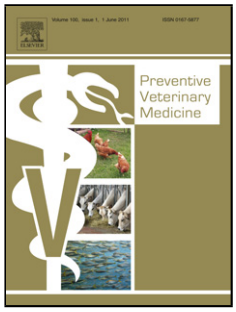

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Abstract

The need to move towards Selective Dry Cow Therapy (SDCT) has become increasingly pertinent as a means to reduce the use of antibiotics in the dairy sector. With the EU 2022 ban on prophylactic antibiotics at drying off, practices on some farms will need to drastically change. In Ireland, one particular challenge to the sector-wide transition to SDCT is the lack of widespread uptake of milk recording across dairy farms, a decision support tool which can support mastitis control and help identify cows to select for SDCT. The current study examined readiness to engage in milk recording amongst Irish dairy farmers, and specifically investigated the role of mastitis risk perceptions in shaping farmers' readiness. The study explores the multifaceted nature of risk perception as a construct shaping farmers' attitudes. An online survey was carried out with 197 Irish dairy farmers exploring their attitudes towards mastitis and milk recording. A cluster analysis classified farmers according to their mastitis risk perceptions, with 3 segments identified with differing risk perception profiles. Elevated mastitis risk perceptions were linked to an increased readiness to milk record. However, this relationship was not universal across all farmers. One segment of farmers in the current study maintain low mastitis risk perceptions and remain unmotivated to engage in milk recording. The study concludes that targeted risk communication strategies related to mastitis and milk recording are needed to encourage the move towards SDCT and reduced AMR. Results suggest that the *types* of risk communication strategies – message framing and two-way risk

communication – should reflect farmers' *types* of mastitis risk perceptions to have the most effective impact on milk recording uptake.

Keywords: antimicrobial use; animal health; behavioural intentions; mastitis; milk recording; multifaceted risk perceptions

1. Introduction

Identified as a major 21st century global health challenge (World Health Organization, 2015), antimicrobial resistance (AMR) poses a key public health threat as well as contributing to large socioeconomic costs worldwide (Speksnijder et al., 2015). Inappropriate and overuse of antimicrobial drugs (such as antibiotics) have resulted in antimicrobial-resistant bacteria which can be transmitted between animals and humans through the food chain, direct contact and the environment (Manyi-Loh et al., 2018). This results in a significant loss of effectiveness of this vital medication when used to treat illness in animal and human health (World Health Organization, 2015). Although antimicrobials are a critical tool for preserving the health and welfare of sick farm animals, the agricultural sector has been identified as an area in which they need to be used more prudently (Tang et al., 2017). Antimicrobials are often used as a means of preventing disease without a clinical diagnosis *(prophylactic use)* or given to the entire herd when only a proportion show clinical signs of disease *(metaphylactic use)* (More, 2020). Actions can be taken to help reduce the need for, and use of antibiotics within the industry, with the expectation of further positive effects on the instance of AMR in humans and animals (Scott et al., 2018).

1.1. The role of milk recording in effective mastitis control and reduced antibiotic use

With respect to the dairy sector, a number of urgent actions are needed at veterinarian and farm level to reduce antimicrobial usage. Mastitis represents one of the main production diseases in dairy cattle (Geary et al., 2012). It is caused by a bacterial infection, which leads to elevated Somatic Cell Counts (SCC). An SCC threshold of above 200,000 cells/ml indicates a high risk of mastitis that can be subclinical and clinical (International Dairy Federation, 1997; Geary et al., 2012). The risk of mastitis occurrence is particularly acute at the drying off stage. In such instance, the most common procedure for dealing with the disease is through the application of blanket dry cow therapy (BDCT) (More et al., 2017). BDCT involves the use of antimicrobials on the entire herd to reduce the incidence of mastitis (prophylactic use). However, with the increasing threat of AMR, the use of BDCT has come into question given that this practice is

a preventative measure that does not make a distinction in the administration of antimicrobials to sick and healthy animals.

In an effort to reduce unnecessary antibiotic use and encourage more responsible use of antibiotics, there is now a movement towards a more sustainable strategy of selective dry cow therapy (SDCT). Indeed, the European Union (EU) will introduce new regulations to ban the prophylactic use of antibiotics (as in BDCT), which will come into effect in 2022 (European Union, 2018b; European Union, 2018a). SDCT means that rather than administering antibiotics to the entire herd at the drying off stage, only cows showing clinical signs of udder infection or have an individual SCC above the 200,000 threshold will receive treatment. This move to SDCT implies a change in practice for many EU farmers, as well as a shift in advice provided to them in how to best manage mastitis.

One of the key challenges to implementing SDCT is that this practice first requires some form of individual cow-level identification system, such as milk recording. Having data on individual/animal specific SCC levels as a result of milk recording allows farmers to identify infected cows, when mastitis is subclinical or when cows have yet to develop any visible symptoms. In Ireland, milk recording is recommended to farmers as a good practice in dairy farming. Irish farmers are advised to use milk recording results to identify cows that qualify for SDCT (Teagasc, 2020, Animal Health Ireland, 2018). The message communicated to Irish farmers is that engaging in milk recording can help farmers to move towards SDCT by assisting them in identifying cows which need antibiotic treatment and thereafter monitor the success of dry cow treatment and management (Dufour et al., 2011). Moreover, it has been shown that milk recording provides information to farmers that helps them to reduce bulk tank SCC (Balaine et al., 2020). In this way, milk recording is a decision support tool to assist effective mastitis control and reduced antibiotic use.

1.2. Farmers' readiness to engage in milk recording

Understanding the barriers to the uptake of a mastitis management practice such as milk recording is an important task, and is hence addressed in the current study. We focus on Irish dairy farms for four main reasons. First, with EU-wide restrictions over the prophylactic use of antimicrobials and BDCT incoming by 2022, farmer engagement with milk recording and SDCT will become essential across Member States. Second, milk recording rates in Ireland are particularly low relative to some of their EU counterparts. For example, in 2018, only 51% of the national herd in Ireland had undergone milk recording; this is in comparison to countries with much higher rates such as Denmark (91%); Germany (88%); Norway (94%); and The

Netherlands (90%) (ICAR, 2019). This suggests that the move towards SDCT may involve a larger shift in practice in Ireland than in other EU countries. Third, as yet, only one study to date (Dillon et al., 2018) has explored the extent to which Irish dairy farmers are engaged in and motivated to take up mastitis management practices and the factors which may play a part in shaping their attitudes and behaviours towards them. Lastly, More et al. (2017) found that during the last two decades, there has been an increase in the use of Highest Priority Critically Important Antimicrobials (including 3rd and 4th generation cephalosporins) in intramammary tubes for both lactation and DCT.

Currently, there are low levels of engagement in milk recording on Irish farms (ICAR, 2019). Milk recording provides cow-level information about milk quality (fat and protein contents and SCC levels) and cow genetic merit. It is a decision-making tool with multiple applications, including mastitis monitoring, and culling and breeding decisions. Milk recording is an investment incurring costs (e.g. purchasing the equipment or services needed to support it) and perceived labour and time resources (Dillon et al., 2018). Meanwhile, the tangible financial, health and farm production benefits of milk recording are gained incrementally over a period of time, and in some cases are not always distinctly observable (e.g. greater disease resistance in the herd). While some benefits can be achieved more quickly (e.g. the herd health impact of taking action on SCC readings), others occur over a much longer period of time (e.g. the impact of decisions related to breeding). As well as this, the SCC data gathered from milk recording requires action by farmers on animals displaying elevated SCC in order to reap the benefits of milk recording and reduce the likelihood and/or incidence of mastitis. Therefore, along with engaging in the uptake of milk recording, the process requires a reactive response from farmers in order to effectively manage mastitis through SDCT.

Research has demonstrated the economic benefits of reducing mastitis on Irish dairy farms (Geary et al., 2012) and of taking up milk recording (Balaine et al., 2020). However, factors beyond cost-saving shape farmers' decisions to engage in recommended farm practices to manage mastitis (Valeeva et al., 2007). Despite the economic benefits of milk recording, changing long-established on-farm practices can be challenging for Irish farmers as they may operate under routine inertia, whereby they do not deviate from their normal routine unless there is a visible indication of infection in the herd (Dillon et al., 2018). Research in international settings has found that farmers cope with mastitis incidence in different ways favouring either reactionary (e.g. taking actions to mitigate spread of existing illness) or precautionary approaches (e.g. taking actions to prevent illness ever occurring) (Hansson and Lagerkvist, 2014). Similar findings have been reported in the Irish context by Dillon et al.

(2018) and may explain, in part, the ambivalence of Irish dairy farmers towards milk recording. Farmers' preferred mastitis control options tend to be influenced by their individual risk perceptions including, for example, perceived incidence in their herd and perceived risk of disease outbreak (Jansen et al., 2009; Hansson and Lagerkvist, 2014; Dillon et al., 2018). In the Irish context, (Dillon et al., 2018) found that a farmer's mastitis risk perception is likely to play an important role in shaping farmers' attitudes towards milk recording; the current study builds on this research by taking a more in-depth and multifaceted approach to defining and measuring risk perception in the context of mastitis and milk recording.

1.3. Defining and measuring risk perception

Risk perception has been operationalized in different ways in the literature, signalling the many and diverse academic disciplines and settings in which the construct is used (Wilson et al., 2019). It is also reflective of the extremely interdisciplinary field of risk communication research, which arguably is the birthplace of risk perception as a defined construct (Rickard, 2019). The epistemological change in how risk and risk judgements are viewed as constructs is the common thread tying together this diverse literature. Up until the 1980s, risk assessments were wholly objective processes and any discrepancies in 'lay' risk judgements were viewed as irrational or illogical (Balog-Way et al., 2020). However, as the contributions from social and psychological scientists to the risk communication literature grew, so did the acknowledgement that risk judgements are a "by-product of social, cultural and psychological influences" (McComas, 2006). It is from this collective research that risk perception became an increasingly central construct in risk communication literature (Fischoff, 1995).

Although there is widespread agreement on the importance of the construct, there has been less unanimity on how to operationalize and measure risk perception. In a recent review of the literature, Wilson et al. (2019) found that risk perception measures tend to be generic in nature (e.g. "How risky is X?"), or concentrate solely on deliberative judgements of probability. The authors also noted two main approaches to risk perception, i.e., one which focuses on the consequences of a risk (e.g. "how serious are the consequences of X?") (Sandman, 2004) and the other which focuses on affective components of the risk (e.g. "how does X make you feel?") (Slovic et al., 2004). As such, it is argued that risk perception as a construct is best operationalised and measured as a multifaceted construct (Ferrer et al., 2016; Wilson et al., 2019). This multifaceted approach to measuring risk perception is mirrored in numerous social psychological health behaviour models where risk and threat assessments are also viewed as a central construct (Rickard, 2019). Models such as the health belief model (Rosenstock et al.,

1988) and protection motivation theory (Rogers, 1983) measure both perceived susceptibility (likelihood) and perceived severity (impact) of a risk, with protection motivation theory also assessing efficacy of coping responses as part of threat assessment.

1.4. Mastitis risk perception

It is known that individual risk perceptions about animal disease impact on a farmer's behaviour with respect to animal health management (Sok et al., 2018). Indeed, research suggests that one of the challenges to encouraging farmers to implement disease control practices is that some farmers will not perceive diseases to be a serious threat to their individual farms and as a result will not be motivated to undertake preventative behaviour (Kristensen and Jakobsen, 2011; Mankad, 2016). While previous work has focused on understanding what role farmers' mastitis risk perceptions can play in influencing their decisions to take action to reduce its spread (Hansson and Lagerkvist, 2014), there has been less research exploring how mastitis risk perception may be associated with farmers' willingness to engage with milk recording specifically. Based on related research in the general animal health and mastitis literature, it would be expected that farmers with higher risk perceptions are more likely to take action to mitigate their risk exposure (Kristensen and Jakobsen, 2011; Hansson and Lagerkvist, 2014; Mankad, 2016; Sok et al., 2018). As milk recording is a recommended means of reducing the risk of mastitis incidence, we propose that farmers with higher mastitis risk perceptions are likely to be more interested and willing to engage in milk recording**.** Drawing on the previously cited collective work on defining risk perception, we define mastitis risk perception as a multifaceted construct comprised of deliberative (or probabilistic), consequential and affective components: (1) *perceived likelihood* of a mastitis outbreak, (2) *perceived impact* of a mastitis outbreak; and (3) *perceived ability to control* a mastitis outbreak. This multifaceted definition informed the study design. This study has two main objectives: 1) to profile Irish dairy farmers based on their mastitis risk perceptions and 2) to explore how these profiles are linked to farmers' interest and intentions to engage in milk recording.

2. Material and Methods

2.1. Survey Design

A cross-sectional quantitative survey was designed to explore farmers' perceptions of mastitis risk and attitudes towards milk recording. Mastitis risk perception was measured using the previously outlined multifaceted definition through three survey items. Two of these items were taken from van Winsen et al. (2016); on 5-point interval scales, participants were asked

to rate the perceived likelihood (very unlikely – very likely) and perceived negative impact (very small impact – very big impact) of a serious mastitis outbreak on their farms. The third item was based on Valeeva et al. (2007) and measured participants' perceived ability to control a serious mastitis outbreak on their farm on a 5-point interval scale (it would be very difficult – it would be very easy). We did not define what a 'serious mastitis outbreak' was in the survey as every farmer is likely to define it in different ways. Defining a 'serious outbreak' from a technical or expert perspective would have imposed views as to what constitutes a serious outbreak. Instead, farmers could answer the risk perception questions in accordance with their interpretation of what a 'serious outbreak' is, based on their own situation, experiences or beliefs.

Farmers' current interest in engaging in milk recording was measured on a 5-point scale (extremely interested – not at all interested). Farmers' behavioural intentions to engage in milk recording was measured by having farmers select one of the following response options: *I intend to begin milk recording in the next month; I intend to begin milk recording before the end of the year*; *I intend to begin milk recording in 2020*; *I have no intention to begin milk recording*.

The survey also included questions on socio-demographic and farm demographic attributes: gender, age, marital status, number living in household, level of agricultural education; and farm characteristics: herd size (number of cows), farm size (number of acres), farm location, labour availability, discussion group membership, bulk tank SCC, and availability of successor for the farm.

The survey was piloted with farmers, animal health professionals, and social scientists (n = 5) to check ease and clarity of interpretation of the survey items. Some minor changes were made to the wording of the survey as a result.

2.2. Data collection

The survey was carried out online between August and October 2019 with dairy farmers in the Republic of Ireland who do not currently milk record. It was administered to dairy farmers via a number of intermediaries including four of the main milk co-operatives in Ireland and a large breeding organisation. The questionnaire could be accessed online through participants' smartphone device or personal computer. Using a combination of e-mails and text messages, the intermediaries sent a direct invitation to farmers in their databases who were not currently milk recording. It was scripted using a survey software (LimeSurvey GmbH, Hamburg, Germany). The introduction page of the survey provided an overview of the study to

participants, as well as information about data privacy and anonymity before requesting their informed consent. At the end of the survey, participants were given a list of websites which they could access for further information on milk recording. The survey took, on average, 10 minutes to complete.

2.3. Analysis plan

In total, 417 participants clicked into the survey; 151 participants did not go further than the introductory page and 66 participants dropped out of the survey along the way. 197 participants completed the survey and thus constitute the final sample. This reflects a return rate of 47%. The demographic break-down of the final sample (n = 197) is presented in Table 1. Data were exported from LimeSurvey in excel format and imported into SPSS. All statistical analyses were carried out using SPSS for Windows, version 24.0 (SPSS Inc., Chicago, IL, USA) and based on guidelines for social science statistical analyses (Norman, 2010). As the survey was relatively short and completed online and dealt with a non-sensitive topic, a forced answering option was employed through the survey software. This meant that the respondent had to answer each question in order to proceed through the survey. As a result, there was no missing data for the final sample of participants who completed the survey. Data cleaning was carried out. Responses for each of the risk perception items were assigned values: perceived likelihood (very unlikely = 1; very likely = 5); perceived negative impact (very small impact = 1; very big impact = 5); perceived ability to control (it would be very difficult = 1; it would be very easy = 5). Responses for current interest in engaging in milk recording were assigned values (extremely interested = 1; not at all interested = 5). Based on low frequencies for the first 2 categories (*I intend to begin milk recording in the next month; I intend to begin milk recording before the end of the year*), the milk recording behavioural intention variable was re-coded into a binary variable with two levels labelled: *I intend to begin milk recording* (1)*; I do not intend to begin milk recording* (2). The level "*I intend to begin milk recording*" included the original first 3 categories (*I intend to begin milk recording in the next month; I intend to begin milk recording before the end of the year*; *I intend to begin milk recording in 2020*).

The first objective of the analysis plan was to classify farmers according to their mastitis risk perceptions. Groups of farmers with similar beliefs about the risks posed by mastitis were identified by carrying out a cluster analysis. For the cluster analysis, the three risk perception variables were included as cluster variates: (1) farmers' *perceived likelihood* of a mastitis outbreak on their farm, (2) farmers' *perceived impact* of a mastitis outbreak on their farm; and (3) farmers' *perceived ability to control* a mastitis outbreak on their farm. The mean scores for

each risk perception variable were used as the cluster variates. Examination of the correlation matrix revealed the absence of any substantial multicollinearity between the cluster variates: correlations between the three risk perception variables were sufficiently low ($r < .4$ in all cases) and the variance inflation factor (VIF) scores were all less than the recommended cut-off of 10 (range: 1.12–1.26). A hierarchical cluster analysis using Ward's (1963) minimum variance method was carried out to determine the optimal number of segments. Squared Euclidean distance was selected as the distance measure. Based on recommendations by Hair et al., (2010), the optimal cluster solution was selected following an investigation of the agglomeration schedule, a visual inspection of the dendrogram, and a profiling of different cluster solutions against the cluster variates.

The second objective was to explore whether different risk perception profiles were linked to different milk recording attitudes. In that regard, one-way ANOVAs were used to explore differences between the segment groups on interest in milk recording, herd size, and farm size. Chi-squared tests were used to explore differences between the segments on behavioural intentions to engage in milk recording; average bulk tank SCC; age; discussion group member; and primary source of agricultural advice.

3. Results

3.1. Cluster analysis

The three-cluster solution provided the most distinct and conceptually meaningful clustering of participants. Table 2 shows the resulting risk perception profiles for the three segments, while Figure 1 shows a visual representation of how the three segments compare across the three risk perception items.

3.1.1. Segment 1: 'Black swan' concern of mastitis

The majority of participants (42.6% of the sample) resided in Segment 1. Participants in this segment had lower than average perceptions about the likelihood of a serious mastitis outbreak happening on their farm. However, they held the highest level of concern about the negative impact that a serious mastitis outbreak would have on their farm. They also had the most concern about being able to control an outbreak if it did occur. We gave this segment the label "Black swan concern", as farmers in this group do not perceive a serious mastitis outbreak to be probable, but in the event that it does happen, it is perceived to have a major uncontrollable negative effect.

3.1.2. Segment 2: Concerned but in control of mastitis

Participants in Segment 2 (28.9% of the sample) held the highest beliefs that a serious mastitis outbreak is likely to occur on their farm. The farmers in this group had around average concerns about the negative impact that a serious mastitis outbreak would bring to their farm. They also held about average beliefs about their ability to control the outbreak if it did occur. Thus, in contrast to Segment 1, farmers in this group believed an outbreak more likely to happen but were less concerned about the impacts and felt more able to deal with it. For this reason, this segment was given the name "Concerned but in control".

3.1.3. Segment 3: Unconcerned and confident about mastitis

The farmers in Segment 3 (28.4% of the sample) held the lowest levels of concern across all three risk perception variables. The farmers in this group judged the probability of a serious mastitis outbreak happening on their farm to be very low. They also had the lowest concern about the negative impact that a serious outbreak would bring to their farm, and held the highest level of confidence in their ability to control the outbreak if it did occur. This group was thus labelled the "Unconcerned and confident" segment.

3.2. Profiling the segments

A series of one-way ANOVAs and chi-squares were used to profile and compare the three segments on key socio-demographic factors and interest and intentions to engage in milk recording. Figure 2 provides a summary of the findings from the cluster analysis and the profiling.

After verifying the assumptions for normal distribution and homogeneity of variance, a one-way ANOVA was carried out to compare segment membership and interest in milk recording revealed a significant association (P = .001). Bonferroni multiple comparison tests were carried out and a significant difference was found between Segment 1 and Segment 3 (P = .001). Segment 1 ('Black swan' concern) (M = 2.57, SD = 1.19*)* was more likely to be interested in milk recording than Segment 3 (Unconcerned and confident) (M = 3.38, SD = 1.29).

A chi-squared test revealed a significant association between segment membership and behavioural intention to engage in milk recording χ^2 (2, n = 197) = 13.48, P = .001. As Figure 3 shows, farmers who had intentions to begin milk recording were much more likely to be a member of the two segments which displayed the highest overall mastitis risk perceptions: Segment 1 ('Black swan' concern) and Segment 2 (Concerned but in control). 53.6% of the

farmers in Segment 3 (Unconcerned and confident) indicated that they did not intend to begin milk recording.

A chi-squared test showed a significant association between segment membership and average bulk tank SCC χ^2 (4, n = 197) = 10.70, P = .030. As Figure 4 shows, farmers with the highest average bulk tank SCC, in the region of 200,001-300,000 cells/ml (i.e. the group most at risk of mastitis), were more likely to be members of Segment 2 (Concerned but in control). There were no significant associations between segment membership and the remaining farm and socio-demographic variables (See Table 3).

4. Discussion

The findings from this study have relevance for future research exploring farmers' risk perceptions, and practical implications for communicating with farmers about mastitis, milk recording, SDCT, and AMR.

4.1. Measuring farmers' risk perceptions

Risk perception as a construct has been defined and measured in numerous ways. This has ranged from one-item measures which focus solely on an individual's judgement of the probability of an adverse event through to validated multi-item scales measuring various affective and cognitive components of risk (Wilson et al., 2019). The findings from the current study revealed interesting inter-plays between the three components of risk perception under consideration. Whilst farmers in Segment 3 ('unconcerned and confident') tended to be low on all three risk perception constructs, the other two segments revealed more multifaceted risk perception profiles, supporting the assertion that risk perception is a multifaceted construct (Ferrer et al., 2016; Wilson et al., 2019). Our study showed that farmers in Segment 2 perceived high risk in terms of *likelihood* of a mastitis outbreak – an item measuring a deliberative/cognitive component of risk perception. However, they did not have high perceived risk related to *impact* and *control* – items which measured consequential and affective components of risk perception. The inverse was also true with Segment 1 perceiving low probability of a mastitis outbreak, but feeling high concern about mastitis impact and control. Similarly to risk research in non-agricultural contexts (Wilson et al., 2019), the current study shows a clear distinction in our findings between the deliberative (or cognitive), consequential and affective components of farmers' risk perceptions.

Previous work has found that a multifaceted measure of risk perception is better at predicting an individual's intention to engage in a protective behaviour (Wilson et al., 2019).

This same research also showed that the more experiential components of risk perception (affect and consequences) tend to have stronger effects on general risk perception compared to probability components of risk perception. The current study supports these findings as farmers in Segment 1 were less concerned about the probability of a mastitis outbreak but held high concern about impacts and their ability to control an outbreak. With the highest level of interest in milk recording and high intention to engage in milk recording, they were also the group most 'ready' to adopt milk recording. Thus, if in this study we had defined and measured risk perception based solely on perceived probability (i.e. deliberative component only), the strength of the relationship between risk perception and the adoption of the protective behaviour in the context of mastitis (milk recording) would have been somewhat masked. Future studies exploring farmers' risk perceptions related to animal health, and beyond, are advised to use multiple items to measure deliberative, consequential and affective components of risk perception. That is because farmers are likely to hold different judgements across these components of risk perception. The use of standardised measures of risk perception in farming studies would also allow for comparisons of risk perception across different hazards, sectors, and contexts.

4.2. Implications for risk communication related to mastitis, milk recording, SDCT, and AMR

Promoting a change to SDCT brings unique communication challenges. In the past, conventional wisdom dictated that farmers were advised and encouraged to undertake blanket treatment of all cows in the herd so as to improve udder health and reduce bulk tank SCC (Scherpenzeel et al., 2016). Now, with the increased threat of AMR and the realisation that antibiotic use practices can, and should, be changed, farmers are being advised to forgo blanket treatment of cows in favour of SDCT. This is the messaging landscape within which farmers are being encouraged to engage in milk recording. When risk-related messages change with incremental knowledge and scientific evidence (such as the case of changes in recommendations over the management of mastitis), coherent and transparent risk communication is pivotal (Markon et al., 2013). Effective risk communication is grounded in an understanding of the audience's risk perception; and targeting risk communications and strategies accordingly (Fischoff, 1995; McComas, 2006). The findings from the current study confirm the central role of risk perception for farmers' readiness to engage in milk recording and there are a number of practical applications where these findings can be considered. The

key implication is that tailored risk communication strategies are warranted for farmers who hold different *types* of risk perception.

Residing in Segment 1 ('Black swan' concern), a large proportion of the farmers in our sample (42.6%) held strong consequential and affective risk perceptions about mastitis (i.e. *negative impact* and *perceived control* of a mastitis outbreak). This same group was also more likely to be interested in and indicate an intention to begin milk recording. This group of farmers is primed for action and likely motivated to positively receive messages about milk recording. They could thus be targeted by a pragmatic approach to risk communication. More specifically, pragmatic risk communication includes a focus on targeted risk messages to influence behaviour change towards mitigation actions for a given risk (Rickard, 2019; Balog-Way et al., 2020). Developing a message which emphasises specifically the negative impacts of a mastitis event on farms and discusses the value of milk recording as an effective control strategy could provide (some) farmers with a reference point for what is important (Vigors, 2019). If these farmers are inclined to hold a strong affective risk perception belief about mastitis, they may be more primed to positively receive the recommendation within the message. In other words, a message that empathises with their concerns is more likely to be impactful. Future research should explore the utility of targeted messaging (i.e. message framing) as a risk communication strategy to activate farmers' specific affective risk perceptions and increase readiness to engage in milk recording.

Farmers in Segment 2 judged it most likely that a mastitis event could happen on their farm. However, they were not overly concerned about the impacts and felt confident in their ability to control an outbreak. Similar to Segment 1, this group was also more likely to indicate an intention to begin milk recording. Unlike Segment 1, elevated levels of affective or consequential risk perception do not explain this willingness to engage in milk recording. An alternative pathway explaining this motivation for behaviour change can be suggested here. According to international guidelines (International Dairy Federation, 1997), these farmers were most at risk of mastitis, with a higher average bulk tank SCC, in the region of 200,001-300,000 cells/ml. The profile of farmers in Segment 2 fits the findings of previous research (Hansson and Lagerkvist, 2014; Dillon et al., 2018), i.e., they may favour reactionary responses over precautionary responses in managing mastitis risk. More precisely, farmers in this group may be currently experiencing the threat of mastitis, hence being primed and activated to take action to manage mastitis on their farms. Indeed, this would explain their increased willingness to engage in milk recording as a decision support tool for mastitis control. Further supporting this, is the finding that, unlike farmers in Segment 1, farmers in this group were not

characterised by an increased *interest* in milk recording. Rather than viewing milk recording as a practice of interest, they may feel forced into changing their behaviour due to the very real threat of mastitis on their farms. For this type of farmer, who is not generally inclined to perceive mastitis as a highly significant threat unless the disease is already present on their farm, message framing centred on affective or consequential risk perception is unlikely to be sufficient to change beliefs and behaviour.

Similarly, top-down risk communication in the form of message framing is unlikely to be an effective strategy for farmers in Segment 3, who held the lowest mastitis risk perceptions and had little interest in or inclination to begin milk recording. This segment represents the 'hard-to-reach' farmer who is neither motivated by concern over mastitis nor interested or willing to engage in milk recording. For farmers in both Segments 2 and 3, simply communicating the risks of mastitis, irrespective of how the message is framed, is not likely to be an effective strategy in raising concern or changing their behaviour. With the incoming EU regulations to ban the prophylactic use of antibiotics (as in BDCT) in 2022 (European Union, 2018b, a), these farmers will be forced into a position of change. Although taking legislative action to address AMR is beneficial, taking a solely top-down approach to enforcing change can have unintended changes to behaviour to circumnavigate regulations. In Denmark, measures to restrict high-priority antibiotics saw an increase in alternative forms of antibiotics used in animal production and therefore an increase in overall use (Borck Høg et al., 2017). Addressing farmers' motivation to make changes and providing tailored, relevant information may help to promote more meaningful and sustainable changes to antibiotic use on farms. While pragmatic risk communication efforts such as message framing often utilise more top-down mechanisms for risk communication, other alternatives are needed when divergent value judgements regarding a risk are evident (e.g. where farmers' perceive low risk of mastitis, or of the contribution of BDCT to AMR, despite scientific evidence to the contrary) (Renn and Klinke, 2014). In that regard, 'constitutive', or two-way, risk communication may be more suited as it argues for a more dialogical partnership approach where the risk communicator engages meaningfully with their audience about a risk (Balog-Way et al., 2020). In such an approach, the emphasis is not on trying to align the audience to an imposed or dominant view of the risk, but rather to listen to the audience and understand values and factors underlying their own risk perceptions

Applying this in the current context would involve tapping into other motivations which the farmers in Segment 2 and Segment 3 may hold regarding herd health management. A more individualised approach to communicating and working with these farmers is likely to be of

benefit. This involves understanding the motivations and beliefs of these farmers – for example, farmers in Segment 3 may not be as motivated by milk recording arguments related to animal health, but could be motivated by milk recording as a practice to inform breeding decisions. The main strategy in this approach is to understand what these types of farmers are motivated by, if not concerns about mastitis risks. Settings for such two-way risk communication to occur include a farmer's extension and communication networks (Hernández-Jover et al., 2012). For farmers, trusted stakeholders on animal health include farm advisors, veterinarians, and other farmers (Garforth et al., 2013). These gatekeepers have the opportunity to engage farmers in dialogue about mastitis, milk recording, SDCT, and AMR in a manner which promotes collaborative working.

4.3. Limitations and future research

The current study focused on one particular construct, risk perception, in shaping farmers readiness to engage in milk recording. In doing so, it provides an in-depth theoretical perspective on the role of this central construct. However, it does not consider other factors which may also be playing central roles in shaping farmers' decisions to engage in milk recording. For example, while some reasons may be related to factors such as costs, labour and convenience, farmers may also be implementing other mastitis control strategies (e.g. through robotic milking systems). In other words, there could be alternative reasons for low risk perception or not engaging in milk recording which are not examined in our survey, but should be explored in future research.

The current study was undertaken in an online platform and with a self-selected sample of farmers; this may have skewed the sample towards farmers with already high levels of digital literacy, and who are more positive towards and, motivated to engage in, new practices (e.g. almost 50% of the participants were members of discussion groups). Hence, the current research needs to be complemented with further work carried out on a nationally representative sample of dairy farmers to verify whether the results are applicable to the wider farming population.

5. Conclusion

Milk recording is a proven decision support tool that can assist farmers' decision-making within the context of mastitis control and SDCT. The findings from the current study highlight that for many Irish dairy farmers, elevated mastitis risk perceptions are linked to an increased readiness to milk record. However, this relationship is not universal across all farmers. One

segment of the farmers in the current study maintain low mastitis risk perceptions and remain unmotivated to engage in milk recording. Further work is required to explore the factors beyond risk perception which may be preventing farmers from engaging in milk recording. Finally, the study suggests that mastitis risk perception is a factor which can be targeted in effective risk communication strategies for some farmers, but consideration also needs to be given to targeting the broader motivations likely to be held by different types of farmers.

Conflict of interest

We declare no conflict of interest.

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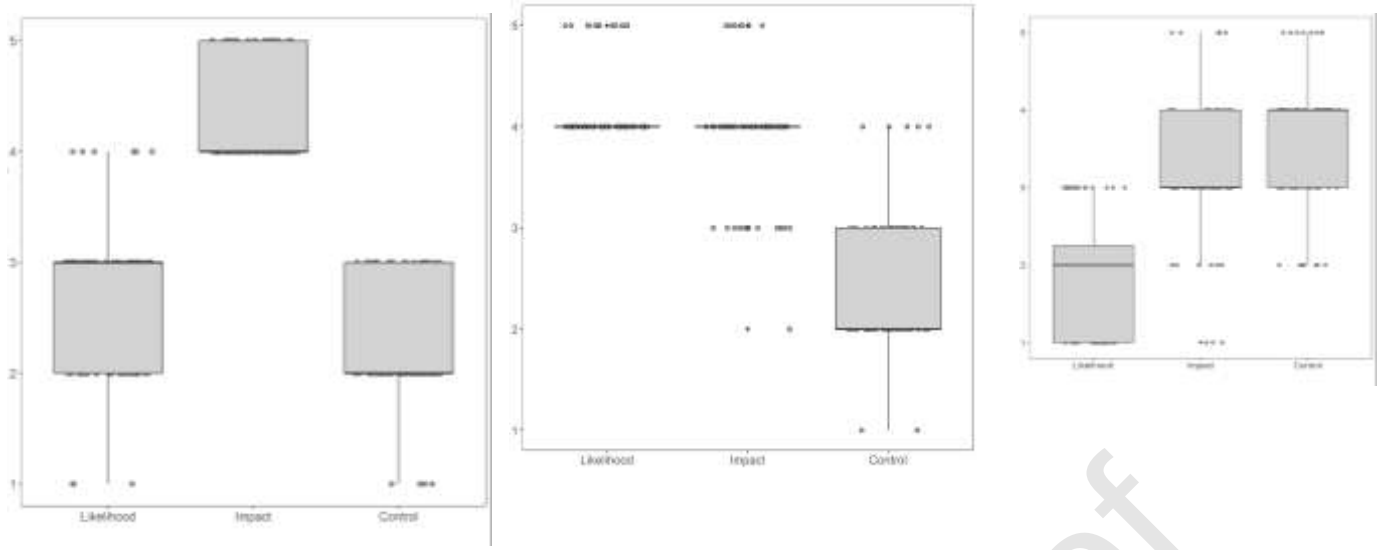
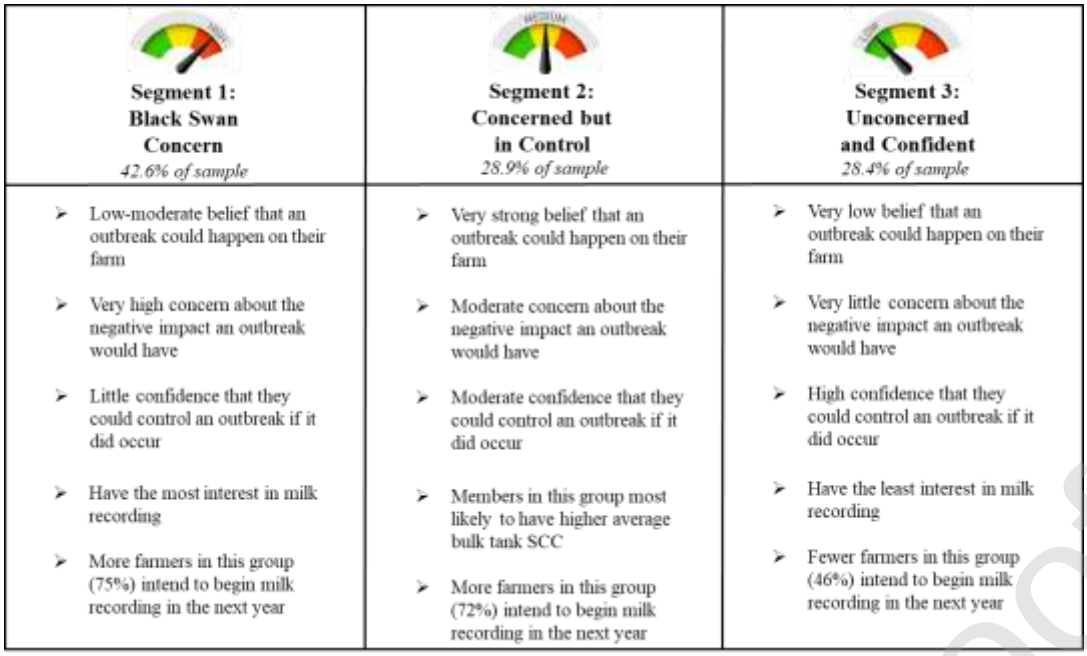


Segment 1: 'Black swan' concern of mastitis **Segment 2: Concerned but in control of mastitis** **Segm**

Figure 1: Mastitis risk perception profiles of 197 Irish dairy farmers classified in three segments.

Figure 1. illustrates the interquartile range (box), medians (dark line) and outliers (black dot) of responses to questions of likelihood, impact and perceived control across the 3 segments with vertical lines illustrating min-max responses excluding outliers. A jitterplot (grey dots) illustrates individual responses across the segments.

Note: Likelihood response range: 1 = very unlikely and 5 = very likely; Impact response range: 1 = very small impact and 5 = very big impact; Control range: 1 = it would be very easy and 5 = it would be very difficult.



Segment 1: Black Swan Concern *42.6% of sample*	Segment 2: Concerned but in Control *28.9% of sample*	Segment 3: Unconcerned and Confident *28.4% of sample*
➢ Low-moderate belief that an outbreak could happen on their farm ➢ Very high concern about the negative impact an outbreak would have ➢ Little confidence that they could control an outbreak if it did occur ➢ Have the most interest in milk recording ➢ More farmers in this group (75%) intend to begin milk recording in the next year	➢ Very strong belief that an outbreak could happen on their farm ➢ Moderate concern about the negative impact an outbreak would have ➢ Moderate confidence that they could control an outbreak if it did occur ➢ Members in this group most likely to have higher average bulk tank SCC ➢ More farmers in this group (72%) intend to begin milk recording in the next year	➢ Very low belief that an outbreak could happen on their farm ➢ Very little concern about the negative impact an outbreak would have ➢ High confidence that they could control an outbreak if it did occur ➢ Have the least interest in milk recording ➢ Fewer farmers in this group (46%) intend to begin milk recording in the next year

Figure 2: Summary findings from segment analysis of 197 Irish dairy farmers' mastitis risk perceptions and profiling based on interest and readiness to engage in milk recording

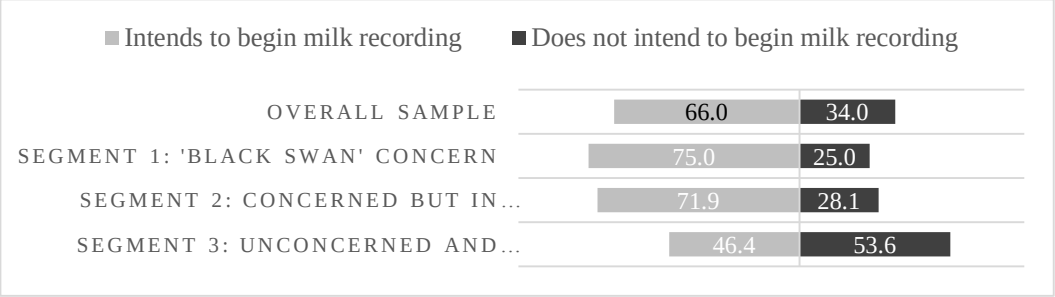


Figure 3: Percentage of Irish dairy farmers (n = 197), grouped into three mastitis risk perception segments, intending to begin milk recording

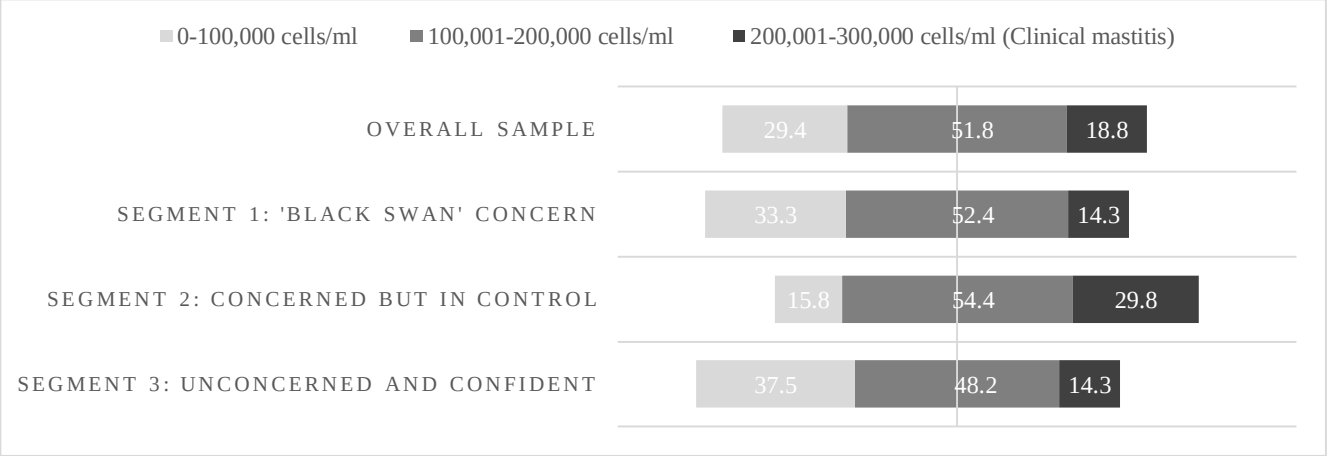


Figure 4: Percentage of Irish dairy farmers (n = 197), grouped into three mastitis risk perception segments, in each of the average bulk tank SCC categories

Table 1: Sample characteristics of dairy farmers participating in an online survey on milk recording and mastitis (*n* = 197)

Sample characteristic	*n* (%)
Gender	
Male	187 (95%)
Female	10 (5%)
Age	
18-34 years	39 (19.8%)
35-44 years	44 (22.3%)
45-54 years	76 (38.6%)
55 years or older	38 (19.3%)
Marital Status	
Married	151 (76.6%)
Single / widowed / divorced	46 (23.4%)
Agricultural Education	
One/two-year certificate in agriculture	110 (55.8%)
Short term agricultural training, less than 60 hours	8 (4.1%)
Short term agricultural training, more than 60 hours	27 (13.7%)
Third level degree in agriculture	20 (10.2%)
Completed apprenticeship	14 (7.1%)
None / not specified	18 (9.1%)
Herd Size	
< 40 cows	13 (6.6%)
40-60 cows	27 (13.7%)
61-100 cows	77 (39.1%)
101-250 cows	64 (32.5%)

> 250 cows	16 (8.1%)
Farm Size	
< 75 acres	17 (8.6%)
76-125 acres	60 (30.5%)
126-250 acres	98 (49.7%)
> 250 acres	22 (11.2%)
Farm location	
North & West	33 (16.8%)
East & Midland	47 (23.9%)
South	117 (59.4%)
Average bulk tank SCC	58 (29.4%)
0-100,000 cells/ml	102 (51.8%)
100,001-200,000 cells/ml	37 (18.8%)
200,001-300,000 cells/ml	
Discussion group member (yes)	97 (49.2%)
Successor available for farm (yes)	87 (44.2%)

Table 2: Means and standard deviations for mastitis risk perception variables on 5-point scales across the three identified farmer segments (n = 197).

Risk perception	**Segment 1: 'Black swan' concern**	**Segment 2: Concerned but in control**	**Segment 3: Unconcerned and confident**	Total
	n = 84 (42.6%)	n = 57 (28.9%)	n = 56 (28.4%)	n = 197

Perceived likelihood of a serious mastitis outbreak on my farm [a]	2.63 (.67)	4.23 (.42)	1.96 (.74)	2.90 (1.09)
Perceived negative impact of a serious mastitis outbreak on my farm [b]	4.26 (.44)	3.89 (.65)	3.21 (.95)	3.86 (.80)
Perceived ability to control a serious mastitis outbreak on my farm [e]	2.24 (0.53)	2.47 (0.71)	3.53 (.87)	2.68 (.88)

Note: [a] Range: 1 = very unlikely and 5 = very likely; [b] Range: 1 = very small impact and 5 = very big impact; [e] Range: 1 = it would be very difficult and 5 = it would be very easy.

Table 3: Profile of 197 Irish dairy farmers grouped into 3 segments and compared on milk recording attitudes, farm variables and socio-demographic variables.

Profiling variable	**Segment 1: 'Black swan' concern**	**Segment 2: Concerned but in control**	**Segment 3: Unconcerned and confident**	*P*
Current level of interest in milk recording [a] (M, SD)	2.57 (1.19)	2.91 (1.21)	3.38 (1.29)	.001[b]
Behavioural intention to begin milk recording (%)	75%	71.9%	46.4%	.001[c]
Intends to begin milk recording	25%	28.1%	53.6%	
Does not intend to begin milk recording				
Average bulk tank Somatic Cell Count (%)	33.3%	15.8%	37.5%	.030[c]
0-100,000 cells/ml	52.4%	54.4%	48.2%	
100,001-200,000 cells/ml	14.3%	29.8%	14.3%	
200,001-300,000 cells/ml				
Age (%)				.213[c]
18-34 years old	27%	21%	16%	
35-44 years old	18%	21%	30%	
45-54 years old	38%	42%	36%	
55 years old or more	17%	25%	18%	
Discussion group member (yes) (%)	57.1%	47.4%	39.3%	.111[c]
Agricultural advice (%)				.768[c]
Professional body	61.4%	60%	67.3%	
Media	16.9%	18.2%	9.6%	
Other farmers	21.7%	21.8%	23.1%	

Herd Size (number of cows) (M, SD)	121.96 (92.04)	122.56 (100.85)	109.61 (61.72)	.660[b]
Farm Size (acres) (M, SD)	170.05 (107.87)	176.14 (135.17)	175.54 (78.22)	.934[b]

[a] Scale of 1 (extremely interested) to 5 (not at all interested). [b] One-way ANOVA. [c] Chi-squared test.