



Antibiotic stewardship and its implications for agricultural animal-human relationships: Insights from an intensive dairy farm in England

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ABSTRACT

The concept of antibiotic stewardship has recently gained prominence in UK and EU policy and practice as part of wider efforts to reduce antibiotic use in agriculture and respond to concerns about antimicrobial resistance. The purpose of the paper is to provide initial insights into what antibiotic stewardship might mean in practice for agricultural animal-human relationships, particularly within intensive systems. We do this by firstly outlining the anticipated implications for agricultural animals by different stakeholders. Secondly, we develop the concept of heterogeneous biosocial collectivities through engagement with the literatures on care and thirdly we apply this concept to one case study (intensive dairy) farm to explore empirically how animal-human relationships are changing in response to antibiotic stewardship. Three on-farm heterogeneous biosocial collectivities are identified, each of which coheres around a particular problem of life associated with distinctive practices of care and antibiotic use resulting in collectivity-specific responses to antibiotic stewardship. These collectivities are: the calf collectivity and the problem of immunodeficient life; the milking cow collectivity and the problem of 'stoic' life; the dry cow collectivity and the problem of fatigued life. In conclusion we point to: the uneven effects for animal-human relationships of changes in antibiotic use including in particular practices of care and their consequences; an intensification of human control over animals with variable implications for their health and welfare. The analysis raises questions for future research, in particular the need to test the assumption that reducing antibiotic use will stimulate systemic change in intensive animal agriculture towards sustainable, high-welfare, and more extensive systems of production.

1. Introduction

The concept of antibiotic stewardship has recently gained prominence in UK policy and practice (Hm Government, 2019) and elsewhere in the EU, including Denmark (Ministry of Environment Food of Denmark and Ministry of Health, 2017), France (Ministere de l'Agriculture et de l'Alimentation, 2017) and Ireland (Department Of Health and Department Of Agriculture Food And The Marine, 2017) as part of efforts to curtail the use of farm antibiotics. Such policy responses are primarily concerned with reducing the risks to human health from antibiotic-resistant infections. However, they increasingly encompass proposals to intervene in animal agriculture in order to secure positive outcomes for animals (Walker et al., 2011, Department Of Health and

Department Of Environment Food and Rural Affairs, 2013, World Health Organisation, 2015, O'Neill, 2016, Hm Government, 2019). Although still evolving, antibiotic stewardship describes a multifaceted approach to maintain the efficacy of antibiotics through reducing and optimising drug use through disease prevention, biosecurity, good animal husbandry and herd health planning (Veterinary Medicines Directorate, 2018; European Commission, 2017; World Organisation For Animal Health, 2016). To deliver this the UK government, following the recommendations of the influential O'Neill Review on antimicrobial resistance (AMR) (2016), has called for industry led action to set targets to reduce antibiotic use and specifically to end the use of so-called Highest Priority Critically Important Antibiotics (HPCIs)¹ (Responsible Use Of Medicines In Agriculture Alliance, 2017). In response to

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¹ These are antimicrobial classes which are critical to human medicine and are used to treat serious bacterial infections. They include; quinolones, 3rd and higher generation cephalosporins, macrolides and ketolides, glycopeptides, and polymyxins.

sector specific reduction targets, total antibiotic sales across all agricultural animals have fallen 49% between 2014 and 2018 (Veterinary Medicines Directorate, 2019).

These targets have been delivered through a neoliberal mode of animal agricultural governance (Enticott et al., 2012; Maye et al., 2014) in which the state has fostered industry led regulation of antibiotic use. The Alliance for the Responsible Use of Medicines in Agriculture (RUMA) and the Food Industry Initiative on Antimicrobials (FIIA) are national level organisations, composed of retailers, farming organisations, food processors, government regulators, agricultural, food and environmental NGOs. These organisations have established collective principles, targets and responsible use standards. Such agreements have been operationalised through farm assurance schemes such as Red Tractor and company (retailer and food processor) specific assurance standards. Of specific relevance for the dairy industry are price privileged buyer groups such as Tesco's Sustainable Dairy Group, Sainsbury's Dairy Development Group, Arla Foods UK-Waitrose Farming Partnership, M&S Select Farm Sourcing Standards.² These standards, which cover a broad array of practices beyond antibiotic use, stipulate both recommendations and obligations for farmers to follow in practice. While the Red Tractor scheme requires farmers to review and monitor their antibiotic use with their vet, retailer dairy groups have more stringent guidelines which mandate specific antibiotic use practices. This includes an end to the use of HPClAs, except in extreme instances of animal need, an end to the routine prophylactic use of antibiotics, and across the board reductions in use to meet national targets set by RUMA. Embedded through contractual obligations and adoption of new administrative systems, they exert considerable influence over on-farm antibiotic use practices. Alongside standards set by the British Poultry Council and National Pig Association, retailer standards are a key driver behind many of the changes in antibiotic use in UK agriculture (Alliance to Save Our Antibiotics, 2020).

Although principally concerned with the antibiotics themselves, how they are used and monitoring such use, it is expected that these standards and targets will “catalyse sustainable and meaningful change not only in antibiotic use but also [for] animal health and welfare” (Hm Government, 2019, p. 19). The impacts of this anticipated ‘meaningful change’ on how agricultural animals are managed in practice has not been the subject of research attention by rural studies scholars even though antibiotic use in animal agriculture has begun to command more interest within this domain. Studies have examined: the framing of antibiotic use in UK national print news (Morris et al., 2016); different national level approaches to regulating antibiotic use (Begemann et al., 2018); farmer decision making around the use of antibiotics (Jones et al., 2015; Schewe and Brock, 2018; Buller et al., 2015) and other antimicrobials such as anthelmintics (Bellet, 2018); the economic and biological drivers of disease and antibiotic use (Hinchliffe et al., 2018); and the history of antibiotic use in animal agriculture (Woods, 2014, 2019). Whether taking a macro-level perspective on antibiotic regulations or micro-level perspective on specific practices of antibiotic use, animal-human relationships are a largely peripheral feature of the emerging empirical story of changing antibiotic use policy and practice. This paper is a response to this relative neglect.

Specifically, the purpose of the paper is to provide initial insights into what antibiotic stewardship means in practice for agricultural animal-human relationships, particularly within intensive systems. We do this by firstly outlining the anticipated implications for agricultural animals by different stakeholders, secondly, we develop a conceptual approach through which changing animal-human relationships, in response to

antibiotic stewardship, can be empirically explored by social scientists and thirdly we apply this concept through a case study of an intensive dairy farm. In terms of concept development, we extend the concept of heterogeneous biosocial collectivities (Morris and Holloway, 2014) through its rescaling, which enables the identification of multiple farm level collectivities, and also by integrating social science research that posits that the logic of care for animals is both central to many animal-human relationships but simultaneously riven with tensions and sometimes deeply implicated in relations of violence (Giraud and Hollin, 2016; Srinivasan, 2013, 2014; Singleton, 2010; Law, 2010). In illustrating how this conceptualisation can be employed empirically, we draw on qualitative research conducted on an intensive dairy farm in England that is responding to new expectations for reducing antibiotic use. In this initial application we identify three on-farm heterogeneous biosocial collectivities, each of which coheres around a particular problem of life requiring distinct uses of antibiotics and responses to antibiotic stewardship: the calf collectivity and the problem of immunodeficient life; the milking cow collectivity and the problem of ‘stoic’ life; the dry cow collectivity and the problem of fatigued life. We conclude by reflecting on the implications of antibiotic stewardship for animal-human relationships in agriculture. Finally, we raise questions for further research from our initial investigations, suggesting that work is needed that interrogates the assumption that reducing antibiotic use to address AMR will stimulate systemic change in intensive animal agriculture.

2. Antibiotic stewardship: competing expectations for animal health and welfare

There are three ways in which antibiotics are used in agriculture: firstly, therapeutic use to treat bacterial infections in sick animals; secondly, prophylactic use where there is risk of infection; and finally, in small quantities in feed and water to promote animal growth (Salyers, 2005). In EU countries where a ban on the use of antibiotics as growth-promoters has been in place since the early 2000s, the implications of reducing antibiotic use are more complicated as they impinge on antibiotics used to prevent and treat disease. As a result, there are diverse expectations as to how antibiotic reductions can be realised and what that might mean for livestock systems, animal health and welfare.

The UK's 2019 five year national action plan anticipates that the adoption of antibiotic stewardship best practices will be a catalyst for sustainable and meaningful change to animal health and welfare (Hm Government, 2019). The plan presents an optimistic vision of what this might mean for agricultural animals stating that it creates opportunities to transition to “high health production systems that result in healthier, more productive animals ...” (Hm Government, 2019, p. 39). This resonates with assumptions outlined in the previous five-year AMR strategy (Department Of Health and Department Of Environment Food and Rural Affairs, 2013) and mobilises a long-standing policy association between responsible medicines use, good animal husbandry, disease prevention, biosecurity and high animal health and welfare (see Department for Environment Food & Rural Affairs, 2004).

Some non-governmental organisations and political actors share this assumption that a positive association exists between reduced antibiotic use and an improvement in animal health and welfare, albeit based on a different fundamental premise. Umbrella organisations such as the Alliance to Save Our Antibiotics that represent 63 members spanning consumer, human health, animal welfare and environmental NGOs, situate reducing antibiotic use in farm animals as necessitating not just a change in particular disease management or animal husbandry practices, but a more significant transition towards less intensive and more humane systems of agriculture. Implicit in this vision is the assumption that antibiotics are fundamental to enabling intensive systems of agriculture, which are positioned as reliant on systemic overuse to sustain animal lives within them (Alliance To Save Our Antibiotics, 2016). A Green MEP made these assumptions explicit in responding to the 2018

² Not all retailers and processors have developed specific buyer groups for products such as milk. The groups highlighted above all have broadly comparable responsible antibiotic use standards as outlined further in the text. The buyer groups highlighted here cover around one third of UK dairy farms, e.g. roughly 4000 farms.

announcement of European legislation restricting the use of human-critical antibiotics in animal farming, describing this as a victory for both public health and animal welfare. These changes, she claimed, would “challenge the factory farming model where animal (sic) suffer appalling conditions and are packed together in unhealthy conditions”³ (Neslen, 2018). The Alliance for instance has heralded antibiotic stewardship as part of a broader strategic change that addresses ‘systemic problems’ of an intensive farming model that relies, in their view, on ‘systematic overuse of antibiotics’ (Alliance To Save Our Antibiotics, 2016).

However, in contrast to these high-level visions from policy makers and NGOs the narrative from farmers, veterinarians and industry organisations highlights more troubling tensions between the aim of reducing antibiotic use and maintaining or improving animal health and welfare. Research by Buller et al. (2015) for Defra and Rural Payments Agency, 2012, involving interviews with veterinarians and farmers from across livestock sectors highlighted how significant changes to antibiotic use would likely result in the increased culling of sick animals to control disease and increased losses from disease. In the dairy sector, this was already a reality for an organic farmer. Similar concerns from veterinarians and farmers were highlighted by Morris et al. (2016) in their examination of UK national print news and farming press reporting of antibiotic use in agriculture. However, in this case the anticipated severity of negative impacts on animal health and welfare was linked to an imagined ban on antibiotic use in animal agriculture. The industry led RUMA also notes potential tensions, drawing attention to the need to measure antibiotic progress against other qualitative and quantitative measures so as not to compromise animal health and welfare in the pursuit of antibiotic reductions (Ruma, 2019).

With no consensus about what antibiotic stewardship might mean in practice for animal health and welfare, how these dynamics play out on-farm is an important question that has yet to be the subject of detailed empirical analysis. Our interest is in how, as social scientists, we can develop an appropriate conceptual tool to address this question. It is to this task that we now turn.

3. Approaching animal-human relationships and antibiotic use in agriculture

Over the last two decades a vibrant literature has developed on ‘more-than-human’ (Whatmore, 2006) or ‘post-human’ geography that examines and takes seriously the active contribution of nonhuman animals, materials, and technologies to ordering and re-ordering agricultural relationships. Whether resulting from the adoption of new practices and procedures, such as biosecurity measures (Enticott, 2017; Enticott et al., 2012; Hinchliffe, 2013; Hinchliffe et al., 2017) or animal welfare assessments (Buller and Roe, 2014; Hinchliffe et al., 2017), technologies such as robotic milking machines (Holloway et al., 2014b) or new genetic knowledges shaping animal breeding decisions (Holloway and Morris, 2012; Morris and Holloway, 2014; Holloway and Bear, 2011; Twine, 2010), the consequences of these changes for animal-human relationships, animal bodies and the qualities of animal lives has been a motivating impetus for much of this literature. A key contention is that changing on-farm animal-human relationships, whether due to the use of new technologies, ‘best practices’ or policy initiatives, is a heterogeneous co-constitutive process. Applied to the empirical issue of interest in this paper this ‘more-than-human’ perspective suggests that the specificities of ‘doing’ antibiotic stewardship involve more than just changing and reducing the use of antibiotic

chemicals, but will likely involve a multitude of changes to the different on-farm arrangements including in particular animal-human relationships. As we outlined in section two, there are different perspectives on the specificities of these changes, their extent and significance for animals lives.

Building on the literature just outlined, this paper develops the ‘more-than-human’ concept of heterogeneous biosocial collectivities (henceforth HBC) as a lens through which to explore the ways in which antibiotic use practices are changing animal-human relationships on the farm. Morris and Holloway (Morris and Holloway, 2014; Holloway and Morris, 2012; Holloway et al., 2009) elaborate this concept within the context of genetic knowledges and techniques in livestock farming and breeding, advancing the idea of ‘biosocial collectivities’ within the biopolitical work of Rabinow (1999) and Rabinow and Rose (Rabinow and Rose, 2006). A key contribution of Rabinow and Rose (Rabinow and Rose, 2006) is unshackling the Foucauldian understanding of ‘population’ from its connection to geographically bounded formulations in particular the nation-state (Holloway et al., 2009). In contrast, Rabinow and Rose position populations as emergent and relational, influenced by new forms of truth discourse such as genetic science (Gibbon and Novas, 2008). As humans are the targets for these truth discourses and their associated interventions, and the key constituents of biosocial collectivities, Holloway & Morris follow Haraway’s (Haraway, 1997) understanding of biopower to extend it beyond consideration of human lives and bodies to include non-human animals. By doing so they introduce heterogeneity to ‘biosocial collectivities’. Indeed, such extension is both timely given the increased emphasis on multispecies ecologies (for instance, Helmreich, 2009; Tsing, 2015), as well as conceptually necessary given that non-human animals are essential constituents of, and agents within animal-based agricultural systems.

The concept of HBC draws attention to assemblages of humans, animals, material infrastructures and technologies that cohere around a particular biological issue, or problem of life (Morris and Holloway, 2014). In our case, this is broadly the biological problem(s) of managing animal health and welfare which is central to our interest in antibiotic stewardship and AMR. Importantly, it attempts to pay equal attention to animal bodies and agencies, materials, technologies and humans in processes of change. The scale at which HBCs form is of interest given that at different scales collectivities are defined by different problems of life with different possibilities for change, implicating how they might be re-constituted. It is in relation to scale that we make our first point of differentiation from the original formulation of the HBC concept. Rather than ‘scaling up’ i.e. moving from the farm, to regional and then national scale collectivities (Morris and Holloway, 2014), we propose a ‘re-scaling’ of the HBC concept, to enable exploration of the different collectivities that constitute the farm. In doing so we complicate the presentation of ‘the herd’ as a singular entity which is a tendency in research, and instead argue that attention needs to be directed to the different collectivities within a farm and their formation around different ‘problems of life’. This provides both useful analytical insights as well as arguably being a necessity given that the spatial segregation of different groups of animals, on the basis of age and production status, is an increasing feature of intensive production systems. By examining the different collectivities on the farm, and the uses of antibiotics within each, we argue that antibiotic stewardship is likely to have differentiated consequences for animal-human relationships and animal life and death.

A further way in which we develop the HBC concept concerns its approach to the animals themselves within the context of animal-human relationships. We argue that the original conceptualisation of HBC lacks explicit engagement with notions of care for animals, an absence which is notable given that an emerging literature argues that care is central to what farmers consider ‘good’ farming practices (Harbers, 2010; Singleton, 2010; Higgins et al., 2018; Holloway, 2019; Wilkie, 2005). Broadly speaking the literature on care aligns very closely with the dimensions of the HBC concept, especially in that caring practices are

³ This statement reveals the belief that there is a fundamental problem with the way animals are managed in intensive farming systems including a reliance on the use of antibiotics. According to this perspective a reduction in antibiotic use will, of necessity, require a move away from intensive methods and their attendant dis-benefits for animals.

understood as situated and varied, with the introduction of new processes and practices of care are co-constituted through heterogeneous, context-dependent, and animal specific developments. As such, a consideration of care can be readily incorporated within the application of the HBC framework. The literature on care introduces three important insights with which we wish to engage.

Firstly, it calls for attention to be paid to the ‘object’ of care i.e. the animals themselves and their conditions of life and to the ambivalence/non-innocence of care and its entanglement with practices of control and violence (Giraud and Hollin, 2016). Although distinguished here, these points are intertwined as work on care routinely highlights (Law, 2010; Giraud and Hollin, 2016; Srinivasan, 2013, 2014). The ambivalence and non-innocence of care is brought into stark relief in many agricultural systems, as specific practices of care to reduce disease risks, improve animal health and welfare operate within a wider system of relations where animals are being rapidly reared for slaughter, where production losses are anticipated and accommodated (Hinchliffe et al., 2017) or where animal bodies are quickly exhausted by the processes of production resulting in culling (Wilkie, 2005). Care practices serve as a means of caring for animals stricken with ill-health, as a mechanism of human control over animal bodies and agencies to produce good animal health, while simultaneously enabling their instrumentalisation and economisation (Buller and Roe, 2014; Higgins et al., 2018; Holloway, 2019; Wilkie, 2005).

Secondly, the desire to maximise productivity of an animal can directly undermine its health and welfare, creating new problems to which care practices must respond. Breeding for ‘double muscling’ in Belgian Blue beef cattle for instance can compromise the welfare of the animal and the ease of calving for the mother, increasing the necessity of caesareans (Morris and Holloway, 2014). The historic justification for the use of battery systems for laying hens was that it would improve chicken health by enabling greater control over individual animal bodies and their exposure to potential infection (Buller & Roe 2014). The work of Enticott (2008; Enticott et al., 2012) and Hinchliffe et al. (2017) has highlighted how the ‘will to closure’ emphasised in bio-security discourses demands practices of care and control that potentially exacerbate and produce other health risks in their effort to exclude certain types of disease (TB and bird flu for instance). These examples highlight the tensions surrounding care that exist in animal agriculture, and how care in animal agriculture can be reduced to meeting selected bio-physical needs of animals that are most relevant to the efficient production of animal products and meat at the expense of an animal’s social, psychological or other biological nature (Wilkie, 2005).

Thirdly, care requires farmers to be responsible for and responsive to a variety of heterogeneous entities and involves managing their competing and varied needs (Singleton, 2010). This is emphasised in the work of Bellet (2018), which is particularly relevant to our study. Specifically, her analysis highlights how managing and treating worm infections in cattle results in farmers over-utilising anthelmintic (anti-parasitic) drugs, actions which are implicated in driving anthelmintic resistance in infectious worms leaving animals at risk of untreatable infections. The need to account for varied entities, in this case better care for antimicrobial drugs, points to the potential tensions between care for the drugs and the needs of animal health i.e. care for the animals.

Through mobilising these literatures our approach seeks to examine the ways in which on-farm collectivities are constituted around different problems of life and to elucidate the resulting care practices (and their inherent tensions) in order to understand animal-human relationships in the context of emerging antibiotic stewardship initiatives. We now move on to elaborate the methods employed to produce empirical material that enables us to illustrate our application of the HBC concept.

4. Methods

The empirical material presented in this paper derives from a larger

multidisciplinary study on antimicrobial resistance in agricultural manure and slurry. The project involved sampling animal wastes from a dairy farm in England for microbial and pharmaceutical analysis. The relationship with the farm was established during a pilot project which did not involve social scientists. The social science component of the multidisciplinary project included participant observations with farm staff and veterinarians to explore farm practices surrounding both waste management and animal health diagnosis and treatment. These observations were conducted over a four-month period between September and December 2017 and aimed to generate insights with relevance to the social science and broader project goals.

The dairy farm was selected for the project as it is broadly indicative of sector wide trends including its use of antibiotics. It is a high input, high output farm, at the time housing roughly 200 milking cows and 300 young stock reared as replacements. Cows are housed indoors all year round and the farm employs automated milking robots. Animals are spatially segregated into different buildings or pens within the same building. For young stock this segregation is on the basis of age, i.e. calves, immature heifers and bulling heifers that have begun being inseminated, and for adult cows according to their status within the production system i.e. dry cows,⁴ sick cows and milking cows. This arrangement reflects trends happening across the UK and European dairy sector specifically: the move towards larger herds in the UK (AHDB: AHDB Dairy, 2016)⁵; increased time spent indoors and reduction in outdoor grazing, including the expansion of farms in which cows are housed all year round (European Grassland Federation, 2014); the use of robotic milking machines which continues to grow with roughly one in ten UK farms using the technology (Riley, 2019).

Prior to the beginning of data collection, the farm antibiotic use had been quantified at 9mg/pcu.⁶ This is well below the dairy sector specific target of 21mg/pcu by Defra and Rural Payments Agency, 2012 in conjunction with RUMA and nearly half the mean sector figure of 17mg/PCU as measured by the Veterinary Medicines Directorate (VMD) based on partial sector data (VMD, 2019). The farm no longer used HCA antibiotics reflecting a cross sector trend away from these antibiotic classes (VMD, 2019). Furthermore, between 2016 and 2017 the dairy sector saw a 29% reduction in antibiotic use over the annual antibiotic use surveillance period (VMD, 2018). This rapid change in antibiotic use during the period in which observations took place is likely to mean that associated changes in the practices of animal health management are particularly prominent and visible making them accessible to research. These factors make the farm an ideal site to observe changes resulting from new obligations to reduce antibiotic use in dairy farming, and animal agriculture more broadly.

Participant observation has become an established qualitative research method in rural research in recognition of the need for in-depth approaches that enable detailed and prolonged engagement with a particular context to examine the situated relations and practices that are more difficult to access through interview or survey methods (Hughes et al., 2000). The extended period of engagement with a specific site often required by participant observation limits the capacity for multi-sited studies but instead provides an opportunity to explore animal-human relationships and other on farm arrangements in detail over time. This produces opportunities to illuminate habitual or hidden relations and practices that are difficult to explore through alternative methods. Although limited to a single site, our approach aims to

⁴ Pregnant animals that are within the rest period before giving birth.

⁵ For example, average herd size in England has risen from 77 in 1997 to 150 in 2017 AHDB: AHDB Dairy, 2018a. Average Herd Size. Kenilworth: AHDB: Dairy.

⁶ Population Correction Unit is used to help measure antibiotic use. PCU takes into account the animal population as well as the estimated weight of each particular animal at the time of treatment with antibiotics to produce a cross sector comparable measurement (Ruma, 2017).

generate culturally salient themes and insights based on detailed and prolonged situated engagement.

The participant observations consisted of two weeks of continuous on-farm participant-observations shadowing farm staff through their daily work routines in September. The two weeks was followed by repeated engagement for shorter periods (one to two days or half days) of shadowing undertaken on a weekly basis throughout the rest of the four-month period. (1st author) undertook all the observational research. The farm staff (FS) include the farm manager (FM) and assistant manager (FS3), two herdsmen (FS2 & FS4) and a calf technician (FS1). The assistant manager were responsible for feeding and bedding cattle, interpreting production data, diagnosing disease and overall oversight of antibiotic use. The two herdsmen were principally responsible for the milking cows and their care, including administering antibiotics to them. The calf technician was primarily responsible for the calves and young stock, and also undertook administrative duties on the farm.

Following an initial discussion outlining the main aims of the observational research, the first week of observations were directed by the farm manager who partnered me with certain members of staff. After this first week, once a degree of trust and rapport had built, the researcher was able to plan their own observations. Invariably, an extra pair of hands was welcomed by farm staff in many of the day-to-day situations occurring on the farm which created opportunities to observe the key animal-human interactions of interest to the research. Veterinarians were shadowed throughout the four-month period on Wednesdays when they visited the farm to conduct routine a general herd health check, sick cow visit and the pregnancy diagnosis check. Further to these routine observations, vets were also shadowed during ad hoc visits to the farm in response to specific animal health developments. Four vets (Vet 1, 2 ...) involved in day-to-day animal health diagnosis and treatment assessments and the provision of consultancy advice to the farm were shadowed whilst on the farm. Veterinarians were only shadowed when on the farm and observations did not extend to the veterinary practice or other farms.

Short notes were made over the course of each day at the end of which effort was made to collate these into more detailed documents which also provided space to expand upon daily observations. This generated a large amount of data comprising snippets of conversation, events of significance and other more general observations and reflections. Analysis of these documents was completed with the MAXQDA software package to identify prominent themes and topics relevant to both to our interest in antibiotic stewardship and changing animal-human relationships on the farm. The approach to analysis was both inductive and deductive. The conceptual approach taken in this paper was not considered in advance or during the process of data collection. It therefore did not influence the types of questions or the observational gaze whilst on the farm. The data highlighted the highly segregated nature of the farm into specific animal groupings entangled in different relations through which their health, welfare and productivity is managed. To make sense of this on-farm organisation the HBC concept was adopted, developed and rescaled from its original application as described in the previous section. From this material, three key collectivities within which antibiotic use figured prominently were identified. Once identified the following questions motivated and guided our analysis of each collectivity and were shaped by our re-formulation of the HBC concept including in particular the integration of insights from the literature on care. These questions, we suggest, can also be used in future applications of the concept. First, what is the particular problem of life around which the collectivity coheres? Second what are the specific animal-human relationships of the collectivity including the use of antibiotics? Third, how is antibiotic stewardship changing the collectivity in particular the practices of care, control and violence? The next section elaborates the results of this analysis.

5. Antibiotic stewardship and the heterogenous biosocial collectivities of an intensive dairy farm

Our empirical material is organised around the discussion of three different collectivities on the farm. These are the calf rearing, milking herd and dry cow collectivities. Each of these coheres around a specific biological problem that contributes to producing the collectivity-specific relations. This is not to suggest that these represent the only collectivities on the farm. However, they are the collectivities within which the use of antibiotics is a regular and routine feature, and where the possibilities for changes in animal-human relationships resulting from antibiotic stewardship were most visible in the empirical material.

5.1. The problem of immunodeficient life: Calves and hutchers

The systemic impetus to remove new-born dairy cows from their mothers shortly after birth creates the problem of managing immunodeficient life. By removing calves at such an early stage in their lives from their mothers they are left highly vulnerable to infectious disease, particularly prior to weaning, until they develop a capable immune system. Pneumonia infection is a particularly significant risk and antibiotics are a crucial treatment of the chronic and acute form of the disease. Consequently, calf rearing is recognised as a potential 'hotspot' for antibiotic treatment and a site requiring interventions to reduce use (Ruma, 2017).

Calf separation also draws attention to the broader process of segregating animals into groups as integral to the functioning of modern dairy systems and the management of animal lives and health on dairy farms. This separation enables increased human control over both of the 'products' of pregnancy i.e. the calf and lactating mother's milk. However, reactive antibiotic treatment once calves show signs of infection is not the only means through which calf vulnerabilities area addressed. Some protection is provided through an initial intake of antibodies from the first milk, known as colostrum. With mother-calf relations disrupted by the very nature of the dairy system, farm staff must step in to mediate. Adult cows are therefore moved into the robotic milking machine and the colostrum is syphoned into containers to be subsequently fed to the calf, ideally 3 L, within a 2-h window of birth. Before this step, the displacement of mother cow-calf relations is further mediated by technology. Colostrum is heat treated (before occasionally being frozen for storage) in an effort to improve the rate of antibody absorption by the calf and prevent transfer of potentially harmful bacteria linked to diseases such as Johne's.

Even with this infusion of antibodies calves remain highly susceptible to infections, particularly respiratory infections such as pneumonia. The acute condition can kill young calves whereas chronic infections can cause lung scarring which stunts animal development. The emergence of such infections is not merely the result of host-pathogen interactions rather they are the consequence of multiple complex relations between systemic practices, human management practices, immune-deficient animal bodies, viruses, bacteria, infrastructures, particularly the capacity of these infrastructures to remain dry, warm and free of drafts, and seasonal weather (AHDB: AHDB Dairy, 2018b).

Prior to the data collection period calves were reared in group housing with ventilation issues, pneumonia infection levels were high as was antibiotic use. Compounding this issue were concerns about stockmanship which were held responsible for the poor treatment efficacy as illustrated in the claims made by two vets:

"Not enough care and attention given to the calves by [the] previous stockperson" (Vet 2).

"Nuflur [antibiotic] has previously had poor efficacy due to administration inconsistencies by the stockperson" (Vet 1).

The consequences of this previous arrangement were aggravated levels of calf death and high levels of antibiotic use. Concern about this

situation of high treatment levels and poor outcomes led to a re-configuration of the calf collectivity resulting in a major intervention in the housing of new born calves and a new member of staff taking over responsibilities of calf rearing.

New born calves, instead of moving into group housing immediately, were instead separated into individual hutches for the first four weeks of their life. In this new arrangement the calves are only able to achieve nose to nose contact with adjacent calves. The relations between calves are significantly altered as the hutches limit movement and interaction between animals. Most obviously this reduces the risk of contagion via calf to calf contact, alongside preventing a newly born calf entering a shared pen with already ill animals. Hutches also allow greater environmental control than the group housing. The hutches themselves are able to be washed once a calf moves into the group housing and before arrival of another calf. Their ventilation can be adjusted to regulate airflow, preventing the build-up of damp or development of a draught.

The time in the hutches gives a new born calf a window in which to gain weight and build their own immunity before entering the group housing where ventilation issues persisted. The development of calf immunity was not the sole responsibility of the calf but an emergent property of relations within the collectivity. Specifically, immunity was positioned by FS1 as being built through a strategy of ‘gently’ exposing calves to bacteria during their time in the hutches. This was achieved through relatively subtle actions to produce the desired types of hygiene and dirt, care and harm to foster the right type of exposure, as FS1 explained:

“[I feed the calves twice a day but] I only disinfect the buckets in the morning, so they have a chance to build up some immunity”.

Other interventions involved the use of a non-antimicrobial treatment for diarrhoea (scours) to help keep calves hydrated and replace lost electrolytes but without directly treating a possible infection. Once calves enter the group housing, they receive antibiotics if judged to be suffering from pneumonia. However, following advisory discussions with the vets that pre-dated the observations, this is limited to two courses of treatment. FS1 stated

“... she won’t get any more [antibiotics], she has to find her own immunity now.”

Once these two treatments had been provided calves were left to overcome (or not) any persistent or re-occurring infections without the provision of antibiotic chemicals with only an anti-inflammatory used in more serious cases.

Calf hutches are not just about shaping animal-human relationships to manage the vulnerabilities of young animal bodies due to a lack of immunity and the risks resulting from infrastructure and transmission of disease between calves. They are also a means of limiting the vulnerabilities calves have previously faced due to being placed in the care of an inexperienced or inattentive stockperson *and* being kept in group housing. Whilst rearing calves in groups was deemed by vets to be readily achievable in the existing set up, it was characterised as requiring the attention of a good stockperson. In the past this had not been forthcoming. The cost was invariably animal lives. Hutches were central to mediating animal-human relationships to make up for past and potential future shortcomings in human care. In this role they are central to enabling individual observation of each calf. The risk of an animal being lost in a crowd and thus over looked is diminished. Hutches enable the observation of individual calf responsiveness, whether it is rising easily, drinking its milk and water, and its faeces a normal consistency. All are signs of good calf health.

Hutches therefore play a significant role in mediating the calf centred collectivities. Although effectively negating a calf’s ability to interact with other animals resulting in animal welfare and behavioural concerns, this was deemed to be balanced by the health benefits. They are utilised to overcome vulnerabilities produced through the interaction of

juvenile cows, humans and material infrastructures of the farm and how this produces particular risks of pneumonia in immunodeficient animals. The consequence of reconfiguring calf collectivities through the use of hutches has been an improvement in calf health and reductions in the level of antibiotic use for pneumonia and the number of calves that are culled due to chronic infections stunting growth.

The reconfiguration in the calf collectivity reveals how interventions in animal-human relations to prevent infectious disease and reduce antibiotic use results in the intensification of human control over animal lives made possible by the relatively small size and weakness of the calves’ bodies which makes them relatively easy to contain. However, such substantial changes in the calf collectivity do little to produce wider systemic change. Similarly, the specified problem of life and the overarching system of animal-human relationships remains unchanged by antibiotic stewardship. Instead, these are reinforced through increased control of animal lives and their environments within this specific collectivity.

5.2. The problem of ‘stoic’ life: Sick cows and changing antibiotics

The milking shed houses the largest single cohort of animals on the farm and constitutes the most intensive set of human, animal, material and technological relations anywhere on the farm. This collectivity is orientated towards the maximisation of milk production whilst managing the ‘production diseases that are a direct product of the system. Mastitis, an infection of the udder, is the most commercially significant disease and the dominant reason for antibiotic use (by dosage) on the farm. Two of the six dairy sector targets on antimicrobial use developed by RUMA relate specifically to treatment of clinical mastitis in lactating cows (Ruma, 2017) (a further two relate to mastitis in dry cows which we address in the following section). Reducing incidences of infection and catching clinical infections early were identified as crucial to reducing antibiotic use and delivering more effective antibiotic treatment. In this context the udder becomes a significant object of care and scrutiny. However, a key management challenge within this collectivity was overcoming animal agency. Cows were considered ‘stoic’, effective at masking signs of injury, discomfort and infection, at least in its initial stages, and blending into the crowd. Such stoicism meant there was a risk that infections could be missed until it was too late, requiring a longer course of antibiotics or even the death of a cow.

Seeing past this ‘stoic’ façade required farm staff to make astute judgements of animal health on the basis of often very minor signs of illness. Attention to a cow’s eyes and whether it ‘looks tired’ was used to explain a judgement that something was wrong with a cow and is a feature of stockmanship that has been noted within the broader literature (Burton et al., 2012; Helliwell et al., 2019). These types of assessment highlight how disease is often characterised by ambiguous symptoms but also the difficulty of articulating the experiential knowledge that is drawn upon when identifying the subtle cues displayed by animals otherwise suppressing expressions of stress or illness.

However, more direct approaches were taken to circumventing animal agency. The phrase stoic was first used on the farm by a vet to describe a cow which had broken a rib when it gave birth. The injury was noticed not because of a change in the animal’s behaviour or posture that was subsequently spotted by a member of farm staff but because the automated milking machine, which monitors daily milk yield, flagged the cow as having reduced milk production. Yield is not the only means through which the milking robots monitor cows for signs of possible distress. Given the commercial implications of sub-clinical and clinical mastitis infections for milk production and quality, a core function of the robotic milking machines was to monitor the milk to make visible the somatic cell count (SCC). A high SCC is a potential indicator of clinical infection. The implications of such technologies for animal-human relationships and animal agency have been documented elsewhere (Holloway et al., 2014a, 2014b; Butler and Holloway, 2016). Therefore, rather than documenting the whole gamut of relationships

produced through the use of this technology we focus instead on how the robots provide a mechanism for catching infections early, thereby overcoming animal agency that acts to mask disease.

The presence of automated milking robots on the farm produces new types of knowledge and distance between animals and humans. An end to human operated milking means that certain types of human animal intimacy are curtailed as FS3 explained:

“You see the cows a lot less because you aren’t seeing every cow twice a day, you are going to miss things, but then you get such good data is the other side of things.”

Robots therefore disrupt animal-human relationships, producing a degree of distance. Into this gap flows electronic data on the milk and milk production from the robots with ambiguous meanings for practices of care. On the one hand, it was a re-occurring and repeatedly voiced concern that the milking robots resulted in a reliance on data that could be misleading and/or invited complacency:

F2: “Yeah it [the cow] didn’t look great, but on the computer everything looks fine”

F1: “You take your eye off a bit.”

On the other, the data were actively mobilised by staff to identify and target animals that might need closer observation. Therefore, rather than efface, or de-skill farm staff their experiential knowledge-practices of animals were actively combined with the data from the robots to make judgements on animal health. Importantly for the farm the robots allow monitoring of the somatic cell count (SCC), a process that casts a more direct light on udder health. This view from robotic milking machine was used to target the daily mastitis check undertaken by FS3 or the farm manager to those animals with high SCCs.

Although part of the daily routine, the mastitis check relies on staff having time to properly mobilise and respond to the data to enable quicker interventions and better animal health outcomes.

RH “Do the robots help [mastitis treatment] you think? – RH

FS3 “Yeah they do, but it’s surprising how quickly it can go up, it’s why we try and catch it quickly. When me and [farm manager] are both working it goes down because we have more time.”

When the farm manager was not on the farm, the mastitis check only occurred in the morning. When both the manager and staff were present, it afforded FS3 additional time to be in the office to look over the data and do a second mastitis check later in the day if necessary. Care, in this case the ability to quickly catch suspected mastitis infections, is interlinked with the availability of labour on the farm.

During the period of observation FS3 was responsible for tracking down each flagged animal, drawing milk from the udder and depending on their judgement of the milk’s consistency identify if the cow has a clinical or sub-clinical infection. In all cases some form of care was provided including the provision of a topical peppermint cream to soothe pain and inflammation in the absence of clinical symptoms, and injection with intermammary or intramuscular antibiotics where clinical signs in the form of thick, discoloured milk, were identified.

Antibiotics are therefore used as a key treatment option once a cow is identified as suffering from a clinical infection. A major consequence of antibiotic stewardship initiatives has been to curtail certain types of antibiotic choices. The farm was in a retailer buyer group and subject to its animal health and welfare standards which limit the use of 3rd and 4th generation cephalosporins and fluoroquinolones as well as applying pressure to reduce antibiotic use across the farm. The major consequence of this change was described by the farm manager as follows:

“... what we are using is old stuff really, [the supermarkets] don’t want us using the 3rd Gens.” FM

Older antibiotics, although usually cheaper, had higher levels of

active ingredient per dose, sometimes requiring more individual treatments and subject to longer mandatory milk withdrawal times. The latter impacts directly on farm revenue, by increasing the amount of waste milk that needs to be discarded to ensure the removal of antibiotic residues. This also limited veterinary choices. Although they retained *de jure* freedom to prescribe and sell antibiotics (including off-license) to farmers, veterinary discretion needs to account for these contractual and monitoring pressures, resulting in a *de facto* limit on their prescription practices.

Changing the antibiotic chemical has become the major stewardship intervention in this collectivity. Although it may have had minor implications for the commercial profitability of the farm this chemical change was not deemed to have impacted on animal health outcomes.

“I think if you talk to the farmers they would probably also agree that since we have stopped using those things, nothing has changed.” Vet 6

This quote is unintentionally revealing in another way, in that mandated changes to antibiotic choices has not been transformative of this collectivity. Practices of care have not been substantively modified and neither have the existing practices of control over animal bodies and agencies. Therefore, pressure to reduce antibiotic use and move away from the HPCAs classified antibiotic class used previously on the dairy farm, was not perceived to have negatively impacted on animal health outcomes, nor resulted in systemic change as anticipated by groups such as the Alliance to Save Our Antibiotics. Instead, it has arguably increased the impetus to overcome animal stoicism and identify signs of infection more quickly with all that this implies for human actions, specifically attentiveness to animals.

5.3. The problem of fatigued life: Selective dry cow therapy & hygiene

The process of milk production has a significant toll on the cow’s body and udder. As a result, cows are given a rest or dry period of around two months prior to their due date in which they are not milked. Antibiotics are routinely administered (known as dry cow therapy) at the beginning of the dry period to eliminate residual mastitis infections acquired during lactation as well as prevent new infections arising. Dry cow therapy to treat and prevent mastitis accounts for a significant proportion of antibiotic use in dairy farming (Hyde et al., 2019). Dry cow therapy is the subject of two of the six RUMA antibiotic stewardship targets and is a site in which reducing antibiotic use appears particularly challenging (Berry and Hillerton, 2002).

The dry period and dry cow therapy is made necessary due to the impact of milk production and changing scientific and veterinary advice which has positioned dry cow therapy as a crucial element of farm mastitis management (the five point plan) for over 50 years (Woods, 2014). Cows will lose weight, particularly during the initial lactation as they consume their bodily reserves because the energy demand for producing high quantities of milk outstrips that recouped through feed. Ideally most, but not all, of this weight will be regained during the latter stages of lactation when milk production is low. Similarly, the udder itself becomes ‘fatigued’ and requires time to repair and recover from milk production. It is only through stopping milking and providing cows with a rest or dry period that animals’ udders and weight can recover fully in preparation for the next lactation. Failure to rest cows between lactations has long been recognised as reducing milk yield in subsequent lactations (Klein and Woodward, 1943; Sørensen and Enevoldsen, 1991). All milking cows on the farm are given a rest period towards the end of their lactation when they are removed from the milking shed collectivity and enter the dry cow collectivity. This involves physically relocating animals to a set of large communal straw pens used throughout the year. As such, the dry cows occupy a distinct set of spaces on the farm and are embedded in a different set of relations to the other adult cows.

Many cows enter the dry period with sub-clinical and clinical mastitis infections. Equally, dry cows are at risk of contracting new mastitis infections, particularly at the beginning and end of the dry period when the udder is in transition. These risks are compounded by the different relations within the dry cow collectivity which results in a major reduction in human and technological oversight in comparison to the milking shed. The gaze from the milking robot has ended and daily interactions between farm staff and dry cows are significantly more sporadic and shorter in duration than for the milking cows. However, the end of milking allows for different practices of care, specifically as these relate to disease control.

Since the 1950s routine antibiotic dry cow therapy has been standard practice and has in the past involved the administration of a strong, long acting antibiotic to all cows at drying off to control mastitis (Biggs et al., 2016). With cows no longer being milked, a process that flushes antibiotics out of the udder, the dry period enables the use of long acting treatments that aim to clear any existing persistent infections and provide a long window of coverage guarding against new ones. More recently, dry cow therapy has also included the use of an internal teat sealant which forms a physical barrier to bacterial incursion into the udder. Such practices of blanket antibiotic administration have meant that dry cow therapy has become a key site at which pressure to reduce antibiotic use in the context of AMR initiatives has catalysed. As a result, there has been a gradual push for farms to adopt selective dry cow therapy.

During ethnographic observations the farm had adopted such a strategy in line with the standards set by the retailer. In contrast to routine therapy, only cows with a SCC greater than 200,000/ml registered in the last three months prior to drying off received antibiotic treatment and a teat sealant. Cows that meet this threshold might be showing signs of clinical infection at drying off, but if not are likely to carry residual sub-clinical infections that need to be treated with antibiotics over the dry period. However, cows below this threshold are assumed to be free of infections and only received the internal teat sealant, which does not treat any existing infection but is effective in preventing new infections that might require antibiotics. Despite the use of selective treatments, the majority of cows required treatment with antibiotics upon entering the dry period.

The selective use of antibiotics in these cases meant that attention was shifting away from antibiotic chemicals to other antimicrobial chemicals used to ensure strict hygiene when administering the teat sealants. Selective dry cow therapy has therefore caused a shift from one set of antimicrobial chemicals to another, although only in the context of some cows. Yet this is not the same as the direct chemical swap observed in the milk cow collectivity. Instead it requires leveraging a different set of chemical and physical practices - sterilising the teat and prevention of contamination when administering the sealant. A consequence of this is that selective dry cow therapy brings with it a different set of risks, produced through the absence of an antibiotic and potentially poor hygiene during administration. Although not observed on the farm but discussed repeatedly in wider stakeholder interactions, poor practices of hygiene when administering dry cow therapy was positioned as potentially condemning a cow to infection and death. Dirty hands, cloths and other materials used during administration, or failure to properly clean and sterilise the teats could result in infectious bacteria being locked in by teat sealants, rather than excluded from the udder. Animals denied antibiotic care were at particular risk with animals being killed presenting the most serious consequence of a potentially minor hygiene lapse.

Antibiotic stewardship initiatives have resulted in what appears to be a relatively minor re-configuration of the dry cow collectivity entailing a reduction in antibiotic use through targeted treatment of cows with a high SCC. For dry cows that do not receive an antibiotic additional emphasis has been placed on the need to ensure excellent hygiene practices that rely on a different set of antimicrobial chemicals. But this alteration relies on the maintenance and efficacy of these practices.

Consequently, the stakes for the dry cow have potentially risen if these practices are inadequate, leading to a contamination of the udder.

6. Conclusions

This paper has sought to provide initial insights into what antibiotic stewardship means in practice for animal-human relationships, with particular emphasis on the ways in which animals are cared for within intensive agricultural systems. In doing so it has developed the HBC concept which enables these relationships to be explored, and provided an illustration of how this approach can be used within empirical research, in this case through a single farm case study. The concept of HBC has been extended through 're-scaling' its emphasis to the sub-collectivities of the farm, and through the introduction of insights from the literature on practices of care. Our illustrative application of the concept has identified three different farm level collectivities within which antibiotics are a prominent component within the context of an intensive dairy farm. Each collectivity is constituted through a particular set of animal-human relationships, mediated by various technologies, infrastructures and practices, and each produces different possibilities of care including through the use of antibiotics. Further, each collectivity is variably reconstituted in response to antibiotic stewardship. Development and application of the HBC concept, through its rescaling and attention to care, has therefore been used to disentangle the heterogeneity of the dairy herd with important implications for understanding the complexities of changes in animal-human relationships as a result of antibiotic stewardship. In doing so we have highlighted both the segregated nature of dairy farms, what this means for what farms do in response to the changing governance of antibiotic use, and the consequences this has for animal lives as they move through and into the collectivities that constitute the farm system.

A key conclusion from our analysis is that antibiotic stewardship has uneven effects for animal-human relationships including with regards to practices of care and their consequences. The different possibilities for change within each collectivity on the farm mean that antibiotic stewardship is not a homogenous intervention related simply to the reduced use of antibiotics within the herd. Rather this goal is achieved through collectivity-specific interventions which have varied and ambiguous implications for the animals and their care. Hutches produce new practices of observation, isolation and intensify animal-human engagement for the individual calf. Although successful in managing the risks to respiratory systems and improving the provision of care for the bio-physical animal body, this is at the cost of social interaction, companionship and behavioural needs that are considered important for positive welfare and development of natural behaviours amongst dairy cows (Pempek et al., 2017; Stull and Reynolds, 2008). For milking cows, the increased pressure to quickly identify and treat the signs of infection are facilitated through the synthesis of data collected through automated milking machines and experiential knowledge-practices of farm staff. Once disease is identified, the main antibiotic stewardship intervention involves a change to older antibiotic classes away from classes now considered HCAs. Otherwise animal-human relationships and practices of care remain unaltered. Dry cows on the other hand were faced with new risks that emerge through a shift to selective dry cow therapy. The withdrawal of antibiotic treatment for some animals in this collectivity means that a failure by farm staff to correctly apply sterilising agents and teat sealants potentially locks in infectious bacteria at a moment when human observations and interactions are reduced. A relatively minor lapse in hygiene practices creates potentially significant risks from infection for dry cows. Consistent across these interventions is that they produce modified or new practices of care that maintain or extend human control over animal bodies and the products of these bodies.

A further conclusion is that although our example suggests that antibiotic stewardship is indeed changing the on-farm practices of care for animals, reductions in antibiotic use do not appear to provide a

catalyst for more fundamental change to animal-human relationships that are expected by some stakeholders. Certainly, in the context of this study, there was no evidence to support the claims of the Alliance to Save Our Antibiotics that antibiotic stewardship might lead to a shift from intensive to extensive systems of animal production. Although some of the grim predictions about escalated losses resulting from reduced antibiotic use were a prospect in some collectivities, for example the changing risks associated with selective dry cow therapy, these were not inevitable. Rather, such outcomes were contingent on careful application of new care practices. As exhibited on the case study farm our analysis suggests that high levels of antibiotic use are not fundamental to maintaining the intensive system of production. This is in line with the findings of historical scholarship that emphasises how antibiotics are just one element through which good animal health is produced and disease managed in livestock farming (Woods, 2014, 2019). Antibiotic stewardship may re-entrench intensive logics of animal management through mobilising a diverse array of non-antibiotic care practices. Whether these systems can be maintained in circumstances where all antibiotic use comes to an end is unclear from this study but worth noting here is that even large-scale and intensive poultry production can be commercially viable without the use of antibiotic treatment according to recent media coverage of so called ‘antibiotic free’ meat products, especially chicken (Moodie, 2017; Zhang, 2018).

Finally, although our research has illustrated a single farm’s response to antibiotic stewardship the farm system, its practices, and the means through which they are governed are by no means unique. The farm was a member of a supermarket buyer group which, as we discussed earlier, has been a key driver in changing on farm antibiotic practices nationally in the UK. Given the original scaling of the HBC, our conceptual approach could be taken forward to examine the national organisations that we have signposted and perhaps international collectivities that are developing around antimicrobial stewardship and AMR in agriculture. Equally, due to the broad impact of these governance standards it is likely that what we have illustrated is indicative of broader trends in the sector. The extent to which there is variation and consistency between farms in their responses to specific antibiotic stewardship governance and regulation, alongside the consequences this has for animal-human relationships and practices of care are important questions for future research. Equally, whether similar dynamics of re-trenchment or transformation play out on other dairy farms subject to different governance standards (including those outside of the retailer-processor schemes), in other animal agricultural sectors both intensive and extensive, conventional and organic, and in the context of different cultures and countries are all key and urgent questions for future research.

Declaration of competing interest

The authors declare that they have no conflicts of interest.

CRediT authorship contribution statement

Richard Helliwell: Conceptualization, Methodology, Investigation, Writing - original draft. **Carol Morris:** Conceptualization, Methodology, Writing - original draft, Supervision, Funding acquisition, Project administration. **Sujatha Raman:** Writing - review & editing, Supervision, Funding acquisition, Project administration.

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Appendix A. Supplementary data

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