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Mapping Careful Epidemiology: Spatialities, Materialities and Subjectivities in the Management of Animal Disease

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Abstract

As a geographical tool, epidemiology represents a distinct way of seeing and knowing disease. Used as a governmental rationality to control animal disease, changes in epidemiological practice have been understood as technological evolutions. In doing so, however, this view disguises the 'messy realities' of epidemiology, the relationship between different epidemiological practices, and the work required to make epidemiology 'matter'. Drawing on a case study of the management of bovine tuberculosis in England and Wales, the paper examines how epidemiological practices are developed, replaced and contested. By focusing on practices of epidemiological record keeping and mapping, the paper argues that epidemiology arranges different spatialities, materialities, and subjectivities in order to enact the presence of animal disease. The paper tracks changes to these arrangements over time, showing how they seek to redefine the appropriate people, places and practices that allow disease to be seen. In doing so, however, the paper shows how versions of epidemiology deposit 'residues of practice' that influence how new epidemiological arrangements are received and negotiated in use. A central theme to these negotiations is an attempt to accommodate complexity by employing a caring and/or careful approach to epidemiology, as revealed through the practices of 're-recording' and 're-mapping'. Whilst this demonstrates the contextual and in-situ nature of epidemiology, highlighting the contribution of a caring/careful epidemiology also serves to make these practices relevant for future iterations of epidemiological practice by making them 'matter'.

Keywords: Epidemiology; bovine tuberculosis; biosecurity; care; subjectivity; materiality; spatiality.

Mapping Careful Epidemiology: Spatialities, Materialities and Subjectivities in the Management of Animal Disease

1. Introduction

As a geographical tool to control the spread of animal disease, epidemiology exerts significant influence in policy makers' and veterinarians' decisions. Conceptualised as a 'spider's web' (Krieger, 1994), epidemiology is concerned with identifying the interconnected risk and protective factors that determine the spatial distribution of disease. This relational, multi-factorial approach has proved increasingly important amongst academics and policy makers alike. Yet, this apparent relational simplicity also effaces critical reflection of epidemiology, disguising how it 'embodies particular *ways* of seeing as well as knowing the world' (Krieger, 1994). Frequently, epidemiological practices are reflected as a simple set of paradigms (Susser and Susser, 1996), evolving through technological change rather than characterised as a set of messy practices in which 'contrasting elements' are continually folded together 'giv[ing] rise to new and novel arrangements through different types of engagement' (Hinchliffe et al., 2013). This complex picture suggests that epidemiology should be seen more as 'a dynamic configuration of practices and ideas' than a 'hermetically sealed conceptual [practice]' (Amsterdamska, 2004).

Following Law and Mol (2011) this paper extends this understanding of epidemiology by directing attention to how different spatialities, materialities, and subjectivities are arranged by its attempts to 'enact' animal disease[1]. We argue that epidemiology comprises a relational field that seeks to stabilise what animal disease is, and defines the appropriate people and practices that allow disease to be seen. Taking a longitudinal approach, however, we track changes to these enactments as relationships shift and fracture. In this

[1] By 'enact', we refer to performative practices that not only describe but 'bring into being what they also discover' (Law and Urry, 2004, p.393).

way, we show how versions of epidemiology deposit ‘residues of practice’ that influence how new epidemiological arrangements are implemented. The paper therefore describes the field-level consequences of the introduction of new forms of epidemiology, revealing how they seek to over-ride familiar subjectivities, materials and spatialities inscribed within the epidemiological practices of record keeping and mapping. A central theme to these negotiations and subsequent reformulations of epidemiological arrangements is an attempt to accommodate complexity by employing a caring and/or careful approach to epidemiology. Given that epidemiological practices are tied to political choices of how to govern disease (Leach and Scoones, 2013), by paying attention to these transitions and practices of care, the paper seeks to highlight their relevance for future iterations of epidemiological practice by making them 'matter' (Lavau and Bingham, 2017).

In exploring the transitions between these different epidemiological arrangements, this paper examines the role of epidemiology in the management of bovine tuberculosis (bTB) in England and Wales. Firstly, the paper views epidemiology through a governmentality perspective, conceptualising the relationships in which epidemiological arrangements – combinations of spatialities, subjectivities and materialities – are situated to enact disease. Secondly, it draws on recent studies of biosecurity, examining how these arrangements change over time but are challenged by field veterinarians. Finally, we show how practices of care and careful epidemiologies are integral to attempts to make epidemiology workable.

2. Arranging Epidemiology

If as Krieger (1994) suggests, epidemiology ‘embodies particular *ways* of seeing as well as knowing the world’ which evolve through technological development, then risk factor epidemiology is the latest dominant paradigm. Reliant on statistical analyses and computer modelling, risk factor epidemiology has assumed a central role in the regulation and management

of disease outbreaks (Christley et al., 2013). In this way, epidemiological practices are no different to other forms of Foucauldian governmentality in which sets of techniques and practices form rationalities of control and rule. Inscribed within these epidemiological governmentalities are materialities, spatialities and subjectivities that simultaneously define epidemiology and enact its subject of interest – disease.

Firstly, *materialities* are vital to epidemiology's enactment of disease. For example, record keeping is central to epidemiological practice, involving pens, papers, maps, measurement tools and recording devices to inscribe data about disease transmission. These material inscriptions allow knowledge about disease to travel between 'dirty' infected bodies and farmyards to the 'clean' spaces of government offices. This mobility allows further disease management decisions to be taken involving additional material practices, such as mapping control zones, to secure the boundaries of the safe and the diseased (Donaldson and Wood, 2004). The centrality of the material 'record' to enact the presence and absence of disease is integral to creating a centre of calculation which articulates particular styles of truth telling to render problems visible and governable (Latour, 1987). Such technologies of knowledge transform governmental rationalities into practical, material tools that shape the conduct of actors (Dean, 2010). Thus, knowledge produced through epidemiological data gathering is linked within complex assemblages that produce effects of 'truth' (Merlingen, 2003).

Such material assemblages both constitute and define the activities of animal disease governance itself. In doing so they also highlight the second element of epidemiological governmentalities – their *spatialities*. Wilkinson (2011), for instance, describes how different spatial orders are inscribed within the activities of disease control. So-called rational approaches to managing disease neatly divide up the policy process into bounded parts, and separate policy from science spatially. Other epidemiological arrangements – such as computer modelling versus field epidemiology – inscribe contrasting

spatialities (Bickerstaff and Simmons, 2004). Computer modelling can seek to flatten space to 'depict relations between sites' (Law and Mol, 2011), in which distant places are brought together by veterinary tools and practices permitting epidemiologists to act at a distance (Mol and Law, 1994). Opposed to these placeless topologies, field epidemiology accepts a more dynamic arrangement in which the identification of disease is situated within localized contexts (Enticott, 2017).

Finally, epidemiology contributes to an arrangement of disease control *subjectivities*. Studies of disease control have focused on attempts to redefine farming identities as a way of promoting new 'biosecure subjectivities' (Barker, 2010) and forms of conduct consistent with disease reduction (Enticott, 2016). However, epidemiological practices also inscribe desirable subjectivities and desirable conduct upon disease control experts. Disease control disputes highlight contrasts in knowledge practices between epidemiologists, veterinarians and farmers, in which material practices and their spatialities are connected to specific identities (Enticott, 2012, 2017). Thus, distant statistical records, and their use in computer modelling, can be seen as a threat to more spatially nuanced and situated perspectives (Bickerstaff and Simmons, 2004). Here, 'local knowledge' derived from personal and embodied experience, spatial and temporal embeddedness, and proximate social connectivity are not just reflective of the practices required to understand disease, but also of the identities of its practitioners. Epidemiological governmentalities instead seek to inscribe new subjectivities, establishing appropriate norms of conduct and scientific investigation in the process of enacting disease. Whilst this may give the impression of paradigmatic change, Wilkinson (2011) suggests a more subtle arrangement in which contrasting disease control subjectivities can happily co-exist, living side-by-side rather than replacing each other.

The arrangements that enact disease should therefore be seen as dynamic rather than the kind of fixed or universal field suggested by governmental

analyses that forsake 'the messy actualities of social relations' (O'Malley et al., 1997) and ignore the lived experiences and material realities of governmental interventions. The danger of such an approach is that it overlooks the ‘interstitial slippages’ (Rutherford, 2007) that occur in the application of power, and the way in which technologies can be shaped and resisted by the people that are subjected to them (O'Malley et al., 1997). Instead, unravelling the messiness and complexity of the struggles around subjectivity requires an approach that accommodates the fluidity of technologies and practices.

Recent studies of biosecurity deploy the concept of the ‘borderland’ to account for these accommodations and the ‘messiness’ of epidemiological practices (Hinchliffe et al., 2013, Enticott, 2017). Here, unexpected biological reactions contribute to the melding together of different disciplines, creating hybrid practices, whilst fixed spatialities become fluid in which technologies, records and materials are less obdurate but equally workable (Mol and Law, 1994). The significance of the borderland leads to a consideration of the multiplicity of disease as practices that enact disease do more than just transition in a series of paradigm shifts, and find ways of accommodating each other (Hinchliffe et al., 2016). Accommodation may be no simple task: obdurate epidemiological practices may provide the basis of resistance, such as the adaptations made in response to universal protocols (Enticott, 2012). The biosecurity subjectivities inscribed within protocols and record keeping, such as the unquestioning rule-follower, may also be challenged and reconstructed by active participants in epidemiology.

As a geographical science, these on-going adaptations are particularly relevant to epidemiology’s use of maps and mapping. In government offices, wall maps provide constant reminders of the spread and scale of animal disease, whilst in the field, maps are indispensable for collecting and identifying epidemiological risks. However, these maps are not objective, neutral products of epidemiological science: as inscriptions they act as

immutable mobiles, standardizing meaning across space (Latour, 1986) whilst reflecting the power of those who construct them (Harley, 1989). This does not mean, however, that the meaning of maps is immutable. Rather, Kitchin and Dodge (2007) argue that maps are ontogenetic: the meaning and utility of maps and mapping is never settled but emergent from everyday use. Maps are therefore 'of-the-moment, brought into being through practices (embodied, social, technical), always remade every time they are engaged with' (Kitchin and Dodge, 2007). The subject of analysis becomes how maps emerge through contingent, relational, context-embedded practices to solve relational problems? This requires attention to the way maps are made, and how people use and collaboratively remake maps in relation to other sources of knowledge and contexts.

In this understanding, mapping mirrors the realities of the day-to-day use of other epidemiological tools like record keeping whose flexibility-in-use provides possibilities to develop new epidemiological practices, reinterpret disease data and advocate alternative epidemiological subjectivities from those inscribed within official practices (Enticott, 2012). This kind of contextual in-situ work may reflect a commitment to the residues of practice from previous epidemiological arrangements, but also reflect an 'ecology of attention' (Lavau and Bingham, 2017) in which a 'logic of care' (Mol, 2008) guides responses to reforms of epidemiological arrangements. Practices of care form a central critique to technocratic and managerial approaches in human and animal health (Carmel, 2013). For Mol (2008), a logic of care eschews market-based treatment in which patients are offered choice, to one in which 'professionals and patients jointly act again and again…they interact, shifting the action around so as to best accommodate the exigencies of the disease with the habits, requirements and possibilities of daily life'. In this sense, care is a process that is open-ended: 'crafting' (Carmel, 2013), 'doctoring' (Mol, 2008) or 'tinkering' (Law, 2010) are its defining characteristics. Medical targets, values and activities are therefore arrived at through practice, and continually adjusted to fit contexts. Similarly,

in relation to animal health, Law (2010) argues that the 'practical is intertwined with the emotional or "the personal"'. Managing disease involves ignoring indiscretions where circumstances demand, or 'learning how to balance empathy and distance' (p.64). Singleton (2010) provides a similar example of caring practices in which cattle inspectors can simultaneously recognise and dismiss errors. However, these systems of control in farming are frequently in tension with care practices, resulting in the loss and damage to practices of care essential to the craft of good farming. A caring/careful approach to epidemiology appears to be essential if it is encourage 'attention in others' (Lavau and Bingham, 2017), such as farmers managing disease, or veterinarians seeking to conduct effective disease control. Yet, a caring/careful epidemiology may also be effaced by the introduction of new governmental epidemiological regimes designed for efficiency, and lacking their attention to detail and context (ibid.).

3. Epidemiological Arrangements in the Management of Bovine Tuberculosis

Epidemiological arrangements of materialities, subjectivities and spatialities change over time as new forms of epidemiology are introduced as part of governmental changes to control disease. However, the residues of practice left behind can be instrumental in guiding how these new arrangements are adapted and/or accommodated, recombining new and old practices to produce hybrids spanning the boundaries between different epidemiological configurations. The rest of this paper describes these epidemiological evolutions in relation to the management of bTB. Specifically, three epidemiological arrangements are identified: field epidemiology, experimental epidemiology, and managerial epidemiology. Analysis of the everyday use of the materialities associated with these forms of epidemiology – record keeping and mapping – shows how residues of practice, and the spatialities and subjectivities inscribed within them, guide attempts to resist, accommodate and develop hybrid forms of epidemiology. Specifically, we

show how these transitions are informed by a 'logic of care' (Mol, 2008) to create a concern for a caring and/or careful form of epidemiology in opposition to universalizing forms of bureaucratic epidemiology. Before describing the characteristics of these arrangements of epidemiology and the transitions between them, brief details of bTB in the UK and our methodological approach are provided.

3.1. Methods and Background

The Department for Environment, Food and Rural Affairs (Defra) considers bTB to be the most challenging animal health challenge facing England and Wales (Defra, 2014). The disease is managed by a national surveillance programme which tests and slaughters infected cattle, whilst also seeking to reduce transmission between badgers and cattle (see Grant (2009) for a review of the history of bTB policy). The test and slaughter policy is currently supported by epidemiological investigations conducted by veterinarians working for Defra's Animal and Plant Health Agency (APHA). The purpose of the investigation is to establish the reasons why cattle have contracted bTB, propose cattle management solutions, and prevent recurring infection.

Two studies form the dataset from which our analysis is drawn. The broad aim of the first study was, drawing on the experience of local veterinarians, to map endemic areas of bTB. The second study provided a qualitative evaluation of a pilot scheme in Wales called 'Cymorth TB' which involved private veterinarians undertaking an epidemiological investigation of a bTB incident (also referred to as a 'breakdown'). In both studies we undertook qualitative research with farmers and veterinarians to explore the epidemiological practices of bTB. Following ethical approval, three focus groups were conducted with government and private veterinarians in which a total of 22 veterinarians participated. An additional 15 veterinarians attended a workshop during which the process and practices of bTB epidemiological investigations were further explored (see supporting information for full

details). In-depth interviews with seven government veterinarians and seven private veterinarians were also conducted.

3.2 Field Epidemiology

Until the mid 1980s, the responsibility for epidemiological investigations of bTB breakdowns lay with local offices of the State Veterinary Service (SVS) which developed its own approaches and tools. Following the discovery of a case of bTB, a government veterinarian would visit the farm during which time they would record details of the bTB breakdown in their own bTB notebook. These details would often refer to the location of badger setts, and various cattle management practices. As well as collecting information on the breakdown, these notebooks provided a method of in-house documentation for bTB. Information within them was shared between veterinarians working together, but not used or communicated to other veterinarians outside the local veterinary office. Rather than being used to communicate local disease levels to central government, bespoke books were used by local veterinarians, who visited farms with a regularity and consistency that allowed them to acquire a detailed knowledge of particular farms and areas related to their pre-given location, to manage the bTB incident 'on-farm', perhaps over a number of years. In this sense they were '*predominantly memory aids*' (government veterinarian, interview) for local government veterinarians who were responsible for the controlling the spread of bTB within the local area.

In 1986, a review of bTB policy (Dunnet, 1986) led to significant changes to the management of bTB incidents. The new approach involved culling badgers on farms where a bTB incident had been confirmed *and* where an investigation had implicated badgers as the likely cause of infection. This required standardised epidemiological reporting systems. Informal bookkeeping began to be replaced with a more formal 'disease report form' called the TB49. The TB49 was the first national attempt to identify the cause

of infection of a herd after a bTB breakdown. To complete the TB49, a government veterinarian would spend two to three hours with a farmer walking their farm boundaries and discussing possible disease origins and biosecurity challenges. The TB49 combined a tick box approach with a detailed open-ended section to allow veterinarians to record their own subjective deliberations. In this way, the TB49 continued the trend started in bespoke books, allowing veterinarians to 'paint a picture' of the farm and disease incidents.

The qualitative nature of the TB49 undermined somewhat its pretensions of standardised epidemiological data at a national scale. Nevertheless, it continued to provide government veterinarians with a means to understand and assemble farm-specific knowledge for use in their local area.

3.3 Experimental Epidemiology

With no sign of a reduction in bTB, the 1990's saw a distinct new era of bTB epidemiology relying on an experimental scientific approach. In 1997 a review of bTB policy (Krebs et al., 1997) called for a scientific examination of the effectiveness of badger culling. Whilst the resulting Randomised Badger Culling Trial (RBCT) grabbed the headlines, this science-led approach also changed the tools, geographies and subjectivities of bTB epidemiology.

From the outset, the Krebs report had been dismissive of the kind of epidemiology veterinarians had been conducting, arguing that government veterinarians were attributing up to 90% of bTB breakdowns to badgers but '*attribution of cause is rather subjective, and not always adequately supported by the evidence. It is therefore difficult to draw firm conclusions from* [the TB49]' (Krebs et al., 1997). The Independent Scientific Group (ISG), established to conduct the RBCT, was also critical of veterinarians' epidemiology. Reviewing the data collected by the TB49, the ISG were scathing, suggesting that its epidemiological value was limited:

> '*The purpose of [the TB49] was to document and manage the incident; it was never designed or intended to be used for epidemiological*

> *investigations…Meeting these needs required a broad but sound scientific base, which up to now has been lacking'* (Independent Scientific Group (ISG). 2007)

Instead, the ISG called for 'more transparent [and] more detailed' data collection to allow for 'statistical analysis of the relative contribution of different risk factors to the risk of herd breakdown[s]' (ibid.). The need to provide a '*sound scientific base'* led to a revamping of the TB49 into a new epidemiological questionnaire called the TB99. The TB99's aim was to capture vast amounts of standardised epidemiological data on a scale never previously attempted. It was, as one veterinarian suggested, a 'game changer'.

Like the TB49, the TB99 was designed to be used by government veterinarians in interviews with farmers following a confirmed case of bTB. The form collected detailed information on the herd and the farm, including age and breeds of cattle, management practices, animal movements, the presence of wildlife, and biosecurity activities. Yet unlike the TB49's qualitative bias, the TB99 emphasised the need for standardised and combinable quantitative data. To assist with these aims, the TB99 was accompanied by detailed definitions and instructions for each question. In doing so, the TB99 became a scientific technology of government to ground bTB control in a rationale of science-based government, mirroring the design and rationale of the RBCT. At the same time, the TB99 created a new epidemiological spatiality, directed from the centre, replacing all local approaches. The TB99 therefore helped establish the ISG as a 'centre of calculation', in which only the ISG could claim to be in the know about the epidemiology of bTB. In that sense, the TB99 was a direct attack on the status of veterinarians conducting farm-level epidemiology and the SVS itself. Given the ISG's concerns about the standard of veterinary epidemiology and training, this was of no surprise. Moreover, when it became apparent that completing the TB99 was highly labour intensive, with each form taking up to 5 hours to complete, the ISG turned to agricultural

consultants to complete them, further eroding the epidemiological credentials of veterinarians in local SVS offices.

3.4 Managerial Epidemiology

Epidemiological practices have also shifted in association with broader changes to the governance and management of animal health. Traditionally, bTB was managed by veterinarians working within the SVS, their position within government symbolising both the value of their expertise and professional status. Change occurred in 2002 when firstly the SVS became a delivery agency rather than a body of expertise responsible for policy. By 2007, the word veterinary was lost altogether with the transformation of the SVS into a new agency called Animal Health (AH, known as APHA from 2014). The result was a new agenda focussed on notions of business quality, efficiency and performance. For bTB epidemiology this meant two things. Firstly, the TB99 was revamped and became known as the Disease Report Form (DRF). The DRF was a shortened version of the TB99 collecting only the most important epidemiological data. However, its use was tied to other business objectives: delivering and enforcing standards effectively was part of the DRF's remit and targets were set for the execution and uploading of DRFs onto a national database. DRF completion rates for local AH offices were monitored, with those not meeting the required target subjected to further scrutiny.

To bolster the efficiency of disease reporting and epidemiological analysis, the DRF was to be uploaded electronically as part of a process of modernisation within AH. The DRF was designed specifically to allow electronic capture of farm-level data, and all DRFs were uploaded to AH's new 'SAM' database. On returning from a farm visit, government veterinarians were expected to upload data manually from the DRF into SAM to 'streamline' data capturing procedures, and to feed in to real time analysis of bTB incidents.

The nature of the DRF reflects the broader restructuring of the role and status of veterinary expertise. As with the TB99, the DRFs tick box approach shifted the centre of epidemiological calculation to managers within AH. Good epidemiological conduct was therefore the ability to complete and upload disease information as quickly as possible. Similarly, epidemiological subjectivities became defined by a commitment to administrative efficiency meaning government veterinarians spent less time in the field and more time at a computer entering data – a task that could have been done by administrative staff.

Like other areas of animal disease management, managerial epidemiology has begun to outsource disease reporting to the private veterinary sector. Partly this reflects the search for business efficiency and cost-cutting, and partly the downgrading of the veterinary profession within government (Enticott et al., 2011). It may also reflect the recognition that the trusting relationship between private veterinarians and their farming clients can positively facilitate epidemiological investigation. Although in its infancy, this shift has resulted in a number of small-scale pilot initiatives designed to involve private veterinarians in the diagnosis and analysis of bTB breakdowns. One example is 'Cymorth TB', a scheme organised by the Welsh Government which recognises that farmers need help and support in the aftermath of a bTB breakdown, and that a farmer's own veterinarian rather than 'the man from the ministry' is the best person to deliver it. Taking advantage of this trusting relationship, veterinarians conduct epidemiological investigations in partnership with farmers, mapping risk factors and discussing solutions that are workable rather than generic.

4. Arranging a Caring/Careful Epidemiology

Whilst epidemiology may appear to shift through different arrangements, these new subjectivities and spatialities are challenged by veterinarians working on farms to manage bTB, finding gaps in the apparent universality of managerial and experimental epidemiology. The subsequent practices they develop make epidemiology workable, through subtle disruptions by

veterinarians dealing with bTB outbreaks allowing different arrangements to co-exist. In doing so, these activities contribute to an alternative mode of ordering that stresses the centrality of 'epidemiological care'. Specifically, in bTB epidemiology, care practices have a local geography and a slow temporality. Significantly, their subjectivity emphasises the importance of the social skills of the veterinary profession, such as empathy, listening and coaching, highlighting what Lavau and Bingham (2017) refer to as an ecology of attention. In what follows, we explore how these transitions are guided by a caring/careful epidemiology in relation to veterinarians' attempts to make two epidemiological materials workable in use – records and maps.

4.1 Re-recording

During the 1980s, government officials perceived bTB to be a problem confined to south-west England. That bTB was significant locally but not nationally allowed or required local SVS veterinarians to develop epidemiological practices organically. This organic experience was palpable with the bespoke books in the pre-1986 era. The books marked a locally collective effort to try to get to grips with disease. The recording of epidemiological information, and its sharing between fellow veterinarians in the same local offices created both the epidemiological practices required to manage disease, and a sense of ownership and expertise amongst veterinarians as epidemiological experts. This sense of identity and ownership in these organic epidemiological practices is overtly captured in the way veterinarians referred to their bespoke books and the sense in which they contained valuable local knowledge:

> *'We had our **own** little books which we would write details in for our **own** use in the offices' (*DE38, government veterinarian, interview*)*

> '*In terms of recording [TB] tests they were all done manually, using paper, reading tags, recording... we used bespoke TB testing books to*

note down what we thought necessary then after a reactor' (DE40, government veterinarian, interview)

The introduction of new standardised epidemiological record keeping presented a challenge to these organic and locally owned practices. For example, the TB99 effectively redefined the nature of disease control expertise: skills and practices developed by government veterinarians in their local office were deemed 'inadequate' and 'subjective' and required replacing by formalised scientific practice. Consequently the time consuming and impersonal TB99 radically altered the everyday practices and procedures in local veterinary offices:

'[TB99 forms] were incredibly more complicated... they were tricky and horrible… the thing was they were collecting information ***for the ISG*** *who were then trying to get all these facts and figures out of it,* ***it wasn't for us****'* (DE39, government veterinarian, interview)

The accompanying centralisation of data collection and analysis contributed to a lack of ownership of the TB99 by field veterinarians. The construction of the form by an anonymous distant committee became a key critique, as well as an important point of distinction between veterinarians' understandings of epidemiology and the ISG's. For many government veterinarians the lengthy process of completing the TB99 became overwhelming. As one government veterinarian suggested, it was a form designed by committee to please everyone but impractical in use, requiring alternative ways of completing the forms to be developed. Ironically, the solution was found in the organic localised practices that the TB99 had tried to replace. These residues of practice reveal the extent to which epidemiology requires crafting in-situ rather than scripting through record keeping. For example, one local SVS office overburdened with the workload developed its own disease report form consisting of three or four pages of what they thought would be the most important information to record. Instead of taking the TB99 to the farm they would take 'bespoke booklets':

> *'We started, actually we invented in this office our own little thing, because we found that these things (TB99) were such a pain, we wanted a quick way of dealing with, it was short and sweet and they were a few aide-memoires down the side, and we could do a time bar if we wanted to. We used these locally to help know what was going on and to help manage the breakdown but they never went any further from our office, because they weren't official'* (DE38, government veterinarian, interview)

The introduction of a calculable form of epidemiology marked a boundary in the epidemiological practices of government veterinarians more used to creating a narrative of a bTB breakdown. Veterinarians argued that these qualitative data were more useful, providing a means to understand and assemble farm-specific knowledge for use at their local level. For example one veterinarian said:

> '*I know the manuscript report is difficult to analyse on a database, but immediately you read it, you know what the farm is like, you know what sort of system they are running, so I think most of the vets actually liked the manuscript report'* (DE38, government veterinarian, interview)

Similarly, the reliance on combinability within this bureaucratic mode of ordering was disrupted by veterinarians' practices of completing forms like the DRF. Rather than the tick boxes, it was the qualitative comments boxes in the DRF that became the most valuable element of these forms to veterinarians who relied on this information to manage a bTB breakdown:

> *'The [DRF] has changed in terms of we haven't got the same complexity about specific management practices but there is an open text box, so the experienced vets tend to stick to that'* (DE39, government veterinarian, interview)

This form of careful epidemiology contrasts with the need for combinable and immutable 'facts' of disease outbreaks. On one level, it is defensive in

that it seeks to protect existing epidemiological subjectivities and the validity of its practices. However, in paying attention to the detail and complexity of disease, it also prompts careful reconsideration of how best to conduct epidemiology.

4.2 Re-Mapping

Mapping the bTB breakdown has been an essential part of understanding why it has occurred, involving walking field boundaries in order to locate biosecurity hazards. As part of the TB49, an area-specific map detailing the specific farm as well as contiguous holdings was generated 'in-house' by local SVS offices, allowing veterinarians to produce and use *bespoke maps* particular to the farm they were visiting. However, a gradual diminution of mapping practices reflects the deskilling of veterinary epidemiological subjectivities inscribed within the DRF. For example, a reduction in the time spent being able to map risk factors when visiting farms as part of the DRF visit has meant that the significance of maps has been eroded such that the standard of the maps that are used are simply 'not as advanced' as those in the past. In addition, the need to conduct DRF visits as quickly as possible to meet delivery targets meant that aspects such as the farm walk to establish risk factors and biosecurity solutions were reduced. For government veterinarians, this contributed to an erosion of the status of veterinary subjectivities and spatialities by shifting veterinary work from field epidemiology to office administration, symbolised by APHA's decision to conduct some DRFs by telephone.

Secondly, the bureaucratic logic of epidemiology resulted in a new geography of mapping skills, centralising the process of mapping bTB and removing these skills from government field veterinarians. When veterinarians make DRF visits, a farm map (and contiguous farms) are included in the DRF 'pack'. Yet, unlike the maps provided used for the TB49, these maps are generated at a regional level. The effect of this shift in the geography of map

production was that maps could no longer be made farm-specific by government veterinarians working on each outbreak. This new approach therefore did not allow for the integration of local veterinary knowledge within the bTB 'mapping' process during a DRF visit. Veterinarians pointed out that these maps would not always include additional land rented by the farmer occasionally, and for which s/he is not claiming the Single Farm Payment on which these maps were based.

Similarly, technical limitations mean that older maps larger than A4 cannot be incorporated into the new SAM database. Instead, maps are printed off on relatively small scale to fit onto sheets of A4 or A3. Perhaps more urgently for private veterinarians taking part in the Cymorth TB project, the maps given to them contained no information on the surrounding disease situation making them epidemiologically redundant. Disease status cannot be communicated to farmers because of data protection issues. Indeed, APHA veterinarians pointed out that the maps for DRF visits must stay in their office and not be shown to farmers in case they reveal neighbouring farmers' bTB status. This was a bone of contention for private veterinarians working with the Cymorth TB project, with one veterinarian commenting:

> *'The map would only be useful if it told you what was going on around. I mean you can get your farmers' own maps and walk the fields, that's not the issue, you don't need a map to do that but you need to have information about what is going on locally – so you can say well you've got Joe Bloggs there and he had a breakdown last year or whatever so you need to be careful how you farm that part of your farm'* (DE23, private veterinarian, TB Cymorth workshop)

The declining status and usefulness of official disease maps and mapping have nevertheless been accompanied by an emergence of counter-mapping in which epidemiological maps are iteratively remade. Just as veterinarians remade their own qualitative bespoke records against the quantitative backdrop of the TB99 and DRF, ways of sustaining the role of maps and

mapping were found. In doing so, veterinarians maintained their status as epidemiologists capable of managing disease, rather than blindly completing paperwork and processes developed for them. To negotiate the bureaucratic logics that forbid veterinarians from disclosing neighbouring farmers' bTB status or other confidential information such as landownership and land-use, veterinarians and farmers developed new terms of engagement. For example, successful disease mapping can require a subtle new language: informing farmers of nearby disease can be achieved by speaking in code, or learning rules of conversation. For example, whilst veterinarians might know of the surrounding disease picture and offer advice accordingly, they can't begin conversations by referring to surrounding cases but must wait until farmers show they know as well. Learning how to navigate these entangled conversations is an essential skill in disease mapping, but veterinarians also learn how to situate the use of maps in different contexts. For example, the inadequacies of the maps issued to veterinarians has led to the creation of completely new maps or the adaptation of farmers' own farm maps.

> *'The map was very small in scale and not easy to follow. The farmer got his IACS[2] map out and we used his instead… we walked a couple of fields where he felt there was a problem, it was very useful because we mapped out the problem'* (DE25, private veterinarian, TB Cymorth workshop)

Skirting around official mapping rules and the development of active mapping may also occur between veterinarians. For example, one private veterinarian described how, upon meeting an APHA veterinarian (who had long worked in the same region, but whom had only recently met), somewhat subversively the first thing they did was pull out their own maps and discuss the bTB disease situation in detail using each others' maps, something that

[2] IACS stands for 'Integrated Administration and Control System' and is the basis by which farm payments are managed and made in European Union member states. IACS maps establish the area and boundaries of the farm for these purposes.

bureaucratic logics would normally forbid. On farms too, veterinarians may develop their own practices and dispense with formalized mapping practices. For example:

> *'I actually gave up on the maps and sort of did it another way which was just walking the fields so you can see the fences and you say "oh who farms there, what goes there?"'* (DE27, private veterinarian, TB Cymorth workshop)

In this alternative practice, it could be argued that physical maps are not essential to mapping epidemiology, but instead a knowledge of the location of disease on and surrounding the farm being visited means that mapping can still be performed without the constrictions of the material technology assigned to bTB reporting as a managerial process. In each of the cases highlighted above, the everyday use of maps leads to alternative disease maps and mappings, that draw on veterinarians' own assessment of local disease incidence and knowledge of local farming practices. As a result, disease mapping becomes a relational achievement where veterinarians and farmers, and veterinarians and veterinarians, attempt to navigate around bureaucratic logics. These forms of counter-mapping therefore make epidemiology in some way 'workable', allowing veterinarians to make sense of disease and communicate its risks to farmers.

Mapping the epidemiology of bTB, therefore shows how practices of care evolve from the 'art of paying attention' (Lavau and Bingham, 2017) involving forensic and emotive practices. In this way, if care is integral to experimental or managerial epidemiology, it shares its materialities in form only and little of its spatiality or subjectivity. In the field, veterinarians adjust their use of maps and mapping to fit disease and social contexts. Given concerns over the loss of detailed practice and the social impacts of disease, bureaucratic processes are transformed into a more 'caring epidemiology':

> *'You have to show some degree of empathy – for some people [bTB] is actually the end of the world – for one of my farmers, we just had a*

chat for about an hour – I'm not sure if it fulfilled [the purpose of the DRF] but, you know, I think he felt a lot better' (DE30, government veterinarian, TB Cymorth workshop)

A 'caring epidemiology' is also 'careful', reflecting an 'economy of attention' (Lavau and Bingham, 2017). To understand bTB fully, veterinarians must cover all the angles, all the possibilities, illustrating them rather than quickly reducing them to binaries. Thus, the high-quality and intimate role played by veterinarians conducting a TB49 visit was described by one veterinarian as a 'Rolls Royce service' to demonstrate the attention to detail, quality of time and local knowledge which they felt was necessary to manage the disease. Senior veterinarians regularly reinforced this in meetings in which a careful and detailed, if not slow, approach to epidemiology was impressed upon their junior colleagues when conducing disease reports:

'*The Regional officer at that time would pore over the report forms, and he'd have a very nice red pen, and he would write "but you haven't clarified why you have come to this decision" and "have you missed this specific angle here?"'* (DE40, government veterinarian, interview)

This attention to detail, and its significance for veterinary subjectivities however, is under threat from reforms to disease governance, and demonstrated in the materialities of epidemiological record keeping.

Field veterinarians' attention to epidemiological practices also reveals how sensitivity towards farmers is a key element of epidemiological care. The lack of care and attention paid to farmers in managerial epidemiology was remarked upon by both private and government veterinarians. However, the close social ties between veterinarians and farmers means that although there are standardised forms to complete, the visits can take different paths with many taking a more discursive rather than formulaic approach. Whilst this may reflect the way veterinarians sensitively situate each visit in context, it also reflects the different social dynamics at play. In conducting

epidemiological visits, veterinarians are careful to engage with farmers as much on an emotional level as on a disease control level, so that managing the biological becomes inseparable from managing the social. As one veterinarian remarked, epidemiology 'has to be flexible to fit the farmer' if they are to respond positively and implement biosecurity measures to prevent further infection. Thus, as Lavau and Bingham (2017) suggest, paying attention to these social contexts has consequences for the ways in which epidemiological practices can fulfil an educative role and leave a legacy of care beyond an epidemiological disease investigation.

5. Conclusion

One consequence of successive outbreaks of infectious animal diseases in the UK and the struggles governments have faced to control them, has been the elevation of epidemiology as a critical governmental rationality. In the UK, resources have been invested into developing new epidemiological centres to provide epidemiological training to veterinarians. As a geographical tool, epidemiology is relied upon to control disease by plotting the relations between different phenomena across space, and predicting the success of disease control actions in different places. However, as Krieger (1994) suggests, epidemiology embodies particular ways of seeing and knowing the world. The aim of this paper has been to highlight the implications of these ways of seeing by exploring how epidemiology enacts animal disease.

This paper suggests that epidemiology can be understood through a dynamic arrangement of specific subjectivities, materialities and spatialities. The 'epidemiological web' that these arrangements create allows disease to be enacted, understood and located. What this paper shows, however, is that epidemiology evolves through different arrangements that invoke different combinations of subjectivities, spatialities and materialities. The three forms of epidemiology identified in this paper – field, experimental and managerial – therefore all enact bTB in different ways. Thus, changes to

materialities between these forms of epidemiology have re-ordered the spatiality of epidemiological expertise as well as introducing new epidemiological subjectivities. The increasing prominence of forms and records has shifted epidemiology from one whose spatial register was locally situated to one that spans terrain from a centre of calculation, to command from a distance. As a result, the skills and subjectivities of epidemiologists are also re-spatialised. Forms and records locate authority at the centre: the status of field veterinarians as epidemiologists is reduced to record takers rather than record makers.

The three epidemiological arrangements documented in this paper may be followed by further iterations. The TB Cymorth project in Wales and latterly the establishment of the TB Advisory Service in England suggest the beginnings of a shift from managerial to a privatized epidemiological order. However, the intention of this paper is not simply to suggest that versions of epidemiology are drastically curtailed and replaced. Rather, as with other forms of governmentality, the way some versions of epidemiology enact disease can be actively resisted or disrupted. In doing so new combinations of epidemiology are created alongside each other. For bTB, the materialities of record keeping and mapping are re-imagined and re-purposed by veterinarians seeking to 'do epidemiology', whilst their care for both their clients and their profession leads to further adaptions and accommodations between different practices.

These transformations are further evidence of epidemiology as a 'borderland' practice (Enticott, 2017, Hinchliffe et al., 2013) in which tools and practices are reshaped to accommodate the specifics of the situation at hand. In tracing the emergence of these borderland practices, we argue that for epidemiology to be workable, greater emphasis needs to be placed on recognising rather than effacing these practices. In doing so, disease management can facilitate caring and careful approaches to epidemiology. Rather than rely on the randomness of disruption, a more caring/careful

epidemiology recognizes the value of the social practices of epidemiology, local relationships between farmers and veterinarians, and bonds of trust rather than generic material processes. In combining both the biological and the social dimensions of disease control, we argue that a caring/careful epidemiology can capitalize on these benefits. Rather than leaving these caring/careful approaches to reside in the margins of epidemiology, it is important, as Lavau and Bingham (2017) argue, to make these practices 'matter'. In this sense, making caring/careful epidemiology matter should be integral to the management of animal disease. Unpacking epidemiological orders must therefore serve to highlight the politics of disease control, and their potential consequences. Changes to the nature and geography of veterinary expertise have the potential to undermine the provision of veterinary services in rural areas and compromise the ability of veterinarians to manage existing diseases, or successfully identify and track new diseases. In this way, understanding the different configurations of epidemiology has practical implications, helping us to remain alert to the implications of the evolving geography of animal disease control and highlighting the value of alternative epidemiological practices.

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Supporting Information

Table 1: Participant characteristics

Unique ID	**Project**	**Vet type (government or private)**	**Interview or focus group**	**Location**
DE1	Defra	Government	Focus Group	Gloucestershire
DE2	Defra	Government	Focus Group	Gloucestershire
DE3	Defra	Government	Focus Group	Gloucestershire
DE4	Defra	Government	Focus Group	Gloucestershire
DE5	Defra	Government	Focus Group	Gloucestershire
DE6	Defra	Government	Focus Group	Gloucestershire
DE7	Defra	Government	Focus Group	Gloucestershire
DE8	Defra	Private	Focus Group	Cheshire / N Wales
DE9	Defra	Private	Focus Group	Cheshire / N Wales
DE10	Defra	Private	Focus Group	Cheshire / N Wales
DE11	Defra	Private	Focus Group	Cheshire / N Wales
DE12	Defra	Private	Focus Group	Cheshire / N Wales
DE13	Defra	Private	Focus Group	Cheshire / N Wales
DE14	Defra	Private	Focus Group	Cheshire / N Wales
DE15	Defra	Private	Focus Group	Cheshire / N Wales
DE16	Defra	Private	Focus Group	Cheshire / N Wales
DE17	Defra	Private	Focus Group	Leicestershire
DE18	Defra	Private	Focus Group	Leicestershire
DE19	Defra	Private	Focus Group	Leicestershire
DE20	Defra	Private	Focus Group	Leicestershire
DE21	Defra	Private	Focus Group	Leicestershire
DE22	Defra	Private	Focus Group	Leicestershire
DE23	Cymorth	Private	Workshop	Wales
DE24	Cymorth	Private	Workshop	Wales
DE25	Cymorth	Private	Workshop	Wales
DE26	Cymorth	Private	Workshop	Wales
DE27	Cymorth	Private	Workshop	Wales
DE28	Cymorth	Private	Workshop	Wales
DE29	Cymorth	Private	Workshop	Wales
DE30	Cymorth	Government	Workshop	Wales
DE31	Cymorth	Government	Workshop	Wales
DE32	Cymorth	Private	Workshop	Wales
DE33	Cymorth	Private	Workshop	Wales
DE34	Cymorth	Private	Workshop	Wales
DE35	Cymorth	Private	Workshop	Wales
DE36	Cymorth	Private	Workshop	Wales
DE37	Cymorth	Private	Workshop	Wales
DE38	Defra	Government	Interview	South-west
DE39	Defra	Government	Interview	South-west
DE40	Defra	Government	Interview	Wales
DE41	Cymorth	Government	Interview	Wales
DE42	Cymorth	Government	Interview	Wales
DE43	Cymorth	Government	Interview	Wales

DE44	Cymorth	Government	Interview	Wales
DE45	Cymorth	Private	Interview	Wales
DE46	Cymorth	Private	Interview	Wales
DE47	Cymorth	Private	Interview	Wales
DE48	Cymorth	Private	Interview	Wales
DE49	Cymorth	Private	Interview	Wales
DE50	Cymorth	Private	Interview	Wales
DE51	Cymorth	Private	Interview	Wales