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Ensuring dairy cow welfare with increasing scale of production.

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Doctor of Philosophy

July 2018

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A thesis submitted in fulfilment of the requirements for the degree of Doctor of
Philosophy

ABSTRACT

Animal welfare is important to the general public and dairy consumers and the dairy industry is coming under increasing scrutiny. There is the potential for community concern arising from perceived intensification of the industry with an increasing number of large herds, and producers adopting a mix of grazing and confined feeding strategies. This thesis examines the particular welfare challenges associated with increased herd size in Australian pasture-based dairy herds including how they might be measured and managed.

A survey of Australian dairy farmers was conducted to assess relationships between herd size and known or proposed risk factors for adverse animal welfare outcomes in Australian dairy herds in relation to increasing scale of production. Increasing herd size was associated with increases in stocking density, stock per labour unit and grain fed per day – all of which could reasonably be hypothesized to increase the risk of adverse welfare outcomes unless carefully managed. However, increasing herd size was also associated with an increased likelihood of staff with formal and industry-based training qualifications. Herd size was not associated with reported increases in mastitis or lameness. Large herds were more likely to use monitoring systems such as electronic identification in the dairy, computerised records, daily milk yield or cell count monitoring and pedometers or activity meters. Increasing herd size was related to increased herd milking time, increased time away from the paddock and increased distance walked.

Animal welfare assessments were conducted on 50 Australian pasture-based dairy farms of varying herd sizes. Findings were generally consistent with the previous survey. Major challenges included heat stress, mastitis, lameness, and longer milking duration. All cows had access to water for more than 12 h in a 24 h period. More larger farms had water points on the farm tracks or at the dairy. Skin and joint lesion prevalence was not related to herd size and they were uncommon. All farms had some form of cooling strategy. Shade in all paddocks was more common on smaller farms than others while sprinklers were more common on large/very large farms. There was wide variation in the avoidance distance of humans but this was not related to farm size. Lameness scoring was conducted on 19154 cows from 50 farms as they left the dairy after being milked. We compared our Results with farmer estimates of lameness prevalence. Farmers detected only 24% of the cows observed/scored as lame. Whilst lameness scoring of the entire herd was necessary to detect all the lame cows, scoring just the last 200 cows milked could be used to estimate the prevalence of lame cows on a given day.

In large Australian dairy herds, it is common for cows to be collected from the paddock as a group, to wait as a group in the dairy yard to be milked and to return individually to the paddock or feed pad immediately after milking. We demonstrated that even in these large herds there is consistency in the order cows are milked. This may have welfare implications

for cows that are regularly milked last because they may spend several hours per day less in a paddock grazing. Lying is a high priority behaviour for cows. We used activity monitors to show that cows in large Australian dairy herds spend an average of 9.5 hours lying each day. Even in large herds, where milking can take up to 4 hours, the time taken to milk the cows did not affect their welfare by significantly impacting on their ability to lie down.

DECLARATION

This thesis comprises only the author's original work towards the Doctor of Philosophy except where indicated in the preface.

Due acknowledgment has been made in the text to all other material used.

The thesis is fewer than 100,000 words in length, exclusive of tables, maps, bibliographies and appendices.

A handwritten signature in blue ink, appearing to read 'DS Beggs', with a stylized flourish at the end.

David Sandford Beggs

29/7/18

PREFACE

Most of the original work in this thesis has been submitted for peer review as described below. In each instance, all fieldwork was conducted by the author. 90% of statistical analysis was conducted by the author, with some assistance from Kym Butler and Mark Stevenson. All transcripts were drafted by the Author, with some modifications made on the suggestion of supervisors and peer reviewers. The Author contributed more than 85% of the work in all cases. No work herein was carried out prior to enrolling the degree.

Chapter 3 has been published in the Journal of Dairy Science:

Beggs, D.S., A.D. Fisher, E.C. Jongman, and P.E. Hemsworth. 2015. A survey of Australian dairy farmers to investigate animal welfare risks associated with increasing scale of production. *J. Dairy Sci.* 98:5330–5338. doi:10.3168/jds.2014-9239.

Chapter 4 is in revision following peer review to the Journal of Dairy Science:

Beggs, D.S., E.C. Jongman, P.H. Hemsworth, and A.D. Fisher. 2018. The effects of herd size on the welfare of dairy cows in a pasture-based system using animal- and resource-based indicators.

Chapter 5 is in press in the Journal of Dairy Science:

Beggs, D.S., E.C. Jongman, P.H. Hemsworth, and A.D. Fisher. 2018. Lameness prevalence on Australian dairy farms: A comparison of farmer estimates and lameness scoring, and the position of lame cows within the milking order.

Chapter 6 has been published by the Journal of Dairy Science:

Beggs, D.S., E.C. Jongman, P.H. Hemsworth, and A.D. Fisher. 2018. Short communication: Milking order consistency of dairy cows in large Australian herds. *J. Dairy Sci.* 101:603–608. doi:10.3168/jds.2017-12748.

Chapter 7 has been published by the Journal of Dairy Science:

Beggs, D.S., E.C. Jongman, P.H. Hemsworth, and A.D. Fisher. 2018. Implications of prolonged milking time on time budgets and lying behaviour of cows in large pasture-based dairy herds *J. Dairy Sci.* 101:10391-10397. doi:10.3168/jds.2018-15049

The work in this thesis was funded by

- Dairy Australia Ltd (Project agreement C100000614)
- Victorian Department of Economic Development Jobs Transport and Resources (CMI 105692)
- This project was also supported through an Australian Government Research Training Program Scholarship.

ACKNOWLEDGMENTS

Firstly, I would like to express my sincerest gratitude to my supervisors Paul Hemsworth, Ellen Jongman and in particular Andrew Fisher, without whose strong encouragement I would not have started down this path.

A sincere thank you to Dairy Australia Ltd, and Kathryn Davis in particular, for agreeing to fund the bulk of my PhD costs and for the constant encouragement and valuable feedback along the way. Also to DEDJTR who funded some of the operational costs.

Thanks to the staff at the Warrnambool Veterinary Clinic for being so accommodating when I kept disappearing off to do my farm visits, and for occasional help in applying or removing IceTags.

Thanks to my colleagues at the University – in particular Peter Mansell, Jo Coombe, Michael Pyman and Kelly Stanger for their tolerance and help when I couldn't be around.

I owe a huge debt to the farmers who answered surveys, allowed me onto their farms, were tolerant of the questions I asked and the inconvenience of applying Ictags or lameness scoring, who lent me their vehicles so I could more easily observe the cows, and on occasion even fed me. The good humour and desire to do things well by their cows which was evident on every farm I went to gives me great hope for the industry.

Lastly, my family. My beautiful wife Elsa, who I lost to breast cancer shortly after completing the fieldwork, gave me constant love and encouragement. In her last months, despite being very unwell, Elsa made sure that I completed the 70 farm visits required in good time before things really got bad. My children, Anna and Kate, who put up with me both being away so much and being cooped up in my office working on this document. Also my parents, who came and looked after the household when I couldn't, and always left things in better shape than when they arrived.

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CHAPTER 1 - INTRODUCTION

1. Introduction

Animal health and animal welfare are key contributors to dairy production efficiency, as well as being important to the general public and dairy consumers. The dairy industry is coming under increasing scrutiny from animal welfare advocacy groups and the general public. There is also the potential for community concern arising from perceived intensification of the industry with an increasing number of large herds, and producers adopting a mix of grazing and confined feeding strategies.

Increasing scale of production can be associated with larger herd sizes, increased stocking densities, longer milking times, longer walking distances, and reduced ability to examine and treat cows individually. Factors such as these have the ability to cause reduced welfare outcomes for dairy cows (Verkerk and Hemsworth, 2010). On the other hand, there are management aspects that often improve outcomes with economies of scale. It seems probable, although there is little objective data available to support it, that larger enterprises are more likely to have more modern rotary dairies that reduce milking time; they may be more likely to have infrastructure to electronically identify and monitor and possibly feed individual cows; they may be more likely to use professional advice and provide superior nutrition and they may have greater capacity for staff training and general quality assurance systems.

There has been little published regarding the welfare outcomes for cows in large Australian dairy herds, particularly when all three animal welfare domains of biological function, affective state and naturalness are considered.

The aim of this thesis included the collection and evaluation of objective, science-backed information on the welfare state of cows in large dairy herds in Australia in order to understand the particular challenges that are associated with increasing herd size. This will provide industry with the option to demonstrate its welfare performance, while at the same time providing guidance on suitable management strategies used by farmers of large herds to optimise cow husbandry and welfare into the future.

In Chapter 2, a review of the literature is presented, as it pertains to animal welfare and the increasing scale of production in dairying.

In Chapter 3, a survey of Australian dairy farmers was conducted to assess relationships between herd size and known or proposed risk factors for adverse animal welfare outcomes in Australian dairy herds in relation to increasing scale of production. Although risk factors such as decreased labour per cow, grain feeding, walking distances and milking times increased with herd size, there was no evidence for a commensurate increase in disease. The survey raised questions about the impact of long milking-times on the time budgets of cows and their ability

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to lie down, the quality of the human-animal-relationship as the contact time between people and stock reduced, and the reliability of self-reported lameness and disease levels as captured using survey methodology.

In Chapters 4 and 5, we developed an animal welfare assessment protocol and conducted assessments on fifty farms of varying sizes to further investigate the questions raised in Chapter 2. We examined farm records for disease, assessed the human-animal-relationship by measuring avoidance distances, lameness scored entire herds, and we conducted detailed observations of cows grazing at pasture.

In Chapter 6, we further investigate the question raised in Chapter 2 regarding the impact of long milking duration. We examined electronic records from farms with infrastructure that recorded when cows were milked each day to investigate how consistent the milking order can be in large groups of cows. This is important because, if the milking order is consistent, then there will be individual cows on farms which may be particularly disadvantaged in terms of access to pasture because they are regularly milked late in the milking order.

In Chapter 7, having established that there is a consistency to the milking order, we applied activity meters to cows at the beginning and the end of the milking order in ten large herds in order to assess the impact of long milking durations on the opportunity for cows to spend time lying down.

CHAPTER 2 – LITERATURE REVIEW

2. Literature Review

2.1. The Australian dairy industry

In 2017, Australian dairy cows produced approximately 9 billion litres of milk from 1.5 million cows on 5780 farms, providing employment for approximately 42,000 people. Approximately 34% of milk produced was exported.

In contrast to many countries, Australian dairy farms are predominantly pasture-based, with approximately 60-65% of cattle feed requirements coming from grazing. Dairy farms fed an average of 1.6 tonnes of grain, grain mixes or feed concentrates per cow in 2015/2016

Most Australian cows graze pasture during the day with supplementary feed provided in the form of concentrates fed in the dairy parlour during milking, and forages fed either in the paddock following milking or on a feed pad (an intermediate area between the exit of the dairy and the paddock) and the feeding of total mixed rations is rare. (Dairy Australia, 2017a). It is common for cows to be collected from the paddock as a group, to wait as a group in the dairy yard to be milked and then individually return to the paddock or feed pad immediately following milking (Scott et al., 2014).

It seems logical that the animal welfare challenges applicable to the Australian pasture-based dairying system may differ from those systems where cows are housed indoors and fed total mixed rations.

2.2. Increasing scale of production

The average size of dairy farms in all developed countries has increased in recent times (Barkema et al., 2015). However, mean herd size is a measure that is likely to underestimate the true extent to which farm size has increased because of skewed distributions containing many small farms, where production is disproportionately concentrated on larger farms (Robbins et al., 2016). Increasing scale of production is a confirmed trend in the Australian pasture-based dairy industry. Table 2.1 shows that farm and cow numbers have decreased over time as the number of cows on each farm and individual cow production have increased. According to a national dairy farmer survey conducted by Dairy Australia in 2015, average Australian herd size has risen 25% over the previous 10 years from 229 in 2005 to 303 in 2015. The proportion of farmers milking less than 150 cows has nearly halved over the past ten years and is now less than 19%. The proportion of herds milking more than 500 cows doubled in the previous ten years with 11% of such farms producing 33% of Australia's total milk volume (Dairy Australia Ltd, 2015). The trend toward larger farms looks set to continue, with 34% of

farmers surveyed expecting to calve more cows in the following year and 62% planning to keep steady numbers. A similar trend is evident in the New Zealand dairy industry where the average herd size was 393 in 2011/12, up 7 cows on the previous season – an increase is consistent with the trend for the past 30 seasons (Anon, 2012).

TABLE 2.1 CHANGES IN AUSTRALIAN DAIRY FARMS SINCE 1980 (ADAPTED FROM DAIRY AUSTRALIA, 2017).

Year	No of registered dairy farms	No of dairy cows ('000 head)	Mean No. of cows per farm	Average annual milk production per cow (l)	Total milk production (million litres)
1980	21994	1880	85	2848	5432
1990	15396	1654	107	3781	6262
2000	12896	2171	168	4996	10847
2010	6883	1596	231	5758	9084
2016	6102	1663	272	5669	9539

Increasing scale of production can be associated with larger herd sizes, increased stocking densities, longer milking times, longer walking distances, and reduced ability to examine and treat cows individually. Factors such as these have the ability to cause reduced welfare outcomes for dairy cows. On the other hand, there are management aspects that often improve outcomes with economies of scale. It seems probable, although there is little objective data available to support it, that larger enterprises are more likely to have more modern rotary dairies that reduce milking time; they may be more likely to have infrastructure to electronically identify, monitor and possibly feed individual cows; they may be more likely to use professional advice and provide superior nutrition and they may have superior staff training and general quality assurance systems (Verkerk and Hemsworth, 2010; Robbins et al., 2016).

A review of more than 150 publications from more than 12 countries that examined the relationship between farm size and at least one animal welfare indicator found little evidence of any simple relationship, negative or positive, between farm size and animal welfare. Instead, the evidence suggested that larger farms provide some opportunities to improve animal welfare but may also create welfare risks (Robbins et al., 2016). For example, larger farms permit more specialized and professional management of animal health but can make it more difficult to accommodate outdoor access that some view as integral to animal welfare

There has been little published regarding the welfare outcomes for cows in large pasture-based Australian dairy herds. A review of livestock disease threats associated with intensification of pastoral dairy farming (Lean et al., 2008) reported that whilst there is evidence that increased production increases the risk of mastitis and culling for udder health, the evidence to support an increased risk of most diseases was sparse and indeed diseases such as bloat and ketosis seem to have lower risk. The same report concludes that mineral nutrition of pasture-fed cattle is being better addressed, with gains in the control of milk fever, hypomagnesaemia and trace-element deficiencies, but that lameness, anthelmintic resistance

and acidosis may be at increased risk with increasing scale of production. Verkerk et al (2010) identified walking distances, time off pasture and reduced human contact time per animal as potential challenges in larger farms. As farms increase in size, cattle walk longer distances to and from the dairy; milking time may take several hours, and economies of scale result in lower stockperson to cow ratios. Both these reports were undertaken when large herds of more than 500 cows were less common than they are now, and further work is needed to understand the specific animal welfare challenges that apply to large Australian pasture-based dairy herds.

2.3. Community Concern

There is considerable evidence of community concern regarding the intensification of farming generally and dairy farming in particular (Stafford and Gregory, 2008; von Keyserlingk et al., 2009; Fisher and Webster, 2013; Robbins et al., 2016). The general public is increasingly interested in how their food is produced (Eurobarometer, 2007; Cembalo et al., 2016), but are also often unaware of common practices on farms (Ventura et al., 2016). Australian farmers are generally considered trustworthy by the general public (Coleman, 2018) and this can lead to public outcry when people discover common practices on farms that are out of step with public values (Weary and Von Keyserlingk, 2017), which can have quite profound consequences.

While many consumers have reported thinking about animal welfare when they purchase meat and meat products, concerns about welfare do not appear to be major drivers of those purchasing decisions (Coleman and Toukhsati, 2006; Eurobarometer, 2007; Curtis et al., 2011; Cembalo et al., 2016). For example, Coleman and Toukhsati (2006) surveyed 516 Australian respondents about their perceptions toward farm animal welfare and meat purchases and found attitudes to animal welfare did not significantly predict point-of-sale sheep meat purchases, and further that Australian consumers ranked animal welfare fifth in a list of 15 attributes. A study from Nevada showed that when food attributes relevant to meat purchasing are ranked in order of importance, freshness, taste, flavor, safety, and price are rated as extremely important, and attributes such as humane treatment and environmentally friendly are rated as very important (Curtis et al., 2011).

However, changes in purchasing decisions resulting from community concern over animal welfare may not be the biggest threat to farming industries. According to Coleman and Toukhsati 2006, “community behaviours that do not require public expression or public identification” are common in relation to livestock issues and “involve taking advantage of situational opportunities to express an attitude through action”. Such behaviors (e.g., signing petitions, donating money, speaking to colleagues about animal welfare issues) and their associated public opinions can influence how Governments either react to publicized “animal welfare events” or regulate contentious management practices in industry. Easy access to social media makes it possible for people to have an involvement in animal welfare activism without making much personal sacrifice at all. In a survey of community behaviours in

opposition to the livestock industries in 2014, 47% of people had donated money to an animal welfare organization and 36% had signed a petition. This contrasted with lower percentages undertaking more onerous tasks such as calling talkback radio (2%) or volunteering time (12%) (Coleman, 2018). The consequences of large numbers of people speaking up in this way can be much greater than simple reduced demand for product – particularly when many of the people speaking up may not be consumers of the product in the first place.

For example in 2006, Animals Australia (an Australian animal welfare organization), launched the “Save Babe” campaign to raise public awareness about the containment of sows in farrowing crates (Animals Australia, 2006). This campaign and the community pressure that followed, led directly to the pork industry voluntarily deciding to phase out sow stalls entirely by 2017. In addition to this, Coles, a major chain of supermarkets in Australia, subsequently announced that its own Coles Brand fresh pork products would henceforth come from sow stall-free farms (Coleman, 2018).

Social licence to operate (SLO) is a term used to describe the way society allows to citizens or industries to exploit resources for their private purposes. It is granted when people trust industries to behave in a manner that is consistent, not just with their legal obligations, but also with community expectations. Failure to properly fulfil these can lead to increased litigation, increased regulations, and increasing consumer demands of industry (Williams and Martin, 2011; Edwards and Trafford, 2016). Experience in the mining and fast food industries suggests that public trust reduces as entities increase in size, and that both transparency and proactive demonstration of responsible outcomes are necessary for the maintenance of SLO as businesses get bigger (Hess, 2007; Moffat et al., 2016). Maintaining social licence will be an important ongoing activity for the dairy industry, especially as farms increase in size.

2.4. Animal welfare, animal protection and animal rights

Debates surrounding the quality of an animal’s life involve philosophical and ethical considerations which by their nature involve differing views surrounding the appropriate use of animals. The *Encyclopedia of Dairy Sciences, Second Edition* provides some definitions which are worthy of consideration (Guither and Curtis, 2002):

Animal protection refers to all efforts to prevent cruelty, improve humane treatment, reduce stress and monitor research with animals.

Animal welfare generally describes the philosophy of those who support the humane treatment of all animals without concern for their ultimate use. Thus, human beings have the right to use animals so long as suffering is reduced or eliminated.

Animal rights is a philosophy encompassing animal liberation which includes some fundamental differences from animal welfarism. It involves the idea that nonhuman animals are sentient beings that consciously experience pleasure and pain; and that animals have certain inalienable moral rights which humans should not violate.

Defining what constitutes good animal welfare is likely to remain controversial because by its nature, it is an ethical construct based on the opinion of individuals. In a review of the different philosophical attitudes to animal welfare and animal rights, it is argued that whilst people may hold any opinion they like on subjects of taste (for example whether they like coffee or not), opinions on subjects such as morality where the Results interfere with the rights of others to do things should be able to be justified with reasons and that these reasons need to have consistency so that a reason given in one place would also apply to other similar cases (Appleby, 2011).

Thus, for a rational discussion about dairy cow welfare with increasing scale of production it is necessary first to define what welfare means in this context and then discuss how it might be measured.

2.5. What is animal welfare?

Defining exactly what constitutes animal welfare is not simple – and indeed the first stated goal of the Australian Animal Welfare Strategy Implementation Plan is that “The welfare needs of animals are understood and met” (Anon, 2011) indicating that more work is needed to refine the criteria by which animal welfare is measured.

In a generic sense, there is an agreed definition of animal welfare adopted by the World Organization for Animal Health (OIE) and many other organizations worldwide, including the Australian Animal Welfare Strategy:

“Animal welfare means how an animal is coping with the conditions in which it lives. An animal is in a good state of welfare if (as indicated by scientific evidence) it is healthy, comfortable, well nourished, safe, able to express innate behaviour, and if it is not suffering from unpleasant states such as pain, fear, and distress. Good animal welfare requires disease prevention and veterinary treatment, appropriate shelter, management, nutrition, humane handling and humane slaughter/killing. Animal welfare refers to the state of the animal; the treatment that an animal receives is covered by other terms such as animal care, animal husbandry, and humane treatment.”

There is general agreement amongst researchers that animal welfare is of concern to consumers and the general public. Whilst there has probably always been an instinctive human aversion to animal cruelty, several authors point to the 1964 publication of Ruth Harrison’s book *Animal Factories* (Harrison, 1964) as the beginning of the more recent tradition of animal welfare that encompasses more than the simple absence of pain and disease. (Guither and Curtis, 2002; Korte et al., 2007; Rushen et al., 2008; McCulloch, 2012; Wathes et al., 2013). In response to public concern about animal welfare in “modern” farming conditions, the British Government established the Brambell committee (Brambell, 1965) to “enquire into the welfare of animals kept under intensive husbandry systems”. Rushen’s textbook *The Welfare of Cattle* identifies this report as being one of the most important and influential writings on animal welfare as it drew particular attention to the problems of

behavioural restriction that resulted from intensive indoor housing systems. The interest in behavioural deprivation was not a topic in veterinary or science education at the time, and the report led many researchers in animal welfare to focus on behavioural indices when considering animal welfare (Rushen et al., 2008).

There is also general agreement in the modern literature that animal welfare as it pertains to dairy cows should be measured across three overlapping quality-of-life domains which could loosely be described as biological function, affective state and naturalness (Fraser et al., 1997; Rushen et al., 2008; von Keyserlingk et al., 2009; Verkerk and Hemsworth, 2010).

Biological function addresses issues surrounding disease, injury, poor growth rates and reproductive problems. Farmers, veterinarians and others with practical responsibility for animal care, give special importance to health and the 'normal' or 'satisfactory' functioning of the animal's biological systems and indeed often use the argument that farmed animals have better health and lower risk of an unpleasant death due to predation as evidence of good welfare outcomes.

The affective state of an animal describes what an animal experiences - its 'feelings' or 'emotions'. Good welfare for animals is thought to require freedom from suffering in the sense of prolonged or intense pain, hunger and other negative states such as fear. Some authors also stress positive states such as comfort, pleasure or contentment.

The concept of naturalness is to do with whether an animal is able to live a relatively natural life and express natural behaviour. There is debate surrounding exactly how much of what behaviours farmed animals should be able to exhibit. For example, Brambell (1965) criticized forms of confinement that prevent much of the natural behaviour of an animal and concluded that animals should be able to stand up, lie down, turn around, stretch limbs and interact with others. Controversy surrounds this aspect of animal welfare measurement as there is often tension between preventing a behaviour and at the same time preventing a different negative outcome. The idea that animals should live as naturally as possible is seen as naïve by some, as exposure to climatic extremes, disease, parasitic infections and predators cannot be good for animal welfare (von Keyserlingk et al., 2009). However, there are contrasting views- and from places that one might not expect. Tom Regan, a prominent animal rights philosopher argues that there is no duty of humans to protect animals against threats from other animals. In his view, rights only hold against moral agents —beings that can themselves recognize and respect rights. As such, antelope do not have rights against lions, because lions are not moral agents and cannot threaten their rights. Thus, humans do not have to act to protect antelope against lions (though they should protect them against other people, because people are moral agents, and do threaten their rights). In Regan's view, humans also do not have duties to rescue wild animals - at least not on the basis of their rights (Appleby, 2011).

These 3 domains of animal welfare are generally included in official definitions. For example, the OIE World Organization for Animal Health defines an animal as being in a good state of

welfare if it is “healthy, comfortable, well nourished, safe, able to express innate behaviour, and . . . is not suffering from unpleasant states such as pain, fear, and distress” (OIE World Organization for Animal Health, 2013). This definition is also used by the Australian Animal Welfare Strategy (Anon, 2011).

Whilst many consider that the three domains listed here are reasonably complete, they are not mutually exclusive. For example, a cow with mastitis might be in pain (poor affective state), have reduced milk production (biological function), and has reduced mobility due to the pain (reduced natural behaviour).

There is also the question of when and over what period animal welfare might be measured. An instantaneous assessment of animal welfare might concentrate on an animal’s feelings at the time of assessment, but a good welfare score on a single day of an animal’s life would not constitute a good outcome for that animal overall. In farm animals, where the end of life is characterized generally by euthanasia or humane slaughter, the definition of good welfare should consider a long term assessment of welfare – for example over the lifetime of an animal (Phillips, 2002).

Further, animal welfare could be viewed at several different levels. Questions such as whether animal welfare is better on a farm where overall longevity is shorter compared with one on which it is longer but some individual animals have very poor outcomes cause ethical dilemmas which may require definitions at individual, herd, and industry or country level to be considered.

Thus, in order to measure animal welfare as it pertains to dairy cattle or indeed a dairy herd, a definition will need to consider how the three domains might be interpreted, over what period measurements should be made, and how to manage the interaction between individual and group outcomes.

2.6. Measuring animal welfare

From a purely theoretical perspective, an index to measure welfare outcomes in dairy herds could be binomial (satisfactory or not), or on a scale that could be quantitative or qualitative. Given the complexity of the welfare space, it is likely that at a minimum, all the three domains would be measured. In order to accomplish this, some form of benchmarks would be necessary. Current outcomes could be measured against these benchmarks to produce some form of score or result.

An alternative (or additional) approach based on a quality assurance model might be to identify the known risks that result in poor welfare outcomes and audit how these risks might be managed.

The most well-known benchmarks that are applicable to dairy cows are undoubtedly the “five freedoms” as published by the UK Farm Animal Welfare Council (FAWC) in 1993. The current

official version of the Five Freedoms, as employed by the FAWC, is documented on the FAWC website (<http://www.fawc.org.uk/freedoms.htm>, 2013) and is listed below:

1. *Freedom from hunger and thirst—by ready access to water and a diet to maintain health and vigour.*
2. *Freedom from discomfort—by providing an appropriate environment including shelter and a comfortable resting area.*
3. *Freedom from pain, injury and disease—by prevention or rapid diagnosis and treatment.*
4. *Freedom to express normal behaviour—by providing sufficient space, proper facilities and appropriate company of the animal's own kind.*
5. *Freedom from fear and distress—by ensuring conditions and treatment, which avoid mental suffering.*

These “Freedoms” are referred to by most papers on the subject of welfare, and the basis for several animal welfare acts and several animal welfare quality assurance schemes around the world (McCulloch, 2012).

However, whilst the Five Freedoms have undoubtedly had a huge impact, several authors have pointed to issues that arise when the Five Freedoms are used as a framework for analysis of measurement of animal welfare.

McCulloch (2002) notes that the Five Freedoms actually denote nine conditions (hunger, thirst, discomfort, pain, injury, disease, expression of normal behaviour, fear and distress) and that some of the freedoms represent freedom *from* something (e.g. Freedom from hunger) whilst some of the freedoms represent freedom *to* do something (e.g. express normal behaviour). Further, words like discomfort and distress are complex concepts which are difficult to quantify; and freedom does not necessarily imply complete freedom. For example, most humans would describe themselves as experiencing discomfort from time to time and most would accept this as a normal part of life; and hunger is the normal physiological mechanism by which animals are stimulated to eat.

Korte (2007) argues that the ability to react to stressors rather than freedom from them should be the focus of animal welfare efforts. Fear is an emotion based on pre-perceptions of impending danger and is quite normal in appropriate situations, and as such, freedom from fear should not be the primary aim of welfare programs. Korte considers a working definition of distress: “a state in which an animal cannot escape from or adapt to the internal or external stressors or conditions it experiences, resulting in negative effects on its well-being”. Whilst this fits well with the proposal that it is often the ability of an animal to cope with stress rather than the stress per se that is important, it is also problematic because there is no clear criteria to mark the point at which an animal experiencing stress becomes distressed. There is no clear justification for assuming that the expression of a stress response always compromises health of welfare. There is a paradox in that the corticosteroid stress hormones and indeed the

sensation of pain itself are also adaptive in nature as they modify the physiology of behaviour of an animal such that its welfare may actually improve (Korte et al., 2007).

Following on from the “Five Freedoms”, the “Five Domains” model (FDM) for animal welfare (originally devised to assess animal welfare compromise in experimental animals) has been extended to overcome some of the limitations of the Freedom based models (Mellor and Beausoleil, 2015). The extended Five Domains model separates the indices used for assessing animal welfare compromise from those that assess animal welfare enhancement and then combines them to assess the animal’s welfare state. In this model there are three domains which describe internal compromises (nutritional, environmental or health related compromise) and one domain (behaviour) that accounts for external aspects of an animal’s environment that may limit its capacity to express behaviours or pose challenges to the behaviour that an animal wishes/needs to express. Once the internal and external factors are assessed, their anticipated affective consequences are assigned to the fifth ‘mental’ domain, and it is these experiences which determine the welfare state of the animal. The FDM provides a systematic framework to recognize and grade both negative and positive animal welfare states, but it relies on subjective interpretation of observations rather than quantitative analysis. The model recognises that it is not possible to be completely free from negative experiences nor to live an entire life of pleasure, and to that end embraces the concept of Quality of Life (QoL) which focuses on the balance between the two. Briefly, the QoL scale has categories of a good life, a life worth living, point of balance, a life worth avoiding and a life not worth living, based on the relative balance between positive and negative experiences. The FDM is a model that could be applicable to any circumstance where the welfare of animals is considered. The framework provides guidance but does not comprehensively cover how animal welfare might be objectively assessed and graded on pasture-based dairying systems.

Various systems have been proposed to measure and audit welfare in dairy cattle. In the Australian context, a “Unified Field Index for Managing Animal Welfare Performance On-Farm” (UFI) has been recently proposed, with a framework that consists of assessment on a suite of domains that are more risk-based than the WQ-ME framework and which could be applied to all livestock sectors (Colditz et al., 2014). The purposes of the UFI welfare assessment are: compliance (with policy, law, regulations; market assurance (to assure consumers and non-consumers that various aspects of welfare that are not necessarily enshrined in regulation are met) and welfare management (to assist producers to monitor and improve livestock welfare). The domains proposed in the UFI are divided into three modules:

1. *The Animal module includes: Behaviours (abnormal, social, self care); Health (mortality, morbidity, current status); Affect (demeanour, avoidance behaviours); Production (targets); Reproductive performance; and holistic attributes*

2. *The Resources module includes: Feed and Water(quality, quantity); Climate (risk of extremes); Social (density and group structure); Comfort (bedding, shelter); and Hygiene (cleanliness and health of companions)*
3. *The Management module includes: Skills (training, experience, attitudes); Husbandry procedures (methods, analgesia, euthanasia methods); Genetics management (environmental suitability, appropriate objectives, culling criteria); Records (training, husbandry, vaccinations, medications, farm chemicals, production, health); and review and action protocols.*

The UFI provides a considered framework for welfare risk management on Australian livestock properties, but it is (rightly) based on a continuous improvement model and does not currently contain sufficient detail in the assessment processes to specifically allow for assessment of differences in welfare risks to dairy cattle as scale of production increases, which is the topic of this thesis.

One of the largest formal welfare quality auditing systems used in dairy cattle is the WelfareQuality® multi-criteria (WQ-ME) model project (Botreau et al., 2007, 2009). In designing the program, it was proposed that a set of criteria was needed that was exhaustive, containing every important viewpoint; minimal, containing only necessary criteria and avoiding duplication; independent of each other; agreed by stakeholders; and legible (a reasonable number of criteria).

As such a set of 12 criteria were adopted:

1. *absence of prolonged hunger*
2. *absence of prolonged thirst*
3. *comfort around resting*
4. *thermal comfort*
5. *ease of movement*
6. *absence of injuries*
7. *absence of disease*
8. *absence of pain induced by management procedures*
9. *expression of social behaviour*
10. *expression of other behaviours*
11. *good human-animal relationship*
12. *absence of general fear.*

These criteria were each assigned a rating of 'Excellent', 'Enhanced', 'Acceptable', and 'Not classified' with numerical scores of 80,55 and 20 assigned to the first three scores.

Whilst widely adopted, the WelfareQuality® scheme does not have universal support. One study in Dutch dairy herds (de Vries et al., 2013) reported difficulties with assigning a score in 17 of 183 herds due to missing data; concerns that some of the measures seemed to have higher impact on the final score and concluded that classification of herds based on the WQ-ME model in its current form might lead to a focus on improving these specific measures and divert attention from improving other welfare measures. In another study (Andreasen et al., 2013), two trained auditors visited 43 Danish dairy cattle farms at different times but highly significant inter-observer differences were found and the study concluded that WQ-ME scores showed some weak correlations to welfare quality measures but there was no meaningful pattern of relationship between these measures.

2.7. WelfareQuality® in the Australian context

The WQ-ME model was developed in Europe, where the dairying system very commonly involves housing cows for some or all of the year. There may be different risks to welfare for cows in these systems than those in the extensive pasture-based Australian systems and it is prudent to examine the twelve WQ-ME criteria more closely to see how they might apply in the Australian context.

2.7.1. Absence of prolonged hunger

The WQ-ME model uses a simple three category (0=regular,1=very lean,2=very fat) body scoring system to assess absence of prolonged hunger, where a penalty equal to the percentage of very thin cows is added to the overall welfare score (Welfare Quality®, 2009).

In Australian dairy cattle, body condition score is commonly measured on a 1-8 scale (Roche et al., 2004; Dairy Australia, 2013a). There is an industry recommendation from Dairy Australia (the Australian Dairy Regional Development Corporation) that dairy herds should have no cows in condition score 1 or 2, and that less than 15% should be below condition score 4.5, above score 5.5 at calving or lose more than one score following calving.

Apart from the welfare implications associated with chronic underfeeding, body condition score has been shown to be important by many authors as it is correlated with disease, production and reproduction (Roche et al., 2000, 2013; DeJarnette et al., 2001; Pryce et al., 2001; Berry et al., 2003; Buckley et al., 2003). Whilst these implications of body condition score are important for health and productivity, disease is assessed via other components of a welfare assessment, even though the root cause may be nutritional.

The Australian Animal Welfare Standards and Guidelines for Cattle (Animal Health Australia, 2014a) take a somewhat different approach. Whilst they note that appropriate body condition is important, they focus on the access to food and water and monitoring of stock rather than having specific metrics. The Standard is that “A person in charge must ensure cattle have reasonable access to adequate and appropriate feed and water”.

There are few if any reports detailing the proportion of very thin cows on Australian farms. One implication of feeding pasture and forage as a major component of the diet is that immediately following calving, the energy density of the diet is such that cows cannot consume sufficient energy for their needs, and they lose body condition. Although the effect on animal welfare was not the subject of the work, low body condition score has been identified by several authors as an important factor on Australian and New Zealand dairy farms through its effect on fertility (Shephard, 2005; Roche et al., 2010; Walsh et al., 2011; Plozza et al., 2016).

As well as having sufficient food, it is important from an animal welfare perspective that the diet is appropriate and well balanced with the requirements of the cows. Grain or concentrates that are pulse-fed to cattle during milking increases the risk of diseases secondary to overfeeding grain. An inadequate transition diet prior to calving has been associated with increased levels of diseases such as hypocalcaemia, ketosis, mastitis, lameness, dystocia and rumen acidosis (von Keyserlingk et al., 2009, Lean et al., 2010).

In order to assess the quality of nutrition and the risks associated with increasing herd size, it will be necessary to consider not just the quantity of feed provided, but also when it is fed, any consequences of the diet and how quickly and effectively such consequences are detected and managed. Further, as the post-partum period is a higher risk time when cows are losing weight, the timing of investigation may be of importance, particularly in seasonally calving herds.

2.7.2. Absence of prolonged thirst

The WQ-ME model describes resourced-based measures surrounding the number of water points, their cleanliness, and the frequency and duration of cows' access to them (Welfare Quality®, 2009). The measures are appropriate for cows in housed circumstances but may not be applicable in the Australian context where cows spend most of the day in outside paddocks which can be some distance from the dairy.

The Australian Animal Welfare Standards and Guidelines for Cattle (Animal Health Australia, 2014a) states that lactating cattle should have access to water at least twice daily.

From an animal welfare perspective, it is worth considering not only how much water dairy cows require, but when they prefer to drink it. There has been little work studying the drinking behaviour of Australian cows, but some New Zealand and overseas work showed that cows being fed total mixed rations drank more often than grass fed cows (5.2 times vs 3.5 times in 24 hours) but they drank less per time (14.9 vs 21.7 litres per drink) (Jago et al., 2005). This study recommended that placement of water points near the dairy or on dairy tracks may be important as New Zealand farms increase in size.

Reports regarding common practices regarding placement of and access to water points in the Australian context are rare. A possible implication of increasing scale of production is that cows are fed increasing amounts of grain and spend longer being milked, and that this may have implications for their water requirements, and is worthy of further investigation.

Water quality may also be a potential animal welfare challenge on farms, especially where the water supply is derived from dams or bores. Whilst it has been shown that saline water may reduce production (Jaster et al., 1978; Solomon et al., 1995), from an animal welfare point of view the supposition that cattle prefer the same type of water that humans do may not be valid. Indeed in one study where high producing Holstein cows were offered tap water or saline water (2500ppm NaCl), mean daily intake of saline water was 9.3 litres higher per day than cows drinking tap water even though their production was reduced (Jaster et al., 1978). It has been shown in New Zealand that faecal contamination reduces palatability and may reduce production (Collins et al., 2007). A further study of dairy cows showed that low levels of iron in water did not affect intake (Genther and Beede, 2013). There are few, if any, reports regarding the water quality on Australian dairy farms and any relationship with herd size.

2.7.3. Comfort around resting

It has long been recognized that cows normally spend a significant part of their day lying down resting, and that this resting makes a significant contribution towards their comfort and welfare.

Assessment of lying behaviour can be divided into “lying-down time” – the time taken to complete the lie down process once it has started and “lying time” – the time spent with the body resting against the ground.

2.7.4. Lying-down time

Injuries and swellings of legs, knees and hocks are associated with lying on hard or rough surfaces, and have been associated with increased lying-down time (Haley et al., 2000; Rushen et al., 2007; Charlton et al., 2015). Thus, dairy cows on pasture may be less likely at risk of compromise for lying-down time as they are less constrained when choosing a place to lie down and lying on pasture is less likely to cause knee and hock injury than indoor situations.

In one study, where pasture based and loose housed cows on deep bedding were compared with tie stall cows, pasture based cows on average spent 8 seconds examining the lying place and then took 47 seconds for total lying-down time, while cows on deep bedding took more than twice as long, and tie stall cows spent 42-51 seconds examining the place to lie down and 118-129 seconds for total lying-down time (Krohn and Munksgaard, 1993).

2.7.4.1. Lying Time

The frequency and duration of lying behaviour are probable indicators of cow comfort, and there is considerable evidence that restricting lying behaviour reduces animal welfare outcomes. In a study where Dutch Friesian bulls were deprived of lying down from 7am until 2pm and 3pm until 10pm for 10 weeks. (Munksgaard et al., 1999), lying-restricted cows showed consistent behavioural changes indicative of both physical strain and frustration, however cortisol rises were not sustained. Where non-pregnant Jersey cows were restricted from lying down between 3pm and 6.45am for 7 days (Fisher et al., 2002), lying-restricted cows showed increases in plasma cortisol, reduced pituitary responsiveness to corticotrophin-releasing hormone (CRH) and increased plasma cortisol/ACTH ratio following CRH challenge.

High-producing dairy cattle spend about 40-60% of the day lying down. Table 2.2 presents a summary of some papers which report the mean voluntary lying time recorded for lactating dairy cows on pasture.

TABLE 2.2. PREVIOUS STUDIES REPORTING MEAN LYING TIME FOR LACTATING DAIRY COWS AT PASTURE

Summary	Mean lying time for lactating cows at pasture	Other comments
Lactating dairy cows with access to pasture as well as a cubicle barn (Ketelaar-De Lauwere et al., 1999)	11.8 hours/day	Cows were milked using automated milking machines at times initiated by the cow
Lactating dairy cows on pasture (Singh et al., 1993)	10.3 hours/day	Patterns of lying and other activities of cows while they were housed were quite different while they were at pasture
Loose housed (open barn with free access to pasture) dairy cows (Krohn and Munksgaard, 1993)	10.1 hours/day	Cows confined to tie stalls lay down for longer (11.8-13 hours/day)
Lactating dairy cows on pasture, divided into dominant and non-dominant groups (Phillips and Rind, 2002)	10.2 hours/day	Combined average lying time of dominant and non-dominant groups
Mid-lactation lactating dairy cows (Botheras, 2006)	9.1-10.1 hours/day	Based on the percentage of 15-minute increments that mid-lactation cows were observed lying down
The lying times of lactating cows on 36 farms with automated milking systems were monitored to see how lying times related to cow level factors such as lameness, leg lesions and body condition score (Westin et al., 2015).	11.4 hours/day	Only a small proportion of lying time was explained by lameness, leg lesions and BCS. These cows, although on pasture, were on demand by automated systems.

The WQ-ME model describes measures such as the time taken to lie down, collisions with housing equipment during lying down, lying outside the lying area and cleanliness of the udder, flank/upper legs and lower legs. There is no measurement index regarding the amount of time a cow spends lying down – and indeed this would be difficult to accomplish or interpret in the context of an on-farm audit.

In the Australian pasture-based system, the appropriateness of these WQ-ME measures is questionable and indeed from a welfare point of view there may be a difference between being caked with mud (from outside) and faeces (from inside). Cleanliness measures may have some relevance, but there is no reported base line data on Australian dairy farms.

If cows are motivated to spend approximately 8 hours grazing and 10 hours lying down, it seems reasonable to hypothesise that the time budgets of cows might be affected when cows spend more than 6 hours (or 240 minutes) away from pasture per day, and accordingly this might impact on their welfare. To our knowledge, the time budgets (walking, standing and lying) of dairy cows in large pasture-based dairy herds where the milking process takes more than three hours, such as are common in Australia, have not been previously examined.

2.7.5. Thermal comfort

The thermoneutral zone for lactating cattle, where effects on production due to temperature are minimal, is reported to lie between 5 and 25°C (Staples and Thatcher, 2011; Polsky and von Keyserlingk, 2017). The lower critical temperature for adult dairy cattle (the ambient temperature below which the rate of heat production must increase to maintain thermal balance) for a lactating dairy cow has been estimated to be as low as -16 to -37°C (Kadzere et al., 2002) which is lower than temperatures reached in the dairying regions of Australia, so severe physiological cold stress is unlikely. However, from an animal welfare point of view, temperature alone is insufficient to predict a level of discomfort. Howling wind and pouring rain seem likely to add to discomfort in cold weather. A New Zealand study in which cows were exposed to artificial wind and rain for 7 days (15 mins of rain per hour, mean temperature of 3.4°C, wind chill of -0.3°C) demonstrated a stress response but it was unclear whether this was due directly to the cold conditions, or due to a decrease in lying time and feed intake (Webster et al., 2008).

The duration of exposure and the ability to seek relief from temperature extremes are important animal welfare considerations. The temperature-humidity index (THI), calculated by combining the air temperature and humidity has been reported as a tool for predicting heat stress by many authors (Kadzere et al., 2002; West, 2003; Berman, 2005; Staples and Thatcher, 2011; Polsky and von Keyserlingk, 2017). The THI has limitations because wind speed, solar radiation, age, species, level of production, diet, coat colour and other factors also impact on the ability of cattle to cope with temperature extremes. The Australian climate poses risks to animal comfort, particularly for heat stress and the Australian dairy industry has developed tools to assist producers manage this risk. The Dairy Heat Load Index (DHLI) uses a black globe thermometer rather than ambient temperature in order to take account of air movement and radiation effects (Dunshea et al., 2013). A software package has been produced that is used by the dairy industry to better manage cows during periods of elevated environmental heat load by equipping producers, managers, and dairy industry personnel with Dairy Heat Load Index (DHLI) values that are calculated based upon site information, stock characteristics, management practices, and mitigation variables specific to their dairy production unit. This is available through a website (www.coolcows.com.au accessed 1/1/2018) which also provides strategies to manage heat stress in dairy cows.

A New Zealand study showed that sprinklers and shade were both beneficial to cows in hot conditions (Kendall et al., 2007). Sprinklers alone and the combined effects of shade and sprinklers reduced the respiration rate by 60 and 67%, respectively, compared with controls. Sprinklers were particularly effective, with a decrease in body temperature being evident for four hours afterwards.

A recent survey of Australian herds found that shade in paddocks remains the main way farmers keep cows cool (77%) compared to cooling infrastructure in the dairy yard or shed

(45%), and 89% of farms had water troughs in all paddocks that cows graze on (Dairy Australia, 2016).

As yet, no measure is developed in WQ-ME to quantify the welfare effects of thermal stress in an audit context. There are clinical signs (such as panting, recumbency, rectal temperature) that can be used to measure whether a particular cow is affected by temperature stress but these do not lend themselves well for on-farm measurements on the day of audit. It seems logical that larger herd sizes could be associated with increased risk of thermal stress through having large expanses of concrete flooring surrounding the dairy infrastructure, larger numbers of cows (which themselves produce heat) in close proximity at the dairy yard and perhaps larger paddocks with less trees. Further work is needed in this area.

2.7.6. Ease of movement

WQ-ME states that animals should have enough space to be able to move around freely, and this is measured by the presence of tethering and access to exercise – both potential issues in housed systems. It seems unlikely that this would present a major animal welfare challenge to pasture-based Australian dairy cows.

2.7.7. Absence of injuries

WQ-ME states that animals should be free of injuries, e.g. skin damage and locomotory disorders. Whilst skin damage is more likely a problem in housed cows that rub against farm infrastructure, lameness remains a common problem of dairy cattle worldwide. As well as being a significant animal welfare concern (von Keyserlingk et al., 2009; Fisher and Webster, 2013; Hemsworth et al., 2015), lame cows have reduced fertility, milk production and bodyweight, as well as incurring treatment costs and being at risk of premature culling (Green et al., 2002; Bruijn et al., 2012; Grant, 2012; Fabian et al., 2014). On Australian pasture-based farms, where cows may often walk several kilometres per day and stand for several hours per day in a crowded concrete yard while they wait to be milked, the potential for lameness to impact negatively on animal welfare is of ongoing concern.

From an animal welfare perspective, the prevalence of lameness is important, but also important are how rapidly lame cows are identified and how they are managed. For example, milking lame cows in a separate herd so they do not have to walk as far or stand in a concrete yard for as long would reduce the impact of lameness for those cows, as might the application of 'blocks' to the sound claw of an injured foot.

Several studies have shown that when farmers do not use systematic lameness scoring systems, they tend to underestimate the incidence of lameness in their herds. A study of 59 New Zealand pasture-based dairy herds reported that only 27.3% (range 0-95%) of cows with reduced mobility had been identified as such by farmers (Fabian et al., 2014). In housed cows there have been similar results. Whay et al., (2003) reported UK farmers estimating the prevalence of lameness to be 5% when the actual prevalence was more than four times that (22%) and Espejo et al., (2006) reported the mean prevalence of clinical lameness to be 3.1

times higher than reported by farmers in free stall barns in Minnesota. Šárová et al., (2011) found that in 14 Czech loose-housed dairy farms, farmers estimated lameness prevalence to be between 0-20% whereas lameness scoring identified 9-64% of the herds as lame and there was no correlation between farmer estimate and true prevalence.

Improving farmer diagnosis/identification of lameness is likely to result in more prompt treatment (Alawneh et al., 2012) which in turn will likely improve clinical outcomes (Leach et al., 2012) and thus also improve animal welfare outcomes. To that end, both the Australian and New Zealand dairy industries have developed extension programs (known respectively as 'Healthy Hooves' and 'Healthy Hoof') promoting the formal lameness scoring of dairy herds on a regular basis (Dairy Australia, 2015; DairyNZ, 2017). Both extension programs use a 0-3 scale based on the AHDB Dairy mobility score (Barker et al., 2010), adapted slightly to suit local conditions and language use. Video instructions and print material resources are available that show farmers how to score lameness in a consistent way as cows leave the milking parlour.

Despite these resources being available, the uptake of lameness scoring in Australia remains low because, anecdotally at least, farmers appear to believe that they are skilled at identifying clinically lame cows, the time/effort required, and because lameness scoring is seen as a low priority at times of year when it is not a major clinical problem (Dairy Australia, 2016). The same study – a large survey of husbandry practices in the Australian dairy industry reported: most farms have lameness prevention strategies in place (95%); lameness strategies are undertaken on almost all dairy farms (95%); laneway maintenance remains the predominant method to manage lameness (77%); Only 1% of farmers said they use lameness scoring as a means of preventing lameness in the herd; since 2014, there has been an increase from 18% to 24% in the proportion of farmers mentioning not pushing their herd to walk too fast as a means of preventing lameness.

It seems logical that increased walking track distances would predispose to increased lameness prevalence but there is little objective evidence to support this. In a study of 63 pasture-based Australian herds, recent rainfall, smoothness of concrete, space per cow in the dairy holding yard and inappropriate handling of cows on the track were associated with lameness, but track length was not. This is consistent with New Zealand work that showed a relationship between lameness and the width of the track, maintenance of the track, cow flow on the track and space in the dairy yard. In this study, track length was not included in the final model because it was correlated with track quality which had a greater effect on lameness (Chesterton et al., 1989). Even if the proportion of lame cows was unchanged, the sheer number of lame cows that need to be detected and treated will produce different challenges on larger farms. The animal welfare impact on individual lame cows that need to walk further on longer tracks also needs consideration.

2.7.8. Absence of disease

In WQ-ME, this criterion is measured through the mean number of coughs per cow per hour, percentage of on-farm mortality, percentage of downer cows, percentage of cows with nasal discharge, ocular discharge, hampered respiration, diarrhea, vulvar discharge, dystocia, and SCC >400,000 cells/mL.

The idea that good health is important for good animal welfare is relatively uncontroversial and in most cases there are economic reasons for effective prevention and treatment of disease. Problems in biological functioning where pain is a feature (e.g. downer cows, clinical mastitis) are clearly animal welfare concerns, whereas in other cases it is less clear (e.g. endometritis, mild parasite burdens, mild increases in individual cell counts). The challenge is to find practical objective measures that reflect animal welfare outcomes.

2.7.8.1. Mortality

Mortality should be considered only as a crude indicator of health and welfare (von Keyserlingk et al., 2009). The relationship between mortality and welfare is not necessarily clear. For example, high culling rates may reflect the aggressive removal and replacement of low-producing cows which may be welfare neutral or even positive to the extent that low production is a result of disease or other problems with the animals' biological functioning. On-farm mortality rates need to distinguish between animals found dead on farm (likely related to poor welfare for that animal) vs. those that were euthanized in order to prevent suffering (Robbins et al., 2016). From an animal welfare point of view, the incidence/prevalence of euthanasia is important, but also the timing and nature of the procedure. In a study that involved 80% of dairy cows in the USA, large farms (>500 cow) that reported having to euthanize a non-ambulatory cow, approximately 72% did so within 2 d compared to only 59% in the case of small farms. The majority of large operations (57%) have standard operating procedures in place for caring for downer cows, compared with 16%-24% of smaller operations (USDA-NAHMS, 2016).

Current legal methods recommended for euthanasia of cattle in Australia include gunshot, captive bolt and lethal injection administered under veterinary supervision. Blunt trauma to the head of calves less than 24 hours of age and exsanguination are permitted if no other methods are available (Animal Health Australia, 2012). The licensing and use of firearms has been strictly controlled in Australia for some time. Euthanasia on farm may be carried out by farmers using firearms (which have special licence, storage and occupational health and safety requirements) or captive bolt guns (which whilst they require care in their use do not have licensing requirements in most states in Australia). Farmers who do not have firearms or captive bolt devices on farm commonly use their veterinarian or a local knackery service for euthanasia. Knackeries have the advantage that they remove and dispose of the carcass, but the possibility of a delayed attendance and thus delayed euthanasia is a risk to animal welfare. Ownership of penetrating captive bolt guns for euthanasia of livestock is being promoted to Australian farmers because they are considered safer, have fewer restrictions than firearms,

and cheaper models are now readily available (Jubb, 2013). Surveys of Australian dairy farmers reported that in 2016, 25% of farms were still using blunt force trauma in calves (decreased from 29% in 2014) and that, nationally, 13% of farmers (or someone else from the farm) have attended a calf euthanasia course (Dairy Australia, 2014a, 2016). More work is required to understand whether euthanasia methods and timing are a particular animal welfare challenge in large Australian dairy herds.

2.7.8.2. Morbidity

Morbidity can be measured either as a point-estimate at the time of an audit or from farm records. The former is problematic because disease incidence varies with the time of year and stage of lactation (Lean et al., 2010). Measuring morbidity from farm records is often problematic because of the need for accurate, standardized and repeatable case definitions (Lean et al., 2009). For example, farmers may record a dystocia whenever a cow is assisted but some farmers are very pro-active and may assist cows to calve much sooner than others. Lean et al (2010) proposed achievable targets and thresholds where farmers should seek advice for several diseases in Australian herds. These are shown in Table 2.3.

TABLE 2.3. ACHIEVABLE TARGETS FOR COW HEALTH PROBLEMS EXPRESSED AS PERCENTAGE OF CASES OF CALVING COWS WITHIN 14 DAYS OF CALVING. ADAPTED FROM LEAN (2010).

Health problem	Target	Seek help if
Milk fever	1% (old cows >8yrs: 2%)	>3%
Clinical ketosis	<1%	>2%
Abomasal displacements	<1%	>2%
Clinical mastitis	<5 cases / 100 cows / first 30 days	>5 cases / 100 cows / first 30 days
Lameness (locomotion scale 1-5)	<2% with > Score 2	>4% with > Score 2
Hypomagnesaemia (Grass Tetany)	0%	1 case
Retained placenta >24 hrs after calving	<4%	>6%
Calvings requiring assistance	<2%	>3%
Clinical acidosis	0%	1%

There is a relationship between quality of nutrition and most diseases and indeed exceeding the thresholds in Table 2.3 has been associated with inadequate transition period nutrition (Lean, 2010). Thus, simply measuring prevalence of disease quantifies the symptom, not the cause of animal welfare challenges. Assessing more sensitive indicators which might be of use before animals are clinically ill or dying should greatly reduce the suffering as a result of disease (von Keyserlingk et al., 2009). Such indicators might include the quality of transition diet, frequency of veterinary herd health visits, access to euthanasia methods such as captive bolt guns, presence of recognized standard operating procedures and similar (von Keyserlingk et al., 2009; Robbins et al., 2016; USDA-NAHMS, 2016).

A recent survey of Australian farms reported that 65% of Australian dairy farms had a documented animal welfare protocol, more than 70% of large and very large farms had a formal feed budget (compared with less than 50% of small and medium farms), 69% of farms

check downer cows three or more times per day, but less than half of farms had a copy of the Australian Animal Welfare Standards and Guidelines for Cattle (Dairy Australia, 2016).

2.7.9. Absence of pain induced by management procedures

Disbudding and tail docking are aversive husbandry procedures that, despite evidence that the practices are painful and that there are effective means to mitigate the pain, may be undertaken on dairy farms without the use of pain relief, and this is of concern to the general public (Robbins et al., 2015; Animals Australia, 2018; RSPCA Australia, 2018).

The practice of removing horns in cattle is routinely undertaken to improve animal welfare in the longer term and for operator safety during handling. There is an increased risk of injury, hide damage and bruising in horned cattle compared to polled cattle, particularly during handling, yarding and transport (Stafford and Mellor, 2005; Knierim et al., 2015). There is a requirement that exported cattle are dehorned, and indeed the Australian Model Code of Practice for the Welfare of Animals: Cattle (Primary Industries Standing Committee, 2004) advises that all horned cattle should be dehorned as young as possible.

2.7.9.1. Disbudding vs Dehorning

Disbudding involves destroying the horn-producing cells of the horn bud in the young animal before it has attached to the skull, before approximately 8 weeks of age. This typically Results in relatively small and superficial wounds. Dehorning involves amputation of the horns in the older animal after the horn has become attached to the bone of the skull. This approach is much more invasive, often involving extensive wounds of the skull and some penetration of the frontal sinuses (Stafford and Mellor, 2005, 2011; Robbins et al., 2015).

The practice of disbudding calves at an early age rather than dehorning of heifers has been promoted through industry media by Dairy Australia although uptake of this has not been universal. In a survey of Australian dairy farmers in 2014, only 63% of farmers disbudded all their stock at less than 2 months of age. In this study, 22% dehorned between 2 and 6 months, 6% after 6 months and 1% did not remove horns at all (Dairy Australia, 2014a).

2.7.9.2. Disbudding by surgical means

Horn buds can be physically removed using knives, shears or dehorning scoops. To prevent horn regrowth, a complete ring of hair surrounding the horn bud should also be removed (Weaver et al., 2018). The primary advantage to farmers of disbudding by surgical means is that the equipment required is inexpensive and portable and farmers are able to perform the procedure themselves without the need for contractors. Disbudding needs to be undertaken by approximately 6 to 8 weeks of age. Disbudding at an earlier age involves the removal of less tissue and Results in less pain and distress and is generally recommended (Andrews et al., 2004; Animal Health Australia, 2014a; Dairy Australia, 2014a; OIE, 2017) .

2.7.9.3. Disbudding by cautery

Cautery (or hot-iron) disbudding involves using an electrical or gas-fired disbudding device and is commonly performed on calves around 6-8 weeks of age. At this age the horn buds are

small, easy to remove completely, usually only require one application of the cautery iron, and are likely to heal more quickly. The process typically involves pressing a very hot ring-shaped iron (electrically or gas heated) onto each horn bud for about 5 seconds so that it burns through the tissues that nourish the horn bud and thereby prevents the horn from developing (Stafford and Mellor, 2005, 2011; Miesner, 2008).

Disbudding using cautery is thought to create less distress than surgical methods because it results in relatively superficial wounds and may mimic a local anaesthetic effect by destroying pain receptors at the burn site, such that pain perception is consequently reduced (Sylvester et al., 1998, 2000; Stafford and Mellor, 2005). In 3-4 month old calves, heat almost eliminated the surge in cortisol 3-7 hours after scoop dehorning under a local anaesthetic, indicating that cauterization may help prevent postoperative pain (Sutherland et al., 2002).

Cautery also ensures that there is little loss of blood and no open wound that may be susceptible to infection. Dehorning contractors are readily available in most of the intensive dairying areas of Australia. One disadvantage of dehorning is that unless significant capital is invested in purchasing the equipment, the procedure tends to be undertaken in batches – possibly only once a season, when the youngest calf is old enough. This increases the likelihood that some calves will be older than is ideal at the time of treatment.

2.7.9.4. Disbudding by chemical means

‘Paste disbudding’ chemically removes the tissue surrounding the horn bud, destroying the horn-producing cells (corium) of the horn bud by applying a caustic paste to the area, usually containing sodium hydroxide or calcium hydroxide, or a mixture of these two strong alkalis (Weaver et al., 2018). Paste disbudding is currently prohibited under Australian law (Animal Health Australia, 2014b) and thus will not be considered in this review.

2.7.9.5. Pain relief for disbudding

That pain relief is a good thing for disbudding from an animal welfare point of view is not controversial. Pain relief is a requirement for horn removal in animals greater than 6 months of age in Australia (Animal Health Australia, 2014b). For animals less than 6 months of age, it is not mandatory but is strongly recommended by industry (Dairy Australia, 2016), the Australian Veterinary Association (Australian Veterinary Association, 2018) and animal welfare organizations (Animals Australia, 2018; RSPCA Australia, 2018). Saputo, one of the largest milk processing companies in Australia has recently made pain relief when disbudding calves a mandatory condition of milk supply (Saputo, 2018), and in New Zealand the use of local anaesthesia for disbudding will be mandatory from October 2019 (Ministry for Primary Industries (NZ), 2018).

Whilst many jurisdictions recommend or mandate the use of pain relief when calves are dehorned, they tend not to describe in detail how that might be achieved. Options for pain relief include local anaesthetic blocks, anti-inflammatory drugs and sedation/anaesthesia.

There have been many papers comparing various treatments and combinations of treatments – a review in 2005 by Stafford and Mellor had over 70 references.

Effective local anaesthesia, usually a cornual nerve block, virtually eliminates pain related behaviour in calves during dehorning (Petrie et al., 1996; Sylvester et al., 2004) as well as preventing the dehorning-induced cortisol response while the block persists. However, after the local anaesthetic block wears off the cortisol concentrations increase markedly for about 6 h (Petrie et al., 1996; Sylvester et al., 1998), and behavioural indicators such as restlessness increase to levels similar to those seen in calves dehorned without local anaesthesia (Sylvester et al., 2004).

Administering a cornual block requires training and skill, and when not performed properly it is ineffective (Weaver et al., 2018). Topical formulations including local anaesthetic that are much easier to administer have shown promising Results for scoop dehorning but further works is needed (Espinoza et al., 2013; McCarthy et al., 2016; Windsor et al., 2016).

The use of various non-steroidal anti-inflammatory drugs in addition to local anaesthesia has been shown to reduce behavioural signs of pain and blood cortisol concentrations (Stafford and Mellor, 2005, 2011). In Australia, only meloxicam is currently registered for this purpose. Meloxicam has a half-life of 26 hours in calves and has been shown to be effective at reducing pain-related behavioural signs as well as cortisol concentrations following disbudding (Heinrich et al., 2009, 2010). A recent meta-analysis looking at the effects of local anaesthetic or systemic analgesia on pain associated with cautery disbudding in calves recommended best practice would include both local anaesthetic and NSAIDs used together, although this study did not consider the use of concurrent sedatives (Winder et al., 2018).

The sedative xylazine also has analgesic effects and its use in calves makes restraint and administration of local anaesthetic easier and has been recommended as best practice for disbudding of calves when combined with local anaesthetic and NSAIDs (Stafford and Mellor, 2005, 2011; Bates et al., 2015; Windsor et al., 2016). The use of sedatives without local anaesthetic is not recommended (Stilwell et al., 2010).

There is evidence that the application pain relief at disbudding is not only a benefit for animal welfare, but also for production. New Zealand work has shown improved growth rates for calved given local anaesthetic, meloxicam and xylazine (Bates et al., 2015, 2016).

A survey of dairy farmers in 2016 showed that whilst 64% of farmers used professional contractors to dehorn their cattle, only 23% mentioned the use of pain relief (Dairy Australia, 2016).

As herds get larger, the group of animals that require dehorning is likely to increase. Whether this leads to economies of scale and an increased likelihood of using professional contractors and pain relief, or whether the increased numbers of animals makes the extra time taken to apply pain relief and sedation less likely due to logistical problems, is unknown.

2.7.9.6. Tail docking

The Australian Animal Welfare Standards and Guidelines for Cattle state mandate that a person must tail dock cattle only on veterinary advice and only to treat injury or disease (Animal Health Australia, 2014b). However, the standards have not yet been adopted as law by all states and a recent survey found that tail docking was present on 13% farms, and that it was more common on larger herds of 301-500 cows (Dairy Australia, 2016). It is likely that tail docking will become less of an animal welfare challenge over time as uptake of the Standards and Guidelines increases.

2.8. Expression of social behaviour

The WQ-ME criteria for social behaviour state that animals should be able to express normal, non-harmful, social behaviours (e.g. grooming). This is measured in a pen, where observations are made regarding agonistic (head butting, fighting, displacement at a feeding bunk etc) and cohesive (licking, head play) behaviours. Previous studies have shown that agonistic behaviours are expressed more often in confined situations compared with cows at pasture (O'Connell et al., 1989; Miller and Wood-Gush, 1991). A study of lactating Holstein cattle reported 47% less aggressive interactions when space at a feeder was increased from 0.5 to 1 m (DeVries et al., 2004). It seems logical that cows at pasture would be more able to seek out or avoid other cows than those confined in pens. However, pasture-based cows spend several hours per day at close quarters when walking along the track to the dairy, waiting in the dairy yard to be milked, and sometimes accessing forage in a feed pad following milking. There are few, if any, reports investigating the expression of social behaviour in large Australian pasture-based dairy herds.

2.9. Expression of other behaviours

The WQ-ME criteria for expression of other behaviours states that animals should be able to express other normal behaviours, i.e. it should be possible to express species-specific natural behaviours such as foraging. In other species it is measured by observing negative (e.g. stereotypies) and positive (e.g. exploration) behaviours (Botreau et al., 2007) but in cattle it is assessed merely by the opportunity to access pasture. It may seem at first glance that since Australian cows are likely to have access to pasture every day, the expression of such behaviours is unlikely to be a major animal welfare challenge. However, in pasture-based herds the process of walking to the dairy, waiting to be milked, and returning to pasture may take several hours. Various studies have reported the typical time spent grazing for lactating cows at pasture to be approximately 8-9 hours : 515-540 minutes (Bargo et al., 2002a), 547 minutes (Botheras, 2006), 430 minutes (Pérez-Prieto et al., 2011). If cows are motivated to spend 8 hours grazing and 11 hours lying down, it seems reasonable to hypothesise that the time budget of cows for expressing behaviours such as grazing or lying might be impacted if cows spend 4 hours (or 240 minutes) away from pasture per day. Further, as it is common for cows to be collected from the paddock as a group, to wait as a group in the dairy yard to be milked and then individually return to the paddock or feed pad immediately following milking

(Scott et al., 2014), cows milked later in the milking order are likely to be away from the paddock for longer than cows milked earlier in the milking order. This has a potential impact on cow health and welfare, particularly if the same cows are consistently milked toward the end of the milking order. As herds get larger, cows walk further and milking can take longer (Verkerk and Hemsworth, 2010; Robbins et al., 2016) and thus this may be an issue of particular importance in larger herds.

2.10. Good human-animal relationship

The importance of stockmanship and the human–animal relationship (HAR) for farm animal welfare, health and performance has been demonstrated in several studies. Handling of farm animals in a positive or negative way can alter reproductive performance, production and will impact cow welfare (Breuer et al., 2000; Hemsworth et al., 2000; Hemsworth and Coleman, 2002; de Vries et al., 2011). Avoidance distance toward an unfamiliar person (AD) has been established as a valid behavioural indicator of HAR (Breuer et al., 2000; Waiblinger et al., 2003; Ebinghaus et al., 2016). Most protocols for AD measurement are described for experimental situations where the environment is standardised as much as possible. Ebinghaus et al., (2016) measured AD at the feeding gate and Waiblinger et al., (2003) measured it at both the feeding rack or in the barn. Both concluded that despite other factors that might impact on AD (such as age, the presence of other cows, time calved and other environmental factors), AD validly reflected HAR.

An Australian study showed that stock handlers' attitudes may be more related to objective assessment of HAR than herd size, however a New Zealand study suggested showed a positive association between AD and herd size (Breuer et al., 2000; Verkerk and Hemsworth, 2010).

2.11. Absence of general fear

The absence of general fear (other than of humans) and indeed the presence of a positive emotional state is assessed in WQ-ME by quantitative behavioural analysis (QBA). QBA is an integrated assessment of the whole animal where the animal's body language is evaluated as an indication of the animal welfare state (Wemelsfelder and Lawrence, 2001). Originally the QBA was developed by the use of spontaneous judgements in a process called Free Choice Profiling. Untrained personnel were asked to observe animals for a period of time and then write down the behaviours or mental states they felt best described the animals' status. The observers showed high agreement and the method had good repeatability and correlated well with other behavioural and physiological measures of animal welfare (Wemelsfelder and Lawrence, 2001). The scale was then further developed to a pre-fixed list of descriptors containing words like happy, content, nervous, frustrated and aggressive, as now used in WQ-ME. There are no reports, to our knowledge, of this technique being applied in Australian pasture-based dairy herds and indeed there would seem to be practical issues with undertaking such observations in large open paddocks.

2.12. Milking Order

As previously described, long milking durations and walking distances as occur on large Australian dairy farms have the potential to impact on the time budgets and ability to express social and lying behaviours of cows. As cows tend to leave the paddock together and return soon after they have been milked, the consistency of the milking order will determine the extent to which some individual cows within a herd may be affected more than others.

The order that cows enter the milking parlour is often termed the milking order, and several authors have demonstrated that there is a system or consistency to the milking order in dairy cattle.

In an early study of 50 Dutch Friesian cows in a free stall barn observed over a year (Soffié et al., 1976), the order of entrance to the milking parlour was systematic and was related to the dominance of cows in the group. This study also looked at the order in which cows exited the barn to enter the dairy yard. Whilst the lead cows were very consistent between the barn and the entrance to the milking parlour, the order became less stable as cows re-assorted themselves in the dairy yard.

Rathore briefly describes four experiments in ten Australian dairy herds ranging in size from 42 to 323 milking cows over 5-6 afternoon milkings (Rathore, 1982). Whilst consistency of the milking order was not the main focus of the experiments, the study showed that cows with higher yields and lower somatic cell counts were milked earlier in the milking order. There was also a relationship between stage of lactation and milking order.

In an early study using electronic motion sensors in a New Zealand research herd of 130 cows, Mitchell calculated the milking order as a percentage ranking within the herd and compared the daily rank position to a running mean in an attempt to diagnose oestrus through changes in yield and milking order position (Mitchell et al., 1996). Using milking order and production, it was possible to detect approximately 70% of oestrus events, but there was a very high false positive rate. It could be concluded from this work that the rank position of cows has some consistency, and that oestrus modifies the milking order position of a cow, but so do other factors.

In a study of 15 visits to ten New Zealand dairy herds focusing on lame cows, the “walking order” of cows on the track 100m away from the dairy had only fair agreement ($Kappa=0.31$) with the “milking order” as cows entered the dairy (Sauter-Louis et al., 2004). Cronbach’s alpha coefficients for the repeatability of milking order measurements was >0.9 and it increased from early to late lactation suggesting an increasing stability in the milking sequence with time. Lameness and dominance both affected milking order in this study.

Botheras studied daily electronic records from a single herd where up to 391 cows were milked on a single day over a period of approximately 6 months as part of a PhD (Botheras, 2006). She calculated normal order scores for the rank positions of cows each day in order to place more emphasis on changes in position early and late in the milking order and less emphasis on

changes toward the middle of the milking order (where the scope for change is larger). Correlations between the milking orders of any two milkings were very high (r generally between 0.8 and 0.9), even for milkings up to 168 days (6 months) apart. Milking order was correlated with age, somatic cell count, and milk yield. Similar to Sauter-Louis et al., (2004) the milking order appeared to become more stable as the season progressed. Botheras noted that even cows which appeared to be inconsistent based on high standard deviations of rank score often had periods of consistency with dramatic variation in position and then settling into a new reasonably consistent position.

A study of Irish herd testing records looked at genetic and non-genetic factors affecting milking order in nearly 2000 herds ranging in size from 40 to 250 cows (Berry and McCarthy, 2012). In order to account for the large number of herds and variation in herd size, Milking order was standardized, within herd test-date, to a mean of zero and variance of one by subtracting the actual cow milking order from the mean milking order of the herd test-day milking and dividing by the respective standard deviation of milking order, so that the mean milking order for each milking in each herd test-date was zero and a positive value was given to cows that entered the milking parlour earliest and a negative value was given to the later entry cows. The variance of milking order was therefore the same within each herd test-day, irrespective of herd size. The study showed that the repeatability of the milking order within test-day, within lactation, and across lactations was 0.63, 0.51, and 0.47, respectively. Milking order was weakly heritable (0.2) and, similar to previous studies, cows with higher yields and lower cell counts were milked earlier in the order.

A study of Australian dairy cows showed that milking order can affect the diet eaten. In one herd of just over 300 cows, serial measurements of pasture quality were made as cows entered the paddock following milking. Cows that arrived first to the paddock ingested pasture with greater CP (19% vs 15%) and lower ADF (26% vs 30%) than those arriving last, with 70% of the pasture (relative to post-grazing mass) being consumed before the last cow entered the paddock (Scott et al., 2014).

A European study of 692 cows divided into 7 feeding groups looked to see whether changes in the milking order could be used to detect disease (Polikarpus et al., 2015). A milking order score was created by averaging the milking position of the three milking sessions in a single day. The correlations between mean milking order positions of three milking sessions within days were between 0.96 and 0.97 and milking order was stable within days, and across days. Ninety-six percent of cows with mastitis entered the parlour later in the milking order than usual however the difference did not always occur before the day the cow needed treatment and thus the diagnostic value in practical terms was questionable. Of 51 cows with metritis, 67% entered earlier and 33% entered later than normal. Of 30 cows diagnosed with pneumonia, approximately half entered earlier and half entered later than normal. Over all treatments the milking position of diseased cows was 11.5 places later compared to cows with no treatments. Given the group sizes were mostly less than 100, such changes in position may

be large enough to have potential uses in the future. The study showed a weak correlation between somatic cell count and milking order with higher cell count cows tending to be later in the milking order. There was only very weak correlations in this study between milking order and parity, age, days in milk and milk yield but this may have been a result of the study design as confounding with feeding groups was likely.

Whilst there is good evidence about milking order consistency in smaller herds, as herd size increases above 500 cows, it seems likely that sheer crowd size combined with the myriad of factors at play that impact on milking order could make a stable milking order less likely. To our knowledge, the consistency of the milking order in larger herds has not been examined closely and more work is needed in this area.

2.13. Conclusions

There is evidence worldwide that although as herd sizes increase and risk factors for animal welfare may change, there is no evidence of a simple relationship between herd size and animal welfare. In contrast to many other countries, most Australian dairy herds are pasture-based rather than housed, thus the particular challenges and opportunities for good animal welfare are likely to differ between the systems. Based on a review of the literature, there are a number of aspects that are worthy of further investigation:

- There are some animal welfare challenges associated with increased herd size that are likely common to all farming systems. Examples include increased stocking densities, longer milking times, reduced ability to examine and treat cows individually, and reduced quality of the human-animal relationship. There are also factors that might promote good animal welfare such as more specialized and professional management of animal health, superior staff training and general quality assurance systems. The relationship between herd size and such factors is not well understood in pasture-based Australian dairy herds.
- There are some animal welfare risk challenges that are likely to be more important in Australian dairy herds because Australian dairy cows are not housed indoors. Examples include exposure to climate, longer walking distances, and a potentially more variable diet (because it is not based on total mixed rations) and water quality. The particular challenges associated with increasing scale of production in the Australian pasture-based dairying system are not well described.
- There are several welfare quality assurance schemes used overseas, but these are predominantly designed for housed dairying systems, and there has been little uptake of their use in Australia.

The aim of this thesis is to fill some of the gaps in our knowledge and to objectively identify and measure factors associated with animal welfare so that industry can recognize and manage them in order to ensure dairy cow welfare with increasing scale of production in Australian dairy herds.

CHAPTER 3

3. A survey of Australian dairy farmers to investigate animal welfare risks associated with increasing scale of production

This paper has been published in the Journal of Dairy Science:

Beggs, D.S., A.D. Fisher, E.C. Jongman, and P.E. Hemsworth. 2015. A survey of Australian dairy farmers to investigate animal welfare risks associated with increasing scale of production. *J. Dairy Sci.* 98:5330–5338. doi:10.3168/jds.2014-9239.

The survey questions are described in appendix 1.

3.1. ABSTRACT

Although large herds (over 500 cows) only represent 13% of Australian dairy farms, they represent more than 35% of the cows milked. A survey of Australian dairy farmers was conducted to assess relationships between herd size and known or proposed risk factors for adverse animal welfare outcomes in Australian dairy herds in relation to increasing scale of production. Responses from 863 Australian dairy farms (13% of Australian dairy farms) were received. Increasing herd size was associated with increases in stocking density, stock per labour unit and grain fed per day – all of which could reasonably be hypothesized to increase the risk of adverse welfare outcomes unless carefully managed. However, increasing herd size was also associated with an increased likelihood of staff with formal and industry-based training qualifications. Herd size was not associated with reported increases in mastitis or lameness treatments. Some disease conditions, such as milk fever, gut problems and down cows, were reported less in larger herds. Larger herds were more likely to have routine veterinary herd health visits, separate milking of the main herd and the sick herd, transition diets before calving and written protocols for disease treatment. They were more likely to use monitoring systems such as electronic identification in the dairy, computerised records, daily milk yield or cell count monitoring and pedometers or activity meters. Euthanasia methods were consistent between herds of varying sizes and it was noted that less than 3% of farms make use of captive bolt devices despite their effectiveness and ready availability. Increasing herd size was related to increased herd milking time, increased time away from the paddock and increased distance walked. If the milking order of cows is consistent, this may result in reduced feed access for late milking order cows due to a difference in time away from the paddock. More than 95% of farmers believed that their cows were content most of the time, and cows were reported as well behaved on more than 90% of farms. Whilst the potential animal welfare issues appear to be different between herd sizes, there was no evidence for a relationship between herd size and adverse welfare outcomes in terms of reported disease or cow contentment levels.

3.2. INTRODUCTION

Animal health and animal welfare are contributors to dairy production efficiency, as well as being important to the general public and dairy consumers. Increasing scale of production is a confirmed trend in most developed dairy industries (Lean et al., 2008; Verkerk and Hemsworth, 2010), including the Australian dairy industry, where dairy farms are predominantly outdoor, pasture based, systems. According to a national dairy farmer survey conducted by Dairy Australia in early 2013, the average Australian herd size has risen 37% over the past 10 years. Since 2004, there has been a significant increase in the proportion of farms with herds milking in excess of 300 cows from 17% in 2004 to 30% in 2013 and at the other end of the scale, small farms (< 150 cows) now account for 26% of all farms compared with 35% in 2004. The trend toward larger farms looks set to continue, with 33% of farmers surveyed expecting to calve more cows in the following year (Dairy Australia, 2013b).

Increasing scale of production in extensive dairy systems can be associated with larger herd sizes, increased stocking densities, longer milking times, longer walking distances, and reduced ability to examine and treat cows individually. Factors such as these have the capacity to cause reduced welfare outcomes for dairy cows if not properly managed (Verkerk and Hemsworth, 2010). On the other hand, there are management aspects that may improve outcomes with economies of scale. It seems probable, although there is little objective data available to support it, that larger enterprises are more likely to have more modern dairies that reduce milking time; they may be more likely to have infrastructure to electronically identify and monitor individual cows; they may be more likely to use professional advice and provide superior nutrition; and they may have greater capacity to provide staff training and general quality assurance systems.

There has been little published regarding animal welfare outcomes for cows in large Australian dairy herds.

A review of livestock disease threats associated with intensification of pastoral dairy farming (Lean et al., 2008) reported that whilst there is evidence that increased production increases the risk of mastitis and culling for udder health, the evidence to support an increased risk of most diseases was sparse and indeed diseases such as bloat and ketosis seem to have lower risk. The same report concluded that mineral nutrition of pasture-fed cattle is being better addressed, with gains in the control of milk fever, hypomagnesaemia and trace-element deficiencies, but that lameness, anthelmintic resistance and ruminal acidosis may be at increased risk with increasing scale of production.

Studies documenting affective state and naturalness are also sparse with regard to larger extensively-managed dairy herds. It has been established that the amount of time a cow spends lying down and resting can substantially affect its comfort and welfare (Overton et al., 2002; Fisher et al., 2003). It seems logical that as herds increase in size, cows may experience reduced lying and resting times as milking time and the time taken to walk to and from the dairy increase – particularly in farms where loafing or feed pads are used (Botheras, 2006).

There is an agreed definition of animal welfare adopted by the World Organization for Animal Health and many other organizations worldwide (Fraser et al., 2013; OIE World Organization for Animal Health, 2014):

“Animal welfare means how an animal is coping with the conditions in which it lives. An animal is in a good state of welfare if (as indicated by scientific evidence) it is healthy, comfortable, well nourished, safe, able to express innate behaviour, and if it is not suffering from unpleasant states such as pain, fear, and distress. Good animal welfare requires disease prevention and veterinary treatment, appropriate shelter, management, nutrition, humane handling and humane slaughter/killing. Animal welfare refers to the state of the animal; the treatment that an animal receives is covered by other terms such as animal care, animal husbandry, and humane treatment.”

It was proposed that a better understanding of these relationships would inform further efforts to mitigate and measure adverse welfare outcomes with increasing scale of production.

In order to assess relationships between herd size and known or proposed risk factors for adverse animal welfare outcomes in Australian dairy herds, we designed a farmer survey with variables that included (1) animal indices of poor welfare (e.g. disease and lameness); and (2) strategies or policies that are known or hypothesized to affect animal welfare (e.g. veterinary and nutritional practices, training and technology to monitor cow behaviour).

3.3. MATERIALS & METHODS

3.3.1. Farm Sample

We aimed to survey Australian dairy farms via a combination of electronic and physical distribution. A physical survey with a link to an electronic version was included in the September 2014 edition of “The Australian Dairy Farmer” magazine – an industry publication which is distributed free of charge to all registered Australian dairy farmers. A link to an electronic survey was also sent by email to a random sample of 1000 farmers who had opted in to receiving communications from Dairy Australia Limited (the national Dairy Research and Development Corporation).

The survey was anonymous, and in the instructions we requested that only one survey per farm be submitted. This study was conducted with human research ethics approval from The University of Melbourne (Ethics identity 1141608 1).

3.3.2. Questionnaire

Data were collected from September to November 2014 by means of physical and electronic questionnaires that were returned in a reply-paid envelope or submitted online via an electronic survey company.

The questionnaire was anonymous and consisted of 28 closed ended questions, some of which contained multiple parts. The first questions gathered information about farm location, herd

size, physical area, level of milk production, grain feeding, dairy type, staffing levels and qualifications.

Other questions were designed to collect information about risk factors for animal welfare outcomes that are 1) indicative of poor welfare (animal-based indices) or (2) strategies or policies that are known or hypothesized to affect animal welfare across the three-overlapping quality-of-life domains of biological function, affective state and naturalness. The survey included questions about reproduction, mastitis and other diseases. Quantitative factors such as disease levels were recorded, but also information about how such levels are monitored on farm. For example, having electronic identification and computerised records may allow for better monitoring of disease. In relation to how quickly cows with welfare needs are identified and treated, there were questions on euthanasia methods, the use of noxious stimuli such as electric wire on backing gates, the use of electric prodders and “poly pipe” (polyethylene pipe) goading implements, and farmer views about the contentment level, behaviour and fear levels of cows. There were also questions on time spent on and off pasture such as the time out of a paddock, the time spent walking, and the likelihood of individual cows spending more than 2 hours standing in a yard waiting to be milked.

3.3.3. Statistical Analyses

Data were entered into a database and checked for typographical errors and duplicates. Herds were stratified into 5 categories based on the maximum number of cows that were milked together as a group for more than three months. Farms were stratified into categories consistent with the Australian National Dairy Farm Survey (Dairy Australia, 2014): <150 (very small); 150-300 (small); 301-500 (medium); 501-700 (large); and 701+ (very large).

Statistical analyses were performed using SPSS (Version 22, IBM Corp). Means were compared between different herd size groups using one-way ANOVA. Confidence intervals of the mean differences between different herd size groups were made using Gabriel’s pairwise method, as sample sizes were not similar between groups (Field, 2013).

Differences in proportions between herd size groups were tested using the SPSS Crosstabs function to perform a chi-square analysis with correction for multiple comparisons using a Bonferroni technique.

3.4. RESULTS AND DISCUSSION

3.4.1. Responses and Data Validation

After discarding blank surveys (n=56) and those which were completed by respondents who did not have an active role in an Australian dairy farm (n=4), a total of 863 valid surveys were returned. Australia’s dairy farms are commonly divided into 8 distinct geographical dairying regions, each serviced by a different regional development program (Dairy Australia, 2014b). The response rate as a percentage of the total number of dairy farms in each region (K Davis, Dairy Australia, pers. comm.) are described in Table 3.1. These response rates varied between 10% and 23% for individual regions and accounted for 13% of Australian dairy farms.

TABLE 3.1. SURVEY RESPONDENTS AS A PERCENT OF THE TOTAL NUMBER OF DAIRY FARMS IN EACH AUSTRALIAN DAIRYING REGION

Dairying Region	Respondents	No of farms	%
Dairy NSW	102	437	23%
Dairy SA	48	279	17%
Dairy Tas	66	413	16%
Gipps Dairy	194	1548	13%
Murray Dairy	177	1663	11%
Subtropical Dairy	72	700	10%
Western Dairy	34	162	21%
Westvic Dairy	169	1438	12%
Total	863	6640	13%

The total number of milking cows accounted for in the survey was approximately 260,000 which was 15.6% of the 1.65 million cows (Dairy Australia, 2013c) that were milked in Australia.

A limitation of the survey design is that we could not be certain that “The Australian Dairyfarmer” magazine that contained the survey was read on all farms, which makes it likely that our response rates are underestimates of the response rates on farms on which the survey was read. It is also possible that duplicate surveys were returned for some farms despite the survey instructions. A check for duplicates based on similar dairying region, dairy type, number of cows, farm size in Ha and number of paddocks did not produce any likely duplicate entries.

The mean herd size was 304 (standard deviation 252, median 230). The distribution of farm sizes and number of cows accounted for are described in Table 3.2. Although large herds (over 500 cows) only represent 13% of Australian dairy farms, they represent more than 35% of the cows milked.

TABLE 3.2. THE PERCENTAGE OF FARMS AND COWS IN HERDS OF DIFFERENT SIZES REPRESENTED IN THE SURVEY RESULTS.

Herd Size	Farms	% Farms	% Cows
< 150	172	20	7
150-300	395	47	33
301-500	166	20	26
501-700	66	8	16
701+	49	5	19
Total	848	100	100

Our responses appear comparable with a 2012 phone survey of 1000 Australian dairy farmers, where the average number of cows milked was 299; 30% of all farms milked more than 300 cows and 26% of farms milked less than 150 cows (Dairy Australia, 2013b).

3.4.2. Farm Management and Economies of Scale

Table 3.3 shows that increasing herd size was associated with known or hypothesized risk factors for adverse welfare outcomes such as increasing stocking densities, number of stock per person and the level of grain/concentrate feeding per cow during milking as farmers attempt to achieve economies of scale.

TABLE 3.3. ASSOCIATION OF HERD SIZE WITH MEAN STOCKING DENSITY, STOCK PER LABOUR UNIT AND GRAIN FED PER DAY

Herd Size	< 150	150-300	301-500	501-700	701+	Probability of farm size effect
Mean ($\pm$SEM) stocking density (cows/ha)	1.42 ^a ($\pm$ 0.06)	1.97 ^b ($\pm$ 0.04)	2.29 ^{b,c} ($\pm$ 0.77)	2.25 ^{b,c} ($\pm$ 0.11)	2.51 ^c ($\pm$ 0.14)	p <0.01
Mean ($\pm$SEM) stock per person (cows/labour unit)	64 ^a ($\pm$ 2.5)	104 ^b ($\pm$ 2.3)	131 ^c ($\pm$ 4.0)	133 ^c ($\pm$ 6.2)	164 ^d ($\pm$ 7.9)	p <0.01
Mean ($\pm$SEM) maximum concentrates fed (kg/cow/d)	4.8 ^a ($\pm$ 0.20)	6.3 ^b ($\pm$ 0.13)	6.9 ^{b,c} ($\pm$ 0.18)	7.1 ^{b,c} ($\pm$ 0.32)	7.8 ^d ($\pm$ 0.34)	p <0.01

^{a-d} Means within a row without a common superscript are significantly different ($P < 0.05$)

As stocking densities increase, there is a theoretical increased risk of infectious disease spread through increased frequency of contact between individuals, although quantitative data to support such an assertion is sparse – indeed a review on the subject reported that smaller herds were more likely to have cows culled for mastitis, although larger herds were more likely to cull cows for lameness (Lean et al., 2008). There is also a risk that reduced paddock area per cow might impact on welfare through competitive and agonistic behavioural challenges associated with closer contact.

As the number of stock per labour unit increases, there is a risk that welfare outcomes might be affected by a reduced ability to monitor for issues and to deal with them appropriately and in a timely manner once identified.

On Australian dairy farms, total mixed ration feeding is uncommon. Most cows are fed a majority of their diet from pasture and other forages in the paddock or on feed pads, with grain mixes (concentrates) pulse fed in the dairy during milking. Increasing the amount of grain or concentrates that are pulse fed to cattle during milking increases the risk of diseases secondary to overfeeding grain. These factors might translate into welfare risks for cows in terms of lameness and other transition cow diseases (Lean et al., 2010, von Keyserlingk et al., 2009).

At the other end of the spectrum, if smaller farms were underfeeding their cows, this would be difficult to assess with our data set, but would likely be expressed through an increase in secondary adverse outcomes such as disease treatment levels.

Although in theory the three mechanisms described above could lead to increased adverse welfare outcomes, no evidence for this was found in this study. It may be possible to mitigate

these risks through infrastructure and/or management changes and it is possible that these changes are easier or more practical to implement on larger farms.

For example, the risk of disease spread can be addressed through biosecurity measures and having superior disease identification and treatment protocols. The risk of reduced observation of problems as the number of stock per labour unit increases could be addressed by better education and superior automated electronic monitoring, and the risk of acidosis as higher grain levels are fed could be addressed through superior transition cow management.

3.4.3. Education, Skills and Herd Size

It seems logical that animal welfare outcomes might be improved when farms have staff that are better qualified. We asked whether any farm employees had completed a range of relevant industry training courses. For the purposes of analysis, we divided training into informal industry courses and formal tertiary education courses that are related to dairying or agriculture. Table 3.4 shows that larger herds were more likely to have employees with formal qualifications or industry training. There may be an opportunity to improve animal welfare outcomes by targeting short industry training courses at small to medium herd sizes.

TABLE 3.4. THE ASSOCIATION BETWEEN HERD SIZE AND THE PERCENTAGE OF FARMS WITH EMPLOYEES THAT HAD COMPLETED INDUSTRY TRAINING OR FORMAL QUALIFICATIONS

Herd Size	< 150	150-300	301-500	501-700	701+
Industry training (%)	39 ^a	57 ^b	69 ^{b, c}	90 ^d	84 ^{c, d}
Formal qualification (%)	21 ^a	39 ^b	55 ^c	71 ^c	63 ^c
Any training/qualification (%)	44 ^a	67 ^b	78 ^b	97 ^c	86 ^{b, c}

^{a-d} Means within a row without a common superscript are significantly different (P<0.05)

3.4.4. Associations between Reported Disease Treatment and Herd Size

Table 3.5 shows that there was no association between increasing herd size and reported levels of treatment for mastitis or lameness. Larger herds were more likely to report fewer milk fever and GI problems, as well as less down cows. A limitation of these data is that there was no standardised way of recording or defining these problems and it is possible that there were differences between farms in the way that the conditions were recorded and the severity of disease where treatment was instituted.

TABLE 3.5. THE ASSOCIATION BETWEEN HERD SIZE AND THE REPORTED MEAN PERCENTAGE OF THE HERD TREATED FOR VARIOUS DISEASE CONDITIONS

Herd Size	< 150	150-300	301-500	501-700	701+	Probability of farm size effect
Mean (±SEM) mastitis in first 30 days of lactation (%)	5.3 (±0.67)	5.9 (±0.31)	7.1 (±0.67)	7.1 (±0.92)	6.6 (±0.85)	p=0.156
Mean (±SEM) treated for lameness (%)	5.7 (±0.44)	6.0 (±0.23)	6.6 (±0.46)	6.9 (±0.79)	6.6 (±1.37)	p=0.341
Mean (±SEM) treated for milk fever (%)	6.6 ^a (±0.48)	5.4 ^{a, b} (±0.24)	4.7 ^{a, b} (±0.35)	3.6 ^b (±0.33)	4.0 ^b (±0.49)	p<0.001

Mean ($\pm$SEM) treated for gastrointestinal problems (%)	2.8 ^a ($\pm$ 0.26)	2.0 ^b ($\pm$ 0.10)	1.4 ^{b,c} ($\pm$ 0.09)	1.3 ^{b,c} ($\pm$ 0.14)	1.2 ^c ($\pm$ 0.21)	p<0.001
Mean ($\pm$SEM) treated as down cows (%)	2.8 ^a ($\pm$ 0.19)	2.2 ^{a,b} ($\pm$ 0.09)	1.9 ^{a,b} ($\pm$ 0.14)	1.5 ^b ($\pm$ 0.17)	2.3 ^{a,b} ($\pm$ 0.77)	p=0.01

^{a-c} Means within a row without a common superscript are significantly different (P<0.05)

Previous reports show that farmers tend to underestimate the incidence of disease, especially when compared with observations from an outside observer (Bartlett et al., 2001; Espejo et al., 2006; Mörk et al., 2009). In one study, the incidence of clinical lameness was underestimated by a factor of 3 (Wells et al., 1993).

We asked farmers to report the number of cows treated for disease conditions in the previous 12-month period (rather than estimate clinical disease levels). It was thought that treatment records, which are required as part of the milk factory quality assurance schemes, should be readily available on most farms, and there was a clear instruction to leave the question blank if the respondent was unsure. It should be noted that the level of treated disease will always underestimate the true underlying level of disease.

3.4.5. Risk Factors for Disease Spread and Treatment

As herd size and stocking density increases, it could be expected that disease spread would be more likely. The Reed-Frost epidemic model that is used to explain population disease spread contains a factor that explicitly accounts for the frequency of contact between animals (Lean et al., 2008). Having a biosecurity plan to prevent disease introduction, milking sick cows separately from others, having routine veterinary herd health visits and having written protocols for disease treatment might impact on the treatment or spread of disease. Table 3.6 shows that larger herds were more likely to milk the sick cows as a separate herd, and very small herds were less likely to undertake routine veterinary herd health visits.

TABLE 3.6. THE ASSOCIATION BETWEEN HERD SIZE AND THE PERCENTAGE OF FARMS UNDERTAKING ACTIVITIES LIKELY TO ASSIST WITH TREATMENT OR PREVENTION OF DISEASE SPREAD

Herd Size	< 150	150-300	301-500	501-700	701+
Routine herd health visits (%)	17 ^a	33 ^b	39 ^b	46 ^b	41 ^b
Sick herd milked separately (%)	19 ^a	27 ^a	51 ^b	69 ^{b,c}	82 ^c
Have biosecurity plan (%)	10	13	17	14	16
Written protocols for mastitis (%)	67	71	75	74	86
Written protocols for disease (%)	47	44	45	52	45
Special transition diet before calving (%)	41 ^a	65 ^b	77 ^{b,c}	76 ^{b,c}	86 ^c
Main herd milked in separate groups (%)	2 ^b	6 ^b	15 ^a	26 ^c	45 ^c

^{a-c} Means within a row without a common superscript are significantly different (P<0.05)

The absence of a biosecurity plan is a risk factor for animal welfare if it is reasonable to assume that following a formal plan would represent a decreased disease risk. We noted that less than 20% of farms had a biosecurity plan and this was not related to farm size. We believe

that this is an area where significant improvement might be made in the Australian dairy industry.

The use of a well-planned transition diet in the weeks prior to calving can have a positive effect on animal welfare through a reduction in diseases such as hypocalcaemia, downer cows, ketosis, udder oedema, abomasal displacement, retained fetal membranes, lameness and grain overload (Lean et al., 2010). Although we could not assess the quality or effectiveness of the transition diet, we noted that as herd size increased, the proportion of herds that used a special transition diet before calving increased but only to a level of approximately 75%. It would seem that there may be scope to improve animal welfare outcomes by increasing the adoption of specific transition diets in farms of all sizes.

3.4.6. Activities to Monitor Health and Disease

As the number of cows per labour unit increases, there are many strategies that can be employed to automate monitoring for problems. Table 7 shows the proportion of herds in each size category which used various monitoring strategies. The percentage of farms with electronic identification in the dairy was related to herd size. Measuring daily cell counts or milk conductivity and having computerised herd records was more likely in herds with more than 300 cows. Despite the extra monitoring in larger herds, over 90% of respondents in all herd sizes agreed that sick cows were identified and treated quickly on their farms.

TABLE 3.7. THE ASSOCIATION BETWEEN HERD SIZE AND THE PERCENTAGE OF FARMS UNDERTAKING ACTIVITIES LIKELY TO ASSIST WITH HERD MONITORING

Herd Size	< 150	150-300	301-500	501-700	701+
Electronic ID in dairy (%)	5 ^a	17 ^b	41 ^c	64 ^d	92 ^e
Measure daily cell counts or milk conductivity (%)	5 ^a	5.8 ^a	12 ^{a,b}	17 ^b	22 ^b
Computerised herd records (%)	22 ^a	53 ^b	72 ^c	82 ^c	90 ^c
Agree sick cows identified and treated quickly (%)	92	96	92	94	94
Pedometers/activity meters (%)	1 ^a	4 ^{a,b}	4 ^{a,b}	11 ^b	8 ^b

^{a-d} Means within a row without a common superscript are significantly different (P<0.05)

3.4.7. Risk Factors for Fear and Distress

Freedom from fear and distress, by ensuring conditions and treatment that prevent mental suffering, is one of the “Five Freedoms” (McCulloch, 2012) and is an important component of both the biological functioning state and affective state domains of animal welfare.

The capacity of farmers to provide effective euthanasia in a timely manner is an important factor in minimising the distress of cattle which are suffering conditions that are untreatable for medical or economic reasons. Current legal methods recommended for euthanasia of cattle in Australia include gunshot, captive bolt and lethal injection administered under veterinary supervision. Blunt trauma to the head of calves less than 24 hours of age and exsanguination are permitted if no other methods are available (Animal Health Australia, 2012). The licensing and use of firearms has been strictly controlled in Australia for some time. Euthanasia on farm may be carried out by farmers using firearms (which have special licence, storage and occupational health and safety requirements) or captive bolt guns (which whilst they require care in their use do not have licensing requirements in most states in Australia). Farmers who do not have firearms or captive bolt devices on farm commonly use their veterinarian or a local “knackery” service for euthanasia. Knackeries are businesses that provide a service for disposal of farm animals that are not fit for human consumption by either processing the carcass for pet food or rendering it into meat and bone meal for incineration and use as fertilizer.

Knackeries have the advantage that they remove and dispose of the carcass, but the possibility of a delayed attendance and thus delayed euthanasia is a risk to animal welfare. Table 3.8 shows the euthanasia methods reported in this survey. Whilst there were no significant differences between large and small farms, it is of concern that 23% of farms overall relied solely on the knackery to provide euthanasia services. Ownership of penetrating captive bolt guns for euthanasia of livestock is being promoted to Australian farmers because they are considered safer, have fewer restrictions than firearms, and cheaper models are now readily available (Jubb, 2013). Despite recent publicity and training programs in Australia, the uptake of captive bolt use is still low (3% of all farms) and this provides an opportunity for welfare improvement. Increased use of captive bolt devices would reduce the need for using blunt trauma for euthanasia of calves less than 24 hours old – a practice that is aesthetically

unpleasant and where there are significant risks of poor welfare outcomes due to issues with operator training and error.

TABLE 3.8. THE PERCENTAGE OF FARMS THAT UNDERTAKE VARIOUS METHODS OF EUTHANASIA

Herd Size	< 150	150-300	301-500	501-700	701+
Use of firearm by farmer (%)	67	72	67	74	69
Use of captive bolt device by farmer (%)	1	3	6	3	6
Use of veterinarian (%)	4	2	2	2	2
Use of knackery (%)	44	56	58	55	55
Only use knackery (%)	26	23	25	20	18
Use of blunt trauma in calves <24h old (%)	9 ^a	14 ^a	18 ^{a,b}	21 ^{a,b}	31 ^b

^{a-b} Means within a row without a common superscript are significantly different (P<0.05)

Assessing distress (or contentment) of dairy cattle using a survey is difficult, but it is possible to measure some known causes of distress (for example, the use of backing gates or goads to move cattle) and it is possible to measure farmer attitudes and opinions regarding indirect and qualitative measures of well-being such as friendliness and contentment. Table 3.9 shows some risk factors for both positive and negative affective state outcomes.

TABLE 3.9. THE ASSOCIATION BETWEEN HERD SIZE AND RISK FACTORS THAT MAY BE ASSOCIATED WITH FEAR OR DISTRESS WHEN COWS ARE BEING HANDLED OR MILKED

Herd Size	< 150	150-300	301-500	501-700	701+
*Electric wire on backing gate (%)	3 ^b	17 ^a	19 ^a	26 ^a	27 ^a
*We use the backing gate to push cows into the dairy (%)	13 ^b	18 ^{a,b}	19 ^{a,b}	33 ^a	27 ^{a,b}
*Cows are fearful when a person walks through the milking yard (%)	4	6	6	5	2
*Cows often stand for more than 2 hours before being milked (%)	5 ^b	10 ^b	20 ^a	33 ^a	27 ^a
Never use "poly pipe" goad on a cow (%)	37 ^{a,b}	33 ^a	49 ^{b,c}	56 ^{b,c}	67 ^c
Never use an electric goad on a cow (%)	90	85	87	89	84
Lose temper with a cow less than weekly or never (%)	95	91	92	94	90
Some cows are friendly toward people (%)	94	93	91	95	92
Cows are content most of the time (%)	99	98	99	95	100
Cows are well behaved in the dairy and yard (%)	93	94	90	94	90

^{a-c} Means within a row without a common superscript are significantly different (P<0.05)

* Denotes factors associated with negative outcomes (a lower percentage is better).

The use of the backing gate to push cows and the presence of electric wire on the backing gate was lower in very small herds. The use of polyethylene pipe goads was lower in larger herds, and the use of electric prodders was similar, with 85% of farms overall never using electric goads.

In over 90% of responses, farmers reported that they lost their tempers with cows less than weekly or never, that some cows were friendly toward people, that their cows were well behaved and that their cows were not generally fearful when someone walked through the dairy yard. There were no effects of herd size for these variables. More than 95% of respondents believed their cows were content most of the time. Fearfulness has been proposed as a means to assess the value of human-animal interactions, and whilst difficult to standardise and interpret, the general principle that good welfare is consistent with friendliness and good behaviour is sound (Verkerk and Hemsworth, 2010).

Herds with more than 300 cows were more likely to have cows standing in the yard for more than 2 hours before being milked (Table 3.9). Whilst this is not necessarily a problem in isolation, increasing time off pasture can reduce the potential for cows to exhibit natural behaviour and may be associated with hunger, thirst or feet problems associated with standing on concrete for long periods. Previous studies have shown that restricting the ability of cows to spend time lying down was associated with negative welfare outcomes (Fisher et al., 2003).

We hypothesised that in larger herds it might be expected that cows need to walk further to the dairy and milking the herd would take longer, which would mean that cows were out of their paddock for longer periods.

Indeed, the survey found that farmers reported that milking the herd took longer, cows were out of the paddock for longer and they walked further as herd size increased (Table 3.10). There was no difference in the minimum time out of a paddock. This may have implications for animal welfare outcomes particularly if cows enter the dairy in a consistent order as the later cows might have consistently longer time off pasture and standing on concrete. This could be mitigated to some extent by milking the herd in more than one separate group, and, as shown in Table 3.6, as herd size increases more farmers milked the main herd in separate groups. Some farms may lock all the cows in the yard before milking commenced, while others may start milking as cows are being brought up from the paddock. The farmer reports on time of a typical milking, the longest time a cow would be out of the paddock and the longest distance walked, are shown in Table 3.10. In our survey, 99% of respondents agreed or strongly agreed that cows usually enter the dairy in a similar order each day except when they are sick or on heat. There is little evidence in the literature on effects of the milking order of cows in larger herds and work in this area is warranted.

TABLE 3.10. THE ASSOCIATION BETWEEN HERD SIZE AND TIME FOR MILKING, OUT OF Paddock AND DISTANCE WALKED FOR FARMS OF DIFFERENT SIZES

Herd Size	< 150	150-300	301-500	501-700	701+
Mean time for typical milking (min)	83 ^a	108 ^b	126 ^c	158 ^c	186 ^d
Mean shortest time out of paddock (min)	57	69	71	75	57
Mean longest time out of paddock (min)	137 ^a	179 ^b	207 ^{b,c}	231 ^c	236 ^c
Walking distance to furthest paddock (km)	1.1 ^a	1.6 ^b	1.9 ^{b,c}	2.0 ^{b,c}	2.3 ^c

^{a-d} Means within a row without a common superscript are significantly different (P<0.05)

3.5. CONCLUSIONS

Although large herds (>500 cows) only represent 13% of Australian dairy farms, they are important in terms of animal welfare because they represent more than 35% of the cows milked. Increasing herd size was associated with known or proposed risk factors for adverse animal welfare outcomes including increased stocking density, decreased labour units per cow, increased grain feeding, increased milking time, increased time away from the paddock and increased distance walked. Increasing herd size was also associated with factors that could be proposed to reduce the risk of adverse welfare outcomes such as greater capacity for strategies such as better training and education of staff, routine veterinary herd health visits, separate milking of the main herd and the sick cows, transition diets before calving and written protocols for treatment of disease. Whilst the potential animal welfare issues appear to be different between herd sizes, there was no evidence for a relationship between herd size and adverse welfare outcomes in terms of reported disease or cow contentment levels. Further work is indicated to examine the effects of increased time away from the paddock on cow welfare. Further emphasis on the development of farm biosecurity plans and the use of captive bolt devices for euthanasia is warranted in herds of all sizes.

3.6. ACKNOWLEDGEMENTS

The authors would like thank the Victorian Department of Environment and Primary Industries and Dairy Australia Ltd for their support of this project.

CHAPTER 4

4. The effects of herd size on the welfare of dairy cows in a pasture-based system using animal- and resource-based indicators.

The following paper is in revision following peer review by the Journal of Dairy Science.

The effects of herd size on the welfare of dairy cows in a pasture-based system using animal and resource-based indicators

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The survey questions are described in appendix 2.

4.1. ABSTRACT

Animal welfare assessments were conducted on 50 Australian pasture-based dairy farms of varying herd sizes: 16 small (<300 cows), 15 medium (300-500 cows), 11 large (501-750 cows) and 10 very large (751+ cows). A protocol based on elements of WelfareQuality® adapted for Australian conditions was developed which assessed the broad categories of good feeding, housing, health and appropriate behaviour. Farm records, BCS, integument injuries, fecal plaques, avoidance distance of humans and fecal pat scoring for acidosis assessment were undertaken. As herd size increased, so did the level of concentrates fed in the dairy during milking. The mean maximum kg of grain fed per day significantly increased with herd size: 5.2 ± 0.38 kg (small), 7.7 ± 0.29 kg (medium), 8.8 ± 0.45 kg (large) and 10.1 ± 0.80 kg (very large). Acidosis was not related to herd size based on either farm records or fecal pat scoring. All cows had access to water for more than 12 h in a 24 h period. More larger farms had water points on the farm tracks or at the dairy. Very large farms (90%) were more likely than others (36-39%) to provide water suitable for human consumption. Integument lesions were not related to herd size and were uncommon. 56% and 84% of farms had no cows with lesions or hairless areas. No farm had >6% integument lesions. Heat stress is an important welfare risk in Australia. All farms had some form of cooling strategy. Shade in all paddocks was more common on smaller farms (>90%) than others (<75%). Sprinklers were more common on large/very large farms (>80%) than others (<65%). Prevalence of lameness, mastitis, downer cows, dystocia and gastro-intestinal disease were not related to farm size. Mastitis and lameness were the most common health conditions, followed by dystocia, downer cows and gastrointestinal diseases. Larger farms were more likely to have electronic infrastructure to monitor or electronically draft cows for inspection. There was wide variation in the avoidance distance of humans but this was not related to farm size. Larger farms had longer walking distances to pasture and longer time away from pasture which could impact on the time available for behaviours such as lying down. Animal welfare risks differ on Australian farms compared with housed cattle. As animal welfare is multi-dimensional both animal- and

resource-based measures can be useful. Animal-based measures have strengths in that when measured accurately they genuinely reflect the outcome being measured, but they also have weaknesses in that the point-estimate of a disease prevalence on a given day may not be representative of other times of year, or there could be differences in case definition when farm records are used. Similarly resource-based measures have strengths in that they may be applicable to longer periods but weaknesses in that simply because a resource is present does not guarantee it is being used. Identifying the major risks to animal welfare on individual farms and ensuring that there is a plan to effectively manage them should be an important element of any on-farm animal welfare assessment protocol.

4.2. INTRODUCTION

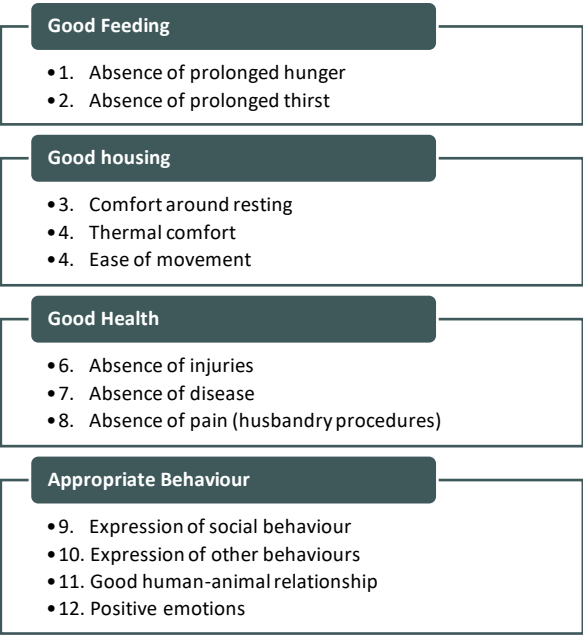
In 2017, Australian dairy cows produced approximately 9 billion liters of milk from 1.5 million cows on 5780 farms, providing employment for approximately 42,000 people. In contrast to many countries, Australian dairy farms are predominantly pasture-based, with approximately 60-65% of cattle feed requirements coming from grazing, and the feeding of total mixed rations is rare (Dairy Australia, 2017a). However, similar to many countries, there has been a trend toward increasing herd sizes. Farms milking more than 500 cows are now common and in a recent survey of Australian dairy farmers, 73% of farmers milking more than 700 cows in 2017 expected to increase numbers further over the next two years (Dairy Australia, 2017b). Larger herd size has been associated with increases in stocking density, stock per labour unit and grain fed per day – all of which could reasonably be hypothesized to increase the risk of adverse animal welfare outcomes unless carefully managed (Lean et al., 2008; Beggs et al., 2015).

The health and welfare of dairy cattle is important to the general public and dairy consumers, and as farms increase in size, there is increasing scrutiny about farming practices and animal welfare outcomes. Benchmarking and objective assessment of animal welfare on individual farms to standards higher than those imposed by animal welfare legislation is not yet common practice in Australia. To the Authors' knowledge, little has been published regarding measurement and management of the particular risks to the welfare of dairy cows that might occur as pasture-based dairy herds of Australia become larger.

Various systems have been proposed to describe, measure and audit welfare in dairy cattle. One of the largest formal quantitative welfare quality auditing protocols is the WelfareQuality® multi-criteria (WQ-ME) model (Botreau et al., 2007, 2009). In this protocol, trained auditors assess a wide range of elements across four categories (good feeding, housing, health and appropriate behavior) which are divided into 12 criteria as shown in figure 4.1. The dairy assessment protocol in WQ-ME, designed primarily for dairy cattle that spend time housed indoors, provides useful measurements that can be used for on-farm measurement and benchmarking, but some of the risks to animal welfare in pasture-based dairy herds are different, and the applicability of WQ-ME to Australian conditions is limited. For example, there is an emphasis within WQ-ME on metrics that are not particularly useful for assessing

animal welfare in pasture-based herds such as pen characteristics, the number and cleanliness of water points, access to loafing areas and access to pasture. Similarly, there is a lack of emphasis within WQ-ME on risks to animal welfare that have been recognized in pasture-based dairy farms such as thermal comfort, long walking distances and pulse feeding of high concentrates when total mixed rations are not being fed (Lean et al., 2007, 2008; Beggs et al., 2015).

FIGURE 4.1. THE FOUR CATEGORIES AND 12 CRITERIA USED BY THE WELFAREQUALITY® TO ASSESS ANIMAL WELFARE ON DAIRY FARMS. ADAPTED FROM (WELFARE QUALITY, 2009)



In this study, we developed a dairy cattle welfare assessment protocol broadly based on WQ-ME principles, designed to assess animal welfare under the same broad categories as WQ-ME, but modified to take account of the particular risks to animal welfare that have been identified in Australian pasture-based dairy herds. Using this assessment tool, we conducted animal welfare assessments on 50 farms of varying sizes in order to investigate the major challenges to animal welfare and the effect of management practices and herd size on the welfare of dairy cows.

4.3. MATERIALS AND METHODS

This study was conducted with animal ethics approval from the University of Melbourne Faculty of Veterinary and Agricultural Sciences Animal Ethics Committee (approval number AE 1513667.1). Fifty seasonal or split calving dairy farms were selected from the local client base (approximately 300 dairy farms) of a large veterinary practice in western-Victoria, the highest producing dairy region in Australia, by one of the researchers who had worked in the veterinary clinic for more than 25 years and thus had some familiarity with local farms. Farms were chosen to be broadly representative of dairy farms in the area. We selected at least 10 farms, based on the maximum number of cows milked, from four categories: <300 (small); 300-500 (medium); 501-750 (large); and 751+ (very large). Observations were conducted over

a 14-month period at times based on convenience for the researcher and the person identified from clinic records as being the farm manager (the person responsible for the day to day management of the herd). We made a positive attempt to time visits during mid- to late-lactation for the majority of cows, because this would maximise the proportion of the herd that was lactating at the time of the visit. All visits and assessments were carried out by the author, a veterinary practitioner with a special interest in dairy cattle medicine and more than 25 years' experience in the local veterinary practice.

4.3.1. Development of Assessment Protocol

A dairy cow welfare assessment protocol was developed by the researchers that allowed for collection of data on a single farm visit. The broad criteria of WQ-ME (Figure 1) were used as a framework. WQ-ME protocols, assessment of the literature and the authors' experience in the field were used to devise a protocol for assessing each criteria in a way that could be assessed at a single visit, and would be practical and relevant to Australian pasture-based dairy farms. The protocol involved a questionnaire, an examination of farm records, assessment of integument alterations and cleanliness, body condition scoring, avoidance distance of humans and assessment of faecal pats in the paddock.

The questionnaire was conducted as a face to face interview with the farm manager, with reference to farm records where necessary. The first questions gathered information about farm location, herd size, physical area, level of milk production, grain feeding and dairy type. Other questions were designed to collect information about risk factors for animal welfare outcomes that are either indicative of poor welfare (animal-based indices) or known or hypothesized to affect animal welfare across the three-overlapping quality-of-life domains of biological function, affective state and naturalness. The survey included questions about reproduction, mastitis and other diseases. Quantitative factors such as disease levels were recorded, but also information about how such levels were monitored on farm. For example, having electronic identification and computerised records may allow for better monitoring of disease. We asked questions regarding the use of analgesia for painful husband procedures, methods of euthanasia, main causes of death and strategies for managing climatic extremes. There were also questions on time spent on and off pasture such as the time out of a paddock, the time and distance spent walking to and from dairy, lame cow prevalence and the likelihood of individual cows spending long periods standing in a yard waiting to be milked.

4.3.2. Paddock Measurements

While cows were grazing in the paddock, further observations were conducted on a sample of 50 cows from the paddock that had the most number of lactating cows grazing in it at the time. The researcher divided the paddock in to four notional quarters based on the distribution of cows within the paddock, and then selected 10- 15 cows from each area. Measurements were made shortly after milking, while cows were focused on grazing behaviour.

Avoidance distance. The avoidance distance of humans (AD) - the distance at which cattle move away from an approaching human – was measured in a standardized way (Rousing and Waiblinger, 2004). The assessor divided the paddock into notional quadrants and ensured that cows from each quadrant were assessed. The assessor wore standard dark clothing, walked quietly into the paddock and stood still for several minutes until the cows became accustomed to their presence. The assessor then approached individual cows at an angle of up to 45° from the front of the cow at a speed of approximately one 60-cm pace per second. The assessor held a small laser distance measuring device which was aimed at the closest part of the cow and could measure up to 8 m. The definition of withdrawal was when the cow first lifted a foot off the ground. The distance was rounded to the nearest 10 cm. If the muzzle could be touched, a distance of 0 cm was recorded.

Body Condition Score (BCS). BCS was measured on a scale of 1-8 using a 2-step “hands-off” scoring method commonly used in Australia (Dairy Australia, 2013a). Under this system, cows with a BCS of 3 or less are considered at the very low end or outside the healthy productive range.

Injuries and lesions from housing or dairy infrastructure. Integument alterations and cleanliness were scored in a similar manner to that described in WQ-ME. The number of hairless patches on a cow was recorded that were greater than 5 cm diameter at the largest extent that are likely due to injury or rubbing, and as having skin lesions if they had lesions or swellings greater than 5 cm (such as joint swellings, wounds, dermatitis, ear lesions due to torn ear tags. The number of integument alterations were recorded for each cow on the lower hind legs, hind quarters or udder if there were plaques (three-dimensional layers of dirt) amounting to the size of the palm of the hand or if more than half the area under consideration was covered with dirt.

Rumen acidosis. To assess the likelihood of rumen acidosis, 50-100 faecal pats were selected from the paddock in approximate proportion to the density of cows in the different areas of the paddock. They were score on a scale of: 1 - extremely liquid, bubbling and containing grain; 2: Runny – stools do not form up – little evidence of fibre; 3: Porridge-like consistency, forms ‘chocolate cake’ stools. Well-digested fibre is evident; 4: Excessive fibre evident throughout stool, forms piles more than 50 mm high. Under this system, rumen acidosis is considered a problem if more than 20% of pats are score 2 or less (Lean et al., 2007).

4.3.3. Statistical Analysis

Data were collected onto standard paper protocol forms and transferred to Microsoft Excel for analysis. Herds were stratified into 5 categories based on the maximum number of cows that were milked together as a group for more than 3 months. Farms were stratified into categories consistent with the Australian National Dairy Farm Survey (Dairy Australia, 2014a) and a previous survey of Australian dairy farmers (Beggs et al., 2015): 150 to 300 (small); 301 to 500 (medium); 501 to 750 (large); and 751+ (very large). Statistical analyses were performed using SPSS (Version 25, IBM Corp., Armonk, NY). Means were compared between different herd-size

groups using one-way ANOVA. Confidence intervals of the mean differences between different herd-size groups were made using Gabriel's pairwise method, as sample sizes differed between groups (Field, 2013). Differences in proportions between herd-size groups were tested using the SPSS Crosstabs function to perform a chi-squared analysis with correction for multiple comparisons using a Bonferroni technique. For AD, based on the distribution of all cows in the study, we calculated the median AD and the inter-quartile ranges (IQR). For each farm, we then calculated the proportion of cows with AD in each IQR.

4.4. RESULTS

Table 4.1 describes the distribution of farms and cows in each herd size category.

TABLE 4.1. NO. OF FARMS AND COWS IN EACH FARM SIZE CATEGORY

Farm Size	Farms	Cows	Stocking rate (cows / ha)	Staffing (cows / full time equivalent employee)
<300 Small	16	3447	1.59 ^a	95 ^a
300-499 Medium	13	4885	1.75 ^a	123 ^{ab}
500-749 Large	11	6532	1.71 ^a	184 ^b
750+ Very large	10	10241	2.07 ^a	157 ^{ab}
Total	50	25055		

There were 50 herds, with at least 10 herds in each category, representing a total of approximately 25000 cows. Most farms (22/50) had a seasonal calving pattern, with 17 of the remaining farms having a split calving pattern (two discreet calving periods during the year) and one very large farm having a year-round calving pattern. There were 25 rotary dairy and 25 herringbone dairy sheds. Visits were conducted between 64 and 310 days from the beginning of the most-recent calving period in all herds except the year-round calving herd and two of the split calving herds where the visit was at least 60 days after the beginning of the major calving period. The majority of visits (35/50) took place during the drier months of November-February, and no visits took place between April and June when a majority of farms in the local area were calving.

4.4.1. Category 1: Good Feeding

Absence of prolonged hunger/good nutrition. Chronic restriction of feed intake was assessed by condition scoring cows to note any cows in condition score 3/8 or less. A minimum of 50 cows per farm were formally scored, and the entire herd was observed for evidence of thin cows during milking. On the 50 farms examined, there were no cows observed in condition score 3/8 or less. The mean maximum kg of grain fed per day significantly ($p<0.01$) increased with increasing herd size: 5.2 ± 0.38 kg (small), 7.7 ± 0.29 kg (medium), 8.8 ± 0.45 kg (large) and 10.1 ± 0.80 kg (very large). Faecal pats were scored to detect the presence of subclinical rumen acidosis (SARA). On the day of assessment, there was no evidence of SARA as a herd problem at the time of monitoring, with more than 80% of pats being score 3 in all cases.

Absence of prolonged thirst. All cows in had access to water for a minimum of 12 hours in a 24-hour period. Table 4.2 shows that as herd size increased, so did the proportion with water points on the track or at the dairy. Very large farms tended to have better water quality with 90% of our farms having water that was suitable for human consumption compared with 36-39% of Small, Medium and Large farms.

TABLE 4.2. THE PROPORTION OF FARMS WITH WATER POINTS ON THE COW WALKING TRACK TO THE DAIRY, AT THE DAIRY AND IN PADDOCKS BY FARM SIZE

Farm Size	% Water > 12 h / day	% Paddock	% Track	% Dairy	% Track or Dairy
<300 Small	100	100	38 ^a	13 ^a	50 ^a
300-499 Medium	100	100	46 ^a	54 ^{a,b}	69 ^{a,b}
500-749 Large	100	100	64 ^a	82 ^b	91 ^b
750+ Very large	100	100	70 ^a	70 ^b	90 ^b

^{a-b} Proportions within a column without a common superscript are significantly different (P < 0.05)

4.4.2. Category 2: Good Housing/Environment

Comfort around resting. A sample of 50 animals were examined for swollen joints, integument injuries and fecal plaques. There was no relationship with herd size and swollen joints or hairless areas and indeed such injuries were uncommon with 56% of farms having no cows observed with lesions and 84% of farms having no cows observed with hairless areas. No cows had more than 2 lesions. Lesions were more prevalent on larger farms but were still at low levels. The maximum prevalence of swollen joints and other lesions was 6%, and this was on two rotary dairies where the hocks of larger cattle seemed to rub against the backing bar on the rotary platform. All other farms had less than 5% of cows affected. The maximum prevalence of hairless areas was 6%, on a single farm. There was no relationship between the proportion of cows with fecal plaques and herd size.

Time away from pasture for milking may affect the opportunity for cows to lie down and rest. We assessed this using the time that cows were away from pasture for the milking process, when opportunities to lie down and rest are generally not available. Table 4.3 shows that as herds increased in size so did the distance walked and the time away from pasture.

TABLE 4.3. TIME SPENT AWAY FROM PASTURE DUE TO THE MILKING PROCESS BY FARM SIZE

Farm Size	Mean max distance walked per day (km)	Mean shortest time away from pasture (min per milking)	Mean longest time away from pasture (min per milking)	Maximum time away from pasture on any farm (min per milking)
<300 Small	1.4 ^a	46 ^a	157 ^a	240
300-499 Medium	1.8 ^{a,b}	48 ^a	175 ^a	210
500-749 Large	2.4 ^b	55 ^a	231 ^b	300
750+ Very large	3.5 ^c	53 ^a	205 ^{a,b}	300

^{a-b} Means within a column without a common superscript are significantly different (P < 0.05)

Thermal comfort. Strategies in place to mitigate the effects of very hot days are shown in Table 4.4. These include the provision of drinking water at least twice daily; shade in the paddock; sprinklers in the dairy yard and changing the milking time to earlier/later in the day. A range of other cooling strategies were mentioned including cooling the concrete yard with water before milking, the use of irrigation sprinklers in the paddock, and fans in the milking parlour.

TABLE 4.4. PROPORTION OF FARMS THAT USING STRATEGIES TO REDUCE HEAT STRESS BY FARM SIZE

	% Shade in all paddocks	% Sprinkler at Dairy	% Change milking time
<300 Small	94 ^a	63 ^a	75 ^a
300-499 Medium	92 ^{a,b}	46 ^a	38 ^{a,b}
500-749 Large	73 ^{a,b}	100 ^b	45 ^{a,b}
750+ Very large	60 ^b	80 ^{a,b}	30 ^b

^{a-b} Proportions within a column without a common superscript are significantly different ($P < 0.05$)

4.4.3. Category 3: Good Health

Absence of injuries/disease. We assessed risk factors for better or worse management, mortality, mastitis, lameness and other disease records. Larger herds were significantly more likely to have infrastructure to monitor individual cows. All large and very large herds used computer software to store cow health records, with 8% of medium and 25% of small herds using paper records only. In our study 90% of large and very large farms had electronic ID and electronic drafting infrastructure compared with medium herds (40% ID, 23% drafting) and small herds where there was no individual electronic ID or drafting ($p < 0.05$). Individual cow daily milk metering infrastructure was present in 23%, 45% and 70% and milk cell count or conductivity meters were used in 15%, 36% and 60% respectively of medium, large and very large herds.

We investigated farm records in order to assess the most common disease problems. The mean incidence of recorded dystocia was approximately 5% (range 0-20%), the mean incidence of downer cows in the previous 12 months was 1.9% (range 0-8%) and the mean incidence of gastrointestinal disease in the previous 12 months was 0.4% (range 0-4%). There were no significant relationships with herd size. No trends or relationships were evident between farm size and lameness, mastitis cases, somatic cell-counts or on-farm mortality measured over a whole year, although large herds were more likely to routinely milk lame cows in a separate “sick herd” (Table 4.5).

TABLE 4.5. MASTITIS AND ON-FARM MORTALITY BY FARM SIZE BASED ON FARM RECORDS

	Mean BMCC (‘000 cells/ml)	% Cows having mastitis within 30 days of calving	% On-farm Mortality	% Lame mows milked in separate Herd
<300 Small	125 ^a	3.5 ^a	2.2 ^a	69 ^a
300-499 Medium	148 ^a	3.7 ^a	1.7 ^a	77 ^{a,b}
500-749 Large	115 ^a	4.1 ^a	2.0 ^a	82 ^{a,b}
750+ Very large	142 ^a	3.8 ^a	2.2 ^a	100 ^b

a-b Values within a column without a common superscript are significantly different ($P < 0.05$)

On-farm euthanasia methods from our study farms are presented in table 5.6. We recorded the major causes requiring on-farm euthanasia and whilst there was a wide range of causes, the three most common were downer cows not responding to treatment, problems associated with calving and acute mastitis.

TABLE 4.6. METHODS OF ON-FARM EUTHANASIA BY FARM SIZE

	% Firearm	% Captive Bolt	% Knackery	% Knackery / off farm only
<300 Small	38 ^a	13 ^{a,b}	75 ^a	44 ^a
300-499 Medium	69 ^{a,b}	0 ^b	62 ^{a,b}	31 ^a
500-749 Large	82 ^b	18 ^{a,b}	27 ^b	18 ^a
750+ Very large	60 ^{a,b}	40 ^a	50 ^{a,b}	20 ^a

a-b Proportions within a column without a common superscript are significantly different ($P < 0.05$)

Absence of pain (husbandry procedures). The use of analgesia during painful husbandry procedures is described in Table 4.7. For disbudding, small herds were less likely to disbud by 8 weeks of age and there was increased use of anaesthesia, analgesia and sedation in larger herds.

TABLE 4.7. PROPORTION OF FARMS USING LOCAL ANAESTHETIC, ANALGESIA AND SEDATION FOR HORN REMOVAL OF CALVES BY FARM SIZE

	% Disbudding < 8w of age	% Local Anaesthetic used	% Other Analgesia used	% Sedation used
<300 Small	63 ^a	13 ^a	6 ^a	13 ^a
300-499 Medium	92 ^{a,b}	31 ^a	38 ^b	31 ^a
500-749 Large	82 ^{a,b}	73 ^b	55 ^b	73 ^b
750+ Very large	100 ^b	30 ^{a,b}	20 ^{a,b}	30 ^{a,b}

a-b Proportions within a column without a common superscript are significantly different ($P < 0.05$)

4.4.4. Category 4: Appropriate Behaviour

Expression of social behaviour and expression of other behaviours. We did not specifically assess the ability of cows to express social behaviours but Table 5.3 shows they are likely to have 12-15 hours per day in a paddock where they might be able to express such behaviours.

Good human-animal relationship. The distribution of avoidance distance from humans from all herds combined is shown in Figure 4.2.

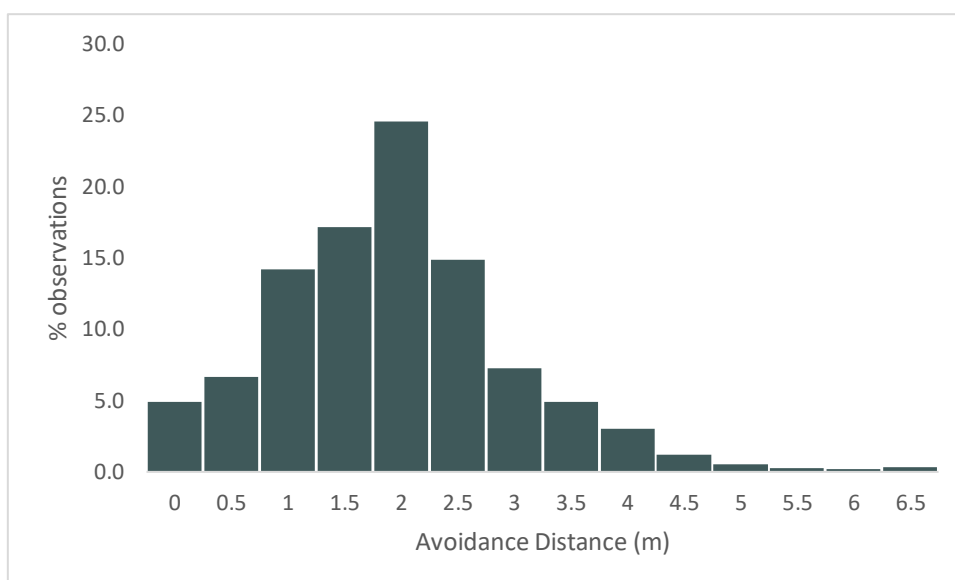


FIGURE 4.2. FREQUENCY OF AVOIDANCE DISTANCE MEASUREMENTS OVER 50 FARMS IN 0.5M INCREMENTS

The mean and median AD were both 1.7m, with SD = 1.2m, interquartile range (IQR) 1.0-2.2m. We calculated the median AD and proportion of cows with AD=0 for each farm as well as the proportion of cows with AD ≤ 1, <1.7 and >2.2 in order to assess farms according to the proportion of cows with AD below population median and the proportion in the top and bottom quartile of the population. None of the metrics we calculated were related to farm size and there was significant variation between farms of all sizes (table 4.8). One farm had all cows with AD in the highest IQR, and another had no cows in that range. On all but 3 farms, there were cows that could be approached to within less than 30 cm, but on one farm there were few cows that could be approached within 2 metres.

TABLE 4.8. AVOIDANCE DISTANCES (AD) OF COWS AT PASTURE OVER FIFTY FARMS

	Median AD (m)	% cows where AD=0m	% cows where AD ≤1.0m	% cows where AD ≤ 1.7m	% cows where AD > 2.2m
Range	0.4-4.2	0-30	0-80	0-96	0-100
Median	1.7	2	19	55	20
Interquartile range	1.2-1.9	0-6	10-38	35-77	8-32

4.5. DISCUSSION

Our sample of 50 farms represented approximately 15% of the client base for the particular veterinary clinic from which the study was conducted, and we estimated that it represents approximately 4% of farms and 7% of cows within the western-Victorian dairying region (Dairy Australia, 2017a). As we were aiming to investigate the effect of herd size, we selected a minimum of 10 herds in each size category (32% small, 26% medium, 22% large, 20% very large). A 2015 survey of dairy farmers reported the proportion of dairy farms nationally to be skewed more toward smaller farm sizes (70% small, 18% medium, 6% large, 5% very large),

although the large and very large farms accounted for 33% of milk production (Dairy Australia Ltd, 2015). Thus, whilst our data are useful for comparing different herd sizes in the local area, they should be used with caution when extrapolating to the wider industry. Similarly, the timing of visits in our study was designed to capture measurements at a time when a majority of the herd would be lactating. We aimed to avoid the concentrated calving periods in our seasonal and split-calving herds because a majority of health problems occur in individual cows around the time of calving (DeGaris et al., 2010), and attending during a calving season would mean that data for 12 months represented half of a calving period from one season and half of another.

4.5.1. Good feeding

As farms increased in herd size, more concentrates were fed to cows in the dairy parlour while they were milking. This is consistent with a previous Australian survey (Beggs et al., 2015). Increasing the amount of grain or concentrates fed can increase the risk of diseases secondary to overfeeding grain such as acidosis and laminitis. These factors might translate into welfare risks for cows in terms of lameness and other transition cow diseases (Lean et al., 2010, von Keyserlingk et al., 2009). Despite the increased risk with increasing herd size, there was no difference in the faecal scores and it seemed that all farms were effectively managing the risk of rumen acidosis at a herd level on the day of observation. It should be noted that our observations were made at times when most cows had been lactating for several weeks, when risk of acidosis is lower than at the time of calving. Our data could suggest that it is possible for herds to have good acidosis control, not that these herds have good acidosis control at all times.

The WQ-ME model describes resource-based measures surrounding the number of water points, their cleanliness, and the frequency and duration of cow's access to them (Welfare Quality®, 2009). The measures are appropriate for cows in housed circumstances but may have less relevance in the Australian context where cows spend most of the day in outside paddocks with water readily available. The Australian Animal Welfare Standards and Guidelines for Cattle (Animal Health Australia, 2014a) states that lactating cattle should have access to water at least twice daily, however these standards define lowest acceptable threshold, rather than that for good animal welfare. From an animal welfare perspective, it is worth considering not only how much water dairy cows require, but when they prefer to drink it. Housed dairy cattle in one study given free access to water drank it in approximately 7 bouts per day (Cardot et al., 2008). There has been little work studying the drinking behaviour of Australian cows, but a New Zealand study showed that cows being fed total mixed rations drank more often than grass fed cows (5.2 times vs 3.5 times in 24 hours) but they drank less per time (14.9 vs 21.7 litres per drink) (Jago et al., 2005). This study recommended that placement of water points near the dairy or on dairy tracks may be important as New Zealand farms increase in size. Cows in our study were fed up to 5 kg of grain or concentrate-mix (over approximately 6-16 mins) in the milking parlour whilst being milked, with larger herds generally being fed more. It is not well understood whether eating high amounts of

concentrates in such a short period induces acute thirst. However, it seems unlikely this was a major animal welfare challenge on our farms because cows would have access to water shortly after being milked, with more than 90% of large and very large herds had access to water either at the dairy or on the track and all farms having water available in the paddock. Timely access to water is a potential risk as farms increase in size and milking duration increases and more work is needed to understand the preferred drinking behaviour of high producing dairy cows that are pulse fed large quantities of concentrates in the dairy twice daily.

We assessed water quality by asking the farmer if the water source was suitable for human consumption. Water that was not suitable for human consumption was either bore water with dissolved mineral salts or water with environmental/fecal contamination. Saline water may reduce production (Jaster et al., 1978; Solomon et al., 1995) and faecal contamination reduces palatability and may reduce production (Collins et al., 2007). Smaller farms were much less likely to have water that was suitable for human consumption (less than 50%) compared with larger farms (more than 90%). We did not specifically record the reasons for poor water quality in our study, but this would be a useful inclusion in animal welfare assessment protocols on pasture-based dairy farms.

4.5.2. Good Housing

Comfort around resting. Injuries and swellings of legs, knees and hocks are associated with lying on hard or rough surfaces (Rushen et al., 2007; von Keyserlingk et al., 2012) and are common in housed cattle. A review article of studies conducted in in British Columbia, France, Austria, Germany, Denmark, Norway and three regions in North America reported hairless area and hock lesion prevalence of more than 40% in all studies (Kester et al., 2014). We found low levels of integument alterations in herds of all sizes, with no skin lesions or hairless areas being recorded in a majority of herds, and a maximum of 6% of single lesions in any herd. Lower levels of integument alterations might be expected in pasture-based cattle that are less likely to be lying on very hard surfaces or to be otherwise rubbed by housing infrastructure, and indeed grazing has been previously shown to be associated with lower levels of integument problems (Keil et al., 2006; Burow et al., 2013). This is a good example of how the risks to animal welfare can be different between housed and pasture-based cattle. The substrate on which cows walk or lie can impact on their welfare. In particular, muddy wet conditions are aversive for cattle (Subcommittee on Environmental Stress, 1981; Fisher et al., 2003; Chen et al., 2017) and this is measured in the WQ-ME system by assessing the level of skin faecal contamination. We did not see a relationship with herd size but it was difficult to differentiate between fecal contamination and mud, and our data was likely confounded by time of year. In some herds in winter, dirty lower legs were common. Mostly, it seemed to the observer, this was likely due to cows walking through muddy areas on dairy tracks rather than dirty resting areas. Muddy areas on laneways were not specifically recorded, but it was a general observation that muddy areas and water over the tracks were rare in larger herds.

The frequency and duration of lying behaviour are probable indicators of cow comfort, and there is considerable evidence that restricting lying behaviour reduces animal welfare outcomes (Fisher et al., 2002). Mean voluntary lying times for pasture fed dairy cows milked twice daily are reported to be between 9 and 11 hours (Krohn and Munksgaard, 1993; Singh et al., 1993; Botheras, 2006). We did not measure the lying time of cows, but rather examined the opportunity for cows to rest by recording the shortest and longest time that a cow was likely to be away from pasture, and the maximum distance walked (Table 3). In larger farms, the furthest paddocks tend to be more distant from the dairy, resulting in longer walking distances. The mean minimum time away from the paddock for milking was less than an hour in all herd sizes. Interestingly, large (500-749) herds had a greater maximum time away from pasture than very large and smaller herds. In the very large study herds, the mean and maximum longest time away from pasture was not greater than in large herds. This was likely due in some cases to larger, more efficient dairies, and in other cases to the herd being milked in separate groups (kept in separate paddocks). When in the paddock, cows will spend time grazing, walking, and lying. The time available for lying will depend on the time they are motivated to graze and perform other functions that require standing (e.g. elimination, self-grooming). Various studies have reported the typical time spent grazing for lactating cows at pasture to be approximately 8-9 hours : 515-540 minutes (Bargo et al., 2002a), 547 minutes (Botheras, 2006), 430 minutes (Pérez-Prieto et al., 2011). If cows are motivated to spend 8 hours grazing and 12 hours lying down, it seems reasonable to hypothesise that the opportunity to lie down may be reduced when cows spend more than 4 hours (or 240 minutes) away from pasture per day. There is a consistency to the milking order of cows in large herds such that there is a group of cows that is regularly milked last (Beggs et al., 2018) and these cows may be particularly impacted by longer milking times. A limitation of our study is that we indirectly assessed the maximum opportunity to lie down based only on the time cows spent away from pasture. Lying time is also be affected by factors within the paddock. For example, forage quality could mean that cows need to spend more time grazing and hot cows need to lie down more. Thus, whilst we can conclude from our Results that time away from the paddock might reduce the time available for lying down, we cannot necessarily conclude that just because cows have adequate time in the paddock, their lying time needs are met. It seems likely that the opportunity for lying may be restricted in larger Australian dairy herds and this is worthy of further investigation.

Thermal comfort. The Australian climate poses risks to animal comfort, particularly for heat stress on very hot days (Dunshea et al., 2013). As yet, no measure is developed in WQ-ME to quantify the welfare effects of thermal stress in an audit context. Clinical signs (such as panting, recumbency, rectal temperature) can be used to measure whether a particular cow is affected by temperature stress but these do not lend themselves well for on-farm measurements on the day of audit. Measuring such outcomes at a single point in time is unlikely to be representative of the true risk to animal welfare. We assessed strategies that farmers had in place to mitigate the effects of high temperature and humidity on hot days. All

farms had some form of cooling strategy. Shade was more common in all paddocks on smaller farms, although most larger farms used paddocks with shade on very hot days. Dairy yard sprinklers were more common on larger farms. A New Zealand study showed that sprinklers and shade were both beneficial to cows in hot conditions (Kendall et al., 2007). Sprinklers alone and the combined effects of shade and sprinklers reduced the respiration rate by 60 and 67%, respectively, compared with controls. Sprinklers were particularly effective, with a decrease in body temperature being evident for four hours afterwards. A lack of shade may be an issue worthy of further examination as a specific animal welfare risk on larger dairy farms, and the ability for cows to access shade and sprinklers may be a useful measure in Australian pasture-based dairy farms. More work is needed to quantify how sprinklers might best be used to mitigate the effects of heat stress on very hot days.

Good Health

Animal welfare may be negatively impacted not only by having a disease, but also because of delayed recognition and treatment of disease and by delayed euthanasia where it is necessary. One of the strategies that can be employed to automate the drafting of animals for and/or detection of disease is the installation of electronic identification infrastructure in milking parlour combined with electronic drafting or monitoring of milk production. Such systems make it easy and practical for farmers to more closely examine cows they have concerns about during the milking process. Automatic drafting can make separation and subsequent inspection of cows easy and practical, which may increase the likelihood that individual cows are attended to. For example, the person putting the cups on cows may notice a cow appearing lame or unwell as it enters the milking parlour, and all that is required in order to draft the cow for later inspection is to press a button as the cups are applied. Some systems alert farmers when milk production suddenly decreases, and these cows can be automatically drafted for inspection. Some systems measure milk conductivity or milk cell count, and alert farmers to the likelihood of mastitis. Some systems individually feed cows based on their level of production and stage of lactation which can reduce the likelihood of rumen acidosis and associated diseases. The increased use of electronic infrastructure to monitor cows in larger farms may help counter the reduced ability for staff to individually inspect cows during milking as herds get larger.

We investigated farm records of lameness, mastitis, downer cows, dystocia and gastrointestinal disease (such as displaced abomasum) as these have been previously shown to be the most common health conditions on Australian dairy farms (Beggs et al., 2015). There was general agreement amongst farmers that mastitis and lameness were the most common health conditions, followed by dystocia, downer cows and gastrointestinal diseases.

A limitation of our study was that in collecting data retrospectively, it was not always possible to have consistent case definitions for health conditions. For example, most farmers recorded a dystocia whenever a cow was assisted but some farmers were very pro-active and assisted cows to calve much sooner than others. Some farmers recorded any cow that became

recumbent as a downer cow, while others recorded only treatment failures. Some farmers did not record gastro-intestinal problems as such if the cow was sold or euthanased rather than treated. Some farmers recorded all lame cows, and others only those that were treated with antibiotics. With these limitations in mind, we could not validly interpret differences between farms of different sizes. The percentage of cows having clinical mastitis within 30 days of calving is a commonly used metric in Australian dairy farms, with an industry 'target' of less than 5% (Lean et al., 2010). Approximately 30% of our herds did not meet that target, suggesting that mastitis remains a major health and welfare issue on Australian farms. On Australian pasture-based farms, where cows may walk several kilometres per day, the potential for lameness to impact on animal welfare is of particular concern. There was no relationship between the proportion of cows treated for lameness and herd size, however a limitation of our study was that herd size was confounded with time of year, and as lameness tends to be concentrated in the wetter months and during early lactation (Ranjbar, 2017) we did not consider that a point-estimate of lameness on the day of observation would be a useful measure for comparison of herd sizes. However, from an animal welfare perspective, whilst the prevalence of lameness is important, so is how rapidly lame cows are identified and how they are managed. For example, milking lame cows in a separate herd so they do not have to walk as far or stand in a concrete yard for as long would reduce the impact of lameness for those cows and in our study larger farms were more likely to milk lame cows in a separate herd.

Cows that die on farm (rather than being sent for slaughter) may present an animal welfare issue, especially if euthanasia, when required, is delayed. Euthanasia on farm may be carried out by farm staff using firearms (which have special licence, storage and safety requirements) or captive bolt guns (which require care in their use but do not have licensing requirements in Australian states). Farmers without access to firearms on farm commonly use their veterinarian or a local "knackery" service for euthanasia. Knackeries are businesses that provide a service for disposal of farm animals that are not fit for human consumption by either processing the carcass for pet food or rendering it into meat and bone meal for incineration and use as fertilizer. Knackeries have the advantage that they remove and dispose of the carcass, but the possibility of a delayed attendance and thus delayed euthanasia is a risk to animal welfare. There is considerable scope for improving the uptake of captive bolt euthanasia on farms of all sizes.

In our study herds, large herd size was associated with increased use of pain relief for disbudding with 73% of large using pain relief compared with less than 40% in other herd sizes. Smaller herd size was associated with disbudding after 8 weeks of age. Australian states and territories are in the process of mandating nationally agreed Animal Welfare Standards and Guidelines for Cattle (Animal Health Australia, 2014a) which prohibit tail docking in cattle unless on veterinary advice and only to treat injury or disease. Disbudding before 8 weeks of age and the use of anaesthetics and analgesics are strongly encouraged, although not mandated.

4.5.3. Appropriate Behaviour

In pasture-based systems, cows are more likely to be able to express behaviours they are highly motivated to undertake such as grazing, lying and social behaviours than in housed systems. However, the implications of larger herds and longer milking times needs further investigation. For example, an Australian study showed that cows toward the end of the milking order consumed pasture of lesser quality (lower protein, higher fibre) than cows that entered a paddock first. This was because the paddock had limited pasture in it and 70% of the available pasture had already been consumed when the last cow entered the paddock (Scott et al., 2014).

The importance of stockmanship and the human–animal relationship (HAR) for farm animal welfare, health and performance has been demonstrated in several studies. Handling of farm animals in a positive or negative way can alter reproductive performance, production and will impact their welfare (Breuer et al., 2000; Hemsworth et al., 2000; Hemsworth and Coleman, 2002; de Vries et al., 2011). Avoidance distance toward an unfamiliar person has been established as a valid behavioural indicator of HAR (Breuer et al., 2000; Waiblinger et al., 2003; Ebinghaus et al., 2016). Most protocols for AD measurement are described for experimental situations where the environment is standardised as much as possible. Ebinghaus et al., (2016) measured AD at the feeding gate and Waiblinger et al., (2003) measured it at both the feeding rack or in the barn. Both concluded that despite other factors that might impact on AD (such as age, the presence of other cows, time calved and other environmental factors), AD validly reflected HAR. As far as we are aware, there are no reported benchmarks of AD for cows grazing at pasture as they do in the Australian situation. We measured the avoidance distance of 50 cows on each farm in the paddock at a time when we expected them to be predominantly engaged in grazing or eating forage, rather than engaging in social behaviour, with the aim of assessing the practicality of the test and gathering benchmark data.

WQ-ME uses the percentage of animals with AD of 0, <50cm, 50-100cm, >100cm as metrics whereas Waiblinger et al., (2003) used the proportion with AD of 0 and the median AD to compare farms. In terms of using AD to assess the HAR on pasture-based farms where measurements are taking place in a paddock, where cows are not used to routinely having human contact, further work needs to be done in order to determine useful benchmarks that could be used as potential indicators of poor HAR. Based on the distribution of AD measurements found in our study, we suggest an initial benchmark of either Median AD > 2.2m or % cows where AD > 2.2m may be a suitable guide on our study farms. This was the cut-off where more than 50% of individual cows in a herd had an AD in the highest quartile of the population, and when applied to our data it identified 10% of farms. Limitations of the test in the commercial environment must be considered as it is difficult to standardise all aspects, and there is a need to validate the results against observed human-animal interactions. For example, smaller farms seemed to have fewer cows that could be approached by an unfamiliar investigator at very close distances. We speculated that this might be because cattle on smaller farms have not generalized to other humans since they may know all of their

stockpeople individually, but further work is required to assess whether cattle on small farms react differently to strangers for this reason. We concluded that there was wide variation in HAR as measured by AD in all sizes of farms, and that it appeared to be unrelated to herd size.

4.5.4. Animal welfare challenges associated with pasture-based dairying
Animal welfare challenges of Australian pasture-based dairy cows differ in some respects from those of cattle kept indoors. Examples of animal welfare challenge indicators used in WQ-ME but which did not seem to be pertinent in a pasture-based system include swollen joints from lying on hard surfaces, integument injuries from rubbing or bumping into farm infrastructure and access to water for sufficient periods of a day. Potential challenges in Australian herds that are not emphasised in QW-ME include management of thermal stress and the potential consequences of long milking times and walking distances.

Major challenges to good animal welfare on Australian pasture-based dairy farms based on our study include the risks of pulse-feeding high levels of concentrates in the milking parlour, management of heat stress, lameness, mastitis, quality of human-animal relationship, management of painful husbandry procedures and euthanasia methods.

4.5.5. Animal welfare challenges associated with increasing herd size
A review of more than 150 publications that examined the relationship between animal welfare indicators and herd size concluded that there was little evidence of any simple relationship between farm size and animal welfare, but rather, larger farms provided both opportunities to improve animal welfare but also created more risks (Robbins et al., 2016). Our Results agree with this. We found considerable variation in both risks to animal welfare and also the use of mitigating strategies across farms of all sizes. For most metrics, there were a range of outcomes in all farm size categories. Some risks to animal welfare clearly increased with herd size, but consistent with a recent survey of Australian dairy farmers (Beggs et al., 2015), there was also an increase in the use of strategies to mitigate those risks. For example, with increasing herd size there are higher levels of concentrates pulse-fed in the milking parlour. However, to mitigate this, there is also increased use of dairy infrastructure that allows for individual identification, monitoring and feeding of cows. Particular animal welfare risks that increased with herd size but where increased use of risk mitigation strategies was not clear included the management of heat stress (where the provision of shade and the ability to alter the milking time on very hot days was reduced in large herds) and the potential for long milking times and walking distances to impact on the ability of cows to lie down and graze.

4.5.6. Measuring animal welfare outcomes

In our study, we measured some outcomes on the day (e.g. integument alterations, prevalence of lame cows being treated), some outcomes based on herd records (e.g. disease incidence) and some outcomes based on the use of effective risk mitigation strategies (e.g. provision of shade, ability to monitor and feed cows individually, milking lame cows in a separate herd). A limitation of conducting welfare assessments on a single day is that outcomes for metrics that

vary daily or seasonally may not be representative, and when collecting retrospective data it can be difficult to ensure consistent case definitions. As animal welfare is multi-dimensional it is necessary to use both animal and resource-based measures. Animal based measures have strengths in that when measured accurately they are genuinely reflective of the outcome being measured, but they also have weaknesses. For example, the point-estimate of a disease prevalence on a given day may not be representative of other times of year, or there could be differences in case definition when farm records are used. Similarly resource based measures have strengths in that they may well be applicable to longer periods and case definitions can be more consistent, but weaknesses in that simply because a resource is present does not guarantee it is being used.

On the basis of our experience in this study, we believe that identifying the major risks to animal welfare on individual farms and ensuring that there is a plan to effectively manage them should be an important element of any on-farm welfare assessment protocol, but more work is needed to understand the particular measures that would best be used in Australian pasture-based dairy farms.

4.6. CONCLUSIONS

The major challenges to good animal welfare on Australian pasture-based dairy farms include managing heat stress, lameness, mastitis, and the management of painful husbandry procedures and euthanasia. There was considerable variation in animal-welfare metrics across farms. Particular issues as herd sizes increase include managing heat stress, and the impact of increased time away from pasture on the ability of cows to lie down. Identifying the major risks to animal welfare on individual farms and ensuring that there is a plan to effectively manage them should be an important element of any on-farm welfare assessment protocol.

4.7. ACKNOWLEDGMENTS

The Authors are grateful to the staff of the Warrnambool Veterinary Clinic and the farmers who graciously allowed us on their farms. We acknowledge the Victorian Department of Economic Development Jobs Transport and Resources and Dairy Australia Ltd for their support of this project. This project was also supported through an Australian Government Research Training Program Scholarship.

CHAPTER 5

5. Lamé cows on Australian dairy farms: A comparison of farmer estimates and lameness scoring, and the position of lame cows within the milking order

The following paper *in press* in the Journal of Dairy Science.

Lame cows on Australian dairy farms: A comparison of farmer identified lameness and formal lameness scoring, and the position of lame cows within the milking order

D.S. Beggs,* E.C. Jongman, P.E. Hemsworth, A.D. Fisher

5.1. ABSTRACT

On Australian pasture-based farms, where cows may often walk several kilometres and stand for several hours per day in a crowded concrete yard while they wait to be milked, the potential for lameness to impact negatively on animal welfare is of ongoing concern. Several studies have shown that farmers tend to underestimate the incidence of lameness. Further, improving farmer diagnosis/identification of lameness is likely to result in more prompt treatment which in turn will improve clinical and animal welfare outcomes. We scored 19154 cows over 50 farms for lameness, in herd groups ranging from approximately 100-1000 cows, as they left the milking parlour. We compared these results with farmer-diagnosed lameness records on the same day. We used a scoring system of 0-walks normally; 1-walks unevenly; 2-lame; 3-very lame. All very-lame cows had been detected by the farmer, but overall, farmers detected only 24% of cows identified by lameness scoring. An analysis of the position of lame cows within the milking order showed that lameness scoring of the entire herd was necessary to detect all the lame cows as only 60% of lame cows appeared in the last 30% of cows to be milked. However, lameness scoring just the last 200 cows to be milked could be used as a screening test to identify herds with a lameness prevalence below a given threshold.

5.2. INTRODUCTION

Lameness remains a common problem of dairy cattle worldwide. As well as being a significant animal welfare concern (von Keyserlingk et al., 2009; Fisher and Webster, 2013; Hemsworth et al., 2015), lame cows have reduced fertility, milk production and bodyweight, as well as incurring treatment costs and being at risk of premature culling (Green et al., 2002; Bruijnis et al., 2012; Grant, 2012; Fabian et al., 2014). On Australian pasture-based farms, where cows may often walk several kilometres per day and stand for several hours per day in a crowded

concrete yard while they wait to be milked (Beggs et al., 2015), the potential for lameness to impact negatively on animal welfare is of ongoing concern.

Several studies have shown that when farmers do not use systematic lameness scoring systems, they tend to underestimate the incidence of lameness in their herds (Espejo et al., 2006; Šárová et al., 2011; Leach et al., 2013; Fabian et al., 2014). Improving farmer diagnosis/identification of lameness is likely to result in more prompt treatment (Alawneh et al., 2012) which in turn will likely improve clinical outcomes (Leach et al., 2012) and thus also improve animal welfare outcomes.

To that end, both the Australian and New Zealand dairy industries have developed extension programs (known respectively as 'Healthy Hooves' and 'Healthy Hoof') promoting the formal lameness scoring of dairy herds on a regular basis (Dairy Australia, 2015; DairyNZ, 2017). Both extension programs use a 0-3 scale similar to that described by Barker (2010), adapted slightly to suit local conditions and language use. Video instructions and print material resources are available that show farmers how to score lameness in a consistent way as cows leave the milking parlour. The uptake of lameness scoring in Australia remains low because, anecdotally at least, farmers appear to believe that they are skilled at identifying clinically lame cows, the time/effort required, and because lameness scoring is seen as a low priority at times of year when it is not a major clinical problem (Dairy Australia, 2016). Farm size may also be a barrier to farmers participating in lameness scoring.

Large herds of more than 500 cows with long milking durations of 3-5 hours are increasingly common in Australia which means lameness scoring entire herds can require significant effort and resources (Beggs et al., 2015; Dairy Australia, 2017c). For welfare auditing purposes, or identifying farms likely to benefit from assistance with their lameness management, it may be useful if herd lameness prevalence could be estimated by lameness scoring a subsample of the entire herd. In the Australian context, where cows walk several kilometres per day to and from the paddock, it seems logical that lame cows might walk more slowly or be slower to leave the paddock, and thus be concentrated toward the end of the milking order. The extent to which this happens has not been previously reported but is worthy of examination. For example, if it were possible to identify most lame cows by lameness scoring only the last half of cows milked it could result in a significant saving of resources.

We lameness scored fifty herds in the order cows left the milking parlour. We: (1) compared the results with farmer recorded lameness in order to test the hypothesis that Australian dairy farmers underestimate the prevalence of lameness in their herds; and (2) examined the extent to which lame cows were concentrated toward the back of the milking order in order to assess whether lameness scoring a subset of cows might be useful for identifying the majority of lame cows or estimating herd lameness prevalence.

5.3. MATERIALS AND METHODS

Fifty seasonal or split-calving dairy farms were selected on the basis of convenience from the client base (approximately 300 dairy farms) of a large veterinary practice in western-Victoria, the highest producing dairy region in Australia. The sample of farms was chosen to be broadly representative of dairy farms in the area, selected to ensure that there was a range of farm sizes. Observations were conducted over a 14-month period at times based on convenience for the researcher. We made a positive attempt to time visits during mid to late- lactation for the majority of cows, because this would maximise the proportion of the herd that was lactating at the time of the visit. All lameness score observations were carried out by the first author, a senior lecturer in cattle medicine at the University of Melbourne, also a veterinary practitioner with more than 20 years' experience diagnosing and treating lame cows, who had familiarity and experience with the Healthy Hooves resources.

Prior to milking, the farmers provided the identities of and cows in the herd that: (a) were currently under treatment for lameness; or (b) were separated into a second herd that walks a lesser distance because they were lame. All cows were then scored for lameness at a single milking in the order that cows left the milking parlour using the "0-3" scale promoted by Dairy Australia, described in Table 5.1.

TABLE 5.1. INSTRUCTIONS FOR LAMENESS SCORING OF DAIRY CATTLE PROVIDED IN THE AUSTRALIAN DAIRY INDUSTRY “HEALTH HOOVES” EXTENSION PROGRAM. ADAPTED FROM DAIRY AUSTRALIA (2015).

Lameness Score	Walking Speed	Stride	Weight Bearing	Backline	Head
0 – Walks normally. No action required.	Confident. Similar walking speed to a person. Maintains position in the herd.	Long, even and regular. Rear foot placement matches front foot placement.	Evenly placed and weight bearing when standing and walking.	Straight (level) at all times.	Held in line or slightly below the backline and steady when walking.
1 - Walks unevenly. Minor action required. Record and keep an eye on her - some cows normally walk unevenly.	Not normally affected, should easily maintain position in the herd.	May have uneven stride and/or rhythm. Rear foot placement may miss front foot placement.	May stand or walk unevenly but difficult to identify which leg/s are affected.	Straight when standing, may be mildly arched when walking.	May have slight bob and or may be held lower than normal.
2 - Lane. Action required. This cow needs to be reported, drafted and examined within 24 hours.	May be slower than normal; may stop, especially when turning a corner.	Shortened strides rear foot placement falls short of front foot placement.	Uneven – lame leg can be identified.	Often arched when standing and walking.	Bobs up and down when walking.
3 - Very lame. Urgent action required. Draft and examine as soon as possible within 24 hours. May require a vet.	Very slow, stops often and will lie down in paddock. Cannot keep up with the healthy herd.	Shortened and very uneven. Non lame leg will swing through quickly.	Lame leg easy to identify - ‘limping’; may barely stand on lame leg/s.	Arched when standing and walking.	Large head movements up and down when walking.

Under this system, cows with scores 0 are not lame, cows with a score of 1 are described as walking unevenly but not requiring urgent treatment. Cows with a score of 2 or 3 are considered to be lame. Cows that could not be lameness scored (for example, because they were walking too closely together or running) were recorded as lameness score X. Such cows were excluded from the analysis of prevalence, but included for the purpose of calculating the

cut off points for the last 10, 20 and 30% of the milking order. Due to the rate of cows exiting the milking parlour, individual cows were not identified unless they were very lame (score 3), in which case their visual identification numbers were recorded and reported to the farmer, to ensure these cows were identified for treatment.

It is common practice on Australian dairy farms to milk sick and lame cows in a separate “hospital herd” which walks a lesser distance. Also, as cow numbers increase, it is common for Australian farmers to milk cows as two to three sub-groups which are kept in paddocks separate from one-another and milked separately. Where groups of cows were milked separately, all cows were included in prevalence calculations, but only the largest group was included in the milking order analysis.

Lameness scores were entered into a spreadsheet where initial calculations were made at the farm level, and then entered into SPSS (IBM Corp V25) for further analysis. The farmer diagnosed prevalence of lame cows was calculated as the percentage of milking cows that the farmer had identified as lame prior to the milking at which observations were taken. The prevalence of lame cows was calculated as the percentage of all cows milked that had a lameness score of 2 or 3.

For each herd, we calculated the proportion of lame cows in the last 10, 20 and 30% of the milking order, to determine whether the majority of lame cows could be successfully identified without the need to lameness score the entire herd.

Linear regression using lameness prevalence as the outcome variable and lameness prevalence of the last 100 or 200 cows and the last 30% of cows (with a minimum of 200 cows) as the predictor was used to examine whether these could be used to predict the overall lameness prevalence. Where the group size was less than the threshold, all cows in the group were included.

The study was conducted with animal ethics approval from the University of Melbourne Faculty of Veterinary and Agricultural Sciences Animal Ethics Committee.

5.4. RESULTS

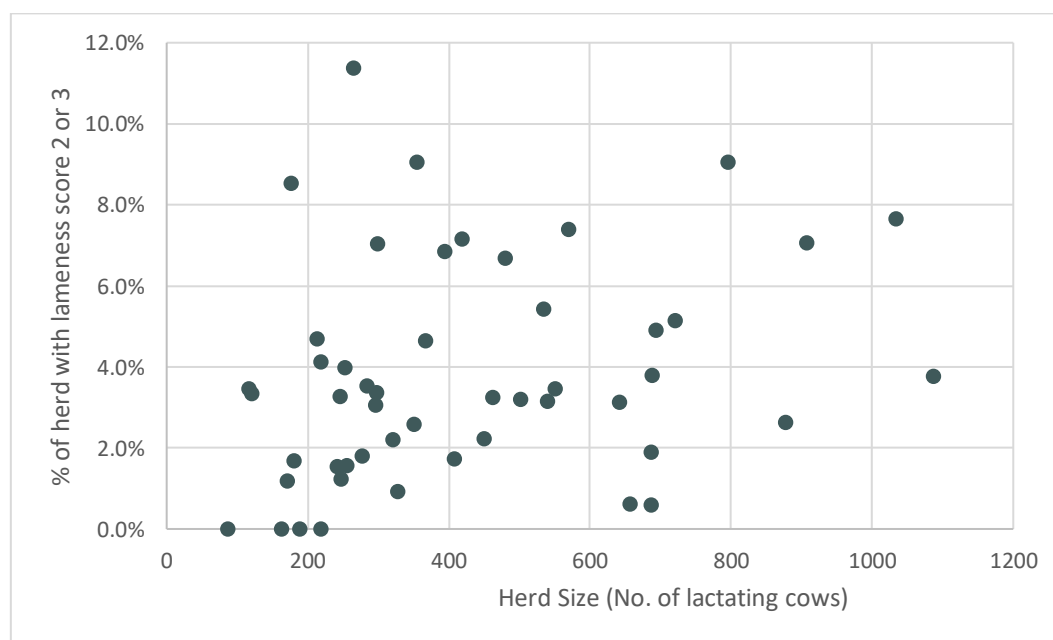
A total of 19154 cows on 50 farms were lameness scored by the same experienced observer. This represented approximately 15% of the client base of veterinary clinic from which the study was conducted, and we estimated that it represented approximately 4% of farms and 7% of cows within the local western-Victorian dairying region of Australia. There was a range of herd sizes with 16 small (<300 cows), 13 medium (300-499), 11 large (500-749) and 10 very large (750-1087) herds. The distribution of herd sizes can be seen in figure 1. Most farms (32/50) had a seasonal calving pattern, with 17 of the remaining farms having a split calving pattern (two discreet calving periods during the year) and one farm having a year-round calving pattern. There were 25 rotary dairy and 25 herringbone dairy sheds. Visits were conducted between 64 and 310 days from the beginning of the most-recent calving period in all herds except the year-round calving herd and two of the split calving herds. The majority of

visits (35/50) took place during the drier months of November-February, and no visits took place between April and June when a majority of farms in the local area were calving. Less than 1% of cows on any farm were excluded from the analysis because they were unable to be lameness scored.

5.4.1. Farmer estimates of lameness prevalence

The mean farm prevalence of lame cows (score 2 or 3) based on lameness scoring ranged from 0-11.4% (mean 3.8%), with 4.2% of cows overall being lame. These results contrast with the farmer estimates of lameness prevalence. On individual farms, the farmer diagnosed prevalence of lameness lay between 0 and 3.6% (mean 0.82%). On average, farmers had diagnosed approximately 24% of cows identified by lameness scoring but there was wide variation between farms (range 0-100%, IQR 4-31%). All the very lame (score 3) cows had been identified by the farmer and were either marked for treatment or in a separately milked hospital herd. There was no evidence of a relationship between herd size and lameness prevalence (Figure 5.1). Having a hospital herd that walked a lesser distance was more common as herd size increased (100% of very large herds, 89% of large herds, 77% of medium herds and 69% of small herds), but it was not related to lameness prevalence or the proportion of lame cows identified by the farmer.

FIGURE 5.1. THE RELATIONSHIP BETWEEN HERD SIZE AND LAMENESS PREVALENCE SCORING FOR FIFTY HERDS LAMENESS SCORED MID- TO LATE- LACTATION ($R^2=0.07$)



5.4.2. The position of lame cows in the milking order

The distribution of group sizes was slightly different for milking order calculations because only the largest group was considered on each farm. Cows were milked in separate groups (aside from hospital herds) on 5 farms, all of which milked more than 680 cows in total. There were 5 groups of >750 cows, 12 groups of 500-749 cows, 11 groups of 300-499 cows, 14 groups of 200-299 cows, 7 herds with 100-199 cows and one herd with 86 cows. Of the smaller farms, all

but two had a separate hospital herd. One of the smaller farms with no hospital herd also had no lame cows.

Lame cows appeared disproportionately toward the back of the herd with 26% (SD 2.4%), 47% (SD 2.7%) and 62% (SD 2.3%) of lame cows appearing in the last 10%, 20% and 30% of the milking order respectively. Table 5.3 and Figures 5.2-5.4 show linear regression analysis estimating prevalence of lameness in a herd of cows based on the last 100 cows, last 200 cows, or last 30% or 200 cows (whichever is the greater). When 100 cows were scored, the lameness prevalence was underestimated in one herd by 2.2%, and in the other 49 it was overestimated between 0 and 11.4%. When 200 cows were scored, and also when the greater of 200 cows or 30% of the herd were scored, the lameness prevalence was underestimated in one herd by 0.2%, and in the other 49 it was overestimated between 0 and 5.5%.

TABLE 5.2. LINEAR REGRESSION ANALYSIS COMPARING THE PREDICTIVE VALUE OF ESTIMATING WHOLE HERD LAMENESS IN 50 HERDS BASED ON EITHER LAMENESS SCORING THE LAST 100 OR LAST 200 COWS TO BE MILKED (OR ALL COWS IF LESS COWS THAN THIS).

	Last 100 cows ^a	Last 200 cows ^b	Last 200 cows or 30% of cows milked (if greater)
R square	0.77	0.84	0.85
Constant	0.55	0.36	0.36
B (Coefficient)	0.38	0.58	0.59
Std. Error	0.03	0.04	0.04
95% CI for B	0.32-0.44	0.51-0.65	0.51-0.66

^a Including was one herd with less than 100 cows

^b Including 8 herds with less than 200 cows

FIGURE 5.2 THE RELATIONSHIP BETWEEN THE PROPORTION OF THE HERD LAME OVERALL AND THE PROPORTION OF LAME COWS IN THE LAST 100 COWS MILKED ($R^2=0.77$)

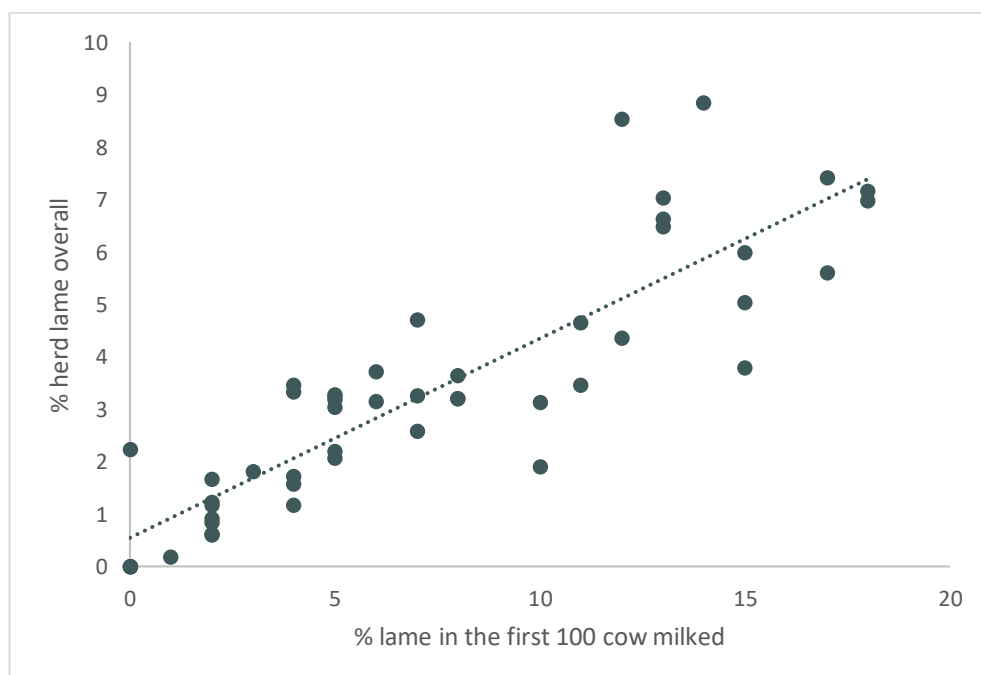


FIGURE 5.3 THE RELATIONSHIP BETWEEN THE PROPORTION OF THE HERD LAME OVERALL AND THE PROPORTION OF LAME COWS IN THE LAST 200 COWS MILKED (OR ALL COWS IF LESS THAN 200 COWS IN THE HERD) ($R^2=0.84$)

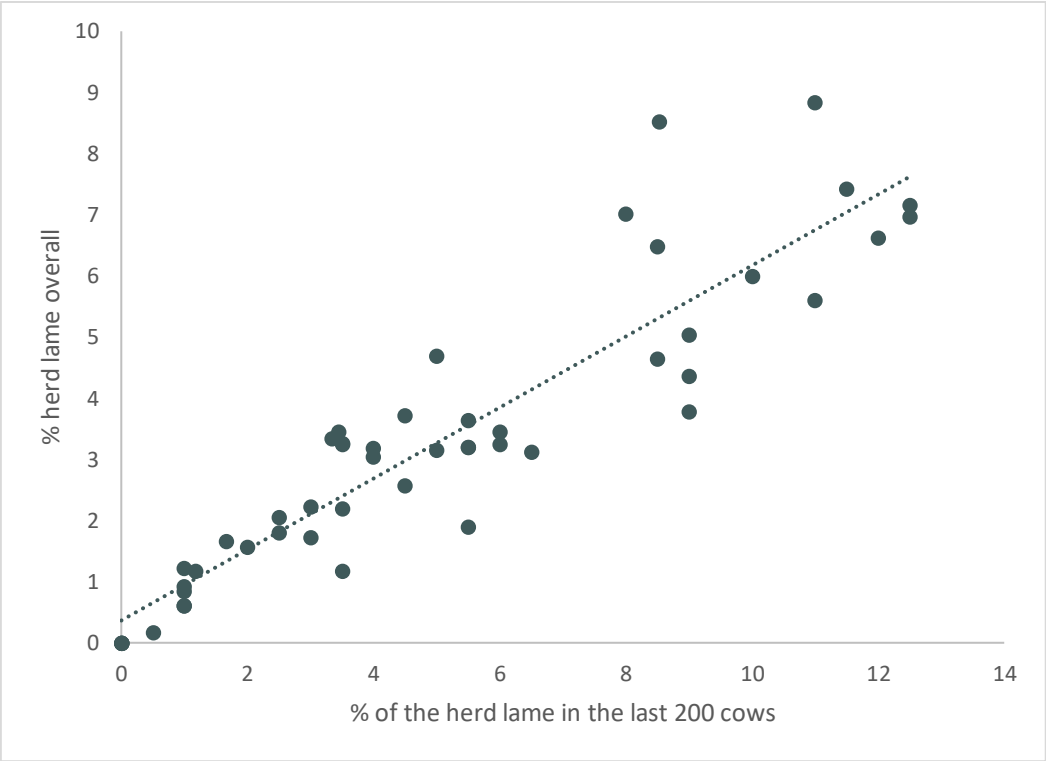
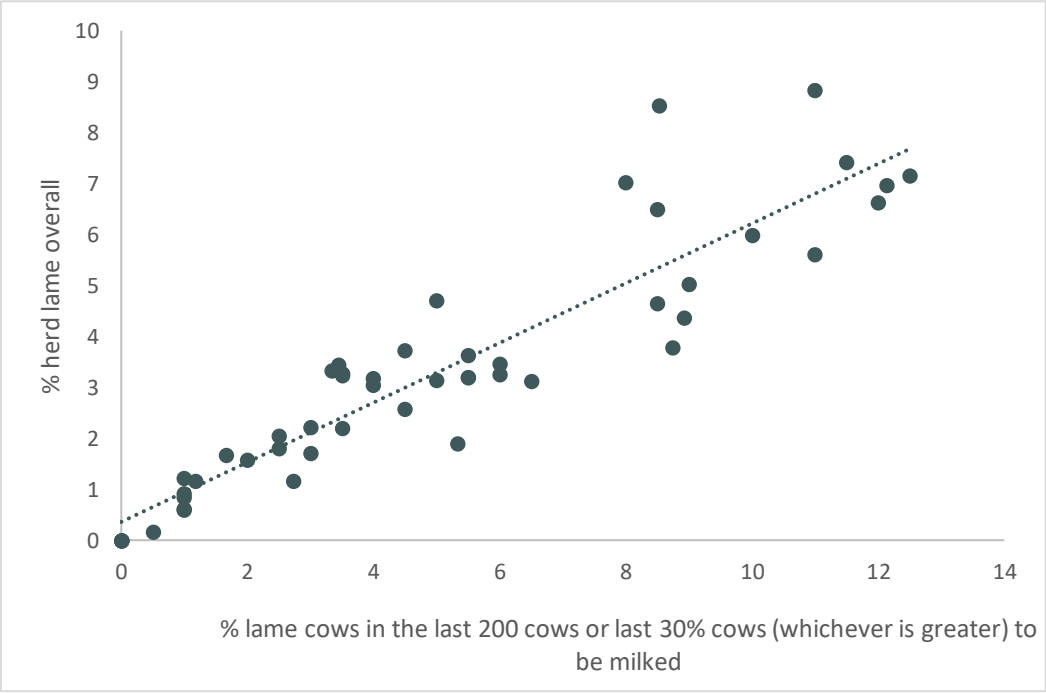


FIGURE 5.4 THE RELATIONSHIP BETWEEN THE % OF LAME COWS IN THE LAST 200 COWS OR 30% OF THE HERD (WHICHEVER IS GREATER) TO BE MILKED AND THE % OF LAME COWS OVERALL. $R^2=0.85$



5.5. DISCUSSION

The incidence of lameness varies with the time of year and stage of lactation in Australia, being more of a problem in the wetter months and during early lactation (Ranjbar, 2017). However, there is potential for lameness to be an important animal welfare issue through the entire year - at times when there is a lower percentage of the herd lame, there is potentially a higher percentage of cows lactating. Rather than timing our visit to coincide with the expected peak of lameness we aimed instead to visit when the maximum number cows were milking and there is not necessarily a management focus on lameness. For most seasonal calving herds most cows are in mid-late lactation at this time. From an animal welfare perspective, our study directly compared the proportion of cows that were receiving some sort of attention for their lameness with those that should have been receiving such attention on a given day.

Our mean farm lameness prevalence of 3.8% was considerably lower than previous studies. For example, a New Zealand study (Fabian et al., 2014) reported 8.3% of cows were lame, but these farms were visited at the time of the expected highest lameness incidence and it seems reasonable that the prevalence of lameness might be more than twice as high when it is at its maximum. A recent Australian study, where 18.9% (range 5 to 44.5%) of cows were lame, included visits throughout a 12 month period and would have included farms at their time of maximum lameness (Ranjbar et al., 2016). Thus, these studies are not directly comparable with our data. Rather than timing our visit to coincide with the expected peak of lameness we aimed instead to visit when the maximum number cows were milking and there is not necessarily a management focus on lameness. For most seasonal calving herds most cows are in mid-late lactation at this time.

5.5.1. Researcher Identified Lameness

The scoring system used in this study, similar to the AHDB dairy mobility score widely used in the UK (AHDB, 2015), was designed as a practical 'on-farm' tool and is promoted by industry in Australia and New Zealand for use by farmers, with little more than posters and videos as initial training, and a general recommendation that lame cows should be examined as soon as practicable and very lame cows should be examined urgently (Dairy Australia, 2015; DairyNZ, 2017). There are no reports, to our knowledge, regarding the effectiveness of this training, but the lameness scoring system has been shown to be robust in terms of inter- and intra-observer agreement in several studies where researchers used each other for calibration (Barker et al., 2010; Main et al., 2010; Fabian et al., 2014). It must be recognised that the results of this study are only true within the limits of the observer's reliability and repeatability, which is difficult to quantify. However, we consider that the results and conclusions remain valid because, from an animal welfare perspective, cows identified as lame by an experienced dairy cattle veterinarian should be examined and treated. If the researcher was in fact underestimating true lameness prevalence, this makes the conclusions of our study more conservative.

5.5.2. Farmer Identified Lameness

Our results in terms of the proportion of lame cows identified by the farmer are broadly similar to other studies, including the studies with higher overall lameness prevalence described above. Fabian et al (2004) in New Zealand pasture-based dairy herds reported that only 27.3% (range 0-95%) of cows with reduced mobility had been identified as such by farmers and Ranjbar et al (2016) reported that the prevalence of lameness estimated by farmers was only 27% of that identified by lameness scoring. In housed cows there have been similar results. In the UK, Whay et al, (2003) reported farmers estimating the prevalence of lameness to be 23% of the actual prevalence and in a study by Leach et al., (2010), the mean estimate of lameness by farmers was 7.9% compared with 36% identified by lameness scoring. Espejo et al., (2006) reported the mean prevalence of detected lameness to be 32% of actual lameness by farmers in freestall barns in Minnesota. Šárová et al., (2011) found that in 14 Czech loose-housed dairy farms, farmers estimated lameness prevalence to be between 0-20% whereas lameness scoring identified 9-64% of the herds as lame and there was no correlation between farmer estimate and prevalence estimated by lameness scoring. Whilst the absolute lameness prevalence was not particularly high in our study herds, small percentages of lame cows can still amount to significant adverse animal welfare outcomes – especially in larger herds when a significant number of lame cows may remain undiagnosed and untreated. Our results highlight the potential animal welfare benefits of formal and systematic lameness scoring of dairy herds for improving identification and treatment of lame cows, even at times of the year when farmer perception is that lameness prevalence is low.

5.5.3. The position of lame cows in the milking order

We concluded that lameness scoring only cows which are milked later in the milking order would not be very useful for identifying all lame cows in a herd for the purposes of treatment as only 60% of lame cows were found in the last 30% of cows to be milked, leaving 40% of the lame cows undiagnosed. As our study was undertaken on a single day, it is worth considering whether the results would likely be repeatable on a given farm. Previous studies have demonstrated a consistency to the milking order, even in large herds (Botheras, 2006; Berry and McCarthy, 2012). A study of large Australian herds pasture-based herds showed that, although cows in the first and last 20% of the milking order maintained their position much more consistently than cows in the middle, milking order position of cows was highly correlated with in a day and between one month and the next, suggesting that cows are motivated to maintain their preferred milking order position (Beggs et al., 2018). Thus, it is probable, even though not demonstrated in our study, that our results would be repeatable within an individual farm.

It is interesting to speculate as to why lame cows would be distributed toward the end of the milking order. One potential explanation is that lame cows walk more slowly or leave the paddock more slowly, and indeed it seems likely that very lame cows (which by definition walk more slowly than the rest of the herd) would filter toward the back of the herd as cows walk to the dairy. In a study of 10 New Zealand herds, the authors examined the position of cows in

the walking order and the milking order both before and after they became lame. They showed that there was fair agreement between the walking order (the order cows walked to the dairy) and the milking order. Cows later in both the walking order and the milking order were more likely to become lame (OR=2.8 and 2.0, respectively) (Sauter-Louis et al., 2004). The authors theorised that the rear group might have been more vulnerable to becoming lame because they were the cows most likely to be affected by an impatient farmer hurrying cows along a track, hurrying them out of the milking yard, or because they were compacted by a backing gate in the dairy yard. Cows being hurried are forced into tighter groups and make more unplanned foot placements. Thus, they have a greater risk of foot damage from the track or yard surface material. Further work would be required to investigate whether a higher proportion of lame cows toward the end of the milking order could be used as an index to assess the extent to which cows are being hurried as they walk along the track.

A potential limitation of our study was that most herds (80%) milked identified lame cows in a separate 'sick herd' group that was milked last and did not have to walk as far, and in these herds the identified lame cows were necessarily excluded from milking order calculations. This might induce a bias into the milking order calculations, but as farmer identified lameness prevalence was generally low (<3.6%) we did not consider this likely to be of major significance, and it makes the study potentially more representative of herds that do milk identified lame cows in separate herds.

As with other welfare measures, lameness assessments may be conducted for a variety of reasons. Apart from the identification and treatment of lame cows, the prevalence of lameness in a herd might be used as part of a certification tool that enables farmers to be members of assurance schemes, to make specific welfare claims, for monitoring the effect of management changes or for benchmarking farms against others (Main et al., 2003; Sørensen and Fraser, 2010). Some have advocated a reduction in sample size as a mechanism for reducing costs (Sørensen et al., 2007; Main et al., 2010). In an Australian context, the most likely use the authors see for such a test would be in animal welfare audits, where having a test that minimises resources but gives some confidence that the overall prevalence of lameness was below a threshold would be useful. Although in a different farming system using housed cows in the United Kingdom, a previous study demonstrated a similar concept showing that lameness scoring 100 cows in the middle of the herd order produced an estimate of prevalence within 5% of the true prevalence on 83% of farms (Main et al., 2010). The study also concluded that by observing the presence of severely lame cows, especially at the end of milking, farms that are most likely to benefit from assistance with their lameness management could be identified. In most Australian dairies, it is possible to determine how many cows have been milked either from the dairy infrastructure in a rotary dairy, or by counting the number of runs milked in a herringbone dairy. Thus, scoring the last given portion of a herd to be milked is a practical option. Given the common herd sizes in Australia, we investigated whether lameness scoring the last 100 or 200 cows to be milked, or in case more cows were required the greater of the last 200 or the last 30% of the herd, would be suitable for this

purpose. There was only one low prevalence herd (2.2% lame cows) where lameness scoring a subset of the herd underestimated the prevalence of lameness overall. When 200 cows were lameness scored, the prevalence of lameness in the last 200 cows was within 5.4% of the overall prevalence. Scoring more cows (30% of the herd if this was more than 200 cows) did not materially change the outcome. This result must be viewed with caution because it is impacted by the overall low prevalence of lameness in our study. For example, in a herd with an overall prevalence of 5%, the estimate of prevalence based on any subset of 100 cows or more cannot be underestimated by more than 5%. However, our data make it seem likely that lameness scoring at least 200 cows at the end of the milking order would give some confidence that the overall lameness prevalence was not notably higher than the result obtained. This could be useful as a screening test, identifying herds that were likely to have lameness prevalence above a given threshold for further attention. Further work would need to validate the relationship in other herds with higher lameness prevalence.

5.6. CONCLUSIONS

Unreported lameness remains a welfare concern on Australian dairy farms. Farmers underestimated the prevalence of lameness, diagnosing only 20-25% of the cases found by formally lameness scoring the entire herd. In order to detect and treat lame cows, lameness scoring of the entire herd is needed, because scoring the last 30% of the herd would only detect approximately 60% of cases. Lameness scoring is a simple test that should be encouraged. Lameness scoring the last 200 cows from the largest group of cows milked in Australian pasture-based dairy herds has the potential for use as a screening test to detect herds with a lameness prevalence below a given threshold.

5.7. ACKNOWLEDGMENTS

The Authors are grateful to the staff of the Warrnambool Veterinary Clinic and the farmers who graciously allowed us on their farms. We acknowledge the Victorian Department of Economic Development Jobs Transport and Resources and Dairy Australia Ltd for their support of this project. This project was also supported through an Australian Government Research Training Program Scholarship.

CHAPTER 6

6. Milking order consistency of dairy cows in large Australian herds.

This paper has been published in the Journal of Dairy Science:

Short Communication: Milking Order Consistency of Dairy Cows in Large Australian Herds

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DOI: 10.3168/jds.2017-12748

6.1. ABSTRACT

We used on-farm records from dairy infrastructure to examine the consistency of the milking order over 150 days in five Australian dairy herds that were milking more than 500 cows as a single group. Within a single day the difference in milking order rank position was less than 20 percentage points for 72% of cows. The correlation coefficient comparing milking rank position in the morning and afternoon was 0.72 with the position of cows at the beginning and end of the milking order being more consistent than cows toward the middle of the milking order. Over a period of 150 days, cows with a mean position in the first and last 20% of the milking order maintained their position more consistently than cows in the middle of the milking order. Milking position of cows between one month and the next month was highly correlated ($r=0.88$). In large herds there are sub-populations of cows that are regularly milked toward the beginning and the end of the milking order. It is common for cows to be collected from the paddock as a group, to wait as a group in the dairy yard to be milked and to return individually to the paddock or feed pad immediately after they have been milked. Thus cows milked later in the milking order are likely to be away from the paddock for several hours longer than cows milked earlier in the milking order. This may impact their welfare though differences in time available for lying down, equality of pasture eaten and time spent standing in the dairy yard.

6.2. Short communication

Large pasture-based dairy herds, where more than 500 cows are milked at a time, are a significant part of the Australian dairy industry, accounting for more than 35% of the approximately 1.65 million cows milked in 2014 (Dairy Australia, 2013c; Beggs et al., 2015).

On most large Australian dairy farms, cows graze pasture during the day with supplementary feed provided in the form of concentrates fed in the dairy parlour during milking, and forages fed either in the paddock following milking or on a feed pad (an intermediate area between the exit of the dairy and the paddock). It is common for cows to be collected from the paddock as a group, to wait as a group in the dairy yard to be milked and then individually return to the paddock or feed pad immediately following milking (Scott et al., 2014). Thus,

cows milked later in the milking order are likely to be away from the paddock for longer than cows milked earlier in the milking order. This has a potential impact on cow health and welfare, particularly if the same cows are consistently milked toward the end of the milking order, as the mean duration of milking in large Australian dairy herds has been reported as exceeding 2 1/2 hours (Beggs et al., 2015).

Consistency in entrance order of dairy cows to the milking parlour in groups of less than 300 cows has been demonstrated by several authors (Soffié et al., 1976; Rathore, 1982; Sauter-Louis et al., 2004; Botheras, 2006; Grasso et al., 2007; Berry and McCarthy, 2012; Polikarpus et al., 2015).

Many factors have been shown to affect the milking position of individual dairy cows including: position in the social hierarchy (Rathore, 1982; Sauter-Louis et al., 2004); Introduction of new animals to the herd (Soffié et al., 1976); stage of lactation (Rathore, 1982; Sauter-Louis et al., 2004); oestrus (Scott Mitchell et al., 1996); lameness (Botheras, 2006); milk yield (Rathore, 1982; Berry and McCarthy, 2012); cell count/mastitis (Rathore, 1982; Berry and McCarthy, 2012; Polikarpus et al., 2015); genetics (Berry and McCarthy, 2012); and the presence of disease such as metritis and pneumonia (Polikarpus et al., 2015). The milking order (order in which cows are milked) is also related to the walking order (the order in which they leave the paddock) (Sauter-Louis et al., 2004).

As herd size increases above 500 cows, it seems likely that sheer crowd size combined with the myriad of factors at play that impact on milking order could make a stable milking order less likely. To our knowledge, the consistency of the milking order in larger herds has not been examined closely.

We examined the consistency of the milking order in five large Australian dairy herds. We assessed the relationship between milking position in the morning versus milking position in the afternoon; the relationship between mean milking position in one month versus milking position in the next month; and assessed whether variation in milking position was related to mean milking position itself.

To achieve this, five south-west Victorian seasonally calving dairy farms were identified that milked more than 500 cows twice a day as a single group in a rotary dairy and had specific infrastructure that recorded the time and milking position of each cow as they entered the milking platform (Identity™, Jantec Systems, Geelong East, Victoria, Australia). The mean number of cows in the 5 milking herds during the study period were 525, 595, 654, 657 and 793.

We chose a study period with the aim of minimizing the number of cows entering the herd in order to maximise the potential stability of the milking order. Two herds did not have any cows calve during the study period, two herds had less than 20 cows calve and one herd had approximately 200 cows calve during the first two months of the five month study period.

In these herds, as cows walk on to the dairy platform, the dairy infrastructure reads a microchip embedded in the ear tag of each cow and records the time and bail position of the cow within the rotary dairy. The process is not failsafe, and occasionally (generally less than 2% of cows at an individual milking) a tag is not read. Ranking methodology should be fairly robust against this as occasional missing cows reduce the sample size a little but will not change the order or alter the rank position of the other cows in a meaningful way.

Daily milking records were extracted from each farm for approximately the same period of 150 days between August 2014 and January 2015. The individual periods varied by up to 14 days and were chosen in order to minimise cows entering or leaving the herd during the period and thus maximise the potential stability of the milking order. Records consisted of a separate file for each milking that contained individual cow records with the cow ID; calving date, age, time the cow entered the milking platform and the platform bail position. The number of cows milked at each morning and evening was calculated, and the rank order (RankPosition) of each cow within each milking was calculated after accounting for empty bails where a cow did not enter the milking platform. A percentile rank position calculated for each cow milking using the formula $\text{RankPercentile} = (\text{RankPosition} / \text{CowsMilked} + 1) * 100$.

The potential to deviate from a rank percentile position decreases toward the beginning and the end of the milking order because the rank percentile positions are bounded by 0 and 100. For example, the cow that enters the milking platform first can only change position in one direction. In order to examine the relationship between rank position and variation in rank position accounting for the effects of bounding by 0 and 100, a normal score (Dickinson Gibbons, 2006) was calculated for the RankPercentile of each cow milked using the formula $\text{NormalScore} = \Phi^{-1}(\text{RankPercentile})$ where Φ^{-1} is the inverse cumulative normal distribution function. The difference in NormalScore places more emphasis on changes early (or late) in the milking order. For example, a cow that changes from RankPercentile 1 to 6 is a change in RankPercentile of 5 and a change in NormalScore of 0.67 while changing positions from 47 to 52 is still a RankPercentile change of 5 but a NormalScore change of 0.1 (Botheras, 2006).

In order to investigate the correlation between morning and afternoon RankPercentile and NormalScore, a database was constructed which included all cow days where a cow was milked at both morning and afternoon milkings. Pearson Correlations were calculated using SPSS (IBM Corp. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.) to assess the correlation between position in the afternoon milking and position in the morning milking; age; and day of lactation.

Data were available for 483887 cows-days where individual cows were recorded at both the morning and evening milking. Correlation between RankPosition at the morning and evening milkings is shown in Table 6.1. Overall, RankPosition in the morning and afternoon milking was strongly correlated ($r^2=0.52$) suggesting that 52% of the variation in position at the evening milking could be explained by position at the morning milking. There was no linear relationship between RankPosition and either DIM ($r<0.1$, $p<0.001$) or age ($r<0.1$, $p<0.001$).

Using the NormalScore instead of the raw RankPercentile did not change the interpretation ($r=0.73$, $p<0.001$) suggesting that there might be less variation at the beginning and end of the milking order.

TABLE 6.1. THE CORRELATION BETWEEN RANK POSITION AT THE MORNING AND AFTERNOON MILKINGS OVER A PERIOD OF 150 DAYS

Farm	Pearson correlation coefficient (r)	Coefficient of determination (r^2)	Significance (p)
A	0.72	0.52	<0.001
B	0.57	0.31	<0.001
C	0.78	0.61	<0.001
D	0.72	0.52	<0.001
E	0.77	0.59	<0.001
Overall	0.72	0.52	<0.001

For each cow-day, the difference between RankPercentile position at the morning and evening milking was calculated. For each farm, we calculated the proportion of cow-days where the rank position changed by 0-20%, 21-40%, 41-60%, 61-80% or greater than 80%. A typical milking in Australian dairy herds that milk more than 500 cows takes 158-186 minutes (Beggs et al., 2015). Thus cows milked within the same 20% range (quintile) would likely be milked within 30-40 minutes of each other and cows that are consistently milked one quintile later in the milking order might be expected to be out of the paddock for 60-80 minutes longer per day. The proportion of cows that changed position by each quintile was calculated using the CrossTabs function in SPSS.

Table 6.2 shows the percentage of cows that changed position from the morning to the evening milking by increments of 20% for each farm. Approximately 70% of cows were milked within 20 percentage points (which approximates to being milked within the same 30-40 minute block) and less than 2% of cows being milked more than 60% apart.

TABLE 6.2. THE PERCENTAGE OF COWS ON EACH FARM THAT CHANGED MILKING ORDER RANK PERCENTILE BETWEEN THE MORNING AND EVENING MILKING. DIFFERENCES ARE EXPRESSED IN INCREMENTS OF 20%.

Difference in rank percentile	Farm A	Farm B	Farm C	Farm D	Farm E	Mean
0-20	70.5	65.9	76.7	70.3	74.2	71.9
21-40	22.1	19.4	17.7	22.1	20.2	20.1
41-60	6.1	9.8	4.7	6.4	4.8	6.2
61-80	1.2	4.0	0.8	1.2	0.8	1.5
81-100	0.2	1.0	0.1	0.1	0.1	0.3

Table 6.3 shows the percentage of cows that changed position from the morning to the evening milking by increments of 20% for cows that appeared in each quintile of the milking order at the morning milking. Interestingly, approximately 80% cows in the first or last quintile changed milking position by less than 20% compared with less than 70% of cows in the middle quintiles. This suggests that cows at the beginning and end of the milking order are more likely to have a consistent position within a day than cows in the middle. This is at odds with what one might expect if cow position was not correlated as cows at the ends of the milking order have more scope for change – a cow in the middle quintile cannot change position by more than 2 quintiles. These data suggest that within a day, individual cows will tend to be milked at a similar time with respect to the beginning of the milking session.

TABLE 6.3. PERCENTAGE OF COWS WHERE THE AFTERNOON MILKING ORDER RANK PERCENTILE CHANGED BY DIFFERING AMOUNTS FROM THE MORNING MILKING

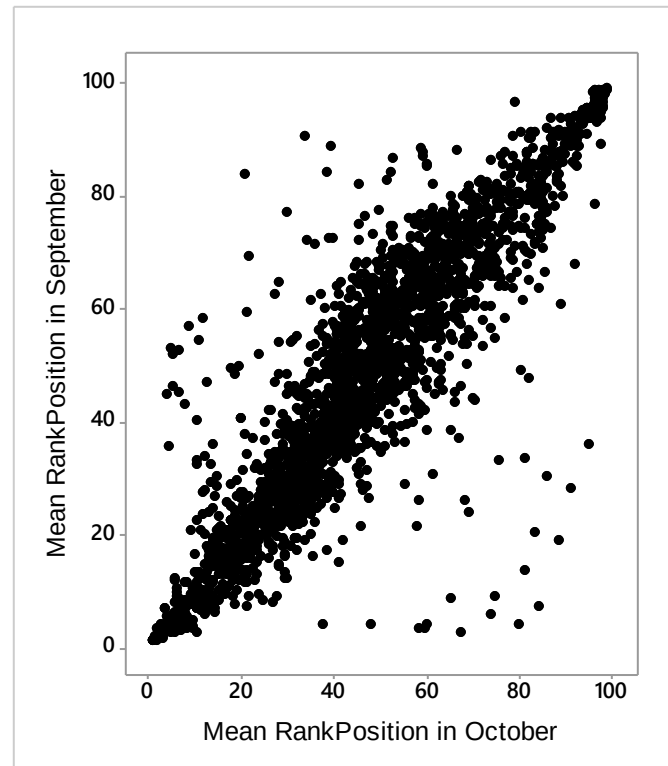
Difference in rank percentile	Milking order rank percentile at the morning milking				
	0-20	21-40	41-60	61-80	81-100
0-20	77.8	68.3	64.0	69.6	80.0
21-40	13.8	24.0	30.7	21.2	10.7
41-60	6.2	6.6	5.3	7.7	5.2
61-80	1.9	1.1		1.5	3.1
81-100	0.4				1.0

In order to examine the consistency of the milking order over a longer period, milking order from month to month, mean and variance of RankPercentile and NormalScore were calculated for each cow that had more than 20 observations in both months for the months of September and October 2014. Pearson Correlations were used to assess the correlation between the first month and subsequent months. To assess the consistency in position of individual cows, the proportion of cows where the mean milking position was within 10 and 20 RankPercentile positions was calculated.

Data were available for 2239 cows which had more than 20 observations in both September and October. These months were chosen because the milking herds were relatively stable during these periods, with less than ten cows calving in four of the herds, and a maximum of 1% of the herd size calving on any day in the fifth herd. Figure 6.1 shows the mean RankPosition of cows in September vs October during the study period. The positions were

highly correlated ($r=0.88$), suggesting that cows can maintain their relative position in the milking order over a prolonged period of at least several weeks.

FIGURE 6.1. MEAN RANK POSITION OF COWS IN THE MILKING ORDER OVER TWO CONSECUTIVE MONTHS



In order to assess whether the variation in milking position was related to mean milking position itself, the mean and variance of RankPercentile were calculated for each cow for all milkings within the 150 day study period where cows were present in both the first and last week of the period and which had at least 200 observations during the period. The mean variance for cows with mean RankPositions in each quintile from 0-100 were compared using ANOVA with significance assessed using Tamhane's T2 method (that does not assume equal variances).

Data were available for 3332 cows across the five farms. The variance and standard deviation for RankPosition classified according to mean RankPercentile are shown in Table 6.4. The standard deviations of 12 and 14 for cows whose RankPosition is within the first and last quintiles suggests that these cows would be within 24 and 28 percentage points of their RankPosition 95% of the time.

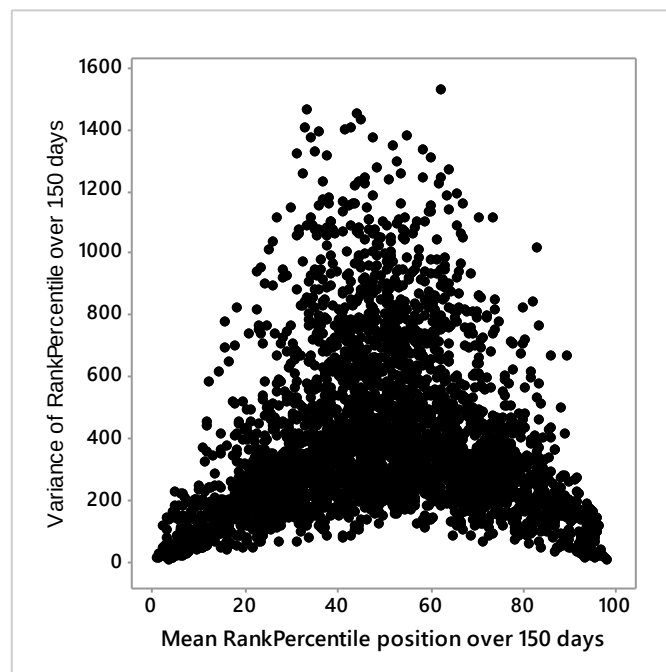
TABLE 6.4. CONSISTENCY OF MILKING ORDER RANK POSITION OVER 150 DAYS FOR COWS WITH DIFFERING MEAN MILKING ORDER RANK PERCENTILES OVER THE SAME PERIOD

Mean rank position	Mean variance of rank position	Mean SD of rank position
0-20	144 ^a	12.0
21-40	387 ^b	19.7
41-60	512 ^c	22.6
61-80	394 ^b	19.8
81-100	199 ^d	14.1
Total	389	19.7

^{abcd} Means within a column without a common superscript differ significantly ($p < 0.05$).

Figure 6.2 shows that the variance of RankPercentile varies with RankPercentile, with variance being lower toward the beginning and end of the milking order, and higher toward the middle of the milking order.

FIGURE 6.2. MEAN RANK PERCENTILE POSITION IN THE MILKING ORDER VS VARIANCE OVER 150 DAYS



These data suggest that cows toward the beginning and end of the milking order are more consistent in their positions over time.

Despite the wide range of factors that have been shown to impact on the milking order of individual cows, we showed that consistency of milking order can be a feature of cows in large herds.

Our Results are broadly similar to others. Several studies in smaller sized herds have reported similar consistency of milking order. Botheras studied daily electronic records from a single herd where up to 391 cows were milked on a single day (Botheras, 2006). Correlations between the milking orders of any two milkings were very high (r generally between 0.8 and 0.9), even for milkings up to 6 months apart. In ten New Zealand herds, with an average group size of 183, Sauter-Louis et al. (2004) reported Cronbach's alpha coefficients for milking

order >0.9, with increasing walking order stability as the season progressed. A study of Irish herd testing records that examined genetic and non-genetic factors affecting milking order in nearly 2000 herds ranging in size from 40 to 250 cows, showed that the repeatability of the milking order within test-day, within lactation, and across lactations was 0.63, 0.51, and 0.47, respectively (Berry and McCarthy, 2012). A point of difference in our Results is the higher consistency that is found for cows which are regularly toward either end of the milking order compared with those normally toward the middle. This is important because we have established that in larger herds there will likely be sub-populations of cows that are regularly milked later in the milking order. In our study, we did not measure the effect of this on individual cows, but it is interesting to speculate as to why this might be important.

One possible consequence of being milked later in the milking order is a reduction in the time available for lying down. High-producing dairy cattle on pasture typically spend about 9 to 11 hours of the day lying down (Singh et al., 1993; Phillips and Rind, 2002; Botheras, 2006). The frequency and duration of lying behaviour are probable indicators of cow comfort, and there is considerable evidence that restricting lying behaviour reduces animal welfare outcomes (Metz, 1985; Fisher et al., 2002; Cooper et al., 2007)

Thus for those cows in large herds where milking times are prolonged, lying times may be reduced. Indeed, cows held in a holding pen for 2 h prior to milking to replicate prolonged waiting times had shorter lying times than cows that were milked and returned immediately to pasture (Botheras, 2006). This is worthy of further investigation.

A second possible consequence of being late in the milking order is nutritional. A study of Australian dairy cows showed that milking order can affect the quality of pasture eaten. In one herd of just over 300 cows where milking time took approximately 105 minutes, serial measurements of pasture quality were made as cows entered the paddock following milking. Cows that arrived first to the paddock ingested pasture with greater CP (19% vs 15%) and lower ADF (26% vs 30%) than those arriving last, with 70% of the pasture (relative to post-grazing mass) being consumed before the last cow entered the paddock (Scott et al., 2014).

A third possible consequence of being later in the milking order relates to the extra time spent standing in the dairy yard prior to milking rather than time away from the paddock. The surface on which cows walk can impact the prevalence of lameness and the experience for cows which are lame (Sauter-Louis et al., 2004; Kremer et al., 2007; von Keyserlingk et al., 2009; Cook et al., 2016). Depending on the dairy yard surface and the condition of the paddock, the effect of being at the beginning or end of the milking order might be positive or negative in terms of animal welfare.

Our data suggest it is likely in large herds that there will be sub-populations of cows that are regularly milked toward the beginning and the end of the milking order. In cases where milking-time lasts for three hours or more (and cows are milked twice a day) there is potential for some cows to regularly spend six or more hours per day than their herd-mates in the dairy

yard waiting to be milked – standing on concrete and away from pasture. Whether that time is spent usefully ruminating, or whether it has implications for production (perhaps because of a variation in grass quality/quantity) or animal welfare (perhaps because of reduced time available to lie down or increased lameness as a result of standing on concrete) warrants further investigation.

6.3. ACKNOWLEDGMENTS

The authors would like thank the Victorian Department of Economic Development Jobs Transport and Resources and Dairy Australia Ltd for their support of this project. This project was also supported through an Australian Government Research Training Program Scholarship. The assistance of Mr Kym Butler with some statistical advice was much appreciated as was the contribution of the farmers who provided their information.

CHAPTER 7

7. Implications of prolonged milking time on time budgets and lying behaviour of cows in large pasture-based dairy herds

The following paper has been published in the Journal of Dairy Science.

DOI: 10.3168/jds.2018-15049

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7.1. ABSTRACT

In large Australian pasture-based dairy herds, it is common for the time taken to milk a herd of cows to be up to 4 hours. Cows are collected from the paddock as a group, wait in turn in the dairy yard to be milked, and then return individually to the paddock or feed pad immediately after leaving the milking parlour. In such herds, we previously found a consistent milking order, resulting in some cows being regularly away from pasture for several hours per day more than others. Increased time away from pasture may affect the time budgets of cows because of decreased opportunity for grazing and/or lying down. Lying behaviour is a high priority behaviour for cows and the duration of lying has been used as an important measure of their welfare. We applied activity monitors for 7 days to 15 cows toward the beginning and 15 cows toward the end of the milking order in ten dairy herds milking 500-730 cows as a single group in order to understand the effect of extra time spent in the dairy on lying behaviour. Study cows typically produced 6000-8000 litres in a 300-day lactation on rotary dairy platforms with 40-80 units, being fed 2.5-6 kg grain mix in the milking parlour daily, with the rest of the diet being supplied as pasture, or forage provided in the pasture or close to the exit of the dairy. Over the ten farms, there were 1948 cow-days available for analysis. The furthest paddocks on each farm were 1.8-3.5 km walking distance from the dairy. There was a wide range of steps taken each day, ranging from 1705 to 15075 (Mean = 5916). The main predictor of the number of steps was the farm on which the cows were located. Cows that spent less than an hour waiting to be milked (and would be unlikely to have their ability to lie down affected by the milking process) lay down for a mean of 9.8 hours per day. Steps walked and delay in the dairy waiting to be milked were both significantly associated with lying-time but the effect was not large. A regression model accounting for the waiting time at the dairy,

steps taken, cow age and farm was used to investigate the relationship with daily lying time. For every 1000 steps, lying time reduced by 0.49 hours, however the number of steps explained only 1% of the variation in lying time. For every hour increase in waiting time at the dairy, lying decreased by approximately 14 minutes, but this explained only 14% of the variation in lying. We conclude that milking time durations of 2-4 hours, common in large Australian pasture-based dairy herds, did not significantly affect the time budget for lying of individual cows in our study herds. Whilst the effect of long milking times does not appear to be a major risk to animal welfare in terms of lying time, the effect on cow health and production warrants further investigation.

7.2. INTRODUCTION

In contrast to many countries, Australian dairy farms are predominantly pasture-based with few farms having lactating cows housed indoors at all. Approximately 60-65% of cattle feed requirements coming from grazing, and the feeding of total mixed rations is rare (Dairy Australia, 2017a). However, similar to many countries, there has been a trend toward increasing herd sizes. Farms milking more than 500 cows are now common and in a recent survey of Australian dairy farmers, 73% of farmers milking more than 700 cows in 2017 expected to increase numbers further over the next two years (Dairy Australia, 2017b). The increasing herd size and intensification of pasture-based dairy production such as occurs in Australia and New Zealand has occurred against a background of a heightened public interest in animal welfare (Fisher and Webster, 2013; von Keyserlingk and Weary, 2017; Weary and Von Keyserlingk, 2017). Potential challenges to pasture-based dairy cow welfare that have been identified with increasing herd size include the long distances cows are required to walk to and from the dairy parlor, and extended time spent at the dairy waiting to be milked (Clark et al., 2013; Beggs et al., 2015, 2018; Webster et al., 2015).

In Australian pasture-based dairy herds, cows are generally milked twice per day. Between milkings, cows spend their time in paddocks which may be up to 4 km walking distance from the dairy. It is common for cows to be collected from the paddock as a group, to wait in turn in the dairy yard to be milked, and to return individually to the paddock (sometimes passing through a feed pad where hay or silage is available not far from the exit of the dairy) immediately after leaving the milking parlour. It is very common for cows to return to different paddocks each day, and in many cases the night paddock is different to the day paddock. When cows are grazing in paddocks further from the dairy, there will be increased time away from pasture for the whole herd as they walk to and from the dairy, which may be associated with an increase in the number of steps taken. When cows wait at the dairy to be milked, there will be increased time away from pasture that will affect individuals differently, depending on their place in the milking order. Increased time away from pasture may affect the time budgets of cows because of decreased opportunity for grazing and/or lying down, which may in turn affect their welfare. Lying behaviour is a high priority behaviour for dairy cows, and the frequency and duration of lying behaviour have been used as important measures of their welfare (Munksgaard et al., 2005). There is considerable evidence that

restricting lying behaviour causes stress and reduces animal welfare outcomes (Munksgaard and Simonsen, 1996; Fisher et al., 2002). Mean voluntary lying times for pasture-based dairy cows milked twice daily are reported to be between 9 and 11 hours (Krohn and Munksgaard, 1993; Botheras, 2006; Hetti Arachchige et al., 2013).

In a survey of 863 Australian dairy farmers, the time taken for milking a herd of more than 500 cows was commonly up to 4 hours, on most farms there were paddocks where cows would be off pasture for a single milking for more than 3½ hours and the mean walking distance to the furthest paddock was more than 2 km (Beggs et al., 2015). Thus, the time cows are out of the paddock can be considerable.

Previous work has demonstrated that in such herds there is a consistency to the order in which cows are milked and, in particular, there are cohorts of cows which are regularly milked in the first and last 20% of the milking order (Beggs et al., 2018). Thus, in herds where it takes up to 4 hours to milk all cows, and cows are milked twice daily, there is likely to be a cohort of cows which regularly have 8 hours longer waiting time in the dairy yard (and thus potentially 8 hours less on pasture) than other cows in the same herd.

The time cows spend lying will depend on the competing motivations to graze and perform other functions that require standing (e.g. elimination, self-grooming). Whilst grazing time would likely vary with pasture availability and supplementary feeding levels, various studies have reported the typical time spent grazing for lactating cows at pasture to be approximately 8-9 hours (Bargo et al., 2002a; b; Botheras, 2006; Pérez-Prieto et al., 2011).

If cows are motivated to spend approximately 8 hours grazing and 10 hours lying down, it seems reasonable to hypothesise that the time budgets of cows might be affected when cows spend more than 6 hours (or 240 minutes) away from pasture per day, and accordingly this might impact on their welfare. To our knowledge, the time budgets (walking, standing and lying) of dairy cows in large pasture-based dairy herds where the milking process takes more than three hours, such as are common in Australia, have not been previously examined. The amount of time cows spend walking, standing and lying can be measured electronically through activity monitors applied to the hind limb of cattle using an ankle bracelet (e.g. IceTags™, Ice Robotics Ltd, Roslin, UK).

We applied activity monitors to cows in ten large pasture-based Australian dairy herds in order to:

- (a) determine the time spent standing and lying in typical, large Australian pasture-based dairy herds; and
- (b) investigate whether increased time out of the paddock due to being milked later in the milking order or walking long distances impacts cow lying time

7.3. MATERIALS AND METHODS

This study was conducted with approval from the University of Melbourne Faculty of Veterinary Science Animal Ethics Committee.

Ten dairy herds known to the authors were selected for the study by invitation based on milking more than 500 cows as a single group over a period of 2-4 hours, having infrastructure that recorded daily milking times of individual cows and agreement to participate in the study.

In order to generate a data set which included cows milked toward the beginning and the end of the milking order, we selected 15 cows as they were being milked in the first 20% of the milking order and 15 cows that were milked in the last 20% of the milking order on the day of device application. Cows were selected to ensure that there was a representative age range in each group (at least four cows in the age ranges: 2yo, 3-5yo, 6+yo). Cows were not selected if they showed any obvious clinical abnormality, or if they were lame on the day of selection. Activity monitors (IceTagsTM) were applied to a hind leg of each cow for 7 days.

Milking records including the time each cow was milked and the position in the milking order were obtained from the dairy infrastructure for all cows at each milking during the study period and imported into Microsoft Excel (Microsoft Excel 2016, Microsoft, Redmond, WA, USA). The time elapsed between when the first cow was milked and the time the study cow was milked was calculated for each milking. The daily waiting time (WT) was calculated for each cow day as the sum of the time spent waiting to be milked from the morning and afternoon milking. Since all cows on a given day walked from and returned to the same paddock, we considered WT to be an approximation of the extra time out of the paddock that was because of the milking duration, relative to other cows. The number of steps taken (STEPS) and the mean daily lying time (LYING) were calculated using the IceTagTM algorithm for a 24-hour period starting from approximately the time the cows finished the morning milking. We did not interfere with normal farm management in terms of the paddocks that cows were placed in following each milking.

Cases were excluded from analysis where data were missing (for example, because the dairy infrastructure had not recorded the cow entering the dairy or a full 24 hours data were not available) or where it was biologically implausible, presumably due to IceTagTM failure.

Statistical analyses were performed using SPSS (Version 25, IBM Corp., Armonk, NY). The Descriptive Statistics and Scatter Graph functions were used to investigate the distribution of STEPS and LYING.

We hypothesised that the number of steps taken in a day would be largely influenced by the farm as the farms varied in size and geography. Within each farm, we hypothesised that the distance walked from the milking parlour to the paddock, which varied each day according to routine farm management, would be a major predictor of the number of steps as might age of the cow. In order to test this hypothesis, a three-stage hierarchical multiple regression was conducted with STEPS as the outcome variable. Farm was entered at stage one of the

regression mode, with Date being added as a categorical predictor at stage two and Age as a linear predictor at stage 3.

The effect of STEPS and WT on LYING was first investigated at the univariable cow-day level. In order to account for differences between individual cows and the possible confounding effect of different farms, a linear regression model was created, using LYING as outcome variable, and using the age, farm and the mean STEPS and WT over the experimental period as predictors.

In order to assess whether extremes of waiting time at the dairy impacted on LYING, an independent-samples t-test was used to compare the mean LYING of cows with mean WT < 1 hour (cows which would not be expected to have their lying time impacted by WT) with cows that had a WT > 4 hours.

7.4. RESULTS

All farms were milking between 520 and 730 Holstein or Holstein-cross cows on rotary dairy platforms with 40-80 units. Cows on the study farms typically produce 6000-8000 litres in a 300-day lactation. They were being fed 2.5-6 kg grain mix twice daily on the platform whilst being milked. Walking distance from the dairy to the furthest paddock ranged from 1.8 – 3.5 km. Prior to the study, farmers estimated that the typical time taken to milk all cows was 150-210 minutes. All cows had calved at least 50 days at the beginning of the study. Data from ten cows were excluded because the activity meters failed (a maximum of three on any one farm). No cows became lame during the study. Over the ten farms, there were 1948 cow-days available for analysis.

The distribution of daily lying time is shown in Figure 7.1.

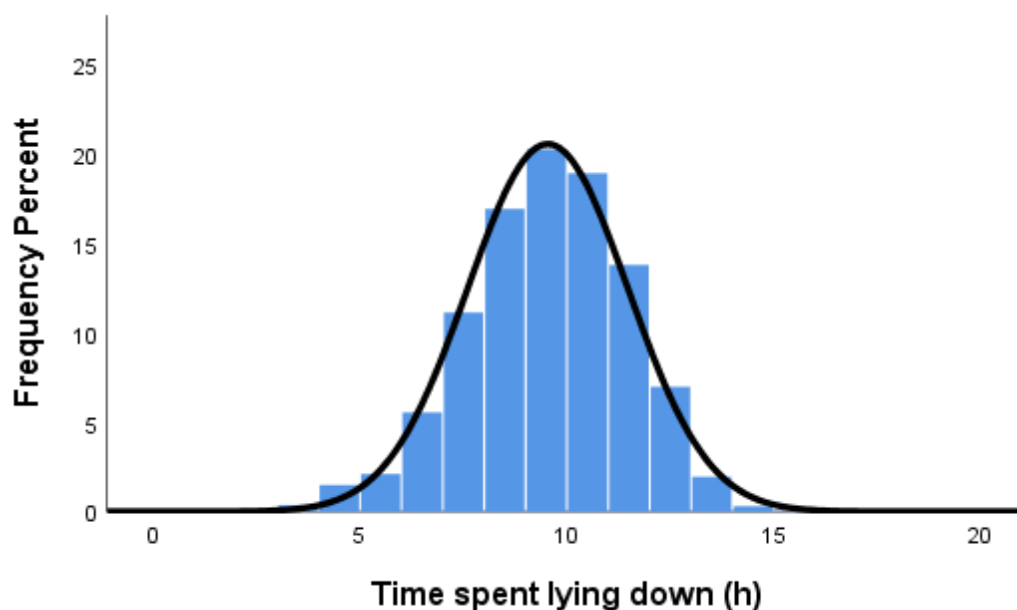


FIGURE 7.1. HISTOGRAM SHOWING THE DISTRIBUTION OF DAILY LYING DOWN TIME IN HOURS OF PASTURE-BASED DAIRY COWS ON TEN FARMS OVER 1948 COW-DAYS. (MEAN=9.53, SD=1.95, MEDIAN=9.65).

There was a wide range of STEPS, ranging from 1705 to 15075 (Mean=5916; Median=5812). The effect of adding date and age to the effect of farm on predicting STEPS in a linear regression model is shown in table 7.1.

TABLE 7.1. HEIRACHICAL MULTIPLE REGRESSION MODEL SHOWING THE EFFECT OF ADDING DATE AND AGE TO THE EFFECT OF FARM FOR PREDICTING THE MEAN STEPS TAKEN OVER 1948 COW DAYS

Model Predictors	R square	Std Error
Farm	0.519	1.057
Farm, Date	0.520	1.057
Farm, Date, Age	0.521	1.055

There was also a wide range of WT, with data for at least 60 cow-days in every 30-minute increment WT of 0 minutes through to 6 hours. The mean WT of 96 minutes (SD=89) for cows selected in the first 20% of the milking order was significantly less the mean WT of 270 minutes (SD=81, $p<0.001$) for cows selected in the last 20% of the milking order. WT and STEPS were graphed against time spent lying (Figures 7.2 and 7.3), which did not show an obvious strong relationship.

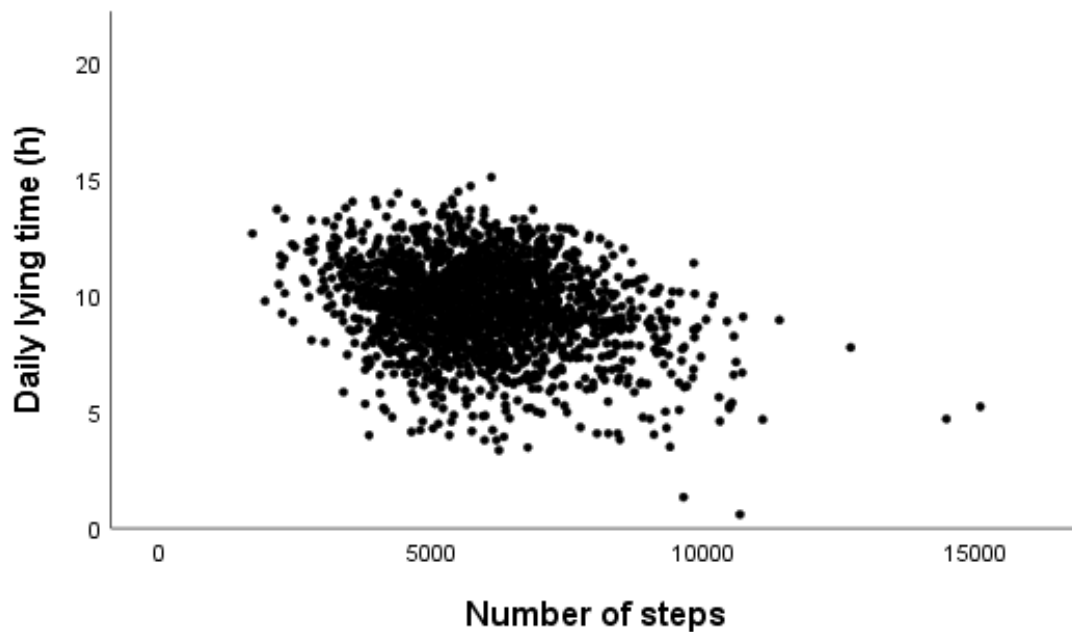


FIGURE 7.2. SCATTER PLOT SHOWING THE RELATIONSHIP BETWEEN TOTAL STEPS TAKEN AND HOURS OF LYING TIME IN THE SAME 24-HOUR PERIOD FOR 1948 COW-DAYS ON 10 FARMS. $R^2=0.058$

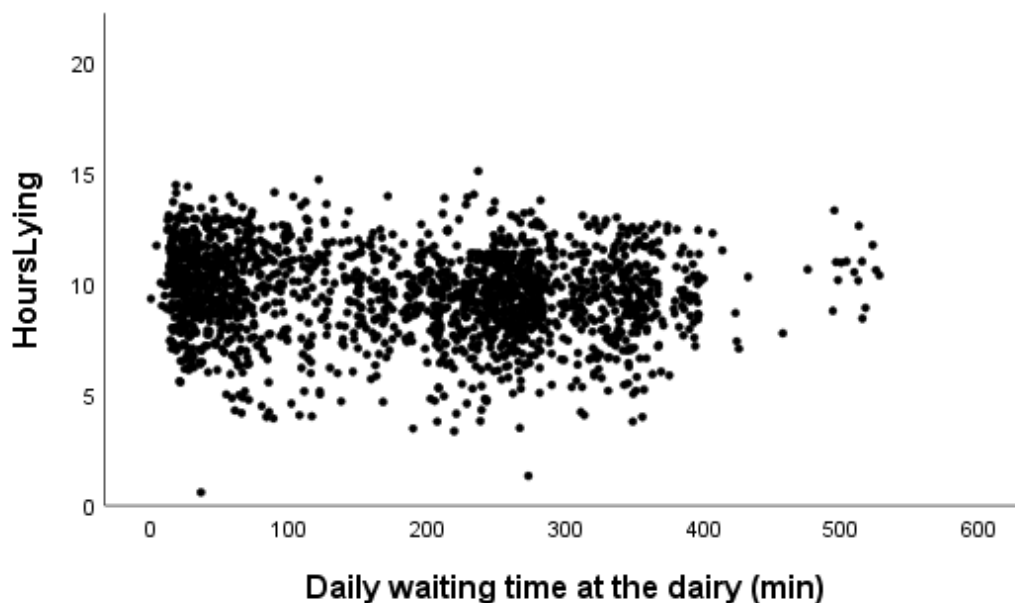


FIGURE 7.3. SCATTER PLOT SHOWING THE RELATIONSHIP BETWEEN TIME WAITING TO BE MILKED AND HOURS OF LYING TIME IN THE SAME 24-HOUR PERIOD FOR 1948 COW-DAYS ON 10 FARMS. $R^2 = 0.014$.

At the cow level, there was still a wide range of mean WT over the study period with at least 30 cows being represented in each group of waiting times for 1 hour increments of 1 to 6 hours per day. The mean STEPS was approximately 6000 steps per day (SD=1300) and the mean LYING was 9.48 hours per day (SD=1.3). Of the cows, 11% had a mean lying time of less

than 8 hours. The linear regression model showing effect of farm, age, STEPS and WT over the study period is shown in Table 2. The mean LYING for cows with a WT > 4 hours was 9.1 hours (n=44, SD=1.2) compared with 9.9 hours (n=117, SD=1.3) for cows which waited < 1 hour (p<0.001).

TABLE 7.2. LINEAR REGRESSION SHOWING THE RELATIONSHIP BETWEEN MEAN STEPS TAKEN, MEAN WAITING TIME AT THE DAIRY, AGE AND TIME SPENT LYING DOWN FOR 291 COWS OVER A 7-DAY PERIOD IN TEN HERDS.

Model*	B	Std Error	Sig.	95% CI	Partial eta squared (proportion of variation in LYING explained)
(Constant)	14.2	0.74	<0.001	12.7 to 15.6	0.57
Steps (*1000)	-0.49	0.094	<0.001	-0.67 to -0.31	0.01
Waiting time (h)	-0.24	0.36	<0.001	-0.31 to -0.17	0.14
Age	-0.04	0.029	0.14	-0.1 to 0.01	0.09

*The model also accounted for the effect of individual farm – data not shown.

7.5. DISCUSSION

Icetags® have been previously used to record the duration and frequency of lying, standing and activity in cattle (for example, Bewley et al., 2010; Tolkamp et al., 2010; Maselyne et al., 2017). Their use for detecting lying and walking has been validated in pasture-based dairy cattle in a study that reported that 95% of lying data points were within 1 percentage point of observed data and 95% of stepping data were within 3 percentage points (McGowan et al., 2007). A potential limitation of our study is that we did not further validate the devices in detail. We assessed data from the devices for being biologically plausible and noted that the devices recorded constant walking at times consistent with when the cows would have been walking to and from the dairy, and the devices did not report cows lying down during the times when cows would have been in the dairy yard.

7.5.1. Lying Time

In this study, the mean daily lying time of 9.53h is toward the lower end of the range of values commonly recorded for dairy cows. Whilst considerable individual variation exists between cows, most studies report mean/median lying times of more than 10 hours. As well as being constrained by time available to lie down, lying times can vary with stage of lactation, milk yield, body condition, lameness, estrus, supplementary feeding rate and other factors (Bewley et al., 2010; Charlton et al., 2014; Maselyne et al., 2017; Silper et al., 2017). There is also considerable variation between cows. For example, in a study of automated milking systems, where it was hypothesised that cows would be less constrained in their ability to lie down, the median lying time was 11.4 hours per day but even in this system 25% of cows lay for less than 9.7 hours (Westin et al., 2015). In our study, we also noted wide variation in lying times – even in cows with a mean WT less than 60 minutes, which would be unlikely to have constrained their lying time. These cows had a mean lying time of only 9.9 hours, suggesting that many

cows in large Australian pasture-based dairy herds choose to lie down for less than 10 hours per day.

Lying is a high priority behaviour for dairy cows and previous studies have reported they will sacrifice other behaviours such as grazing and social behaviour to a greater extent than they sacrifice lying behaviour when time is constrained (Munksgaard et al., 2005; Cooper et al., 2007). This is consistent with our data. As can be seen from figure 7.3, more than half the cows with a WT of >500 minutes (which would likely have been away from pasture for 10 or more hours after taking into account walking time) had lying times of at least 10 hours. Presumably these cows reduced other behaviours in order to do so.

7.5.2. Steps taken

We hypothesised that a major contribution to the number of steps cows take in a day would be the distance from the milking parlour to the paddock. Farmers in our study generally grazed cows in a different paddock each day, and often used different day and night paddocks. As expected, because all cows on a given farm grazed in the same paddocks and walked the same distance to the dairy each day, FARM was a major predictor of the mean STEPS taken with nearly 52% of variation in STEPS being explained by FARM alone ($R^2 = 0.519$). When date and age were added to the model, the variation in STEPS explained by the model only increased to 52.1% suggesting that difference in daily walking distance was only a minor contributor to STEPS taken. Figure 7.2 shows that, at a univariable level, there is a relationship between STEPS and LYING, but it is not strong, explaining less than 6% of the variation in LYING. Perhaps this result is not surprising. It is likely that a typical distance walked to and from the paddock each day was approximately 4km. The mean stride length of Holstein cattle walking on a track has been estimated at between approximately 130cm and 165cm and the walking speed estimated at approximately 4-5km/h (Carvalho et al., 2007; Telezhenko, 2009; Alsaad et al., 2015). The walking speed of cows walking in a large group constrained by a narrow track is likely to be lower than this, and indeed, in a study of New Zealand pasture-based cows in herds of 350-380 cows, the average walking pace of cows was approximately 3 km/h. At a stride length of 1.5m, only 3333 steps would be required walking to and from the dairy – less than half the mean daily STEPS recorded in our study – and this would take less than 1.5 hours out of a 24-hour day.

7.5.3. Relationship between Steps, Delay in the Dairy and Lying Time

As shown in Table 7.2, STEPS and WT were both significantly associated with LYING. For every 1000 steps, lying time reduced by 0.49 hours, however this needs to be interpreted with caution because the number of steps explained only 1% of the variation in lying time. There is an association between STEPS and LYING, but our data cannot conclude that it is causal. Indeed, it seems logical that cows that spend less time lying for any reason would spend more time walking. For every hour increase in waiting time at the dairy, lying time decreased by approximately 14 minutes, but this explained only 14% of the variation in lying time. Cows which waited more than 4 hours at the dairy lay on average 48 minutes less than cows milked

within the hour, but there was still significant overlap with the SD of both groups being more than an hour.

Our data showed that time spent at the dairy waiting to be milked did not have a major impact on the lying time of individual cows, which seem to be very inelastic. Thus, it seems that typical times of 2-4 hours taken to milk large Australian pasture based dairy herds do not constitute a major animal welfare issue because of restricted ability to lie down.

Presumably, if cows spend several hours less in the paddock, but do not spend much less time lying down, they must spend less time undertaking other behaviours such as grazing, idling and social interactions. Cows milked toward the end of the milking order would not only have less time in the paddock to graze, but there would likely be less grass available. In one Australian study where cows entered the paddock following milking over a 90 minute period, 70% of the pasture mass had been consumed before the last cow entered the paddock (Scott et al., 2014). Previous studies have shown that both competition as well as restricted amount of food can increase the rate of feed intake (Nielsen et al., 2000; Munksgaard et al., 2005). Although we did not specifically analyse milking order consistency, the mean WT for cows selected in the last 20% of the milking order was nearly three hours more than for cows selected in the last 20% of the milking order suggesting that cows can be consistently early or late in the milking order, and thus some individual cows would be consistently affected more by longer milking duration than others within a herd. The implications of potential reduced grazing time on cow health and production warrant further investigation.

7.6. CONCLUSIONS

There is considerable variation in the lying time of individual cows in large Australian pasture-based herds. Cows may spend 1-3 hours walking to and from the dairy and a further 6-8 hours waiting to be milked during a day. The time taken to milk a herd of cows is commonly 2-4 hours and some cows may regularly be away from the paddock for several hours more than others, this did not significantly affect the time budget for lying in our study cows. The effect of long milking times does not appear to be a major risk to animal welfare in terms of lying time, the effect on cow health and production warrants further investigation.

7.7. ACKNOWLEDGMENTS

The authors are grateful to the staff of the Warrnambool Veterinary Clinic and the farmers who graciously allowed us on their farms. We acknowledge the Victorian Department of Economic Development Jobs Transport and Resources and Dairy Australia Ltd for their support of this project. This project was also supported through an Australian Government Research Training Program Scholarship.

CHAPTER 8

8. General Discussion

Over the course of this thesis, we first surveyed 863 dairy farmers regarding putative animal welfare risks and mitigation strategies, to collect baseline information and ascertain areas worthy of further investigation. There were some limitations associated with measuring animal welfare using a survey – including the potential for under-reporting of disease (particularly lameness) and the difficulty of measuring aspects of affective state and naturalness. We considered that the aspects of lameness, human-animal interaction and the effect of long milking times were worthy of further investigation. On-farm studies were conducted to examine these further. We developed a protocol, based on WelfareQuality® principles designed to make an assessment of animal welfare on a pasture-based farm during a single visit, and used this protocol to make assessments on 50 farms of varying sizes. In parallel with this, we used farm records to establish that there was a consistency to the milking order in very large herds, and thus there were cohorts of cows within herds that might regularly spend much longer than others out of the paddock, waiting to be milked in the dairy yard. In order to investigate this further, we applied activity meters to cows that were milked toward the beginning and the end of the milking order in 10 large herds and examined the relationship between time waiting to be milked at the dairy and lying time. The Results of each study have been previously discussed in chapters 3-7 but there are some themes and messages arising from the study as a whole that are worthy of general discussion.

Firstly, there are some clear messages arising as a result of our research:

8.1. Animal welfare risks that increase with herd size

We identified some clear risk factors for good animal welfare that increased with herd size.

8.1.1. Stocking Rate

Farm stocking rate increased with herd size in both our survey and on-farm studies. As stocking densities increase, there is a theoretical increase risk of infectious disease spread through increased frequency of contact between individuals, although quantitative data to support such an assertion is sparse in the dairy industry (Lean et al., 2008; Robbins et al., 2016). We did not observe any particular increase in disease that could be related to increased stocking rate in our studies.

There is also evidence that agonistic behaviours are expressed more often when cows are in more confined situations (O'Connell et al., 1989; Miller and Wood-Gush, 1991). It seems logical that cows at pasture would be more able to seek out or avoid other cows than those confined in pens. However, pasture-based cows spend several hours per day at close quarters when walking along the track to the dairy, waiting in the dairy yard to be milked, and sometimes accessing forage in a feed pad following milking. There are few, if any, reports

investigating the expression of social behaviour in large Australian pasture-based dairy herds and this might be a useful area for further work.

On the other hand, farms with increased stocking rates might have a benefit as in pasture-based farms it would also reduce the distances walked, because the farm area is by definition smaller per cow.

8.1.2. Stock per labour unit

The number of stock per labour unit increased with herd size in both our survey and on-farm studies.

As the number of stock per labour unit increases, there is a risk that welfare outcomes might be affected by a reduced ability to monitor for issues and to deal with them appropriately and in a timely manner once identified (Lean et al., 2008; Robbins et al., 2016). We saw a relationship between farm size and some of the strategies that can be employed to detect disease and draft cows (for example, electronic monitoring and drafting infrastructure) and strategies that might reduce disease (for example, the use of a nutritionist, individual feeding, having a biosecurity plan). We did not see a relationship between disease prevalence and farm size. This might, in part, be due to increased use of such strategies but there was a wide range of outcomes in farms of all sizes. We conclude that preventing, monitoring and treating disease is important on all farms but there are particular strategies that are commonly used by larger farms and that these are important. We noted that as herds become larger, activities such as lameness scoring cows become more problematic simply because the scale of the job increases but the methodology (just one person taking observations) tends not to change. It was the author's experience that lameness scoring more than 500 cows in a single setting requires great concentration and is not an easy job. We showed that lameness scoring the last 200 cows or 30% of the herd could be used as a simple test that could determine whether lameness scoring the entire herd was necessary.

As the number of stock per labour unit increases, there is also the potential for a reduction in the quality of the human-animal relationship because of decreased contact time per cow. Previous studies have provided evidence for this effect. For example, a New Zealand study showed a positive relationship between avoidance distance of humans and herd size (Verkerk and Hemsworth, 2010) and a USA study showed that dairies with lower stocking densities had more cows willing to approach an observer when they left the parlour (Fulwider et al., 2008). On the other hand, an Australian study showed that stock handlers' attitudes may be more related to objective assessment of HAR than herd size (Breuer et al., 2000). We did not see a relationship between herd size and avoidance distance of humans, and indeed there was wide variation at all farm sizes. We did not assess the stock handler's attitudes and indeed we noted that this assessment would become more difficult as herd size and the number of staff that cows are exposed to increased.

8.1.3. Level of grain/concentrate feeding

The number of stock per labour unit increased with herd size in both our survey and on-farm studies. In our study herds there were no total mixed rations fed. Cows were fed a majority of their diet from pasture and other forages in the paddock or on feed pads, with grain mixes (concentrates) pulse fed in the dairy during milking. Increasing the amount of grain or concentrates that are pulse fed to cattle during milking increases the risk of diseases secondary to overfeeding grain. These factors might translate into welfare risks for cows in terms of lameness and other transition cow diseases (Lean et al., 2010, von Keyserlingk et al., 2009). We did not see a relationship between diseases that might be associated with grain feeding and herd size, probably because there was an increase in the use of strategies to promote good nutrition in larger herds such as using a nutritionist, having a specific transition period ration, and individual feeding of concentrates to cows.

8.1.4. Walking distance from paddock to dairy

As herd sizes increased, so did the distance that cows walk to the dairy.

It may seem logical that increased walking distances would predispose to increased lameness prevalence but there is little objective evidence to support this. In a study of 63 pasture-based Australian herds, recent rainfall, smoothness of concrete, space per cow in the dairy holding yard and inappropriate handling of cows on the track were associated with lameness, but track length was not (Ranjbar, 2017). This is consistent with New Zealand work that showed a relationship between lameness and the width of the track, maintenance of the track, cow flow on the track and space in the dairy yard. In this study, track length was not included in the final model because it was correlated with track quality which had a greater effect on lameness (Chesterton et al., 1989). We did not observe a relationship between herd size and lameness prevalence. Although it was not specifically measured, it was the view of the author that larger farms were more likely to have very good walking tracks, as good cow flow is particularly important on larger farms.

As walking distances increase, the animal welfare impact on individual lame cows that must walk further will increase. We noted that larger farms were more likely to keep lame cows in a separate mob which did not walk as far, but they were no better (or worse) than smaller farms at detecting lameness.

8.1.5. Time taken to milk cows

As herd sizes increased, so did the time taken to milk the herd, which when combined with increased walking distances resulted in significant time away from pasture, particularly for cows that are milked later in the milking order. There is considerable variation in the lying time of individual cows in large Australian pasture-based herds. Cows may spend 1-3 hours walking to and from the dairy and a further 6-8 hours waiting to be milked during a day. The time taken to milk a herd of cows is commonly 2-4 hours and some cows may regularly be away from the paddock for several hours more than others, this did not significantly affect the time budget for lying in our study cows, but presumably the time spent grazing was reduced.

Whilst the effect of long milking times does not appear to be a major risk to animal welfare in terms of lying time, the effect on cow health and production warrants further investigation.

8.2. Animal welfare challenges not associated with increasing herd size

We also noted several challenges that did not appear to be related to herd size, but where there are clear messages for industry.

8.2.1. General disease prevalence

Mastitis and lameness remain the most prevalent diseases in the dairy industry, although the overall reported prevalence was not related to farm size. Large herds have the potential to better manage mastitis through the use of automatic detection infrastructure and this appears to be an increasing trend. Lameness scoring, in particular, is a useful tool and the dairy industry needs to promote its use.

8.2.2. Cooling strategies on hot days

Although larger farms were less likely to have shade in all paddocks, they were more likely to have other cooling strategies in place. Although it varies with location, the Australian climate poses a particular risk of heat stress in dairy cattle. The Australian dairy industry has developed tools to assist producers manage this risk, available through a website (www.coolcows.com.au accessed 1/1/2018) which predicts when heat stress is likely at a given location and also provides strategies to manage heat stress in dairy cows.

It is clear that heat stress is a potential animal welfare challenge in Australia. Animal welfare is all about how an animal is coping with its environment. Avoiding hot days is not possible, but providing relief from the heat is relatively straight forward. For example, having sprinklers in the dairy yard and timely access to water would likely be expected by the general public. Industry needs to promote the use of such strategies.

8.2.3. Pain relief for disbudding

That pain relief is a good thing for disbudding from an animal welfare point of view is not controversial. There is also evidence that the general public expect pain relief to be used where it is practical (Robbins et al., 2015). It is strongly recommended by industry (Dairy Australia, 2016), the Australian Veterinary Association (Australian Veterinary Association, 2018) and animal welfare organizations (Aniamals Australia, 2018; RSPCA Australia, 2018). Saputo, one of the largest milk processing companies in Australia has recently made pain relief when disbudding calves a mandatory condition of milk supply (Saputo, 2018), and in New Zealand the use of local anaesthesia for disbudding will be mandatory from October 2019 (Ministry for Primary Industries (NZ), 2018).

Whilst large herds have a better uptake of disbudding at an early age, there is a clear message that industry needs to further promote the practice. Further work is needed to understand the barriers to adoption.

8.2.4. On farm euthanasia with captive bolts

Whilst the use of firearms was common for euthanasia (69-74%), uptake of captive bolt use was low across all farm sizes ($\leq 6\%$) and a significant number of farmers reported that they required external help to euthanase cows (18-26%). This constitutes a risk to animal welfare because of the delay in timely euthanasia that may result. (The use of blunt trauma in calves was higher in larger farms but captive bolt uptake has been included as a risk for all farms because blunt trauma does not necessarily constitute an animal welfare challenge at an individual level). The licensing and use of firearms has been strictly controlled in Australia for some time. Captive bolt guns (which whilst they require care in their use) do not have licensing requirements in most states in Australia. Ownership of penetrating captive bolt guns for euthanasia of livestock is being promoted to Australian farmers because they are considered safer, have fewer restrictions than firearms, and cheaper models are now readily available (Jubb, 2013). There is clearly potential for improved uptake of captive bolt use in the Australian dairy industry.

8.3. Social Licence

The ability to demonstrate good animal welfare will be important for maintaining social licence to operate for the dairy industry. The general public are increasingly interested in how their food is produced (Eurobarometer, 2007; Cembalo et al., 2016). Australian farmers are generally considered trustworthy by the general public (Coleman, 2018) but there is a risk that this trust will be eroded if people discover that common practices on farms that are out of step with public values (Weary and Von Keyserlingk, 2017). The consequences of a loss of trust can be profound and extend well beyond simple changes in purchasing decisions and a reduction in demand for product. Indeed, many critics of the livestock industries are not consumers of meat at all. However, easy access to social media makes it possible for people to have involvement in animal welfare activism without making much personal sacrifice at all. In a survey of community behaviours in opposition to the livestock industries in 2014, 47% of people had donated money to an animal welfare organization and 36% had signed a petition. This contrasted with lower percentages undertaking more onerous tasks. In the same survey only 2% of people reported calling talkback radio and 12% of people volunteered time (Coleman, 2018). The public pressure as a result of people speaking up in this way can impact on the social licence to operate by forcing changes on farm through regulation, or by pressure from supermarkets.

We hope that the findings from this thesis will help the Australian industry focus on managing the particular challenges to welfare that are associated with increasing scale of production, as well as focusing on some areas where improvement could be made across the board.

CHAPTER 9

9. Summary

Animal health and animal welfare are key contributors to dairy production efficiency, as well as being important to the general public and dairy consumers. The dairy industry is coming under increasing scrutiny from animal welfare advocacy groups. There is also the potential for community concern arising from perceived intensification of the industry with an increasing number of large herds, and producers adopting a mix of grazing and confined feeding strategies.

The purposes of the project included the collection and evaluation of objective, science-backed information on the welfare state of cows in large dairy herds in Australia in order to understand the particular challenges that are associated with increasing herd size. This will provide industry with the option to demonstrate its welfare performance, while at the same time providing guidance on suitable management strategies used by farmers of large herds to optimise cow husbandry and welfare into the future.

During the project, the following studies were undertaken:

1. A survey of Australian dairy farmers to investigate animal welfare risks associated with increasing scale of production. A survey sent to all Australian dairy farmers to investigate trends in dairy herd and farm size, associated management practices and problems encountered. This study is complete and has been published in a peer reviewed journal.

We showed that:

- 35% of cows milked are in large herds
 - Increasing herd size associated with decreased labour; increased stocking density, grain fed and milking time
 - There was no evidence for a commensurate increase in reported disease
 - This may be partially explained by greater capacity for mitigating strategies such as staff training, herd health visits, milking separate herds, electronic ID and monitoring, written protocols, transition diets
 - Further work needed on effects of time away from paddock
 - There are messages for industry about biosecurity plans and captive bolts in farms of all sizes
2. An on-farm study of 50 herds to examine in more detail findings from the survey. The aims were: to conduct welfare assessments on 50 farms using a method based on Welfare Quality®, but modified to suit Australian conditions, in order to investigate associations between management practices and herd size of the welfare of dairy cows and provide industry benchmarks for key welfare indices; to investigate the relationship between

lameness score Results and reported lameness prevalence; and to investigate the relationship between milking order position and lame cows. The data collection for this study is complete. An analysis of the data has been undertaken with Results presented in this document. Further analysis and journal publication will be undertaken.

We showed that:

- Animal welfare on the farms measured was generally very good
 - Areas of concern for larger farms include the provision of shade on hot days, management of lame cows and the design of rotary dairy stalls.
 - On average, farmers only detected 25% of truly lame cows
 - Lameness scoring of the entire herd was necessary to detect all the lame cows
 - 60% of lame cows appeared in the last 30% of cows to be milked.
 - Lameness scoring just the last 200 cows to be milked could be used as a screening test to identify herds with a lameness prevalence below a given threshold.
3. A Milking Order Consistency Study was conducted using farm records to confirm the hypothesis that while milking order in large herds is likely to be less consistent than in smaller herds, cows can nevertheless be divided into groups based on where they commonly sit in the milking order. This study is complete and has been submitted to a peer reviewed journal.

We showed that:

- Even in large herds, the milking order has a degree of consistency and there are groups of cows that are consistently milked at the beginning and the end of the milking order
 - When the rank position of cows was calculated, 72% of cows were milked within 20% percentage points of the rank position and 85% were milked within 35% points
 - Within a single day the difference in milking order rank position was less than 20 percentage points for 72% of cows.
 - Over a period of 150 days, cows with a mean position in the first and last 20% of the milking order maintained their position more consistently than cows in the middle of the milking order.
4. An on-farm study where motion sensing leg bands (IceTags®) were applied to cows at the beginning and end of the milking order on ten farms in order to investigate the hypothesis that cows that are regularly milked toward the back of large herds might spend less time lying down than cows that are regularly milked toward the front of the herd. The data collection for this study is complete. An analysis of the data has been undertaken with

Results presented in this document. Further analysis and journal publication will be undertaken.

We showed that:

- For every for every 1000 steps, lying time reduced by 0.49 h, however the number of steps explained only 1% of the variation in lying time
- For every hour increase in waiting time at the dairy, lying decreased by approximately 14 minutes, but this explained only 14% of the variation in lying
- Milking time durations of 2-4 hours, common in large Australian pasture-based dairy herds, did not significantly affect the time budget for lying of individual cows in our study herds.
- Whilst the effect of long milking times does not appear to be a major risk to animal welfare in terms of lying time, the effect on cow health and production warrants further investigation.

Animal welfare risks that increase with herd size included stocking rate, stock per labour unit, level of grain/concentrate feeding, walking distance from paddock to dairy and time taken to milk cows. These were generally being well managed and did not result in increased adverse animal welfare outcomes.

Animal welfare challenges not associated with increasing herd size included Mastitis, Lameness, Heat stress, failure to use pain relief for disbudding, lack up uptake of euthanasia with captive bolts.

We hope that the findings from this thesis will help the Australian industry focus on managing the particular challenges to welfare that are associated with increasing scale of production, as well as focusing on some areas where improvement could be made across the board.

CHAPTER 10

10. References

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APPENDIX 1

11. Appendix 1 - Questions from the survey used in Chapter 3

Dairy Farmer Survey – Animal Health and Welfare

Instructions

- This survey should be answered by dairy farmers. Farm owners, managers and workers are all eligible but we ask that only one survey per farm is returned.
- When answering this survey, please consider an individual dairy farm. If you own or work on more than one dairy farm, feel free to fill in a survey for each farm individually.
- If you do not know the answer to a question, simply leave it blank.
- Please ensure that only one survey per dairy is completed.
- It is not compulsory to fill out any part of the survey.
- The survey can also be completed online at <https://www.surveymonkey.com/s/dairywelfare>
- Please return the survey in the reply-paid envelope.

Survey Questions

Section 1 – About you

1. What is your position in the dairy business?

(tick all that apply)

- ☐ I am involved in milking the cows
- ☐ I am involved in farm business management decisions
- ☐ I am involved in the treatment of sick cows
- ☐ I am involved in calf rearing
- ☐ I am involved in moving the herd to and from the milking shed

2. In which region are you located?

- ☐ Tasmania- Dairy Tas
- ☐ Victoria – Westvic Dairy
- ☐ Victoria – Gipps Dairy
- ☐ Vic/NSW – Murray Dairy
- ☐ Dairy NSW
- ☐ Subtropical Dairy
- ☐ Dairy SA
- ☐ WA – Western Dairy

Other (postcode) _____

3. What type of dairy do you have?

- ☐ Rotary
- ☐ Swing-over herringbone
- ☐ Double-up herringbone
- ☐ Quick release exit
- ☐ Walkthrough

4. If a rotary, how many stands ?

If a herringbone/walkthrough, how many a side ?

Answer:

5. At peak lactation, how many labour units are involved with the management of the milking cows on this farm ?

(please fill in the table)

Full-time owners/managers?		(no. of people)
Full-time employees ?		(No. of people)
Casual or part-time		(Total hours per week)

6. Have any employees completed the following training (tick any that apply)

- ☐ University qualification in Agricultural Science
- ☐ University Qualification – Other
- ☐ TAFE qualification relevant to dairy
- ☐ Cups On Cups Off course
- ☐ Other Countdown course
- ☐ InCalf Course
- ☐ ProHand Dairy
- ☐ Euthanasia of Livestock
- ☐ Health Calves
- ☐ Other training relevant to dairy

Section 2 – About your herd

7. Which type of calving pattern best describes your herd ?

- ☐ Seasonal – one main calving period per year
- ☐ Split – two to four distinct calving periods each year
- ☐ Year Round – calving all year

8. How many cows do you milk?

(the maximum number of cows milked as a single group for more than 3 months) ?

Answer:

cows

9. How many Hectares do you use for milking cows?

Answer:

hectares

10. What is your average lactation production per cow in litres ?

- ☐ <4000
- ☐ 5001-6000
- ☐ 6001-7000
- ☐ 7001-8000
- ☐ >8000

11. What is the maximum amount of grain or pellets you feed to cows per day?

Answer: kg

12. How are gravely ill or injured animals put down on the farm? (tick all that apply)

- ☐ a firearm
- ☐ a captive bolt device
- ☐ blunt trauma (on newborn animals)
- ☐ the local knackery does this for us
- ☐ other please describe

Section 3 – Time off pasture

13. How long does a typical milking take (from first cups on to last cups off)?

Answer: minutes

14. When a cow is in a paddock close to the dairy during the day, what is the shortest and longest time a cow is likely to be out of the paddock ?

Shortest time: minutes

Longest time: minutes

15. When a cow is in a paddock far away from the dairy during the day, what is the shortest and longest time a cow is likely to be out of the paddock ?

Shortest time: _____ minutes

Longest time: minutes

16. Do you use a feed pad before or after milking ?

- ☐ all or most of the year
- ☐ some of the year
- ☐ no

17. How many paddocks do you use for the milking herd ?

Answer: _____ paddocks

18. How far do cows walk to the paddock farthest from the dairy ?

Answer: _____ km

19. Which of the following apply to you ?

(Tick all that apply)

- ☐ Electronic identification in the dairy
- ☐ Individual feeding in the dairy
- ☐ Equipment to measure daily milk production
- ☐ Equipment to measure daily cell counts or milk conductivity
- ☐ Monthly herd testing
- ☐ Herd testing less often than monthly
- ☐ Early pregnancy diagnosis
- ☐ Cows have a special transition diet before calving
- ☐ Calving induction is practised
- ☐ Computerised herd records
- ☐ High producing cows
- ☐ Fertile herd
- ☐ Routine veterinary herd health visits
- ☐ Main herd is milked in separate groups
- ☐ Sick herd is milked separately
- ☐ A biosecurity plan
- ☐ Electric wire on the backing gate
- ☐ Cows have pedometers/activity meters
- ☐ Synchrony programs are used on milkers

Section 4 – Mastitis and milk quality

20. What was your highest and lowest Bulk Milk Cell Count (BMCC) in the last 12 months?

Lowest BMCC: _____ ,000 cells/ml

Highest BMCC: _____ ,000 cells/ml

21. How many cases of mastitis per hundred cows occur within the first 30 days of calving?
(Leave blank if you are unsure)

Answer: cases per 100 cows

22. Please rate how strongly you agree or disagree with the following statements:

a. Clinical mastitis is a major problem in this herd

Strongly disagree ☐	Disagree ☐	Neutral ☐	Agree ☐	Strongly agree ☐
--	-----------------------------------	----------------------------------	--------------------------------	---

b. Bulk Milk Cell Counts (BMCCs) are usually less than 200,000 cells per ml

Strongly disagree ☐	Disagree ☐	Neutral ☐	Agree ☐	Strongly agree ☐
--	-----------------------------------	----------------------------------	--------------------------------	---

c. Clinical mastitis cases are found and treated as soon as they occur

Strongly disagree ☐	Disagree ☐	Neutral ☐	Agree ☐	Strongly agree ☐
--	-----------------------------------	----------------------------------	--------------------------------	---

d. Most cows respond to mastitis treatment on the first attempt

Strongly disagree ☐	Disagree ☐	Neutral ☐	Agree ☐	Strongly agree ☐
--	-----------------------------------	----------------------------------	--------------------------------	---

e. We follow written protocols for dealing with mastitis

Strongly disagree ☐	Disagree ☐	Neutral ☐	Agree ☐	Strongly agree ☐
--	-----------------------------------	----------------------------------	--------------------------------	---

Section 5. Reproduction

23. For a seasonal herd, what was your six-week in calf rate for the last joining period?
For a year-round calving herd what was your 100 day in calf rate last year?

Answer: (leave blank if unsure)

24. Please rate how strongly you agree or disagree with the following statements:

a. Reproductive performance in our herd is a problem

Strongly disagree ☐	Disagree ☐	Neutral ☐	Agree ☐	Strongly Agree ☐
--	-----------------------------------	----------------------------------	--------------------------------	---

b. We have a successful herd health monitoring program

Strongly disagree ☐	Disagree ☐	Neutral ☐	Agree ☐	Strongly Agree ☐
--	-----------------------------------	----------------------------------	--------------------------------	---

c. Our reproductive records are reliable and accurate

Strongly disagree ☐	Disagree ☐	Neutral ☐	Agree ☐	Strongly Agree ☐
--	-----------------------------------	----------------------------------	--------------------------------	---

Section 6. Other Disease

25. How many cows would you treat each year for:
(Leave blank if unsure)

Lameness	
Milk Fever	
Gut Problems (eg LDA, RDA, Diarrhoea)	
Down cows	

26. Please rate how strongly you agree or disagree with the following statements:

a. *Lame cows are identified and treated quickly*

Strongly disagree ☐	Disagree ☐	Neutral ☐	Agree ☐	Strongly Agree ☐
--	-----------------------------------	----------------------------------	--------------------------------	---

b. *LDAs and RDAs are not a problem*

Strongly disagree ☐	Disagree ☐	Neutral ☐	Agree ☐	Strongly Agree ☐
--	-----------------------------------	----------------------------------	--------------------------------	---

c. *Sick cows are identified and treated quickly*

Strongly disagree ☐	Disagree ☐	Neutral ☐	Agree ☐	Strongly Agree ☐
--	-----------------------------------	----------------------------------	--------------------------------	---

d. *Our disease treatment records are reliable and accurate*

Strongly disagree ☐	Disagree ☐	Neutral ☐	Agree ☐	Strongly Agree ☐
--	-----------------------------------	----------------------------------	--------------------------------	---

e. *We have written protocols for the diagnosis and treatment of disease*

Strongly disagree ☐	Disagree ☐	Neutral ☐	Agree ☐	Strongly Agree ☐
--	-----------------------------------	----------------------------------	--------------------------------	---

f. *Calf Scours is a problem on our farm*

Strongly disagree ☐	Disagree ☐	Neutral ☐	Agree ☐	Strongly Agree ☐
--	-----------------------------------	----------------------------------	--------------------------------	---

g. *Newborn calves are supplemented with colostrum within 12 hours of birth*

Strongly disagree ☐	Disagree ☐	Neutral ☐	Agree ☐	Strongly Agree ☐
--	-----------------------------------	----------------------------------	--------------------------------	---

h. *Cows often stand for more than 2 hours before they are milked*

Strongly disagree ☐	Disagree ☐	Neutral ☐	Agree ☐	Strongly Agree ☐
--	-----------------------------------	----------------------------------	--------------------------------	---

Section 7. Cow Behaviour

27. Please rate how often you:

a. *Use an electric prod on a cow*

Daily ☐	Several times a week ☐	Less than weekly ☐	Never ☐
-----------------------------------	--	--	-----------------------------------

b. *Use Poly Pipe on a cow*

Daily ☐	Several times a week ☐	Less than weekly ☐	Never ☐
-----------------------------------	--	--	-----------------------------------

c. *Lose your temper with a cow*

Daily ☐	Several times a week ☐	Less than weekly ☐	Never ☐
-----------------------------------	--	--	-----------------------------------

28. Please rate how strongly you agree or disagree with the following statements:

a. *The cows in our herd are fearful when a person walks through the milking yard*

Strongly disagree ☐	Disagree ☐	Neutral ☐	Agree ☐	Strongly Agree ☐
--	-----------------------------------	----------------------------------	--------------------------------	---

b. *We use the backing gate to push cows into the dairy*

Strongly disagree ☐	Disagree ☐	Neutral ☐	Agree ☐	Strongly Agree ☐
--	-----------------------------------	----------------------------------	--------------------------------	---

c. *Our cows are well behaved in the dairy and yard*

Strongly disagree ☐	Disagree ☐	Neutral ☐	Agree ☐	Strongly Agree ☐
--	-----------------------------------	----------------------------------	--------------------------------	---

d. *Our cows are flighty*

Strongly disagree ☐	Disagree ☐	Neutral ☐	Agree ☐	Strongly Agree ☐
--	-----------------------------------	----------------------------------	--------------------------------	---

e. *Our cows are aggressive towards people*

Strongly disagree ☐	Disagree ☐	Neutral ☐	Agree ☐	Strongly Agree ☐
--	-----------------------------------	----------------------------------	--------------------------------	---

f. *Some of our cows are friendly toward people*

Strongly disagree ☐	Disagree ☐	Neutral ☐	Agree ☐	Strongly Agree ☐
--	-----------------------------------	----------------------------------	--------------------------------	---

g. *Our cows are content most of the time*

Strongly disagree ☐	Disagree ☐	Neutral ☐	Agree ☐	Strongly Agree ☐
--	-----------------------------------	----------------------------------	--------------------------------	---

h. *Cows usually enter the shed in a similar order each day except when they are sick or on heat*

Strongly disagree ☐	Disagree ☐	Neutral ☐	Agree ☐	Strongly Agree ☐
--	-----------------------------------	----------------------------------	--------------------------------	---

APPENDIX 2

12. Appendix 2 - Dairy cow welfare assessment protocol questionnaire used in Chapter 4

The following questionnaire was used for the on-farm assessment as described in chapter 4. Methodology for the other components of the assessment are described within the chapter.

Administration

Date of visit _____

Assessor _____

About the Farm

Description of Business: (not for publication)

Name: _____

Contact No: _____

Email: _____

Postcode: _____

1. What type of dairy do you have?

- ☐ Rotary
- ☐ Swing-over herringbone
- ☐ Double-up herringbone
- ☐ Quick release exit
- ☐ Walkthrough

2. If a rotary, how many stands ?

3. If a herringbone/walkthrough, how many a side ? _____

4. How many sets of cups ? _____

5. At peak lactation, how many labour units are involved with the management of the milking cows on this farm ?

Full-time owners/managers?		(no. of people)
Full-time employees ?		(No. of people)
Casual or part-time		(Total hours per week)

6. Have any employees completed the following training (tick any that apply)

- ☐ University qualification in Agricultural Science
- ☐ University Qualification – Other
- ☐ TAFE qualification relevant to dairy
- ☐ Cups On Cups Off course
- ☐ Other Countdown Downunder course
- ☐ InCalf Course
- ☐ Other training relevant to dairy

About the herd

7. Which type of calving pattern best describes your herd ?

- ☐ Seasonal – one main calving period per year
- ☐ Split – two to four distinct calving periods each year
- ☐ Year Round – calving all year

When did you start your most recent calving period ? [/ /]

8. How many cows do you milk?

What is the maximum number of cows milked as a single group for more than 3 months? [] cows

How many cows are you milking today? [] Cows

9. How many Hectares do you use for milking cows? [] Ha

10. What is your average lactation production per cow in litres ?

- ☐ <4000
- ☐ 5001-6000
- ☐ 6001-7000
- ☐ 7001-8000
- ☐ >8000

11. What is the maximum amount of grain or pellets you feed to cows per day? [] kg/day

12. How many kg grain or pellets are you feeding the cows today ? []

Absence of prolonged hunger / Good nutrition

This was measured by condition scoring as described in chapter 5.

Acidosis risk was assessed by dung pat scoring as described in chapter 5.

Absence of prolonged thirst

Which best describes access to water ?

13. Cattle have access to water:

- [] limited access, but at least once daily
- [] limited access, but at least twice daily
- [] for a minimum of 8 hours in a 24 hour period
- [] for a minimum of 12 hours in a 24 hour period
- [] in all paddocks at all times
- [] in the laneways
- [] at the dairy

14. Stock drinking water is:

- [] town water supply
- [] suitable for human consumption
- [] unsuitable for human consumption

Comfort around resting

15. How long does a typical milking take (from first cups on to last cups off)?

☐ Minutes

16. What is the shortest and longest time a cow is likely to be out of the paddock for milking ?

Shortest time: ☐ minutes

Longest time: ☐ minutes

17. How far do cows need to walk to the nearest and furthest paddocks from the dairy ?

Nearest: ☐ Km

Furthest: ☐ Km

Thermal comfort

18. On very hot days, cows have access to: (tick all that apply)

☐ Drinking water at least twice daily

☐ Shade in the paddock

☐ Sprinklers in the dairy yard

☐ Change the milking time to earlier/later in the day

Other cooling strategies: _____

Good Health

In order to answer these questions, farm records are consulted. If the answer to any question is unknown, record this in the appropriate places. If the answer is estimated rather than confirmed from records, write EST following the answer.

19. Which of the following apply?

☐ electronic identification in the dairy

☐ electronic drafting

☐ milk volume meters in the dairy

☐ cellcount meters in the dairy

☐ Herd testing (How often ? ☐ Monthly ☐ every 2 months ☐ Other _____

20. Farm records of disease and disease treatment are :

☐ Paper based

☐ Recorded on a computer regularly

☐ A combination, but less than 80% are recorded on computer within 7 days of occurring

21. What computer software do you use?

☐ Easy Dairy

☐ Identity

☐ Dairy Data

☐ Other _____

22. How many lame cows are currently being treated in the herd either by
- having blocks applied ☐
 - treated with antibiotics ☐
 - being separated into a second herd that walks a lesser distance? ☐
23. Lame cows are routinely milked in a separate herd which walks a lesser distance? ☐
- Comment: _____
24. How many cows are currently under a withholding period for mastitis? ☐
25. What is your latest BMCC? ☐
26. How many cases of mastitis per hundred cows occur within the first 30 days of calving? ☐
27. Mortality: How many adult cows died on the farm in the last 12 months? ☐
28. What were the main causes of death?
- _____
29. How are gravely ill or injured animals put down on the farm? (tick all that apply)
- ☐ a firearm
 - ☐ a captive bolt device
 - ☐ blunt trauma (on newborn animals)
 - ☐ the local knackery does this for us
 - ☐ other please describe
- _____
30. Dystocia: How many cows required assistance calving in the last 12 months ☐
31. Downer cows: How many downer cows required treatment in the last 12 months: ☐
32. LDAs/RDAs: How many LDAs/RDAs were diagnosed in the last 12 months? ☐
33. For a seasonal herd, what was your six-week in calf rate for the last joining period? ☐
34. For a year-round calving herd what was your 100 day in calf rate last year? ☐

Painful husbandry procedures

35. Last time calves were disbudded or dehorned:
- ☐ They were less than 8 weeks old
 - ☐ They were less than 6 months old
 - ☐ Local anaesthesia as used
 - ☐ Analgesia (pain relief such as Metacam) was used
 - ☐ Sedation was used
 - ☐ Hot Iron Disbudding was used
 - ☐ Physical (surgical) dehorning was used
 - ☐ Caustic paste was used
 - ☐ Other _____