

Challenges for the management of Johne's disease in the UK: Expectation management, space, 'free riding', and vet-farmer communication

by Morrison, R., Hanks, J., Orpin, P.G., Strain, S., Taylor, E.N. and Rose, D.C.

Copyright, publisher and additional information: Publishers' version distributed under the terms of the [Creative Commons Attribution License](#)

[DOI link to the version of record on the publisher's site](#)



**Harper Adams
University**

Morrison, R., Hanks, J., Orpin, P.G., Strain, S., Taylor, E.N. and Rose, D.C. (2024) 'Challenges for the management of Johne's disease in the UK: Expectation management, space, 'free riding', and vet-farmer communication', *Preventive Veterinary Medicine*, 231, article number 106295.



Challenges for the management of Johne's disease in the UK: Expectation management, space, 'free riding', and vet-farmer communication

Rosie Morrison^a, James Hanks^b, Peter Guy Orpin^c, Sam Strain^d, Emma Nicole Taylor^{b,1}, David Christian Rose^{a,e,*},²

^a Cranfield University, Cranfield, Bedford MK43 0AL, UK

^b PAN Livestock Services Ltd., UK Veterinary Epidemiology and Economics Research Unit (VEERU), University of Reading, School of Agriculture, Policy and Development, Earley Gate, PO Box 237, Reading, RG6 6EU, UK

^c MyHealthy Herd, 10 The Old Manor House, 10 Churchgate, Hallaton, Leicestershire LE16 8TY, UK

^d Animal Health and Welfare Northern Ireland, Dungannon, BT71 6JT, UK

^e Food, Land and Agribusiness Management, Harper Adams University, Edgmond, Newport, TF10 8NB, UK

ARTICLE INFO

Keywords:

Animal disease
Behaviour change
Disease control
Disease management
Johne's disease
Mycobacterium avium ssp. *Paratuberculosis*
(MAP)

ABSTRACT

Johne's disease in cattle is a significant global animal health challenge. Johne's disease is chronic, affecting the gastrointestinal tract of cattle and other ruminants and is caused by the bacteria *Mycobacterium avium* ssp. *Paratuberculosis*. Many countries have introduced schemes and programmes to try and control the spread of Johne's disease, including the UK. Despite efforts to control it, however, Johne's disease remains consistently ranked by UK producers as the top ranked disease negatively affecting productivity, indicating that schemes are not perceived to have solved the problem fully. Building on a global systematic review of the literature on barriers and solutions for Johne's disease control on-farm, we conducted an empirical study with over 400 farmers and 150 veterinary professionals across the UK. The study used workshops and semi-structured interviews to understand better the challenges dairy farmers and veterinarians face in implementing on-farm Johne's disease management schemes with the aim of identifying solutions. The study found that four main challenges are faced in the on-farm control of Johne's – (1) Management of farmer expectations around Johne's disease, with eradication near impossible, (2) Issues regarding space for segregation and the related economics of control (3) A 'free-riding' problem which can be influenced by the voluntary nature of control plans and (4) Challenges in vet-farmer communication, including levels of knowledge. Our findings have relevance for the control of Johne's disease in the UK and other countries, including for regions with voluntary and compulsory control programmes.

1. Introduction

Johne's disease (JD) in dairy cattle is a significant global animal health challenge (Robinson, 2020). JD is chronic, affecting the gastrointestinal tract of cattle and other ruminants and is caused by the bacteria *Mycobacterium avium* ssp. *Paratuberculosis* (MAP) (Collins et al., 2010). Approximately 80 % of MAP infections occur within a calf's first month of life (Action Johne's, 2020b). Faecal-oral transmission is the most common route of MAP transmission, but it also spreads through drinking contaminated colostrum and *in utero* (Action Johne's, 2020b). Delayed manifestation of MAP infection causes challenges to

JD management as a potentially MAP infected cow may not present a positive test but can still be an infection risk within the herd (Imada et al., 2023). The disease is present in countries across the globe and has negative impacts on animal welfare, productivity, and farm income (Whittington, 2019). Many countries have introduced schemes and programmes to try and control the spread of JD, which usually takes considerable time. Participation in these schemes is usually voluntary (Sorge, 2010; McAloon, 2016; Hop et al., 2011; Whittington, 2019) and therefore their success is largely reliant on farmers' self-motivation to act (Robinson, 2020).

Focusing on dairy in this paper, the disease remains a significant

* Correspondence to: Harper Adams University, Edgmond, Newport, UK.

E-mail address: drose@harper-adams.ac.uk (D.C. Rose).

¹ ORCID ID (0000-0002-8326-2799),

² ORCID ID (0000-0002-5249-9021)

problem despite evidence of farmer participation in schemes (Morrison and Rose, 2023). For example, in Ontario where there was a voluntary control program for dairy farmers between 2010 and 2015, evidence seemed to suggest increasing prevalence (Imada et al., 2022). In addition, in Great Britain where 95 % of dairy producers participate in the National Johne's Management Plan (see Section 2), the disease was still ranked number one in terms of its impact on national production efficiency in a survey of 794 professionals in the sector and 441 dairy farmers (AHDB, 2021). Over 80 % of UK herds that have undertaken surveillance have evidence of JD infection (Action Johne's, 2020b). It is therefore imperative that we better understand the challenges to on-farm Johne's control, both in the UK and elsewhere, as disease prevalence remains too high even in targeted programmes.

Scholars have conducted several studies around the world to understand barriers and solutions to on-farm JD control, with a focus on farmer, and to a lesser extent, veterinarian behaviour (Ritter, 2017). In their systematic review of relevant literature from the last ten years, Morrison and Rose (Morrison and Rose, 2023) highlighted five key barriers to JD control: the time taken to see results, a lack of space, a lack of interest in JD control, economics, and concerns with tests.

Both Enzyme Linked Immunosorbent Assay (ELISA) and faecal sampling are commonly used to test for JD, however both tests have received criticism for their low sensitivity (Imada et al., 2023; Nielsen, 2009), with the diagnosing of 'light shedders' proving challenging (Espejo, 2015; Bakker, 2013). In the UK context, the milk ELISA is the most commonly used test (Beasley, 2011) and is often carried out by large milk recording companies who test farmers' milk for a variety of health indicators. The ELISA test detects the level of MAP antibodies present in milk and provides farmers with a test result that is based on this. Jordan et al. (Jordan et al., 2020) found that test results that show levels of MAP antibodies were confusing for farmers who were more familiar with making decisions based on binary positive or negative test results.

Due to the epidemiology of the disease, controlling JD in a herd can take several years. As a result, farmers may view the costs associated with control as too expensive when compared to the delayed future benefits (Rasmussen, 2021) and also can result in them developing programme fatigue (Morrison and Rose, 2023).

Recommended JD control measures include the introduction of separate calving pens and the segregation of cows that have high levels of JD antibodies identified through testing, both of which require considerable space on farms. Many farmers, especially in the UK, do not have the luxury of excess space and housing and therefore cannot implement such measures (Collins et al., 2010; Sorge, 2010; Orpin, 2017).

Direct experience of a disease has previously been found to affect farmers' perceptions of how legitimate and necessary control schemes are (Naylor et al., 2018). This also applies to JD where it has been found that farmers who have not experienced clinical disease on farm are less likely to participate in control programmes (Sorge, 2010; Jordan, 2020), which is also affected by level of knowledge about control programmes and the disease itself (Imada et al., 2023; McAloon et al., 2017; Horan et al., 2023). Only 10–15 % of infected cows develop clinical signs (Olsen, Sigurðardóttir, & Dønne, 2002) meaning a significant number of infected cows do not develop clinical signs but are still an infection risk. It is therefore important that farmers participate in JD management schemes regardless of their experience of clinical disease on the farm.

The cost of culling cattle who have a high prevalence of MAP antibodies, indicating the presence of JD, and the cost of regular JD tests can result in farmers viewing the cost as too high (Kirkeby, 2016; Collins et al., 2010; Wolf et al., 2015). In smaller herds or herds with a low prevalence, there tends to be a low or negative return on investment in JD control, which has resulted in farmers choosing not to control the disease (McAloon, 2016).

Further insights from the literature also identify the importance of farmer-veterinarian relationships and good communication in effective

disease control (Morrison and Rose, 2023). Though not specific to JD, research shows the value of veterinarians in controlling disease on-farm with 98 % of UK/US vets surveyed by McDermott et al. (2015) ranking communication skills as similarly or more important than clinical knowledge. Improving veterinarian communication skills by tailoring advice to individuals, improving non-verbal communication, and developing motivational techniques have been widely proposed as a way of better controlling livestock diseases (e.g. (Atkinson, 2010; MacGillivray, 2020; Bard, 2022).

Notwithstanding the scholarly interest in challenges of on-farm Johne's control, relatively few studies on decision-maker behaviour have focused on both farmers and veterinarians. Exceptions include Wolf et al. (Wolf et al., 2015), who used risk assessments compiled by farmers and vets to explore Johne's management in Alberta (Canada) and Bhattarai et al. (2014) who surveyed farmers and vets in US beef cow-calf operations about prevalence and control. In England, Robinson (Robinson, 2020) conducted 17 dairy farmer and 7 veterinarian interviews focused on management behaviours, highlighting a number of challenges; for example, lack of farmer knowledge, the key role of the veterinarian, and the need for long-term relationship building and social pressure to change. The study also indicated that some veterinarians may not place JD at the top of their list of priorities.

To summarise the discussion above, there remains significant prevalence of JD in UK and global dairy herds and limited qualitative data gathering exercises from both farmers and veterinarians. Thus, there remains a need for a more detailed and holistic understanding of what drives on-farm JD control. This paper advances our understanding of the challenges affecting on-farm JD control through a UK case study, involving data collection from a substantial number of farmers and veterinarians.

1.1. Global control programmes with a focus on the UK

This paper focuses on the UK, however insight into JD control in other countries can offer vital context around controlling the disease. Therefore, a selective overview of insights into JD control strategies will follow. In Australia, JD is notifiable despite there being no regulatory response, with control projects focusing more generally on biosecurity and endemic diseases. Each Australian state has slightly different rules and there are a variety of voluntary tools that farmers can use to help (Barwell, 2022). In Austria, JD is also notifiable with compensation offered for the slaughtering of positive cows. There is also a voluntary MAP-control and surveillance program. A case study from Austria suggested 7.5 % herd-level MAP prevalence in 2013 compared to 0.97 % in 2018/19 (Khol, 2023). In Germany, MAP-control is governed only by recommendations made at the national level with a mixture of province-level voluntary and mandatory control programmes, which differ substantially as does prevalence of the disease in different places (Donat and Eisenberg, 2023). In Italy, and Lombardy specifically, a voluntary control program from 2014 to 2021 has seen the percentage of herds participating increasing from 56 % to 81 %, with the percentage of infected herds decreasing from 74.2 % to 52.4 % and the percentages of herds with a MAP apparent prevalence above 5 % decreasing from 29 % to 4 % (Norma, 2023). Finally, in Canada, JD is controlled at a provincial level with the different provincial programmes having different approaches to testing and culling (Barkema, 2018). This has been noted as a hindrance to control of the disease as differing regulations and rules can be confusing to farmers (Barkema, 2018).

In Great Britain (England, Scotland, Wales), the National Johne's Management Plan (NJMP, voluntary scheme) helps farmers control JD on their farm. The first year of the plan requires farmers to assess their risks and herd JD status and then adopt a management plan which is created in collaboration with a British Cattle Veterinary Association (BVCA) Accredited JD advisor (Action Johne's, 2020a). Each plan is created to meet the needs and aspirations of the farmer and will be unique to the farm. From the second year of the scheme, it is expected

that the plan will be reviewed annually and that the right practices and protocols are being implemented in line with the agreed plan. Breeding to terminal sire, improved biosecurity, improved farm management and strategic testing are often recommended as common control measures in the management plan (Orpin et al., 2020). Despite being voluntary and not governed by legislation, many milk purchasers in Great Britain have made participation in the NJMP a compulsory element of milk contracts (Robinson, 2020) and as a result, around 95 % of farmers participate in it (Orpin et al., 2021). The NJMP is a framework for control, as opposed to a national control or surveillance programme, therefore processors often only require farmers to work with their vet to conduct a risk assessment, produce a management plan and to conduct a targeted 30-cow milk ELISA screen annually as a minimum surveillance requirement.

In addition to this programme, individual animal test data for JD antibodies in milk are available. Recent work commissioned by Action Group on Johne's resulted in the development of the Johne's Tracker tool which was launched by the major milk recording organisations in June 2021 (IDF, 2023; Action Johne's, 2023). The Johne's Tracker uses the JD test data, comprised of individual milk ELISA data, to provide powerful analyses and graphic outputs that support farmer/veterinarian collaboration in disease management that is invariably required to bring the disease under control. These data complement discussions on wider herd level risk factors such as the risks posed by the purchase of replacements or the farm's calving facilities.

The Northern Ireland JD Control Programme (NIJDCP) for Dairy Herds is managed by Animal Health and Welfare NI (AHWNI), a not-for-profit organisation funded entirely by the Northern Ireland Agri-Food Industry (Strain et al., 2021). Approximately 90 % of dairy farms within Northern Ireland participate in the programme. The core mandatory component of the NIJDCP is the provision of a Veterinary Risk Assessment and Management Plan (VRAMP) carried out by an Approved Veterinary Practitioner who has been trained by AHWNI. The VRAMP is a standardised assessment of the risks of introduction, establishment and spread of infection within a herd, leading to the provision of bespoke advice on risk mitigations that the herdowner agrees to carry out. Each herd is required to undergo an annual VRAMP, with each subsequent VRAMP focussing on changes to risk and a re-evaluation of advice to ensure it is both relevant to the infection risks on the farm as well as achievable by the herdowner. All VRAMPs are captured electronically by AHWNI using a bespoke online tool. The NIJDCP has been designed to align with Animal Health Ireland's JD Control Programme in the Republic of Ireland, and so facilitate the all-island trade in milk and milk products as well as comply with UK Red Tractor quality assurance standards.

2. Data collection and methods

The data collection for this study took place between October 2022 and April 2023 and was approved by an ethics committee at Cranfield University. It comprised of 22 workshops (mostly online) and 28 in-depth online interviews with both farmers and veterinary professionals from across the UK. Data for this paper were collected from across the UK (England, Scotland, Wales, Northern Ireland).

The 22 workshops were arranged in collaboration with vet practices, vet nutritionists, and dairy consultants from across the UK. 20 of these workshops were conducted online via zoom whilst two were in-person. The in-person workshops took place in the south-west of England and Leicester. The online workshops were attended by a range of farmers from different practices across England, Scotland, and Wales. Two of the online workshops were solely for farmers in Northern Ireland.

Meetings began with a 1.5-hour pre-meet with veterinary professionals from up to four separate organisations, followed by a 1.5-hour interactive workshop with farmers and veterinary professionals (farmers were invited by their vet practice). An estimated total of 154 veterinary professionals attended across all pre-meets and 418 farmers associated with the respective vet practices attended the workshops. Attendance

ranged from 7 to 49 farmers per workshop and 4–16 vets per workshop. It was challenging to gather exact numbers of attendees as individuals joined and left the workshops throughout, and in some cases, farmers did not have their cameras on so it was not possible to know how many people were joining from their location (each 'off' camera was counted as one person). Guaranteed anonymity in the workshops prevented the socio-economic makeup of participants being known. Both the pre-meet and workshops operated as focus groups for the research.

Before the workshops, farmers and vet practices were asked to supply their JD data to the research team. This data was then processed by InterHerd+ (a JD tracker developed by PAN Livestock Services Ltd) which transformed the data into a JD tracker report for each farmer making it easier to see their JD tests results from previous years and other statistics such as their likelihood of culling a JD positive cow. These reports were shared with farmers ahead of the workshop and explained in the meeting. Industry experts facilitated the workshops and provided an update on JD developments, conducted interactive polls, and asked questions regarding engagement in JD control. A sample of the poll questions are shown in Annex A. Detailed notes were made during each workshop by different members of the research team, but it was not recorded to create a more informal meeting. These notes were then uploaded onto Nvivo (Version 13) (Lumivvero, 2023), which facilitates qualitative analysis, and key themes were identified using an inductive approach. The data contributed to the establishment of key factors affecting Johne's control with supporting quotes in the results taken from the in-depth interviews subsequently carried out with former workshop and other participants (since we did not have verbatim notes from the workshops).

The interviews were carried out in parallel with the workshops and offered the opportunity to collect more in-depth qualitative data with some of the individuals who had participated (and some who had not). Three different semi-structured interview guides were used; one for farmers, one for the majority of veterinary professionals and a third for veterinary professionals who were directly involved in the development of processor JD requirements. Each of the semi-structured interview guides are included in the Annex B. We tried to include farmers who were both more engaged and disengaged on JD control (Ritter, 2016).

Several channels were used particularly to identify farmers who are disengaged in JD control for interview. Vet referrals and a review of the farmers' JD data provided for the workshops helped to identify farmers who had high levels of JD in their herd and therefore were expected to be less engaged in JD control. These farmers were contacted for interview. A short Qualtrics screening survey (Annex C) was also created which asked farmers their opinions on JD control and whether they would be willing to be interviewed. The survey was sent out to vet practices, farming cooperatives, and other farming organisations who then disseminated it amongst their farmers. Farmers who were willing and were identified as being less engaged in JD control via the questionnaire, were contacted for interview. Veterinary professionals were identified through industry contacts.

The 28 interviews (15 farmers and 13 veterinary professionals) lasted up to 36 minutes. The interviews all took place over zoom or via the phone and were either voice recorded and transcribed, or written notes were used. Written notes were made during each interview in case the voice recording was of poor quality. These written notes were analysed for two of the interviews due to participants being outside on the farm and in their car during the interviews resulting in poor audio recordings. These written notes were thematically analysed using Nvivo through a process of inductive interview coding (Young et al., 2018).

3. Results

The farmers interviewed had a range of herd sizes from 30 to 800 milking cows. One of the farmers operated a certified organic farm. Farmers from Wales, England, Northern Ireland, and Scotland were interviewed. All the farmers interviewed had experienced significant JD

problems on farm, which given the recruitment method was to be expected. However, not all the farmers interviewed were fully disengaged with JD control. Five ‘proactive’ farmers were interviewed who consistently went above and beyond any required JD control from their buyers/processors. Seven ‘transition’ farmers were interviewed who were beginning to understand the importance of JD control on their farm but still had doubts over some of the methods being recommended. Three ‘disengaged’ farmers were interviewed who did the bare minimum required of their processors/buyers and did not fully engage in JD control. The veterinary professionals interviewed were at different stages in their careers, ranging from 4 to 28 years’ experience working as a dairy vet. Several of the vets interviewed had other jobs including a dairy farmer, a farm consultant, and an advisor to large supermarket chains.

3.1. Challenges for on-farm Johne’s disease control

From the workshops and interviews, four themes related to barriers to on-farm JD control were identified. Each theme had sub-themes. These are shown in Fig. 1: 1) expectation management, 2) space and economics, 3) free-rider problems and 4) vet-farmer relationships.

3.2. Theme 1: expectation management

The ways in which the disease itself and the control measures are communicated to farmers, as well as challenges with tests, were found to be a significant barrier to on-farm JD control, mirroring conclusions from a recent systematic review (Morrison and Rose, 2023). These communication issues fell into two sub-themes. The first of these focused

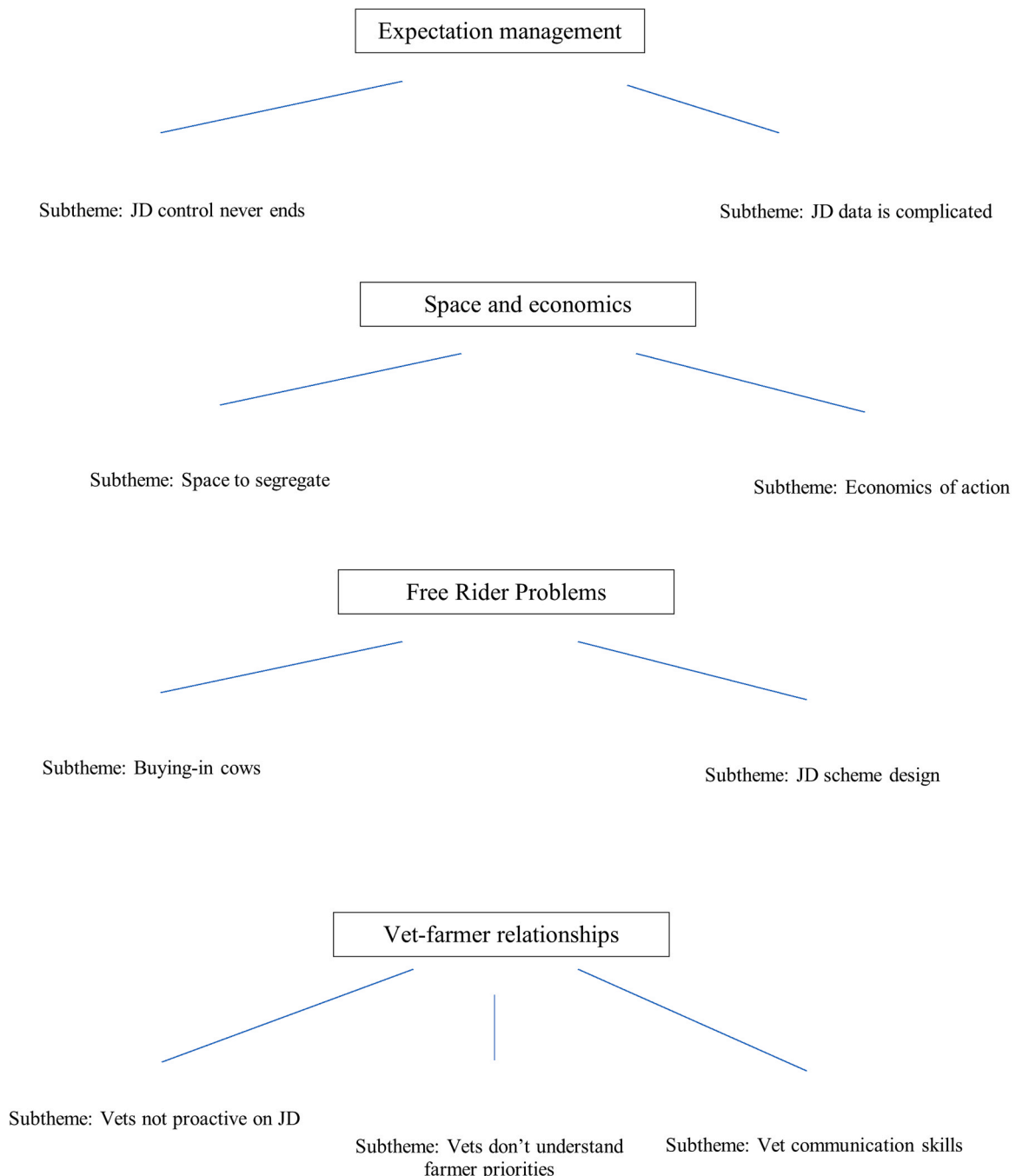


Fig. 1. Challenges for Johne’s disease control identified by our empirical study.

on how farmers view JD control as ‘never-ending’ as they seek to eradicate the disease rather than control it. The second sub-theme focuses on how farmers interpret and comprehend their JD data.

3.2.1. JD control never ends

The overall aim of JD control programmes is not to eradicate it, but to control its prevalence (Action Johnes, 2023). Dairy farmers are familiar with disease control, for example increased hygiene practices are commonplace to reduce incidences of mastitis (Krömker and Leimbach, 2017). However, it was a common occurrence in both interviews and workshops that farmers believed that their ambition and aim was to eradicate JD from their herds. They felt that their inability to achieve full eradication within a reasonable time period was a significant demotivator to engage in JD control. One producer noted that *“it’s one of the things that hard thing with Johnes is you’re not going to cure it overnight. Yeah, it’s a bit demoralizing”* (Farmer 15). Another likened JD control to being *‘stuck on a hamster wheel’* (Farmer, Workshop 4), and another as *‘walking an endless road’* (Farmer 2). One interviewee who had also attended one of the workshops stated that *‘at the [workshop] I learned that we couldn’t eradicate Johnes disease, which I was disappointed about’* (Farmer 13). The focus on JD eradication instead of control also appeared in a vet interview, with one vet stating there needs to be *‘proactiveness from the vet to advertise [JD control measures] as a tool for disease eradication’* (Vet 3).

These quotes show there is a communication gap between what farmers believe they can achieve versus what is actually achievable. Farmers regularly control diseases on farm and the inability to eradicate them is not a barrier to their control.

3.2.2. JD data is complicated

The literature extensively speaks about the uncertainty and confusing nature of JD testing as a barrier to effective control (Morrison and Rose, 2023). All the farmers that were interviewed and the vast majority of those in the workshops carried out some form of regular JD testing to meet the requirements of their buyers/processors. Concerns were raised in the workshops over the complexity of milk ELISA results and the complexity of the JD tracker which can be accessed through InterHerd+ software and other web-based environments. This may be due to some farmers receiving the tracker a short time prior to the workshop, resulting in them not having it explained thoroughly to them. The JD tracker converts milk ELISA results into a series of parameters which measure the persistence, progression and management of JD on farm. The results are colour-coded (‘traffic lights’) according to benchmark values derived from a sample of herds that are already used for production parameter benchmarks (Orpin et al., 2020). Cow parameters can move up and down the scale in consecutive tests. Communicating tests results in this manner was confusing for farmers. One farmer stated *‘I still don’t get the test results. You get a lot of them’* and that *‘It’s hard to understand what you’re actually trying to interpret [with the test results]’* (Farmer 9). One of the veterinary professionals interviewed echoed this sentiment stating *‘farmers are like, well we all like, black and white answers...this test is positive. Kill it. This test is negative, don’t. Whereas Johnes only gives that sliding scale...it’s infected with map, but that might not mean it’s going to get Johnes’* (Vet 3). In a similar manner, farmers liked the idea of having all their JD data presented like on InterHerd+, however they found that individuals had to be a *‘fairly high level to interpret it’* (Farmer 1) and said *‘it would be good if they could do a report just on the last test’* (Farmer 9) to make it simpler for them to interpret. This statement particularly highlights a lack of understanding of how to control JD as previous test results, not just the most recent, are important in making control decisions. Some vets agreed with the sentiment that the data provided on the tracker was too complicated, with one arguing that they will *‘probably even get more confused because they’ve got all this different data of all their milk results and things like that’* (Vet 3).

3.3. Theme 2: space and economics

In our empirical study, we found the lack of space to segregate and the associated economics of control, which partially influences space, were key factors influencing decision-making. Even if farmers had the willingness and understanding to take action, these barriers restricted their ability to do so.

3.3.1. Space to segregate

Segregation of cows who are shedding MAP is important, particularly keeping them away from calves and young stock. Farmers at the workshops and in the interviews recognised this, but identified lack of space as a key barrier to implementation. This was the most highlighted barrier to taking effective action in the farmer workshops and many interviewees (farmers and vets) raised it as an issue. One farmer (3) said *‘there is a problem of space. That is the biggest gripe. I think the real practical barriers are space. Space and staffing. It’s just not possible for us to segregate cows’*. Others agreed, a farmer (2) said: *‘I’ve spent a lot of time doing... academic research, but you know, inhibited by the practical realities of space. And yeah...the physical reality of [the] farm.’*

3.3.2. Economics of action

Partially related to lack of space was the cost of taking action on JD. A farmer (1) said: *‘our normal milk recording cost is about 220 pounds for 280 cows, 290 cows, but you add Johnes recording into that, and that suddenly goes up to 800 pounds...That is a huge burden on a lot of farmers, especially if you have a smaller farm and you’re obliged [to test].’* Whilst this affected JD decision-making in multiple ways, particularly the reluctance of a struggling farmer to cull cattle if they appeared well, economics also affected farm infrastructure required to segregate cows. Two interviewees spoke about this issue, one (farmer 4) saying that *‘3 or 4 years ago, when the milk price was poor, and you couldn’t build anything or get more space, I can understand that [spacing] is an issue’* whilst another (vet 5) argued *‘some farmers will go whole hog and go and put up new infrastructure for calving and everything else but a lot of farmers haven’t got that position.’*

3.4. Theme 3: free-rider problems

JD does not only spread within herds, but between herds. There is evidence that JD can spread through slurry that has been imported from other livestock farms, or that remains on shared equipment (Orpin et al., 2020). When farmers buy in cattle to join the herd they also risk buying in a JD positive animal (Imada et al., 2022). This creates free-rider problems, as farmers who buy in cattle feel that whatever they do regarding JD management, others will still do nothing which may cause a JD problem on their farm. This de-motivated farmers from taking action on JD themselves. The sub-themes related to free riding were buying in cattle and the lack of compulsory legislation.

3.4.1. Buying-in cows

The NJMP in Great Britain does not provide accreditation or certification to show that a herd is low-risk, nor is there any obligation for a farmer to share their JD status with other farmers or their processor. This means that farmers cannot be certain that any animals they buy into their herd will be JD free. Seven of the farmers interviewed and three of the veterinary professionals noted this as a significant problem. One farmer felt that anything they do to prevent JD was *‘pointless’* as *‘we bought the problem in’* (Farmer 14). Other farmers attempted to reduce the risk of buying Johnes in – *‘I ask for their Johnes status. If they’re in an auction and they won’t give me that assurance. I won’t bid on them’* (Farmer 7). However, another farmer noted that *‘you can’t really be 100 %’* (Farmer 6) even if the farmer says they have no JD. This was a common issue. One farmer talked about how he had never had a JD problem until he bought in five cattle, all of which were JD positive – *‘the guy was adamant that he didn’t have Johnes on the farm, and I was like ‘obviously*

you do' (Farmer 8). One of the farmers who was interviewed and is classified as 'transitioning' talked about how difficult he found buying in heifers stating 'we had quite a high replacement rate, and then I would be bringing in heifers...I wasn't trying to do away with the source of the problem.' (Farmer 15) This farmer also talked about the need to buy-in new cows after being hit with TB meaning he 'lost a lot of cows, bought in cattle who, brought more Johnes in. I started losing more cattle, but I didn't do anything'. Vets also felt that not enough precautions existed when buying in – 'pre-purchase testing just one or two animals. It isn't going to give you the herd status' (Vet 3).

3.4.2. JD Scheme design

Like most JD control schemes, the NJMP in Great Britain is voluntary, however many retailers and processors are enforcing it for their producers. Adherence to the plan is also a compulsory element of the Red Tractor assurance scheme of which 95 % of milk producers are members (Red Tractor, 2023). Participation in the scheme does not involve any checks or requirements for farmers to actively reduce the level of JD in their herd, aside from a signed declaration which states that the vet and farmer have agreed on a plan to control the disease. This means farmers who underestimate the significance of the disease, may potentially be ignorant to the levels of JD on their farm, or are struggling to get JD under control can still sell their cattle on markets and also increase the amount of MAP in the environment. This worried one farmer who felt that 'unless it is made compulsory, everybody will not take it on board...They are under no restrictions at all regarding anything and so I think it is spreading around quite a lot' (Farmer 13). Another echoed this opinion stating 'if a herd has it, it's a big problem...it's the sort of thing you would need the likes of Red Tractor or your processor to really make you do one testing the year, or to give you some sort of incentive' (Farmer 15). However, the ability of farm accreditation schemes to effectively regulate farms was questioned by a veterinary professional who said that 'a few vets that kind of feel a bit exasperated that certain farmers are getting red tractor assurance when if it was up to the vet, there was no way they would have that' (Vet 11). As a result, some farmers wanted a certification scheme – 'It'd be nice to be able to say that they are Johnes free' (Farmer 13)

Making JD control, or at least JD testing, compulsory was supported by some of the veterinary professionals interviewed. A vet from Northern Ireland argued that 'it's not compulsory in Northern Ireland for [farmers] to do testing just yet, but possibly that's coming in... it would be great. We could be a bit more proactive about it, but I think that's a big hurdle' (Vet 11). More stringent rules for farmers were supported by a different vet who felt that 'the really disengaged ones without government or the milk buyers driving stuff has to be done. Some of those disinterested guys, I don't think any amount of trying helps. They need to be beaten with a stick, unfortunately, to get it done' (Vet 6)

3.5. Theme 4: vet-farmer relationships

The relationship between veterinarians and farmers is crucial to the successful management of JD as outlined in the introductory section (Robinson, 2020) - 'the expectation is and the requirement is, that they engage with their vets' (Vet 13). However, it was clear from the interviews with farmers and vets that often poor communication, farmer perceptions, and vets' own knowledge limited the fruitfulness of these relationships.

3.5.1. Vets not proactive on JD

One interviewee argued that 'I think the vets understand ... not all of the nuances of [Johnes] disease control, I think they probably get so disillusioned [and] ... put off pushing harder' (Vet 8). This finding is supported by other studies on veterinary advice where increased knowledge and training have been associated with proactiveness to discuss disease with farmers (Higgins et al., 2013; Svensson, 2018). In an English case study, Robinson (Robinson, 2020) had reported that not all veterinarians rank

JD top of their list of 'personal crusades'. Some farmers in our study also acknowledged that vets had not discussed JD with them. When asked if their vet recommends any JD control measures one farmer responded 'no, not really' (Farmer 7). Another farmer said that their 'vets previously just really weren't that interested or didn't have enough time to advise' (Farmer 1).

3.5.2. Vets don't understand farmer priorities

One of the vets interviewed noted that 'we're bad as vets talking about disease in silos instead of general biosecurity' (Vet 3). This tendency to focus on a single disease at a time, rather than considering other disease priorities, or more general biosecurity activities, frustrated farmers. Farmers felt that JD control was just 'another thing to add to a never-ending list which I can't keep on top of' (Farmer 9). Another stated that 'if you got me on the phone and said, 'your sole job is to manage Johnes', I could quite confidently and happily do that. But yeah, if you ask me to manage all the other bits at the same time there's a problem' (Farmer 2). Different communication strategies that consider all diseases and biosecurity as a single issue were desired by a vet who felt that to be more successful, they needed a plan that said 'feed these cows this, put these cows in this pen and don't always mention your Johnes' (Vet 4). Farmers in areas with high levels of TB felt that controlling TB was their priority and therefore did very little in terms of JD control 'because of TB, we've got a load of Johnes. We've probably got five or six Johnes dams' (Farmer 1).

Vets also need to consider the economic priorities of farmers. Due to the nature of JD infection, high yielding and healthy presenting cows can often be high priority culls as they pose significant transmission risk. However as stated by a farmer, 'people are kind of resistant to culling cows, which they think look extremely healthy, because I think sometimes you get a high Johnes positive cow and it's a high producer and you just would never expect it.' (Farmer 8).

3.5.3. Vet communication skills

The literature on veterinarian skills illustrates that communication is considered important by trainee vets (McDermott et al., 2015), but that extra training in motivational techniques, non-verbal communication, and tailoring advice is needed (Bard, 2022; MacGillivray, 2020). In our study about JD, when vets were asked in interviews and workshops about engaging farmers who were generally more resistant to introducing JD control measures, most of them said they relied on their own instinct and knowledge of the farmer to try and best persuade them. However, often vets felt that farmers 'think they know everything and won't be told what to do' (Vet 1) or 'there's a small group that just seem to be impossible to get through to' (Vet 5) or 'I often feel that farmers don't act on my advice on any subject' (Vet 8). Despite this, most of the vets interviewed had never received any formal training on how to communicate with difficult farmers – 'I wouldn't even know where to look to find any CPD or training and that sort of thing' (Vet 1), 'we never had any training in how to communicate with farmers' (Vet 9). When pressed further on what could be done to help them engage these farmers, five of the vets expressed a need for better communication training. 'it's something we've got to know, we've got to know how to talk to people about Johnes' (Vet 7) and 'we need more help to try and work out different personalities and how you can communicate to clients' (V10).

Poor communication from vets was also identified by the farmers interviewed – one said, 'I went up the vets yesterday for watery mouth stuff ... young vet went off on a tangent and give me a print out. Well, it's generalized, you know what I mean? Yeah. It's too much of a general information'. (Farmer 7). Vets also need to consider farmers' relationship with their cows when communicating. The nature of JD means that healthy looking and high yielding cows can often be considered a high-priority cull despite them not showing signs of disease. However, some farmers may have an emotional attachment to the cows; as one said, 'she's a bit of a pet, but she's, you know, she's been J5 for forever. And she's fat as a barrel. Yeah, never misses a beat. She's a high yielding cow.' (Farmer 10) which makes them resistant to culling.

4. Towards solutions for on-farm Johne's disease control behaviours

This study has identified four key themes that prevent farmers from implementing JD control measures on-farm – expectation management, space and economics, free-riding and farmer-vet communication. Elements of these themes have been identified as barriers to JD control before in other literature (Morrison and Rose, 2023) though our study was able to gather qualitative data from a high number of both dairy farmers and veterinary professionals as compared to previous literature. Bringing these themes together, this section will consider how they interact and how they relate to the wider literature on livestock disease control. This discussion is framed in solutions-focused sections aimed at addressing the barriers.

4.1. Farmer-vet communication and managing expectations

The first and third themes are closely linked since it is veterinarians that are often the key actor in helping farmers interpret tests and to participate in control schemes (barrier 1), which is in turn influenced by communication skills (barrier 3). Several studies on UK agriculture have found that vets are an information source for farmers on a variety of disease issues (Richens, 2015; Shortall, 2016; Shortall, 2022; Pate, 2023). Therefore, issues surrounding vet-farmer relationships may directly affect and exacerbate farmers lack of understanding of JD. The data in this study indicate that vet-farmer interactions around JD are negatively affected by elements of poor communication skills, a lack of vet knowledge preventing them from proactively raising JD with farmers, and vets' failure to acknowledge the competing priorities of their farmers. It was apparent from the data collected in this study that vets felt as though certain farmers were simply 'hard to reach' and therefore do not listen to their advice. This is a common perception of vets who often feel as though they are 'unable to convince their clients' (Lam, 2011), p. 8). As a result, vets may avoid discussing certain subjects with farmers who may receive less information on disease management. However, a study by Jansen et al. (Jansen, 2010) argues that the idea of 'hard to reach' farmers is a myth. The vets in our study self-identified a need for additional communication training to help them engage farmers in JD control, which in turn may help them reach farmers who have typically not listened to their advice or who may be preoccupied with other issues on their farm. Evidence shows that training vets to be conscious communicators and teaching them methods such as motivational interviewing can be an effective way of engaging 'hard to reach' clients (Bard, 2022; Lam, 2011). In a similar vein, farmers need to be willing to listen and collaborate with their vets and be able to effectively communicate their needs and desires if the farmer-vet relationship is to improve (Bard, 2019).

Inherent to good communication skills, a key element in building effective vet-farmer relationships is understanding the competing priorities and motivations of farmers. Previous attempts at achieving this have involved tailoring advice based on-farm risk analyses (IDF, 2012). Bard et al. (Bard, 2019) finds that veterinarians could learn how to tailor advice in line with farmers' motivations and worldviews better. A study of Swedish farmers also identified differing priorities as a reason for nonadherence to veterinary advice (Svensson, 2019). In their study, Svensson et al. (Svensson, 2019) argued that the severity of the disease, the needs of the farmer and the farmers attachment to animals, amongst other things, affected how much a farmer prioritised disease control. These factors were also noted as important to farmers in this study. Understanding the different priorities, motivations and circumstances is therefore crucial to understanding how to communicate with farmers and help them make biosecurity decisions. Vets need to understand their clients and focus on specific aspects of JD control, whether it is herd health, economics or sustainability to ensure they engage them (Bard, 2022). Vets could also consider how they speak about the wider context of biosecurity and help farmers prioritise certain actions which indirectly

help prevent and control other diseases (besides JD).

It was clear from the data gathered in this study that farmers were seeking an end-goal to JD and were demotivated by the feeling that it could never be achieved. Vets themselves talked about JD 'eradication' in their interviews. However, the control programmes across the UK focus on controlling the disease and this should be clearly communicated to farmers to manage expectations and prevent farmers becoming frustrated. It has previously been noted that as part of communication vets need to be trained to manage farmer expectations and this study supports these claims (Bradley et al., 2011; Grant et al., 2023). Dairy farmers are familiar with disease control, as opposed to eradication, for example mastitis (Green, 2011) and bovine viral diarrhoea (AHDB, 2023). It is therefore recommended that communication training for vets examines how control of these diseases is communicated to farmers so that a similar approach can be taken for JD.

With regards to the first barrier of expectation management, the vet-farmer relationship is important in helping farmers interpret JD tests results and making JD culling and segregation decisions. Farmers felt that often the milk ELISA results were too complicated and that the JD tracker could be confusing. It is a key component of strategies in all parts of the UK that farmers and vets work as a team, with regular reviews and joint analysis of results (Orpin et al., 2020). Whilst understanding the data can be difficult for farmers, simplifying the milk ELISA data can result in incorrect decision making. Therefore, again, it is important vets have better communication training in order to engage and build relationships with these farmers to work together to interpret data.

4.2. Addressing free-riding

The second barrier related to the problem of free-riding, which may be tackled through control scheme design. JD control schemes are almost always voluntary (Sorge, 2010; McAloon, 2016; Hop et al., 2011) which creates the potential for free-riders. This means that the success of the programmes ultimately depends on the self-motivation of farmers (Robinson, 2020). It is clear from this study and other studies on the issue that some farmers are currently not motivated to join the schemes and control JD, creating concerns over free-riders. Therefore, more action may be required by control schemes to encourage participation and reduce free riders, yet there may also be disadvantages with disease control schemes that are mandatory. For example, the compulsory bovine TB control programme in Great Britain has been met with overwhelmingly negative responses from farmers, who have suffered economically and mentally from its implementation (Hamilton et al., 2019). Despite being compulsory, the bovine TB programme has not been successful in eradicating the infection (Allen et al., 2018) resulting in disengagement and resistance to other forms of compulsory disease control.

One of the main concerns regarding free-riding was the likelihood of buying in JD positive cattle. Certification schemes can help overcome this risk. A study on certification schemes for other dairy diseases, such as bovine TB have also found a desire amongst farmers for third-party certification of disease risk in their herd (Little and Edge, 2017). The Netherlands introduced a certification programme for JD over 20 years ago, yet uptake of the scheme remained low (Weber et al., 2007). It is suggested that additional motivators were needed for farmers to participate, for example a premium on the milk price for certified low-risk farmers (Weber et al., 2007). However, issues surrounding the long incubation period of the disease and silent infections can pose challenges to a certification scheme. There may also be benefit in training and educating farmers so they are aware of the risks associated with buying-in cattle and how they can minimise them. The NJMP in Great Britain most likely needs to consider more incentives to engage farmers if it is to succeed in overcoming the issues of free riding.

4.3. Economic incentives, including for farm infrastructure

Building on the need to motivate farmers to take action, the use of financial incentives as well as ‘sticks’ could be more widely considered. In addition to improving knowledge of JD and motivating farmers to test and take action, efforts are needed to help farmers. For spacing, new farm infrastructure may be required and this needs the wider use of policy instruments such as grant support. Support for new infrastructure and putting other measures in place to improve good biosecurity in general goes beyond the remit of JD control programmes and should be seen as part of wider activities to control other diseases by implementing good practice.

5. Conclusion

Engaging with both farmers and veterinarians to understand decision-making around the issue of JD control is vital to gather a clear picture on challenges to, and solutions for, better management. Building on a relatively limited set of empirical studies that had engaged both groups, our research finds that the challenges of expectation management (linked to farmer knowledge and understanding of the disease), space and economics, free-riding, and complex farmer-vet relationships have an impact on JD control on-farm. Whilst there may be scientific solutions for some of the challenges, most notably addressing the reliability of testing, improving JD control will predominantly need to address social and behavioural aspects of decision-making. Solutions focused on improving vet communication skills, managing farmer expectations, and incentivising farmers to implement on-farm controls are key recommendations to improve the control of JD in dairy cattle, both in the UK and elsewhere.

CRedit authorship contribution statement

David Christian Rose: Writing – review & editing, Writing – original draft, Supervision, Methodology, Funding acquisition, Data curation, Conceptualization. **Emma Nicole Taylor:** Writing – review & editing, Methodology, Investigation. **Sam Strain:** Methodology, Investigation, Conceptualization. **Peter Guy Orpin:** Writing – review & editing, Methodology, Investigation. **James Hanks:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Rosie Morrison:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

None.

Data Availability

Interview and workshop data are available here in line with UKRI data archiving standards - <https://doi.org/10.5255/UKDA-SN-857338>.

Acknowledgements

We acknowledge funding from the Biotechnology and Biological Sciences Research Council as part of their call to develop solutions for endemic livestock disease (grant code BB/W020483/1). We thank Nick Wheelhouse and Abel Ekiri for their input into the wider grant. We thank all veterinary professionals and farmers who took part in our research. We thank two anonymous reviewers and the editor for comments.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.prevetmed.2024.106295](https://doi.org/10.1016/j.prevetmed.2024.106295).

References

- Action Johnne's, 2020a. National Johnne's Management Plan – Phase 2. [Online] Available at: <https://actionjohnnesuk.org/latest-news/national-johnnes-management-plan-phase-2/> [Accessed November 2023].
- Action Johnne's, 2020b. National Johnne's Management Plan. [Online] Available at: https://actionjohnnesuk.org/wp-content/uploads/2020/01/national-johnnes-management-plan-2020_FINAL-1.pdf [Accessed November 2023].
- Action Johnne's Practical Use of the NJMP Johnne Progress Tracker – Pete Orpin Session 1 (Part 1 of 4). [Online] Available at: <https://actionjohnnesuk.org/videos/> [Accessed 2023].
- Action Johnne's, 2023. The National Johnne's Management Plan. [Online] Available at: <https://actionjohnnesuk.org/the-njmp/> [Accessed August 2023].
- AHDB, 2023. BVD Free England. [Online] Available at: <https://ahdb.org.uk/bvdfree-england> [Accessed 2024].
- AHDB (2021). Ruminant Health & Welfare Cattle and sheep health and welfare priorities – a ‘grassroots’ survey across the four nations of the UK MAY 2021. <https://ruminanthw.org.uk/wp-content/uploads/2021/05/Cattle-and-sheep-HW-priorities-survey-May-2021-FINAL.pdf>.
- Allen, A.R., Skuce, R.A., Byrne, A.W., 2018. Bovine Tuberculosis in Britain and Ireland – a perfect storm? the confluence of potential ecological and epidemiological impediments to controlling a chronic infectious disease. *Front Vet. Sci.* 5, 109.
- Atkinson, O., 2010. The role of the vet in knowledge transfer in the dairy industry, s.l.: Nuffield Farming Scholarships Trust.
- Bakker, D., 2013. Danish designs on the control of bovine paratuberculosis. *Vet. J.*
- Bard, A.M., et al., 2019. To change or not to change? Veterinarian and farmer perceptions of relational factors influencing the enactment of veterinary advice on dairy farms in the United Kingdom. *J. Dairy Sci.* 102 (11).
- Bard, A.M., et al., 2022. Veterinary communication can influence farmer change talk and can be modified following brief motivational interviewing training. *PLOS ONE*.
- Barkema, H., et al., 2018. Lessons learned from the Canadian Johnne's disease programs. *WCDS Adv. Dairy Technol.* Volume 30.
- Barwell, R., 2022. Johnne's disease management in Australia: update. Dublin, Bulletin of the International Dairy Federation.
- Beasley, L., et al., 2011. Prevalence of Johnne's disease among cattle in Orkney. *Vet. Rec.* 169, 50.
- Bradley, A.J., Breen, J.E., Hudson, C.D., Green, M.J., 2011. Monitoring Treatment Outcomes: Understanding and Managing Expectations. In: Hogeveen, H., Lam, T. (Eds.), *Udder Health and Communication*. Wageningen Academic Publishers, Wageningen.
- Collins, M., Eggleston, V., Manning, E., 2010. Successful control of Johnne's disease in nine dairy herds: results of a six-year field trial. *J. Dairy Sci.* 93 (4), 1638–1643.
- Donat, K., Eisenberg, S. (2023). Paratuberculosis control in Germany: regional differences in MAP prevalence ask for different control approaches, pages 12-21. *donIn International Dairy Federation. Proceedings of the 7th and 8th IDF Paratuberculosis For a (Bulletin of the IDF No. 523/2023)*.
- Espejo, L., et al., 2015. Evaluation of performance of bacterial culture of feces and serum ELISA across stages of Johnne's disease in cattle using a Bayesian latent class model. *J. Dairy Sci.* 98 (11).
- Grant, N., Buchanan, H., Brennan, M.L., 2023. Factors within A veterinarian-cattle farmer relationship that may impact on biosecurity being carried out on farms: an exploratory study. *Vet. Sci.* 10, 7.
- Green, M.J., et al., 2011. National Mastitis Control Schemes: Experiences from Implementation of A Nationwide Scheme in Great Britain. In: Hogeveen, H., Lam, T. (Eds.), *Udder Health and Communication*. Wageningen Academic Publishers, Wageningen.
- Hamilton, L., Evans, N., Allcock, J., 2019. “I don't go to Meetings”: understanding farmer perspectives on bovine TB and biosecurity training. *VetRecord* 184, 13.
- Higgins, H.M., Huxley, J.N., Wapenaar, W., Green, M.J., 2013. Proactive dairy cattle disease control in the UK: veterinary surgeons' involvement and associated characteristics. *VetRecord* 173, 10.
- Hop, G., Velthuis, A., Frankena, K., 2011. Assessing Dutch farmers' incentives to join a voluntary Johnne's disease programme. *NJAS - Wagening. J. Life Sci.* 58 (1-2), 57–64.
- Horan, L., Mee, J.F., Field, N.L., et al., 2023. Farmers' knowledge of Johnne's disease and opinions of the Irish Johnne's Control Programme: results of an online survey answered mostly by young farmers. *Ir Vet J* 76 (31). <https://doi.org/10.1186/s13620-023-00260-x>.
- IDF, 2012. *Proceedings from the 3rd paraTB forum. IDF, Sydney.*
- IDF, 2023. *Bulletin of the IDF N° 523/2023: Proceedings of the 7th and 8th IDF Paratuberculosis Fora.* Dublin, IDF Paratuberculosis Fora.
- Imada, J., et al., 2022. Descriptive analysis of the changes in Johnne's disease management practices on Ontario dairy farms through repeat risk assessment. *J. Dairy Sci.* 105 (11).
- Imada, L.J.B., Roche, S.M., Thaivalappil, A., Bauman, C.A., Kelton, D.F., 2023. Investigating Ontario dairy farmers motivations and barriers to the adoption of biosecurity and Johnne's control practices. *Journal of Dairy Science* 106 (4), 2449–2460. <https://doi.org/10.3168/jds.2022-22528>.
- Jansen, J., et al., 2010. Debunking the myth of the hard-to-reach farmer: effective communication on udder health. *J. Dairy Sci.* 93 (3), 1296–1306.
- Jordan, A., et al., 2020. Johnne's disease in Irish dairy herds: considerations for an effective national control programme. *Ir. Vet. J.* 73 (18).
- Khol, J.L. (2023). Current activities in the surveillance and control of MAP in Austria, pages 8-11. In *International Dairy Federation. Proceedings of the 7th and 8th IDF Paratuberculosis For a (Bulletin of the IDF No. 523/2023)*.
- Kirkeby, C., et al., 2016. Simulating the epidemiological and economic impact of paratuberculosis control actions in dairy cattle. *Front. Vet. Sci.* 3 (90).

- Krömker, V. & Leimbach, S., 2017. Mastitis treatment—Reduction in antibiotic usage in dairy cows. *Reproduction in domestic animals*.
- Lam, T., et al., 2011. What veterinarians need to know about communication to optimise their role as advisors on udder health in dairy herds. *N. Z. Vet. J.* 59 (1).
- Little, R., Edge, S., 2017. Developing a risk-based trading scheme for cattle in England: farmer perspectives on managing trading risk for bovine tuberculosis. *VetRecord* 180, 6.
- Lumivero. 2023. NVivo (Version 13). www.lumivero.com.
- MacGillivray, F., et al., 2020. Can communication in farm animal veterinary practice be improved through a focus on the non-verbal element? A clinical forum. *Livestock Volume* 25.
- McAloon, C.G., et al., 2016. Bayesian estimation of prevalence of paratuberculosis in dairy herds enrolled in a voluntary Johne's disease control programme in Ireland. *Prev. Vet. Med.* 128 (1), 95–100.
- McAloon, Conor G., Macken-Walsh, Áine, Moran, Lisa, Whyte, Paul, More, Simon J., O'Grady, Luke, Doherty, Michael L., 2017. Johne's disease in the eyes of Irish cattle farmers: A qualitative narrative research approach to understanding implications for disease management. *Preventive Veterinary Medicine* 141, 7–13. <https://doi.org/10.1016/j.prevetmed.2017.04.001>.
- Michael P. McDermott, Victoria A. Tischler, Malcolm A. Cobb, Iain J. Robbé, Rachel S. Dean. (2015). *Veterinarian–Client Communication Skills: Current State, Relevance, and Opportunities for Improvement*. 42 Issue (4), 305-314. <https://doi.org/10.3138/jvme.0115-006R>.
- Morrison, R., Rose, D.C., 2023. Factors that influence dairy farmers' decisions to implement Johne's Disease control practices: a systematic review. *Prev. Vet. Med.* Volume 220.
- Naylor, R., Hamilton-Webb, A., Little, R., Maye, D., 2018. The 'Good Farmer': farmer identities and the control of exotic livestock disease in England. *Sociol. Rural.* 58 (1), 2018.
- Nielsen, S., 2009. Use of diagnostics for risk-based control of paratuberculosis in dairy herds. *Practice* 31 (4).
- Norma, A. et al. (2023). Bovine paratuberculosis in Italy: review of the national guidelines after eight years of their application, pages 22-23. In *International Dairy Federation. Proceedings of the 7th and 8th IDF Paratuberculosis For a* (Bulletin of the IDF No. 523/2023).
- Olsen, I., Sigurðardóttir, Ó.G., Djønné, B., 2002. Paratuberculosis with special reference to cattle A review. *Veterinary Quarterly* 24 (1), 12–28. <https://doi.org/10.1080/01652176.2002.9695120>.
- Orpin, P., 2017. Dairy UK Johne's survey – winning farmer engagement. *Cattle Practice*.
- Orpin, P., Sibley, D., Bond, K., 2020. Johne's disease in dairy herds 1. *Underst. Dis. Pract.* 42 (1), 3–64.
- Orpin, P., Sibley, D., Bond, K., 2020. Johne's disease in dairy herds 2. Effective control using the National Johne's Management Plan. *Practice* 42 (3).
- Orpin, P., Sibley, D. & Taylor, N., 2021. An update on the UK National Johne's Management Plan. [Online] Available at: <https://johnes.org/wp-content/uploads/2021/09/An-update-on-the-UK-NJMP-IDF-1-Final.pdf>.
- Pate, L.A., et al., 2023. Factors influencing Scottish dairy farmers' antibiotic use. *Vet. Rec.* 192 (12).
- Rasmussen, P., et al., 2021. Estimation of the value of Johne's disease (paratuberculosis) control to Canadian dairy producers. *Prev. Vet. Med.*
- Red Tractor, 2023. *Red Tractor Standards*. [Online] Available at: <https://redtractor.org.uk/our-standards/> [Accessed 2024].
- Richens, I.F., et al., 2015. Farmers' perception of the role of veterinary surgeons in vaccination strategies on British dairy farms. *Vet. Rec.* 117 (18).
- Ritter, C., et al., 2016. Dairy farmers' perceptions toward the implementation of on-farm Johne's disease prevention and control strategies. *Dairy J. Sci.* 99 (11).
- Ritter, C., et al., 2017. Invited review: determinants of farmers' adoption of management-based strategies for infectious disease prevention and control Author links open overlay panel. *J. Dairy Sci.* 100 (5).
- Robinson, P.A., 2020. They've got to be testing and doing something about it': farmer and veterinarian views on drivers for Johne's disease control in dairy herds in England. *Prev. Vet. Med.* Volume 182.
- Shortall, O., et al., 2016. Broken biosecurity? Veterinarians' framing of biosecurity on dairy farms in England. *Prev. Vet. Med.* Volume 132, 20–31.
- Shortall, O., 2022. Lessons learned for animal health governance from bovine viral diarrhoea eradication schemes in Scotland and Ireland. *Front. Vet. Sci.* Volume 9.
- Sorge, U., et al., 2010. Attitudes of Canadian dairy farmers toward a voluntary Johne's disease control program. *J. Dairy Sci.* 93 (4), 1491–1499.
- Strain, S., Verner, S., Campbell, E., Hodnik, J.J., Santman-Berends, I.M.G.A., 2021. The Northern Ireland control programmes for infectious cattle diseases not regulated by the EU. *Front. Vet. Sci.* 8 <https://doi.org/10.3389/fvets.2021.694197>.
- Svensson, C., et al., 2018. Veterinary herd health management—experience among farmers and farm managers in Swedish dairy production. *Prev. Vet. Med.* Volume 115, 45–52.
- Svensson, C., et al., 2019. Trust, feasibility, and priorities influence Swedish dairy farmers' adherence and nonadherence to veterinary advice. *J. Dairy Sci.* 102 (11).
- Weber, M., Nielen, M., Verhoeff, J. & Stegeman, J., 2007. Certification and surveillance programmes for paratuberculosis in dairy herds. Wageningen, Dutch society for veterinary epidemiology and economics.
- Whittington, R., et al., 2019. Control of paratuberculosis: who, why and how. A review of 48 countries. *BMC Vet. Res.* 15 (1).
- Wolf, R., Barkema, H., Buck, J., Orsel, K., 2015. Factors affecting management changes on farms participating in a Johne's disease control program. *J. Dairy Sci.* Volume 98, 7784–7796.