Technical Advisory Group (TAG): Summary of Evidence on the Role of Wildlife in the spread of Bovine TB (bTB) in Wales and efficacy of wildlife interventions.

This paper was produced for the TB Programme Board and summarises evidence on the role of wildlife in the spread of Bovine TB in Wales and on interventions that have been used in the British Isles to reduce the transmission of bovine TB from badgers to cattle. It is not a comprehensive literature review but has been informed by a number of such reviews including both Godfray Reviews (Godfray et al., 2018 and 2025), Annex IV of the recent Northern Ireland consultation on potential wildlife intervention options (O'Hagen et al., 2025) and the Badger Trust's 'Tackling Bovine TB Together' (2024) and by evidence presented to TAG by a number of organisations including NFU Cymru, FUW, Iechyd Da, Mentera, the Wildlife Trust, the Badger Trust, APHA and Natural England.

Presence of *Mycobacterium bovis* in wildlife in Wales.

In Wales, *Mycobacterium bovis* (which is a member of the *M. tuberculosis*-complex) is almost exclusively the cause of bovine tuberculosis amongst cattle and wildlife. *M. bovis*, can infect a broad range of mammalian species. A recent review of bovine tuberculosis transmission risk in European wildlife communities concluded that despite the limited data on *Mycobacterium bovis* infections in the wildlife community at large, badgers, fallow deer, wild boar and red foxes appear to be species of concern for the transmission of bovine tuberculosis between wildlife species (Justus et al., 2024).

There is strong evidence from the All Wales Badger Found Dead surveys that badgers are infected with *M. bovis* across Wales (Schroeder et al., 2020) and that *M. bovis* isolates from badgers tend to align with the genotypes of cattle in the same area, except in the Low TB Area (Schroeder at al., 2020; Healey et al., 2026).

There is little data on the prevalence of *M. bovis* infection in wild deer in Wales and there have been no carcass submissions since 2022. Genomic studies of *M. bovis* in Wales (such as recent research covering Welsh wildlife samples including fallow deer isolated in Carmarthenshire) show that the genetic structure of the bacteria closely ties to cattle distribution and other local wildlife reservoirs like badgers (Healey et al., 2026). We advise that information on the disease prevalence in wild deer in areas of endemic bovine TB in Wales should be gathered as a matter of priority.

Although *M. bovis* infection has been detected in wild boar in the Forest of Dean (Man and Williamson, 2022), there is no evidence that this species play a role in bovine TB epidemiology in Wales. However, this has been little studied and any opportunity to increase our knowledge of disease prevalence in this species should be taken.

Surveys of wildlife in South–West England and Wales have detected very low levels of *M. bovis* infection in fox, polecat, ferret, mink, stoat, brown rat, wood mouse, common shrew, field vole and grey squirrel (Delahay et al., 2002; 2007). Detailed analyses of carcasses collected suggests that these species are unlikely to excrete

M. bovis. Many of these species also occur at very low densities or have limited interaction with cattle or environments used by cattle. Thus, any risk posed to cattle is likely to be very low.

Assessing the threat of TB transmission from badgers.

The TAG concludes that badgers can transmit *M. bovis* to cattle and contribute to the persistence of bTB. However, we advise that this threat will vary from one area to another and from one farm to another. It is therefore important to estimate the magnitude of this potential threat in different areas of Wales to assess whether measures need to be taken to tackle the disease in wildlife. These measures should be evidence based, targeted and proportionate with a clear exit strategy (see also Smith et al., 2022).

In assessing the degree to which badgers pose an epidemiological threat to cattle, a total evidence approach is needed using information from multiple sources including, where possible, whole genome sequencing (WGS) studies. Assessing this threat is important, as it will inform the need for, and design of, interventions tailored to prevent the spread of infection under local circumstances.

Whole Genome Sequencing (WGS) has the potential to uncover epidemiological patterns that would otherwise be difficult or impossible to characterise, and this technology is now in routine use at APHA (Sandhu et al., 2025). A limited number of studies, described below, have used WGS to quantify the rates and directionality of transmission between badgers and cattle in high-density endemic bovine TB areas in England and Northern Ireland.

Though the number of published studies is still small, the results to date suggest that the magnitude of different transmission routes is likely to depend on local farming practices and the farmed environment. For example, analysis of WGS data collected as part of a long term ecological study of badgers and bovine TB at Woodchester Park, Gloucestershire, where badger densities are high, showed that within-species transmission occurred at much higher rates than between species transmission and that badger to cattle transmission occurred approximately 10 times more frequently than from cattle to badgers (Crispell et al., 2019). In contrast, WGS data collected as part of the Test, Vaccinate or Remove research project in Northern Ireland showed that cattle to cattle transmission was the major transmission pathway with cattle to badger transmission much more common than from badger to cattle (Akhmetova et al., 2023). In this study badger to badger transmission was not detected suggesting that badgers were acting as a ‘spillover’ host rather than a self-sustaining reservoir.

The largest study to date analysed 1442 *M. bovis* genomes from cattle and badgers collected during the Randomised Badger Culling Trial (RBCT) in South-west England. It found that clusters in different trial areas had been seeded from initial infections (chiefly through cattle movement) some years previously during the period when disease prevalence was rapidly rising in England (van Tonder et al., 2021). Cross-species transmission was identified with badger to cattle infection occurring at about twice the frequency of the reverse. Within-species transmission was considerably higher than between-species and highlighted the importance of cattle to cattle transmission in the spread and maintenance of bTB in cattle.

The results of whole genome sequencing (WGS) from samples obtained from badgers in Wales show that *M. bovis* isolates from badgers and cattle in the same geographical areas are closely related (Schroeder et al., 2021; Seery et al, 2024, Healey et al., 2026). However, the limited local sampling of *M. bovis* from both species means that disease transmission routes cannot be inferred from the current WGS data except for the introduction of infection into an area through cattle movements if the genotype is not usually found in that area.

WGS data will be required from more extensive sampling of *M. bovis* isolates obtained from badgers and cattle in TB hotspots in Wales along with the sequencing of historical isolates obtained from badgers and cattle in the same areas if WGS is to be used to elucidate local disease transmission pathways. That said, inferring transmission rates from WGS data is at the cutting edge of molecular epidemiology and requires a careful appraisal of possible sampling biases and the assumptions behind the models employed.

It will also be important to develop methods that do not rely on WGS to obtain accurate source attribution for BTB outbreaks as it may not always be possible to obtain *M. bovis* isolates from infected cattle and badgers for technical reasons such as animals being in the early stages of infection (such as NVL animals) where culture has a low rate of success. Such methodologies are under development at APHA. Evidence that could be used for source attribution include increase in cattle TB incidence in new hot spots, apparent increase in the prevalence of *M. bovis* infection in badgers and information from local field epidemiology investigations.

Evidence for the effectiveness of wildlife interventions on the spread of bovine tuberculosis in the UK.

The Randomised Badger Control Trial (RBCT).

The RBCT is the only source of evidence from the UK on the effect of culling badgers as a single intervention for bTB control. Data from the RBCT have been subject to multiple statistical analyses that have sometimes come to different conclusions. These often arise from subtle differences in statistical assumptions or interpretation, making it difficult for the non-specialist to get a clear overview of the evidence.

Initial published results from the RBCT suggested reactive culling increased herd breakdowns and this arm of the RBCT was stopped prematurely (Donnelly et al, 2003). All subsequent analysis of the RBCT have been comparisons of areas where proactive badger culling was performed using cage trapping and shooting with control areas where no culling took place. Most of the discussion and analysis of the RBCT has been in terms of “confirmed breakdowns”.

The original analysis (Donnelly et al., 2006) found that while bTB outbreaks declined inside the proactive badger cull areas, an increase was seen in the surrounding 2km area. Recent re-analysis by the same group of researchers obtained results consistent with the earlier analysis (Mills et. al., 2024 a &b). The reason for this increase is thought to be due to the increased perturbation of the badger social

groups surrounding culled areas leading to increased bTB transmission. The increase was short lived and was seen to disappear within 18 months after the end of culling (Jenkins et al., 2010). The estimated reduction in herd breakdowns in the proactive areas due to culling, taking into account the decrease within cull areas and the increase in the surrounding areas, was estimated to be 19 % (CI:6% to 29%). Across the combined during- and post-trial period, the incidence of confirmed breakdowns was 28.7% lower (95% CI: 20.8% to 35.8% lower) in proactive areas than in no-culling areas (Jenkins et al. 2010).

A recent analysis of the RBCT using a number of mathematical models disputes this conclusion (Torgerson et al., 2024, 2025). These analyses found that the result obtained depended on the model used to analyse the data and that no models showed an effect of culling when all bTB breakdown herds were included in the analysis.

This disparity in findings was addressed in the recent Godfray Review (Godfray et al., 2025) which concluded that the RBCT provides some evidence that culling as implemented in the experiment reduced the number of confirmed herd breakdowns by 17% (95% CI: 3% to 30%) but that the evidence is not as strong as initial analyses suggested. Although there are no statisticians on the TAG, which limits our ability to come to definitive conclusions on the published analysis, it is clear that culling as performed in the RBCT (i.e. cage trapping and shooting) will only at best provide a limited reduction in the number of confirmed herd breakdowns.

In Ireland, a large scale cull trial known as the four area study (Griffin et al., 2005) demonstrated a that proactive culling resulted in a significant reduction in cattle herd bTB incidence compared with areas where reactive culling had taken place with the benefits extending several years after the cessation in culling (Byrne et al., 2014). In this study natural geographical barriers were used as much as possible to decrease the risk of perturbation and badgers were caught using restraints rather than cage traps.

Wide Spread Industry-led Badger Culls.

Until recently England had been implementing an industry-led badger culling policy aimed at controlling bovine TB in cattle which began in 2013. The culls were carried out under license by trained contractors using two approved methods: cage trapping followed by shooting, and controlled (free) shooting of badgers at night. Over time, free-shooting became the dominant method, accounting for over 77% of badgers killed by 2020. The operational objective was for no more than 30% of the starting population to remain on conclusion of the cull. Intensive culls typically took place over a continuous six-week period. Most culled badgers were uninfected.

By 2025, a total of 73 culling licences had been granted, covering approximately 33,000 km^2 encompassing almost all the HRA and worst affected parts of the Edge Area as well as in 3 areas of the LRA. The total number of badgers culled under this policy was 246,772 (Godfray et al., 2025). In all these areas culling was accompanied by enhanced surveillance and testing along with increased biosecurity measures. A particularly important intervention in the culled areas, from 2017 onwards, was the mandatory use of interferon gamma testing in OTF-W breakdown

herds; the test was used in a more discretionary manner in other areas. In the period 2017 to 2021, this involved around 339,000 individual tests, with an estimated 19,580 interferon gamma-positive cattle slaughtered in addition to 18,578 tuberculin-positive cattle detected by routine testing in the same period.

It is clear that the package of measures in operation during the industry-led culls has led to a reduction in herd breakdowns although this has varied considerably from cull area to cull area. Overall, the herd incidence rate of bTB reduced by 56% (95% CI: 41–69%) up to the fourth year of interventions, with the largest drops in the second and third years (Birch et al., 2024). However, it is not possible statistically to separate the effects of culling from the other measures introduced at the same time. Given other evidence of badger to cattle transmission, and the reduction in herd breakdowns observed before interferon gamma testing in OTF-W breakdown herds became mandatory, it is reasonable to assume that culling itself has had some reduction effect on herd breakdowns but that it was the combination of measures that addressed all transmission pathways that led to the observed reductions in bovine TB within the cull areas.

The use of culling to tackle specific bovine TB hotspots in areas of the country otherwise considered low risk was introduced in England after consultation in 2018. In these areas culling was accompanied by enhanced cattle surveillance and testing and it is not statistically possible to distinguish the role of these types of intervention in reducing incidence. An example of where this approach has been particularly successful is in the HS21 hotspot in Cumbria, south of Penrith. WGS showed that the hotspot arose from a novel Northern Irish *M. bovis* strain identified in 2014 and since then there have been 59 herd breakdowns (Rossi et al., 2022). Intensive culling was initiated in 2018 when 11.1% of the 369 badgers culled were culture-positive. By 2020 measured prevalence in badgers fell to zero and vaccination was initiated (224 badgers were vaccinated in 2024). The area remains under review but has now entered annual testing and is on track for hotspot closure after five years with no reports of TB in wildlife (Godfray et al., 2025). The hotspot areas of England have demonstrated that this targeted approach to TB control is most effective when it is informed by epidemiological evidence and it is driven forward and owned by local people.

Trap, Test and Remove

In Wales, a trap, test and remove intervention was introduced on nine farms with persistent TB incidents between 2017 and 2024. In 2018 test negative badgers were also vaccinated with BCG prior to release. The full programme of four years of twice-yearly trap and test followed by a fifth year of trap and vaccinate only as an exit strategy was only completed on two of the nine farms and so analysis of the impact of this approach will be severely limited. A final report of the project outcomes is not yet available.

Test, vaccinate and remove (TVR)

Test, vaccinate and remove (TVR) programmes are similar to vaccination programmes but badgers are tested in the field for bovine TB and infected individuals are killed. Models of TVR programmes suggest that this combined

approach could be more effective than either non-selective vaccination or non-selective culling alone but only in situations where TVR does not result in social perturbation of the badger population. If this is the case, the model also predicts that TVR results in an 83% reduction in the number of badgers killed compared with proactive culling (Smith et al., 2016).

Between 2014 and 2018, a 100km^2 trial was conducted in County Down, Northern Ireland, to explore a Trap, Vaccinate and Remove (TVR) intervention (Menzies et al., 2021) Badgers were caught using baited traps and tested in the field for bovine TB infection. The test used was a lateral-flow serological test (DPP VetTB) that has high (98%) specificity (95% CI: 96%-99%) and a sensitivity of ~70% (Arnold et al., 2021). Animals that tested positive were removed and euthanised by veterinarians while the remainder were vaccinated with BCG. Issues with the supply of BadgerBCG necessitated a switch from BCG Copenhagen 1331 to BCG Sophia SL222 for years 4 and 5. During the course of the study the prevalence of infection in badgers declined from 14 to 2% (Arnold et al., 2021), roughly in line with model predictions (Smith and Budgey, 2025). TVR in this area did not appear to affect the size of the badger population nor cause any badger perturbation with the social group structures remaining undisturbed (Allen et al., 2022). These results were consistent with that of Woodroffe et al. (2017), who reported that vaccination had no significant effect on monthly home range size whereas proactive culling increased home range by 180% and reactive culling by 74%. The effect on the frequency of herd breakdowns was less clear, though this was probably because most were due to cattle-to-cattle transmission (Akhmetova et al., 2023; Doyle et al., 2023).

The recent Godfray Review (Godfray et al., 2025) concluded that “Euthanising infected individuals (whose welfare will suffer from the disease and who will possibly infect other badgers) will be seen by some (but not all) people otherwise opposed to culling as ethically acceptable. TVR is more complicated and expensive than vaccination, but has the advantage of removing infected animals from the population immediately. More data on the potential efficacy of TVR is needed but we recommended that Government explores with industry and wildlife groups the possibility of the limited use of TVR (for example in emerging hotspots).”

A four-year pilot TVR study commenced in France in 2023, but no results are available at the time of writing.

Humaneness of Badger Culling

Following the introduction of industry led badger culls involving the use of controlled (free) shooting of badgers at night, Defra commissioned a Humaneness Monitoring Investigation to determine the humaneness of this approach. This study, which was conducted between 2013-2014, found that badgers were often nonfatally shot, and up to 22.8% of badgers took more than five minutes to die. The report raised serious concerns about the likely suffering endured by badgers killed by controlled shooting and on this basis the panel recommended that only shooters who have demonstrated a high standard of marksmanship in the field, and who have a good knowledge of badger behaviour, be licensed (Munro et al., 2014). As a consequence, badger culling can only be carried out by licensed contractors who have undertaken government-approved training. Contractors must adhere to strict

licence conditions stipulated by Natural England. Monitoring of the safety, effectiveness and humaneness of badger culls is carried out each year and published on GOV.UK.

Shooting accuracy is used as a proxy measure for ‘humaneness’ and is assessed using observations from Natural England Monitors of free-ranging badgers being shot at under controlled shooting conditions. However, only a relatively small number of controlled shooting events are now observed by Natural England monitors (e.g. n=27 for 2024). The latest report by Natural England (Defra, 2024) includes the following statement by the Chief Veterinary Officer: ‘the likelihood of suffering in controlled shot badgers which were observed by Natural England in 2024 is similar to that reported for killing of other terrestrial wild species. However, it is difficult to make an inference on the likely suffering of the whole population of controlled shot badgers in 2024 using the monitoring data currently available.’

The International Consensus for Ethical Wildlife Control

This paper (Dubois et al., 2017) sets out seven ethical principles for managing human-wildlife conflict and offers a framework for ensuring welfare standards in wildlife management programmes. These principles can reduce controversy and opposition to wildlife control by balancing human concerns, community values, and animal welfare. The approach is intended to ensure ethical decision-making that accounts for the need, benefits, feasibility, and costs of control actions. The TAG advises that this is a useful framework to help inform and implement disease control interventions.

Badger Vaccination

BadgerBCG vaccine was licensed for use in badgers in 2010 to reduce the severity of infection in badgers and hence the risk of onward transmission to cattle. The vaccine reduces the severity and progression of disease in badgers (Chambers et al., 2011) and limited field data supported by modelling shows this is a viable way of controlling bovine TB in wild badger populations (Smith et al., 2016). The Badger Vaccine Deployment Project (BVDP) in England found that vaccinated badgers were 76% less likely to test positive for TB infection compared to unvaccinated ones (Carter et. al., 2012). It also provided evidence of "herd immunity", where vaccinating at least a third of adult badgers in a social group reduced the infection risk for unvaccinated cubs in the same group by 79% (Carter et al., 2012).

Mathematical and simulation models consistently predict that a sustained badger vaccination programme will lead to a decline in TB prevalence within badger populations in GB. Models estimate that achieving a vaccine coverage of 30–40% could be sufficient to reduce the disease's reproductive ratio (R_0) to below 1, leading to the eventual eradication of TB from the badger population, although this could take 20–30 years of annual vaccination (Wilkinson et al, 2004; Aznar et al., 2018).

Models generally predict that culling is more effective than vaccination at reducing the numbers of infected badgers quickly in high-density populations and that vaccination results in a gradual, consistent reduction in TB prevalence across both the core vaccination area and the surrounding buffer zone (Smith et al., 2012; Smith

et al., 2016). Badger vaccination has the added benefit of reducing the risk of cattle to badger transmission.

There have been few studies that have assessed the effect of badger vaccination on bovine TB incidence in cattle. To date, the only large-scale field trial designed to investigate this took place in the Republic of Ireland from 2011–2017 (The Irish "Non-Inferiority" Study). It compared areas transitioning from culling to vaccination with areas continuing targeted culling. The study concluded that in five of the seven counties, vaccination was "not inferior" to culling at controlling bovine TB in cattle (Martin et al., 2020).

The two largest areas in GB where badger vaccination has been deployed are the Badger Vaccine Deployment Project (BVDP) in Gloucestershire and the Intensive Action Area (IAA) in Wales. Badger vaccination was not the only measure introduced into IAA, other specific measures included six-monthly testing, compulsory pre-movement testing, increased use of gamma interferon testing, annual biosecurity visits by private veterinarians and goat and camelid testing. Bovine TB incidence in cattle fell in both the BVDP and IAA areas during vaccination, but it also fell in comparison areas, making it difficult to attribute the decline specifically to badger vaccination. Although, bTB prevalence and incidence has markedly reduced in the IAA over the years, it still remains relatively high compared to Wales as a whole.

There are strong, polarised views on badger vaccination. The general public is largely supportive of vaccination (and opposed to culling) while farmers are generally negative or sceptical (Chivers et al. 2022). This scepticism is driven by concerns about its effectiveness, cost and the limited evidence of its direct impact on cattle TB. Badger vaccination projects on the Gower peninsular and a small-scale project in Cornwall (Woodroffe et al., 2024) supported by the National Farmers Union and the Zoological Society of London provide examples of how different stakeholders can be brought together to support badger vaccination although it has proved challenging to sustain the approach over multiple years due to the cost and effort required especially on the Gower peninsular.

Experience in Wales, England and the Republic of Ireland has highlighted the significant challenges of running a successful badger vaccination campaign. A major issue is the costs and difficulties of catching sufficient badgers. Better understanding of badger ecology and epidemiology is also required to design and monitor effective vaccination campaigns in Wales (McKeown et al., 2026). The issue of economies of scale for badger vaccination is being addressed as part of England’s refreshed TB Strategy (Defra, 2026). As part of this initiative, Defra have awarded a contract for a new Badger Vaccination Field Force to expand local, farming community-led approach to badger vaccination. These large-scale vaccination programmes will also generate more evidence on the impact of badger vaccination on cattle TB (Robertson et al., 2025).

A recent publication from the Republic of Ireland, where badger densities are lower than in Wales, used a two-host and multi-route transmission model to evaluate the effectiveness of badger vaccination combined with cattle test-and-removal in managing bovine tuberculosis. The authors report that badger vaccination when combined with the cattle test-and-removal programme might not be sufficient to

achieve bTB eradication in their study area of Kilkenny (Chang et al., 2025). The authors suggest that achieving bTB eradication might require a more comprehensive intervention strategy that simultaneously targets multiple transmission routes including badgers, cattle and cattle movements. Such interventions include cattle vaccination, improved farm biosecurity, badger vaccination and risk based trading. A similar analysis would be useful to inform a future bTB eradication strategy for Wales.

Biosecurity

Getting better evidence about the efficacy of different biosecurity measures to prevent the transmission of *M. bovis* between wildlife and cattle is very important, both to know how to interrupt disease transmission but also to demonstrate to the farming community their value, especially those that are costly to implement.

Evidence from England suggests that indirect transmission of *M. bovis* from cattle to badgers and from badgers to cattle is more important than previously thought (Drew et al., 2013; Chang et al., 2023). Pastures where cattle graze and badgers forage offer many opportunities for indirect contact (Woodroffe, 2016). Badger latrines have been identified as key potential sources of infection along with farm buildings and yards.

An important meta-analysis of work up to 2024 investigating the efficacy of biosecurity measures based on Defra's five biosecurity principles (Voller et al., 2025) found that evidence to support the principle of restricting contact between badgers and cattle at pasture, in farm buildings and via shared feed and water was weak and inconsistent highlighting the need to strengthen the evidence base for biosecurity measures that address these principles. The recently published Godfray Review (Godfray et al., 2025) also highlighted the need for more social science research around the willingness to adopt particular biosecurity measures and how to improve the targeting of information and advice.

The review of Cymorth TB presents an opportunity to reform how biosecurity advice surrounding TB is given and received in Wales. The Pembrokeshire Project may offer some important insights into best practise. The experience shared by those involved to date suggests that buy-in to biosecurity measures from those involved exceeds that observed for Cymorth TB.

Fertility Control

This option shares with vaccination the advantage of avoiding killing a wild animal, as well as the disadvantages of not removing infected animals immediately and the expense of a continuing campaign of badger capture and handling. Reliable fertility control for badgers is not currently available although research continues to test potential options of which an injectable contraceptive vaccine. GonaCon, is the lead candidate which could potentially be used in conjunction with BCG vaccination. Vaccination of female badgers with GonaCon in June successfully inhibited subsequent cub production the following spring (Cowan et al., 2019). Vaccination in November had no effect suggesting that the optimal vaccination window is June to August. Infertility was maintained as long as anti-GnRH antibody

titres remained above the threshold values, with a median longevity of 647 days (requiring re-vaccination roughly every 2 years). No negative welfare consequences were observed. Recent studies have demonstrated that co-administering BCG and GonaCon does not affect the measured responses of each vaccine although the protective effects of the vaccines given in combination were not assessed (Palphramand et al., 2026). The product is not licenced by VMD for use in the UK and there is uncertainty about the time and cost involved in securing full authorisation.

As highlighted by the Godfray Review in 2018, naturally occurring reproductive suppression in badgers limits the number of females that breed, but more than 75% of adult females carry blastocysts (very early stage embryos) each year and can potentially breed. It is therefore likely that a high proportion of females would need to be caught and treated before population numbers began to decline, increasing costs and logistic requirements. A simulation model of the impact of post-cull strategies in England indicated there was little difference in outputs between various intermittent culling regimes, badger vaccination and use of BCG vaccination combined with fertility control (Smith and Budgey, 2021).

Economics of disease control in Badgers

We recommend that value for money assessments for badger vaccination, culling and test, vaccinate and remove strategies are conducted to assess the cost-benefit of these approaches in Wales.

Social and Behavioural Factors Associated with Wildlife Control

The Effect of Wildlife Interventions to Farmer's Behaviour

Reductions in risk can result in other behavioural changes that may offset the benefits of risk reduction (known as risk compensation). Alternatively, they may drive additional risk reduction behaviours (known as spillover effects). Where farmers believe that wildlife is a significant source of infection, it is possible that wildlife interventions (either culling or vaccination) may be associated with other TB risk management decisions with positive or negative effects.

Whilst evidence exists for these behavioural consequences in a range of policy areas, there is limited evidence associated with TB interventions. One study in England has assessed the behavioural impacts of badger vaccination. There was no evidence of either risk compensation or spillover behaviours. Rather, risk-taking behaviours were associated with a loss of trust in government decisions (Enticott et al., 2020). Another study examined cattle purchasing practices during the RBCT, comparing them between the proactive culling area and the control area where no culling occurred. The study found no association between farmers' cattle purchasing decisions and the presence or absence of badger culling (Brunton and Enticott, 2024). As these data reflect an old policy regime (from 20 years ago), analysis of the recent farmer-led culling in England would provide a better understanding of these impacts. However, there has been no assessment of these behavioural consequences.

Illegal Badger Culling

Some studies have assessed the extent to which illegal badger culling takes place. One study used the Randomised Response Technique (RRT), a survey method specifically designed to elicit honest responses about illegal activities. Analysis suggests that 10.4% of Welsh livestock farmers reported killing badgers in the preceding 12 months (95% confidence interval 5.1%–15.7%) (Cross et al., 2013). Another study uses a qualitative methodology to explore the reasons for illegal badger culling, suggesting that the underlying causes are connected to mistrust of government and veterinary authorities, and a sense of rural marginalisation (Enticott, 2011).

There is limited *robust* evidence on public attitudes towards badger culling in Wales. Whilst a number of surveys exist, they either suffer from a range of methodological problems that can induce bias, or fail to communicate the complexity of the issues at stake. As such, they are often best treated with caution. One study of the public's attitudes towards the scientific evidence of badger culling found that rural Welsh residents were often willing to support badger culling in principle, particularly in high-bTB areas. However, most believed the actual scientific evidence showed benefits far too small to justify a cull: they expected a cull to be over three times more effective than contemporary scientific evidence suggested. As a result, they stated preferences were for vaccination-based alternatives (Enticott, 2015).

Organisational Aspects

It is important to remember that badger culling takes place within a social and organisational context which affects how it is perceived. For instance, the distrust of the RBCT by farmers is not simply because of its findings, but because of the way it conducted and communicated its science. Farmers were not part of the scientific process. Rather, science was done to farmers, rather than farmers being part of the scientific process. This style of science is often referred to as the 'deficit mode' in which the public are kept at arm's length and their knowledge and expertise dismissed. The consequence is a lack of trust and sceptical view of science.

The recent farmer-led badger culls in England reflect the opposite approach in which farmers were directly involved in organising and conducting badger culls. However, it is important to note that this is not without consequences. On the one hand, farmer involvement can facilitate wider participation within the farming community. Farmers' involvement also explains why they are likely to perceive culling to have benefitted TB. On the other hand, farmer-led culls were reliant on voluntary labour within the farming community. For some, the amount of work involved was too much, leading to dropping out and a small number of committed individuals being responsible for managing culls.

Challenges associated with relying on volunteers to conduct wildlife interventions is not limited to badger culling, but associated with vaccination. Analysis of badger vaccination volunteers in England found that people often joined badger vaccination projects to control bTB or oppose culling. Whilst the apparent lack of success of vaccination for some led to them dropping out, for others, long-term participation was

sustained primarily through the social relationships, sense of purpose, and community that vaccination projects created.

General comments on evidence gaps to inform disease control options to prevent the spread of *M. bovis* from badgers to cattle badgers.

There is limited information on badger density, badger population structure and TB prevalence in badgers in Wales. Moreover, although 'no regret' biosecurity measures can be taken on farm to reduce the risk of transmission of *M. bovis* between cattle and wildlife, there is only a weak evidence base on which to identify the most cost effective biosecurity measures for farmers to use to prevent the transmission of *M. bovis* between wildlife and cattle on pasture or in farm buildings. These are all evidence gaps that should be addressed as a matter of priority.

Local epidemiological information alongside WGS data on *M. bovis* strains found in badgers and cattle from the same area will be required to better understand local disease transmission. This data, along with improved economic and epidemiological modelling studies should be used in the future to inform a holistic approach to local bovine TB control interventions so that the most effective disease control interventions are used in the right place at the right time. It will also be important to be able to monitor and measure the effectiveness of these interventions in order to identify which interventions work best under any given epidemiological situation and thereby inform future bTB eradication programmes in Wales. Current knowledge gaps in such intervention strategies include evidence on the efficacy of TVR compared with badger vaccination alone in reducing TB in cattle which, ideally, should be addressed.

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