186/s13620-018-0125-1

[38] Brennan ML, Christley RM. Cattle producers' perceptions of biosecurity. BMC veterinary research. 2013 Dec 1;9(1):71. doi: 10.1186/1746-6148-9-71

Butler et al. (2010)[39] showed that innovation in bTB control is less of a priority for farmers than might be expected given the cost, stress and ‘hassle’ that breakdowns routinely generate, which suggests that bTB has been present for so long that farmers are now resigned to living with it.

There are areas where further research to improve the understanding of farmers’ feelings towards bTB and the control programme would be beneficial. For example, having a clearer idea how attitudes vary in different regions of the country would be a useful indicator.

While no similar piece of research has been undertaken to assess the feelings of vets toward bTB, it is not unreasonable to imagine that many vets who have been working closely with farmers suffering bTB breakdowns are likely to share the feelings of powerlessness, resignation and concern fatigue. Furthermore, as vets and farmers work closely together, the feelings of vets might then compound the feelings of the farmers, and vice versa.

2.3 The relationship between farmers and vets

Measures to eradicate bTB are strengthened when farmers and their private vets work together. Farmers see their private vet as a “reliable and trustworthy” source[40] and also understand the importance of local knowledge and familiarity with specific localised bTB situations on a particular farm. Consequently, overly generic messages can be counterproductive as every farm is different. Farmers recognise that private vets can provide tailored advice due to their knowledge of a particular farm or cattle herd.[40]

Consequently, strengthening collaboration between farmers and their private vets has the potential to be pivotal in achieving changes in farmer attitudes and decision making.

Farmers perform a wide range of preventive measures to reduce the risk of bTB and use various sources of information but generally welcome and listen to advice from their vet.[41,42] Private vets are trusted advisors to farmers and uniquely positioned to offer advice and provide essential surveillance services which play a key role in the package of measures necessary to address bTB control and eradication. Vets have a duty to be well informed, unbiased, and to keep up to date with the latest research and best practice guidance. Farmers value local knowledge and the trust attached to a pre-existing relationship

Government vets play an equally essential role as experts in legislation, licensing and risk assessment, outbreak investigation and notifiable disease control. The evaluation of the Cymorth TB programme in Wales found that farmers value the support they receive from

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[39] Butler A, Lobley M, Winter M. Economic Impact Assessment of Bovine Tuberculosis in the South West of England. CRPR Research Paper No 30. Exeter, UK: Exeter University, 2010. doi: 10.22004/ag.econ.94718

[40] Maye D, Enticott G, Naylor R. Using scenario-based influence mapping to examine farmers’ biosecurity behaviour. Land use policy. 2017 Jul 1;66:265-77. doi: 10.1016/j.landusepol.2017.04.026

[41] Pothmann H, Nechanitzky K, Sturmlechner F, Drillich M. Consultancy to dairy farmers relating to animal health and herd health management on small-and medium-sized farms. Journal of dairy science. 2014 Feb 1;97(2):851-60. doi: 10.3168/jds.2013-7364

[42] Frössling J, Nöremark M. Differing perceptions–Swedish farmers’ views of infectious disease control. Veterinary medicine and science. 2016 Feb;2(1):54-68. doi: 10.1002/vms3.20

government vets, noting that farmers see how the work of private vets and government vets, "complemented each other and that collaborative working added value."[43]

Adequate and efficient data sharing between government vets and private vets has been identified as a key enabler to building relationships and delivering improved outcomes. On the other hand, a failure to share data can cause a disconnect between government and private vets and is likely to result in contradictory advice being given to farmers. As Enticott notes, limits on the sharing of government data with private vets can be interpreted by private vets as "a perceived lack of trust in private veterinarians' epidemiological skills by Government".[44] There are legal and regulatory reasons why data sharing is not always possible, but it can easily be misinterpreted as a lack of trust. However, introducing systems to allow data sharing between government vets and private vets should be explored. As a first step, results from routine testing, including a positive result, should be shared with a farmer's private vet to allow a swift, coordinated response between all parties.

Most farmers have a network of influencers who have varying degrees of influence on their decision-making. These may be family, friends, peers, other farmers and, in the case of tenant farmers, the landowner. Especially on larger farms, senior employees will be enabled to make some decisions. There is a need for vets to be mindful of those who have influence on-farm to ensure advice is shared with the correct people when appropriate.

Recommendation 3: To support partnership working, there should be a specific mechanism for direct contact between a named government and named private vet so they can engage more fully and provide joined-up and long-term support to farmers. To facilitate this, government should explore how to introduce systems to allow greater data sharing between government vets and private vets.

2.4 Building capability in the veterinary profession

Farm animal practice continues to evolve. The role of the farm vet is increasingly that of a communicator of knowledge, with herd health planning and advisory work seen as key areas of farm practice. Vets not only identify matters that limit health and productivity but also find solutions and work with their clients to make the necessary changes. Engaging clients to implement changes on-farm can be a challenging yet rewarding element of veterinary practice: achieving improvements in health, welfare and productivity.

Already, through undergraduate training, further CPD and postgraduate qualifications, vets are well-equipped to make accurate diagnoses and offer solutions. Clinicians are also aided by information about their clients' herds, particularly in the dairy sector, where advanced data capture and sophisticated analysis tools are available.

The veterinary curriculum has evolved to place greater emphasis on equipping the profession with appropriate communication, decision making and co-production skills, giving students opportunity to learn how to engage clients and develop solutions together.

Vets should have the knowledge to guide farmers on all aspects of bTB control. This includes knowledge of which interventions reduce the risk from wildlife in different circumstances, and how cattle movement controls can reduce the risk of introducing bTB

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[43] Welsh Government, Cymorth TB Evaluation Report, 2014.

[44] Enticott G, Mitchell A, Wint W, Tait N. Mapping disease data: a usability test of an internet-based system of disease status disclosure. Frontiers in veterinary science. 2018 Jan 5;4:230. doi: 10.3389/fvets.2017.00230

into a herd. The evidence is constantly being updated, and vets are expected to stay up to date on the relevant research and epidemiological reports. There are useful and reliable online information sources to help vets to keep abreast of the latest regulations, research, and best practice guidance.

The TBhub website is a joint industry-government initiative,[45] intended as the 'go-to' place for industry to find advice and information on dealing with the disease. The website was launched as part of a wider cross-industry bTB biosecurity campaign which included the Bovine TB Biosecurity Five Point Plan[46] to improve infection prevention on-farm and in the cattle trade. Since 2015, the website has grown and now hosts information that is primarily aimed at farmers, vets, other advisors and educational providers. In 2020, following feedback from stakeholders, the website was revamped to provide additional support, now covering a very broad range of information about biosecurity measures, bTB testing and cattle trading rules.

The TB Knowledge Exchange website has published a series of fact sheets on some of the topics related to bTB.[47] Each fact sheet is a valuable resource providing a comprehensive yet concise answer to some of the key questions related to each topic.

Vets must use their insight and judgement to take information and apply it to the specific context of each sector, farm and farmer. The skills necessary for this need to be developed over time. Vets understand that farms are complex systems with many people having a role in decision making.

To provide a level of consistency and quality of advice amongst vets in relation to bTB management and control strategies, there are examples that could provide a useful template. BCVA has already delivered advisor training and online accreditation for the BVD Free and National Johne's Management Plan initiatives. This ensures that vets are fully up to speed with the details of disease management and control. It could be replicated to give private vets additional training for bTB and provide a similar level of consistency and quality of advice amongst vets.

Recommendation 4: bTB advisor training should be developed in line with the BCVA BVD Free and National Johne's Management Plan initiatives. This should complement the existing programmes and learn from their experiences, e.g. holding practical training workshops which proved beneficial to Cymorth TB training.

2.5 Reliable and accessible local data

Good decisions are based on reliable, accessible and timely information. Once farmers have access to this information, it can be used to guide trading practices which reduce the risk of introducing bTB into their herds.

Government produces regular epidemiology reports which describe the bTB epidemic in cattle in each part of the UK. These reports include commentary and analyses in light of the associated disease eradication policies and present and discuss the level of disease, change over time, and the impact of control measures.

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[45] Agricultural and Horticultural Development Board (AHDB), with support from Defra, the Animal & Plant Health Agency (APHA), the British Cattle Veterinary Association (BCVA), Landex and the National Farmers Union (NFU).

[46] https://tbhub.co.uk/biosecurity/protect-your-herd-from-tb/

[47] https://www.tbknowledgeexchange.co.uk/tb-fact-sheets/

As Enticott et al.[48] note, a common critique of government bTB policy has been the absence of information given to private vets and farmers about bTB incidents in their local area.[49,50,51] Legislation was amended in October 2014 allowing the government to "publish information regarding that herd in any form that the Secretary of State sees fit for the purpose of helping other persons to protect against the further spread of tuberculosis."[52] A number of tools have been developed to make this information more accessible and farmer focussed.

ibTB is an online interactive mapping tool which, since 2015, has provided information on the geographic location of all herd breakdowns in England and Wales. Vets who were part of the usability trials for ibTB all "welcomed the development of ibTB. Private veterinarians in particular were pleased to be able to see these data, suggesting that the information was vital for them to work with their clients to help them manage bTB."[48] However, ibTB appears to be of limited use at auctions unless the sale is catalogued to allow purchasers to research vendor bTB status in advance[53] and the proportion of farmers using it for risk management is unknown.[54]

The Cattle Health Certification Standards (CHeCS) TB herd accreditation scheme in England and Wales provides participating farms with enhanced biosecurity advice and requires additional post-movement tests beyond regulatory requirements. Farms receive a score reflecting the amount of time since their last herd breakdown, which is used to inform potential purchasers of the low risk of infection spread posed by their cattle. The CHeCs scheme provides an excellent example of risk-based trading and to date has almost 200 accredited herds.

The annual epidemiology report for England published by Defra in 2015 and 2016 included county reports which showed changes and risk factors in the epidemic for each county.[55] Each report had a 'traffic light indicator' showing how the level of bTB in that county compared with others and a series of bullet points and graphics that provided an overview of epidemic behaviour in that county. These enabled individuals to see how their holding compared with others in the county and provided local data for county eradication boards. It is not clear why these have been discontinued.

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[48] Enticott G, Mitchell A, Wint W, Tait N. Mapping disease data: a usability test of an internet-based system of disease status disclosure. Frontiers in veterinary science. 2018 Jan 5;4:230. doi: 10.3389/fvets.2017.00230

[49] Defra, Bovine TB Risk Based Trading Group, Bovine TB Risk-Based Trading: Empowering Farmers to Manage TB Trading Risks. 2013.

[50] Defra, Defra Bovine TB Citizen Dialogue. Cross-Cutting Summary. 2014.

[51] Defra, Draft Strategy for Achieving 'Officially Bovine Tuberculosis-Free' Status for England. Summary of Responses. 2014.

[52] UK Statutory Instruments. The Tuberculosis (England) Order 2014. 2014.

[53] Defra, A strategy for achieving Bovine Tuberculosis Free Status for England: 2018 review. Para: 5.19. 2018 Feb.

[54] Enticott G, National Assembly for Wales, Research Briefing Bovine TB in Wales: governance and risk. 2018 Jan.

[55] APHA, Bovine tuberculosis in England in 2016 County reports Supplement to the epidemiology report. 2017 Nov.

The Behavioural Insights Team[56] emphasises that interventions to change behaviour should be timely, i.e. prompt people when they are most likely to be receptive. When discussing animal movements, that moment is likely to be the point of sale. In future, technology may offer solutions that could incorporate more health data and risk scores at that point. There are systems in place in Northern Ireland (APHIS) and Scotland (ScotEID). Defra and the livestock industry are currently investing in the Livestock Information Service (LIS) which will provide information on the movements of all cattle in the UK linked to electronic identification tags. LIS will have multiple functions, of which providing information that can be used in bTB control will be one of the most important. Building this functionality into existing or new systems will require investment and time.

Behaviour cannot be changed simply by providing more data. It is also necessary to provide farmers with the tools to make use of the data and apply it to the particular context of their herd and any trading decisions. Therefore, as farmers are provided with more information the role of the vet as the key advisor remains and is strengthened. Better data can be utilised by private vets for the following:

- Epidemiological knowledge: Private vets can build up a picture of bTB in their local area and understand its spread.
- Reassurance: Vets can use data to show farmers other herds with bTB breakdowns, thereby helping to reduce the stigma of a TB incident on their farm.
- Advising: Vets may be in a better position to provide bespoke advice to farmers on best practice such as biosecurity and cattle movements in the context of being better informed of the "true" incidence of bTB in their local area.
- Counter misinformation: Farmers are likely to hear rumours[57] that could lead to them being misinformed about the bTB risk in their area. Access to data will allow vets to provide accurate and authoritative evidence to counter misinformation.
- Explaining tests: The regulations around bTB testing are complex. Farmers can be confused about why they must test their herd so soon after their last herd test (this can be due to a new bTB incident on a nearby farm). Vets could use the data to check local bTB incidents to help explain any unexpected tests.
- Farm biosecurity: Vets can use data to help farmers to identify whether they should improve their on-farm biosecurity (because of a nearby bTB incident) or assess the riskiness of potential stock purchases from an area or specific farm.

Recommendation 5: bTB data should routinely be collated, analysed and published showing local parameters such as incidence, average number of reactors and typical duration of restrictions in that area. Private vets should become adept at using these data sources to provide the best advice to their clients and maintain their role as key advisors.

Recommendation 6: Knowledge-based trading should be accepted as standard practice with provision made for this to become mandatory. To facilitate this the provision of information must be user-friendly and provided in a timely manner. The

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[56] The Behavioural Insights Team, EAST Four simple ways to apply behavioural insights. 2014.

[57] Burton RJ. Seeing through the 'good farmer's' eyes: towards developing an understanding of the social symbolic value of 'productivist'behaviour. Sociologia ruralis. 2004 Apr;44(2):195-215. doi: 10.1111/j.1467-9523.2004.00270.x

expansion of government traceability IT systems should incorporate animal health data at the point of sale.

2.6 On-farm advice schemes

As the Bovine TB Strategy Review, led by Professor Charles Godfray, notes, an important part of farmers taking more ownership of the disease is ensuring that they receive the best advice from trusted sources.[58] **Error! Bookmark not defined.** There are web-based advisory services and programmes which seek to provide veterinary advice on farm, which are discussed above. There are a number of sources of practical bTB information for farmers available in different parts of the UK. Each of these methods of delivering advice has strengths and weakness.

The Cymorth TB programme is funded by the Welsh Government. The programme is managed by the Animal and Plant Health Agency (APHA) and delivered by private vets subcontracted to the two Welsh Veterinary Delivery Partners. The programme helps farmers who have TB breakdowns, through their private vets. Farmers receive a free vet visit either during a bTB breakdown and/or when the bTB breakdown has ended. The programme is centred on the fact that a farmer's private vet has local knowledge, an overview of the health of the relevant herd and an established working relationship. The programme requires the private vet to have undertaken additional training before carrying out Cymorth TB visits such that they can advise on disease control measures to help protect cattle and reduce the risk of the bTB infection and aid eradication.[59]

The Welsh Government has developed other Cymorth TB programmes providing additional well-being support for cattle keepers, by contracting with the Farming Community Network. To address the increase in incidence in the Intermediate bTB Area North (ITBAN), additional contiguous testing around Officially bTB Free Withdrawn (OTFW) breakdown herds was introduced on 13 November 2018. To support farmers in this area, government subsidised Cymorth TB 'Keep it out' veterinary visits are being provided to farmers whose cattle have tested negative to a contiguous test.

In October 2017 a three-year contract to run a TB advisory service (TBAS) in England was agreed by Defra, funded by the Rural Development Programme for England (RDPE). TBAS provides free, bespoke advice to cattle keepers in the High-Risk and Edge Areas of England. Farmers can take advantage of a free on-farm advice visit where an experienced adviser assesses the farm at a convenient time for the farmer. The farm receives a bespoke report including recommendations of practical biosecurity measures that can be put in place to reduce the bTB risk on-farm, and a follow-up call from TBAS a few months after the visit. Additionally, TBAS provides a telephone advice service as well as one-to-one advice 'drop-in' clinics.

Both Cymorth TB and TBAS seek to provide a consistent quality of advice to farmers as well as engaging farmers alongside their private vet. In England, consistency is accomplished by utilising a cadre of experienced TBAS advisors who encourage farmers to involve their own vet throughout this process. In Wales, both goals are accomplished as a farmer's private vet provides the guidance having completed the Cymorth TB accredited training.

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[58] Defra, A strategy for achieving Bovine Tuberculosis Free Status for England: 2018 review. Para: 10. 2018 Feb.

[59] Welsh Government & APHA, Cymorth TB Frequently Asked Questions. 2016 Sept.

With both programmes, there have been concerns about uptake amongst farmers and the ongoing implementation of the advice given. The Welsh Government is changing the programme from “an opt-in system to an opt-out system to see if that will make any difference”.[60] The change to an opt-out system is similar to the successful behaviour-based policy used in pension reform.[61]

In Northern Ireland, there is no dedicated online or on-farm advisory service similar to Cymorth TB or TBAS. Currently, farmers can source information and guidance from DAERA's website, on-farm engagement, College of Agriculture, Food and Rural Enterprise (CAFRE) delivered training and publications available at local DAERA offices. However, the TB Eradication Partnership (TBEP) notes this range of information has had limited impact in communicating key messages.[62] In 2019, the TBEP recommended that Northern Ireland should also have a separate dedicated website which should be more user-friendly and provide a positive step in the education of herd owners.

DAERA has developed a bTB Biosecurity Questionnaire for use by farmers, which was introduced under the bTB testing contract. The annual questionnaire is completed for every herd in Northern Ireland by the farmer’s private vet alongside a herd test. The form, completion of which only takes a short time, is designed to start discussion and raise awareness of biosecurity at individual farm level. The questionnaire is for the benefit of the farmer and, to encourage accurate completion, DAERA does not receive a copy of the completed form, which helps to foster trust between the farmer and their vet. However, the TBEP believes that, in its current form, it doesn’t stimulate discussion on infection control and is seen by many as a box-ticking exercise. Feedback from private vets indicates that most herd owners do not answer objectively.

TBEP believes, subject to further training, that private vets are in a unique position to advise their clients on overall infection control and disease prevention, and they have an important role to play in disease investigation. They note that private vets have experienced “frustration and disappointment due to their limited involvement in the TB eradication scheme whereby their role is confined to carrying out the tests.”[62]

Scotland has OTF status and, as such, while vigilance remains essential, there is less need for a dedicated bTB advisory programme. Instead, the Scottish Government, APHA and industry have been able to focus resources and attention on tackling other endemic diseases including BVD.

Recommendation 7: Government should secure the long-term funding for dedicated bTB advisory services, providing permanence and assurance for service users and incorporating lessons from social scientists into the wider design.

2.7 Positive reinforcement and earned recognition

There is evidence from human healthcare that positive messaging (or ‘gain messaging’) influences people’s behaviour more significantly than negative scenarios (‘loss

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[60] Loeb J. Cymorth TB uptake with farmers is' very low'. Veterinary Record. 2019 Oct 18;185(13):390. doi: 10.1136/vr.l5845

[61] Hardcastle R. How Can We Incentivise Pension Saving?: A Behavioural Perspective. Great Britain: Department for Work and Pensions; 2012.

[62] The TB Strategic Partnership Group, Bovine Tuberculosis Eradication Strategy for Northern Ireland. 2016.

messaging').[63] One study argued that gain messages on NHS letters (e.g. if you adopt this behaviour your life will benefit in these ways), rather than loss messages (e.g. if you don't do this, you will suffer from x), were more effective in stimulating uptake of advice on diabetes.[64] The literature, therefore, suggests that there is some benefit in adopting an approach that uses positive language/scenarios to encourage behaviour changes.

Positive reinforcement of behaviours can also be achieved by associating them with positive recognition in the market or as a means to demonstrate compliance. Several papers[65,66,67] have found that compliance was a key determinant of behaviour and financial rewards for behavioural change were also seen as vital. Jones et al.[68] found that dairy farmers in Spain, Sweden, France, and Germany were more likely to prioritise herd health if there was a perceived reward. One means of providing positive reinforcement to farmers for demonstrating appropriate behaviour is via the compensation regime.

Currently, when an animal tests positive for bTB as part of the testing regime, it will be removed and culled. The Government pays statutory compensation when it has deprived someone of their property to help eradicate a disease.[69] The use of compensation has behavioural effects; it encourages participation with the government programme and removes a disincentive to report disease where it is suspected.

Each part of the UK has a different method for determining the value of cattle. In Scotland and Wales, a cap has been set as to the maximum amount that will be paid for a slaughtered animal. In England, the use of monthly valuation tables results in a similar capping and lower average compensation payments than in other parts of the UK[70]. No cap is in place in Northern Ireland, where the full market value, as calculated by a DAERA Valuation Officer, is paid.

In England, Wales and Scotland, governments have introduced new regulations that withhold compensation for those who undertake risky behaviour. For example, in Scotland, provisions have now been introduced to reduce the amount of compensation paid, where an owner has allowed their statutory bTB testing to go overdue by more than 60 days. The

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[63] Rose DC. Keating C. Morris C. Understanding how to influence farmers' decision-making behaviour: a social science literature review, report for the Agriculture and Horticulture Development Board. 2018.

[64] Kullgren JT, Hafez D, Fedewa A, Heisler M. A scoping review of behavioral economic interventions for prevention and treatment of type 2 diabetes mellitus. Current diabetes reports. 2017 Sep 1;17(9):73. doi: 10.1007/s11892-017-0894-z

[65] Cary J, Roberts A. The limitations of environmental management systems in Australian agriculture. Journal of Environmental Management. 2011 Mar 1;92(3):878-85. doi: 10.1016/j.jenvman.2010.10.055

[66] Gourdet CK, Chriqui JF, Piekarz E, et al. Carrots and sticks: compliance provisions in state competitive food laws—examples for state and local implementation of the updated USDA standards. Journal of school health. 2014 Jul;84(7):466-71. doi: 10.1111/josh.12168

[67] Prager K, Curfs M. Using mental models to understand soil management. Soil Use and Management. 2016 Mar;32(1):36-44. doi: 10.1111/sum.12244

[68] Jones PJ, Sok J, Tranter RB, et al. Assessing, and understanding, European organic dairy farmers' intentions to improve herd health. Preventive Veterinary Medicine. 2016 Oct 1;133:84-96. doi: 10.1016/j.prevetmed.2016.08.005

[69] Hansard. House of Commons, Vol 670, Col 340WH. 2020 Jan 29.

[70] European Court of Auditors, Special report 06/2016: Eradication, control and monitoring programmes to contain animal diseases. 2016.

reduction is applied on a sliding scale which means that the longer the delay in testing the greater the reduction in compensation.

In England, the compensation regime has been used to encourage membership of the bTB health scheme accredited under the Cattle Health Certification Standards (CHeCS). A 50% reduction in compensation payment on animals purchased after the onset of a TB breakdown does not apply where the herd is accredited under the scheme, provided that accreditation was gained prior to the herd losing its OTF status.

This approach should be expanded and integrated within a wider system of "earned recognition" based on the past performance, biosecurity measures and local risk faced by each farm. This would allow more positive messaging to be deployed: rewarding farmers for best practice instead of just applying penalties.

This system should be simple and clear for farmers and their private vet, perhaps taking inspiration from New Zealand where all cattle herds receive an individual ranking, known as the 'C Score' indicating the number of years they have been clear of bTB (e.g. C7 is 7 years free) up to a maximum of 10 years. Infected herds are ranked similarly, for example, I2 is a herd infected for two years. A system could be applied to the UK with performance linked to increased bTB testing intervals as well as part of information-based trading schemes and compensation eligibility.

Recommendation 8: Government, in collaboration with industry, should develop a framework of earned recognition based on past performance, implementation of biosecurity measures and local risk factors. It is imperative that the veterinary profession is involved in the development and use of such a programme. The framework should include a practical and accessible scoring system derived from centralised national databases to enable verification and assess compliance. This could build on the lessons of the CHeCS (Cattle Health Certification Standards) TB Herd Accreditation Scheme.[71]

[71] CHeCS (Cattle Health Certification Standards), bTB Herd Accreditation Scheme.

Bovine Tuberculosis controls in cattle

There is a complex system of cattle controls across the nations and regions of the UK, with a range of approaches that have evolved over time in response to improved understanding of the infection and both local and regional risk factors.

3.1 Cattle biosecurity

Central to the prevention and management of any infection is good biosecurity, the series of measures that protect against the entry and spread of pests and diseases. In order to improve biosecurity on the ground, policies, innovations, and best practices, must be implemented on-farm.

According to the study by Crispell et al. (2019),[16] the majority of bTB transmission is within species, both cattle to cattle and badger to badger. This confirms that transmission within the cattle population is important for spreading bTB. One of the greatest threats to the health status of an established herd is through contact with cattle from outside of the herd. In the context of bTB control, improving biosecurity involves stopping TB-infected cattle entering the herd and reducing the bTB risk from neighbouring cattle herds. There is also increasing awareness of the potential infection risk posed by manure from bTB infected cattle.

When cattle enter a farm, they should ideally be quarantined from other cattle in the herd to ensure that they are not able to transmit any infection (not just bTB) and to give time to perform tests. This applies to all cattle entering the herd, including newly purchased stock, hired bulls, and cattle that are already under the same herd ownership but that return from being away, e.g. from shows, markets, common grazing and from other premises. The risk is greater for purchased stock and hired bulls than for animals that have been off the farm for a short time, nevertheless, it is important to assume that even short spells off-farm can give the opportunity for infection at other premises.[72]

The practicality of quarantining cattle depends upon several factors, including the number of animals purchased, their purpose (management stage) within the herd and the availability of suitable isolation facilities. Therefore, if isolation cannot be achieved then considering a post movement test 60 days after arrival should be considered to reduce the risk of an undisclosed reactor becoming a shedder into the herd.

On-farm isolation facilities should be physically separate from any buildings used for other livestock.[72] Facilities should have solid walls, and no shared airspace, water supply, or drainage with other animal accommodation. All discharges, effluent and manure should be retained in the building or disposed of in such a way that they do not encounter other livestock. Where fields are used to isolate bought-in animals, they should be physically separate from any fields or buildings used for other livestock on the premises.

Effective barriers between neighbouring herds is another important biosecurity measure. The study on herd-level risk factors after the 2001 foot-and-mouth disease epidemic reported that contacts with cattle from contiguous herds and sourcing cattle from herds with a recent bTB history were associated with an increased risk of a bTB breakdown.[73]

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[72] TBhub, Responsible cattle movements.

[73] Johnston WT, Vial F, Gettinby G, et al. Herd-level risk factors of bovine tuberculosis in England and Wales after the 2001 foot-and-mouth disease epidemic. International Journal of Infectious Diseases. 2011 Dec 1;15(12):e833-40. doi: 10.1016/j.ijid.2011.08.004

The review of cattle-to-cattle transmission, risk factors and susceptibility recommended that secure fencing and physical barriers between herds should be enforced.[74]

Recommendation 9: Farmers should agree and implement a herd policy for introducing any new animals and isolation with their private vet as part of their herd health plan.

3.1.1 Faeces

Research suggests that *M. bovis* can survive in stored slurry for up to six months.[75] On pasture, *M. bovis* can survive in cattle faeces for up to two months in warm summer conditions and up to 5-6 months in cold winter conditions.[76] Survival of *M. bovis* is typically higher in cool, moist, dark conditions and lower in hot, dry, sunny conditions.

Solid manure goes through a composting process resulting in high temperatures of 50°C+ which will likely kill the bacteria. However, composting conditions can be variable, so it is possible that it could survive in parts of a manure stack. The risk of infection from manure is believed to be lower than from slurry, but bTB transmission from manure is still possible.

The full risk of infection with different cattle manure systems is not fully understood, and further research examining this would be beneficial. However, farmers can take steps to reduce any potential risk of infection by properly storing slurry for more than six months and ensuring full composting of solid manure before use.[77]

3.2 Testing cattle for bTB

The success of any system of bTB controls in cattle is underpinned by our ability to detect the presence of infection, primarily at herd level but also in individual live animals. Surveillance is also undertaken on carcasses in slaughterhouses.

It is vital to understand the specific context and establish clear goals before considering which test or tests should be applied. Different tests have different strengths and weaknesses that determine their suitability in different situations.

As is the case for any disease, tests for bTB would ideally provide both high sensitivity and high specificity. However, no currently available test can provide 100% sensitivity and specificity. This means there is a need to prioritise outcomes. If the priority is to detect as many bTB infected cattle as possible, a highly sensitive test is the appropriate tool. If the priority is to avoid removing uninfected cattle, then a highly specific test should be applied.

The choice of test may also have implications for international trade, where a prescribed test is required. A prescribed test is one where the test validation data has been accepted as meeting international standards by the World Organisation for Animal Health (OIE) and it has been officially adopted by the national competent authority for statutory use. Where a test has neither been prescribed nor EU approved, the results of that test cannot be

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[74] Skuce RA, Allen AR, McDowell SW, Branch B. Bovine tuberculosis (TB): a review of cattle-to-cattle transmission, risk factors and susceptibility. Bacteriology Branch Veterinary Sciences Division Agrifood and Biosciences Institute. 2011 Oct.

[75] Scanlon MP, Quinn PJ. The survival of Mycobacterium bovis in sterilized cattle slurry and its relevance to the persistence of this pathogen in the environment. Irish Veterinary Journal. 2000;53(8):412-5.

[76] Williams RS, Hoy WA. The viability of B. tuberculosis (bovinus) on pasture land, in stored faeces and in liquid manure. Epidemiology & Infection. 1930 Nov;30(4):413-9. doi: 10.1017/S0022172400010561

[77] Phillips CJ, Foster CR, Morris PA, Teverson R. The transmission of Mycobacterium bovis infection to cattle. Research in veterinary science. 2003 Feb 1;74(1):1-5. doi: 10.1016/S0034-5288(02)00145-5

utilised to demonstrate an individual animal, herd, or region is free from bTB for trade purposes. Therefore, this could limit the ability to trade internationally.

Other factors also influence the appropriateness of any test and how widely it can be rolled out for statutory use. These include the complexity, cost of delivery and whether there is enough laboratory infrastructure to process the expected number of samples and expand in the event of increased demand. A key consideration is also the health and safety of those involved in administering the tests.[78]

3.2.1 The Single Intradermal Comparative Cervical Test (SICCT)

Across the UK the SICCT is the primary test utilised as part of government bTB eradication programmes. The test has been validated for use in cattle and can be delivered by Official Veterinarians (OVs) and Approved Veterinary Surgeons (AVS) in Northern Ireland.[79] In England, Scotland and Wales, Approved Tuberculin Testers (ATTs) working under the supervision of APHA vets can also deliver the test. Non-veterinary, paraprofessional testers are not used in Northern Ireland, although a pilot was carried out in 2011.

Following a public consultation in 2018, a pilot study ran from December 2018 to February 2020 to evaluate the use of ATTs in private veterinary practices in England. BVA indicated broad support for the study, subject to appropriate checks and balances being in place. APHAAPHA reported that the pilot had been very successful and recommended that the use of ATTs should be rolled out more widely across veterinary businesses in England, subject to certain conditions. This recommendation has been approved and rollout should commence from late 2020.[80]

SICCT makes use of a cocktail of proteins (termed tuberculin or Purified Protein Derivative, PPD) obtained from cultures of M. bovis. Two types of tuberculin are utilised *M. bovis* and *M. avium*. If an animal has acquired immunity against these mycobacteria from previous exposure, then it will react to the injection of tuberculin into the skin by producing a local swelling. *M. bovis* and *M. avium* derived tuberculins are injected adjacently into the skin of the animal's neck according to a set protocol. A comparison of the immune reaction in the skin is made three days later.

An animal is classed using the below table in England and Scotland.[81] This compares the response of the *M. bovis* tuberculin, i.e. a swelling or lump that can be measured using callipers, to the response to *M. avium* tuberculin. This process relies on the interpretation of the professional undertaking the test. The diagram below illustrates the complexity in undertaking the test at different levels of interpretation. Because of this complexity, human error can also mean that infected animals are not identified.

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[78] BVA, Voice of the Veterinary Profession Panel Autumn 2018 Survey Report, where 61% of large animal vets experienced an injury in the course of their work during the previous year.

[79] These are private practice veterinary surgeons who perform work on behalf of the state.

[80] APHA, APHA Briefing Note 05/20: Outcome of the pilot to explore the use of Approved Tuberculin Testers (ATTs) in private veterinary businesses to carry out tuberculin skin testing of cattle in England. 2020 Mar 18.

[81] APHA, http://apha.defra.gov.uk/external-operations-admin/library/documents/tuberculosis/TB64(ES).pdf

TB 64 (ENG/SCOT)

TO BE USED WHEN READING TB TESTS AT STANDARD ***AND*** AT SEVERE INTERPRETATION IN ENGLAND AND SCOTLAND ONLY FROM 01/01/2010.

Standard and Severe Interpretation in England and Scotland

Bovine increase (and description of reaction)			Avian 0 C (-)	Avian 0 SO (+)	Avian 1 C (-)	Avian 1 SO (+)	Avian 2 C (-)	Avian 2 SO (+)	Avian 3 C/SO (+)	Avian 4 C/SO (+)	Avian 5 C/SO (+)	Avian 6 C/SO (+)	Avian 7 C/SO (+)	Avian 8 C/SO (+)	Avian 9 C/SO (+)	Avian 10 C/SO (+)
10	SO / C	+	R	R	R	R	R	R	R	R	R	I	I	I	I	--
9	SO / C	+	R	R	R	R	R	R	R	R	I	I	I	I	--	--
8	SO / C	+	R	R	R	R	R	R	R	I	I	I	I	--	--	--
7	SO / C	+	R	R	R	R	R	R	I	I	I	I	--	--	--	--
6	SO / C	+	R	R	R	R	I	I	I	I	I	--	--	--	--	--
5	SO / C	+	R	R	I	I	I	I	I	I	--	--	--	--	--	--
4	SO / C	+	I	I	I	I	I	I	I	--	--	--	--	--	--	--
3	SO / C	+	I	I	I	I	I	I	--	--	--	--	--	--	--	--
2	SO	+	I	I	I	I	I	--	--	--	--	--	--	--	--	--
2	C	-	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1	SO	+	I	I	I	--	I	--	--	--	--	--	--	--	--	--
1	C	-	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0	SO	+	I	--	I	--	I	--	--	--	--	--	--	--	--	--
0	C	-	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Avian increase (and description of reaction)

* C = No oedema (i.e. Circumscribed or none), SO = Some oedema (SO)

** + = Positive Reaction, - = Negative Reaction

R Reactor (Fail - remove)

I Inconclusive Reactor at standard and severe interpretation (IR - retest)

-- Pass (retain)

I Inconclusive reactor (IR) at standard int., **reactor at severe int.**

TB64 (Eng/Scot) (01/10)

Animal and Plant Health Agency, TB64(ES) - Interpretation Guide Card (England and Scotland) http://apha.defra.gov.uk/external-operations-admin/library/documents/tuberculosis/TB64(ES).pdf

Standard interpretation

Bovine Increase (and description of reaction)	*	**	Avian 0 C -	Avian 0 SO +	Avian 1 C -	Avian 1 SO +	Avian 2 C -	Avian 2 SO +	Avian 3 C/SO +	Avian 4 C/SO +	Avian 5 C/SO +	Avian 6 C/SO +	Avian 7 C/SO +	Avian 8 C/SO +	Avian 9 C/SO +	Avian 10 C/SO +
10	SO/C	+	R	R	R	R	R	R	R	R	R	I	I	I	I	- -
9	SO/C	+	R	R	R	R	R	R	R	R	I	I	I	I	- -	- -
8	SO/C	+	R	R	R	R	R	R	R	I	I	I	I	- -	- -	- -
7	SO/C	+	R	R	R	R	R	R	I	I	I	I	- -	- -	- -	- -
6	SO/C	+	R	R	R	R	I	I	I	I	I	- -	- -	- -	- -	- -
5	SO/C	+	R	R	I	I	I	I	I	I	- -	- -	- -	- -	- -	- -
4	SO/C	+	I	I	I	I	I	I	I	- -	- -	- -	- -	- -	- -	- -
3	SO/C	+	I	I	I	I	I	I	- -	- -	- -	- -	- -	- -	- -	- -
2	SO	+	I	I	I	I	I	- -	- -	- -	- -	- -	- -	- -	- -	- -
2	C	-	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
1	SO	+	I	I	I	- -	I	- -	- -	- -	- -	- -	- -	- -	- -	- -
1	C	-	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
0	SO	+	I	- -	I	- -	I	- -	- -	- -	- -	- -	- -	- -	- -	- -
0	C	-	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

Avian Increase (and description of reaction)

* C = No oedema (i.e. Circumscribed or none), SO = Some oedema (SO)

** + = Positive Reaction, - = Negative Reaction

R Reactor (Fail - Remove)

I Inconclusive Reactor (I/R - Retest)

- - Pass (Retain)

TB 64(W) (Rev. 7/06)

Severe interpretation

Bovine Increase (and description of reaction)	*	**	Avian 0 C -	Avian 0 SO +	Avian 1 C -	Avian 1 SO +	Avian 2 C -	Avian 2 SO +	Avian 3 C/SO +	Avian 4 C/SO +	Avian 5 C/SO +	Avian 6 C/SO +	Avian 7 C/SO +	Avian 8 C/SO +	Avian 9 C/SO +	Avian 10 C/SO +
10	SO/C	+	R	R	R	R	R	R	R	R	R	R	R	I	I	I
9	SO/C	+	R	R	R	R	R	R	R	R	R	R	I	I	I	I
8	SO/C	+	R	R	R	R	R	R	R	R	R	I	I	I	I	I
7	SO/C	+	R	R	R	R	R	R	R	R	I	I	I	I	I	- -
6	SO/C	+	R	R	R	R	R	R	R	I	I	I	I	I	- -	- -
5	SO/C	+	R	R	R	R	R	R	I	I	I	I	I	- -	- -	- -
4	SO/C	+	R	R	R	R	R	I	I	I	I	I	- -	- -	- -	- -
3	SO/C	+	R	R	R	I	R	I	I	I	I	- -	- -	- -	- -	- -
2	SO	+	R	I	R	I	R	I	I	I	- -	- -	- -	- -	- -	- -
2	C	-	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
1	SO	+	R	I	R	I	R	I	I	- -	- -	- -	- -	- -	- -	- -
1	C	-	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
0	SO	+	R	I	R	I	R	I	- -	- -	- -	- -	- -	- -	- -	- -
0	C	-	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

Avian Increase (and description of reaction)

* C = No oedema (i.e. Circumscribed or none), SO = Some oedema (SO)

** + = Positive Reaction, - = Negative Reaction

R Reactor (Fail - Remove)

I Inconclusive Reactor (I/R - Retest)

- - Pass (Retain)

TB 64(W) (Rev. 7/06)

[Animal and Plant Health Agency TB64(W) - Interpretation Guide Card (Wales)]

At standard interpretation, the skin test has a high specificity reported to be around 99.98%[82]. Test sensitivity is more variable and is within the range of 50-80% at standard interpretation, depending on the stage/severity of infection and other factors.[83,84]

A single round of SICCT testing may not detect all infected animals in a herd. Some animals may be tested while infected but within the 3-6 weeks period before developing an immune response that can be detected by the SICCT. Furthermore, if an injection is administered too soon after the previous test without sufficient time for the animal's immune system to recover, this can result in failure to react and therefore to identify infected cattle as reactors. Therefore, there is a required minimum period of 60 days between skin tests, to reduce the potential for such desensitisation. There is also evidence that the bacterium which causes Johne's disease (*Mycobacterium avium* subspecies paratuberculosis (MAP)) may interfere with the test.[85,86,87,88,89]

The more infected animals in a herd, the greater the chance that at least one of them will be detected. This means that SICCT is good at detecting infected herds, even though all infected animals in a herd will not always be identified.

The SICCT can detect infected cattle long before they develop signs of clinical disease. This means that cattle can be culled before serious animal welfare concerns develop the opportunity for infection to spread to more animals is reduced.

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[82] Goodchild AV, Downs SH, Upton P, et al. Specificity of the comparative skin test for bovine tuberculosis in Great Britain. The Veterinary Record. 2015 Sep 12;177(10):258. doi: 10.1136/vr.102961

[83] Karolemeas K, de la Rua-Domenech R, Cooper R, et al. Estimation of the relative sensitivity of the comparative tuberculin skin test in tuberculous cattle herds subjected to depopulation. PloS one. 2012 Aug 21;7(8):e43217. doi: 10.1371/journal.pone.0043217

[84] Nunez-Garcia J, Downs SH, Parry JE, et al. Meta-analyses of the sensitivity and specificity of ante-mortem and post-mortem diagnostic tests for bovine tuberculosis in the UK and Ireland. Preventive Veterinary Medicine. 2018 May 1;153:94-107. doi: 10.1016/j.prevetmed.2017.02.017

[85] Dunn JR, Kaneene JB, Grooms DL, et al. Effects of positive results for Mycobacterium avium subsp paratuberculosis as determined by microbial culture of feces or antibody ELISA on results of caudal fold tuberculin test and interferon-γ assay for tuberculosis in cattle. Journal of the American Veterinary Medical Association. 2005 Feb 1;226(3):429-35. doi: 10.2460/javma.2005.226.429

[86] Hope JC, Thom ML, Villarreal-Ramos B, et al. Exposure to Mycobacterium avium induces low-level protection from Mycobacterium bovis infection but compromises diagnosis of disease in cattle. Clinical & Experimental Immunology. 2005 Sep;141(3):432-9.

doi: 10.1111/j.1365-2249.2005.02882.x

[87] Aranaz A, Bezos J, Álvarez J, et al. Assessment of diagnostic tools for eradication of bovine tuberculosis in cattle co-infected with Mycobacterium bovis and M. avium subsp. paratuberculosis. Veterinary research. 2006 Jul 1;37(4):593-606. doi: 10.1051/vetres:2006021

[88] Álvarez J, de Juan L, Bezos J, et al. Effect of paratuberculosis on the diagnosis of bovine tuberculosis in a cattle herd with a mixed infection using interferon-gamma detection assay. Veterinary microbiology. 2009 Mar 30;135(3-4):389-93. doi: 10.1016/j.vetmic.2008.09.060

[89] Roupie V, Alonso-Velasco E, Van Der Heyden S, et al. Evaluation of mycobacteria-specific gamma interferon and antibody responses before and after a single intradermal skin test in cattle naturally exposed to M. avium subsp. paratuberculosis and experimentally infected with M. bovis. Veterinary immunology and immunopathology. 2018 Feb 1;196:35-47. doi: 10.1016/j.vetimm.2017.12.007

Approximately 60% of SICCT reactors show no visible/typical signs of bTB in their organs at meat inspection in the slaughterhouse.[90] These are known as 'Non-visible Lesion' (NVL) reactors and in moderate to high bTB prevalence areas they usually represent early *M. bovis* infections (due to the poor sensitivity of meat inspection in detecting small localised bTB lesions), rather than false positive results.[91] This relatively high percentage of NVL reactors can lead to mistrust in the test that underpins the UK bTB programme. However, it is important to remember that the main purpose of post-mortem examination is not to confirm the findings of the SICCT, but to assess the severity of infection in the slaughtered animals and, where required, collect tissue samples for culture and molecular typing of *M. bovis* to support epidemiological investigations into the sources of infection.

Recommendation 10: Communication with farmers regarding 'TB confirmed or non-confirmed' should be simplified, to remove unnecessary industry confusion, particularly on the value of different tests. To support this, policy should be aligned with the true value of the Single Intradermal Comparative Cervical Test SICCT by applying the same controls to breakdowns regardless of post-mortem examination or culture results in moderate or high prevalence areas.

3.2.2 Interferon-gamma (IFNγ) test

The second official (prescribed) test for bTB in cattle in the UK is the interferon-gamma blood test (IFNγ), a supplementary blood test used in addition to the SICCT. It is approved for use in cattle by the OIE and is the only blood test currently approved in the EU to supplement the SICCT for bTB in cattle. It is used for statutory testing in the UK. The IFNγ test is more sensitive than SICCT, with around 90% sensitivity. It is however, slightly less specific (96.6%) than the SICCT. [92]

As with the SICCT, IFNγ is a comparative test that detects the host's immune response to *M. bovis*, rather than the bacterium itself. It measures the animal's immune response to avian and bovine tuberculins in vitro. Instead of injecting tuberculins into the skin, the animal's white blood cells are stimulated with avian and bovine tuberculins in the laboratory. Blood samples from TB-infected animals release greater amounts of IFNγ in response to bovine tuberculin compared to avian tuberculin and this is measured using an ELISA reaction.

Being a laboratory-based test, the IFNγ test is subjected to strict quality controls, it is more objective, and it is easier to standardise than the SICCT. However, samples must be transported to one of two APHA laboratories quickly in temperature-controlled packaging systems to preserve the viability of white blood cells. This can limit the availability of the test in remote areas where the distance from farm to lab may be too great. The IFNγ test is also more expensive to perform that than SICCT.

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[90] O'Hagan MJ, Courcier EA, Drewe JA, et al. Risk factors for visible lesions or positive laboratory tests in bovine tuberculosis reactor cattle in Northern Ireland. Preventive Veterinary Medicine. 2015 Jul 1;120(3-4):283-90. doi: 10.1016/j.prevetmed.2015.04.005

[91] Animal Health and Veterinary Laboratories Agency, Analysis of bovine tuberculosis surveillance at routine slaughter of cattle in Great Britain (2009-2013). 2014 Aug.

[92] De la Rua-Domenech R, Goodchild AT, Vordermeier HM, et al. Ante mortem diagnosis of tuberculosis in cattle: a review of the tuberculin tests, γ-interferon assay and other ancillary diagnostic techniques. Research in veterinary science. 2006 Oct 1;81(2):190-210. doi: 10.1016/j.rvsc.2005.11.005

IFNγ has become a key part of the bTB programmes in all four administrations of the UK. We would like to see wider, government-funded roll-out of this more sensitive test, as a supplement to the SICCT, to support the prompt removal of infected animals in bTB breakdown herds. There is potential benefit in using the test as a supplement to the SICCT when herds are placed under restrictions, as the IFNγ test can be deployed within the 60-day interval between Short Interval Tests (SITs) allowing infected animals to be detected and removed more quickly.

Recommendation 11: Government should fund, and continue to roll-out, the IFNγ test as a more sensitive supplement to the SICCT and explore the potential for wider use of IFNγ as part of the testing regime, including pre- and post-movement testing and between short interval tests.

3.2.3 IDEXX ELISA

The IDEXX test is an antibody blood test that gained OIE approval as a supplementary bTB test for cattle in 2012, but it has not been officially recognised by the EU.

It is a third-line test occasionally used by APHA in chronic bTB breakdown herds where repeated tuberculin skin testing and use of the IFNγ test has already occurred. In Wales, the IDEXX antibody test is considered a relevant test under bTB legislation, which means that APHA does not need permission from the herd owner to use the test or to remove test-positive animals.

OIE data suggest an overall moderate test sensitivity of 65% and a specificity of 98% for the IDEXX antibody test in cattle. To maximise the sensitivity of the test, a prior tuberculin skin test is required to boost *M. bovis*-specific antibody levels in TB-infected cattle.

Data from Great Britain show that antibody tests are less sensitive overall compared with the tuberculin skin test and IFNγ test.[93] However, they can be useful for identifying small numbers of infected cattle that are skin and IFNγ test negative.

3.2.4 Other tests

We are aware of the development of a number of tests including the Actiphage bacteriophage test, which has no approval, and the Enferplex TB test, which has progressed further than other tests not routinely deployed in the UK.

The Enferplex TB test is a blood test that can detect antibodies to *M. bovis* in serum (and potentially milk samples) from infected cattle. It gained OIE approval as a supplementary bTB test for cattle in May 2019, but, like the IDEXX test, it has not yet been officially recognised by the EU. This test is currently not used in the UK for statutory bTB testing of cattle, although it can be used on a private basis in certain situations and subject to prior permission from the appropriate authority.

More work is needed to assess the potential benefits and uses of all of these tests. We continue to support the development of new ante-mortem tests for bTB in cattle, and, if appropriate, their validation, which could prove useful in tackling the disease.

Recommendation 12: Government should build on the success of the roll-out of IFNγ and encourage research and trials to assess the potential for additional tests or combinations of tests.

[93] DEFRA, Validation of new serology tests for bovine tuberculosis in cattle - SE3263.

3.3 The testing regime

Following the accession of the UK to the European Community (EC; later the European Union, EU) in 1973, British cattle producers were required to comply with the rules laid down in Directive 64/432/EEC (as amended),[94] including certification of bTB testing of exported animals and official bTB freedom of herds. To comply with this legislation, the UK must have a testing regime in place.

Cattle can be tested for bTB at a number of points as part of a wider testing regime. This can include:

- Regular testing as part of the active surveillance of Official TB free (OTF) herds to confirm freedom from bTB and provide assurance for trade.
- Testing of herds that have lost OTF status to show bTB has been cleared (i.e. a clearing test) and restrictions can be lifted.
- Targeted ad hoc testing of certain herds considered to be at a higher risk of infection (e.g. radial surveillance tests in the Low Risk and Edge Areas, contiguous and back-traced herd testing, check herd tests following detection of slaughterhouse cases).
- Testing of individual cattle before and/or following movements to reduce the risk of spreading infection between herds.
- Post-mortem meat inspection of all cattle in slaughterhouses. In 2016, 12% of all new breakdowns (544/4495) and 17% (535/3171) of all breakdowns where official TB-free status was withdrawn (OTFW breakdowns) were initiated by slaughterhouse surveillance.[95]

3.3.1 Active surveillance

Active surveillance of OTF herds, primarily using the SICCT, is undertaken in all parts of the UK. There is variation in terms of the regularity of that testing reflecting the regional risk profile. The process is designed to provide confidence that herds are genuinely free of bTB and enable trade in cattle and produce.

In England, there are three regions based on disease incidence where different testing intervals are in place. The default bTB testing interval for herds in the Low-Risk Area is 48 months and for herds in the High-Risk Area and parts of the Edge Area is 12 months. Certain counties (or parts of counties) in the Edge Area are on a six-monthly testing frequency. The High-Risk Area will be transitioning to six-monthly from 2020 according to Defra.[96]

In Wales, there is a similar regional approach with Low, Intermediate and High bTB Areas which were established on 1 October 2017 based on disease incidence. Whole herd annual bTB testing takes place across the whole of Wales except in the Intensive Action Area where six-monthly testing continues.

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[94] EU Council Directive 64/432/EEC on animal health problems affecting intra-Community trade in bovine animals and swine. 1964 Jun 26.

[95] APHA, Analysis of bovine tuberculosis surveillance at routine slaughter of cattle in Great Britain 2013-2016. 2018 Jan.

[96] Defra, Next steps for the strategy for achieving bovine tuberculosis free status for England. The government's response to the strategy review, 2018. 2020 Mar.

Northern Ireland forms a single region where all herds are tested annually, as a minimum requirement, but some are tested more frequently if they are considered at increased risk. The risk to a herd is assessed by the DAERA vet for the local area.

In September 2009 Scotland was designated officially TB free (OTF) by the European Commission. As a result, changes were introduced to exempt low-risk herds from the default routine testing regime of 48 months that applies to all other non-exempt herds. APHA annually assesses each herd’s eligibility for exemption from bTB testing. Low-risk herds must fully comply with one of the following:

- herds with fewer than 50 cattle which have had fewer than two consignments of cattle moved on from high incidence bTB areas (including Northern Ireland and the Republic of Ireland) in the previous four years
- herds that slaughter more than 25% of their stock annually and have had fewer than two consignments of cattle moved on from high incidence bTB areas (including Northern Ireland and the Republic of Ireland) in the previous four years
- herds that slaughter more than 40% of their stock annually

We welcome the efforts in each part of the UK to provide a bTB testing regime that is reflective of the risk of infection within specific regions. We would welcome efforts to use this approach beyond high-level regions and better reflect the risk profile of the individual farm.

3.3.2 When a herd receives a positive bTB test

When a herd tests positive for bTB, it will lose its OTF status. This process is generally comprehensive and robust. However, we believe there are areas where improvement could be made.

Currently, two terms are used where there is a positive test. The OTF status of the herd is either withdrawn (OTFW) or suspended (OTFS). From an infection control point of view, there is no clear benefit attached to these two distinct categories. A factor in determining when OTF status is either withdrawn or suspended is the presence of lesions on the test-positive animal at post-mortem examination. This could lead to confusion amongst farmers and undermine trust in the test that is the foundation of the entire bTB programme. We believe these statuses should be reconsidered. In moderate and high prevalence areas the high risk of failure to clear the herd of infection following the use of OTFS status to limit control measures outweighs the benefit to farmers of more rapid removal of restrictions. We recommend a single status of OTFW following a positive SICCT in herds in these areas.

Movement restrictions placed on herds that have tested positive are an appropriate approach to restricting the spread of infection from that herd into other herds. We support the continuation of this approach with the exception of moves off farm to APHA-approved finishing units following a thorough risk assessment with appropriate biosecurity safeguards in place (note approved finishing units are discussed below in section 3.4.2).

Animals entering herds that are under restriction is a complex issue. There is a need to balance the risk of infection spreading to new incoming arrivals against the impacts on the viability of affected farming businesses. Therefore, a blanket ban of movement on to restricted herds would be too simplistic. However, as discussed in chapter 2, we are supportive of reducing compensation payments for any animals that are moved onto restricted farms and are subsequently found to be infected. This would need to factor in other local factors, such as the availability of approved finishing units.

The relationships between farmers, private vets and government vets are central to managing the response to a positive bTB test. There is more scope for both private and government vets to engage with farmers and put risk-based biosecurity plans in place following the withdrawal of OTF status. The ability of a farmer's private vet to advise them and collaborate effectively with government vets is hindered by poor coordination of information between farmer, private vet, and government vets during a breakdown. As a first step, results from routine testing, including a positive result, should be shared with a farmer's private vet (who will not necessarily have been the testing vet) to allow a swift, coordinated response between all parties. There may be a duty to share this data with the private vet under the RCVS Code of Conduct.[97]

Recommendation 13: Where possible, the results from bTB testing should be automatically shared with a farmer's private vet, to allow a swift, coordinated response between all parties. This would bolster the ability of a farmer's private vet to advise appropriately.

Recommendation 14: Government should no longer use the Officially TB Free suspended (OTFS) status for moderate and high bTB prevalence areas and instead use a single status of OFTW.

3.3.3 Lifting restrictions

In order to remove restrictions and regain OTF status, a farm must demonstrate that bTB has been removed from the herd. The whole herd are tested with the SICCT until no reactors are found. This can take a significant amount of time as there must be minimum intervals of 60 days between short interval tests (SIT).

In the HRA and Edge Area of England, across Wales and Northern Ireland, all bTB breakdown herds (irrespective of OTFS/OTFW status) must complete at least two consecutive SITs with negative results before the OTF status of the herd can be restored. In the LRA of England, bTB breakdown herds must complete one (OTFS) or two (OTFW) short interval tests before the OTF status of the herd can be restored. The number of tests and the interpretation depends on certain criteria. In Scotland, the herd must pass either one or two consecutive SITs following removal of any reactors.

There is an opportunity to apply new science to potentially streamline processes and reduce resource costs. This is already happening with the increasing use of IFNγ testing to supplement the SICCT across the UK. This has a number of benefits. Firstly, as IFNγ is a more sensitive test than the SICCT, it detects reactors that may be missed by SICCT testing alone. It is proposed that IFNγ may also detect a different subset of the infected population, so the combined sensitivity of both tests is likely to be greater than either alone. Additionally, as the IFNγ can be deployed within the 60-day interval between SITs, infected animals can be detected and removed more quickly, which can limit the spread of infection and reduce the period under movement restrictions.

A significant weakness of the UK bTB programmes has been the frequency with which herds that have had OTF status restored, subsequently suffer a new breakdown again, either through reinfection or residual cattle infection that was missed. Enhanced diagnostics combining appropriate available tests may limit the amount of residual infection. However, more needs to be done to determine what risk exists. A greater understanding of the risk of infection should inform the working between farmers, private vets and government vets when reacting to a breakdown. This approach needs to be wide-

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[97] RCVS, Code of Conduct for Veterinary Surgeons, Supporting Guidance 13: Clinical and client records.

ranging and holistic, not only seeking to regain OTF status, but to maintain that status when it is granted.

In England in both 2016 and 2017, approximately 80,000 cattle were moved off-farm using the clearing short interval test as a pre-movement test.[98] It is unknown if these animals pose a greater risk than others. However, it is a concern that undetected infected animals could be moved during this time. More evidence is needed to determine if a significant risk is posed by these movements, and we would encourage government to prioritise research on this topic.

We believe there may be merit in slowing down the movements off farms that have regained OTF status. In Wales, cattle cannot be moved out of a herd that has recently regained OTF status after a chronic[99] breakdown unless those animals undergo bespoke pre-movement testing at least 60 days after the clearing short-interval test. This reduces the risk of moving infected cattle to other herds following the lifting of restrictions.

Recommendation 15: Government should evaluate if animals moved off-farm shortly after receiving OTF status pose an increased risk. To support this, the Welsh Government should provide an evaluation of its policy requiring chronic breakdown herds to undergo bespoke pre-movement testing after the clearing SIT before movements off farm are permitted.

3.3.4 Testing outside of government programmes

Currently, farmers are not allowed to conduct additional tests outside the statutory regime, even at their own expense, without seeking permission from the relevant authority.

Some farmers, and their private vets, would like to employ additional tests to accelerate the removal of infected individuals and better manage within-herd transmission.[100] This would give vets the ability to apply a suitable testing regime on-farm just as would be done with other diseases. Greater flexibility in allowing the use of additional alternative tests could also give a greater sense of ownership for farmers and their private vets to tackle the disease and its prevention on their farms. This shift could also empower farmers and private vets to feel more ownership of the disease as the decision to use or not use an additional test will be theirs.

While the official use of IFNγ has been expanding, further benefits could be realised by improving cost-effectiveness and facilitating access for farmers who do not currently qualify under statutory policy. Where there is appropriate partnership working between farmers and their private vet, private testing should be encouraged and facilitated.

There can also be situations where a farmer, in consultation with their private vet, may wish to deploy an unvalidated test, or a non-statutory validated test, to enhance the

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[98] Defra statistical evaluation of movement data

[99] The Welsh Government's definition of a chronic herd breakdown is a cattle herd that has had its Officially TB Free Status Withdrawn (OTFW) and:

- Has been OTFW for a duration of 18 months or more (i.e. a persistent breakdown); OR
- Became OTFW at or before the 12-month check test, following an earlier OTFW breakdown (i.e. a recurrent breakdown), but excluding recurrent breakdowns, where all reactors are animals brought in since the close of the previous incident, unless subsequent molecular typing information does not support a purchased origin.

[100] Defra, A strategy for achieving Bovine Tuberculosis Free Status for England: 2018 review. Para: 3.40. 2018 Feb.

detection of potentially infected cattle missed by statutory testing. We welcome efforts in England[101] and Wales[102], where APHA can now approve requests from private vets for the exceptional private use of non-validated or non-statutory tests for bTB in cattle herds sustaining chronic or persistent breakdowns.

Subject to permission from the APHA, the use of alternative tests can also be allowed where a herd is OTF. Clear processes are needed to ensure that vets and farmers are aware of their duties to notify the appropriate authorities where test-positives are detected. A restricted herd would remain OTFW until it has passed the usual two short internal SICCT tests. We support the use of non-statutory testing, particularly for farms that are part of a wider programme of "earned recognition".

Recommendation 16: Where appropriate, and subject to appropriate partnership working, government should encourage and facilitate the use of private IFNγ testing by farmers and their vets.

Recommendation 17: The relevant authority should permit the exceptional private use of non-approved tests for bTB on cattle under certain conditions with reactors statutorily notified and the herd remaining OTFW until the usual two tests.

3.4 Movements of cattle

Movements of cattle present a substantial risk of spreading bTB to cattle and wildlife. Each year APHA publishes an epidemiological analysis of the data and historical trends.[103] This analysis finds that cattle movements were the primary cause of new cases in the Low-Risk Area of England in 2018, and the second most likely cause in the HRA and Edge Area of England. It can be inferred from this data that the movement of cattle with undetected infection is the most likely way that infection can spread to new areas, where it can then pass through the cattle and wildlife populations. Achieving a reduction in high-risk cattle movements through behavioural insights is an essential element of reducing the spread of bTB.

3.4.1 Pre- and post-movement testing

Pre- and post-movement bTB testing has been introduced in England, Wales and Scotland to reduce the risk of spread of bTB through movements of cattle. These procedures are primarily designed to protect the low incidence regions and nations of the UK from the introduction of infection. Currently, neither pre- nor post-movement testing are required for movements onto farms in Northern Ireland.

In England and Wales, all cattle 42 days old and over moving out of an annually, or more frequently, tested herd must have tested negative to a bTB test within 60 days before movement (unless the herd or type of movement meets any of the exemptions). In Scotland, all cattle 42 days old and over in a two-yearly or more frequently tested area must be pre-movement tested before they move from or enter any Scottish herd within 60 days prior to the move (unless an exemption applies).

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[101] APHA, Exceptional private use of non-validated or non-Defra approved tests for TB on cattle in England.

[102] Waters A, Loeb J. Wales gives green light for 'novel' TB tests. Veterinary Record. 2019 Nov 30; 185(21):640. doi: 10.1136/vr.l6728

[103] APHA, Bovine TB epidemiology and surveillance in Great Britain, 2018. Analysis of the results of bovine TB epidemiology and surveillance in England and Great Britain in 2018. 2019 Sept.

Herd owners in the Low TB Area of Wales must arrange and pay for post-movement tests for cattle moving on from the High and Intermediate bTB Areas of Wales or from High Risk and Edge Areas of England. Herd owners in the Low Risk Area (LRA) of England must arrange and pay for post-movement tests for cattle bought from herds in annual (or more frequent) surveillance testing areas of England and Wales. All cattle moving from a two-yearly or more frequently tested area must be post-movement tested between 60-120 days after their arrival in a Scottish herd.

Currently, the only type of test that can be used for such movement testing is the SICCT. As noted above the SICCT has limited sensitivity and is best utilised as a herd-level test. Therefore, isolation, post-movement testing and other appropriate biosecurity measures should also be considered, depending on the risk of the particular movement. There may also be further scope to utilise the more sensitive IFNγ test as part of this process.

Further analysis is needed to determine how effective the introduction of pre- and post-movement requirements has been at reducing new cases of bTB in lower prevalence regions. However, anecdotally, a requirement that can reduce the speed at which movements can happen, by requiring the performance of a test, can prompt more reflection on the part of farmers leading to fewer risky movements.

Recommendation 18: Government should thoroughly evaluate the effect of the introduction of pre- and post-movement test requirements. This should consider any reduction in new cases of TB in lower prevalence regions as well as any behavioural changes that may arise from slowing the movement process.

3.4.2 Movements to finishing units

Approved Finishing Units (AFUs) in England and Wales provide a route for rearing, fattening or finishing cattle from bTB restricted and un-restricted farms. AFUs must be approved and licensed by APHA and can only be approved in the High Risk and Edge Areas of England and the High TB Areas of Wales. AFUs cannot be approved in Scotland, Northern Ireland, the Low Risk Area of England or the Low and Intermediate bTB Areas of Wales.

A Licensed Finishing Unit (LFU) is a type of biosecure, indoor finishing unit intended for cattle originating from OTF herds that can be approved by APHA in the Low Risk Areas of England. Cattle in LFUs remain under permanent TB movement restrictions and can only be moved off to slaughter, but are exempt from live TB testing.

There are numerous categories of finishing units, with potential confusion over terminology, as different finishing units have similar names but do not necessarily carry out the same function.

At present, there are two options of AFUs available, with or without grazing, depending on where the unit is located. However, APHA is currently removing licences for AFUs with grazing in badger control areas as the indoor-only (without grazing) AFUs have a reduced risk of disease transmission.

We support the principle of the specialist TB finishing unit, which provides a useful outlet for farms affected by TB movement restrictions. They can be beneficial for animal welfare, by allowing movement off farm and thereby reducing the risk of overcrowding. They also provide business continuity for farmers by providing an option to take animals out of circulation quickly.

However, inappropriately managed finishing units could potentially pose a risk of spreading infection to other farms and wildlife. Therefore, appropriate biosecurity practices should be in place in keeping with the risk assessment undertaken by the appropriate authority.

We support the monitoring of finishing units to determine if there is an increased risk of infection to both cattle and wildlife and an appropriate evaluation of the policy based on these findings.

Recommendation 19: Government should monitor finishing units to determine if there is an increased risk of infection to both cattle and wildlife and evaluate the policy based on these findings. Government should support research into the effects of approved finishing units on farmer attitudes to risk and behaviours as part of a wider programme of social science research.

3.5 Cattle vaccination

In the longer-term, vaccination of cattle can and should play an important role in any bTB eradication programme, alongside other disease control measures. At present, the vaccine agent for tackling bTB in cattle is Bacillus Calmette-Guérin (BCG).[104]

A cattle vaccination policy would also require a validated DIVA test (a test that can differentiate infected and vaccinated cattle). We strongly support efforts to develop and produce a cattle vaccination and DIVA test and support the continued prioritisation of this goal by government.

The benefit of vaccination will need to be considered holistically, with an assessment of its effect on animal health, welfare, trade, and cost.

Recommendation 20: Government should continue to prioritise the development of a cattle vaccine and DIVA test (a test that can differentiate between infected and vaccinated cattle). In the longer term, vaccination of cattle, could play an important role in any bTB eradication policy, alongside other disease control measures.

3.6 Cattle genetics

Progress has been made in understanding the genetic basis of bTB resistance in cattle, enabling genetic selection for higher resistance. This sensible approach could, in the long term, make a valuable contribution to disease control.

Scientists have identified genetic traits in cattle that might allow farmers to breed livestock with increased resistance to bTB.[105,106,107] The research demonstrates that resistance of dairy cattle to *M. bovis* is partly heritable. The extensive research was undertaken jointly

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[104] Buddle BM, Vordermeier HM, Chambers MA, de Klerk-Lorist LM. Efficacy and safety of BCG vaccine for control of tuberculosis in domestic livestock and wildlife. Frontiers in veterinary science. 2018 Oct 26;5:259. doi: 10.3389/fvets.2018.00259

[105] Raphaka K, Matika O, Sánchez-Molano E, et al. Genomic regions underlying susceptibility to bovine tuberculosis in Holstein-Friesian cattle. BMC genetics. 2017 Dec 1;18(1):27. doi: 10.1186/s12863-017-0493-7

[106] Tsairidou S, Woolliams JA, Allen AR, et al. Genomic prediction for tuberculosis resistance in dairy cattle. PLoS One. 2014 May 8;9(5):e96728. doi: 10.1371/journal.pone.0096728

[107] Bermingham ML, Bishop SC, Woolliams JA, et al. Genome-wide association study identifies novel loci associated with resistance to bovine tuberculosis. Heredity. 2014 May;112(5):543-51. doi: 10.1038/hdy.2013.137

by the University of Edinburgh, Roslin Institute and Scotland's Rural College (SRUC), and supported by Defra and the Welsh Government.

This work showed genetic variation between animals and forms the basis of the TB Advantage, a genetic index utilising data on over 650,000 Holstein cows who have bTB data recorded by APHA. This data has been used to establish breeding patterns and identify more resistant bloodlines. TB Advantage is only currently available for the Holstein breed, but work is under way to establish if the index can be extended in the longer term to other dairy and beef breeds.

Breeding cattle with a reduced susceptibility to bTB is a long-term approach to disease control. Furthermore, genetic differences are not the only factor in determining whether or not an animal will become infected with bTB; various environmental factors as well as differences in the bTB bacteria may also affect susceptibility. However, if farmers can choose animals with better genotypes for bTB resistance, then this information can be applied in new breeding programmes alongside other control strategies.

Bovine Tuberculosis controls in the badger population

4.1 Introduction

The control of bTB in cattle is complicated by bTB infection in wild badgers (*Meles meles)* which can act as reservoir hosts[108] in areas where bTB is endemic in cattle. Interaction between cattle and badgers can occur where they share the same environment (e.g. pasture) or where there's encroachment (e.g. badgers entering cattle facilities in farmyards).[109,110,111] This creates opportunities for the transmission of bTB from infected badgers to cattle via direct contact (nose to nose) or indirect contact (e.g. cattle feed contaminated by infectious badger excretions).

Tackling the rates of bTB in cattle by applying controls in the badger population (particularly culling) has proven to be one of the most contentious aspects of bTB policy creating divisions in the general public, between stakeholders and within the veterinary profession itself.

Below we consider the pertinent issues beginning with the available evidence linking infection between cattle and badgers. We then examine the different methods of control (biosecurity, culling, vaccination, contraception, and combined methods) that might be applied. This information is then processed through the ethical framework before we reach our recommendations.

We are mindful that different approaches have been taken by the four governments in the UK, and differences exist within jurisdictions with regionalised approaches. We examine the evidence from across the UK, and further afield, and develop principles that could be applied to the situation anywhere in the UK with consideration of the circumstances of the particular area.

4.2 Is there a need for controls in the badger population?

The link between badgers and bTB in cattle was first recognised when badgers were found to be hosts of the disease in the UK following investigations on a farm in Gloucestershire in 1971.[112]

In 1996, Professor Sir John Krebs and the Independent Scientific Review Group were asked by the UK government to review the incidence of bTB in cattle and badgers and

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[108] Corner LA, Murphy D, Gormley E. Mycobacterium bovis infection in the Eurasian badger (Meles meles): the disease, pathogenesis, epidemiology and control. Journal of comparative pathology. 2011 Jan 1;144(1):1-24. doi: 10.1016/j.jcpa.2010.10.003

[109] Tolhurst BA, Delahay RJ, Walker NJ, et al. Behaviour of badgers (Meles meles) in farm buildings: Opportunities for the transmission of Mycobacterium bovis to cattle?. Applied Animal Behaviour Science. 2009 Feb 1;117(1-2):103-13. doi: 10.1016/j.applanim.2008.10.009

[110] Garnett BT, Delahay RJ, Roper TJ. Use of cattle farm resources by badgers (Meles meles) and risk of bovine tuberculosis (Mycobacterium bovis) transmission to cattle. Proceedings of the Royal Society of London. Series B: Biological Sciences. 2002 Jul 22;269(1499):1487-91. doi: 10.1098/rspb.2002.2072

[111] Robertson A, Delahay RJ, Wilson GJ, et al. How well do farmers know their badgers? Relating farmer knowledge to ecological survey data. Veterinary Record. 2016 Oct 18. doi: 10.1136/vr.103819

[112] Murhead RH, Burns KJ. Tuberculosis in wild badgers in Gloucestershire: epidemiology. Veterinary Record. 1974 Dec 14;95(24):552-5. doi: 10.1136/vr.95.24.552

assess the scientific evidence for links between them. Their report concluded that "the strength of the circumstantial evidence leads us to conclude that transmission from badgers is likely to be a significant contributor to the TB problem in British cattle."[113]

The Krebs report recommended a large-scale field experiment, the Randomised Badger Culling Trial (RBCT), that ran from 1998-2005. The RBCT has provided a substantial source of information on the contribution of badgers to bTB infections in cattle and has deepened our understanding of the relationship between *M. bovis*, cattle and badgers. The Independent Scientific Group agreed that 'badgers are clearly a source of cattle TB' but also concluded that 'badger culling could not meaningfully contribute to the control of bTB in cattle in Britain, as a result of the high costs and low benefits' (Bourne, 2007).[114] However, a predicted 12-16% improvement in bTB in cattle in the HRA using RBCT methodology was agreed by Government to be worth investment in badger culling (Defra, 2010).

Donnelly & Nouvellet (2013) employed data from the RBCT to model the contribution of badgers to TB in cattle in high incidence areas in England.[115] The models involved a series of equations, which taken together with the results from the RBCT support the conclusion that badgers play a major role in maintaining *M. bovis* infection in cattle in areas where badgers are infected. The model estimates the overall contribution of badgers to cattle bTB breakdowns to be 52%, with a wide confidence interval (9%-100%). However, the paper stresses that cattle to cattle transmission plays the major role in the spreading of infection.

Whole genome sequencing (WGS) technology holds great promise as a tool for the forensic epidemiology of bTB infections and is increasingly being utilised by APHA as part of its surveillance operations. In its update on bTB surveillance in wildlife September 2019,[116] WGS was carried out on all *M. bovis* isolates from cattle and badgers in Cumbria and shed more light on the transmission dynamics between the two species.

Currently, a proportion of new bTB incidents are fully investigated by the APHA in England.117 In such selected incidents, an APHA case vet conducts a thorough on-site investigation, supplementing information recorded during the visit with routinely collected data; such as cattle movement records and the results of molecular analyses. During the assessment, the APHA veterinary officer applies their expert veterinary judgement and local epidemiological knowledge and selects up to three risk pathways of infection for each herd, indicating their relative order of likelihood. This is a vital source of information, but it is noted that although well informed by the local investigation, it is a subjective process

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[113] Krebs R and the Independent Scientific Review Group, Bovine Tuberculosis in Cattle and Badgers. 1997.

[114] Independent Scientific Group on Cattle TB, Bovine TB: The Scientific Evidence. A Science Base for a Sustainable Policy to Control TB in Cattle. An Epidemiological Investigation into Bovine Tuberculosis. 2007.

[115] Donnelly CA, Nouvellet P. The contribution of badgers to confirmed tuberculosis in cattle in high-incidence areas in England. PLoS currents. 2013 Oct 10;5. doi: 10.1371/currents.outbreaks.097a904d3f3619db2fe78d24bc776098

[116] Defra, An update on TB surveillance in wildlife September 2019. 2019 Sep.

[117] All new TB incidents in the LRA (both OTF-W and OTF-S) undergo an epidemiological assessment. For the Edge Area, as many assessments as possible are completed with the finite resources available, and the level is close to 100%. In situations where not all incidents can receive an assessment, new incidents are randomly selected for assessment in order to maintain a representative overview of the area. Additionally, one third of new incidents in the HRA are randomly selected, as well as those that meet specified criteria (e.g. those with more than 15% of the herd or 20 cattle removed as test reactors).

and very dependent on the level of knowledge, risk aversion and assumptions of the APHA veterinary officer.

APHA compiled findings for England in 2018[118] that found that the most likely source of bTB infection, assessed for each bTB incident varied by region. Within the HRA, badgers constituted 64% of the attributed source, weighted by the level of veterinary certainty. In the Edge Area, the source was still most strongly ascribed to badgers (57%), but cattle movements (22%) were also identified as posing a high risk of introduction, and considerable variation was seen between counties. In the LRA, bTB incidents were most strongly attributed to cattle movements (32%).

Conclusion: Badgers are a wildlife reservoir for bTB in areas where the disease is endemic in cattle and contribute to sustaining the disease in cattle. Measures are needed to control the transmission of bTB between the two species in both directions; badgers to cattle and cattle to badgers.

Conclusion: We support the efforts to expand the use of Whole Genome Sequencing (WGS) to increase the understanding of the disease and the nature of the transmission between cattle and badgers in both directions.

4.3 Which controls?

4.3.1 Biosecurity measures

Cattle exposure to direct or indirect contact with badgers will vary between farms, depending on the farm management practices.[119] A study[120] on the effectiveness of biosecurity measures in preventing badger visits to farm buildings concluded that badgers:

- Enter farm buildings when gates are left open or when a new potential entrance point in the building is not repaired
- Are attracted to some farms more than others, for reasons that have not been determined. So, the benefits of measures to exclude badgers will vary
- Are more likely to access farms where food is easily accessible

[118] APHA, Bovine tuberculosis in England in 2018. Epidemiological analysis of the 2018 data and historical trends. 2019 Sep.

[119] Ward AI, Judge J, Delahay RJ. Farm husbandry and badger behaviour: opportunities to manage badger to cattle transmission of Mycobacterium bovis?. Preventive veterinary medicine. 2010 Jan 1;93(1):2-10. doi: 10.1016/j.prevetmed.2009.09.014

[120] Judge J, McDonald RA, Walker N, Delahay RJ. Effectiveness of biosecurity measures in preventing badger visits to farm buildings. PloS one. 2011 Dec 29;6(12):e28941. doi: 10.1371/journal.pone.0028941

Woodroffe et al. (2016)[121] provides evidence that direct badger-cattle contact is extremely unusual, however indirect contact e.g. via the same feeding area can be common.[122] Cattle may potentially become infected with bTB at pasture.[123]

Grazing will carry a potential risk of infection when infectious badgers, or their excreta, are present.[124] Cattle may sniff or even move badger droppings/faeces to gain access to the grass below, which increases the risk of transmission.[125] Cattle may sniff badger urine, which is more difficult to detect and urine from infected badgers has been reported to contain up to 250,000 colony forming units per millilitre. In comparison, up to 75 colony forming units per gram of faeces have been observed.[125]

Farmers can take practical and highly effective steps to prevent badgers accessing cattle.[120] Exclusion measures include:

- Solid aluminium sheeted gates
- Aluminium sheeting on rail fences
- Retractable electric fencing – badgers are less likely to visit unfenced facilities on farms that use electric fencing around feed stores. This is known as the ‘deterrent effect’[126]
- Aluminium feed bin
- Rail gate with adjustable galvanised aluminium panels

Feed stores, water troughs, and mineral licks all provide opportunities for indirect bTB infection between badgers and cattle.[127] If badgers and cattle can access the same feed and water, either when housed or at pasture, this increases the risk of bTB breakdown and

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121 Woodroffe R, Donnelly CA, Ham C, Jackson SY, Moyes K, Chapman K, Stratton NG, Cartwright SJ. Badgers prefer cattle pasture but avoid cattle: implications for bovine tuberculosis control. Ecology letters. 2016 Oct;19(10):1201-8. doi: 10.1111/ele.12654

122 Boehm M, Hutchings MR, White PC. Contact networks in a wildlife-livestock host community: identifying high-risk individuals in the transmission of bovine TB among badgers and cattle. PLoS One. 2009 Apr 29;4(4):e5016. doi: 10.1371/journal.pone.0005016

123 Benham PF. The behaviour of badgers and cattle and some factors that affect the chance of contact between the species. Applied Animal Behaviour Science. 1985 Dec 1;14(4):390-1.

124 Gallagher E, Kelly L, Pfeiffer D, Wooldridge M. A quantitative risk assessment for badger to cattle transmission of Mycobacterium bovis. Proc. Soc. Vet. Epidemiol. Prev. Med. 2003 (pp. 33-44).

125 Hutchings MR, Harris S. Effects of farm management practices on cattle grazing behaviour and the potential for transmission of bovine tuberculosis from badgers to cattle. The Veterinary Journal. 1997 Mar 1;153(2):149-62. doi: 10.1016/S1090-0233(97)80035-4

126 Tolhurst BA, Ward AI, Delahay RJ, et al. The behavioural responses of badgers (Meles meles) to exclusion from farm buildings using an electric fence. Applied Animal Behaviour Science. 2008 Sep 1;113(1-3):224-35. doi: 10.1016/j.applanim.2007.11.006

127 O'Mahony DT. Use of water troughs by badgers and cattle. The Veterinary Journal. 2014 Dec 1;202(3):628-9. doi: 10.1016/j.tvjl.2014.10.016

spread.[128] As a result, a study of bTB in County Down, Northern Ireland [129]suggests that farmers:

- Make feed stores badger-proof
- Prevent badger access to buildings
- Feed cattle from raised feed troughs

4.3.2 Badger culling

4.3.2.1 Effectiveness

Culling of badgers has been used in England in an attempt to reduce disease in the cattle population for decades. Initial government-led culling in England started in 1975 with several iterations. There were subsequent uncertainties over the effects of culling, welfare concerns, and rising bTB incidence in cattle. Culling was suspended in 1996 and at the same time the UK government established the Krebs review, which led to the commissioning of the RBCT.

The RBCT consisted of thirty 100 km^2 areas arranged in ten triplets, with each of the three areas in each triplet assigned a different treatment (proactive culling, reactive culling and control areas). The methods used to cull badgers was cage trapping and shooting and analyses were conducted to investigate changes in cattle bTB incidence.

- Reactive culling: Badgers culled around affected farms in response to bTB in cattle.
- Proactive culling: Badgers actively culled across the whole area
- No culling: Used as a control to assess the effect on interventions.
- Reactive culling was halted during the trial (November 2003) following a 27% increase, relative to the control areas, in bTB incidence in cattle.

Proactive culling was continued and, during the four-year period of the cull, incidence in cattle decreased by 23% relative to the control areas. Five years after the cessation of the cull, incidence had fallen by 28% relative to the control areas. In the 2km buffer area that surrounded cull areas the picture was different. During the four-year culling period incidence rose by 25% relative to control areas. However, five years after culling the difference was not significant.

The increase in bTB in cattle in areas subjected to reactive culling, and the 2km buffer surrounding proactive cull areas led to consideration of a perturbation effect. This is the theory that culling badgers results in badger social group disruption, changes in badger behaviour and subsequent changes in disease patterns. Research[130] has shown significant increases in both the frequency of individual badger movements between

[128] Johnston WT, Vial F, Gettinby G, et al. Herd-level risk factors of bovine tuberculosis in England and Wales after the 2001 foot-and-mouth disease epidemic. International Journal of Infectious Diseases. 2011 Dec 1;15(12):e833-40. doi: 10.1016/j.ijid.2011.08.004

[129] O'Hagan MJ, Matthews DI, Laird C, McDowell SW. Agri-Food and Biosciences Institute, Belfast. Bovine tuberculosis biosecurity study, County Down, Northern Ireland 2010–2011. 2013.

[130] Carter SP, Delahay RJ, Smith GC, et al. Culling-induced social perturbation in Eurasian badgers Meles meles and the management of TB in cattle: an analysis of a critical problem in applied ecology. Proceedings of the Royal Society B: Biological Sciences. 2007 Nov 7;274(1626):2769-77. doi: 10.1098/rspb.2007.0998

groups and an increase in the prevalence of bTB in badgers in response to culling. However, no direct evidence was found to link the two phenomena.[131]

The Independent Scientific Group on Cattle TB (ISG) published its final report on the outcome of the RBCT (published 18/06/2007). The Government's Chief Scientific Adviser, David King, considered those findings and other scientific evidence relating to badgers and bTB in cattle and presented these findings to the Secretary of State on 30 July 2007.[132] Based on those conclusions, in 2013, Natural England began issuing licences based on strict criteria for groups of English farmers and landowners to cull badgers. This is referred to as industry-led badger culling. The requirements to receive a licence are detailed in Guidance to Natural England by Defra.[133]

Proactive culls began in two areas (Somerset and Gloucester), and by the end of 2018 this had been expanded until 32 licensed cull areas were in operation. This required estimated cull rates of approximately 70% over an area deemed sufficiently large to mitigate the perturbation effect. We would note that if initial culls are to be judged as effective based on a 70% reduction in the estimated number of badgers in a cull area, it is critical that both population estimates, and evaluation of numbers culled are as accurate as possible. Direct estimation of badger numbers is challenging, owing to their underground and nocturnal habits[134]. Furthermore, applicants must satisfy Natural England that they are able to deliver an effective cull that can be sustained, for the duration of the licence (minimum of 4 years).

Brunton et al. (2017) looked at the effects of the pilot badger culls on the incidence of bTB in cattle.[135] The paper cautioned that only two years data of the planned four years of culling were available for analysis, meaning that the results were preliminary. A subsequent study from Downs et al. (2019)[136] investigated the effect of culling in the first three licensed badger cull areas in England using data from 2013 – 2017 (Gloucester and Somerset) and 2015-2017 (Dorset). A direct comparison between bTB incidence rates in cull areas and comparison areas found few differences. Deeper analyses, accounting for other factors, showed that after four years of culling there were reductions in bTB incidence rates of 66% in Gloucestershire and 37% in Somerset relative to comparison areas although there was no similar reduction in Dorset at this earlier stage in the process. bTB incidence rates in the buffer areas surrounding cull areas were lower after four years in Gloucestershire and after two years in Dorset relative to comparison area buffers.

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[131] Riordan P, Delahay RJ, Cheeseman C, et al. Culling-induced changes in badger (Meles meles) behaviour, social organisation and the epidemiology of bovine tuberculosis. PloS one. 2011 Dec 14;6(12):e28904. doi: 10.1371/journal.pone.0028904

[132] David King, (2007) Bovine Tuberculosis in Cattle and Badgers. A report by the Chief Scientific Advisor to the Secretary of State.

[133] Defra. Guidance to Natural England Licences to kill or take badgers for the purpose of preventing the spread of Bovine TB under Section 10 (2)(a) of the Protection of Badgers Act 1992. 2018 May.

[134] Judge J, Wilson GJ, Macarthur R, et al. Abundance of badgers (Meles meles) in England and Wales. Scientific Reports. 2017 Mar 21;7(1):1-8. doi: 10.1038/s41598-017-00378-3

[135] Brunton LA, Donnelly CA, O'Connor H, et al. Assessing the effects of the first 2 years of industry-led badger culling in England on the incidence of bovine tuberculosis in cattle in 2013–2015. Ecology and evolution. 2017 Sep;7(18):7213-30. doi: 10.1002/ece3.3254

[136] Downs SH, Prosser A, Ashton A, et al. Assessing effects from four years of industry-led badger culling in England on the incidence of bovine tuberculosis in cattle, 2013–2017. Scientific reports. 2019 Oct 11;9(1):1-4. doi: 10.1038/s41598-019-49957-6

Reactive culling is not used as part of government sanctioned badger control. However, there are concerns and evidence[137] that illegal badger culling is still occurring in parts of the UK[138] and could potentially be leading to increased bTB incidence in cattle populations as well as inflicting welfare harms on badgers.

Conclusion: The available evidence shows that proactive badger culling can result in significant reductions in incidence of bTB in cattle. However, results have been variable. Therefore, it is possible that culling badgers in other areas could have different results.

Conclusion: Cull design should be based on the best available evidence, applying the findings from the RBCT and from the recent and ongoing culls, including mitigation for the "perturbation effect".

4.3.2.2. Culling methods

Where culling is undertaken, it must be as humane as possible, recognising that 'humane' is a relative rather than absolute concept. Two methods of culling have been deployed in the UK in recent years: free/controlled shooting, and cage trapping and shooting. Most badgers culled as part of the programme are culled by free/ controlled shooting[139] i.e. the use of a rifle to kill a badger from a distance.

Cage trapping and shooting

The RBCT established that cage trapping and shooting can deliver a safe, effective and humane cull. Throughout the RBCT, all badgers were closely inspected at post- mortem examination and several observable characteristics of their condition recorded. The substantial majority of badgers (87%) showed no evidence of detectable injuries as a result of confinement in the trap.[140]

As Woodroffe et al. (2005) note:[141]

> "[C]onfining badgers to cage traps prior to despatch inevitably has implications for their welfare. However, the incidence of injuries is low and the great majority of these are minor. Because neither the incidence nor the severity of injuries was related to the time at which badgers were despatched, we conclude that current procedures for checking traps are adequate. Modification of traps has successfully reduced the incidence of skin abrasions. Further modifications of trap design may be needed to reduce the incidence of less common but more serious injuries (eg cuts, tooth damage). However, all aspects of the conduct of trapping operations must balance badger welfare with concerns for the health and safety of field staff."

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[137] National Wildlife Crime Unit, Tactical Assessment – UK Wildlife Crime: May 2019. 2019 May 22.

[138] Wildlife and Countryside Link, Wildlife Crime in 2017: A report on the scale of wildlife crime in England and Wales. 2017

[139] Defra, Bovine TB: Summary of badger control operations during 2018. 2018 Dec 18.

[140] Independent Scientific Group on Cattle TB, Bovine TB: The Scientific Evidence. A Science Base for a Sustainable Policy to Control TB in Cattle. An Epidemiological Investigation into Bovine Tuberculosis. 2007.

[141] Woodroffe R, Bourne FJ, Cox DR, et al. Welfare of badgers (Meles meles) subjected to culling: patterns of trap-related injury. Animal Welfare. 2005 Feb 1;14(1):11-7.

Defra has published best practice guidance 2018[142] to industry-led cull companies in England, which seeks to ensure every badger killed using this method experiences minimal pain and distress. For example, regular checking to ensure badgers are not left in traps for extended periods of time. There should be a mindset of continual evaluation and improvement to further improve this guidance and further minimise avoidable harm.

Ongoing recording and analysis of observational data during culling is necessary to determine best practice for this iterative improvement. There will also need to be the sharing of knowledge between researchers and those involved in culls and vaccination programmes where cage trapping is also utilised.

Free/controlled shooting

In December 2011, the UK government announced its decision to licence a badger cull in two areas in South West England. An Independent Expert Panel (IEP) was appointed to monitor the effectiveness, humaneness and safety of controlled/free shooting during the pilots. The IEP's report in April 2014 raised concerns about the humaneness of shooting as a culling method as the pilot culls had failed to meet the parameters set out by the IEP. The IEP concluded that standards needed to be improved if culling was to continue in the pilot areas.

The IEP estimated that 6-19% of badgers may not be retrieved following a rifle shot and may be at risk of marked suffering if hit but not killed by the first shot. This issue could be addressed, at least partially, by licensing only those shooters who have demonstrated a high standard of marksmanship in the field and have a good working knowledge of badger behaviour.

Recommendations were made to Government by the IEP report in an attempt to improve the humaneness of free/controlled shooting. In light of the results following the second year of pilot culling, we concluded that it had not been demonstrated conclusively that controlled shooting could be carried out effectively and humanely based on the criteria that were set for the pilots.[143]

As the cull operation has expanded, there have anecdotally been improvements in the use of controlled/free shooting including improved levels of training leading to increased accuracy. In 2018 the non-retrieval rate was 10.1% (95% confidence interval 5.1%-17.6%). In total 89 controlled/ free shootings were observed from a total of 20,905 badgers killed using this method. If the sample was representative, then it shows that the technique has not deteriorated. However, we do not consider the sample to be large enough to provide definitive reassurance, or convincingly demonstrate improvement'.

[142] Defra, Cage-trapping and dispatch of badgers under licence to prevent the spread of bovine TB in cattle: Best practice guide. 2018 Sept.

[143] BVA, BVA Council position on the pilot badger culls and badger culling policy in England. 2015 Apr.

The failure to appropriately monitor the use of controlled/ free shooting as part of the expanded badger cull policy in England means there is no substantive evidence base to show that the use of this method has shown improved humaneness or challenged any of the assumptions of the IEP.

Conclusion: When culling takes place, pain and distress should be minimised as much as possible. It is likely, based on the available evidence that cage trapping and shooting is preferable to controlled shooting.

Conclusion: Efforts to further reduce any pain and distress experienced by badgers through cage trapping and shooting should be a priority.

Conclusion: Appropriate monitoring of cull activities is important to ensure the effectiveness and humaneness of operations can be assessed during culling operations. Monitoring data should be published regularly. If data are not available, events of concern will not be recorded, and it will neither be possible to make decisions regarding whether culling should proceed or be improved, nor to ensure development and sharing of best practice. We are unable to support the use of controlled/free shooting as no substantial evidence of improved humaneness has been published.

4.3.2.3 Vaccination

The injectable BCG badger vaccine is the first tuberculosis vaccine authorised for use in badgers in the UK. Vaccination of badgers aims to reduce transmission of bTB between badgers and from badgers to cattle by reducing the severity of disease and shedding of bacteria from infected individual badgers.[144]

Captive trials have shown that vaccination reduces the severity and progression of disease[145] in badgers. Research suggests vaccination could also reduce the spread in badger populations as vaccinated badgers are much less likely to become infected with bTB[146]. There is a direct beneficial effect of vaccination in individual badgers and an indirect protective effect in unvaccinated cubs. Vaccination also carries few risks:

- The BCG bacterium is not excreted by badgers
- There is no evidence of the vaccination process affecting the social structures of badger populations causing a perturbation effect.147

[144] Brown E, Cooney R, Rogers F. Veterinary guidance on the practical use of the BadgerBCG tuberculosis vaccine. In Practice. 2013 Mar 1;35(3):143-6. doi: 10.1136/inp.f1186

[145] Chambers MA, Rogers F, Delahay RJ, et al. Bacillus Calmette-Guérin vaccination reduces the severity and progression of tuberculosis in badgers. Proceedings of the Royal Society B: Biological Sciences. 2011 Jun 22;278(1713):1913-20. doi: 10.1098/rspb.2010.1953

[146] Carter SP, Chambers MA, Rushton SP, et al. BCG vaccination reduces risk of tuberculosis infection in vaccinated badgers and unvaccinated badger cubs. PloS one. 2012 Dec 12;7(12):e49833. doi: 10.1371/journal.pone.0049833

[147] Lesellier S, Palmer S, Dalley DJ, et al. The safety and immunogenicity of Bacillus Calmette-Guerin (BCG) vaccine in European badgers (Meles meles). Veterinary immunology and immunopathology. 2006 Jul 15;112(1-2):24-37. doi: 10.1016/j.vetimm.2006.03.009

- Vaccination of badgers is likely to have little effect (positive or negative) on the course of existing infections in badgers (Godfray et al. 2013)[148].

Unlike culling, there are no specific scientific trials or experiments that have been conducted with the explicit aim of investigating the effect of badger vaccination on bTB in cattle. Understanding the effect of vaccinating one species to protect a different species is relatively complex. Consequently, the effects of badger vaccination in cattle would likely require a large-scale field trial, alongside comparison areas with no vaccination.

BCG is best used as a population vaccine on a large scale, with local small-scale vaccination projects likely to be less effective (Wilkinson et al. 2004)[149]. There are two areas in the UK where large-scale badger vaccination has been conducted, these are the Badger Vaccine Deployment Project (BVDP)[150] in England and Intensive Action Area (IAA) in Wales.[151] The authors of both reports make it very clear that neither of these projects were intended as a scientific study to prove or disprove the effects of badger vaccination on incidence in cattle. Until further trials or analyses are conducted it is not possible to say definitively what effect badger vaccination will have on bTB in cattle.

However, as noted above there is some scientific evidence that vaccination may have an effect on disease spread in badgers. If the aim is to reduce the prevalence of infection in badgers, then vaccination is potentially a tool to achieve this. Vaccination may also be a viable option in parts of the country where the badger population is currently free of bTB, as a way of reducing the risk of disease spread in the badger population following a new outbreak of cattle disease related to cattle movements.

Although badger vaccination was licensed in 2010, there remains much confusion and misunderstanding, including amongst vets and farmers, over the research conducted on the subject and the interpretation of the results. Vets as scientists, animal advocates and key advisors to farmers have a role to play in improving understanding of the role of vaccination as part of a holistic package of measures, its limitations, and its potential value to their clients and the general public. As noted in chapter 2, vets providing bTB advice should ensure they are basing their advice on unbiased information and are keeping up to date with the latest research and best practice guidance.

[148] Godfray HC, Donnelly CA, Kao RR, et al. A restatement of the natural science evidence base relevant to the control of bovine tuberculosis in Great Britain. Proceedings of the Royal Society B: Biological Sciences. 2013 Oct 7;280(1768):20131634. doi: 10.1098/rspb.2013.1634

[149] Wilkinson D, Smith GC, Delahay RJ, Cheeseman CL. A model of bovine tuberculosis in the badger Meles meles: an evaluation of different vaccination strategies. Journal of Applied Ecology. 2004 Jun;41(3):492-501. doi: 10.1111/j.0021-8901.2004.00898.x

[150] Benton C, G Wilson G. APHA, Badger Vaccine Deployment Project: Final Lessons Learned Report. 2015 Mar.

[151] Welsh Government, Bovine TB Eradication Programme IAA Vaccination Project – Year 4 Report. 2016

Conclusion: Vaccination of badgers reduces the severity and progression of bTB in badgers. Vaccination may provide a non-lethal method of reducing bTB in badgers with no evidence of associated perturbation effect.

Conclusion: The effect badger vaccination has on cattle bTB incidence is uncertain, but if it leads to reduced bTB in the badger population then it is possible that this would eventually have a beneficial effect on bTB in cattle. Research is needed to determine the effect of badger vaccination on incidence in cattle and whether this is affected by badger population density.

Conclusion: Vaccination of badgers could provide a benefit as a 'firebreak' to mitigate the spread of the disease as a way of reducing the risk of disease spread in the badger population in a new outbreak related to cattle movements.

4.3.2.4 Fertility control

There has been thought given to the application of fertility control using contraceptives to manage badger populations. Studies have looked at injectable and oral contraception. Cowan et al. (2019)[152] note the single-shot injectable immunocontraceptive vaccine targeting the gonadotropin-releasing hormone (GnRH), has been tested in key mammal species in the UK and shown to be a safe method for reducing population size in areas where human interests and wildlife come into conflict.

Compared to culling, fertility control has the potential disadvantage that it will generally take longer to achieve equivalent population reduction. Fertility control could also result in behavioural changes in individual badgers and on badger social structure and might lead to unintended consequences such as perturbation. Consequently, fertility control does not offer a viable option for badger control at this time.

Conclusion: The use of an immunocontraceptive vaccine has been tested in key mammal species in the UK and shown to be a safe method to reduce population size in areas of high human wildlife conflict. Further research would be needed to determine the effect on badger social structures, welfare and bTB incidence in cattle before making a firmer assessment.

4.3.2.5 Combined approaches

Northern Ireland has been researching a combined approach as part of a scheme designed to carry wider public support. In 2014, a five year "test and vaccinate or remove" (TVR) research project began in County Down, Northern Ireland. The TVR project was trialling an approach to controlling bTB in badgers by vaccinating bTB negative badgers and culling test positive badgers. The full TVR approach involves the capture, micro-chipping, sampling, vaccination and release of test negative badgers. All TB test positive

[152] Cowan D, Smith GC, Gomm M, et al. Evaluation of a single-shot gonadotropin-releasing hormone (GnRH) immunocontraceptive vaccine in captive badgers. European Journal of Wildlife Research. 2019 Aug 1;65(4):59. doi: 10.1007/s10344-019-1296-0

badgers would be removed. This approach has also been deployed on a limited number of chronic breakdown farms in Wales.[153]

This method relies on a pen-side bTB test for badgers. The serological test currently used in the UK is the Dual Path Platform (DPP) which has a sensitivity of 55.3% a specificity of 97.5%.[154] 55.3% sensitivity means the test will mean miss 44.7% of infected badgers i.e. a high level of false negative results leading to the release of infected badgers.

Conclusion: Until the final report of the TVR study is reported it is too early to say how effective this approach will be. However, there are concerns that this method relies on a test with low sensitivity.

Conclusion: An improved test for bTB in badgers with higher sensitivity alongside high specificity could be beneficial and potentially offer new possibilities for control methods.

Conclusion: Combining approaches or developing a narrative around the use of multiple tools, stands a higher chance of achieving wider support with the public and wider stakeholders and has been the case with the approach in Northern Ireland.

4.4. Ethical considerations

We believe that the seven consensus principles for ethical wildlife control, as described by Dubois et al. (2017)[155] are valuable tools for assessing the ethical considerations associated with badger controls. They are individually considered below.

Can the problem be mitigated by changing human behaviour?

Improved biosecurity on farm is essential and proven to work. Judge et al. (2012)[120] evaluated the effectiveness of simple exclusion measures in improving farm biosecurity and preventing badger visits to farm buildings. Simple exclusion measures were 100% effective in preventing badger entry into farm buildings, providing they were appropriately deployed. Furthermore, the installation of exclusion measures also reduced the level of badger visits to the rest of the farmyard. The findings of that study clearly demonstrate how relatively simple practical measures can substantially reduce the likelihood of badger visits to buildings and reduce some of the potential for contact and disease transmission between badgers and cattle.

Controls in badgers should only be carried out once there have been changes to human behaviour. Therefore, cull licences should not be issued until the respective farmers are able to demonstrate appropriate changes to their ‘human behaviours’.

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[153] APHA, Report on the delivery of badger trap and test operations on chronic TB breakdown farms in Wales in 2018: Report for project TBOG0235 (Year 2).

[154] Mullineaux E, Phoenix J, Brown E. Rehabilitating and releasing badgers in England. In Practice. 2019 Jun 1;41(5):198-204. doi: 10.1136/inp.l1998

[155] Dubois S, Fenwick N, Ryan EA, et al. International consensus principles for ethical wildlife control. Conservation Biology. 2017 Aug;31(4):753-60. doi: 10.1111/cobi.12896

As part of Defra guidance to Natural England,[133] reasonable biosecurity measures are a necessity for farmers participating in cull operations to provide a strong protection against the spread of infection. We suggest that these requirements are formalised and monitored.

Are the harms serious enough to warrant wildlife control?

The animal health, animal welfare, public health, economic and social harms associated with the current prevalence of bTB in the UK are outlined the introductory chapter of this paper. These harms are wide reaching and serious and we believe they warrant the application of controls in the badger population based on the available epidemiological evidence in the locality where licencing requirements including biosecurity are met.

Is the desired outcome clear and achievable, and will it be monitored?

As Wobeser (2002)[156] notes:

> "Management of disease in wild animals must be based on sound knowledge of the biology of the disease agent and the species affected, and particularly of the population ecology of the disease process. The initial step in any management programme is to clearly define its objective."

The outcome that is sought from a badger control strategy is a reduction in incidence of bTB in the cattle population. For badger culling, there is evidence from the RBCT and later research that this outcome is achievable. For other methods of badger control this evidence is not as strong and should be sought.

Monitoring of bTB incidence in cattle is essential. We welcome efforts by government to ensure evidence has been peer reviewed and published. High quality research has been undertaken to evaluate the effectiveness of proactive badger culling in meeting the outcome of reduced bTB incidence in cattle with appropriate comparisons. Monitoring of the effect of culling should continue as further evidence emerges from more cull areas.

Monitoring the effects of controls on the badger population is also a necessity to ensure pain and distress are minimised as much as possible.

Does the proposed method carry the least animal welfare cost and to the fewest animals?

If the killing of an animal is undertaken humanely, it is not a welfare harm per se. Where culling takes place, all animals should receive as humane a death as possible, one that is rapid and free from avoidable pain and distress where pain and distress are minimised as much as possible.

Badger culling is at present the only method of badger control that can be shown to reduce the incidence of bTB in cattle. Of the methods of culling available, there is evidence that cage trapping and shooting is the method available that provides the least pain and distress. Therefore, we support cage trapping and shooting as the preferred method of culling and are unable to support the use of controlled/ free shooting.

Non-lethal methods which may carry less welfare costs should also be further explored, especially vaccination of badgers which reduces the severity and progression of bTB in

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[156] Wobeser G. Disease management strategies for wildlife. Revue Scientifique et Technique-Office international des epizooties. 2002 Apr 1;21(1):159-78. doi: 10.20506/rst.21.1.1326

badgers and reduces spread in badger populations. Research is needed to determine the effect of badger vaccination on incidence in cattle and whether this is affected by badger population density.

Have community values been considered alongside scientific, technical, and practical information?

We have consistently heard that the successful operation of any badger control policy (culling, vaccination or combinations of both) should aim to achieve broad support from farmers, vets, government, non-governmental organisations, and the wider public but this remains one of the greatest challenges in bTB policy. More needs to be done to achieve further understanding of these issues and lower the temperature of the debate thereby building trust between stakeholders. Vets as facilitators, scientists and communicators have a central role to play in achieving this aim. Vets are uniquely positioned to provide a balanced view of scientific and ethical considerations.

Is the control action part of a systematic, long-term management program?

We have presented our considerations on badger controls within a wider document that envisages a systematic, long-term management program. BVA will engage governments across the UK and other stakeholders to ensure a similar joined up approach is taken.

A weakness in the current cull policy in England has been a failure to illustrate "how Government might develop an exit strategy" from the current badger cull policy once the desired outcome is achieved.[157] Badger vaccination offers one of the few possible exit strategies from the policy of large repeated culls, yet we cannot say today whether it is feasible. Modelling studies can provide some insights into this question but cannot provide definitive answers because of our uncertainty about the underlying epidemiology. It is vital to obtain new evidence on vaccination.

Are the decisions warranted by the specifics of the situation rather than negative labels applied to the animals?

We recognise that, as in society at large, there are different attitudes towards different animals amongst veterinary professionals. As part of our working group process, consultation, and democratic decision-making, we have gathered views that have utilised a shared working definition of animal welfare and widespread recognition of the veterinary profession as an animal welfare-focused profession that avoids the use of negative labels.

BVA has a responsibility to provide analysis, information and leadership and will endeavour to provide communications to vets, farmers, Government and the general public that does not employ negative labels for animals.

Recommendation 21: Licences to cull badgers should not be issued until the respective farmers are able to demonstrate appropriate implementation of biosecurity best practice and risk-based trading as part of a wider earned recognition programme.

Recommendation 22: Badger culling should be deployed in a targeted, effective and humane manner only where cull design is based on the best available evidence and mitigates against the "perturbation effect". Efforts to further reduce any pain and distress experienced by badgers through cage trapping and shooting should be a priority for government.

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[157] Defra, A strategy for achieving Bovine Tuberculosis Free Status for England: 2018 review. 2018 Feb.

Recommendation 23: Control activities should be appropriately monitored in order to ensure the effectiveness and humaneness of operations can be assessed during culling operations, and to inform continuous improvement. The appropriate body should put in place the necessary capacity to monitor an adequate proportion of all badger culls.

Recommendation 24: Government should prioritise research to evaluate the impact of badger vaccination on bTB incidence in cattle. This evidence should provide a greater understanding of this control method as part of any 'exit strategy' or as a firebreak to stop the spread of the disease into new areas.

Recommendation 25: Longer term, research budgets should seek to encourage the development of improved diagnostics for bTB in badgers which could open additional possibilities for control methods.

Recommendation 26: The veterinary profession and farming unions should work in partnership to communicate the potential adverse effects of illegal badger culling, highlighting the potential for local increase in the incidence of bTB in cattle.

Bovine Tuberculosis in species other than cattle and badgers

The bacterium, *M. bovis,* that causes bTB in cattle and badgers can also affect a broad range of other species. *M. bovis* has the broadest host range of pathogenic mycobacteria[158] and consequently, a thorough examination of bTB policy cannot be limited to considerations of cattle and badgers.

Understanding the epidemiology of *M. bovis,* and how it moves between cattle and other species, is essential to controlling the disease. Different species can be classed as maintenance hosts when infection can persist by intra-species transmission, and spillover hosts where infection does not persist indefinitely without re-infection from another host species. Spillover hosts may be either:

- 'dead-end' hosts (if the incidence and pathology of the disease indicates they play no significant role in its onward transmission) or
- 'amplifier' hosts (if they appear capable of transmitting *M. bovis* to other species).

As noted in the introductory chapter of this document, human cases of *M. bovis* infection are rare. An official guidance[159] published in 2014 by Public Health England in association with Defra and the Department of Health analysed the risk of humans contracting bTB from species other than cattle:

> "It had always been assumed that there was a theoretical risk of transmission from nonbovine animals (such as pets) to humans although this risk had not been documented. However, recent incidents involving infected cats have provided evidence that both latent and active TB infections in humans can result from close contact with an infected domestic animal. Nonetheless, a risk assessment has concluded that the transmission risk of *M. bovis* from cats to humans is still very low.
>
> There are concerns about the potential for transmission from other animals, particularly camelids, which have rapidly progressive and extensive disease and a tendency to spit (a mixture of gastric contents and saliva). There have been two confirmed cases in the UK of human disease acquired from infected alpacas."

5.1 Non-bovine farmed animals

Non-bovine farmed animals in the UK are largely considered 'spillover' hosts i.e. individual animals are at risk of becoming infected from the major carriers of *M. bovis* (cattle and badgers), mostly in areas of the country where *M. bovis* infection is known to be endemic.

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[158] Ojo O, Sheehan S, Corcoran GD, et al. Mycobacterium bovis strains causing smear-positive human tuberculosis, Southwest Ireland. Emerging infectious diseases. 2008 Dec;14(12):1931. doi: 10.3201/eid1412.071135

[159] Public Health England, Bovine tuberculosis: Guidance on management of the public health consequences of tuberculosis in cattle and other animals (England). 2014

There has been research to suggest that fallow deer populations in some areas of England may have become maintenance hosts.[160]

Non-bovine species vary in the extent to which the disease can persist in their populations. Given the right conditions, they can also infect other animals and herds of the same species (e.g. via movements of undetected infected animals between holdings).

Currently in the UK there is no statutory routine bTB surveillance programme for *M. bovis* in non-bovine farmed species. bTB may be identified in clinically ill animals, diagnostic post-mortem examination or at slaughter. South American camelids, farmed deer and goats are also tested if they are co-located on (or contiguous to) farms with bTB lesion or culture-positive cattle herds.

Defra publishes quarterly statistical tables with the number of cases, tests, and holdings restricted[161]. However, with no statutory surveillance programme for these species, there is some uncertainty around the true prevalence of infection. One indication available is the number of slaughterhouse animal specimens that were culture positive for *M. bovis* between 2011 and 2018, found in the table below.[162]

Species	2011	2012	2013	2014	2015	2016	2017	2018
South American Camelids	17	45	36	34	39	20	30	22
Sheep	35	20	3	1	7	2	4	0
Goats	0	2	7	29	0	27	7	12
Pigs	44	20	35	18	23	31	24	25
Deer[163]	23	17	30	26	34	29	29	25
Other	22	12	30	26	42	30	11	11

As can be seen above, the numbers of infected non-bovine animals based on these figures alone are relatively low and stable. Typically, only a handful of infected animals occur in these species annually, although large 'explosive' breakdowns involving hundreds of animals and leading to herd slaughters have occasionally been recorded on dairy goat farms in England between 2014 and 2018.

160 Crawshaw T, De La Rua-Domenech R, Brown E. Recognising the gross pathology of tuberculosis in South American camelids, deer, goats, pigs and sheep. In Practice. 2013 Oct 1;35(9):490-502. doi: 10.1136/inp.f5683

161 https://www.gov.uk/government/statistical-data-sets/other-tb-statistics

162 Defra, A strategy for achieving Bovine Tuberculosis Free Status for England: 2018 review. Table 7.1. 2018 Feb.

163 Note this data does not differentiate between different species of deer.

Small numbers of cases can fail to convey just how devastating the disease can be for the individual owners when their livestock become infected and restrictions are put in place. In England in 2018[164], the highest proportion of premises with non-bovine species under movement restrictions due to a bTB incident was goat premises (40%), followed by South American camelid premises (27%) and pig premises (17%).

Data on bTB in species other than cattle in England in 2018	South American camelids [165]	Sheep	Goats	Pigs	Deer [166]	Other
Premises under movement restrictions at the end of the period due to bTB incident	60	6	87	38	18	10
Total tests carried out on individual animals	4,314	2,132	24,325	122	500	162
Reactors slaughtered	72	6	97	5	8	0
Animal specimens which underwent laboratory culture	61	16	17	261	54	30
Animal specimens that were culture positive for *M. bovis*	22	0	12	25	25	11

Although bTB in such animals is an important problem, there is far less well-validated data for the diagnosis of the disease in live animals other than cattle. The SICCT is used in goats, sheep, pigs, South American camelids, and deer. As in cattle, the test is the internationally accepted test for *M. bovis* in live animals, although its performance characteristics in non-bovine species are not fully understood. SICCT is used for International Trade and has been used in pig herds affected by bTB breakdowns. It is not validated under UK conditions and may be difficult to perform in large numbers of pigs. While the Enferplex bTB serological test has only received OIE approval for use in cattle, it has been adapted for use in other species. The test has been validated and used in South American camelids and is currently being used as part of the Camelid Voluntary

[164] APHA, Bovine tuberculosis in England in 2018. Epidemiological analysis of the 2018 data and historical trends. 2019 Sep.

[165] Note this data does not differentiate between llamas and alpacas

[166] Note this data does not differentiate between the different species of deer.

Health Scheme for bTB. It has also had some evaluation and use in goats[167,168], deer[169], and pigs.

Cousins & Florisson (2005)[170] note the importance of having appropriately validated diagnostics for these different species. However, the small numbers of animals involved has resulted in difficulties securing the data needed for test validation.

Farmers of non-bovine species must immediately notify the appropriate authority if they or their vet suspect that a carcase is infected with TB. Suspicion of bTB in all deer, whether farmed, park or wild, is also notifiable.[171] Farmed animal species kept as pets most often include goats, camelids, pygmy pigs and sheep. In the event that any farm animals that are kept as pets become infected with *M. bovis*, they will be treated as livestock and the method of disease management applied will depend on the species involved.

In England, the Tuberculosis (Non-bovine Animals) Slaughter and Compensation (England) Order 2017[172] introduced specific rates of statutory compensation for pigs, sheep, goats, captive deer, alpacas, llamas, vicuna and guanaco) that are subject to compulsory slaughter for bTB disease control purposes. At present, there is no equivalent piece of legislation in place for the other UK jurisdictions.

Across non-bovine farmed animals, there are issues that are common across all species. Government and industry communications on the issue of bTB are largely designed with cattle farmers as the intended audience, which is understandable given the relative significance of bTB within the cattle sector. However, as a result, farmers of non-bovine species can be less aware of the risk of bTB to their animals. Government, industry and the veterinary profession should tailor messages to the farmers of non-bovine farmed species

The TB Hub website is described as “the ‘go-to’ place for British beef and dairy farmers to find practical advice on dealing with bTB on their farm”. This website is an excellent resource providing clear information to farmers. Utilising this resource to provide the same level of information to non-bovine farmers should be explored.

Recommendation 27: Government should seek to evaluate and validate existing bTB tests for susceptible non-bovine farmed species. Government should also seek to develop new validated tests for bTB diagnosis in live animals.

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[167] Shuralev E, Quinn P, Doyle M, et al. Application of the Enfer chemiluminescent multiplex ELISA system for the detection of Mycobacterium bovis infection in goats. Veterinary microbiology. 2012 Jan 27;154(3-4):292-7. doi: 10.1016/j.vetmic.2011.07.028

[168] O'Brien A, Whelan C, Clarke JB, et al. Serological analysis of tuberculosis in goats by use of the enferplex caprine TB multiplex test. Clinical and Vaccine Immunology. 2017 Feb 1;24(2). doi: 10.1128/CVI.00518-16

[169] Busch F, Bannerman F, Liggett S, Griffin F, Clarke J, Lyashchenko KP, Rhodes S. Control of bovine tuberculosis in a farmed red deer herd in England. The Veterinary Record. 2017 Jan 21;180(3):68. doi: 10.1136/vr.103930

[170] Cousins DV, Florisson N. A review of tests available for use in the diagnosis of tuberculosis in non-bovine species. Revue scientifique et technique (International Office of Epizootics). 2005 Dec 1;24(3):1039-59.

[171] UK Statutory Instruments. Tuberculosis (Deer) Order 1989.

[172] UK Statutory Instruments. The Tuberculosis (Non-bovine Animals) Slaughter and Compensation (England) Order 2017.

Recommendation 28: Government, industry and the veterinary profession should tailor messages to the farmers of non-bovine farmed species. There should be exploration of providing information to non-bovine farmers through the TB Hub website.

5.2 Specific consideration of TB in relevant non-bovine farmed species

The pathology, clinical presentation, and epidemiology of bTB infections and disease can vary considerably across the farmed species. There are also wider social and economic factors between and within different sectors and it is important to be mindful of the differing relationships that keepers will have to their animals. Within each species there will be a wide range from large scale farmers to those who have a relationship that is more akin to that of a pet owner. We address each in turn below.

5.2.1 Goats

TB is very difficult to diagnose in goats on clinical examination alone, as the signs of the disease are not very specific. Chronic loss of condition and appetite, reduced milk yield, chronic cough, and debilitating disease are typical signs in goats. However, animals may also be latently infected without exhibiting any obvious clinical signs.

The goat sector in the UK is comparatively small and very diverse. They are kept for many varied reasons, a significant pet/hobby keeping sector with herds of fewer than ten animals to commercial dairy herds of over 4000 goats. There is a small meat sector and an angora/cashmere fibre sector. Goats are also kept at public attractions, such as zoos, open farms and theme parks[173] and public interaction with goats at these attractions could potentially pose a public health risk if an animal was infectious.

Awareness of bTB will vary both between and within these different groups. The level of awareness will also be influenced by the local prevalence of the disease in cattle and badger populations. Even amongst veterinary surgeons the risks of bTB in goats may not always be well known and understood.

Historically, the UK has seen very few cases of bTB in goats. Although two sporadic isolates were confirmed in individual goats in 1981 and 1996, the first documented incident in which bTB was confirmed involved two goats on a smallholding in Wiltshire in 2007.[173] In this and subsequent incidents, goats were considered to be a ‘spillover’ host within known heavily infected areas of the country.

Although considered a ‘spillover species’ in relation to first exposure, it is apparent that spread within a large herd of goats kept commercially (many of which are housed all year round) can be very rapid.

In previous cases, all milk leaving infected goat (and sheep) herds was pasteurised so there was no threat to the consumer. However, there is a growing trend for non-pasteurised goat and sheep milk consumption. There is a potential risk to those farm personnel in daily contact with clinical and subclinical cases that may be shedding infection.

5.2.2 Sheep

Sheep can be infected with *M. bovis* and act as spillover hosts. If infected, sheep can occasionally transmit the disease to other animals and humans, i.e. some of them may act as amplifier hosts.[174] Information on bTB in sheep is scarce, and there appears to be

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[173] Harwood D. Bovine TB in goats. Veterinary Record. 2014 May 3;174(18):456. doi: 10.1136/vr.g3007

[174] APHA, Tuberculosis in Sheep Overview.

conflicting opinions about the relative susceptibility of sheep to infection. Mixed farming of cattle and sheep is commonly practised which would imply an increased risk of interspecies transmission of *M. bovis*. However, despite this opportunity for contact, cases of bTB in sheep have been limited. Consequently, the literature describing the disease in sheep is limited to a small number of reports.

Single cases (Houlihan el al. 2008,[175] Marianelli el al. 2010[176]) and flock outbreaks (Cordes et al. 1981,[177] Davidson et al. 1981,[178] Malone et al. 2003,[179] Muñoz Mendoza et al. 2011[180]) have been reported. *M bovis* infection was typically detected by the recognition of suspicious lesions at slaughter or at a diagnostic post-mortem examination where the lesions have often been incidental findings. In two outbreaks, infected sheep were detected after SICCT testing of sheep in contact with infected cattle. Muñoz Mendoza et al. (2011) report a flock outbreak of *M. bovis* where there were clinical signs in two sheep, namely coughing and dyspnoea.

5.2.3 Pigs

Of the over 10 million pigs slaughtered annually in the UK, very few are found to be infected with *M. bovis* at slaughter. The vast majority of the small number of confirmed cases are detected at post-mortem examination during routine meat inspection where samples are cultured to confirm the presence of *M. bovis*.

Infection in pigs is typically located in the head lymph nodes,[181] suggesting infection via an oral route (i.e. consumption of contaminated material). Pigs are spillover hosts and although susceptible to *M. bovis*, it is believed that onward transmission is unlikely among domestic pigs in the UK. Hence, bTB breakdowns in pig herds often affect only individuals or a handful of animals.[181]

Close contact between domestic pigs and cattle is rare. Most incidents of bTB occur in outdoor-reared pig herds which accounts for around 40% of the UK industry.[182] This suggests wildlife and environmental sources of infection are the most significant source of infection. Indoor pig farms can also occasionally experience cases and, in these incidents direct contact between pigs and wildlife or indirect contact with feed stores has been suspected.

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[175] Houlihan MG, Williams SJ, Poff JD. Mycobacterium bovis isolated from a sheep during routine surveillance. Veterinary Record. 2008 Jul 19;163(3):94-5. doi: 10.1136/vr.163.3.94-b

[176] Marianelli C, Cifani N, Capucchio MT, et al. A case of generalized bovine tuberculosis in a sheep. Journal of Veterinary Diagnostic Investigation. 2010 May;22(3):445-8. doi: 10.1177/104063871002200319

[177] Cordes DO, Bullians JA, Lake DE, Carter ME. Observations on tuberculosis caused by Mycobacterium bovis in sheep. New Zealand Veterinary Journal. 1981 Apr 1;29(4):60-2. doi: 10.1080/00480169.1981.34798

[178] Davidson RM, Alley MR, Beatson NS. Tuberculosis in a flock of sheep. New Zealand Veterinary Journal. 1981 Jan 1;29(1-2):1-2. doi: 10.1080/00480169.1981.34775

[179] Malone FE, Wilson EC, Pollock JM, Skuce RA. Investigations into an outbreak of tuberculosis in a flock of sheep in contact with tuberculous cattle. Journal of Veterinary Medicine, Series B. 2003 Dec;50(10):500-4. doi: 10.1046/j.1439-0450.2003.00714.x

[180] Mendoza MM, de Juan L, Menéndez S, Ocampo A, Mourelo J, Sáez JL, Domínguez L, Gortázar C, Marín JF, Balseiro A. Tuberculosis due to Mycobacterium bovis and Mycobacterium caprae in sheep. The Veterinary Journal. 2012 Feb 1;191(2):267-9. doi: 10.1016/j.tvjl.2011.05.006

[181] Bailey SS, Crawshaw TR, Smith NH, Palgrave CJ. Mycobacterium bovis infection in domestic pigs in Great Britain. The Veterinary Journal. 2013 Nov 1;198(2):391-7. doi: 10.1016/j.tvjl.2013.08.035

[182] AHDB, Pig Production information.

Where pig herds are placed under restrictions there can be severe implications for animal welfare. UK authorities may take a risk-averse approach, placing restrictions where there is suspicion of bTB (where a lesion is found at meat inspection), pending final results of laboratory tests performed on pathological samples. Once movement restrictions are put in place they will not be lifted until negative culture results are received, which can take several months. This can have severe implications for the affected farms which may become ineligible for export of pig meat to important foreign markets.

Recommendation 29: Government should enact clear and consistent protocols for bTB in pig herds. Where there is suspicion of bTB in a pig herd, the application of restrictions should be based on an appropriate veterinary risk assessment. Furthermore, government should develop improved and rapid methods to confirm the presence or absence of M. bovis in pig carcasses.

5.2.4 South American Camelids

Llamas and alpacas are susceptible to *M. bovis* infection, often developing extensive bTB lesions in their lungs and other organs.[183] Clinical signs are predominantly weight loss with later development of respiratory signs, lethargy, anorexia and death. Clinical signs of the disease tend to appear early allowing for rapid containment of infected animals which will limit the opportunity for the spread of infection further.

Historically, camelids were seen as spillover, dead-end hosts posing a negligible risk in the bTB epidemiology. This has meant eradication efforts have almost completely passed them by. However, understanding of the disease in camelids has evolved in recent years, with more evidence suggesting transmission within the herd. This capacity to function as an amplification host and reservoir (de la Rua-Domenech, 2006[184] Twomey et al, 2009[185]) implicates a potential for a far more active role in the epidemiology of bTB than was previously assumed. However, it is important to note there has been no documented spread of the disease from camelids to cattle.

Approved tests are available for camelids, which is not the case for other non-bovine farmed species. The Interferon gamma test (IFNγ) has been evaluated in alpacas under UK conditions. The test is resource-intensive particularly with regard to sample handling and has now largely been superseded by antibody tests. Antibody tests validated under UK conditions are available for statutory testing of camelids.

There are no statutory testing requirements for camelids in the UK, apart from those co-located with or contiguous to infected cattle herds. However, government encourages private surveillance testing of camelids, but this testing is not subsidised by the government and owners will bear the full cost.

The Camelid Voluntary Health Scheme for Bovine Tuberculosis was set up to provide a voluntary private system for herd surveillance for bTB in the camelid industry. The scheme was developed in conjunction with DEFRA, APHA and representative groups of the

183 Broughan JM, Downs SH, Crawshaw TR, et al. Mycobacterium bovis infections in domesticated non-bovine mammalian species. Part 1: review of epidemiology and laboratory submissions in Great Britain 2004–2010. The Veterinary Journal. 2013 Nov 1;198(2):339-45. doi: 10.1016/j.tvjl.2013.09.006

184 De la Rua-Domenech R. Human Mycobacterium bovis infection in the United Kingdom: incidence, risks, control measures and review of the zoonotic aspects of bovine tuberculosis. Tuberculosis. 2006 Mar 1;86(2):77-109. doi: 10.1016/j.tube.2005.05.002

185 Twomey DF, Crawshaw TR, Foster AP, et al. Suspected transmission of Mycobacterium bovis between alpacas. Veterinary Record. 2009 Jul 25;165(4):121-2. doi: 10.1136/vetrec.165.4.121

camelid industry. The scheme aims to maintain the integrity and security of the British Camelid Industry health status and thereby increase commercial opportunities for its members including the export of stock to Europe. By testing animals, the scheme seeks to clarify the herd or individual animals' bTB infection status. It is important to note that this scheme is not an accreditation scheme for bTB and does not guarantee a herd will have continued freedom from infection.

In England, compensation for camelids which are compulsorily slaughtered as bTB reactors or bTB affected animals is:

- £1500 for a stud male or breeding female over 18 months old
- £750 for a non-breeding animal over 18 months old
- £750 for an animal 18 months old or younger

However, high quality breeding females can be worth £3,000 – 15,000 while stud males may be worth up to £60,000. The purpose of compensation is to:

- Encourage people to report disease
- Encourage people to present animals for culling instead of selling them when they are sick
- Reflect government responsibility. If the government destroys the private assets of citizens for public purposes, it should compensate them.

The disparity between the market value of an animal and the compensation paid to camelid owners may limit the ability to meet these objectives.

5.2.5 Farmed deer and park deer

There is a wide variety within and between different deer systems. Wild deer, farmed deer and parkland deer all experience the disease and controls differently (wild deer are considered below). There are several species of deer farmed in the UK.[186]

There is no routine statutory bTB testing programme for live deer. However, any suspicion of bTB in live farmed or park deer (or any deer carcass including wild deer), must be notified to the appropriate authority.

The SICCT test is the primary test applied to deer. However, this raises specific concerns as park deer cannot be handled without a high risk of injury and mortality to the animal, as well as a risk of injury for the vet performing the test. In addition, farmed deer cannot easily be handled during several seasons due to calving, antler growth, or the rutting season. This leaves short windows during which testing can take place. The sensitivity is also limited but can be improved by supplementing with serological (antibody) tests.[187]

In England, the Tuberculosis (Deer and Camelid) (England) Order 2014 provides the statutory powers to require testing of deer herds infected with *M. bovis* to be undertaken at the owner's expense in order to ascertain freedom from disease (i.e. a clearing test). In Scotland and Wales, statutory SICCT testing of deer in confirmed infected deer herds is

[186] Over 95% of farmed deer are red deer. Parks have more fallow than red, and some parks will have exotic species. Wild deer are numerically in descending order roe, muntjac, fallow (or red in Scotland), and Chinese water deer.

[187] Busch F, Bannerman F, Liggett S, et al. Control of bovine tuberculosis in a farmed red deer herd in England. The Veterinary Record. 2017 Jan 21;180(3):68. doi: 10.1136/vr.103930

funded by the Scottish and Welsh governments respectively under the Tuberculosis in Specified Animals (Scotland) Order 2015 and the Tuberculosis (Wales) Order 2011.

Where SICCT is used to clear a herd and remove movement restrictions, two clear consecutive tests will be required at 120-day intervals. In New Zealand 80 days is considered preferable and has proved highly effective. We would welcome consideration of this being introduced in the UK.

Recommendation 30: For farmed and park deer, Government should consider changing the requirement for two clear consecutive bTB tests at 120-day intervals. We recommend that government undertake an appraisal of following the example from New Zealand where 80 days is considered preferable and has proved highly effective.

5.3 Wild animals

5.3.1 Farmed wild animals

Bison and buffalo are both farmed in the UK in small numbers for meat or milk. However, under bTB legislation both species are treated in the same manner as domesticated cattle. Herd keepers are required by law to have their animals tested for bTB as part of statutory bTB testing regime. This can lead to considerable animal welfare compromise and safety issues, when wild animals undergo a stressful process that was designed for domesticated animals and this has been reported in the news media.[188]

The Chillingham wild white cattle herd is considered here. This is a breed of cattle that live in a large enclosed park at Chillingham Castle, Northumberland. The animals are not tamed in any way and behave as wild animals.

Officially the herd is treated separately from the general cattle population. The herd has never been SICCT tested. This is rationalised because of an "absence of evidence of tuberculosis, the isolation of the herd, the fact that the cattle do not enter the food chain and the likelihood that confining the herd for testing might provoke panic and possibly lead to the deaths of young animals, all argue against any imposition of a testing regime."[189] Instead approximately 14% of the population has undergone post mortem examination.

As dispensation from testing has been afforded to the Chillingham wild white cattle herd it could also be applied to other species. There could be consideration of dispensations where there is a defined population in a defined area, with relevant APHA or DAERA risk assessments in place. We would ask government to consider the rationale behind the current dispensation and seek to apply it elsewhere, where possible and where this can be done under international trading obligations on animal and public health.

5.3.2 Wild animals that form part of zoological collections

Cases of *M. bovis* infection in zoological collections are rare. However, when it is detected, it can have devastating consequences for the affected animals and their keepers.

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188 The Telegraph, Bison farmer shoots healthy herd in protest at TB testing that is 'stressful' for animals. 2016 Apr 13.

189 Hall SJ, Fletcher J, Gidlow J, et al. Management of the Chillingham wild white cattle. Government Veterinary Journal. 2005;15(2):4-11.

There are several possible routes of transmission to a zoological collection, including import of infected animals and feeding infected raw meat. There has been at least one example where transmission from badgers was the attributed source of infection.[190]

The Balai Directive[191] governs much of the trade of zoological collections within the EU. Ensuring infectious diseases do not spread between collections is a central feature of the directive. All ruminants traded between institutions must come from officially TB free herds. Moreover, to be 'Balai-approved', an institution must be free of bTB for at least 3 years, or free of bTB for primates, felidae and ruminants, if the Member State has a control monitoring programme regarding these species. Balai requires full post-mortem examination of all animals that die and ad hoc screening but does not require pre-movement testing.

Where *M. bovis* infection is confirmed in a zoological collection, movement restrictions are put in place and Balai-approved status withdrawn, which can have an effect on animal welfare. Managed voluntary culling of infected animal groups can also be used to control the outbreak if movement restrictions are enforced in zoos. Authorities will then work with the collection to recommend a TB surveillance programme and removal of any infected animals until bTB infection is cleared. Where *M. bovis* infection is confirmed, the need to cull animals that are part of a conservation sensitive species can have disastrous effects on the breeding population and wider impact on the genetics of that species going forward. In 2018, a Devon zoo gave animals contraceptives to avoid overcrowding amid an outbreak of TB. The zoo was unable to send any animals to other zoos because of movement restrictions to prevent the spread of the disease.[192]

There is a very limited range of validated tests available for zoological animals. Applying the SICCT test to these wild species can prove challenging which is in keeping with the difficulties faced testing deer, bison and buffalo mentioned above.

Recommendation 31: Government should consider the rationale behind the current dispensation from routine SICCT testing afforded to the Chillingham wild white cattle herd and seek to apply it elsewhere following appropriate risk assessment. There is potential merit to applying dispensation for both farmed wild animals, wild deer and zoological collections where the SICCT poses risks for animal welfare and the personal safety of the tester. This should be considered alongside other obligations such as food safety regulations or international trading obligations on animal and public health.

5.4 UK wildlife other than badgers

In the UK badgers are the primary wildlife host implicated in transmitting *M. bovis* to cattle, but the bacterium can also infect other wild mammal species.[193]

Wild deer are susceptible to *M. bovis* infection and are widely considered to be spillover hosts. There is evidence that wild deer can be a reservoir of *M. bovis* and can transmit the

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[190] Sayers G, Head of Veterinary Services, Paignton Zoo. E-mail communication with BVA bTB Working Group. 2020 Jun.

[191] EU Council Directive 92/65/EEC. 1992

[192] BBC News, Paignton Zoo animals given birth control amid TB outbreak. 2018 Mar 9.

[193] Delahay RJ, Smith GC, Barlow AM, et al. Bovine tuberculosis infection in wild mammals in the South-West region of England: a survey of prevalence and a semi-quantitative assessment of the relative risks to cattle. The Veterinary Journal. 2007 Mar 1;173(2):287-301. doi: 10.1016/j.tvjl.2005.11.011

infection to both other deer and cattle. *M. bovis* has been found in 5 of the 6 deer species found in the UK (Roe deer, Red deer, Fallow deer, Sika deer and Muntjac).[194] The data on the prevalence of infection, pathology, abundance and ecology suggest that fallow deer and possibly muntjac and red deer are the only wild mammals other than badgers that could act as potential sources of *M. bovis* for cattle in the South West of England and Wales.

There is the potential that deer could be involved in the transmission of *M. bovis* to cattle, where they are infected. However, this has not been confirmed and any risk from deer is unclear as there is little data on levels of *M. bovis* excretion, local deer abundance and contact with cattle.

Wild deer surveillance is carried out by hunters where carcasses are intended for human consumption with any suspicious lesions reported to the appropriate authority. Training is through the Deer Stalking Certificate, where there is a strong emphasis on locating and examining lymph nodes. Furthermore, hunters are required to issue declarations that accompany wild deer carcasses going to approved Game Handling Establishments (GHEs). Authorities will periodically declare potential bTB hotspots for enhanced surveillance, this should be actively communicated to the deerstalking community to ensure they are vigilant to the signs of *M. bovis* in deer.

Feral wild boar populations occur in several locations in the UK. Wild boar can act as a maintenance host for *M. bovis* and the infection has been detected in feral wild boar in southern England.[195] The evidence from other countries indicates that boar can excrete and transmit *M. bovis*.[196,197] Boar generally prefer woodland habitats and are currently not widespread, so any risk to cattle in the UK is likely to be very localised. The relative risk of bTB from feral boar is still small compared to the risk of them transmitting other diseases, such as African Swine Fever, as pigs are generally regarded as spillover hosts of *M. bovis*. Their bTB infection status reflects local infection pressure primarily from other wildlife, but it remains important to monitor their bTB status to ensure the risk to other species is minimised.

As well as deer and boar, surveys of wildlife[193,194] have found very low levels of bTB in other wild mammals.[198] Detailed analyses of carcasses collected in the UK suggests that these species are unlikely to excrete *M. bovis.*

Recommendation 32: Government should evaluate the safeguards in place (including training, qualifications and declarations) to ensure infected wild deer

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[194] Delahay RJ, De Leeuw AN, Barlow AM, et al. The status of Mycobacterium bovis infection in UK wild mammals: a review. The Veterinary Journal. 2002 Sep 1;164(2):90-105. doi:10.1053/tvjl.2001.0667

[195] Foyle KL, Delahay RJ, Massei G. Isolation of Mycobacterium bovis from a feral wild boar (*Sus scrofa*) in the UK. Veterinary Record. 2010 May 22;166(21):663-4. doi: 10.1136/vr.c2681

[196] Naranjo V, Gortazar C, Vicente J, de la Fuente J. Evidence of the role of European wild boar as a reservoir of Mycobacterium tuberculosis complex. Veterinary microbiology. 2008 Feb 5;127(1-2):1-9. doi: 10.1016/j.vetmic.2007.10.002

[197] Boadella M, Vicente J, Ruiz-Fons F, et al. Effects of culling Eurasian wild boar on the prevalence of Mycobacterium bovis and Aujeszky's disease virus. Preventive veterinary medicine. 2012 Dec 1;107(3-4):214-21. doi: 10.1016/j.prevetmed.2012.06.001

[198] Fox, Polecat /Ferret, Mink, Stoat, Brown Rat, Wood / Yellow necked mouse, Common shrew, Field vole, Grey squirrel.

meat does not pose a public health risk through entering the human or pet food chains.

Recommendation 33: Where authorities declare potential bTB hotspots for enhanced surveillance, this should be actively communicated to the deerstalking community to ensure they are vigilant to the signs of bTB in deer.

5.5 Cats and dogs

There has recently been documented evidence of transmission to cats[199] and dogs.[200] In both cases these individual incidents made headlines in the national press.[201,202]

One incident involved a specific brand of raw cat food made from wild venison which subsequently faced a nationwide recall. Five clusters of cases came to light when individual cats with varying clinical signs were presented to different practices, a positive example of the vital disease surveillance undertaken by small animal vets. Six cats were found to be clinically affected and researchers found evidence of infection with *M. bovis* in seven in-contact cats without clinical signs. Since November 2018, the number of cases has increased to include at least 30 clusters involving over 90 cats.

The other case involved an outbreak in a hunt kennel in the south of England that housed up to 180 working Fox hounds. In a similar fashion to many hunt kennels, the hounds were predominately fed raw meat, permitted offal and bone from fallen stock.[203] While uncertainty exists with regards to the source of infection, it seems likely that contaminated fallen stock carcasses were involved. This represented the only documented occurrence of *M. bovis* infection in a canine species with evidence of onward dog-to-dog transmission within the affected group.

Both cases were dependent on very specific circumstances that are unlikely to pose a wider risk to animals and importantly to public health. However, it reinforces the need to be vigilant to disease and the contribution of all vets to disease surveillance.

Recommendation 34: Vets who work with cats and dogs should be vigilant to the risk posed by bTB in these species and be aware of the appropriate reporting process if they suspect the disease.

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[199] O'Halloran C, Ioannidi O, Reed N, et al. Tuberculosis due to Mycobacterium bovis in pet cats associated with feeding a commercial raw food diet. Journal of feline medicine and surgery. 2019 Aug;21(8):667-81 doi: 10.1177/1098612X19848455

[200] O'Halloran C, Hope JC, Dobromylskyj M, et al. An outbreak of tuberculosis due to Mycobacterium bovis infection in a pack of English Foxhounds (2016–2017). Transboundary and emerging diseases. 2018 Dec;65(6):1872-84. doi: 10.1111/tbed.12969

[201] The Times, Posh 'natural' pet food recalled as cats and their owners develop bovine tuberculosis. 2019 May 19.

[202] The Times, TB outbreak forces Kimblewick Hunt to kill nearly 100 hounds. 2018 Aug 3.

[203] So called "flesh feeding" as permitted under Animal By-Products legislation (Article 18, Commission Regulation (EC) No. 1069/2009

Research

6.1 Introduction

New research is vital to our understanding of bTB and the efforts to control and eradicate it. bTB is a complex challenge that requires a multifaceted response. A successful research programme will need to gather the expertise of multiple disciplines to increase understanding of the factors behind bTB transmission and develop new tools to tackle infection.

The importance of epidemiology is impossible to overstate. As a discipline, it is central to the understanding of bTB transmission and how it is influenced by different interventions and controls. The evidence provided by epidemiological research underpins the design and delivery of bTB policy. Government should support further research into the epidemiology of bTB, to highlight gaps in our understanding of the disease.

Research in the social sciences provides insight into farmers' decision-making regarding cattle purchasing, the application of biosecurity measures on farm and how decisions that promote disease control can be incentivised. The prominence of social science research within animal health policy design is growing. UK veterinary schools have undertaken interdisciplinary research using social science to address important issues such as antimicrobial resistance[204]. Greater application of social science should form a central aspect of the bTB control and eradication programmes.

Equally as important as commissioning new research, is the dissemination of research and new information to vets, farmers and the public. Consideration should be given to what information is useful to farmers and there should be greater utilisation of behavioural approaches to encourage the application of research findings of into practice.

To date, governments in the UK have supported the development of new research in many areas. Research has also been funded by a wide range of bodies and this diversity is a strength. Nevertheless, there would be a benefit in providing greater strategic direction to research.

Previously, Defra published a Bovine Tuberculosis Evidence Plan 2013/14 – 2017/18.[205] This provided a portfolio of projects to increase understanding of the disease epidemic and to support the development of new tools such as vaccination and diagnostics. A new evidence plan should be developed with all relevant stakeholders and disciplines. There should be a focus on commissioning research that will have practical impacts on farm, and therefore the inclusion of practitioners is essential.

Recommendation 35: Government should undertake to continue their research and develop a plan which ensures the inclusion of all relevant stakeholders and disciplines in setting priorities.

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[204] Reyher K, Bristol University Research, Driving responsible use of antimicrobials.

[205] Defra, Bovine Tuberculosis Evidence Plan. 2013 March.

The veterinary profession's research priorities

This policy position identifies many areas where additional research or evidence would be beneficial. However, it is imperative that the limited resources available for research are directed to those solutions which would have the greatest impact.

Below is a table of the five key research priorities for the next five years.

Areas of Research	Detail
The development and validation of a cattle vaccine and DIVA test	A validated DIVA test (a test that can differentiate infected and vaccinated cattle) is essential to realizing any benefits from cattle vaccination. The benefit of vaccination will need to be considered holistically, with an assessment of its effect on animal health, welfare, trade, and the cost necessary to deliver any vaccination programme. Social science should be included within this research to consider the possible effects of a vaccine programme on farmer decision making. According to reports,[206] researchers have developed two candidate skin tests for cattle that can distinguish between animals that are infected with bTB and those that have been vaccinated against with BCG vaccine. The next stage is to evaluate these tests in field trials to a level conforming to World Organisation for Animal Health (OIE) standards.
Better understanding of the effects of badger vaccination on the incidence of bTB in cattle.	The effect of badger vaccination on cattle bTB incidence is currently uncertain. However, as vaccination leads to reduced bTB in the badger population it is to be expected that this would eventually have a beneficial effect on bTB in cattle. An evidence base is needed to increase the understanding of badger vaccination in order to design programmes that are appropriate to the different circumstances across the country.
Evidence to establish the role of cattle faeces in the transmission of bTB	Research suggests that *M. bovis* can survive in stored slurry for up to six months, however, the risks of infection with different cattle manure systems are not fully understood. Evidence showing the comparative frequency of repeat breakdowns between farms with different slurry systems would be useful. Authoritative evidence could allow vets to inform their advice to farmers and help farmers take steps to reduce any potential risk of infection.
Better understanding of the causes of repeat breakdowns	Certain farms repeatedly experience breakdowns, while other apparently similar farms (same area, same husbandry and similar size) do not. There is a need to better understand the risk factors that lead to this inconsistency. Determining these risk factors will require a holistic examination of epidemiological and behavioural factors.

[206] Case P. Farmers Weekly, Breakthrough in quest for TB cattle vaccine. 2019 July 17.

Estimate of the true costs of bTB breakdowns to farms	There would be a benefit in determining a fuller assessment of the wider cost of a bTB breakdown. This could support farmer decision making by putting the cost of applying preventative biosecurity measures into perspective and thus enable behaviour change.

Annex A:
Glossary of terms and abbreviations

AFU	Approved Finishing Unit, used to channel cattle from bTB restricted herds to slaughter
AHDB	Agriculture and Horticulture Development Board
APHA	Animal and Plant Health Agency
ATT	Approved Tuberculin Testers
Badger controls	This refers to all methods to control infection in the badger population including biosecurity, culling, vaccination and contraception.
BCG	Bacillus Calmette-Guérin, an attenuated strain of *M. bovis*, which is the main component of tuberculosis vaccines.
BEVS	Badger Edge Vaccination Scheme
Biosecurity	Procedures or measures designed to reduce the risk of transmission of infectious diseases
Bovine Tuberculosis	An infectious disease in cattle caused by *Mycobacterium bovis (M. bovis)*
Breakdown	Detection of exposure to *M. bovis* infection in a herd (e.g detection of one or more bTB test reactors, or animals with suspected lesions of bTB at routine post-mortem meat inspection that prove positive for *M. bovis* on laboratory culture). Declaration of a breakdown is followed by adoption of bTB control procedures including movement restrictions and enhanced herd testing. The duration of a breakdown depends on the success of the breakdown measures in clearing infection from the herd.
CAFRE	College of Agriculture, Food and Rural Enterprise
CHeCS	Cattle Health Certification Standards
Defra	Department for Environment, Food and Rural Affairs
DIVA	A test used to differentiate infected from vaccinated animals
Edge Area	The counties of England situated between the HRA and LRA where bTB is not yet considered to be endemic and herd prevalence is lower than in the HRA but there is a great likelihood of further geographical spread from the HRA.
Endemic disease	A disease which is continuously present in a specific population
Epidemiology	A study of the distribution and dynamics disease in a population

Herd Prevalence	This statistic can be expressed in different ways but depicts the proportion of herds that are affected by a disease/condition in a specific population
HRA or High-Risk Area	A geographic area of England in which cattle herds have a greater likelihood of experiencing a bTB breakdown and there is a relatively high herd prevalence of bTB
Host	Animals which can routinely become infected with a pathogen (for example, *M. bovis*) if exposed
IAA	Intensive Action Area (South West Wales)
ibTB	Website (ibtb.co.uk) with an interactive map showing the locations of bTB breakdowns in England and Wales.
IFNy/ Interferon Gamma test	A rapid (24-hour) whole blood in-vitro assay to detect an immune response to *M. bovis* for the diagnosis of bTB
Incidence	This statistic reflects the number of cases of infection or disease in a population as a rate per time unit
Inconclusive reactor	An animal which gives an inconclusive reaction to the tuberculin skin test as defined in Council Directive 64/432/EEC
Lesions	Characteristic tubercles or larger abscess-like structures typically found in lymph nodes and organs such as the lungs, liver and spleen
LIS	Livestock Information Service.
LRA or Low-Risk Area	A geographic area of England in which cattle herds have a lower likelihood of experiencing a bTB breakdown and there is a very low herd prevalence of bTB. The disease is not believed to be maintained by badgers and is primarily caused by cattle movements.
Mycobacteria	A family of bacteria which includes *Mycobacterium bovis*
Mycobacterium avium (M. avium)	A bacterium which causes tuberculosis in birds and swine, and is responsible for the mycobacterium avian complex (MAC) in humans.
Mycobacterium bovis (M. bovis)	The main bacteria which causes tuberculosis in cattle. It can also infect other mammals including humans and wildlife.
OIE	World Organisation for Animal Health
OTF	“Officially Bovine Tuberculosis Free” as defined in Council Directive 64/432/EEC. OTF status may apply to herds, regions or Member States

OTFS	"Officially Bovine Tuberculosis Free status Suspended", as defined in Council Directive 64/432/EEC. This status is used for those cattle herds where the infection is not confirmed by culture of *M. bovis*
OTFW	"Officially Bovine Tuberculosis Free status Withdrawn", as defined in Council Directive 64/432/EEC. This status is used for those cattle herds where the infection is confirmed by culture of *M. bovis* or by finding typical lesions in a carcase of an animal
OV	Official Veterinarian, a private veterinarian permitted to undertake official controls such as tuberculin skin testing
Perturbation	Disruption of badger social organisation or structure which causes badgers to range more widely than they would normally and come in contact more often with other animals (including both cattle and other badgers).
Pre-Movement Test	A tuberculin skin test applied to an animal before it has moved between premises
RBCT	Randomised Badger Culling Trial, a scientific study carried about from 1998 – 2005 to quantify the impact of two forms of culling badgers on bTB incidence in cattle
Reactor	An animal which gives a positive reaction to the tuberculin skin test as defined in Council Directive 64/432/EEC
Reservoir Host Population	A population in which the pathogen is endemic and from which infection is transmitted to a particular target population
Routine herd testing	The programme of routine surveillance testing of breeding cattle in herds using the tuberculin skin test in line with Council Directive 64/432/EEC. Routine herd testing is applied to four-yearly tested herds
Severe Interpretation	A more rigorous interpretation of the tuberculin skin test (than the "standard interpretation") in line with Council Directive 64/432/EEC
SICCT	Single intradermal comparative cervical test.
Spillover Host	A population which can become infected with the pathogen but from which the infection is not transmitted to a particular target population.
Standard Interpretation	The routine interpretation of the tuberculin skin test in line with the Council Directive 64/432/EEC
TBAS	Tuberculosis Advisory Service
TVR	A wildlife intervention research study in Northern Ireland, looking at the effects of implementing a test and vaccinate or remove intervention on badgers