A Commentary on Current Policy

A preamble to Badger Trust's report *'Tackling Bovine TB Together: Towards Sustainable, Scientific and Effective bTB Solutions'*

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November 2023

Respecting his decades of expertise in badger ecology and bovine tuberculosis, Badger Trust invited Professor David Macdonald of the WildCRU, University of Oxford, to offer his own commentary on the current policy as a preamble to our report *Badger Trust Tackling Bovine TB Together: Towards Sustainable, Scientific and Effective bTB Solutions*.

We are grateful for his thoughtful perspective and pleased to publish his commentary here in association with our own report.

Badger Trust December 2023

When I was asked to write a preamble to Badger Trust's *Tackling Bovine TB Together: Towards Sustainable, Scientific, and Effective bTB Solutions*, my impulse was to decline on the grounds that I had nothing new to say, but I was dissuaded by the inclusion in their title of one word: together.

I took this to signal, loudly, the collaborative, even conciliatory, spirit in which their report had been drafted. In a fifty-year debate, verging too often too close to the blinkered strangulation of tribalism, for Badger Trust to set out explicitly to look for common ground and ways of solving a problem together, struck me as importantly refreshing. That is the spirit in which I have written this short preamble on recent developments in the saga of bovine tuberculosis (bTB) and badgers in the UK.

As to Badger Trust's report, they wrote it, I did not; but I commend their desire to assemble evidence and evaluate it even-handedly. I hope my introductory commentary will prime readers to appreciate the complexity of the issues that the Trust is addressing, and from that complexity to realise that this is a 'wicked' problem; that is, it is a problem without a simple solution.

Before leaving tribalism, of which a symptom is deafness to truths that are inconvenient, let me distinguish it from argument, in the sense acted out by prosecution and defence barristers in a court of law, or opposing parliamentarians. At its purest, science is about the impartial power of evidence and argument to distinguish truth from falsehood. However, strict impartiality is difficult, because scientists are people, and so science can advance quite honourably through the attempt to defend, or defeat, essentially adversarial positions with the strongest evidence and the best argument each side can muster. This may sometimes characterise those motivated most strongly to argue for the wellbeing of badgers, or for the wellbeing of dairy farmers. Such contests are fine so long as each side, with its priorities, is attentive to, and respects, the strength of the other's evidence and argument, and evolves their conclusions accordingly.

With these thoughts in mind, for the avoidance of doubt, I should perhaps declare my own healthily schizophrenic background: as a field biologist and conservation scientist I have

studied badgers for more than 50 years, and consider their conservation important, and that they have intrinsic value that means their interests should be considered; during the same half-century I have almost always worked on farms, with farmers, and indeed for about twenty years I was a stockman with my own small livestock farm (albeit with sheep not cattle). I may not be truly impartial, whatever that might mean, but I declare a sympathy for both badgers and farmers, and even for the officials that have to decide the fates of both (having been one of those too).

The discussion about how best to contain bovine tuberculosis now spans generations of scientists, farmers and the Secretaries of State responsible for farming issues (25 of them since 1971, 6 since 2013) – I first published on it from the perspective of badger ecology in 1984 (Macdonald 1984) and many of the big questions then, still have equivocal answers now. In 2022, I attempted a stock-take, devoting an entire chapter of my book on badger behaviour, ecology and evolution (Macdonald & Newman 2022) co-authored with my long-time colleague, Chris Newman, to a critical review of the evidence. We focussed on four candidate practical interventions arriving, after much scrutiny of diverse evidence, at the following brief summary of what might work:

"(i) vaccinating cattle—the most attractive option, solving the problem at a stroke, but sadly blocked until the prerequisite DIVA[1] exists (as it may already do with Actiphage) and is validated, and thereafter, to gain significant traction could take decades; (ii) better diagnosis and regulation to weed out infected cattle—feasible and apparently immediately within reach by combining SICCT and Enferplex antibody test or Actiphage; (iii) vaccinating badgers—feasible if undertaken assiduously, although labour intensive, logistically challenging[2], and prohibitively expensive unless by oral delivery using baits (and, if cattle-to-cattle transmission is solved by better cattle diagnosis and regulation or vaccination, necessary only to limit reinfection of cattle); and (iv) killing badgers—marginal benefit unconvincing, undermining the financial (and ethical) justification. Anything less than total and absolute commitment to eradicating cattle-to-cattle transmission brings any marginal benefit of killing badgers closer to fruitlessness and correspondingly greater indefensibility".

Others reviewing the same evidence manifestly draw different conclusions, but these were ours.

With respect to the efficacy and appropriateness of culling badgers as a means of reducing the incidence of bovine tuberculosis in herds of (predominantly) dairy cattle (the central topic of this report by Badger Trust), salient amongst the evidence was the conclusion of the Randomized Badger Culling Trial (RBCT). That conclusion was that, after nine years, the proactive badger culling in 100km2 plots was associated statistically with a percentage change in herd breakdowns varying between -19% and -32% (these being 95% confidence limits) with a central tendency of -26% within the cull zone. Counter-productively, in the surrounding 2km buffer, it varied between -14% and +35% (centring on +8%, Godfray et al. 2013). Extrapolating from these results, and making some hopeful assumptions, Defra estimated that five years of proactive badger culling within a 150 km2 circular area would give an anticipated average net benefit of a 16% reduction in herd breakdowns. However, this comes with a 95% confidence interval of 3–21%, which means (assuming the assumptions hold) that any figure between these limits would not be considered implausible. Notwithstanding the statistical significance of the RBCT results, reviewing the ambiguous practical outcomes of the new culls, begun as 'pilots' in 2013, Chris Newman and I concluded in 2022 that *'contemplating the balance of benefits and harms, one can only wonder whether an effect that is so hard to demonstrate has been worth the cost of bringing it about'*.

In the end, while almost every detail of the evidence is contentious and the problem is a wicked one suffused with tragedy (for badgers, farmers, taxpayers and the many people of good faith who have striven to solve it) we further concluded that *'the gains from culling badgers with the purpose of curtailing the spread of bTB in cattle seem to have been marginal—*

close to the point of futility'. This conclusion, despite the dozens of scientific papers and anguished policy debates of the intervening 10 years since these pilot culls commenced, was not much different to the oft-quoted statement of John Bourne on behalf of the Independent Specialist Group (ISG) that evaluated the evidence of the RBCT in 2007, *'badger culling cannot meaningfully contribute to the future control of cattle TB in Britain'* further, that *'some policies under consideration are likely to make matters worse rather than better'* and that *'weaknesses in cattle testing regimes mean that cattle themselves contribute significantly to the persistence and spread of disease in all areas where TB occurs'* (Bourne, Donnelly et al. 2007). Bourne's statement was echoed in the conclusion of the then Secretary of State, George Eustice in 2020, that badger culling was 'unacceptable', albeit 140,000 dead badgers later.

Our arrival at that same conclusion in 2022 came with the added benefit of a new and particular strand of evidence. In 2013, in response to the distressing geographical spread and growing prevalence of bTB in cattle, the government had initiated that new and differently constructed cull of badgers (the original idea had been to kill about 1500 badgers over four years in each area of at least 150km2, in the hope that the larger area to perimeter ratio would lessen the peripheral perturbation effect detected in the RBCT).

Despite the lamentable, one might say irresponsible, lack of either monitoring the tuberculous status of the culled badgers, or any experimental control whereby the efficacy of the intervention could be measured, we noticed an unplanned but potentially revealing comparison. This comparison was between England and Wales, where, to cut a long story short, policy-makers had opted for radically different interventions in their attempts to lower the incidence of bTB in cattle herds. Indeed, this difference had provoked a wry remark from Professor John Beddington, the then Chief Scientist, that it was 'interesting' that exactly the same scientific evidence was used to decide, on the one hand, for a badger cull in England, but, on the other, against a cull in Wales. Anyway, the upshot was that while in Wales, policy strove to do everything it could to curtail bTB in cattle without killing badgers, in England, it pursued the same objective, but with the addition of killing badgers. What we noticed was that the graphs documenting progress in the two countries were similar – in particular, England was not doing markedly better than Wales and, if anything, it might be doing worse (according to measures of bTB incident rates in cattle).

The comparison was, of course, not perfect – apart from anything else, farming is not identical in the different countrysides of England and Wales, and complicated by, for example, the movement in July this year of infected cattle from England into Wales – but if the expensive, and ethically problematic, culling of badgers was really 'worth it', that is, justifiable, we would have expected to see that it delivered a clearcut, and substantial, benefit to the English farmers. Then, just as our book, *The Badgers of Wytham Woods*, went to press, a new paper was published in the Veterinary Record, which arrived at exactly this conclusion through statistical analysis. As I will touch on below, there has been much subsequent discussion, even acrimony, about the statistical validity of this conclusion, but wherever the holy grail of statistical elegance may lie, the obvious question is whether an effect that is so difficult and tendentious to demonstrate is a safe justification for an intervention so grave.

This, then, was where we were when Chris Newman and I packed the page proofs of our book off to the printer (I should add that only one of 19 chapters was about tuberculosis – there are many other reasons to be interested in badgers). I had not expected to spill more ink on the topic unless something changed. Thus, when invited to write this preamble to Badger Trust's report, I asked what's new and is there anything useful to be said about it?

Of particular interest among recent developments is a statistical analysis, by a team led by Colin Birch, of trends in new outbreaks of bTB amongst cattle in the 52 areas where what is called the Badger Control Programme (BCP) has been implemented in England between

2013 and 2020 (Birch et al. 2023). This paper became available in a system called **bioRxiv**, which enables scientists bravely to expose their work to critical scrutiny as a 'pre-print' before peer-review and eventual publication in a journal of the final version. Therefore, although one might expect the final version to differ, in the meantime, what can be gleaned from the pre-print? Specifically, are the interventions working? The good news is that it looks like they are insofar as, according to analyses of two epidemiological measures; there is a statistically significant reduction in bTB in cattle over the four intervention years of the BCP. Birch et al. analyse data recording different types of bovine TB incidents (the incidence rates in a population are distinct from the prevalence of the disease)[3]. They consider Officially TB Free-status (OTF), which is the desired status, in terms of two undesired outcomes: 'OTF suspended' (OTF-S) and 'OTF withdrawn' (OTF-W) incidents. This reduction averages 56% in herd OTF-W incidence rate (analysing data for OTF-Withdrawn incidents alone), and 45% in 'total incidence' rates (analysing the aggregate of OTF-W and OTF-S)[4]. The finding that both these measures have declined will become relevant below, in that an earlier analysis of pro-active badger culling in the RBCT recorded a statistically significant decline in herd breakdowns only when OTF-W was analysed alone, an effect not apparent when OTF-W + OTF-S was analysed. Anyway, at the time of writing, a frustration to analytical readers of the pre-print is that the conclusions cannot be reproduced because neither the full data[5] nor the analytical code are available.

To return to the crucial question, are the interventions working, Birch et al.'s new statistical approach (called Difference in Difference, which, in the absence of a treatment versus control comparison – remember, there was no experimental design – involves before vs after comparisons) suggests a trend in the right direction (although to see this as the overall trend requires more than the eye of faith when scrutinising the trends graphed for each of the 52 areas, so great is the 'noisy' variation amongst them).

The next, and piercingly policy-relevant, question is, which aspects of the interventions are delivering these benefits? Remember, the BCP is an ill-fitting name in that the programme is not only about badger control: it is about a whole suite of tightening veterinary actions (such as improving the frequency and interpretation of testing cattle for bTB, and regulating their movements and husbandry) – all the things attempted in both England and Wales – as well as killing badgers. Sadly, in the aforementioned and regrettable absence of a scientific 'control' for comparison, and as Birch et al. are careful to acknowledge, it is impossible to dissolve the overall result into its component parts. The badger culling component may be delivering something or nothing, and the analysis leaves us none the wiser. This logical truth is also clear in APHA[6] reports, which include a straightforward statement that the herd breakdown data alone (those are the data Birch et al. analyse) cannot be used to evaluate the effect of the BCP; indeed, APHA correctly note that to do so *'requires consideration of other factors that could affect cattle TB incidence in addition to badger culling.'* (APHA 2022).

So, while one answer to the question what's new from the broader perspective of bTB control is indeed the Birch et al. pre-print, another answer from the particular perspective of the badger issue seems to be: not much, insofar as there is still no clearcut answer regarding the impact of this approach to badger culling on controlling bTB in cattle or, more broadly, whether it's worth it. This is not to diminish the doubtless hundreds of hours of effort Birch's team put into questing for the answer, nor the doubtless hundreds more that will be devoted to dismembering their findings, but merely to emphasise that they do not claim to have measured the consequences of badger culling, and indeed they have not[7]. However, can any further insight be gleaned from this pre-print?

The trends in herd breakdowns graphed for the 52 intervention areas analysed by Birch et al. reward scrutiny. First, there is huge variability between areas and years in breakdown rates (their Figure 6). Second, as they note in an appendix, less than 2% of this variability in the rate of breakdowns is attributable to the BCP – this confirms the intuition that a lot of other

factors are at work in the complicated world of dairy farming in the countryside. The 56% (or 45%) estimated reduction in herd incidence of bTB adjusts for the effects of year, area, and pre-BCP site-specific trends. There was strong evidence that trends before the onset of BCP differed between areas. The figures for herd breakdowns prior to implementing the BCP are lumped in their statistical model, for each area, into one average. Birch et al. do not, therefore, present the average pre BCP incidence rates for different years – further insight might lie in the year-by-year direction of travel during those preceding years.

On the topic of the tangle of interacting factors that may confound a clear appreciation of the processes threaded through this epidemiological bundle of loose ends, those concerned with the testing of cattle and regulation of their movements are especially fascinating – after all, it is they that appeared, in the absence of killing badgers, to be delivering improvements in Wales. In this context, an important confounding factor is that in England both badger culling and a 60-day interval between SICCT retests of reactor herds were introduced in 2016 to the High Risk Area.

Another confoundment is the introduction of additional gamma interferon testing: this and other measures, including more stringent cattle movement controls, were implemented in England in 2017 (APHA briefing note 09/17). Birch et al. note that the increased gamma testing did not start until year three of BCP, so the smaller (c 28.7%), but statistically significant decrease in bTB incidence at year 2 of their analysis (their Table 2) may not be affected by that particular source of confoundment. Might this then, be an unconflated measure of the impact of killing badgers? It is hard to argue that, considering that during these early years, and earlier (hence the interest in the annual trends – rather than lumped data – prior to the BCP), the screws were tightening on every aspect of farm biosecurity, movement regulations, test protocols and the severity of their interpretation. And anyway the data published in APHA (2022) appear to show that there were gamma reactors before 2017. Birch et al. comment in their discussion that the influence of additional gamma testing might be explored by estimating the contribution of reduced recurrence of infection to the overall decline in incidence rate.

It would be interesting, although potentially more depressing than enlightening, to review meticulously the total list of confounding factors changing between 2013 to 2020 that might affect interpretation of the apparent BCP effect. Such a list, doubtless a morass of complication, might be relevant to the original comparison between the approaches in Wales and England. For example, praise is rightly given to the Welsh authorities for their forward-thinking attention to tightening up every aspect of cattle management that might curtail bTB – was this greater assiduousness compared to their English counterparts translated into greater rewards, or were the English efforts sufficient, in practical terms, to keep them neck-and-neck in progress with the Welsh? The question is relevant regarding the effort to parse out the impact, if any, of badger culling in England[8]. All such explorations converge on the practical question of whether the magnitude of benefit attributable to each component of the policy, even if statistically real, is practically worth it.

The topic of statistical realities brings us to the second answer to the question of what's new: another paper, at the time of writing also a preprint, authored by a team led by epidemiological statistician Paul Torgerson (Torgerson et al. 2023). While Birch et al.'s conclusions are not sensitive to whether only the herds whose reactors were confirmed at post mortem (OTF-W) or all reactor herds (OTF-W + OTF-S) are analysed (nor to some variations in the analytical method), this was not true of the original analysis of the RBCT data. That original analysis reported a 19% decrease in herd breakdowns attributable to badger culling, but this result was statistically significant only when OTF-W cases alone were analysed (the effect disappeared when all breakdowns, including OTF-S were considered) (Donnelly et al. 2006). Indeed, it is a puzzling aspect of Birch et al.'s results that while the rate of OTF-W cases declines over the four years of BCP[9], and a decline can be

seen in the 'raw' trend in rate (their figure 1a), the rate of OTF-S trundles along largely unchanged (their figure 1 c)[10].

To appreciate why this is puzzling, it is necessary to remember the distinction between Withdrawn and Suspended status and the continuing importance of the SICCT test[11]. According to the most recent account (Gov.uk 2023), and to expand on footnote 4, OTF-S incidents are those: *'where OTF status was suspended because of reactors in the herds, but post-mortem evidence of TB is not detected. The status remains suspended until further herd tests confirm no infection remains[12] on the farm.'* The initial diagnosis of a test 'reactor' is based on a somewhat arbitrary evaluation of the sizes of two bumps[13] on the cow's neck skin. Subsequently, OTF-W status incidents are those where *'OTF status was withdrawn from the herd due to the detection of lesions typical of TB during post-mortem examination of one or more test reactors or inconclusive reactors, or where samples from one or more reactor, inconclusive reactor or a slaughterhouse case produce positive culture results for Mycobacterium bovis.'*

Does the different trajectories of the OTF-W and OTF-S graphs (a decline in the former, roughly flat-lining in the latter) shed any light on the key question of the relative contributions of cattle testing and management versus killing badgers to the decline in case incidence detected by Birch et al.? No, insofar as both interventions would be expected to improve OTF-W and OTF-S in parallel. As a separate matter, might the difference in the trajectories be explained by the assiduousness with which cattle testing is being applied? In our book, we drew attention to the 'leakage' that results from the low sensitivity of the SICCT as being more like a geyser than a dripping tap (overall, its herd-level sensitivity ranges between 27-75%, averaging 49%, but there are circumstances under which as few as 25% of infected cattle may return a positive test (references in Macdonald & Newman 2022). Perhaps early or quiescent infections are particularly likely to go undetected and thus to risk perpetuating the disease. This seems to be one plausible explanation for the existence of reactors without lesions (and thus, along with false positives, an explanation of the existence of OTF-S herds), but does not straightforwardly explain why increased assiduousness of testing should not cause some decline in the apparently flat-lining OTF-S. The puzzle of the two trajectories (W declines and S flat-lines) remains[14], but in any case, does not seem to have material bearing on the relative contributions of managing cattle or killing badgers to the decline in herd breakdowns associated with the BCP: for that, the principal insight lies in comparing the outcomes of the Welsh and English strategies.

The sensitivity of the RBCT's finding to which data set was analysed prompted Torgerson's team to reanalyse exactly the same data (these are in the public domain) using different methods. They found that the conclusions of the 2006 analysis are sensitive to the method of analysis used. Indeed, the analytical approach that Torgerson's team judge to be the most obvious for the purpose, provides no statistical evidence for a culling effect, whereas a model comparison method aimed at selecting a model with the best out-of-sample predictive power indicates that the best model does not include the treatment effect of killing badgers. According to those statistics, killing badgers during the RBCT made no difference to the herd breakdowns, whether measured by either OFT-W or by OFT-W + OFT-S. Policy-makers reflecting on the statistical merits of these findings should hold in mind John Bourne's quote (above) about the practical usefulness of badger culling even when the ISG accepted their statistical robustness.

With thoughts about the distinction between statistical and practical significance in mind, it is worth returning briefly to the analysis of the English badger culls in the High Risk Area published by Tom Langton's team in 2022 just as our book went to press (Langton et al. 2022a). Their approach was largely dependent on comparisons with unculled areas and, therefore, hinges on how confident one can be that the comparisons are meaningful as 'experimental' and 'control' treatments. (they look plausible, but one can't be certain). The nub

of their conclusion was that a comparison of culled and unculled areas revealed no evidence for a difference in herd breakdowns. In March of 2022, this was questioned by Middlemiss and Henderson (2022a) who argued that the effect in culled areas had been diluted in the Langton et al. analysis by including areas only recently under culling. If the disease experts agree that an effect is not expected in the first year, then this appears to be a valid point, and Middlemiss and Henderson produced a revised graph (their Figure 1) showing a decline in herd breakdowns in culled areas compared with these redefined unculled areas.

In their rebuttal, Langton and his colleagues (Langton et al. 2022a) showed that the Middlemiss and Henderson analysis was strongly affected by their particular choice of unculled areas: if all areas not culled at the time of the comparison are included there is little evidence for a culling effect – the incidence rate in not-culled areas declines with what appears to be a similar trajectory to that in the culled areas. The pattern in 'never culled' areas, about a third of the area which could be included, is quite different, and shows no such trend – there is no evidence for any change, increase or decrease. Then, in May 2022, Middlemiss and Henderson (2022b) published a correction (Middlemiss and Henderson 2022b), acknowledging errors in the 'never culled' data used in their original (2022a) paper, but stating that their corrected graph (their Figure 1) did not alter their original conclusions: that corrected pattern in the culled areas compared with never-culled data appears to be more consistent with a decline in incidence in the culled areas, arguably attributable to badger culling, since 2016. The immediate response from Langton et al. (2022b) declared an impasse insofar as those data analysed by Middlemiss and Henderson are not in the public domain. In an interview on BBC R4's *Farming Today* programme, on 26/5/22 Christine Middlemiss (co-author of Middlemiss and Henderson, and Defra's Chief Vet) pointed out that the release of the data was not her decision. She also stated that it was 'very difficult' to compare culled and unculled areas so as to isolate the effect of badger culling on bovine TB, a statement with which few observers acquainted with the details would disagree.

On the topic of the effect of badger culling, a team led by Michael and Linda Griffiths published, in 2022, a deep dive into the background to the so-called 'epiculling' policy that was being proposed and its Cumbrian pilot case-study (Griffiths et al. 2023). This involves the attempt to kill all the badgers in culling areas, rather than the 70% that had hitherto been the aim (partly out of deference to the Berne Convention, and partly a nod to pragmatism). Their four salient conclusions were that a) risk pathways, based on protocols operated by veterinary inspection, overplay badgers as a source of herd infection, b) evidence of genetic strains of bTB shared by cattle and badgers in an Edge area do not provide convincing support for a culling policy, c) whole genome sequencing has yet to provide sufficient evidence to support generalisations about the direction of transmission between badgers and cattle and d) herd breakdowns have continued in the Cumbrian pilot area since culling started, offering little comfort that the culling is effective. Griffiths' team also draw attention to the continuing parallel in infection trends in England (with BCP) and Wales (without badger culling but with a head start on more stringent cattle measures), again raising the question over the robustness of evidence that culling is worth it.

So, what's new and where does it leave us? Of course, some truly heartbreaking things are new: around 210,000 badgers have been killed in England since 2013. More than 30,000 were killed in 2022 alone, along with more than 20,000 cattle, and the labours and aspirations of the farmers tending some 3,000 herds losing their TB-free status in the same year have been cruelly dashed, all on the basis of rather unpromising evidence that culling the badgers was ever going to make much difference, and even with unfolding hindsight no definitive evidence that it is doing so. That is not to say that those on both sides of the debate have not pursued their convictions with good intentions, even if these sometimes appear to have been held more theologically than scientifically. Nobody can take pleasure in the uncertainty that still stubbornly prevails.

So, what next? Considering the metaphorical bucket from which bTB infections leak to new herds of cattle is punctured by a gaping hole through which infection gushes, and another indisputably smaller one through which it may drip, it seems prudent to focus first on staunching the former. The metaphor seems apt insofar as it has been estimated that on average about 94% of infections flow from cow to cow, about 5.7% from badger to cow. I am aware that the statistical model published by Christl Donnelly and Pierre Nouvellet in 2013 argued (Donnelly and Nouvellet 2013), with the notable simplifying assumption of no transmission from cattle to badgers, that the seeding of infection arising from that original 5.7% of badger to cow transmission could, through the unspecified mechanism of a multiplier effect, end up with 50% of cows acquiring an infection whose genealogy had begun in a badger.

The fact remains that a diversity of evidence makes clear that the great majority of cows catching bTB do so from another cow; that, as a general rule, is the gushing leak in the epidemiological bucket. A subsequent modelling exercise (Brooks-Pollock & Wood 2015), was also partly parameterised using RBCT data (and used the badger-to-cattle secondary transmission rate calculated by Donnelly and Nouvellet), but also allowed for cattle-to-badger transmission. This suggested that generalisations about the effect of culling badgers were, predictably, likely to be misleading. Those authors concluded that whether cattle infection was affected by badger controls was likely to depend on how close to eradication the disease was: in high infection regions, even large reductions in badger numbers might have little effect. But closer to eradication, cattle prevalence could be sensitive to small changes in transmission from badgers.

With the continuing difficulty of demonstrating that killing badgers delivers a material benefit to dairy farmers (or the wider society of which the roughly 7,500 dairy farmers in Great Britain are but one element), it would seem logically, fiduciarily and morally sensible to conclude, like the Welsh, to pause on tackling the potential drip while ramping up every means of damming the gush. What might these means be? This little commentary is not the place for a treatise on cattle husbandry, but the options are well-known and referred to in the Badger Trust report (and lengthily elaborated in the aforementioned chapter (chapter 16, pages 365 to 368) of the Macdonald & Newman book). They include more severe interpretations of more sensitive combinations of diagnostic tests applied more frequently, stricter regulation of cattle movements between holdings and more assiduous attention to biosecurity.

Only slightly more blue skies would be continued urgency in the implementation of cattle vaccination, facilitated by discerning DIVA and DID tests, and overhauled legislation to enhance the cost-effectiveness of beef and dairy trade regulations. Of course, all these things cost money, but insofar as the £60m estimated by Badger Trust (UK) to have been spent on killing 210,555 badgers since 2013, as yet to no quantifiable benefit, which has also burdened the taxpayer and demoralised the farmer, one could hope for a better return on investment.

Mention of costs and benefits brings us to the broader balance sheet against which the question of 'what next?' should be accounted. Obviously, many currencies, many of them incommensurable, are involved. The monetary costs and benefits of farming cattle and culling badgers are important, and so too are the heavy mental strains endured by farmers, the welfare of both domestic cattle and wild badgers (an estimated 7-23% of 'free=shot' badgers take more than 5 minutes to die), the broader ecosystem (and epizootiological) consequences of abstracting one of Britain's largest remaining Carnivores from its natural community (to the distress of the largest group of citizens devoted to any wild mammal).

This tangle of legitimate considerations can be viewed from at least two vantage points. First, the wider framing of land-use: how important, and by what criteria, is dairy farming in different landscapes within twenty first century, post-Brexit, Britain with its emerging values in terms of the environment, food security, sustainability, biodiversity and rural cultures,

and beset by climate change – do the answers reveal it to be cost-effective to kill badgers to no as yet uncontroversially quantifiable gain, or even to do so if the gain were guaranteed.

Second, the ethical framing of the thorny trade-offs: in the absence of clearcut evidence that it would deliver material benefit to beleaguered dairy farmers, or even to the wellbeing of their cattle, how ethically appropriate was it in 2013 to take a punt, just in case, on the lives of up to 40,892 badgers a year (in 2020), without even checking bTB prevalence amongst them, or on what averages something like £6m a year of taxpayers money, and how ethical is it in 2023 to continue doing so, when the answer to "what's new?" is: not much.

No thoughtful person could pretend that the answers to either set of questions are easy, or that the responsibilities on those labouring to answer them are not brutal, but in 2023, much as in 2007, it is hard to see that killing badgers will make a meaningful contribution.

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1st November 2023

Footnotes

[1] Differentiating Infected from Vaccinated Animals

[2] Interesting behavioural questions abound, e.g. if the most trappable or least bait-phobic minority of badgers get repeatedly re-vaccinated might this risk an inflated impression of coverage, or distract their immune system from other infections (Stabell Benn et al 2020).

[3] Incidence is the number of new cases in a specified time period, whereas prevalence is the proportion of the population that are infected in a specified time period.

[4] OTF stands for Officially TB Free, a status that can be lost in two ways. OTF-S incidents are herds where reactors to the Single Intradermal Comparative Cervical Tuberculin (SICCT) tests have been detected, but infection has not yet been confirmed. OTF-W incidents are those where the disease was confirmed by finding lesions at slaughter, or positive bacterial cultures thereafter. The two measures together, OTF-W and OTF-S are an approximation of prevalence, but only an approximation in that they do not include cryptic infections, revealed only at the abattoir.

[5] It is clear that much of the data used by Birch et al. are available via the links given in APHA (2022). Birch et al. however appear to use longer sequences for some areas than are given in the available data.

[6] Animal and Plant Health Agency

[7] The obsessive reader will detect some ambivalence in the pre-print version of Birch et al.. Although they are careful to conclude, correctly, that 'this data analysis cannot explicitly distinguish the effects of the BCP's component measures', earlier in their text they write, in contradiction, 'The effect of badger culling is shown to increase each year… ' – I suspect this mention of 'badger culling' is a hasty misprint for 'the BCP' which, as explained, involves much more than killing badgers.

[8] Eye-balling the unfolding trends, for example as depicted in Figure 16.11 of Macdonald and Newman, does look as if Wales was doing better than England from around 2013

[9] APHA (2002) states 'in otf-w incidents, infection has been confirmed through post-mortem tests in at least one animal from the herd'. Plotting the data from sheet B4 in the excel file available at: https://www.gov.uk/government/publications/bovine-tb-epidemiology-and-surveillance-in-great-britain-2021 shows what appear to be short cycles with a period of approximately 2 years superimposed on the downward trend.

[10] Considering the c. 94% specificity of the SICCT test, these OTF-S cattle are unlikely to be false positives in high risk areas at least; they may be early stage infections, and early stage infections may be important to perpetuating the disease.

[11] The SICCT test, the Single Intradermal Comparative Cervical Test (SICCT) is described like this on the gov.

uk TB website: “if tuberculin (a purified sterile cocktail of proteins derived from M. bovis cultures) is injected into the skin of an animal infected with M. bovis, this will cause a localised allergic reaction characterised by temporary swelling of the skin, which is measured 72 hours after the injection. The principle is very similar to the skin tests for TB in humans.”

[12] Although the definition refers to confirming that ‘no further infection remains’, this is an optimistic interpretation of the absence of reactors, insofar as the poor test sensitivity means that infection goes undetected; about 15% of herd breakdowns arise from cattle from OTF herds, with no reactors, nonetheless found to have lesions in the abattoir.

[13] Induced by a delayed-type hypersensitivity reaction as a result of a cell-mediated response to the SICCT test.

[14] Might the puzzle arise because a countermanding effect gives the appearance of flat-lining? That is, could more assiduous testing cause both a decline in herd incidence and a loosely matched increase in the detection of more infections?

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