Environment and Planning A 2013, volume 45, pages 1372 – 1386

doi:10.1068/a45668

Coalition culls and zoonotic ontologies

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Received 30 June 2012; in revised form 27 November 2012

Abstract. Diseases which can pass between animals and humans (zoonoses) have been headline news several times in the last ten years. This paper looks at bovine tuberculosis (bTB) in the United Kingdom, which, although not a major health hazard for humans, has been problematic for farmers and the veterinary health institutions. At its current rate of spread, the disease will cost the authorities £1 billion in compensation to farmers for slaughtered animals and in administrative expenses over the next decade. The present Coalition government is planning to cull badgers in England because they are the principal wildlife reservoir of bTB and are said to pass infection to cattle. We argue in five stories that the heterogeneities of bTB help explain the difficulties in dealing with it. In our opinion, the present reductive set of policies would be improved by taking this ontological multiplicity into account.

Keywords: badgers, bovine tuberculosis, zoonoses, ontology

> "That clinic, lab and epidemiology enact different worlds implies that their differences are relevant to the way the world comes to be shaped. It implies the importance of the question: 'what to make of the world?' This is an ontological question."
>
> Law and Mol (2011, page 14)

Introduction

Tuberculosis is an example of what Morton (2010a) calls a 'hyperobject'. For over a century the disease has been so widely distributed that one third of the world's population exhibit latent infection (WHO, 2012), although most people have no symptoms and tuberculosis can lie dormant for decades in the body, appearing only as ghostly traces on x-rays or as a positive Mantoux skin test.

Tuberculosis is also widespread among nonhuman species. The present paper looks at one variant, bovine tuberculosis (bTB), which is found in humans, farm animals, and wildlife. This is a relatively slow-moving zoonosis by comparison with other pathogens emerging from nonhumans. For historical and ecological reasons associated with intensive livestock husbandry, it just so happens that the United Kingdom (UK) and Republic of Ireland (RoI) have the worst cattle bTB problem in the Global North, usually mostly attributed to infection from badgers (Defra 2011a). As a result, expensive control measures are necessary—possibly up to £1 billion over the next ten years in England alone (Spelman, 2011).

Our argument will be that understanding and dealing with the disease depends upon the ontic constitution of the bovine-TB–badger problem as a matter of multiplicity. Along with writers such as Mol (2002) and Law, we see multiple natureculturetechnics, "and how they relate together is an empirical (but also a political) issue" (Law, 2004, page 6). In July 2011 the Conservative–Liberal Democrat Coalition government announced a new policy in England (Defra, 2011a) enabling farmers and landowners to cull badgers, in the hope of at least slowing the spread of *Mycobacterium bovis*, the bacterium responsible for the disease. The cull was intended to start in 2012 but has been postponed to the summer of 2013

(Paterson, 2012). We will show how the associated ontological politics (Law and Mol, 2011) are a site of contestation.

Rather than presenting an exposed profile for investigation, bTB emerges diffidently from a series of human practices and animal ecologies. In response, this paper is a collection of five short stories about these shy trajectories. The first section reminds us of the forgotten and devalued history of bTB, once responsible for over 4000 UK deaths a year: men, women, and especially young children (Francis, 1947). The storyline attached to its latest incarnation is completely different; bTB is now seen mainly as a threat to the neoliberal agrarian economy rather than a public health hazard. Second, we will embark on an ontological adventure in which we will see that the bacterium is difficult to know and even more difficult to govern. This challenge was first accepted by the state in late-19th-century Britain but today there remains a colossal and intractable problem. Third, we pick up the banner of environmental irony, one of the least worked of the discursive tropes of hazard and risk (Atkins et al, 2007), not in any playful sense but rather the tragic irony that the mass killing of wild animals may have exactly the opposite effect to that intended. Indeed, badger culling may already be one of the reasons behind the upsurge in bTB incidence in cattle in Britain since the 1970s. Fourth, there is the question of a difference of zoonotic imaginaries between the UK and the RoI, which will help us to highlight alternatives in the bTB policy space. Fifth, we will investigate the assumptions and anxieties behind models and cartographic representations of the spread of bTB, and, finally, the paper will conclude that ontological multiplicity demands a spatially nuanced policy for bTB and badgers.

Ontologies

Ontology is very much to the fore amongst the philosophically minded in the social sciences and humanities at the moment. This is partly a radical reaction to the perceived excesses of the linguistic and representational turns of the 1980s and 1990s and their associated human-centred themes of enquiry. The last ten years have seen a series of challenges to this mainstream that stretch from nonrepresentational theory and speculative realism to, most recently, object-oriented ontology (Bryant, 2011; Bryant et al, 2011; Harman, 2010; 2012; Shaw, 2012). These recent interventions have their metaphysical differences, but the shared vision is to expose the anthropocentrism of much scholarship and to set a refreshed agenda that takes seriously the flattened ontologies of the in-/non-/post-/more-than-/other-than-/human.

Science and technology studies in its several traditions has been a continuous inspiration. First, there was social constructionism and the analysis of objects created from shared meanings, often aligned with the interests of particular groups. This knowledge is sometimes seen as culturally embedded and emergent as the imaginaries that guide practice. More recently ontologies have increasingly come to be seen as emerging from webs of relations that are enacted through the pooled agency of humans and objects. An increasingly popular version of this is the unveiling of multiple material realities (Law, 2012). In this style,

> "Empirical studies of ontology are not trying to explain why differences arise within a single cosmological grounding. Instead, and quite differently, they are looking at what objects come to *be* in a relational, multiple, fluid, and more or less unordered and indeterminate (set of) specific and provisional practices" (Law and Lien, 2012, page 3, emphasis in original).

In his Norwegian salmon project, for instance, Law looks at a number of chains of mediation that soften the nature–culture binary and so make salmon farming possible (Law, 2012; Law and Lien, 2012; 2013). He looks at the vaccination of the young fish against the diseases they are prone to; he considers the difference between farmed and wild salmon; and he thinks about the productivity of the fish, which is difficult because they are mostly out of sight. Our equivalent here is the 'badger multiple', a wild creature dissolved into hybrids that have human practices embedded within them. Each badgerstory is enacted through different practices of analysis, policy, and management, which yield a spectrum of material–semiotic realities (Law, 2008). Because there are many cattle and badger practices with regard to bTB, there are in effect many different cattle–badger outcomes: what Law calls fractional natures and enacted bodies (Law, 2004).

By way of example, the ordering and regulating protocols of modern farming and veterinary practice are never entirely successful. Indeed as Law and Lien (2012, page 10) aver, "ordering practices ... fail, and to fail is to generate a trail of unexpected entities." This is certainly true of bTB, whose embodied manifestations in cattle and badgers are unpredictable and unruly. In fact, we might reasonably say that bTB is an ontological curiosity. Its slipperiness and indeterminacy are seriously problematic. It is not a quick-fire and evocative disease like Foot and Mouth Disease (FMD) with its signature image of piles of burning carcasses. Nor does it have dramatic symptoms like the staggering gait of cows suffering from Bovine Spongiform Encephalopathy. As we will see, it is a zoonosis with few human victims (in the UK) and without outward animal symptoms. It is connected in an unknown way with a wildlife reservoir that is largely invisible. It is a disease that often cannot accurately be diagnosed because of a relatively insensitive skin test. It is also untreatable in animals and, as yet, there is no accepted cattle vaccine by way of prophylaxis. There are now hundreds of scientific papers and reports on bTB and there has been a generous Department for Environment, Food and Rural Affairs (Defra) research budget and yet, on the basis of essentially the same body of scientific evidence (veterinary and ecological), successive governments have implemented strikingly different policies in an attempt to control the disease (Grant, 2009; Spencer, 2011). Since the 1970s these have embraced various forms of badger culling, despite the starkly contrasting opinions between farmers (in favour) and the general public (majority against). All of this together makes bTB one of the most intractable zoonotic health problems of the last 200 years.

Story 1. Ontological histories: forgetting and re-imagining

Studies of historical ontology demonstrate clearly that objectness is imagined and enacted differently through time according to the particular intellectual context and resources of the day. As Hacking (2002, page 12) would have it, these were the "general and organizing concepts and the institutions and practices in which they are materialized." bTB is an interesting example of this point because it was one of the most vigorously debated topics in public health in the Western world until the mid-20th century, but then it faded for several decades until its recent rediscovery. The same was true of FMD, another historic cattle disease, that recently also came back to haunt the state veterinary services and drain the Treasury.

There was an understandable complacency—by 1960 human health had been protected from bTB by the widespread adoption of the pasteurization of milk and also, by then, most infected cattle had been compulsorily slaughtered. But our claim here is that in its recent recrudescent phase (1980s to present) bTB is ontologically distinct from the period 1850–1960. Earlier it was humans who were seen as vulnerable to infected meat and milk (Atkins, 2000; Waddington, 2005) but nowadays the focus is on cattle and wildlife species.

The pockets of bTB in cattle that persisted immediately after 1960 were in the southwest of England. Then the discovery in 1971 of a tuberculous badger in Gloucestershire hinted at a wildlife reservoir of the disease that had not previously been suspected. This was an important ontological threshold for two reasons. First, farmers were no longer held solely responsible for the spread of disease, cattle-to-cattle, and so the argus eye of the state blinked. Henceforward the previously invisible wildlife ecology of the farm came under the Whitehall gaze. Second, the peeling away of aetiological certainties forced us to imagine histories for which no evidence existed before 1971. Were badgers and deer carriers of bTB before that date or had the disease only recently leaked across the species barrier? The best we can do is to revert to irrealist histories of what Roth (2012) calls *the pasts*.

In the early 1970s there were immediate calls for the shooting or gassing of badgers and since 1975 there have been several waves of official badger culls aimed at control (Independent Scientific Group, 2007). It is remarkable how quickly the call to kill wildlife came to the fore, facilitated no doubt by a poor image in rural areas that has been called 'bad badger' (Cassidy, 2012). This framing was due to crop damage, the undermining of buildings, and the killing of chickens, none of which endeared badgers to the farming community. Indeed, historically badgers were widely persecuted (Cresswell et al, 1990), to the extent that their absence locally is not necessarily a sign of an unfavourable ecology. Badgers and their diseases have emerged out of these practices and interventions. The strongest indirect evidence of this is that badger numbers are said to have increased from 250 000 to 400 000 between the mid-1980s and the mid-1990s, associated with the statutory protection beginning with the Badger Act of 1973 (Roper, 2010). But whether they are heroes or monsters, badgers are certainly elusive. Their nocturnal habits and underground living make them difficult to count and the various surveys and maps of their distribution are indicative only. In November 2011 Defra commissioned its Food and Environment Research Agency to undertake a badger sett survey in England and Wales, to be completed soon. This is the third in a series of studies (1985–88, 1994–97, 2011–13).

It is ironic that the piecemeal policy of badger culling (1975–2005) coincided with the resurgence of bTB as a cattle disease, probably due to the circulation of the new, fluid, human-made ecologies that have been called 'perturbation'—the scattering of survivors. From its lowest point in 1982, when there were only just over 500 reactor cattle, there was a steady rise to an annual average of over 40 000 reactors identified and slaughtered each year 2008–11 in the UK. In England the problem is greatest in the southwest, where 22.7% of herds were under movement restrictions at some point in 2010, with farmers unable to sell or move their cattle (Defra, 2011a).

The bTB outbreak accelerated from 2001 onwards and attracted political attention in the form of an 'outbreak narrative' (Leach et al, 2010). This stressed top-down interventions and was heavily informed by the contemporary slaughter programmes of cattle infected with BSE (from 1986, peak 1992) and FMD (2001, 2007), two cattle diseases that had a major impact on the national psyche. On occasion an outbreak narrative can be a hegemonic coalition of framings that sweep over alternative viewpoints. In the case of the narrative that has led to the 2013 Coalition badger culls, popular views as expressed in an online citizens' petition and opinion polls have been ignored, as has a free vote in the House of Commons in October 2012 (BBC, 2011; Bow Group, 2012; Defra, 2011b; House of Commons, 2012; May, 2012). And yet the government has been forced to agree to some emollient ingredients in the practicalities of the cull. Each farmer group applying for a licence will have to practise biosecurity, for instance, making their farm buildings badger proof, and costs will be paid for by farmers rather than taxpayers.

Story 2. Uncooperative bacteria

But are we getting ahead of ourselves? After all, we haven't yet defined bTB as it is found in badgers and cattle. This is partly because we find it so difficult to tie down. One place to start is with the *M. bovis*, the causative agent, but it is important to note that its impact is both uneven and unpredictable. In badgers the toll of morbidity and mortality is relatively light; the disease often becomes dormant and there is some evidence of immunity. Also in UK cattle, bTB rarely these days reaches its advanced stage and all of the financial loss to the farmer is from the slaughter of infected animals and the restrictions on cattle movement that follow rather than from the bodily inscription of the disease. What then is the problem

(Torgerson and Torgerson, 2009)? The answer is that there is a legal requirement upon member states of the European Union to eliminate enzootic disease, with public health in mind and also the stability of the livestock industries and the international trade in their products.

The problem is not the need to act but how to act. Because of what Coole and Frost (2010, page 1) call "the intransigence of materiality", it has proven to be exceptionally difficult to know and to follow the infection in bodies, whether bovine, badger, or human. bTB presents in different organs and proceeds at speeds that vary. In the case of slaughtered cattle, even in the abattoir infection may be evident only as the result of microscopic necropsy.

The measurement technique used for diagnosing infection in cattle since the early 20th century is a crude ontonorm (Mol, 2012). The extraordinary complexity of the disease is reduced to one external sign: the swelling of a patch of skin that follows the injection of a bovine antigen, tuberculin. There have been variants of this over time and the current version in use in the UK is the single intradermal comparative cervical tuberculin test (SICCT). This checks for an immune response (an allergic swelling) in the animal's skin and compares it with the response to another common, avian mycobacterium. Three days later, if the swelling attributable to *M. bovis* is more than 4 mm greater than that of the comparator then there is said to be a positive 'reaction', whereas a swelling of 1–4 mm more than the comparator is an 'inconclusive'. Reactors are slaughtered with compensation paid at market value and inconclusives are retested after sixty days.

A crucial point for our ontonarrative is that the SICCT is imperfectly sensitive and is thought to detect reliably only about 80% of infected animals (de la Rua-Domenech et al, 2006; Independent Scientific Group, 2007). This is the test's Achilles heel and the greatest single cause of indeterminacy in dealing with bTB. Possible reasons for false negatives include cattle that are anergic (do not react), or have been immunosuppressed because of pregnancy, early lactation, or the presence of concurrent disease such as liver fluke (Claridge et al, 2012; Green and Cornell, 2005). Other heterogeneities include the antigen used and sometimes even differences in strength between batches. False positives are a lesser risk because the specificity of the test is said to be above 99.9%.

The deployment of the injection and measuring with callipers is a ritual well known to one of us (PAR), a veterinary surgeon with years of experience in applying this skin test. So, we are well aware of the stress for all concerned. The farmer knows that the test has flaws and the vet knows that the farmer's ability to trade and future prosperity may depend on getting the 'right' result (a negative). And yet there is a strict protocol to follow and the authorities demand a rigour that eliminates (in theory) any feelings or subjectivities for humans or cattle. Much depends on the veterinary performance of a test that includes equipment and analytical skills, as well as the bacterial and immunological performances within the bovine body. There is a material heterogeneity (Singleton and Law, 2012) here in which the repetitive performativity cannot establish a reliable rhythm of outcome. This is because the objects involved clash and their interpenetration never achieves metastability. The on-site enactment of bTB by the testing veterinarian is a vital element in its emergence or nonemergence, along with her or his willingness to apply rigorous standards, as specified in the government's contract, under pressure from interested parties, especially the farmer (Enticott, 2012). From participant observation of vets acting on behalf of the government agency, Animal Health, Enticott (2011, page 76) found that the official protocol laid down was "replaced and transformed by the creation of informal and situated practices." The precision of testing is affected by uncooperative animals, by speed when dealing with large herds, and on occasion by sympathy for the farmer's plight. Testing then is a socially contingent as well as a scientific procedure.

As we have seen, up to 20% of infected cattle tested may escape detection. Some animals resolve the disease by themselves but others, an unknown proportion, develop subclinical symptoms and become infectious, either by passing on bacteria in their faeces, through droplet broadcast, or via nose-to-nose contact across a boundary fence. In this way, cattle may infect other cattle and there is also a risk to wildlife. Indoor management systems, particularly where air circulates in enclosed sheds, are a risk, as are intensive grazing systems where animals are in frequent proximity to each other (Phillips et al, 2003).

The British Cattle Movement Service database that started in 2001 records every transaction and, when coupled with the location of reactors, it provides raw material for spatial and network-based epidemiological research. Established as a precautionary measure, the service represents a panopticist imaginary that makes animals ontologically accessible. Cattle now have their own passports, electronic records, and a call upon the state's concern for their welfare. Badgers and bacteria are more opaque, inhabiting liminal interstices often beyond observation. They have emerged, to adapt Braun's (2011, page 401) words, as the "faceless, unseen and unseeable enemy". At first it was thought that badgers had no direct contact with cattle and that the bacteria were exchanged through excreta and urine deposited on pastures used by both. In recent years, however, badgers have been seen in feed stores and in cattle sheds, where there is a sharing of air that might contain bacteria (Böhm et al, 2009). This is a different kind of bodily disposition and *with*ness (Whatmore and Hinchliffe, 2010). Such alternative materializations have opened up an ontological politics in the realm of biosecurity. Farmers are now advised to make their farm buildings badger proof but there are some who are sceptical as to how this could practically be achieved and others who are reluctant to invest capital. Their alternative conception of biosecurity is heavily weighted towards controlling the supply-side threat from badgers: that is, by culling.

Story 3. The environmental irony of the badger's dark world

There has been a coevolution of badgers and society. We have already commented that badger absences are due to the activities of farmers, gamekeepers, and sett diggers: for, instance in the intensive arable counties of East Anglia (Cresswell et al, 1990). In the pastoral regions further west badger numbers correlate with the presence of their favourite food, earthworms: for instance, on the rich grasslands of counties such as Gloucestershire. This 'making' of badger geography has been the result of many small day-to-day farmer decisions over decades or even centuries and was not in any policy realm until the 1970s.

In a more active register it seems that for one section of society badgers are politically constituted as outsiders and the cuddly black and white striped hero of children's stories has become a biohazard. At the risk of anthropomorphism, one is reminded of Craddock's (2000) description of San Francisco's four major smallpox epidemics in the second half of the 19th century which were blamed on Chinese immigrants. For badgers there is even an underground dimension of symbolic mapping to match the sewers that were thought to play a part in disease in San Francisco. The dark world of badgers is an elsewhere within. They are the strange strangers in Morton's (2010a) encounters with the uncanny because they are familiar and strange simultaneously. As he observes, "the antagonistic energy of the community is pasted onto the scapegoat, who is then sent outside the community to purge it of its contradictions" (Morton, 2010b, page 278).

European badgers (*Meles meles*) are burrowing animals that are nocturnal and omnivorous by habit. They are Britain's largest wild mammal and are distributed all over the country, being particularly abundant in the southwest of England. Their setts are complexes of tunnels and chambers, sometimes substantial in spatial extent and longevity of use. They are humid and stable in temperature from day to day and lacking in ultraviolet light, the ideal conditions for the survival of *M. bovis* (Moore and Roper, 2003).

It is not difficult to imagine the underground exchange of bacteria-laden air between individual badgers in the enclosed spaces of the sett and several studies confirm that the respiratory system is the main locus of their infection (Gallagher and Clifton-Hadley, 2000). There are alternatives, however, including infected bite wounds and postnatal maternal transmission to cubs. This is not to say that proximity guarantees infection because the occupation of setts seems to involve some separation or zonation as dictated by the aggression of the dominant boars.

15% of culled badgers are tuberculous, and 42% of these have some form of pathology (Woodroffe et al, 2009). But at the microscale there is no clear correlation between badger population density and bTB infection. This is partly because, at the highest densities, badgers are superterritorial and migration is rare between neighbouring groups. The degree of clustering is such that it is not unknown to have a highly infected group living next to one with no disease (Cheeseman et al, 1981; 1985). Thus for the infection of badgers it seems, *ironically*, that population density is less important than the dispersal of individuals (Vicente et al, 2007). But where culling has happened in the past it has caused perturbation—the disruption of badger sociospatial organization and their consequent wider ranging, resulting in contact between groups that would not otherwise have occurred (Carter et al, 2007). There is solid evidence from British studies that this presents an unrivalled opportunity for disease diffusion that would otherwise not be present in high-density areas. This is an *irony* pointed out in the Independent Scientific Group's (2007) analysis of the Ranhdomised Badger Culling Trial (RBCT), which has direct relevance for the Coalition cull. There is a strong possibility that, if the culling is not comprehensive enough and efficiently undertaken, the surviving members of disturbed groups will escape into the surrounding countryside, taking their infection with them to naive badger communities and cattle herds. The favoured 'remedy' may therefore be responsible for serious unintended consequences.

The biopolitics of culling is a matter of framing the inconvenient as an object of control and elimination. Agamben's (1998) concept of 'bare life' is relevant, along with his 'spaces of exception' where lives are weighed against particular sociopolitical norms and the abnormal is eliminated (Lorimer and Driessen, 2012). As Hinchliffe (2013, page 7) notes, "disease is always more than a matter of infection, it is a pathogenic entanglement of hosts, environments and microbes, a relational achievement." In the case of culling, one ontology has emerged as the foundation of action in England despite the alternative natureculturetechnics playing out in neighbouring countries (Wales—vaccination of badgers; Scotland—no cull; RoI—different type of cull; Northern Ireland—proposal to test badgers and vaccinate or remove). Until the cull actually begins there may still be room for what Stengers (2010–11) calls cosmopolitics (see also Rose, 2012), showing an inclusive attentiveness to the full range of expertises deployed by farmers, scientists, the Badger Trust, and vernacular others, through affirmative deliberation.

Story 4. Field experiments and national imaginaries

Our fourth enactment of bTB is through the lens of veterinary science and badger ecology as these interact with the world of policy. The first cut of this is through Jasanoff's depiction of sociotechnical imaginaries. Consider her characterization of the British approach to environmental policy making (Jasanoff, 1997, page 227):

> "In British advisory committees, trust is created through embodiment in trustworthy people ... such individuals have proved their right to represent the public interest through years of devoted service. Many have earned knighthoods or other honours in recognition of their contributions to public life ... . People who have attained this status can be said, with little exaggeration, to constitute an elite tier of civic virtue that stands, and is seen to stand, above self-interest and even party politics."

Just such a description could be applied to John Krebs FRS, then Royal Society Research Professor in Zoology, Oxford University, who was appointed to chair the RBCT from 1998 to 2007.[1]

When asked to provide an in-depth commentary on badgers and bTB, Krebs and his committee recommended a scientific field experiment to be overseen by an independent group of experts (Krebs, 1997). This in their view was the best way to settle the issue as to whether the culling of badgers helps to reduce the risk of infection for cattle. With the support of Defra, triplets were established in ten hotspot areas in the southwest. These were clusters of three neighbouring 100 km^2 blocks, each triplet having a zone of 'proactive' (repeated, annual) culling across the whole area, one of 'reactive' culling in localized areas where there were tuberculous cattle, and a control 'no cull' or 'survey' area. This application of the experimental scientific method was designed to guarantee the political neutrality of the project and controlling for chance was planned to yield results of greater statistical significance. The RBCT has been characterized as Europe's largest ever ecological experiment. It was certainly expensive, at nearly £50 million, and controversial. One of its limitations was that some of the badger trapping was disrupted by animal welfare activists and a number of landowners refused access. In addition, the long pause in work during the 2001 FMD outbreak was an inconvenience and the reactive culling part of the trial was stopped ahead of schedule by the government because of early indications that it was causing an upsurge in cattle TB outbreaks in those areas.

Recourse to the scientific method is sometimes seen as necessary when views diverge and mutual trust among the various parties is at a low ebb due to communication problems (Jasanoff, 2010). In the RBCT the state was looking for a way to move into a policy space suitably cleansed of prejudice and bias. Although Krebs had formulated his ideas under a Conservative administration, it was a Labour government that appointed the Independent Scientific Group and implemented the RBCT in 1998.

The RBCT is an example of what Enticott (2001) calls 'nature as numbers', which then in turn facilitates 'statistical governmentality'. Its main finding was that, although badgers were implicated in the spread of bTB, "badger culling can make no meaningful contribution to cattle TB control in Britain" (Independent Scientific Group, 2007, page 5). This conclusion was controversial not least because different results have been obtained in the RoI, where culling and perturbation have not led to a surge of bTB in either cattle or badgers (More, 2009; O'Connor et al, 2012). Indeed, the national imaginaries of the exercise of biopower have been so different across the Irish Sea that there has since been a questioning of each other's methods and the validity of the conclusions drawn (Bourne et al, 2007; Dunlop, 2010; More et al, 2007).

A key point here, according to Jasanoff and Kim (2009), is that [veterinary] science and the state are co-produced and re-produced through such extended programmes. This co-production is so powerful that it even has the potential to destabilize political alliances. In 2010 the Welsh government, then a coalition of Labour and Plaid Cymru (the Welsh nationalist party), announced that it would proceed with its own badger cull, but after a vigorous and high-profile campaign by badger interest groups and a legal judgment in their favour, the policy was put on hold. When Labour subsequently formed their own single-party Welsh administration, they commissioned a further review of the evidence, and changed direction. In March 2012 the Welsh devolved government announced a policy based upon the vaccination of badgers rather than culling. This contrasts with England where the different balance of interest groups and their political alliances has led to uncertainties in government policy.

[1] Krebs was knighted in 1999 and ennobled in 2007.

Story 5. Molecular geographies and statistical modelling

The fifth enactment of bTB exhibits ontological tension between behavioural ecology and ecological modelling. One is observational and the other virtual, but the two come into frequent, close contact—for instance in major projects such as the RBCT—because the statistical models require field data for calibration and the estimation of parameters. Yet the scientific styles are at variance.

By way of example, Woodroffe et al (2009) observe that field studies have so far found little to support the commonly assumed positive correlation between badger group size and bTB infection. Their own work on evidence from areas in the RBCT proactive culls suggests a lower than expected prevalence in large groups, although the size of those groups nevertheless meant higher absolute numbers of infected badgers, therefore maintaining the risk of spread to cattle.

Ecological models, particularly those employing multiple simulations, tell a different story. Anderson and Trewhella (1985) found badgers to be a possible maintenance host of bTB on the basis of a model that predicted an equilibrium prevalence of about 18% after thirty to forty years. By an extension of this logic, White and Harris (1995) found persistence in 95% of their simulation outcomes over a 100-year period. Overall they concluded (page 404) that bTB "has the potential to persist in the badger population for a long time, even at small group sizes and at low prevalences, without any reinfection being required." By 'small group' they meant six adults and yearlings, although eight adults and yearlings were required for a higher probability of intragroup infection and disease persistence. Smith et al (1995) and Hardstaff et al (2012) found something similar and according to Smith et al (2001, page 530), "when social group size drops below about 6.3 adults and yearlings disease extinction may occur within 50 years." Groups of this size tend to be found in what Feore and Montgomery (1999) call Type-I habitats: low to medium altitude with woodland interspersed with good agricultural land, as seen in classic badger study sites such as Wytham Woods, Oxfordshire, and Woodchester Park, Gloucestershire. Type-II habitats (low to medium altitude, primarily pastoral farmland with limited woodland), and Type-III (medium to high altitude with upland vegetation) are less likely to facilitate disease persistence or spread, because they have mean group sizes of 5.1 (with cubs) and 3.5, respectively.

Even within the modelling community there are divisions between the deterministic and stochastic approaches and between aspatial and GIS-based models. As a result, the analysis of the spread of FMD in 2001 descended into bickering about whose models should be used as the basis of government slaughter policy (Bickerstaff and Simmons, 2004; Law and Moser, 2012).

As a result of such professional disagreements, we are still not clear whether badgers are maintenance hosts or spillover hosts of bTB. In a maintenance host a disease persists due to the circulation of an infection among a group of individuals, sometimes for lengthy periods. Spillover hosts in contrast require occasional reinfection from outside for disease persistence (Corner et al, 2011; Nugent, 2011). A third possibility is that bTB has maintenance status in some regions at some times but is otherwise only a spillover disease.

Given the heavy concentration of bTB in both the cattle and badgers of southwest of England, south Wales, and a few other localities (Fisher et al, 2012), it seems hard to justify the claim that the disease is "endemic in many badger populations *throughout* England" (Anderson and Trewhella, 1985, page 374, emphasis added). Woodchester Park in the Cotswolds, where much work has been done on badger ecology, has among the highest badger densities (about 20 per km^2) anywhere in Europe and care is therefore needed in extrapolating the work done there beyond its regional context. Necropsies on badgers killed on the roads from 1972 to 1998 indicated a clear distance decay of bTB in that species away from the southwest (Krebs, 1997) and this may be because badger ecologies at lower densities in other parts of the country are less favourable to the spread of the disease, from badger to badger and from badger to cattle. A point opaque to homogeneous spatial thinking is that the highest peak of bTB in cattle before 1960 was to be found in Cheshire, in northwest England, in a part of the country where bTB in badgers has since been found to be low (Atkins and Robinson, 2013). This suggests the need for a fundamental review of the indeterminacy of bTB and its implications for national-level policy making.

One element missing from much of the literature is dissonance of scale. While maps of the spread of bTB in the last two decades have concerned policy makers at the regional scale, most of the ecological literature is pitched, rather, at the local scale. The value of an intermediate view of scale is encapsulated by Allen et al (2011, page 11), who see bTB as “a series of [separate] mini epidemics”. Their understanding is based upon the molecular geographies of *M. bovis* genetics. The Animal Health and Veterinary Laboratories Agency has a website (http://www.mbovis.org) devoted to different strains of the bacterium known as spoligotypes and it is clear from the maps displayed there and in Smith et al (2006) that over time clusters of each type have reproduced in relative isolation and spread within radii of only 10–50 km. Any outliers beyond these distances are probably the result of long-distance cattle movements (Gopal et al, 2006). Given that the cattle-tracing system shows that most sale movements are within 20 km of the farm of origin, we have one possible explanation for the granularity of the spatial pattern. By comparison, in the absence of perturbation, badgers range only a few kilometres from their home setts and so, in view of the ecology that we traced for them above, a wave diffusion of badger-to-badger infection is unlikely to move any faster than at a glacial pace across the country.

More Defra-sponsored work is now proceeding on the home ranges of these bTB genotypes and it seems that each local variety has found expression in the bodies of both cattle and badgers (Olea-Popelka et al, 2005; Woodroffe et al, 2009). As a result, the interspecies pooling of infection is now more certain than ever, although Goodchild et al (2012) found that over short distances genotype dissimilarity is greater in cattle than in badgers and they conclude (page 8), as a result, that this is “evidence that cattle were exposed to other sources of infection”, presumably other cattle.

Conclusion: from ontological politics to ontological policies?

The governance of bTB has proven difficult over the last 100 years. Since 1971 it has seemed to some that eliminating the risk of infection from wildlife, or if necessary eliminating the wildlife itself, is one policy worth pursuing. To others the ability of bTB to jump the species barrier (badger–cattle–humans) proves its opportunism and adaptability and the impossibility of containing certain life forms. bTB appears to be adventitious because of the epidemiological fog masking individual cases. The best that can be done by way of proving badger–cattle or cattle–badger infection is circumstantial colocation, occasionally (and expensively) backed up with the laboratory identification of their common spoligotypes. A sensible alternative in our view is to embrace the ontological multiplicity that we have uncovered in this paper and therefore to abandon the search for a one-size-fits-all policy solution. The multiple cattle–badger hybrids uncovered by Atkins and Robinson (2013), for instance, suggest that a cull, even if successful in the southwest of England, cannot be justified on the present rationale in all parts of the country, where heterogeneities of ecology and livestock husbandry indicate the need for a reconsideration of the Defra/NFU (National Farmers’ Union) plan.

At the time of writing, the politics of bTB resemble Jasanoff’s (1997) ‘civic dislocation’. Farmers, scientists (ecologists and veterinarians), and the public are talking past each other (as is typical of knowledge controversies) from entrenched positions that owe much to each of them investing in only one of the multiple ontologies that have emerged. The public are generally against the killing of charismatic animals such as badgers, and members of the former Independent Scientific Group continue to be sceptical about the benefits of culling. Despite this, the Coalition government appears to be sensitive to one of its core constituencies, the farmers. Indeed the then Secretary of State of Defra, Caroline Spelman, claimed at a conference of the NFU in February 2012 to have "one of the most farmer-centred ministerial teams ever." In the same speech she also announced that the first two cull areas were chosen "from a short list proposed by the farming industry" (NFU, 2012).

The movement towards biosecurity in the broadest sense has involved extensions of state power. Farmers with confirmed cattle disease have seen their rights of livestock movement restricted, along with their former unquestioned 'rights' to kill wildlife on their farms. Defra already governs cattle bodies and is now also seeking control over both the bodies and performances of badgers. Injectable badger vaccine is one element, to be followed by vaccine that will be delivered through bait. Meanwhile, trapping and free shooting are other means of attaining control.

It is entirely understandable that "groups compete to represent nature on their own terms" (Jasanoff, 2010, page 237). Farmers commonly seem to have a sense of hopelessness with regard to bTB, as expressed by Mark from Cornwall: "one of the worst things with TB is that you have no control over it .... Living with TB on your farm is really depressing. Losing cows you have cared for and bred for fantastic pedigrees is soul destroying." (2) He takes his "biosecurity seriously but it just doesn't seem to be enough. I see badgers here in the yard at night and there's nothing I can do. I am forced to watch my cattle get killed while I know the cause is walking around."

Mark 'knows' that badgers are responsible for bTB in cattle. Elsewhere the NFU asks "do badgers spread TB to cattle?" and their answer, without equivocation, is "unfortunately, yes" (NFU, no date). In the face of such confident claims-making from this and other sides of the argument, the government must play for time. The two culls to start in the summer of 2013 are, once again, experimental and the full programme will take years to extend to the whole country. One senses the frustration of officials and politicians with the fugitive nature of *M. bovis*. Their investment of hope in anti-bTB technology is about to be tested with the roll-out of the injectable badger vaccine that was licensed in 2010 but, although this shows promise in protecting badgers from bTB, there is as yet no hard evidence that vaccinating badgers will in turn reduce cattle disease (Robinson et al, 2012). If and when a vaccine for cattle is finally launched, it will take a further unknown period of years or even decades for bTB finally to come under control. Meanwhile, a spatially nuanced policy would be welcome that showed some awareness of the heterogeneities of the disease and which matched any interventions to the ontological slipperiness and multiplicities of the *M. bovis*.

Acknowledgements. The authors wish to thank the Wellcome Trust for a Fellowship (PJA) and the Department of Agriculture and Rural Development, Northern Ireland for a doctoral scholarship (PAR). Three anonymous referees made a major contribution in clarifying the argument but full responsibility for errors remains with the authors.

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