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Assessing and addressing the welfare of extensively managed ewes

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Doctor of Veterinary Medicine, Master of Animal Science

A thesis submitted in total fulfilment of the requirements for the degree of Doctor of
Philosophy-Agricultural Sciences

August 2019

Faculty of Veterinary and Agricultural Sciences

The University of Melbourne

Abstract

The sheep industry is currently facing increasing social demands for assurances of good animal welfare, which indicates that assessing and addressing the welfare of sheep is critical if the current 'social license to farm sheep' is to be maintained. Farmers are key players in improving sheep welfare because they are responsible for the care of their animals and make the management decisions on their farm. Hence, a better understanding of the main factors underpinning farmer behaviour is important. According to the Theory of Planned Behaviour, farmer attitudes towards sheep management are likely to influence their behaviour in terms of the implementation of improved management practices. Subsequently, farmer management behaviour may impact on the welfare of their sheep. The aim of this thesis was therefore to examine the relationships between farmer attitudes, management behaviour and sheep welfare outcomes. To examine these relationships, animal welfare assessments and questionnaire interviews with farmers were conducted.

A total of 6200 ewes (aged 2-5 years) and 32 farmers were sampled across Victoria, Australia. Farms were visited at mid-pregnancy and weaning, and the ewes were examined using six animal-based measures: body condition score (BCS), fleece condition, skin lesions, tail length, dag score and lameness. In addition, the number of ewes that needed further inspection/care (such as sick or injured sheep) was recorded and reported to the farmers. The welfare of the ewe flocks, based on the six indicators measured, was good overall. However, individual welfare compromise was considered significant. There were 185 (3.0%) ewes needing further care and cases were identified

in all farms. Main reasons for further inspection/care were lameness or foot-related issues, BCS ≤ 2 and active dermatophilosis or broken wool. Farmer attitudes to sheep and management were in general positive and welfare was considered an important aspect of farm productivity. In terms of management, it was found that farmers relied mostly on visual monitoring to assess the flocks and pasture quality and quantity. However, close inspection of the flock and more detailed practices such as body condition scoring of sheep, veterinary interventions or keeping accurate records were less common activities. Indeed, mortality rates were frequently underestimated.

Positive farmer attitudes were associated with positive management behaviour (active management style), and positive management behaviour was associated with positive ewe welfare outcomes. Farmers with an active management style had fewer ewes in need of further inspection/care after both welfare assessments (mid-pregnancy and weaning). Main results indicated that farmers were more likely to perform an activity (management behaviour) if they perceived the activity was valuable (behavioural attitudes) and if they perceived the activity could be realised (perceived behavioural control). The results of this thesis demonstrate that there is an opportunity to create change in farmer management behaviour and potentially improve sheep welfare via education programs targeting attitudinal change. The results reported in this thesis provide what is believed to be the first comprehensive study investigating the on-farm welfare of extensively managed ewes and the farmer-sheep relationship in extensive systems. Controlled trials to assess if education programs or other interventions are able to improve farmer attitudes and management behaviour, as well as sheep welfare, would allow causality to be investigated and would be a valuable next research step following on from the current work.

***“Outer changes always begin with an inner change of
attitudes”***

Albert Einstein

Declaration

I hereby declare that this PhD thesis is an original body of work. Contributions to the research made by my co-authors have been indicated in each chapter. The thesis is less than 100,000 words in length. I have made the largest contribution to this thesis by planning and conducting the research and writing the associated chapters.

Carolina A. Munoz

Ethical statement

As outlined in each chapter of research, all the procedures conducted in this thesis were approved by ethics committees in accordance with the Australian Code of Practice for the Care and Use of Animals for Scientific Purposes and the Australian National Statement on Ethical Conduct in Human Research (2007).

Acknowledgements

During my PhD, I had the fortune to be surrounded by an amazing group of people that made my PhD journey a great experience of knowledge, laughs and excitement! Firstly, I would like to thank my principal supervisor, Rebecca Doyle for all her guidance, support and advice throughout my thesis. For always pushing me to be better. I genuinely could not have had a better advisor, or one so inspiring, passionate and willing to go on different farms with me and revise numerous drafts of chapters and manuscripts. I also wish to thank my co-supervisor, Professor Paul Hemsworth. It was his expertise in animal behaviour that first led me to the Animal Welfare Science Centre (AWSC) in 2013. Certainly, this was the stepping stone of my transition from working in the field of animal production to animal welfare. I am sincerely grateful for the opportunity to work with Paul and for all his support and feedback during my project. I am also very grateful to my co-supervisor Dr Angus Campbell for all his invaluable feedback on sheep health and management. Thank you so much for all those catch-ups to talk about sheep and the body condition scoring training!

I am very grateful for the support, advice and feedback of Professor Grahame Coleman, who kindly and very generously taught me about focus groups and questionnaire development. Thank you so much, Grahame! it was a pleasure working with you. To my thesis committee: Prof. Peter Mansel, Prof. Andrew Fisher and Dr Stuart Barber, thank you so much for your constant support, positive feedback and for the opportunity to collaborate on your various teaching activities. Special thanks to Stuart who spent so many hours collecting milk samples for my first trials. Thank you for your tremendous

help and commitment. I would also like to acknowledge Profesor Ian Gordon and Dr Dave McGill who provided me with great statistical advice and always had good disposition to answer all my questions related to the complex universe of SAS and R! My great appreciation also goes to Lauren Hemsworth, who very generously provided me with great guidance with my research and proofread my work. I would also like to acknowledge the financial support of Meat & Livestock Australia Ltd. (MLA) and red meat producers and the Australian Commonwealth Government, and the Becas Chile program for funding my PhD studies.

To Cathy Dwyer from Scotland's Rural College, who kindly provided me with advice and spent time with me chatting about sheep during my visit to Scotland. To Francoise Wemelsfelder, who generously shared her QBA methodology with me and spent considerable time and effort guiding me. Her contribution was invaluable, and I am now spreading the word about QBA! To Claire Morgan-Davis, who spent a whole day with me showing me the research facilities and Scottish sheep! Thank you so much for your great hospitality and great research advice!

I really enjoyed the time working on the farms that I visited, and I am truly grateful for the farmers that kindly agreed to participate in this study. Thank you for opening your gates to me, to that little lady with a Chilean accent that spent considerable time assessing your sheep and learnt immensely from your experiences and opinions about sheep management. Thank you for welcoming me to your farms and homes, for all your positive feedback after my visits and for your genuine interest in my project.

This work would not have been possible with the great support of the AWSC team. Big thanks to Tracie, Sam B, Maria Fernanda, Peta, Hannah, Leigh, Rutu, Sam and Max. Thank you so much for your commitment to this project. Chapter 4 would not have been possible without you! To all my AWSSUM friends for making my time at the centre both enriching and enjoyable. It has been a pleasure sharing with you all those endless hours of work, laughs, tears and coffees. Bel, Leigh, Megs, Nat, Sam, Mark, Laura, Maddy and Rutu, thank you so much for the tremendous support during the writing stage of my PhD, for proofreading my work, for the chocolate treats, the neck massages and the motivational speeches. To my friend Nicole, for always guiding and helping me with uni paperwork. I miss you, my friend!

I am truly grateful to my family for the education that they gave me, the work ethic and all the emotional support. I have missed you every day during the time that I have lived in Australia pursuing a career in research and academia. Thank you mum, for being a great mum, and for supporting me with this adventure, you are always in my heart. To Nati, Seba, Tami and Javi, for being such amazing siblings. Please come and visit us soon! And last, but certainly, not least I would like to thank Pablo, my dear husband. Thank you for always being there for me. For all your help during my data collection. Thank you for going to the farms with me during Christmas, your ice hockey season and even when the waves were good for a surf session! Thank you for your love, kindness, advice, for proofreading my work and listening to all my sheep stories. You have made this journey amazing. I am looking forward to the next chapter of our lives, but I am warning you though, there will be more stories about sheep....

Publications

Peer-reviewed journals

- Munoz, C.; Campbell, A.; Hemsworth, P.; Doyle, R. (2017). Animal-Based Measures to Assess the Welfare of Extensively Managed Ewes. *Animals*. 8: 2
- Munoz, C.; Campbell, A.; Barber, S; Hemsworth, P.; Doyle, R. (2018). Using Longitudinal Assessment on Extensively Managed Ewes to Quantify Welfare Compromise and Risks. *Animals*. 8: 8
- Munoz, C. A., Campbell, A. J. D., et al. (2019) 'Evaluating the welfare of extensively managed sheep', *PLOS ONE*. Edited by E. Hillmann, 14(6), p. e0218603. doi: 10.1371/journal.pone.0218603
- Munoz, C. A., Coleman, G. J., et al. (2019) 'Positive attitudes, positive outcomes: The relationship between farmer attitudes, management behaviour and sheep welfare', *PLOS ONE*. Edited by E. Hillmann. Public Library of Science, 14(7), p. e0220455. doi: 10.1371/journal.pone.0220455

Manuscripts that I contributed to during my PhD but do not form part of my thesis

- Cramer S, Munoz C, McGill D, Rice M and Doyle R. Investigating the group flight distance of extensively managed ewes (submitted to *Applied Animal Behaviour Science*).
- Woodruff ME, Doyle RE, Coleman GJ, Hemsworth LH and Munoz CA. 'Knowledge and attitudes are important factors in farmers' choice of lamb tail docking length' (submitted to *Vet record*).

Oral presentations

Scientific conferences

1. Munoz, C. A., Hemsworth, P. H., Coleman, G. J., Campbell, A. J. D., Doyle, R. 'La actitud de los agricultores y su relación con el manejo y bienestar ovino. (ISAE regional) Chile, Diciembre, 2018.

2. Munoz, C. A., Coleman, G. J., Campbell, A. J. D., Hemsworth, P. H., Doyle, R. E. 'Farmer attitudes and the relationship with sheep welfare'. The International Society for Anthrozoology (ISAZ), 27th International Conference, Sydney, July 2018
3. Carolina A. Munoz, Angus J. D. Campbell, Paul H. Hemsworth and Rebecca E. Doyle. On-farm ewe welfare and its relationship with farmer management styles. International Conference on the Assessment of Animal Welfare at Farm and Group Level, Wageningen, September 2017.
4. Carolina A. Munoz, Angus J. D. Campbell, Paul H. Hemsworth and Rebecca E. Doyle. 'Indicators to examine sheep welfare'. The International Society for Applied Ethology regional meeting, Auckland, New Zealand, October 2016
5. Munoz, C. A., Coleman, G. J., Campbell, A. J. D., Hemsworth, P. H., Doyle, R. E. 'Reliability and feasibility of animal-based indicators to assess the welfare of extensively managed ewes.' Australian Society for Animal Production, Adelaide, Australia, July 2016

Academic seminars

6. Munoz, C. A. 'Towards a sustainable sheep production, Australian and Chilean context'. The V Chilean Graduate Conference, Sydney, October 2017.
7. Munoz, C. A. 'Assessing and addressing the welfare of extensively managed ewes': Seminar for Scotland's Rural College, Edinburgh, Scotland, September 2017
8. Munoz, C. A. 'Assessing and addressing the welfare of extensively managed ewes': Seminar for the Institut für Tierhaltung und Tierschutz der Vetmeduni, Vienna, Austria, September 2017
9. Munoz, C. A. 'Identifying sheep welfare measures.' Faculty of Veterinary and Agricultural Science (FVAS) Symposium, Melbourne, December 2016
10. Munoz, C. A. 'Assessing sheep welfare in Australia and opportunities to apply welfare assessments in Chile'. The IV Chilean Graduate Conference, Brisbane, October 2016

Industry outputs

11. Munoz, C. and Doyle, R. E. 'Assessing and addressing the welfare of extensively managed ewes.' SheepNET Oceania Workshop, opportunities for international collaborations to improve sheep productivity, Sydney, January 2018.
12. Munoz, C. and Doyle, R. E. 'On-farm welfare assessment and farmer attitudes.' Goorambat Producer Group presentation. Goorambat, Victoria May 2017.

Poster presentations

Scientific conferences

13. Munoz, C. A., Hemsworth, P. H., Coleman, G. J., Campbell, A. J. D., Doyle, R. E. 'Using qualitative behaviour assessment and flight distance to examine the farmer-ewe relationship in extensive systems.' International Society of Applied Ethology (ISAE), Canada, September 2018
14. Munoz, C. A., Coleman, G. J., Campbell, A. J. D., Hemsworth, P. H., Doyle, R. E. 'Assessment of human-animal relationship in extensively managed ewes.' International Society of Applied Ethology, Edinburgh, Scotland, July 2016
15. Munoz, C. A., Coleman, G. J., Campbell, A. J. D., Hemsworth, P. H., Doyle, R. E. 'Farmers' opinions about sheep management and welfare'. International Society of Applied Ethology, Edinburgh, Scotland, July 2016
16. S. Cramer, C. A. Munoz, D. M. McGill, M. Rice and R. E. Doyle. 'Investigating the effect of pen size and pen shape on group flight distance of extensively managed ewes.' UFAW, Hong Kong, 2018.

For all publications included in this thesis, co-authors of published work have completed The University of Melbourne's co-author authorisation form. All co-authors have certified that the contribution of the candidate is greater than 50% and is the primary author of these publications. The candidate's advisory panel has approved the inclusion of the published work listed in this thesis. The principal supervisor of this thesis Dr Rebecca Doyle has signed The University of Melbourne's declaration for a thesis with publication.

Funding to conduct the research described in this thesis was provided by Meat & Livestock Australia Ltd. (MLA) and by red meat producers and the Australian Commonwealth Government.

Thesis structure

This thesis consists of six chapters (Figure 1). Chapter 2, 4 and 5 are presented as published scientific papers. Because of this, formatting may differ and the explanation of some methodology and references have been repeated. These chapters are displayed in the final published PDF version with a separate preface in order to link the individual papers to the broader aim of the thesis.

Chapter 1 provides the background to the topic and is presented in two sections. The first section discusses the risks and opportunities for extensively managed ewes. This section is presented in a manuscript form (*in draft*) which will be submitted to the journal *Animals*. The second section discusses the aspects of the human-animal relationship and its implication for farm animals, with particular attention to sheep. Chapters 2 and 3 describe the methodology of this thesis. Chapter 3 is presented in a manuscript from (*in draft*) which will be submitted to the journal *Small ruminant research*. The examination of the farmer-ewe relationship, which is the core aim of this thesis, is then presented in Chapters 4 and 5. Chapter 4 presents the results of the welfare assessment of 6,200 ewes and identifies main welfare issues likely to be encountered in large-scale extensive farms. Chapter 5 examines the relationships of ewe welfare outcomes and the attitudes and management practices of the 32 farmers that manage the sheep. This chapter provides insight into farmer attitudes and management behaviour. Results indicate that the way farmers manage their ewes influences ewe welfare outcomes, and management decisions are influenced by positive attitudes towards sheep management. Chapter 6 discusses the main findings of this thesis, the implications, limitations and future directions. Finally, all relevant supporting information is presented in the appendix section.

AIM: To examine the relationships between farmer attitudes, management behaviour and sheep welfare outcomes.

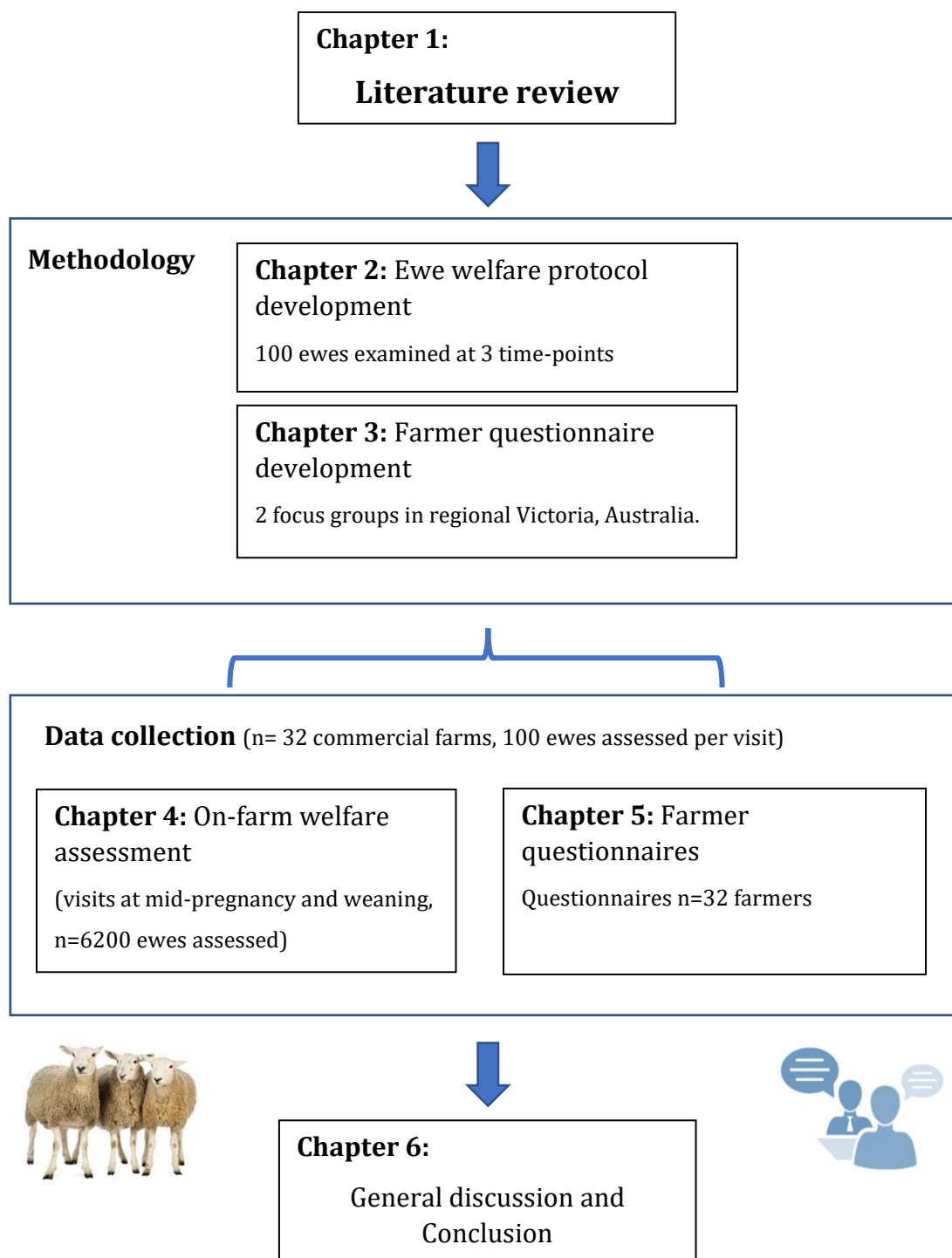


Figure 1. **Thesis structure**

Table of Contents

Thesis structure	XIII
Chapter 1: Literature Review	01
The Welfare of Extensively Managed Ewes	01
Abstract	02
Introduction.....	03
Natural living.....	05
Biological functioning	10
Affective states.....	20
Conclusion	24
Farmer attitudes, behaviour and the human-animal relationship	32
Farmer attitudes	33
The relationship between beliefs, attitudes and behaviours	36
The human-animal relationship in livestock production	37
The human-animal relationship in extensive sheep farming systems	40
Conclusions	42
Chapter 2: Ewe welfare protocol development	46
Animal-Based Measures to Assess the Welfare of Extensively Managed Ewes	46
Abstract	47
Introduction.....	47
Materials and Methods.....	48
Results.....	50
Discussion.....	56
Conclusions	59
Using Longitudinal Assessment on Extensively Managed Ewes to Quantify Welfare Compromise and Risks	63
Abstract	64
Introduction.....	65
Materials and Methods.....	65
Results.....	68
Discussion.....	70
Conclusions	73
Main findings/implications of Chapter 2.....	77
Chapter 3: Farmer questionnaire development	78

'If you say sheep are stupid it is probably because you are doing something wrong': farmers' opinions about sheep welfare and management in extensive systems.....	78
Abstract	79
Introduction.....	80
Materials and Methods.....	81
Results.....	84
Discussion.....	89
Conclusion	92
Main findings/implications of Chapter 3.....	94
Chapter 4: Evaluating the welfare of extensively managed sheep	95
Abstract	96
Introduction.....	97
Materials and methods.....	97
Results.....	99
Discussion.....	102
Conclusion	106
Main findings/implications of Chapter 4.....	110
Chapter 5: Positive attitudes, positive outcomes:	111
The relationship between farmer attitudes, management and sheep welfare.....	111
Abstract	112
Introduction.....	113
Materials and Methods.....	114
Results.....	117
Discussion.....	125
Conclusion	127
Main findings/implications of Chapter 5.....	130
Chapter 6: General Discussion.....	131
Main findings and implications.....	132
Limitations	138
Implications for further research	140
Conclusions	141
Appendix 1.....	146
Individual welfare assessment	146
Appendix 2.....	150
Questionnaire.....	150
Appendix 3: ISAE 2016.....	167

Assessment of human-animal relationship in extensively managed ewes	167
Appendix 4: ISAE 2016	168
Farmers' opinions about sheep management and welfare	168
Appendix 5: ASAP 2016	169
Reliability and feasibility of animal-based indicators to assess the welfare of extensively managed ewes.....	169
Appendix 6: ISAE regional 2016	172
Indicators to examine sheep welfare	172
Appendix 7: WAFL 2017	173
On-farm ewe welfare and its relationship with farmer management styles	173
Appendix 8: ISAZ 2018	174
Farmer attitudes and its relationship with sheep welfare	174
Appendix 9: ISAE 2018	175
Using qualitative behaviour assessment and flight distance to examine the farmer-ewe relationship in extensively managed ewes	175
Appendix 10: ISAE Regional 2018	176
La actitud de los agricultores y su relación con el manejo y bienestar ovino.	176
Appendix 11: UFAW 2018	177
Investigating the effect of pen size and pen shape on group flight distance of extensively managed ewes.....	177
Appendix 12: UFAW 2018	178
Too short: understanding farmer knowledge of and attitudes towards appropriate lamb tail length	178
Appendix 13: Abstract of manuscript submitted to Applied Animal Behavioural Science	179

List of tables and figures

Chapter 3: Farmer questionnaire development

Table 3.1 Common productivity statistics, main concerns at each reproductive stage and some management practices that can lead to improvements according to participants.....86

Figure 1.1 Three frameworks to assess animal welfare, redrawn from Fraser (2003).....05

Figure 1.2 The Theory of Planned Behaviour redrawn from Schifter and Ajzen (1985) 37

Figure 1.3 The Human-Animal relationship model based on the Theory of Planned Behaviour redrawn from (Hemsworth et al., 2018b).....38

The tables and figures related to Chapters 2, 4 and 5 are not included in the above list because they are presented in the pdfs

Chapter 1: Literature Review

This chapter provides the background to the topic and is presented in two sections. This first section discusses the risks and opportunities for extensively managed ewes. This first part of the literature review is presented in a manuscript form (in draft) which will be submitted to the journal *Animals*.

The Welfare of Extensively Managed Ewes



Manuscript (*in draft*)

Abstract

There is a general public perception that extensive farming systems provide good welfare for animals. Sheep managed extensively are able to live in a 'natural' environment and have more opportunities to express behaviours that are known to be rewarding for sheep such as grazing, resting, ruminating and affiliative behaviours. However, a number of aspects related to extensive farming systems may not always be recognised, such as the potential for hunger, discomfort and pain. This review evaluated the key challenges and benefits that extensive farming can pose to ewe welfare. We have argued that the naturalness of the environment and the free choice of performing behaviours are indeed important but not sufficient to ensure positive ewe welfare. The main areas of welfare concern identified in this review are related to environmental variability, the risk of undernutrition and dystocia, exposure to diseases (e.g. parasitism and lameness), low frequency of monitoring and human intervention, limited opportunities for positive human-animal interactions and exposure to negative affective experiences of fear, distress and pain. The solutions to the welfare problems identified here will involve a broader evaluation of producer and community expectations, research to underpin the required changes, and an assessment of the feasibility and impact of the improved welfare strategies.

Keywords: Extensive systems, on-farm welfare, sheep, welfare assessment.

Introduction

There are around 1 billion sheep in the world, and most of them are managed under extensive farming systems (FAO, 2012; Skapetas and Kalaitzidou, 2017). There are many different types of extensive farming systems, therefore, it is difficult to describe them all. However, some of the shared characteristics are that they rely mainly on pasture feeding as animals are managed outdoors all year, or at least for most of their lives, with limited monitoring and human intervention (Turner and Dwyer, 2007; Morris, 2017). These are typical production systems in the United Kingdom (UK) and in the southern hemisphere, including Australia, New Zealand, Southern Africa and South America (Kilgour et al., 2008; FAO, 2012; Morris, 2017). Extensive sheep production systems allow sheep to live in a more natural environment and allow them to perform an extensive amount of natural behaviours. Under these systems, and when resources are available, sheep have more choice in, and control over their day to day activities, such as grazing, ruminating and socially interacting with conspecifics (Dwyer and Lawrence, 2008). Some ethical views place an important value on animals being able to live a 'natural life' (Fraser et al., 1997; Hemsworth et al., 2015), and there is a perception that sheep have evolved in extensive systems, therefore they are well adapted to their environment. Possibly, the fact that sheep, as ruminants, are able to survive long periods without access to food and water may have also contributed to the general perception that they are well adapted to these systems (Turner and Dwyer, 2007; Dwyer and Lawrence, 2008).

While behaviour is less restricted, extensive systems create a number of other welfare challenges. Sheep managed extensively are more susceptible to climate variability, which affects quantity and quality of resources, they are more exposed to predation, and there

is less opportunity for monitoring, which leaves sheep at greater risk of chronically compromised welfare (Turner and Dwyer, 2007; Goddard, 2008). With this in consideration, it is possible that the welfare of extensively managed sheep is poorer than what is currently perceived.

This review discusses the risks and opportunities for ewe welfare that extensive systems present. The focus of this review is ewe welfare because ewes are the most productive/valuable class of sheep, and therefore maintaining ewes in good welfare has the largest effect on farm welfare and productivity. Ewes also spend the longest time in the production cycle, so both the opportunities for good welfare and risks are greater. Ewe welfare can be defined as a state within the animal (Hemsworth et al., 2015), which can be assessed by using three key questions: is the animal able to live according to its nature? (e.g. perform natural behaviours that are thought to be important to it, such as grazing), is the animal functioning well? (e.g. good health, productivity, etc.), and is the animal feeling well? (e.g. absence of pain, stress, etc.). As highlighted by von Keyserlingk et al., (2009) these three components of animal welfare should not be considered in isolation to each other (Figure 1.1). Not only are they synergistic but trying to address only one of these issues can unbalance the other areas. Specific issues can also cross the three components. For example, chronic lameness creates a negative affective state of prolonged pain and limits natural foraging behaviours, and the impact of both can lead to reduced biological functioning in the animal.

By reviewing the welfare of ewes in accordance with this framework, we evaluate what the welfare state of extensively managed ewes is, where issues need to be addressed and what remains unknown.

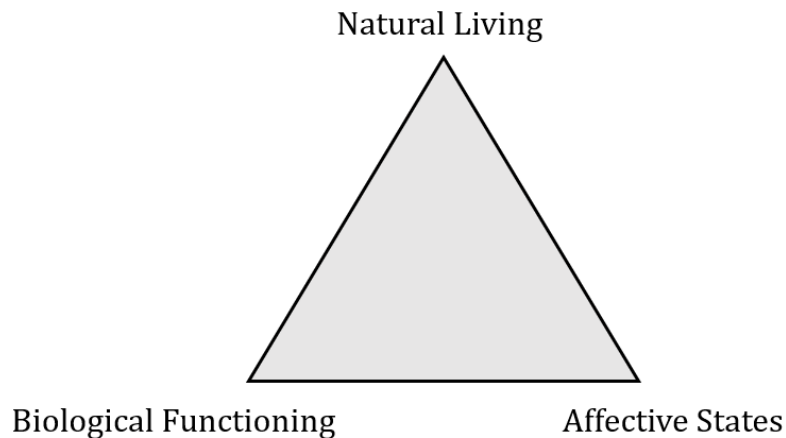


Figure 1.1 Three frameworks to assess animal welfare, redrawn from Fraser (2003)

Natural living

This framework is based on the view that welfare is positive if animals are managed under 'natural' conditions and able to perform 'natural' behaviours (Fraser et al., 1997). Of the three frameworks mentioned above, natural living is the least clearly defined, as there is a limited understanding of what are the natural behaviours that relate to good or poor welfare and what is the rationale behind their inclusion or exclusion (Barnett and Hemsworth, 2009; Hemsworth et al., 2015). Although this framework faces this limitation, there is neuroscience evidence that animals perform certain behaviours because they find them rewarding (Panksepp, 2005). These behaviours include playing, exploration, hunting or foraging, social behaviours, maternal behaviours and sexual behaviours (Mellor, 2015). As reward relates to a positive experience, these findings also

contribute to the third conceptual framework (affective state) (Hemsworth et al., 2015). Even though the natural living framework does not provide a strong guide for welfare assessment, it raises attention for the potential benefits of providing animals with the opportunity to perform natural behaviours that are related to positive experiences (Mellor, 2015).

Natural behaviours

When resources are available, extensively managed ewes have the free choice to graze, explore, ruminate, seek for shelter or interact with conspecifics (Dwyer and Bornett, 2004). Sheep are also usually kept in large homogenous groups, which allow them to fulfil their social needs, including their strong flocking instinct which is one of their main methods of defence (Lynch et al., 1992). In addition, the benefits of space can be clearly seen in extensive systems where there is limited resource competition, compared to the increased aggression observed in feed lotted sheep (Vik et al., 2017). However, it should be recognised that extensively managed sheep do not live in similar conditions to their wild counterparts. Compared to wild sheep, extensively managed sheep will have different social structures and flock sizes as they tend to be kept in more homogenous groups and large-size flocks. They would also have more restricted movements, and more human contact although they may only see humans once or twice a year (Deag, 1996).

Environmental challenges

Sheep managed extensively are more exposed to thermal stress such as low temperatures or heatwave conditions. Furthermore, if environmental challenges (hypo- or hyperthermia) are accompanied by undernutrition and/or dehydration, and/or coincide

with shearing, the ability of sheep to cope with the environment is significantly reduced (Dwyer, 2008). Providing sheep with sources of shelter and shade (e.g. trees, tree belts, bushes or rocks) is important to help them cope with adverse weather conditions (Taylor et al., 2011). For example, pregnant ewes will seek for shelter at lambing time during cold and wet weather, which significantly increases lamb survival (Pollard, 2006), and shorn sheep use shelter more than unshorn sheep during cold and windy nights (Lynch et al., 1980). Traditional hill farming systems, which are common in the UK, facilitate these shelter-seeking behaviours. However, in other parts of the world such as Australia, New Zealand, South Africa and South America, where sheep are managed in large-size flocks and fenced paddocks, an appropriate provision of shelter might be difficult due to cost and practicality. A few survey studies have reported that Australian farmers believed that provision of shelter is beneficial to both sheep welfare and productivity (Phillips et al., 2009; Doughty et al., 2017), however, there is a lack of information on how many farmers actually provide shelter to their sheep. This should be a major area of concern to the industry as extensively managed sheep will be more affected in the future by extreme environmental challenges.

Predation

Extensively managed ewes are more exposed and susceptible to predator attacks for two main reasons. First, sheep are largely defenceless to predator attacks, as their main mechanism of defence is a flight response (Dwyer and Bornett, 2004; Johnson and van Bommel, 2017). Domestic sheep also show weaker antipredator behaviours compared to their wild counterparts and other domesticated animals, probably due to genetic selection for docility over the years (Price, 1999). Secondly, their intermediate body size

makes them susceptible to a wide range of predators including wild dogs, feral pigs, foxes, coyotes and mountain lions (Johnson and van Bommel, 2017). All sheep are vulnerable to attacks, however, lambs, sick individuals and ewes with lambs are more at risk (Gluesing et al., 1980). The extent of predation is variable and depends on location and management such as wildlife management and feral animal control (Johnson and van Bommel, 2017).

Predation can directly or indirectly affect sheep welfare. The direct effects include the acute stress and fear induced by the attacks of predators, injuries sustained during attacks and death. The indirect effects are related to the chronic stress that sheep can experience after recurrent persecutions by predators (Johnson and van Bommel, 2017). Common injuries found after attacks are around the neck, body or limbs, and they can range from superficial wounds to mutilation and death/fatal injuries (Jennens, 1998). Instant death resulting from predators may be considered 'humane', but some predators may be more effective than others in killing sheep. Dogs, for example, are not effective (Johnson and van Bommel, 2017), causing prolonged stress, fear and pain. This becomes a serious welfare concern as injured or mutilated sheep that survive the attacks may remain unnoticed for several days due to the typically low frequency of monitoring in extensive systems (Dwyer, 2008). Sheep that survive do not only experienced the stress and pain due to the attack but also must go through a process of recovery, which usually involves restriction of movements, isolation from the flock and regular handling. All of which can induce stress and fear in the sheep and prolonged times could lead to chronic stress (Dwyer and Bornett, 2004; Johnson and van Bommel, 2017). Sheep that are not directly attacked may also experience fear and stress provoked by the presence of predators. In addition, as sheep are social animals that can recognise other sheep and

form strong social bonds, another indirect effect could be related to the stress of losing a member of the flock (Boissy and Dumont, 2002; Napolitano et al., 2008).

Limited monitoring and human intervention

Extensive systems are characterized by limited human monitoring, a high sheep human ratio, and infrequent human-sheep interactions (Kilgour et al., 2008). This limited interaction is a result of the natural living opportunities provided by extensive systems, but it can create welfare challenges from both biological functioning and affective state standpoints. Infrequent management means there are fewer opportunities for sheep to get habituated to human presence and actions (Goddard et al., 2006). When interactions do happen, they are associated with stressful husbandry procedures that may include vaccination and parasite control, shearing, ultrasound pregnancy diagnosis, lamb marking and weaning (Hargreaves and Hutson, 1990a). These practices require mustering, handling and individual management, which for a species whose defence mechanism is group safety and fleeing, can invoke fear. In combination, the opportunities for positive human-animal interactions to develop are limited.

Despite the importance of monitoring and human-animal interactions on sheep welfare, most regulations and codes of practice recommend that sheep are inspected 'as often as necessary', instead of stipulating the appropriate level of care and supervision needed in extensive systems (The Scottish Government, 2012; Animal Health Australia, 2016; INIA, 2017). It is important therefore to identify the appropriate level of monitoring and the number of labour units required to achieve it to secure sheep welfare in extensive systems.

Biological functioning

The biological functioning framework is based on the premise that animals use a wide range of physiological and behavioural stress responses to cope with changes or challenges with the environment, however, even though biological regulation in response to adverse situations is constant, an adequate adaptation might not always occur (Hemsworth et al., 2015). The ewe's ability to cope with challenges can be affected by her nutrition, health, age, breed and reproductive status, along with the environment in which she lives. Combinations of these factors will create situations that will be biologically beneficial or costly, which will be reflected in positive or negative reproductive, health and growth outcomes. Some extreme situations can overwhelm the ewe's ability to cope and may result in death (Broom and Johnson, 1993). The following section focuses on some of the key examples of welfare risks when biological functioning is compromised: mortality, under and over nutrition, dystocia, parasitism and lameness. These challenges have been specifically chosen as they represent globally relevant biological welfare challenges and have the potential for improvement with management intervention and existing treatment options.

Ewe mortality

Ewe mortality acts as an integrated welfare measure since multiple welfare challenges within a sheep farming system (e.g. nutrition management, husbandry procedures and lambing management) influence ewe survival (Dwyer, 2008; Kilgour et al., 2008; Phythian, 2011). While Mellor and Stafford 2004's review of neonatal lambs suggested that welfare is not significantly compromised if mortality occurs in the early stages of life, particularly prior to their first breath, causes of mortality in the sentient ewe create

suffering. The suffering can be either acute or prolonged, but in both situations, the affective state of the ewe is compromised. Symptoms in the former situation cause rapid deterioration and are often described as being accompanied by extreme pain. In both scenarios, isolation can be a side effect, which can be distressing for the ewe as sheep have a strong flocking behaviour. Some of the main causes of ewe mortality identified in extensive systems include undernutrition, pregnancy-related disorders, internal parasite infestations (or combinations of these three), post-shearing thermal stress, infectious diseases (e.g. Johne's disease) and flystrike (Goddard, 2003; Phythian, 2011; Doughty et al., 2019).

Ewe mortality creates important costs for the profitability of the industry. However, estimation of the impact may be difficult as accurate records of ewe mortality are lacking. Previous studies in extensive farming settings in the UK, New Zealand and Australia indicate that ewe mortality usually ranges from 4 to 6% annually. In Australia, this corresponds to 1.65 million ewes lost every year in a 'normal' season (Lovatt and Strugnell, 2013; Ferguson et al., 2014), but in years of drought, mortality can be as high as 10.5% (2002-03, ABARES, 2019). While these are officially reported rates, record keeping is not common among sheep farmers. A detailed government report on the topic by McGregor (McGregor, 2007) proposes that sheep mortality is being underestimated by farmers, and could potentially be up to double the reported rate. It is possible that this underestimation of mortality has given the impression that sheep mortality levels are currently acceptable and/or that little can be done to improve them (McGregor, 2007). If losses are not identified and quantified correctly, then it is difficult to make management decisions accordingly. Thus, effective and practical ways of record keeping on

commercial farms are much needed to confirm existing information and improve farm performance and productivity.

Under and overnutrition

Free grazing in extensive settings means that both under and over nutrition may occur within the ewe's lifetime, with both situations creating welfare risks. Undernutrition, either chronic or acute during pregnancy, is one of the most common and important welfare concerns as it can result in high levels of lamb and ewe mortality (Dwyer, 2003, 2017; Doughty et al., 2019). The risk of undernutrition may be exacerbated in periods of climate extremes. While sheep express physiological adaptations to cope with these situations, such as a reduction in appetite, they may experience hunger and changes in biological functioning (Dwyer, 2009). For instance, if pregnancy coincides with periods of low pasture growth e.g. a cold winter or dry summer, ewes may not be able to consume enough pasture to meet their nutritional requirements, having to mobilise their own body reserves to sustain pregnancy and meet nutritional needs (Kenyon and Cranston, 2017). These underfed ewes are more at risk of metabolic problems such as pregnancy toxemia. If food intake is limited, glucose levels in the blood are low, resulting in fat mobilization, ketonemia, and ketonuria in susceptible animals (Rook, 2000). Other welfare issues faced by underfed ewes include; hypocalcaemia, dystocia, reduced mammary gland development, reduced colostrum production, delayed milk letdown, reduced milk production and decreased maternal instinct (Kenyon et al., 2009; Fthenakis et al., 2012; Rooke et al., 2015; Kenyon and Cranston, 2017), all of which reflect both biological compromise to the ewe's welfare and significantly increase the risk of mortality in offspring.

Overnutrition, or ewe fatness, can also have negative consequences for reproduction and ewe welfare. Over-conditioned pregnant ewes are more likely to have offspring with insulin resistance and associated cardiovascular diseases (Wang et al., 2010). As with underfed ewes, overfed ewes are also at risk of metabolic problems in late pregnancy. They may have a depressed appetite, which generates mobilization of ketones, also resulting in pregnancy toxaemia (Dwyer, 2017). Fat single bearing-ewes are also more likely to have high-birth weight lambs, which is one of the main predisposing factors to dystocia (Smith, 1977).

While adequate nutrition is not always achieved easily in extensive systems, there are some management practices that can be implemented to mitigate the impacts of under and overnutrition. For example, ultrasound pregnancy diagnosis, to identify single or multiple foetuses and body condition scoring of ewes with subsequent nutritional management for single versus twin-bearing ewes (Kenyon and Cranston, 2017, Richmond et al., 2017). However, while improved management practices are available for farmers, engagement is low. As an example, studies in Australia and the UK have reported that only 32% of farmers either scored the body condition of their sheep by physically touching the animals or were willing to start doing it (Jones et al., 2011; Owen et al., 2017). As management practices play a significant role in mitigating welfare risks associated with nutrition, this indicates a need for a better understanding of the main barriers to best practice in order to achieve a sustained change in farming practices in the sheep industry.

Dystocia

Dystocia is one of the most important causes of lamb and ewe mortality at lambing (Horton et al., 2018). Related to under and overnutrition, dystocia occurs when lambs are too large and heavy, have abnormal presentations such as one or both forelimbs retracted, or when more than one lamb is present in the birth canal simultaneously (Dwyer, 2017). According to Larsen (1975), the mean incidence of dystocia in Merino ewes is 4.1%. Birth difficulties or prolonged deliveries can cause pain, stress and physical damage to the ewes, and hypoxia and physical trauma to the lambs such as broken bones and haemorrhage (Dwyer, 2017). To mitigate the risks and welfare compromise associated with dystocia, the provision of adequate human intervention is beneficial, but not always delivered (Fisher and Mellor, 2002).

Several factors prevent effective intervention when complications at parturition occur. For example, there are less frequent observations than in more intensive situations (Scott et al., 2007), and less frequent veterinary attention (Kaler and Green, 2013). In addition, when assistance is provided by farmers or stockpeople, obstetrical skills may not be very effective. Studies have found that assistance is usually performed without appropriate hygiene, and only a low proportion of farmers provide their ewes with antibiotics following assistance. However, farmers that do provide antibiotics, frequently use the inadequate type (Scott, 2003). Pain relief is rarely given either. Appropriate human interventions at lambing may reduce ewe and lamb mortality (Dwyer and Lawrence, 2005) but require good technique and a positive (or at least neutral) human-animal relationship to avoid undue distress to the dystocic ewe (Boivin et al., 2000; Dwyer and Lawrence, 2005). Since sheep managed extensively are not used to close human presence,

interventions at lambing can produce stress to the ewe, the handler, as well as other sheep in the paddock which may lead to mismothering (Fisher and Mellor, 2002). Thus, while birth assistance can be necessary for an individual animal, it is sometimes avoided for the benefit of the flock (Mellor and Stafford, 2004).

Parasitism: Ectoparasitism

External parasites still remain an important cause of economic losses and welfare concerns in extensive systems (McLeod, 1995; Morgan-Davies et al., 2006; Lambertz et al., 2018). Important external parasites include lice (*Bovicola ovis*), sheep scab (*Psoroptes ovis*), ked (*Melophagus ovis*) and blowflies (*Lucilia* and *Calliphora* species) (Plant, 2006). Welfare concerns of ectoparasites such as lice and scabs relate to intense pruritus, which in some cases, may lead to severe skin damage (Corke and Broom, 1999; Berriatua et al., 2001). Also, severe infestations may produce excessive biting of skin and head tossing (Corke and Broom, 1999). The time sheep spend scratching, rubbing or biting of skin lesions decreases the time spent grazing and ruminating, which might affect weight gain and productivity (Berriatua et al., 2001).

As mentioned above, flystrike is another important ectoparasitic disease in extensive sheep-farming countries. The mean prevalence of flystrike in Australia is 0.9% (ranging from 0 to 2.5%) for both, mulesed and non mulesed sheep (Larsen et al., 2012). This disease is caused by the oviposition of blowflies and mostly occurs in warmer and humid weather and where sheep are kept in high stocking densities (French et al., 1994). Thus, flystrike is a common problem in parts of Europe, the UK, South Africa, the United States, Australia and New Zealand (Hall and Wall, 1995; Morgan-Davies et al., 2006; Bisdorff and

Wall, 2008; Windsor and Lomax, 2013). Risk factors for flystrike include the presence of wounds, followed by urine and faecal soiling in the perineal zone or the presence of skin wrinkles, which makes Merino sheep highly susceptible (Wall, 2012). Therefore, flystrike in Australia is of particular concern due to suitable climatic conditions for blowflies and the presence of susceptible breeds of sheep (Phillips, 2009). Infected sheep can have important tissue damage, particularly in the back, breech and tail area (Windsor and Lomax, 2013), and it has been documented that flystrike is an important risk to adult sheep mortality (Doughty et al., 2019). The severe discomfort caused by flystrike affects grazing and ruminating activities, reducing feed intake, growth rate and wool production (Farkas et al., 1997). Affected sheep present elevated plasma cortisol and adrenocorticotrophic hormone (ACTH), increased body temperature and decreased plasma glucose (Shutt et al., 1988; Walkden-Brown et al., 1999).

To control external parasites and avoid excessive suffering of animals, an integrated approach is recommended such as appropriate use of chemical control, control of scouring, adequate selection of shearing and crutching times, control of fly numbers, and genetic selection (Windsor and Lomax, 2013). However, poor application of chemicals and poor biosecurity are continuing issues in the industry (Morgan-Davies et al., 2006; Levot and Sales, 2008; James, 2010; Doherty et al., 2018). To control flystrike in Australia, mulesing has traditionally been used over the past 80 years, particularly in wool enterprises. Mulesing is a surgical procedure that involves the removal of excessive perineal skin of lambs, helping to reduce the accumulation of breech moisture (Windsor and Lomax, 2013). This procedure results in a significant wound area and associated pain, and scrutiny of the mulesing procedure has led to significant research on alternatives

(Phillips et al., 2009; Wells et al., 2011; Hemsworth et al., 2012; Windsor and Lomax, 2013; Fisher et al., 2013; Small et al., 2018b). Farmers' engagement into new alternatives is variable and, to date, the cessation of mulesing has been unsuccessful. However, some improvements have been made such as the use of pain relief (e.g. Tri-Solfen®, Bayer Australia Ltd.) (Small et al., 2018b) and the accreditation of mulesing contractors (Windsor and Lomax, 2013). Undoubtedly, further research into suitable alternatives to control flystrike is needed to maintain the current 'social license to farm sheep' in Australia. Potentially, further genetic analysis of the fly may allow the development of suitable vaccines or drugs to control blowfly populations (Sandeman et al., 2014).

Parasitism: Endoparasitism

The main internal parasites in sheep are lungworms (*Dictyocaulus spp. or Muellerius capillaris*) (Asmare et al., 2018), gastrointestinal worms (e.g. *H. contortus*, *Te. circumcincta* and *Trichostrongylus spp.*) (Nari et al., 1996; Roeber et al., 2013), liver flukes (*Fasciola hepatica*) and intestinal parasites (*Eimeria* or *Isospora*) (Sykes et al., 1980; Kamaludeen et al., 2019). Parasitic gastroenteritis disease, caused by infection of the gut with gastrointestinal worms (e.g. *H. contortus*), is one of the most important (Nieuwhof and Bishop, 2006). In general, sheep are more susceptible to endoparasitism than other farm animals because their small faecal pellets disintegrate very easily, thus releasing the worm larvae onto pastures (Barger, 1993). They are also slow to acquire immunity, and high stocking rates and insufficient pasture rest periods further contribute to the incidence of endoparasitism (Barger, 1993). Parasitic gastroenteritis disease produces important protein and electrolyte losses, which may result in diarrhoea, anaemia, behavioural depression, anorexia and death. Infected sheep usually present poor body

condition, low growth rates, reduced wool condition and milk production, and they are more susceptible to other diseases (e.g. flystrike) (Festa-Bianchet, 1988; Dwyer and Bornett, 2004). Sheep also spend less time grazing and are less active compared to uninfected sheep (Hutchings et al., 2000). The effects of parasitism are more severe in pregnant and lactating ewes, especially maiden and older ewes (Houdijk et al., 2001). High levels of parasitism are positively associated with chronic stress in sheep, which can have a severe impact on productivity as chronic stress reduces immunity, affects body weight, decreases reproductive performance, meat quality and wool production (Barger, 1993; Dwyer and Bornett, 2004). Control of parasitic gastroenteritis disease has usually relied on chemical anthelmintic drugs (Taylor, 2012). However, parasite resistance is an increasing welfare issue in the industry (Love et al., 2011; Lovatt et al., 2019; Kamaludeen et al., 2019), that needs to be addressed.

Lameness

Lameness is a common and serious welfare problem in sheep worldwide. Clinical symptoms of lameness depend on its degree and may vary from clear shortening of the stride to reluctance to stand or move (Kaler and Green, 2009). Lameness can be caused by non-infectious or infectious factors, but it is largely caused by bacterial infections. Main causes of sheep lameness include; interdigital dermatitis (scald), contagious ovine digital dermatitis (CDD) and footrot (Roger, 2008; Lovatt et al., 2019). The latter being reported as the most prevalent cause of lameness (Wassink et al., 2003, 2010; Winter, 2004; Conington et al., 2010). Footrot is a contagious disease caused by *Bacteroides nodosus* in conjunction with *Fusobacterium necrophorum* and has a reported prevalence of between 0.4 and 23.3% (Conington et al., 2010; Gelasakis et al., 2015). Sheep with

severe footrot disease, have elevated plasma cortisol, adrenaline and noradrenaline levels, which are the main physiological indicators of stress (Ley et al., 1992; Fitzpatrick et al., 2006). The pain and discomfort reduce feed intake and weight gain, which decreases body condition and wool production, resulting in important sales restrictions and economic losses for the industry. Furthermore, sheep affected are more likely to be affected by other diseases, such as flystrike, as infected material from the foot can reach the fleece attracting blowflies and therefore predisposing animals to myiasis (Winter, 2004).

Regardless of the cause, prevention, early detection and adequate treatment are essential tools to reduce the incidence of lameness in the flock (Kaler and Green, 2008). In extensive sheep farming conditions, where sheep may walk on average 17 km daily (Squires et al., 1972), and where there is limited monitoring of individuals, the potential for lameness to impact animal welfare is of particular concern. Without appropriate treatment, the ability of a ewe to move pain-free, feed easily and keep up with the flock is compromised. Thus, early detection and intervention of lame sheep are important. There are, however, important discrepancies on how farmers treat the lame animals of their flock (Kaler and Green, 2008; FAWC, 2011). For example, it has been found that some farmers identify and treat the first lame sheep in the flock, while others prefer to wait until several sheep are clearly lame to treat them as a group (FAWC, 2011) or wait until lameness is more severe (Kaler and Green, 2008). This issue could be partially explained by the cost, labour and other resources involved in controlling lameness, which may also produce physical and mental stress in farmers. Clearly, a better understanding of farmers'

management decisions regarding lame animals is needed to promote adequate and prompt intervention.

Affective states

This framework defines animal welfare in terms of affective experiences or emotions (Fraser et al., 1997). Animals' emotions reflect the internal biological functioning of the animal and how the animal perceives its environment (Mellor, 2012). Thus, issues previously discussed in this review overlap with this framework. On one hand, extensively managed ewes may experience a wide range of positive affective experiences as they have more opportunities to live a 'natural life' and more control over performing or not performing behaviours such as exploration, food acquisition and affiliative behaviours, which have been demonstrated to be rewarding for animals (Mellor, 2015). On the other hand, ewes are more susceptible to climatic variability, exposed to diseases, predators and limited human monitoring and intervention which could lead to negative affective experiences.

When considering the range of affective states ewes can experience, the focus tends to be on negative states, which are often subtle. These subtle states are largely an evolutionary adaptation of sheep. As a prey species, their defences are limited to flocking and flight responses, with ewes also displaying stamping and occasionally charging behaviours, particularly when lambs are at foot (Nowak et al., 2008). While subtle, Wemsfelder and Farish (2004) have described the following qualitative categories in sheep that relate to potential affective states: fear, timidity, agitation, pain, calmness, curiosity and play. The

focus of this review is on fear, distress and pain, as well as opportunities for positive affective states as they align with the specific welfare challenges described above.

Fear and distress

As described in the Natural Living section, extensively managed sheep are not habituated to human contact. It has been shown that extensively managed lambs have increased heart rates during handling situations when compared with intensively managed lambs (Goddard, 2008). Furthermore, domestic dogs are often used for handling and mustering purposes, introducing another stressor for sheep. Stressful situations activate the sympathoadrenal medullary system and the hypothalamus-pituitary-adrenal axis, and this can contribute to acute distress as well as a cumulative fear (Broom and Johnson, 1993; Cockram, 2004). When exposed to negative handling, animals will learn to anticipate negative outcomes in subsequent handling events (Rushen, 1986; Rushen and Congdon, 1986). This makes handling situations more stressful for both the handler and the animal (Hemsworth and Barnett, 1991; Hemsworth et al., 1993; Waiblinger et al., 2006; Coleman et al., 2012), also creating hazards for the handler (Irandoust et al., 2013).

Adequate human-animal interactions are key to reduce the negative affective experiences sheep may have when they are been handled. As with intensively managed sheep, quantifying sheep behaviour during routine handling situations can be a way to potentially measure negative experiences in extensive sheep farming systems (Hutson, 1982; Hargreaves and Hutson, 1990c; Napolitano et al., 2011). For example, how flight distance and the behaviour of sheep during routine handling may differ across farms, and

how they may be associated with farmer attitudes to sheep could provide further insights on the affective state of sheep and the farmer-sheep relationship in extensive systems. However, issues with the flight distance test exist (Cramer et al., 2018) and further research should examine practical alternatives to standardise it.

Fear and vigilance will also be triggered in ewes when predators are present. When being vigilant and experiencing fear, ewes stop performing other behaviours of maintenance such as feeding, mating and maternal care to cope with the situation. Thus, by just being exposed to predators, there may be consequences for the biological functioning and mental state of ewes managed extensively (Dwyer, 2008).

Pain

The low frequency of monitoring and a low sheep: human ratio increases the risk of sick or injured ewes being unnoticed, exposing animals to long-term stress, pain and suffering. There is a vast amount of scientific evidence from studies on the physiological and behavioural responses of sheep to some diseases (e.g. flystrike, lameness, mastitis), to traumatic injuries, and to some management practices, supporting the supposition that sheep can feel pain (Festa-Bianchet, 1988; Ley et al., 1992; Cockram, 2004; Dwyer and Bornett, 2004; Fitzpatrick et al., 2006). Behavioural responses of pain include reluctance to walk or move, altered postures (Gougoulis et al., 2010), changes in feeding (Villalba et al., 2010), lying and resting behaviours (Berriatua et al., 2001), and isolation from the rest of the flock (Lynch et al., 1992). However, it should be recognised that sheep, as prey animals, show subtle signs of negative mental states to avoid communicating disease or injury to predators. Thus, a failure of humans to recognise behaviours indicative of

negative affective experiences does not necessarily mean that sheep do not experience these emotions under extensive systems (Stubsj  en et al., 2009). In addition, it should be noticed that behavioural indicators of pain have been based on human judgements (Molony et al., 2002), which means that the assessment of the level of pain experienced by sheep is strongly influenced by the beliefs, attitude, experiences and knowledge of the assessors.

Painful husbandry practices are breed-specific, with ear tagging/notching being the most widely occurring practice for ewes, and castration being common for males. Also, some painful procedures are more common in extensive systems (e.g. castration, tail length and mulesing) as animals managed extensively are more exposed to welfare risks (e.g. flystrike). Thus, a trade-off between pain and natural living may occur. Ear identification in sheep is not perceived to be a particularly painful or invasive practice, with only one paper dedicated to the topic alone (Edwards and Johnston, 1999). Tail docking is common to a number of breeds, and for particular breeds of sheep, like merinos, mulesing is also practised, although this practice is becoming less common (Windsor and Lomax, 2013). It is worth noting that some painful procedures are more common in extensive systems (e.g. castration/mulesing) as animals are managed more extensively. Thus, a trade-off between pain and natural living may occur. Evidence of pain caused by tail docking and mulesing are well represented in the literature (Molony et al., 2002; Lee et al., 2008; Sutherland and Tucker, 2011; Fisher, 2011; Wall, 2012; Hemsworth et al., 2012; Small et al., 2018b), and mechanisms for pain relief continue to be explored. Now, as these husbandry practices occur once early in life, aside from assessments of overall quality of life, they are limited in their impact when considering the welfare of ewes specifically. Current options for pain management in sheep include products that use combinations

of nonsteroidal anti-inflammatory drugs e.g. meloxicam, and local anaesthetics e.g. lignocaine and bupivacaine (Fisher, 2011; Windsor and Lomax, 2013; Small et al., 2018b; a). However, while pain management is commercially available, recent survey data on 600 extensive sheep producers reported that only 39% of farmers would be willing to use pain relief for painful husbandry procedures (Howard and Beattie, 2018).

While not painful *per se*, shearing is a common, again breed-specific, husbandry practice that ewes would experience. Proven to be a stressful process for sheep, shearing constitutes an acute short-term stressor as indicated by significant physiological stress response and is characterized by close human contact, unfamiliar handling (catching, upending, dragging) and noise (Hargreaves and Hutson, 1990a; b; Casella et al., 2016). The combination of these components makes shearing an important short-term stressor that creates a transient negative welfare state (Sanger et al., 2011). While transient, the potential for skin injury is high. Skin injuries may be painful, and they create a risk of infection and thus, other diseases. Further research is needed to first quantify injuries related to shearing, and secondly, to assess the long-term impact of shearing injuries on the welfare and productivity of extensively managed ewes.

Conclusion

This literature review examined the potential risks to ewe welfare in extensive systems and the implications in terms of the physical and affective experiences of ewes. There is a general view that the welfare of ewes managed extensively is good as they have more opportunities to live a 'natural life'. However, while extensive systems possess several benefits for sheep, we have argued that the naturalness of the environment and the free

choice of performing behaviours are indeed important but not sufficient to ensure positive ewe welfare. The main areas of welfare concern discussed in this review are related to environmental variability, the risk of undernutrition and dystocia, exposure to diseases (e.g. parasitism and lameness), low frequency of monitoring and human intervention, limited opportunities for positive human-animal interactions and exposure to negative affective experiences of fear, distress and pain. The existence of many welfare problems in extensive production systems suggests that the welfare of ewes requires more attention than what it has currently received. Solutions to the welfare problems identified in this review will involve a broader evaluation of producer and community expectations, research to underpin the required changes, and an assessment of the feasibility and impact of the improved welfare strategies.

Acknowledgements

This review was funded by Meat & Livestock Australia Ltd. (MLA) and by red meat producers and the Australian Commonwealth Government. The authors also wish to acknowledge the support of the Chilean government scholarship program 'Becas Chile' for financially supporting the PhD studies of C.A.M.

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Chapter 1: Literature Review

This second section of the literature review discusses the aspects of the human-animal relationship and its implication for farm animals, with particular attention to sheep.

Farmer attitudes, behaviour and the human-animal relationship



Farmers are key players in improving sheep welfare because they are responsible for the care of their animals and make the management decisions on their farm. Therefore, a better understanding of the main factors underpinning farmer behaviour is important. This information may help in promoting farmer adoption of best practice with the ultimate goal of increasing sheep welfare and farm productivity. The following section of the literature review will discuss the influence of attitudes in farmer behaviour and the implications of the human-animal relationship on animal welfare, with particular attention to sheep and the potential relationship between farmer attitudes, behaviour and sheep welfare.

Farmer attitudes

Improved management practices to increase sheep welfare and productivity are widely available for farmers (1–4). However, farmer adoption of best practice is somewhat limited and warrants further investigation. For example, survey data suggests that only 32% of farmers either measure the body condition of their ewes or would be willing to do so, and only 47% of farmers did or would be willing to allocate pregnant ewes in different groups according to nutritional needs (5). Another survey conducted in 2013, identified that only 11% of farmers, out of the 1225 farmers surveyed, used best practice to treat footrot e.g. intervention within the first 3 days, combined with the use of injectable and topical antibiotics (6). More recently, a broad industry survey on 600 sheep farmers identified that only half of producers use ultrasound pregnancy diagnosis regularly, and only 31% of them separate ewes into different mobs according to their nutritional needs (7).

Economic drivers significantly influence farmers' willingness to adopt improved farm practices, and thus many programs aimed at increasing practice change focus on highlighting the costs and benefits to farmers (8–10). Yet, drivers that shape the decision making and behaviours are complex. They are influenced partly by financial returns, but they are also influenced partly by psychological and social factors (11,12). Studies from the field of psychology have demonstrated that the most important factor predicting human behaviour is attitude (13). Attitude is defined as a “psychological tendency that is expressed by evaluating a particular entity with some degree of favour or disfavour” (13). This definition indicates that attitudes: (1) are directed towards/at something; (2) are based on a tendency or disposition; and (3) they express a positive or negative evaluation (14).

Psychologists have identified three main components that contribute to an individual's attitude: cognition, affect and conation (13,14). Cognition refers to the particular beliefs or thoughts that a person may have towards a subject or object. For example, if a farmer believes that sheep are intelligent, and that sheep can be easily trained to a routine, these beliefs may suggest an underlying positive attitude towards working with sheep. The affect component refers to the feelings that a person may have to a subject or object. For instance, a farmer that enjoys working with sheep and feels rewarded from his job may reflect an underlying positive attitude. Finally, the conation component refers to the way a person may act or behave towards a subject or object. For instance, a farmer who regularly monitors his flock and treats sick animals promptly may also indicate a positive attitude towards working with sheep.

Cognition, affect and conation are all interrelated. This means that the beliefs that people hold, when combined with their evaluations of those beliefs lead to the formation of attitudes. This means that measuring any of these three components contribute to an understanding of a person's attitude (15). Attitudes cannot be measured directly, but they can be indirectly measured by assessing a person's responses to several statements in, for example, a questionnaire (14). Such statements should be designed to measure one or more of the three components mentioned above, a person's belief towards a subject (cognition), a person's emotional response to the object (affect) and/or the way a person may act or behave towards an object (conation) (14).

The relationship between farmer attitudes and management behaviour

In recent years, a few studies have assessed the relationship between sheep farmer attitudes and management behaviour. A study by Kiliç and Bozkurt (2013) found that farmers with high welfare perceptions provided better shelter conditions for their sheep and had better-trained personnel when compared with farmers with lower welfare perceptions. Findings from Jack et al. (2017) indicated that improving farmer attitudes and knowledge of nematode control may influence the adoption of best practice on Scottish farmers, and a study in the UK by O'Kane et al. (2017) reported that an increased risk of sheep lameness was associated with negative emotions of farmers and feeling of hopelessness towards footrot. While these studies relied mostly on self-reported information, they support the hypothesis that farmer attitudes are likely to reflect their management behaviour.

The relationship between beliefs, attitudes and behaviours

While attitudes influence intention and behaviour, beliefs influence attitudes (18). A major conceptualisation of the relationship between beliefs, attitudes and behaviours came with the Theory of Reasoned Action (18). This theory proposes that the beliefs a person holds regarding a particular behaviour (behavioural beliefs) and the social pressure to perform the behaviour in question (normative beliefs) form a person's attitudes and their subjective norms, which in turn, determines their intention and behaviour (19). The basis of the Theory of Reasoned Action is that intention predicts behaviour. Thus, as long as there are no constraints, such as external forces preventing the behaviour, a person is likely to perform the behaviour in question.

The main limitation of this theory is that intention does not always translate into behaviour (19). To address this, the concept of perceived behavioural control was developed to expand upon the existing Theory of Reasoned Action. From this emerged The Theory of Planned Behaviour (TPB) (19,20). The concept of perceived behavioural control refers to the ease or difficulty that a person anticipates regarding the performance of a behaviour. A person considers control beliefs, such as previous experience and perceived obstacles, to assess his/her control over performing a certain behaviour. The TPB does not account for the degree of actual control that a person may have over performing a behaviour, rather how perceived control influences their actions (21). The relationship between beliefs, behavioural attitudes, subjective norms, perceived behavioural control, intentions and behaviour is illustrated in Figure 1.2.

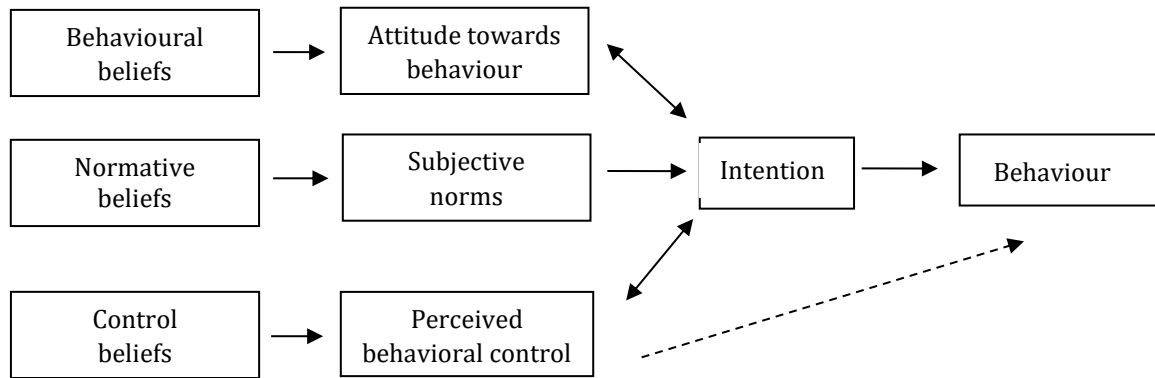


Figure 1. 2 The Theory of Planned Behaviour redrawn from Schifter and Ajzen (1985)

An important consideration is that behavioural, normative and control beliefs are formed during a person's life. A person may have learned these beliefs through personal experience, interactions with others or exposure to information through school, television, radio, etc (14,19). Therefore, these beliefs can be changed by exposure to new information and experiences relevant to the behaviour in question, meaning that human behaviour can be modified (22–24).

The human-animal relationship

The human-animal relationship in livestock production

Research in a number of livestock industries has demonstrated that behavioural beliefs, normative beliefs and control beliefs, form human attitudes which determine intention and influence human behaviour (interactions, husbandry and management behaviour). This, in turn, has implications for animal behaviour, productivity and welfare (25–31). The Human-Animal Relationship (HAR) model developed by Hemsworth and Coleman (2011) is a major conceptualisation of these relationships. It is based on the Theory of

Planned behaviour and describes the influence of human-animal interactions on the productivity and welfare of intensively managed animals (Figure 1.3).

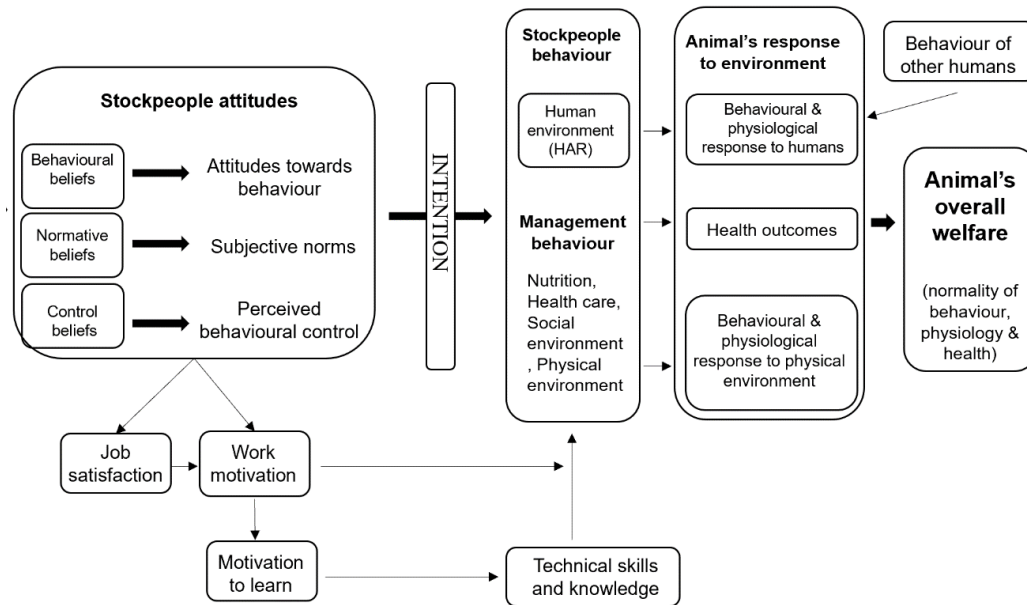


Figure 1. 3 The Human-Animal relationship model based on the Theory of Planned Behaviour redrawn from (Hemsworth, Sherwen and Coleman, 2018).

Human-animal relationships are formed by the type (positive, neutral or negative) and extent of interactions between humans and animals, as well as the context in which they occur (14,33–35). According to the HAR model, the human component of this relationship involves both behavioural and psychological aspects. From the human perspective, the human-animal relationship can be measured by assessing how people interact with an animal and their attitudes about a specific behaviour or the animal in question. Indeed, one of the most important factors to measure is human attitudes, as attitude is the most robust influence on human behaviour (12,18,20). While factors such as gender, previous experience, culture, working environment, motivation, technical skills, knowledge and job satisfaction also play an important role on these relationships, these factors have an

indirect influence on intention and motivation (14,33,36). From the animal perspective, the human-animal relationship can be measured by assessing behavioural and physiological responses to humans such as flight distance and cortisol levels (25,26,29,37). Previous studies have also assessed body condition, presence of lesions, diseases and lameness in recreational horses (38), as well as the animal's productive performance e.g. milk yield in dairy cows (31,39,40).

As reviewed by Waiblinger et al. (2006), there is a vast amount of research demonstrating the sequential relationships between human attitudes and behaviour and animal welfare (26,28–31,33,39,41,42). For instance, negative attitudes and unpleasant handling by stockpeople (e.g. brief shocking or brief slapping) increase the levels of fear and stress while also reducing the productivity of growing and breeding pigs (23,25,27,43), laying hens (29), and dairy cattle (31,40). If negative interactions between human and animals are sustained over time, a negative feedback cycle may be established meaning that stockperson behaviour worsens and the animal's fear of humans increases (34).

The fact that relationships have been observed between human attitudes, behaviour, and animal welfare indicates the opportunity to improve animal welfare by modifying the beliefs underpinning human behaviour. Examples of this include research in the pig and dairy industries, which have demonstrated that intervention strategies targeting the key attitudes and behaviour of stockpeople are suitable strategies to motivate practice change and improve the productivity and welfare of farm animals (22–24).

The human-animal relationship in extensive sheep farming systems

The sequential relationships between human behaviour and animal welfare have been successfully demonstrated in a number of intensively managed animals, where there are many opportunities for human-animal interactions to arise (21,23,28,31). In sheep, however, there is limited information about these relationships. A study by Hemsworth et al. (2011) observed significant correlations between stockperson attitudes and behaviour at sheep abattoirs. In this study, it was found that control beliefs (e.g. perceived time constraints and perceived effect of poor facilities) were associated with frequent forceful handling behaviours by the stockperson. A follow-up study by the same authors identified several significant correlations between stockperson behaviour and sheep behaviour (45). The authors identified that whistles, touches and pushes by stockpeople were associated with increased head down and cortisol concentrations in sheep.

More recently, it has been reported that negative stockperson behaviours such as fast locomotion and lifting/pulling lambs, along with dog behaviour such as lunging and barking at the lambs, predicted variables of stress and metabolic change (glucose and lactate) post slaughter (46). All these studies support the well demonstrated sequential relationships of stockpeople attitudes on handling behaviour and the effect of handling on fear and stress responses in livestock. While the aforementioned studies were conducted on sheep, they were conducted post-farm gate and during intensive handling situations where there are many opportunities for human-animal interactions to occur. The understanding of these relationships is important to develop adequate training programs to stockpeople (22,24), however, a better understanding of how these relationships are formed at the farm level is needed as this information has the potential

to create a broader impact on sheep welfare. If farmer attitudes determine farmer behaviour, on-farm welfare issues may potentially be reduced by creating change in the beliefs, attitude and subsequent behaviour of sheep farmers.

To the best of the author's knowledge, there are no studies on the human-animal relationship in extensive sheep farming conditions, where the human: sheep ratio is low and human-animal interactions are infrequent (47,48). The limited human contact observed in extensive systems means that there are fewer opportunities for sheep to get habituated to human presence and actions (47,49). This also means that there are fewer opportunities for a positive human-animal relationship to develop. When interactions do happen, a number of stressful husbandry procedures occur, which may include: vaccination, shearing, castration, tail docking and ear tagging (50). All these practices required mustering and individual handling, which can largely increase fear and stress in sheep. With this in consideration, two main questions arise 1) how do farmer-sheep relationships develop in extensive systems if there are limited opportunities for human-animal interactions? and 2) Do farmer attitudes influence the welfare of extensively managed sheep? Assessing farmer attitudes to sheep welfare and management behaviour along with an objective welfare assessment may help to understand if these sequential relationships are also formed in extensive systems.

This thesis used the Human-Animal Relationship Model (HAR) developed by Hemsworth and Coleman (2011) to examine the relationships between farmer attitudes and sheep welfare. This approach is in agreement with a number of studies conducted in intensively managed animals.

Conclusions

Farmers are key players in improving sheep welfare. Thus, a better understanding of why practices aimed at increasing welfare and productivity are not being widely adopted is important. The scientific literature indicates that farmers attitudes may influence both their handling and management behaviour. However, more extensive research is required to better understand the farmer-sheep relationship in extensive systems and whether farmer attitudes influence the welfare of their sheep. By understanding the underlying beliefs that underpin farmer behaviour, as well as main barriers for adoption to best practice, it will be possible to create a broad industry impact. If farmer attitudes towards sheep welfare and management practices determine farmer management behaviour, the welfare concerns observed in extensively managed ewes may potentially be reduced by creating change in the beliefs, attitude and subsequent behaviour of sheep farmers.

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Chapter 2: Ewe welfare protocol development

To achieve the aim of this thesis, it was first necessary to develop a valid, reliable and practical welfare assessment for extensively managed ewes, as a protocol that suited the extensive Australian environment was not available. Chapter 2 comprises two published papers describing the methodology of the welfare assessment protocol developed for extensively managed sheep. This component of the thesis was conducted on one flock of 100 ewes that were individually identified and assessed during mid-pregnancy, mid-lactation and weaning.

This first part of chapter 2 has been published as:

Munoz C, Campbell A, Hemsworth P, Doyle R. Animal-Based Measures to Assess the Welfare of Extensively Managed Ewes. *Animals*. Multidisciplinary Digital Publishing Institute; 2017;8: 2. doi:10.3390/ani8010002



Article

Animal-Based Measures to Assess the Welfare of Extensively Managed Ewes

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Received: 31 October 2017; Accepted: 19 December 2017; Published: 24 December 2017

Simple Summary: The aim of this study was to assess the reliability and practicality of 10 animal-based welfare measures for extensively managed ewes, which were derived from the scientific literature, previous welfare protocols and through consultation with veterinarians and animal welfare scientists. Measures were examined on 100 Merino ewes, which were individually identified and repeatedly examined at mid-pregnancy, mid-lactation and weaning. Body condition score, fleece condition, skin lesions, tail length, dag score and lameness are proposed for on-farm use in welfare assessments of extensive sheep production systems. These six welfare measures, which address the main welfare concerns for extensively managed ewes, can be reliably and feasibly measured in the field.

Abstract: The reliability and feasibility of 10 animal-based measures of ewe welfare were examined for use in extensive sheep production systems. Measures were: Body condition score (BCS), rumen fill, fleece cleanliness, fleece condition, skin lesions, tail length, dag score, foot-wall integrity, hoof overgrowth and lameness, and all were examined on 100 Merino ewes (aged 2–4 years) during mid-pregnancy, mid-lactation and weaning by a pool of nine trained observers. The measures of BCS, fleece condition, skin lesions, tail length, dag score and lameness were deemed to be reliable and feasible. All had good observer agreement, as determined by the percentage of agreement, Kendall's coefficient of concordance (W) and Kappa (k) values. When combined, these nutritional and health measures provide a snapshot of the current welfare status of ewes, as well as evidencing previous or potential welfare issues.

Keywords: animal-based indicators; animal welfare; kappa statistics; observer agreement; on-farm welfare assessment; sheep

1. Introduction

On-farm welfare assessments can be used for immediate or ongoing on-farm monitoring and benchmarking by farmers and veterinarians, and to demonstrate compliance with national and international legal welfare standards and farm assurance schemes [1,2]. For welfare assessments to be effective and acceptable to all key stakeholders (i.e., industry, animals, scientists, consumers and society), they must incorporate welfare measures that are meaningful with respect to animal welfare, provide repeatable outcomes when applied by different observers and practical under farm conditions; that is they must be valid, reliable and feasible [2,3]. Welfare measures can be classified into categories that assess housing and facilities (resource-based measures), farmer policies and management strategies (management-based measures), and direct animal observations (animal-based measures) [4,5]. Animal-based measures often reflect the outcome of resource inputs and management

practices, and therefore there is increasing interest to incorporate these measures in welfare assessments, as they provide an integrative and direct measurement of the welfare state of animals [6–8]. Some examples of animal-based measures include the assessment of the nutritional state (e.g., body condition score), environmental conditions (e.g., fleece cleanliness) and diseases (e.g., lameness). Welfare measures, however, cannot automatically be extrapolated from one species to another [3].

Welfare challenges differ depending of the species, production system, reproduction cycle and geographical location [9–11]. The unique characteristics and welfare challenges of extensive sheep systems highlights the importance of the development of reliable and feasible welfare measures that can be able to detect current welfare problems and risk of future welfare compromise. For instance, the nature of extensive systems, where sheep are managed in large flocks and outdoor all year, makes adequate monitoring, treatment and prevention of diseases more difficult to address. Extensively managed sheep are more exposed to predators and variation in climatic conditions. Variation in food quality and availability during the year leads to changes in body condition, which highlights the importance of measures that can be able to detect these differences. Body condition is widely accepted as a valid and important welfare measure that reflects the nutritional state of sheep [12,13], but discrepancies exist in the literature on the scoring scales and the precision needed (full-unit, half-unit or quarter-unit) to provide meaningful results on the nutritional status of sheep [13–15]. In Australia for example, flystrike (cutaneous myiasis) is a main welfare concern, and therefore, it is important to have sensible measures that can identify the risk of this disease. Larsen et al. [16] developed a detail 6-point scale to assess dags, lump matted faecal material hanging from the wool, and although this scoring system has been proved to be effective in assessing the risk of flystrike, it has not been tested for reliability and practicality to be included in welfare assessments. Previously, sheep have received considerably less attention in the development of welfare measures when compared with animals farmed intensively such as pigs, poultry and dairy cattle. Furthermore, most of the research has been conducted in European countries [10,13,15,17,18], where sheep are managed in small flocks and usually in more intensive, indoor-lambing systems [2]. The aim of the present study was to test the reliability and feasibility of some animal based measures for sheep welfare assessment. We hypothesized that some measures previously identified may not be reliable or feasible for sheep managed under extensive farming conditions.

2. Materials and Methods

2.1. Animals and Management

This study is part of a longitudinal on-farm study that was performed in Victoria, Australia between July and December, 2015 [19]. This study was approved by the University of Melbourne ethics committee (ethical review number 1513562.1). A total of 100 Merino ewes, aged 2–4 years, from a large flock of approximately 3000 breeding ewes were individually identified by a unique ear tag number and repeatedly examined at three-time points: Mid-pregnancy (MP; July), mid-lactation (ML; October) and weaning (WN; December). These periods were selected because they are known to be critical times affecting ewe welfare [15,18]. The ewes were managed under extensive conditions, in a year-round outdoor system, grazing annual/perennial pastures, and managed under commercial conditions. The ewe sample size was selected based on a power calculation assuming 50% prevalence of the trait under observation (the proportion requiring the greatest sample size when observing binomial traits), a 95% confidence interval and precision of $\pm 10\%$. This number was supported by the AWIN sheep protocol which recommends a sample of 92 animals when the farm size is ≥ 2000 breeding ewes [10].

2.2. Animal-Based Welfare Measures

The animal-based measures examined in this study were selected after a review of the relevant literature and consultations with veterinarians and animal welfare scientists. The measures selected were: Body condition score (BCS) [14,20–22], rumen fill [23,24], fleece cleanliness [10], fleece

condition [10], skin lesions [10], tail length [25,26], dag score [16], foot-wall integrity [27–29], hoof overgrowth [27–29] and lameness [10]. They were considered valid on the basis that they have been shown to have validity in previous studies, further details are reported in Munoz et al. [19]. The measures selected address main welfare concerns for sheep, covering freedom from hunger, pain, injury or disease. The assessment criteria of the welfare measures are listed in Table 1.

Table 1. Animal-based welfare measures used to assess the welfare of extensively managed ewes.

Measure	Assessment Criterion
Body condition score	Scored on a 5 point scale from 1 (thin) to 5 (obese), using a quarter-unit precision [14,21]. Sheep were assessed by palpation of the backbone, muscle and short ribs [20,22].
Rumen fill	Scored on a 2 point scale: (0) If the animal's left-hand side is not sunken/or is convex between the hip bone and the ribs and (1) if the animals' left-hand side is deeply sunken between the hip bone and the ribs [23,24].
Fleece cleanliness	Scored on a 4 point scale: (0) Clean and dry (1) dry with slight mud/dirt (2) Wet with some areas contaminated by mud or dung (3) Filthy, very wet and coated in mud or dung [10].
Fleece condition	Scored on a 3 point scale: (0) Good fleece condition, when parted, the fleece has no scurf or lumpiness or signs of ectoparasites (1) some fleece loss, small shed or bald patches of no more than 10 cm diameter. When parted, the fleece may have some lumpiness or scurf, little evidence of ectoparasites, and (2) significant fleece loss with bald patches of greater than 10 cm in diameter, clear evidence of ectoparasites [10].
Skin lesions	Assessed by recording number, location and severity of the skin lesions. Lesions were classified as cuts, open wounds, old wounds or scars and abscesses [10].
Tail length	Scored on a 2 point scale: (0) The tip of the vulva is covered by the tail when held down (1) the tail is over-shortened or almost not present, or if the vulva and anus cannot be covered [25,26].
Dag score	Scored on a 6 point scale: (0) No evidence of fecal soiling, (1) very light soiling on the breech area, (2) moderate dag on the breech area extending ventrally, (3) severe dag predominantly on the breech area, extending ventrally and dorsally over the tail some soiling and dag around anus, (4) excessive dag on the breech area and on the hind legs (5) Very severe dag on the breech area and on the hind legs or below the level of the hocks [16].
Foot-wall integrity	Scored on a 4 point scale: (0) An undamaged wall, (1) 25% or less damaged wall (2) moderately damaged wall (from 25% to 75%), (3) severely damaged wall (>75%) [27–29].
Hoof overgrowth	Scored on a 3 point scale: (0) Appropriate length of the hoof and perfect shape of the wall area, (1) moderately misshapen/overgrowth, (2) a severely misshapen/overgrowth [27–29]
Lameness	Scored on a 4 point scale: (0) Not lame, (1) clear shortening of stride with obvious head nodding or flicking as the affected limb touches the floor, (2) clear shortening of stride with obvious head nodding and not weight-bearing on affected limb whilst moving, (3) reluctant to stand or move [10].

2.3. Welfare Assessment of the Ewes

The assessment of the ewes was always conducted between 900 h and 1600 h. To perform the assessment, and for practical reasons, the ewes were managed in four groups of 25 animals. The first nine measures, BCS, rumen fill, fleece cleanliness, fleece condition, skin lesions, tail length, dag score, foot-wall integrity and hoof overgrowth, were assessed in a single-file race within the farm's regularly-used sheep yards. The ewes were then released from the race (in small groups of 2 to 4 animals) and encouraged to walk to assess lameness. Feasibility of the assessment was measured by timing the assessment at each time-point, evaluating the resources required and the ability to collect these measurements across different farms. The advice of farm consultants, veterinarians and animal welfare scientists was also considered.

2.4. Observers and 'Test Standard Observer'

A pool of nine observers from the University of Melbourne Veterinary and Agricultural Sciences Faculty (details provided in next paragraph) were recruited. Reliability was assessed by evaluating inter- and intra- observer agreement. Observer agreement was assessed in line with previous reliability studies [3,13,15,23]. Briefly, inter- observer agreement and pair agreement was calculated by referencing the score given by each observer against a 'test standard observer' (TSO, CM). This approach is

commonly used to assess if observers could be trained to apply a specific on-farm welfare assessment protocol and to identify any assessment bias [30,31]. To assess intra-observer reliability, the degree to which measurements taken by the same observer are consistent, all sheep were reassessed by the observers within a 15-day period in MP, and within a 24h period at both ML and WN. In an effort to maintain objectivity, observers did not have access to health or production records of the farm before performing the welfare assessment.

Observer 1 (CM), a veterinarian that developed the list of measures and provided training to all observers was nominated as the TSO. Observer 2 was a research assistant with 25 years of experience in working with sheep and classed as experienced assessor. Observers 4 and 7 were veterinarians classed as mid-experienced observers, and observers 3, 5, 6, 8 and 9 were graduate animal science students, classed as inexperienced observers. From the pool of nine observers, combinations of four observers performed the assessments on each observation period, and the TSO performed the assessment in all the observation periods. This approach was taken because it was difficult to have all the observers in all the farm visits.

Prior to individual assessments, observers were provided with an assessment protocol, containing details of the scoring scales and pictures. In addition, an on-farm training session was provided using 20 ewes at MP, and this training lasted for about 30 min, 25 ewes were used for training at ML, and this training lasted for about 1 h, and 30 ewes were used at WN and this training lasted for about 1 h 30 min. The animals used for training purposes were not included in the analyses. Thereafter, each observer independently evaluated the first nine measures on each sheep. Observers were placed in different locations of the race and were not allowed to exchange their observations. After the assessment in the race, ewes were encouraged to walk to detect lameness. For practical reasons, all the observers assisted with the identification of lame animals. One person was required to move the sheep along the race, another person was required to manipulate the gate at the end of the race and two persons were required to catch the lame sheep for individual identification. Therefore, only intra-assessment agreement was assessed for lameness.

2.5. Statistical Analysis

Data analysis was performed using SAS statistical package (Statistical Analysis System, Release 9.4 2012; SAS Institute Inc., Cary, NC, USA). The welfare scoring scales consisted of categorical, ordinal (BCS, fleece cleanliness, fleece condition, skin lesions, dag score, foot-wall integrity, hoof overgrowth and lameness) and binary data (rumen fill and tail length). For ordinal scores, Kendall's coefficient of concordance (W) was used to assess overall observer agreement [32]. The scale used to assess agreement was as follows: a value of 0 indicates no agreement, from 0.10 to 0.40 poor agreement, 0.41 to 0.70 moderate, 0.71 to 0.90 substantial, 0.91 to 0.99 almost perfect and 1 perfect agreement. Pair-agreement, agreement between individual observers and the TSO, were assessed by the percentage of agreement; Kendall's W and the weighted kappa statistic (Kw). For binary scores, Fleiss's Kappa (k) [33] and Cohen's kappa (k) were used to assess overall observer agreement and pair-agreement respectively. All k results were interpreted according to Landis and Koch [34], therefore values ≤ 0.40 suggested 'poor' agreement, values from 0.41 to 0.60 suggested 'moderate' agreement, values ranging from 0.61 to 0.80 suggested 'substantial' agreement, and values ≥ 0.81 suggested 'almost perfect' agreement.

In addition, one-way ANOVA analysis was used to examine differences in the 'time spent assessing the ewes' between mid-pregnancy, mid-lactation and weaning. Multiple comparisons between means were performed using Fisher's Least Significant Difference (LSD) test.

3. Results

A total of five ewes were lost from the study period, with three ewes dying at lambing (reported dead by the farmer) and two presumed dead, which resulted in different numbers of ewes examined across the three-time points: Mid-pregnancy $n = 100$, mid-lactation $n = 96$ and weaning $n = 95$.

3.1. Inter- and Intra-Observer Agreement at Mid-Pregnancy

At mid-pregnancy, there was ‘almost perfect’ overall observer agreement for fleece cleanliness and fleece condition, ‘moderate’ agreement was found for BCS, skin lesions, foot-wall integrity and hoof overgrowth, and ‘poor’ agreement for rumen fill, and tail length (Table 2). In the same way, pair agreement was higher for fleece cleanliness and fleece condition, while BCS, rumen fill and tail length presented the lowest. Overall, the TSO and observer 2, the most experienced observer, had better percentage of pair-agreement for most of the measures compared to the results obtained by the TSO against observers 3 and 4, the less experienced observers. Results for intra-observer agreement are presented in Table 3. Overall, fleece cleanliness and fleece condition were the most repeatable measures. Dag score, foot wall-integrity and hoof overgrowth had moderate repeatability, while BCS and skin lesions had the lowest. Observer 1 and 2 showed the highest levels of repeatability for most of the measures compared to the other observers as determined by W and k values. Lameness was not assessed for intra-observer agreement because all the observers assisted with the identification of lame animals, but showed moderate intra-assessment agreement $W = 0.53$. According to the observers, rumen fill was the least feasible measures followed by foot-wall integrity and hoof overgrowth. Based on this, rumen fill was not included in the subsequent visits and therefore intra- observer agreement was not assessed.

Table 2. Overall observer agreement (OA), percentage of agreement (%) and pair agreement at mid-pregnancy.

Measures	OA (W)	Pair Agreement				
		Observer Identity	%	Kendall's (W)	Weighted Kappa (95% CI)	Interpretation (W/Kw)
BCS	0.60	2	30	0.78	0.38 (0.28–0.54)	Substantial/poor
		3	24	0.74	0.30 (0.16–0.38)	Substantial/poor
		4	23	0.71	0.25 (0.09–0.33)	Substantial/poor
Rumen fill	0.14 *	2	73	n/a	0.12 ** (−0.11–0.32)	Poor
		3	70	n/a	0.13 ** (−0.08–0.34)	Poor
		4	75	n/a	0.31 ** (0.09–0.47)	Poor
Fleece cleanliness	1.00	2	100	1.00	1.00 (1.00–1.00)	Perfect agreement
		3	100	1.00	1.00 (1.00–1.00)	Perfect agreement
		4	100	1.00	1.00 (1.00–1.00)	Perfect agreement
Fleece condition	1.00	2	100	1.00	1.00 (1.00–1.00)	Perfect agreement
		3	100	1.00	1.00 (1.00–1.00)	Perfect agreement
		4	100	1.00	1.00 (1.00–1.00)	Perfect agreement
Skin lesions	0.41	2	98	0.50	0.66 (0.65–0.67)	Moderate
		3	99	0.83	0.66 (0.04–1.00)	Substantial/moderate
		4	99	0.69	0.39 (−0.17–0.93)	Moderate/poor
Tail length	0.35 *	2	86	n/a	0.38 ** (0.14–0.64)	Poor
		3	77	n/a	0.28 ** (0.10–0.45)	Poor
		4	71	n/a	0.28 ** (0.10–0.45)	Poor
Dag score	0.70	2	77	0.81	0.59 (0.43–0.72)	Substantial/moderate
		3	76	0.77	0.52 (0.37–0.66)	Substantial/moderate
		4	74	0.83	0.62 (0.48–0.76)	Substantial/moderate
Foot-wall integrity	0.44	2	90	0.68	0.47 (−0.15–1.00)	Moderate
		3	97	0.50	0.21 (−0.15–0.57)	Moderate/poor
		4	95	0.57	0.55 (0.20–0.90)	Moderate
Hoof overgrowth	0.65	2	91	0.84	0.66 (0.51–0.80)	Substantial/moderate
		3	79	0.75	0.50 (0.33–0.68)	Substantial/moderate
		4	66	0.63	0.43 (0.27–0.60)	Moderate

* Inter-observer agreement for nominal measures determined by Fleiss's Kappa (k); ** Pair-agreement with the test standard observer for nominal measures determined by Cohen's Kappa (k).

Table 3. Intra-observer agreement at mid-pregnancy.

Measures	Observer Identity	W	Kw	Interpretation (W/Kw)
BCS	1	0.68	0.22	Moderate/poor
	2	0.80	0.31	Substantial/poor
	3	0.61	0.10	Moderate/poor
	4	0.68	0.20	Moderate/poor
Fleece cleanliness	1	1.00	1.00	Perfect agreement
	2	1.00	1.00	Perfect agreement
	3	1.00	1.00	Perfect agreement
	4	1.00	1.00	Perfect agreement
Fleece Condition	1	1.00	1.00	Perfect agreement
	2	1.00	1.00	Perfect agreement
	3	1.00	1.00	Perfect agreement
	4	1.00	1.00	Perfect agreement
Skin lesions	1	0.49	0.48	Moderate
	2	1.00	1.00 **	Perfect agreement
	3	0.49	−0.01 **	Moderate/poor
	4	0.48	0.56 **	Moderate
Dag score	1	0.63	0.37	Moderate/poor
	2	0.64	0.39	Moderate/poor
	3	0.63	0.43	Moderate
	4	0.6	0.45	Moderate
Foot-wall Integrity	1	0.64	0.37	Moderate/poor
	2	0.58	0.39	Moderate/poor
	3	0.50	0.43	Moderate
	4	0.59	0.45	Moderate
Hoof overgrowth	1	0.79	0.57	Substantial/moderate
	2	0.78	0.50	Substantial/moderate
	3	0.83	0.59	Substantial/moderate
	4	0.72	0.44	Substantial/moderate

** Pair-agreement for nominal measures determined by Cohen's Kappa (k). Intra-observer agreement was done within a 15-day period.

3.2. Inter- and Intra-Observer Agreement at Mid-Lactation

At mid-lactation, 'substantial' to 'almost perfect' overall agreement was found for fleece cleanliness, fleece condition, BCS and skin lesions. 'Moderate' overall agreement was found for dag score, foot-wall integrity and hoof overgrowth, while tail length showed the lowest agreement (Table 4). Similarly, pair agreement was higher for fleece cleanliness, fleece condition and skin lesions. 'Moderate' to 'substantial' pair agreement was obtained for BCS and dag score while tail length, foot-wall integrity and hoof overgrowth presented the lowest showing from 'poor' to 'substantial' pair agreement. The results of the intra-observer agreement are present in Table 5. Overall, fleece cleanliness, fleece condition, skin lesions and dag score were the most repeatable measures followed by BCS and tail length, while foot-wall integrity and hoof overgrowth presented the lowest levels of repeatability. The TSO showed the highest levels of repeatability for most the measures, and her repeatability increased at mid-lactation when compared to mid-pregnancy, particularly for the measures BCS and dag score that increased from 'moderate/poor' to 'substantial/moderate' agreement. The intra-assessment agreement of lameness increased to 'substantial' W = 0.79.

Table 4. Overall observer agreement (OA), percentage of agreement (%) and pair agreement at mid-lactation.

Measures	OA (W)	Pair Agreement				
		Observer Identity	%	Kendal's (W)	Weighted Kappa (95% CI)	Interpretation (W/Kw)
BCS	0.74	2	48	0.85	0.55 (0.53–0.76)	Substantial/moderate
		5	23	0.83	0.41 (0.29–0.50)	Substantial/moderate
		6	26	0.85	0.45 (0.36–0.55)	Substantial/moderate
Fleece cleanliness	1.00	2	100	1.00	1.00 (1.00–1.00)	Perfect agreement
		5	100	1.00	1.00 (1.00–1.00)	Perfect agreement
		6	100	1.00	1.00 (1.00–1.00)	Perfect agreement
Fleece condition	0.75	2	98	0.83	0.66 (0.04–1.00)	Substantial
		5	100	1.00	1.00 (1.00–1.00)	Perfect agreement
		6	100	1.00	1.00 (1.00–1.00)	Perfect agreement
Skin lesions	0.99	2	100	1.00	1.00 (1.00–1.00)	Perfect agreement
		5	100	1.00	1.00 (1.00–1.00)	Perfect agreement
		6	100	1.00	1.00 (1.00–1.00)	Perfect agreement
Tail length	0.18 *	2	97	n/a	−0.01 ** (−0.03–0.00)	Poor
		5	97	n/a	−0.01 ** (−0.03–0.01)	Poor
		6	97	n/a	−0.01 ** (−0.03–0.01)	Poor
Dag score	0.69	2	65	0.87	0.62 (0.49–0.76)	Substantial
		5	64	0.85	0.47 (0.34–0.61)	Substantial/moderate
		6	63	0.77	0.40 (0.24–0.55)	Substantial/poor
Foot-wall integrity	0.45	2	96	0.65	0.75 (0.44–1.00)	Moderate/substantial
		5	86	0.60	0.32 (−0.18–0.81)	Moderate/poor
		6	94	0.47	0.53 (−0.02–1.00)	Moderate
Hoof overgrowth	0.56	2	66	0.80	0.48 (0.31–0.64)	Substantial/moderate
		5	66	0.75	0.30 (0.22–0.48)	Substantial/poor
		6	40	0.79	0.27 (0.10–0.36)	Substantial/poor

* Inter-observer agreement for nominal measures determined by Fleiss's Kappa (k); ** Pair-agreement with the test standard observer for nominal measures determined by Cohen's Kappa (k).

Table 5. Intra-observer agreement at mid-lactation.

Measures	Observer Identity	W	Kw	Interpretation (W/Kw)
BCS	1	0.87	0.57	Substantial/moderate
	2	0.79	0.49	Substantial/moderate
	5	0.76	0.37	Substantial/poor
	6	0.62	0.22	Moderate/poor
Fleece cleanliness	1	1.00	1.00	Perfect agreement
	2	1.00	1.00	Perfect agreement
	5	1.00	1.00	Perfect agreement
	6	1.00	1.00	Perfect agreement
Fleece Condition	1	1.00	1.00	Perfect agreement
	2	0.83	0.89	Substantial
	5	1.00	1.00	Perfect agreement
	6	0.75	0.78	Substantial
Skin lesions	1	0.83	0.66 **	Substantial
	2	0.75	0.49 **	Substantial/moderate
	5	0.83	0.66 **	Substantial
	6	0.69	0.49 **	Moderate
Tail length	1	n/a	0.58 **	Moderate
	2	n/a	1.00 **	Perfect agreement
	5	n/a	0.50 **	Moderate
	6	n/a	0.02 **	Poor

Table 5. Cont.

Measures	Observer Identity	W	Kw	Interpretation (W/Kw)
Dag score	1	0.87	0.60	Substantial/moderate
	2	0.85	0.61	Substantial
	5	0.90	0.67	Substantial
	6	0.70	0.32	Substantial/poor
Foot-wall Integrity	1	0.73	0.65	Substantial
	2	0.62	0.31	Moderate/poor
	5	0.54	0.21	Moderate/poor
	6	0.48	0.30	Moderate/poor
Hoof overgrowth	1	0.77	0.49	Substantial/moderate
	2	0.74	0.39	Substantial/poor
	5	0.79	0.55	Substantial/moderate
	6	0.60	0.13	Moderate/poor

** Pair-agreement for nominal measures determined by Cohen's Kappa (k). Intra-observer agreement was done within a 24 h period.

3.3. Inter- and Intra-Observer Agreement at Weaning

At weaning, most of the welfare measures presented from 'moderate' to 'almost perfect' overall agreement (Table 6). 'Almost perfect' pair agreement was obtained for fleece cleanliness, fleece condition and skin lesions. Body condition score, dag score and hoof overgrowth ranged from 'poor-moderate' to 'almost perfect' pair agreement. Foot-wall integrity and tail length had the lowest pair agreement, however k values for tail length ranged from 0.22 ('poor') to 1.00 ('almost perfect'). The intra-observer agreement results are presented in Table 7. The most repeatable measures at weaning were fleece cleanliness, fleece condition, skin lesion and BCS followed by dag score and tail length. The least repeatable measures were foot-wall integrity and hoof overgrowth. The intra-assessment agreement of lameness also increased significantly at weaning showing substantial levels of repeatability $W = 0.86$. The TSO showed the highest levels of repeatability, and her repeatability increased significantly, particularly for BCS, dag score and tail length which increased from 'substantial/moderate' at mid-lactation to 'substantial/almost perfect' at weaning.

Table 6. Overall observer agreement (OA), percentage of agreement (%) and pair agreement at weaning.

Measures	OA (W)	Pair Agreement				
		Observer Identity	%	Kendall's (W)	Weighted Kappa (95% CI)	Interpretation (W/Kw)
BCS	0.80	7	38	0.90	0.63 (0.54–0.72)	Almost perfect/substantial
		8	39	0.88	0.59 (0.48–0.70)	Substantial/moderate
		9	31	0.86	0.39 (0.27–0.50)	Substantial/poor
Fleece cleanliness	1.00	7	100	1.00	1.00 (1.00–1.00)	Perfect agreement
		8	100	1.00	1.00 (1.00–1.00)	Perfect agreement
		9	100	1.00	1.00 (1.00–1.00)	Perfect agreement
Fleece condition	0.93	7	90	0.88	0.60 (0.41–0.80)	Substantial/moderate
		8	99	0.96	0.88 (0.73–1.00)	Almost perfect
		9	99	0.92	0.88 (0.71–1.00)	Almost perfect
Skin lesions	0.96	7	99	0.96	0.92 (0.76–1.00)	Almost perfect
		8	100	1.00	1.00 (1.00–1.00)	Perfect agreement
		9	99	0.96	0.92 (0.76–1.00)	Almost perfect
Tail length	0.49 *	7	97	n/a	0.65 ** (0.29–1.00)	Substantial
		8	100	n/a	1.00 ** (1.00–1.00)	Perfect agreement
		9	94	n/a	0.22 ** (–0.19–0.62)	Poor

Table 6. Cont.

Measures	OA (W)	Pair Agreement				
		Observer Identity	%	Kendall's (W)	Weighted Kappa (95% CI)	Interpretation (W/Kw)
Dag score	0.68	7	79	0.75	0.35 (0.22–0.48)	Substantial/poor
		8	90	0.83	0.53 (0.40–0.65)	Substantial/moderate
		9	87	0.83	0.52 (0.39–0.64)	Substantial/moderate
Foot-wall integrity	0.52	7	92	0.63	0.43 (0.07–0.79)	Substantial/moderate
		8	92	0.83	0.64 (0.36–0.93)	Substantial
		9	93	0.68	0.37 (−0.03–0.76)	Substantial/poor
Hoof overgrowth	0.61	7	76	0.70	0.52 (0.37–0.67)	Substantial/moderate
		8	75	0.71	0.51 (0.36–0.65)	Substantial/moderate
		9	73	0.77	0.48 (0.32–0.64)	Substantial/moderate

* Inter-observer agreement for nominal measures determined by Fleiss's Kappa (k); ** Pair-agreement with the test standard observer for nominal measures determined by Cohen's Kappa (k).

Table 7. Intra-observer agreement at weaning.

Measures	Observer Identity	W	Kw	Interpretation (W/Kw)
BCS	1	0.90	0.64	Almost perfect/substantial
	7	0.87	0.56	Substantial/moderate
	8	0.87	0.58	Substantial/moderate
	9	0.85	0.59	Substantial/moderate
Fleece cleanliness	1	1.00	1.00	Perfect agreement
	7	1.00	1.00	Perfect agreement
	8	1.00	1.00	Perfect agreement
	9	1.00	1.00	Perfect agreement
Fleece Condition	1	0.92	0.88	Almost perfect
	7	0.91	0.65	Almost perfect/substantial
	8	0.86	0.74	Substantial
	9	0.77	0.69	Substantial
Skin lesions	1	0.86	0.82	Substantial/almost perfect
	7	0.95	0.90	Almost perfect
	8	0.86	0.71	Substantial
	9	0.90	0.65	Almost perfect/substantial
Tail length	1	n/a	0.80 **	Substantial
	7	n/a	0.54 **	Moderate
	8	n/a	0.80 **	Substantial
	9	n/a	0.18 **	Poor
Dag score	1	0.79	0.61	Substantial
	7	0.70	0.37	Substantial/poor
	8	0.65	0.41	Substantial/moderate
	9	0.76	0.48	Substantial/moderate
Foot-wall Integrity	1	0.79	0.58	Substantial/moderate
	7	0.48	0.23	Moderate/poor
	8	0.66	0.48	Moderate
	9	0.70	0.34	Substantial/poor
Hoof overgrowth	1	0.77	0.54	Substantial/moderate
	7	0.75	0.49	Substantial/moderate
	8	0.62	0.32	Moderate/poor
	9	0.63	0.33	Moderate/poor

** Pair-agreement for nominal measures determined by Cohen's Kappa (k). Intra-observer agreement was done within a 24 h period.

The welfare assessment of the ewes using 10 animal-based measures took from 4 to 6 h. No differences in the time spent assessing the ewes were found between mid-pregnancy and mid-lactation, means were 3.4 min/ewe (SD $\pm$ 0.63) and 4.1 min/ewe (SD $\pm$ 1.03) respectively. However, the time spent performing the assessment significantly decreased ($p = 0.001$) at weaning to 2.5 min/ewe (SD $\pm$ 0.56), Figure 1.

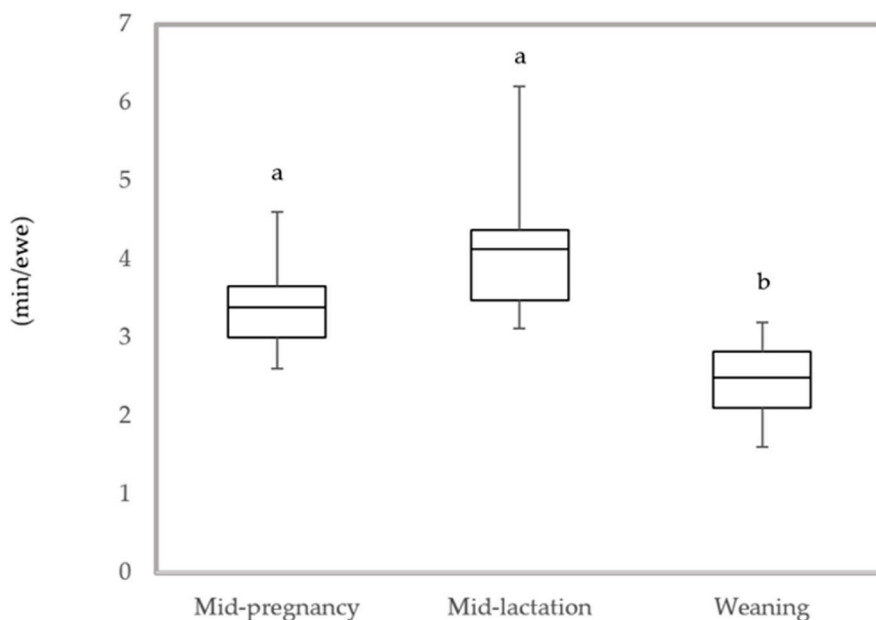


Figure 1. Time spent assessing the ewes (min/ewe) at mid-pregnancy, mid-lactation and weaning. Different letters indicate statistical difference ($p < 0.05$).

4. Discussion

This study assessed the reliability and feasibility of 10 animal-based welfare measures for extensively managed ewes. Body condition score, fleece condition, skin lesions, tail length, dag score and lameness are proposed for on-farm use in welfare assessments of extensive sheep production systems. These six valid measures address the main welfare concerns for ewes, and they are reliable and feasible. When combined, they provide an overview of the nutritional, health and welfare state of the ewes as well as evidencing previous or potential welfare concerns.

4.1. Reliability of the Animal-Based Welfare Measures

High inter- and intra- observer agreements, from ‘substantial/moderate’ to ‘substantial/almost perfect’ agreements, were found for BCS, fleece cleanliness, fleece condition, skin lesions, tail length, dag score and lameness. In the present study, BCS was the measure that increased the most, the inter-observer agreement and the intra-agreement of the TSO increased from ‘moderate’ at mid-pregnancy to ‘almost perfect’ at weaning. Body condition is widely accepted as a valid and important welfare measure that reflects the nutritional state of sheep [13,14]. Results in the present study suggests that a quarter-point scale is reliable, but that operators require sufficient training and experience to achieve high agreement in this measurement [27,35,36]. In this study, the experienced observers (TSO, observers 2 and 7) showed the highest agreement and repeatability for this measure. The increased training sessions and the clarification of the descriptive terms used may have help to achieved ‘almost perfect’ inter- and intra- observer agreement at the end of the study. Although individual differences, observer expertise and differences in intervals of reassessment (15-day period at MP vs. 24 h at ML and WN) may have influenced in the levels of agreement obtained, there is evidence that the level of observer agreement increases significantly when sufficient training is provided [13,18].

Rumen fill, foot-wall integrity and hoof overgrowth were the measures with lower agreement in this study. This is likely the result of difficulties associated with assessing these measures, e.g., presence of fleece and the fact that ewes often moved backwards and forwards along the race, which particularly affected how easily foot-wall integrity could be assessed. In addition, the scoring scales and the descriptive terms used for foot-wall integrity may have affected the levels of observer agreement. Simplifications of the scoring scales as well as clarification of the description terms may provide higher agreement and may be more useful for future on-farm assessments.

The performance of each welfare measure was evaluated in agreement with previous reliability studies [13,18,23,27]. Percentage of agreement was used as it provides an easy illustration of observer agreement. However, as this method does not estimate the amount of agreement that could occur by chance, Kendall's coefficient of concordance (W) and Kappa (k) were selected to statistically assess the inter and intra-observer agreement of ordinal and binominal measures. Care is needed however when interpreting k values, because they are affected by the prevalence of the condition under consideration. Populations with few animals presenting the condition of interest will provide very low values of k that may not necessarily reflect low levels of observer agreement [37]. In the present study, the length of the tail was a simple binominal scale and presented high percentage of agreement across the three-time points examined (MP: 71–86%; ML: 85–97%; WN: 96–100%). However, k values were consistently low; from 0.28 to 0.39 at MP, from −0.01 to 0.56 at ML and from 0.37 to 1.00 at WN. Discrepancies between the percentage of agreement and k values may be a consequence of the low number of animals that had adequate tail length in this study ($n = 8$, as determined by the TSO, while 92% $n = 87$ had short-docked tails at weaning), and may not necessarily mean low inter-observer agreement. It is possible that higher k values would have been achieved if more animals in this study had adequate tail length. Similar difficulties in the interpretation of k values have been reported in previous studies [23,37,38]. Other factors that need to be considered when evaluating reliability is intervals of reassessments. In the present study, low intra observer reliability at mid-pregnancy cannot be completely attributed to lack of consistency of the observers, as the length of the reassessment at this stage (15-day period) may have affected the levels of intra-observer agreement of dag score, skin lesions, foot-wall integrity and hoof overgrowth.

Overall, there is wide variation in the scientific literature on how reliability of welfare measures is assessed. Currently, there is no agreement on the number of animals, number of observers or the methodology that should be used. For instance, a reliability study in lambs used four observers to assess 966 lambs [23], a study of welfare assessment for adult sheep used two observers and 360 ewes [15], and studies assessing reliability on locomotion scoring in various species have used five observers and 83 cows [39], three observers and 30 video clips of sheep [40], and three observers and 80 photographs and videos of foot-rot lesions in sheep [27]. The sample size selected in the present study was based on a power calculation and recommendations by the AWIN sheep protocol [10], and the fact that the performance of the measures was tested on-farm during different stages of production of sheep further supports their reliability and applicability under farm conditions.

4.2. Feasibility of the Animal-Based Welfare Measures

Welfare measures need to be practical if they are to be valuable. Sheep farms in Australia can commonly have 12,000 animals, and they are usually managed by a single person [9,41]. This, highlights the need for feasible measures that can be taken in short periods of time with low need of resources and personnel as time and labor force are limited in extensive sheep systems. When assessing the feasibility of the measures of this study a variety of factors were considered such as time spent in the assessment, resources required and the ability to collect these measurements across different farms. Feasibility was assessed for a third party to perform the assessment, not a farmer. Generally, the measures tested proved to be feasible, requiring on average 2.5 min to assess an individual ewe at weaning. The significant decrease in the time spent in the assessment at weaning might have been influenced by individual differences of the observers, and familiarization with the scoring scales

and assessment protocol. Although no differences were found in the time spent assessing the ewes between mid-pregnancy and mid-lactation. Lactation was considered the least practical period due to the presence of lambs, which made sheep handling difficult during the assessment. This needs to be considered when deciding for key times to perform on-farm welfare assessments.

The most feasible measures were found to be BCS, fleece cleanliness, fleece condition, skin lesions, tail length, dag score and lameness. Clear advantages of these measures in terms of practicality are that no measures required specialized equipment; the only infrastructure required is a raceway, which is a common facility on sheep farms, and other than the labor required to bring the sheep into the yards, they do not interrupt farm management practices. It should also be considered that most farmers visually monitor their sheep in the paddock, rather than gathering them into the yards. In this context, it has been shown that some of these measures, e.g., thin body condition, lameness and dags can be examined from the distance during key stages of the production cycle [2,42] with minimal interference with farm work. Thus, the measures selected may be considered more acceptable by producers. Foot-wall integrity and hoof overgrowth on the other hand, were found less practical as they were time-consuming and they were not easy to assess as ewes often moved backwards and forwards. Additionally, their implementation across farms is limited as they should be assessed in races with no covered walls alongside.

4.3. Recommended Measures for On-Farm Welfare Assessment of Extensively Managed Ewes

This research is important because it identified measurements that are suitable for use under commercial conditions [43]. The validity of these measures reported in Munoz et al. [19], plus their reliability and feasibility examined in this study indicate that these six animal-based measures; BCS, fleece condition, skin lesions, tail length, dag score and lameness are appropriate/recommended to include in welfare protocols for ewes managed extensively, particularly in Australia. When these measures are combined, they provide a snapshot of the current welfare status of ewes, as well as providing evidence of past or potential welfare risks. For example, combining a decline in BCS, poor fleece condition and high dag score helps to identify that the welfare of that animal is compromised, while also facilitating the identification of the problem and the appropriate treatment. These measures address important welfare issues identified by producers, industry, specialist and general public [10,38,44].

Fleece cleanliness, although repeatable and feasible, might not be meaningful for extensive systems. Fleece cleanliness has previously been proposed as an important welfare measure for sheep, as it can provide information about the quality of the environment [10,15,18,23,45]. However, this measure is more valuable for intensive indoor lambing systems where it is important to assess the cleanliness of the floor/bedding and how the animal is coping with this environment. Rumen fill, foot-wall integrity and hoof overgrowth were discarded based on poor reliability and feasibility. Rumen fill has been identified as a relevant animal-based measure for sheep and lambs as it provides short-term information of food access [38]. In the present study, rumen fill was difficult to assess and this was reflected in the poor levels of agreement achieved. The presence of the fleece was the main factor affecting the levels of inter-observer agreement. Similar results have been obtained in a previous study on lambs where only 'moderate' inter-observer agreement was obtained [2]. In view of the difficulties of assessing rumen fill in ewes that are not in short wool and its limitations in assessing sheep welfare, the measure was excluded. Foot-wall integrity and hoof overgrowth showed poor repeatability and feasibility to be implemented across different farms. It should also be considered that broader measures, such as lameness, may be more relevant to assess ewe welfare than foot-wall integrity and hoof overgrowth.

Besides the importance of discriminating which welfare measures would be more suitable for extensive conditions, it is also important to identify alternatives that could be used to measure on-farm welfare in sheep. For instance, limited research has been done to develop practical assessments of fear of humans in sheep, and studies on this topic vary in methodology and performance [46]. The

majority of this research has been focused on intensively managed sheep [15,47–49], and usually under experimental conditions [41,47,50]. Further work is needed to validate a practical on-farm assessment of fear of humans that could be applied to extensive systems. Recent studies by Hazard et al. [51,52] have investigated several behavioral traits in sheep that could be used to validate the assessment of fear of human in extensive farming conditions. Additionally, limited work has been done to develop practical on-farm assessments for clinical and sub-clinical mastitis [10]. Udder examination and collection of milk samples to perform an on-farm test (e.g., California mastitis test) is time-consuming and labor intensive, which make these assessments less appealing for on-farm use. Further studies in the development of practical welfare assessments should consider the incorporation of new technologies for practical assessment of mastitis and to track grazing behavior and sheep movement to detect sick/lame animals. Finally, it should be considered that extensive systems are characterized by seasonal variation in both, climate and food availability, which results in seasonal variation in the welfare status of sheep [18]. Welfare measures therefore must be able to detect variation in the welfare status of ewes over main risk periods of the production cycle [18], as well as be sensible to identify differences between farms. Further research into the development of welfare assessment for extensive systems should assess both seasonal variation of the measures selected and their ability to detect differences between farms as only one property was examined in the present study.

5. Conclusions

The results obtained in the present study suggest that BCS, fleece condition, skin lesions, tail length, dag score and lameness are reliable and feasible measures that can be included in welfare protocols for extensive sheep production systems. The high levels of inter- and intra- agreement found for these measures also suggests that the scoring scales and the descriptive terms used are reliable. When these measures are used in combination with resource-based and management-based measures they can be used to address welfare compromise. Lactation was considered the least practical period due to the presence of lambs, which needs to be considered when deciding for key times to perform on-farm welfare assessments. Further research examining the ability of these measures to detect seasonal variation and between-farm differences will provide further evidence of their effectiveness in assessing the welfare condition of ewes managed extensively.

Acknowledgments: This research was funded by Meat & Livestock Australia Ltd. (MLA) and by red meat producers and the Australian Commonwealth Government.

Author Contributions: Carolina Munoz, Angus Campbell and Rebecca Doyle designed the study; Carolina Munoz performed the on-farm visits and the assessments of the ewes at each reproductive stage; Carolina Munoz analyzed the data; Carolina Munoz and Rebecca Doyle wrote the paper; Rebecca Doyle, Angus Campbell and Paul Hemsworth contributed with feedback and editions to the paper.

Conflicts of Interest: The authors declare no conflict of interest. The funding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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Chapter 2: Ewe welfare protocol development

This second part of chapter 2 has been published as:

Munoz C, Campbell A, Barber S, Hemsworth P, Doyle R. Using Longitudinal Assessment on Extensively Managed Ewes to Quantify Welfare Compromise and Risks. *Animals*. Multidisciplinary Digital Publishing Institute; 2018;8: 8. doi:10.3390/ani8010008



Article

Using Longitudinal Assessment on Extensively Managed Ewes to Quantify Welfare Compromise and Risks

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Received: 31 October 2017; Accepted: 5 January 2018; Published: 8 January 2018

Simple Summary: Sheep managed extensively can be exposed to several welfare challenges during the year, and the risk of some diseases can increase in warmer and wetter seasons. In this study, the welfare of Merino ewes was examined over a calendar year. The welfare of these animals, kept on a single farm with consistent management, varied substantially. Overall, the largest number of ewes experienced compromise and risk to welfare at weaning, indicating that this was the most vulnerable time. The main welfare issues identified were under and over feeding, ewe mortality, lameness, ecto-parasites (flystrike) and mastitis, all of which could be improved by modifying management practices, such as improved nutritional management and monitoring and better tail docking procedures. Future research must consider that significant variation in the on-farm welfare of ewes occurs during a calendar year, which needs to be accounted for when conducting on-farm assessments.

Abstract: This study examined variation in the welfare of extensively managed ewes and potential welfare risks. A total of 100 Merino ewes (aged 2–4 years) were individually identified and examined at three key stages: pregnancy, lactation and weaning. Eight animal-based welfare measures were used to assess welfare: flight distance, body condition score (BCS), fleece condition, skin lesions, tail length, dag score, lameness and mastitis. Data were analysed by ANOVA and McNemar's statistics. Overall, the average BCS of the group was in agreement with industry recommendations. However, a number of animals were classified with inadequate condition (either too thin or too fat) across the three observation periods. The presence of heavy dags was greatest at mid-lactation (87%, $P < 0.0001$), lameness was greatest at weaning (14%, $P = 0.01$), clinical mastitis was 1% annually, and five ewes were lost from the study. Ewes had better health at mid-pregnancy compared to mid-lactation and weaning. The main welfare issues identified were under and over feeding, ewe mortality, lameness, ecto-parasites (flystrike) and mastitis, all of which have the potential to be reduced with improved management practices. Future welfare assessment programs must consider that significant variation in on-farm welfare will occur in extensively managed systems and this needs to be accounted for when evaluating farms.

Keywords: animal-based indicators; animal welfare; on-farm welfare assessment; sheep

1. Introduction

The sheep industry is facing increasing financial and social pressures for assurances of good animal welfare and to maintain its 'social license' to operate [1]. In order to do this, further investigation of the current on-farm welfare status of sheep and potential welfare risks are needed [1,2]. Sheep that are farmed extensively in large flocks, in a year-round outdoor system and with low labour input, have the opportunity to live under more natural conditions and express natural behaviours [2]. This behavioural freedom creates opportunities for a better quality of life and a perception of positive welfare. Other aspects of extensive systems, however, do not necessarily guarantee good welfare, as extensively managed sheep can be at risk of several welfare challenges from a fluctuating environment and intermittent, unpredictable human interactions [3,4]. For example, fluctuation in environmental and climatic conditions produce important differences in food quality and availability. This, combined with changes in the sheep reproductive cycle, leads to variation in body condition over the course of the year [5,6]. Different seasons also increase the risk of some diseases in warmer and wetter periods, such as cutaneous myiasis [7] and foot rot [8]. In addition, the extensive nature of the industry makes feeding, predation control and prevention and treatment of diseases more difficult to monitor and promptly address, as there is limited individual care and supervision of animals [9]. Recent studies have suggested that the main on-farm welfare problems include poor nutrition (under and over-feeding), ecto- and endoparasites, reproductive health (e.g., mastitis, vulval cancer), lameness (and associated foot diseases) and mortality [2,4,10,11]. While the issues have been clearly identified, the extent of the issues are unknown as many sheep producers cannot accurately estimate the mortality rates in their farms [2].

Ewes' health and welfare relates closely to both lamb and weaner survival, with healthy ewes in a good welfare state producing strong offspring at lower risk of chronic welfare compromise throughout their lives [12–14]. Ewes are vital to farm productivity, and maintaining ewes in good welfare has a significant impact on farm health and profitability. To date, most of the studies investigating sheep welfare have been conducted on lambs at transport [15,16], abattoirs [17,18], or in more intensive sheep farming conditions [1,6,19,20] and less attention has been given to the on-farm welfare of extensively managed ewes. This could be attributed to the general perception of positive welfare under extensive conditions but also to the complexity of assessing welfare in extensive systems, where time and labour limitations make it difficult to observe ewes in an undisturbed state, particularly in larger flocks and/or paddocks [7]. The present longitudinal study was designed to address this knowledge gap by examining variation in the on-farm welfare of one flock of extensively managed ewes and potential welfare risks over the course of three key stages; pregnancy, lactation and weaning.

2. Materials and Methods

2.1. Animals and Husbandry

This study is part of a longitudinal on-farm study that was performed in Victoria, Australia between July and December, 2015 [21]. The study was approved by the University of Melbourne ethics committee (ethical approval number 1513562.1). A total of 100 adult Merino ewes (aged 2–4 years), randomly selected from a larger flock of approximately 3000 breeding ewes, were individually identified by a unique ear tag number and examined at three-time points: mid-pregnancy (June), mid-lactation (October) and weaning (December). These reproductive periods were selected because they are known to be critical times for sheep welfare [1,7]. The ewes were managed under extensive commercial conditions, in a year-round outdoor system, and grazing a mix of annual and perennial pastures. The ewe sample size was selected based on a power calculation assuming 50% prevalence of the trait under observation (the proportion requiring the greatest sample size when observing binomial traits), a 95% confidence interval and precision of $\pm 10\%$. This number was supported by the AWIN sheep protocol which recommends a sample of 92 animals when the farm size is ≥ 2000 breeding ewes [22]. Animals were not scanned for pregnancy before the study. However, farm records over

the past three years were: 120% pregnancy rate, 100% lamb marking rate and 98% weaning rate. Upon physical examination of the udder at mid-lactation, it was found that 26% of the ewes ($n = 25$) failed to lamb or rear a lamb. This information was considered and the factor ‘reproductively active’ and ‘non-reproductively active’ was included in the analyses of the data.

2.2. Identification of Welfare Measures

The measures used to examine on-farm ewe welfare were derived from a review of the relevant scientific literature (including research papers, conference proceedings, theses and literature reviews published from 1994 to 2016). A total of 73 papers were identified, and those that included suitable animal-based measures for Australian extensive sheep farming conditions were evaluated for validity, reliability and practicality [23]. Valid welfare measures are those that provide meaningful information with respect to animal welfare, reliable measures provide repeatable outcomes when applied by different observers and practical measures are able to be collected in a large number of animals (≥ 100), in a short period of time, with minimum labour input.

The welfare measures identified in the literature were compared to welfare measures identified in a large on-line survey of producers, industry experts and the general public [4], the AWIN sheep protocol [22], the Welfare Quality Assurance program [24], consultations with veterinarians and animal welfare scientists, and were then matched with the five domains of welfare compromise [25]. Table 1 shows the main animal-based welfare measures identified in the literature. The measures used in the present study were flight distance (FD), body condition score (BCS), fleece condition, skin lesions, tail length, dag score, lameness and mastitis. They were selected based on their reported validity (Table 1), and their reliability and feasibility reported in Munoz et al. [21].

2.3. Assessment of Seasonal Variation in the Welfare of Ewes

In order to perform the assessment, the ewes were managed in four groups of 25 animals. The assessment consisted of a group flight distance test (FD), and individual examination of BCS, fleece condition, skin lesions, tail length, dag score, lameness and mastitis. The assessment was performed using a holding pen (9 m $\times$ 8 m) and a single-file race within the farm’s regularly-used sheep yards, and was always conducted between 900 h and 1600 h.

The first step of the assessment was to measure flight distance (FD). The ewe’s response to an unfamiliar human was assessed with the assumption that the behavioral response of sheep to an individual will reflect the way in which they would respond to the farmer and/or external contractors and veterinarians, reflecting the process of stimulus generalization [26,27]. To test FD, a single human stimulus, always the same person (CM), quietly entered the pen holding a group of 25 ewes, walked around the perimeter and stood again at the entry point. From here, the observer waited for an ewe to be orientated towards her before approaching the animal. The ewe was approached by the observer in a standardised way (e.g., taking one step per second, maintaining the right arm in an angle of 45° in front of the body and the palm pointing towards the floor) [20,22]. The test ended when the ewe withdrew, defined as stepping away from the observer. Flight distance was estimated by counting the steps between the observer’s hand and the ewe’s head at the moment of withdrawal, and the behaviour of the ewe when approached by the observer was scored by using a 4-point score system as follows: a score of (0) if behaved calmly when approached; a score of (1) if there is some avoidance; a score of (2) if there is marked avoidance and struggling to escape; and a score of (3) if the ewe attempt to escape by jumping out of the pen [1]. Flight distance was measured in 5 ewes randomly selected from each of the four groups of 25 ewes, and was repeated at each stage. The ewes were not individually identified during the test, but the ewes tested were randomly selected from different locations within the group. The probability of not testing the same animal was 65%.

The group of ewes was then moved to the single file race for individual examination of BCS, fleece condition, skin lesions, tail length, dag score, lameness and mastitis. The assessment criteria of the welfare measures are listed in Table 2. Mastitis was assessed by physical inspection of the udder

and milk collection at mid-lactation and weaning. Ewes were restrained during this procedure in a purpose-built crate that allowed the ewe to remain in a standing position. At mid-lactation and weaning, all lactating ewes had approximately 35 mL of milk collected via hand milking. Prior to milk collection, teats were cleaned using an 80% ethanol solution. Milk was collected for both California Milk Test and somatic cell counts, with the person collecting the milk wearing gloves to eliminate any transfer of bacteria between human and sheep and vice versa.

Table 1. Animal-based welfare measures identified for extensively managed ewes.

Five Domains Principles	Category	Indicator	Animals	Validity	Reference
Nutrition	Nutrition	Body condition score	Lambs/ewes	H	[1,7,28–30]
	Feed and water	Rumen fill	Lambs/ewes	L/M	[31,32]
Environmental challenge	Shade and shelter	Panting	Ewes	H	[19,33,34]
		Fleece cleanliness	Ewes	H	[1,7,19,20]
Disease, injury, functional impairment	Gastrointestinal health	Faecal soiling	Ewes	H	[6,7,35]
	Integument alterations	Fleece condition	Ewes	H	[1,6,7]
		Skin lesions	Ewes	H	[1,7,20]
	Foot condition and lameness	Foot-wall integrity	Ewes	L/M	[7,36–39]
		Hoof overgrowth	Ewes	M	[7,20,37,40]
		Gait score	Ewes	M/H	[6,7,19,20,41,42]
	Reproductive health	Mastitis	Ewes	M/H	[7,43]
		Tail length	Lambs/ewes	H	[7,44]
Behavioural restriction	Systemic disease	Social withdrawal	Ewes	M	[6]
	Agonistic behaviour	Aggression	Ewes	M	[5,45,46]
	Abnormal behaviour	Stereotypies	Ewes	H	[46,47]
Mental state	Behaviour	QBA *	Wethers/ewes	M/H	[6,31,48–51]
	HAR #	Flight distance	Lambs/ewes	L/M	[1,20,52,53]

* QBA refers to Qualitative Behaviour Assessment; # HAR refers to human-animal relationships. Validity scale was as follows: H = high, M = moderate and L = low. High validity was given to animal-based measures validated in previous research, medium validity was given to measures without a reliable method of assessment and low validity was given to measures that have been suggested in scientific literature but without evidence that they assess welfare.

Table 2. Animal-based welfare measures used to assess the welfare of extensively managed ewes.

Welfare Measure	Assessment Criteria
Flight distance	Flight distance was estimated by counting the steps between the observers' hand and the ewes' head at the moment of withdrawal [20,22]. The behaviour of the ewe when approached by the observer was scored by using a 4-point score system as follow: (0) behaved calmly when approached; (1) some avoidance; (2) marked avoidance and struggling to escape; and (3) attempts to escape by jumping out of the pen [1].
Body condition score	Scored on a 5 point scale from 1 (thin) to 5 (obese), using a quarter-unit precision. Sheep were assessed by palpation of the backbone, muscle and short ribs [28,30]
Fleece condition	Scored on a 3 point scale: (0) good fleece condition, when parted, the fleece has no lumpiness or signs of ectoparasites; (1) some fleece loss, small shed or bald patches of no more than 10 cm diameter. When parted, the fleece may have some lumpiness or scurf, little evidence of ectoparasites; and (2) significant fleece loss with bald patches of greater than 10 cm in diameter, clear evidence of ectoparasites [22].
Skin lesions	Assessed by recording number, location, type and size of the skin lesions. Lesions were classified as cuts, open wounds, old wounds or scars and abscesses.
Tail length	Scored on a 2 point scale: (0) the tip of the vulva is covered by the tail when held down; (1) the tail is over-shortened or almost not present, or if the vulva and anus cannot be covered [22,54]

Table 2. Cont.

Welfare Measure	Assessment Criteria
Dag score	Scored on a 6 point scale: (0) no evidence of faecal soiling; (1) very light soiling on the breech area; (2) Moderate dag on the breech area extending ventrally; (3) Severe dag predominantly on the breech area, extending ventrally and dorsally over the tail some soiling and dag around anus; (4) excessive dag on the breech area and on the hind legs; (5) Very severe dag on the breech area and on the hind legs or below the level of the hocks [35]
Lameness	Scored on a 4 point scale: (0) not lame; (1) clear shortening of stride with obvious head nodding or flicking as the affected limb touches the floor; (2) clear shortening of stride with obvious head nodding and not weight-bearing on affected limb whilst moving; (3) reluctant to stand or move [22].
Mastitis	Scored on a 5 point scale: (0) normal udder; (1) a small fibrotic lesion within the mammary tissue, normal secretion; (2) A more extensive fibrosis of the udder. Milk ranged from normal to purulent; (3) Extensive swelling of the udder, that could be abscessed or ruptured; (4) Peracute mastitis. Complete udder involvement with severe inflammation. Secretion from serum-like to purulent. Mammary lymph nodes enlarged. Body temperature elevated [55].

2.4. Statistical Analysis

The welfare measures scoring scales consisted of numerical and categorical, ordinal data. Descriptive analysis of the data was performed in Excel[®] before data were transferred to SAS statistical package (Statistical Analysis System, Release 9.4 2012; SAS Institute Inc., Cary, NC, USA). A two-way ANOVA (group composition $\times$ stage of reproduction) was used to examine differences in flight distance between the three reproductive stages examined. Multiple comparisons between means were performed using Fisher's Least Significant Difference (LSD) test. Group composition refers to the four groups of 25 animals assessed each time. As the test depends on how the ewes behave towards the experimenter, ewes were not individually identified during the test. However, we identified the composition of each of the four groups at each stage, and this showed that different groups of sheep were formed at each time. In addition, a one-way ANOVA analysis was used to examine differences in BCS between 'reproductively active' and 'non-reproductively active' ewes.

A within animal comparison, to test differences in ewe welfare at the three stages, was performed by McNemar's statistics (test for dependent dichotomous variables). McNemar's statistic is used to examine the change in a binary repeated measurement, and can be used to test change in agreement over time [56]. To conduct this test, the seven animal-based welfare measures used for individual examination were transformed to binominal data. Body condition score was classified as adequate or inadequate according to industry recommended values [57], and 'reproductively active' and 'non-reproductively active' ewes were assessed independently. Fleece condition was transformed to adequate/inadequate (adequate fleece corresponding to ewes with a score of 0, see in Table 1). Skin lesions, dag score, lameness and mastitis were reclassified as present/absent.

3. Results

Assessment of Seasonal Variation in the Welfare of Ewes

The results of the individual welfare assessment are presented in Table 3. Five ewes were lost from the study period, with three ewes dying at lambing (reported dead by the farmer) and two presumed dead. Thus, different numbers of ewes were examined at mid-pregnancy ($n = 100$), mid-lactation ($n = 96$) and weaning ($n = 95$), and equals to a 5% mortality rate for ewes between mid-pregnancy and weaning. At mid-pregnancy, the mean BCS was 2.8 for 'reproductively active' ewes and 2.9 for 'non-reproductively active' ewes, and no statistical differences were found ($F = 0.47$, $P = 0.49$). At mid lactation, the mean BCS of the 'reproductively active' ewes was 3.1, while the mean BCS of the

‘non-reproductively active’ ewes was 3.3. The ANOVA analysis showed that the BCS between these groups were significantly different ($F = 3.81$, $P = 0.05$). At weaning, the mean BCS of the ‘reproductively active’ ewes was 2.9, whereas the mean BCS of the ‘non-reproductively active’ ewes was 3.1, and the ANOVA analysis showed that they were significantly different ($F = 4.84$, $P = 0.03$). In general, the number of animals classed with adequate/inadequate body condition varied over the course of the study. At mid-pregnancy, 29% of the ewes were below and 11% were above the recommended values. At mid-lactation, 10% of the ewes were below and 48% were above recommended values, and at weaning 12% of the ewes were below and 34% were above recommended values. A within animal comparison showed that the BCS of the ‘reproductively active’ ewes significantly decreased from mid-lactation to weaning ($P = 0.03$). The BCS of the ‘non-reproductively active’ ewes on the other hand, did not change over time ($P = 0.73$). Most of the ‘non-reproductively active’ ewes had a BCS of $3.5 \geq$ (above recommended values) at mid-lactation and stayed in this category at weaning.

Table 3. Mean, minimum and maximum scores, recommended values (RV), percentage of ewes identified within recommended values (% within RV) and above recommended values (% above RV) at mid-pregnancy, mid-lactation and weaning; standard deviation in parentheses.

Measures	Mean Score	Min	Max	RV	% within RV	% above RV
Mid-pregnancy						
BCS	2.83 (0.45) *	2	3.75	2.7–3.3 #	60%	11%
Fleece condition	0.02 (0.14)	0	1	0 ^a	98%	2%
Skin lesions	0.00 (0.14)	0	1	0 ^a	99%	1%
Dag score	0.54 (0.76)	0	3	0–1 ^a	99%	1%
Lameness	0.06 (0.27)	0	2	0 ^a	95%	5%
Mid-lactation						
BCS	3.11 (0.42) *	2.5	4	2.7–3 #	42%	48%
Fleece condition	0.03 (0.17)	0	1	0 ^a	97%	3%
Skin lesions	0.01 (0.08)	0	1	0 ^a	92%	8%
Dag score	3.94 (0.89)	1	5	0–1 ^a	13%	87%
Lameness	0.06 (0.28)	0	2	0 ^a	95%	5%
Clinical mastitis	0.00 (0.00)	0	0	0 ^a	100%	0%
Weaning						
BCS	2.88 (0.52) *	1.5	3.75	2.5–3 #	54%	34%
Fleece condition	0.09 (0.39)	0	2	0 ^a	95%	5%
Skin lesions	0.07 (0.27)	0	1	0 ^a	93%	7%
Dag score	0.94 (0.25)	0	3	0–1 ^a	98%	2%
Lameness	0.13 (0.35)	0	1	0 ^a	86%	14%
Clinical mastitis	0.06 (0.49)	0	4	0 ^a	99%	1%

* Mean BCS of ‘reproductively active’ ewes; # Industry recommendations of BCS [57]; ^a Score recommended by [22].

Fleece condition was overall adequate during the three periods examined. The percentage of ewes scored with adequate fleece condition ranged from 99% at mid-pregnancy to 95% at weaning. Skin lesions followed the same trend, with lesions mostly observed at weaning and related to cutaneous myiasis (flystrike; 86% of affected ewes, $n = 6$) and dermatophilosis (lumpy wool; 14% of affected ewes, $n = 1$). Dag scores were within the recommended values (scores 0–1) at mid-pregnancy and weaning, but significantly increased at mid-lactation ($P < 0.0001$) where 87% of the ewes had dag scores between 4 and 5. It was identified that 84 ewes that presented low dag score at mid-pregnancy (score 0–1) later presented high dag score at mid-lactation (score 4–5), and four ewes remained with a dag score of 3 at weaning, and their BCS ranged from 2.5 to 2.25. A total of 92% of the ewes at weaning ($n = 87$) had short-docked tails. Lameness increased significantly over time, from 5% ($n = 5$) at mid-pregnancy to 14% ($n = 13$) at weaning ($P = 0.01$). One ewe was lame at all three data collection times, and her lameness score increased from a score of 1 (clear shortening of stride) at mid-pregnancy to a score of 2 (not weight-bearing on affected limb) at weaning, and her BCS decreased from 2.75 at mid-pregnancy to 1.5 at weaning. At mid-lactation, no signs of clinical mastitis were observed, but the California

Mastitis Test and somatic cell counts showed that 10% of the lactating ewes presented weak or distinct positive results to subclinical mastitis and somatic cell counts ranged from 29,000 to 4,022,000 cells/mL of milk. At weaning, the California Mastitis Test and somatic cell counts showed that 8% of the ewes presented weak or distinct positive results to subclinical mastitis, and somatic cell counts ranged from 38,000 to 17,177,000 cells/mL of milk. At this stage, 1% clinical mastitis was found and the affected ewe presented gangrenous mastitis, which corresponded to a score of 4. Ewes flight distance (FD) differed between each reproductive stage ($P < 0.0001$). The mean FD at mid-pregnancy was 5.15 m ($SE \pm 0.2$), this significantly increased to 6.17 m ($SE \pm 0.3$) at mid-lactation and decreased to 4.00 m ($SE \pm 0.2$) at weaning (Figure 1). The behaviour score of the ewes when approached by the experimenter ranged from a score of 1 to a score of 2 during the study, and did not differ between reproductive stages.

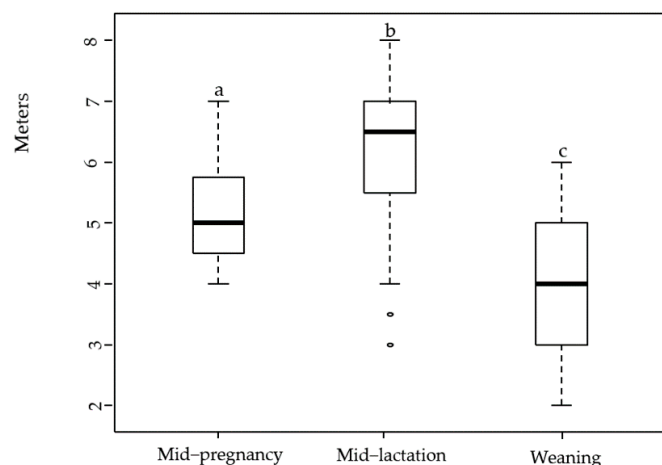


Figure 1. Median, minimum and maximum flight distance (FD) observed at mid-pregnancy, mid-lactation and weaning. Different letters indicate statistical difference ($P < 0.05$).

4. Discussion

The welfare of extensively farmed ewes on a single farm with consistent management varied substantially. This variation was seen both between individuals and within individuals during the study period. The animal welfare measures included in this study show both welfare compromise (evident at weaning) and welfare risk (high dag scores at mid-lactation). When assessing the biological functioning of the ewes, the largest number of ewes experienced compromise and risk to welfare at weaning. At this stage, 12% of the ewes were classed with a BCS below 2.5, 6% of the ewes presented skin lesions related to flystrike, there was 1% clinical mastitis and 14% lameness, indicating that this was the most vulnerable time. Results show that some welfare measures such as BCS, dag score and lameness can detect differences at key time points and predict the likelihood of individual ewes experiencing future welfare compromise. While identified welfare issues may be exacerbated by the season, there is potential for improvement with changed management practices at each stage of the reproductive cycle. As a result, we discuss the results of the welfare assessment in conjunction with management activities that could reduce these issues.

In this study, the average BCS of ewes studied was in agreement with industry recommendations. However, a number of animals were classified with inadequate condition, either too thin or too fat, across the three observation periods. Body condition scoring of sheep has been validated [7,21,28,58] and is widely accepted as an animal-based measure that can be used to monitor past nutritional management and potential welfare risks of sheep [7,59]. It is possible that some of the pregnant ewes classed with low body condition at mid-pregnancy, particularly the ones classed with a BCS < 2.5 , may have experienced reduced placental development and foetal growth [60,61], and were more susceptible to metabolic diseases, such as pregnancy toxemia [59]. The ewes scored fat at mid-pregnancy, besides being at more risk of metabolic diseases, may also be more likely to experience

difficulties at lambing [62]. Results from udder inspection at mid-lactation detected that 26% of the flock failed to lamb or rear lambs, suggesting that either a significant number of ewes were not pregnant, had lost pregnancies or lost lambs at or soon after birth. Based on the farm history on reproductive rates and results for BCS in the study, it is likely that a large number of ewes had lost lambs soon after birth [63]. By tracking the same ewes over the study, a 5% mortality rate between mid-pregnancy and weaning was identified. Generalizing this figure across the whole flock, it would translate to 150 ewe deaths in the 6 months of the study, which has welfare and economic consequences. Previous studies suggests that lack of information on farm mortality could produce a disconnection between perceived and actual ewe mortality, and this underestimates welfare issues on the farm and may lead to a lack of interest by producers to address particular welfare concerns [10]. To comprehensively assess ewe welfare, measures such as BCS cannot be taken in isolation, and they need to be integrated with further details of farm records, management and resources. The fact that a consistent number of animals had inadequate body condition during the study, making them susceptible to several diseases, highlights the importance of appropriate nutritional management to reduce individual welfare compromise. Overall, the main welfare risks identified in this study may have arisen because of both under and over feeding. Condition scoring at key times and pregnancy scanning of ewes to identify ewes that are not pregnant, or carrying single or multiple lambs allows farmers to use a targeted feeding approach to ensure that ewes carrying multiple lambs receive adequate levels of nutrition [63].

The presence of heavy dags is an important indicator of potential welfare risk of flystrike. A ewe with a dag score of 4 is seven times more susceptible to flystrike than a ewe with a dag score of 1 [64]. In addition, the presence of heavy dags could also indicate current welfare compromise as scouring and dags could be related to worm burdens or larval challenge in ewes with depressed immunity, but it could also be reflection of rapid changes in the diet, which causes nutritional scours. In the present study, a large percentage of ewes (87%) were classed with high dag scores (scores 4 to 5) at mid-lactation. A possible cause for this increase may be related to a rapid change to a high-quality pasture with high water content of spring grass, as the number of ewes presenting high dag scores significantly decreased by weaning (late spring). This decrease in scouring and dags may be indicating an adaptation to the spring grass, however, four ewes remained with a dag score of 3 until weaning, and they had a BCS of ≤ 2.5 which may be an indication of worm burdens or larval challenge or other gastrointestinal condition [7,35,64]. Parasitised sheep usually present poor body condition, low growth rates, reduced wool and milk production, and are more susceptible to other diseases such as flystrike [59,65]. In addition, the fact that 6% of the group presented skin lesions related to flystrike highlights the importance of early treatment in extensive systems. Effective management of dags and scouring is essential. Dags can be managed by 'crutching' (wool from around the tail and between the rear is shorn), but it is important to perform worm egg counts to monitor worm burdens and improve worm management and drench programs to understand the cause and appropriate treatment for any scouring [7,64,66].

Lameness is a worldwide problem in sheep, and it is an important health and welfare concern due to the pain, discomfort and debilitation that it causes [36]. In this study, the percentage of lame ewes increased significantly from 5% at mid-pregnancy to 14% at weaning, similar to a previous study investigating seasonal variation in lameness in extensive systems in the UK [8]. An increase in lameness at weaning may be associated with footrot lesions [41], hoof overgrowth, and foot abscess due to environmental conditions such as warmer and wetter conditions [67,68]. In some areas of South Eastern Australia, footrot is considered an endemic disease, with more than 20% of the farms affected [69]. In this study, it was not possible to identify the cause of lameness on the farm since the ewes were not individually restrained for further inspection. Although this assessment cannot give details of what is causing lameness, a high lameness percentage can alert farmers to a musculoskeletal problem affecting animal welfare that warrants more investigation. Previous studies have shown that lame sheep may experience pain and discomfort which reduces mobility, feed intake and weight gain, decreasing body condition and wool production [37,70]. The fact that a number of ewes were lame at

weaning (14%) emphasize the importance of early intervention and frequent monitoring to reduce individual animal welfare compromise [37].

Overall, 92% of the ewes assessed had short-docked tails (less than three palpable joints) when compared with recommended guidelines [54]. Since the vast majority of the ewes had short docked tails in this study, relationships between tail length and welfare issues were not examined. However, previous studies have demonstrated that sheep with short-docked tails may experience more pain and poor healing after tail docking and may be more susceptible to bacterial arthritis [71], rectal prolapse, dags, flystrike [72] and vulva cancer [54]. By using tail length as an indicator of past welfare compromise and future welfare risks, it is possible that a number of the ewes in the flock experienced or would be at risk of one or more of these welfare compromises.

Mastitis is increasingly recognised as an important health and production concern in extensively-managed sheep flocks. Mastitis can be categorised as clinical or sub-clinical and the majority of the cases occur in the month post lambing or before weaning, and/or following adverse weather conditions [43]. In the present study, no signs of clinical mastitis were observed at mid-lactation, but 10% of lactating ewes had subclinical mastitis. At weaning, 8% of the ewes presented subclinical mastitis and 1% clinical mastitis (gangrenous mastitis). These results are in agreement with previous studies that have reported 7% subclinical mastitis and 1–2% clinical mastitis in Merino ewes [73]. However, since little is known about the prevalence and incidence of mastitis in Merino flocks, it is possible that figures may be higher than currently identified. It has been shown that ewes affected may experience pain and discomfort, which can result in body condition loss, lameness and mismothering of lambs [55]. While it represents compromised welfare and productivity of ewes and their lambs, assessing mastitis on-farm in sheep that are not managed as milking flocks, is time-consuming, labour-intensive and frequently impractical. Since this study was conducted in one flock, further research is needed to describe mastitis prevalence in extensively-managed wool and meat flocks, and its impact on ewe and lamb welfare.

Flight distance (FD) was used to examine the quality of the human-animal relationships (HAR) of extensively managed ewes [20,74]. There is currently limited information on these relationships in animals farmed extensively, where human-animal interactions are infrequent and often stressful for both animals and farm staff e.g., at castration, tail docking and shearing [5,74]. The ewes examined in the present study had a mean FD of 5.15 m at mid-pregnancy, 6.17 m at mid-lactation and 4 m at weaning. In addition, ewes usually presented marked avoidance to the experimenter, indicating fear towards humans, particularly at mid-lactation. The FDs and the behaviour scores recorded in this study were higher than what has been observed in intensively managed ewes [1,20] but in agreement with results obtained by Hutson [75] who examined FD in sheep farmed extensively. It is possible that results observed in the present study do not necessarily indicate a negative HAR, as the likelihood of having a short FD, in systems where animals do not frequently receive human contact, would be low, suggesting that the current interpretation of this measure is unrealistic for extensive systems. While only one flock at one farm was assessed, the variation observed in FD suggests that this measure may be influenced by the time-point of the assessment, and/or ewes' familiarity with the test/experimenter. Previous studies have shown that FD varies significantly between pregnant and non-pregnant ewes [76,77]. Ewes with lambs at foot tend to be more reactive to external stimulus to protect their off spring [78], which could explain the significant increase in FD at mid-lactation. Following the removal of lambs, FD reduced significantly at weaning to a level lower than mid-pregnancy. This may be related to habituation to the testing situation as well as the experimenter of this study, as it has been shown that repetitive exposure or habituation to certain procedures changes the animal's response/perception of that stimulus [79]. The test performed in this study is consistent with other human-approach tests for livestock; however, results in this study indicate that the short FD suggested for intensively managed sheep cannot be extrapolated to sheep managed extensively and that the time-point of the assessment may affect FD. A limitation of this group test is that ewes were not individually identified during the test, and therefore, some ewes may have been assessed repeatedly during the study. Further work is

needed to validate a reliable and practical on-farm assessment of fear of humans that could be applied to extensive systems.

5. Conclusions

When assessing the biological functioning of the ewes, the largest number of ewes experienced compromise and risk to welfare at weaning than at mid-pregnancy and mid-lactation which needs to be considered when deciding key times to conduct on-farm welfare assessments. The main welfare issues identified were poor nutrition (under and over feeding), ewe and potentially lamb mortality, lameness, flystrike and mastitis. The main welfare risks identified were the possibilities of metabolic diseases and dystocia due to inadequate BCS, flystrike from heavy dags, and reproductive problems due to short tail length. The majority of the welfare issues and potential welfare risks identified in this study could be improved by modifying management practices, such as improved nutritional management and monitoring and better tail docking procedures. Further information on disease records, early detection and intervention of sick animals and mortality records need to be incorporated in the assessment to examine prospective welfare issues. Further research must consider that significant variation occurs at key periods of the sheep production cycle which needs to be accounted for when conducting on-farm welfare assessments.

Acknowledgments: This research was funded by Meat & Livestock Australia Ltd. (MLA) and by red meat producers and the Australian Commonwealth Government.

Author Contributions: Carolina Munoz, Rebecca Doyle and Angus Campbell designed the study; Carolina Munoz performed the on-farm visits and the assessments of the ewes at each reproductive stage; Stuart Barber performed the mastitis inspection and milk collections at mid-lactation and weaning; Carolina Munoz analyzed the data; Carolina Munoz wrote the paper; Rebecca Doyle, Angus Campbell Stuart Barber and Paul Hemsworth contributed with feedback and edits to the paper.

Conflicts of Interest: The authors declare no conflict of interest. The funding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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Main findings/implications of Chapter 2:

- Based on the two studies described in this chapter: Body condition, fleece condition, skin lesions, tail length, dag score and lameness are proposed for on-farm use in welfare assessments of extensive sheep production systems.
- Significant variation occurs between pregnancy, lactation and weaning, which needs to be accounted for when assessing farms.
- Taking into account practicality, mid-pregnancy and weaning are likely the most feasible and useful times to conduct assessments.

Chapter 3: Farmer questionnaire development

This chapter describes the first step of the questionnaire development process. Two focus groups with farmers were conducted in regional Victoria, Australia to gather farmers' opinions and concerns about ewe welfare and management. This information was used to develop two farmer questionnaires; an attitude questionnaire and a management questionnaire that were further used in this thesis to assess the relationship between farmer attitudes and sheep welfare outcomes (details of these questionnaires are presented in Chapter 5).

'If you say sheep are stupid it is probably because you are doing something wrong': farmers' opinions about sheep, welfare and management in extensive sheep farming systems.



Short communication (*in draft*) formatted to *Small Ruminant Research*

Abstract

There are around 1 billion sheep in the world, and most of them are managed under extensive farming conditions. Still, information on farmer attitudes to sheep welfare and management practices in extensive systems is limited and warrants further investigation. This present study addresses this lack of knowledge. Two focus groups were conducted in regional Victoria, Australia to gather qualitative information on farmers' opinions about sheep welfare, sheep management, sources of trust and barriers to best practice. Both focus groups were conducted for 60 min, followed a semi-structured agenda and comprised eight and seven farmers respectively (all participants were male and their age ranged from 35 to 65 years of age). A total of 14 sheep enterprises were represented, as two people in the first focus group work on the same farm. Overall, farmer attitudes to sheep were positive and sheep welfare was considered an important aspect of farm productivity. Positive attitudes towards moving and handling sheep were considered important, but farmers acknowledged that occasionally they felt that they had little control over contractors' handling behaviour. All farmers reported that monitoring of the flock and feed on offer was performed visually, from a distance. Farmers all visually assessed behaviour and body condition as indicators of sheep welfare but did not assess either measure in close proximity to the flock. The extensiveness of the farming conditions seemed to be an important barrier to frequent/detailed monitoring. In addition, the weather conditions and farm location usually dictated the need for inspection. Farmer attitudes towards ultrasound pregnancy diagnosis were positive and participants engagement to this practice was high. Other detailed management practices, however, such as tactile condition scoring of sheep, the use of pain relief during husbandry procedures, record keeping and veterinary intervention were uncommon and

were perceived as difficult and time-consuming or sometimes not important. Results indicate that behavioural attitudes (the perceived importance of performing a specific activity) and a perceived lack of behavioural control in some aspects of sheep management are likely barriers to welfare monitoring and improvements in extensive systems. Thus, strategies aimed at increasing the adoption of improved management practices should mainly target farmer behavioural attitudes and perceived behavioural control. Overall, farmer attitudes to sheep were positive and welfare was described as an important consideration; however, the fact that we used voluntary recruitment may have introduced a participation bias into the study skewed towards more 'proactive' farmers. Therefore, it is possible that the adoption of improved management practices, welfare issues and productivity statistics that the participants reported here are poorer on the majority of sheep farms. The results obtained in this study will be used to inform subsequent research to further investigate farmer attitudes to sheep welfare and management in a broader population of extensive sheep farmers to confirm these findings.

Keywords: attitudes, barriers to adoption, ewe welfare, farmer management, focus groups.

Introduction

Extensive sheep farming systems are facing increasing social demands for assurances of good animal welfare in order to maintain its current 'social license to farm sheep' (Coleman, 2017). At the same time, farmers are under important financial constraints as sheep numbers have been in constant decline over the past 30 years due to drought,

reduction in wool prices and more competitive lamb markets (Elliott et al., 2011; Ward et al., 2011; Meat & Livestock Australia, 2018). These societal and financial issues indicate that improvements in sheep welfare and farm productivity are critical for the continued sustainability and profitability of the industry. To achieve this, one of the first steps is to identify farmers' opinions about sheep welfare, sheep management and main barriers to best practice. An in-depth understanding of the opinions and beliefs of farmers is crucial to translating research into practice to improve welfare and productivity.

In this exploratory study, focus groups were conducted in regional Victoria, Australia, to gather qualitative information on farmers' opinions about sheep welfare, particularly regarding the welfare of ewes under extensive sheep farming systems, sheep management, main sources of trust and advice to farmers and main barriers to best practice.

Material and Methods

This study was approved by the Veterinary and Agricultural Sciences Human Ethics Advisory Group of The University of Melbourne (Ethics Application 1545238.1).

Participants

Purposive sampling was used to invite Victorian sheep farmers to participate in this study. Participants were recruited through the Australian sheep network 'best wool/best lamb' and by nomination through neighbours. Suitable participants had to be commercial farmers with sheep as their main farming enterprise. The two focus groups comprised eight and seven Victorian farmers respectively, from 35 to 65 years of age, with an

average age of 53 years. A total of 14 farm businesses were represented, as two people in the first focus group represented one farm. All participants were male, and the majority of farmers were meat-focused producers 50% (n=7); 35.7% (n=5) were dual-purpose producers and a 21.4% (n=3) were wool-focused producers. This distribution of farms is a fair representation of the current trend of the Australian sheep industry (Department of Economic Development Job Transport & Resources, 2014), and suggest that the opinions and concerns identified in this study are not limited to one sheep farming sector.

Focus groups

Two focus groups were conducted in regional Victoria, Australia. Both focus groups were conducted after pre-organised farmers meetings and were performed in two privately-owned farms conveniently located near the participants. Focus groups are considered an appropriate exploratory research approach to gathering qualitative information on the opinions of farmers about sheep welfare and management. This method allows investigators to understand general beliefs and attitudes about specific topics (Ajzen and Fishbein, 1980b). The focus groups began with a short introduction by the student researcher (C.M) and a broad explanation of the project. Both focus groups were facilitated by G.C, a male psychologist, part of the research team, with more than 30 years of experience conducting qualitative research in the livestock sector. The facilitator asked a series of questions using a semi-structured agenda pertaining to the farmers' work, e.g. sheep management, sheep health and welfare. The questions were developed based on the Theory of Planned Behaviour (Ajzen, 1985), thus, aimed to identify attitudes towards sheep welfare and some common management behaviours (refer as behavioural attitudes), subjective norms (such as main sources of trust and advice to farmers) and

perceived behavioural control (ease or difficulty) over performing certain management practices.

Farmers were encouraged to discuss their opinions in an informal manner and had the opportunity to raise other related topics outside the semi-structure agenda. The facilitator ensured that all participants engaged in the conversations and maintained the direction of the conversation by guiding topics back to relevance when necessary. The first focus group ran for approximately 60 minutes and the second focus group ran for 90 minutes approximately. The focus groups were audio-recorded and written notes were taken during the discussions. In the last 30 minutes of the second focus group, a draft questionnaire was handed out and completed by the farmers from whom feedback was gathered. The focus group findings and feedback on the draft questionnaire were used to refine the content and format of an attitude and management questionnaire to be used in subsequent research.

Qualitative analysis

Thematic analysis was used to analyse the focus group transcripts (Maxwell, 2013). Topics discussed by participants during the focus groups were classified into primary and secondary themes. Secondary themes consisted of specific issues which were discussed within the context of the primary themes. The thematic analysis was performed only by the candidate and the analysis was performed manually. At the end of the two focus groups, the researchers were satisfied with the level of data saturation obtained from the discussions as both focus groups provided similar key themes.

Results

Farmers' general attitudes to sheep

In general, farmers had positive attitudes to sheep and perceived them as easy to train to a routine, with good memory and different personalities. There was a strong acknowledgement that behaviour and attitudes towards moving sheep were important and influenced success in moving sheep. Some direct quotes included 'if you say sheep are stupid and you are getting angry at them, it is probably because you are doing something wrong' and 'the worst you can do is to set a time, for example, I am going to have the sheep in the yards by 9 am. Do not put a time on it, do not rush and everybody would be happy'. Farmers acknowledged however that there are always a few sheep that can be frustrating to work with during handling situations, which influences their attitude and behaviour particularly when they are tired and angry, with direct quotes including 'everyone has a breaking point, I'm not going to say that I never [crack it] to a sheep before'. Farmers also acknowledged that they sometimes see contractors roughly handling the sheep 'once a shearer gets tired and frustrated they lose their cool and starts handling the sheep wrong', but they recognised that they do not always say something or intervene because 'getting good contractors can be difficult sometimes'.

Flock monitoring

All farmers agreed that monitoring of the flock was important and was performed visually and from a distance when driving around the paddock and/or feeding or moving sheep. Farmers acknowledged that frequency of monitoring depends on the season (e.g. summer is critical), year (e.g. dry seasons), reproductive stage and location, as there are important geographical differences within Victoria. At joining, ewes are generally

monitored once a week, whereas at lambing, the frequency of monitoring increases to once or twice daily. Some relevant statements included: ‘not many things can go wrong at joining’, ‘you do a risk analysis, in your head, and if the risk is there, you go and inspect your sheep’ and ‘how often you check your animals or what we need to do is not written down’.

Welfare indicators used by farmers

Sheep behaviour such as normal grazing patterns and behaviours indicative of disease (e.g. isolation) and body condition were identified as the main indicators of sheep health and welfare used by farmers. Behaviours indicative of stress and pain, however, were described as difficult to identify. Participants perceived castration, tail docking and mulesing as painful husbandry procedures. Farmers believed that the use of pain relief (Trisolfen) makes a ‘huge difference’ in how lambs recover after procedures such as mulesing and castration but acknowledged that the use of pain relief is rare.

Main on-farm welfare concerns for ewes according to farmers

Participants’ comments on main concerns at each reproductive stage, common productivity statistics and some management practices that can lead to improvements in welfare and productivity are reported in Table 3.1. The most common welfare issues raised in the focus groups were undernutrition, flystrike (particularly under warm and humid conditions), dystocia, mismothering, mastitis, lameness and painful husbandry procedures such as tail docking and mulesing.

Table 3.1 Common productivity statistics, main concerns at each reproductive stage and some management practices that can lead to improvements according to participants.

Productivity percentages	Main concerns	Management considerations
Joining		
3% of dry ewes in good years	With Merinos, you expect a high return rate.	Ultrasound pregnancy diagnosis
up to 20% dry ewes in bad years	Low body condition	Separate non-pregnant and pregnant ewes, and twin and single bearing ewes
		Pasture management; check quality and quantity of feed on offer
		Nutrition management; supplementary feeding when necessary.
Lambing-Marking		
Merinos 90%	Low or fat body condition	Not under or overfeeding sheep
Cross-breeds 130%	Cold weather	Recently shorn ewes with low body condition can be kept in the shed in case of bad weather
	Mismothering	Sheep should be kept in most protected paddocks at lambing
	Lamb mortality	Pick up dead lambs to record mortality
	Pasture quality and availability	
Weaning		
1% losses up to 12% in bad years	Water availabilities (in dry seasons)	Prevention measures for flystrike e.g. crutching earlier and increasing monitoring.
In general, not many losses between marking and weaning	Skinny lambs	
	Flystrike	

Adoption of improved management practices

Most participants used ultrasound pregnancy diagnosis. Farmers widely stated that detecting non-pregnant and pregnant ewes and twin-bearing and single-bearing ewes is an important management strategy that helps them make better management decisions. However, there was a consensus that, in terms of productive parameters, ‘what is acceptable for the industry and what you get are two different things’ suggesting that farm productivity might be lower than currently identified. It was also widely accepted

that ultrasound pregnancy diagnosis was not a common management practice among other farmers in their area. Measuring the quality and quantity of feed on offer was also considered important and was mainly assessed visually when driving around the farm. Checking drinking troughs regularly during summer was also pointed out as critical. The majority of participants do not keep mortality records but recognised that picking up dead animals to keep accurate records can be an important management strategy. Body condition scoring of sheep was also uncommon and farmers recognised that although they attended workshops on body condition, and that resources are available, they did not use a numerical scoring or physically touch the back of the sheep to condition score their animals. Some direct quotes included 'I know how to do it, but I don't feel confident' other reasons were related to a lack of importance as 'you get a good sense of their condition when you look at them in the paddock'.

Perceived barriers to best practice

Time and labour availabilities were the most common reasons given for why farmers did not perform more frequent/detailed management. In addition, record-keeping was perceived as time consuming and difficult with most farmers stating that 'you get busy with other things', 'I always meant to do it but....' and 'I've always had good intentions to be better, but when it comes to records...that is not one of my strengths'. Other reasons focused on not wanting to know the answer as picking dead animals can be 'too depressing at times.' Another important consideration raised by participants were farmer age and low generational succession, with some related quotes including 'At our age, you get tired after doing all' and 'none of our sons is getting involved with the farms'.

Industry engagement and main sources of trust and advice

Farmers acknowledged that farmer engagement with industry activities is not common generally. In contrast, farmers in this study actively engaged with industry and perceived workshops to be important. They participated in approximately four to six workshops throughout the year, and statements like ‘knowledge is power’ and ‘any welfare aspect that we can improve in our sheep will have a production outcome’ were commonly raised during the discussions. Participants stated that they probably represent the top 10 to 20% of the farmers in their region; there was a consensus among participants that there is a number of farmers that do not take appropriate care of their stock and that are not interested in engaging with industry activities. Some direct quotes included ‘the ones who really need to be in these courses aren’t’, ‘in tougher conditions you really see the difference between good and poor farmers’ and ‘we’ve tried to engage more farmers, but our group hasn’t grown in years, no matter how many farmers you talk to they always have an excuse.’

More experienced farmers were commonly mentioned as main sources of trust and advice, followed by industry consultants, family members and veterinarians. However, while the advice of veterinarians was perceived to be somewhat important, farmers considered themselves to be self-sufficient when dealing with sheep health issues, acknowledging that seeking veterinary intervention was rare and reserved largely to check the rams before mating or if something ‘unusual’ occurred.

Discussion

The aim of this qualitative study was to identify farmers' opinions about sheep welfare, sheep management and main barriers to best practice. Overall, farmer attitudes to sheep were positive and sheep welfare was expressed as an important consideration. However, behavioural attitudes (the importance of performing a specific activity) and a perceived lack of behavioural control due to the extensiveness of the farming conditions, time constraints and labour abilities are likely barriers to welfare monitoring/improvement in extensive sheep farming systems.

When assessing the main topics discussed by the participants, it was clear that farmers relied mostly on visual monitoring to assess the flocks and pasture quality and quantity. Similarly, the main welfare indicators used by farmers were behavioural indicators that can be detected from a distance such as normal feeding behaviours as indicators of good welfare or behaviours indicative of diseases, such as social isolation as indicators of poor welfare. While this approach may be more practical, particularly in Australia where the average flock size is 2,857 head (Australian Bureau of Statistics, 2017), visual observations may make early identification and intervention of sick/injured animals difficult. Clearly, practical and effective methods to monitor the flock are needed, but first, a better understanding of the extent to which welfare issues are present in extensive sheep farming systems or farmers' ability to recognise animals in need of further care in large-size flocks warrant further investigation.

While visual monitoring was common, close inspection of the flock and more detailed practices such as body condition scoring of sheep, keeping accurate records or veterinary interventions were uncommon activities. The lack of veterinary intervention raised

during the discussions agrees with finding by Kaler and Green (2013) who reported that most farmers in their study had very little contact with veterinarians due to farmers' perceptions that only bad farmers need veterinary help, that veterinarians have limited knowledge of sheep farming and perceptions of the high costs associated to veterinary assistance.

Attitudes towards ultrasound pregnancy diagnosis were positive and participants engagement to this practice was high. However, participants recognised that most farmers around their area do not use ultrasound pregnancy diagnosis as a management tool. Farmers' perception about this is in line with results of a recent survey on producers' husbandry practices in Australia. According to this survey, only 50% of producers use ultrasound pregnancy diagnosis, with only 31% of them separating their flock according to dry, single-bearing or twin-bearing ewes. Main reasons to not use ultrasound pregnancy diagnosis were 'see no benefit' (31%), 'time/labour availability' (17%) and 'impractical in current system' (16%) (Howard and Beattie, 2018).

When farmers in this study were asked about why they or other farmers do not engage in best practice, perceived behavioural control and farmer attitudes emerged as likely barriers for adoption of improved management practices. These results are in agreement with Elliott et al (2011), who reported that some producers perceived that external factors such as weather conditions, time and resource availability and financial circumstances prevent them from engaging in practices to improving lamb survival.

Farmers acknowledged that their attitudes and behaviour influence sheep fear response and vice versa. However, while positive attitudes towards moving and handling sheep were perceived to be important, farmers recognised that sometimes they have little

control over contractors' handling behaviour and that tiredness and mood can lead to rough handling of sheep. These results are in agreement with the Theory of Planned Behaviour (Ajzen, 1985) and the human-animal relationship model developed by Hemsworth and Coleman (2011), and add to the limited existing knowledge of farmer attitudes, behaviour and sheep welfare (Morgan-Davies et al., 2006; Kaler and Green, 2009a; Phillips and Phillips, 2010; Elliott et al., 2011; Coleman et al., 2012b; O'Kane et al., 2017; Hemsworth et al., 2018a). A further examination of farmers' and contractors' attitudes and behaviour during handling is warranted as contractors play an important role during routine husbandry practices. It is possible that educational programs could have a greater impact on sheep welfare if farmers and contractors are involved.

The fact that we used voluntary recruitment may have introduced a participation bias into the study skewed towards more 'proactive' farmers. The farmers involved in the focus group discussions engaged with educational activities and perceived themselves as being the top 10-20% of the farmers in their area. Although these are qualitative results, farmers would have a reasonable sense of what others in their districts are doing. If the focus group participants are indeed more proactive farmers and are ahead of the curve, it means that the adoption of improved management practices, welfare issues and productivity statistics they reported here are likely to be poorer on the majority of sheep farms. In fact, the common perception that there is a number of farmers that do not take appropriate care of their stock needs further investigation and more efforts to engage this group of farmers in industry activities and adoption of best practices is important to safeguard the reputation of the industry.

Another point that needs consideration is that farmers in this study highly valued the opinions and advice of more experienced farmers. These findings are consistent with previous studies on sheep farmers (Elliott et al. 2011) and dairy farmers (Garforth et al., 2006). In practice, this indicates that promoting the adoption of best practice through the experience of other farmers may be a good way of engaging producers. Engagement could also be improved by making animal welfare training courses mandatory for farmers and farmworkers.

Conclusion

Farmer attitudes to sheep were positive and welfare was expressed as an important consideration. However, the fact that we used voluntary recruitment may have introduced a participation bias into the study skewed towards more 'proactive' farmers. Thus, it is possible that the adoption of improved management practices, welfare issues and productivity statistics they reported here are poorer on the majority of sheep farms. The results obtained in this study suggest that behavioural attitudes (the importance of performing a specific activity) and a perceived lack of control in some aspects of sheep management are likely barriers to welfare monitoring and improvements. Therefore, strategies aimed at increasing the adopting of best practice should target farmer attitudes in order to achieve a sustained change in farmer management and handling behaviour. The development of these strategies should be a priority in order to ensure the sustainability of the industry and maintain its current social licence to farm sheep. The results obtained in this study will be used in subsequent research to further investigate farmer attitudes to sheep welfare and management practices in a broader population of extensive sheep farmers to confirm these findings.

Acknowledgements

The authors would like to thank all the farmers that kindly participated in this study.

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Main findings/implications of Chapter 3:

- Farmer attitudes to sheep were positive and welfare was described as an important consideration.
- Farmers relied mostly on visual monitoring to assess the flocks and pasture quality and quantity. However, close inspection of the flock and more detailed practices such as body condition scoring of sheep, keeping accurate records or veterinary interventions were uncommon activities.
- Behavioural attitudes (the perceived importance of performing a specific activity) and a perceived lack of behavioural control in some aspects of sheep management are likely barriers to welfare monitoring and improvements in extensive systems.
- The results obtained in this study will be used to inform subsequent research to further investigate farmer attitudes to sheep welfare and management in a broader population of extensive sheep farmers to confirm these findings.

Chapter 4: Evaluating the welfare of extensively managed sheep

This chapter presents the results of the welfare assessment of 6,200 ewes and identifies main welfare issues likely to be encountered in large-scale extensive farms.

This chapter has been published as:

Munoz CA, Campbell AJD, Hemsworth PH, Doyle RE. Evaluating the welfare of extensively managed sheep. Hillmann E, editor. PLoS One. 2019;14: e0218603. doi:10.1371/journal.pone.0218603



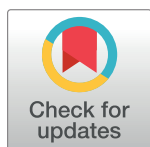
RESEARCH ARTICLE

Evaluating the welfare of extensively managed sheep

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Abstract

The aim of this study was to identify the main on-farm welfare issues likely to be encountered in extensive sheep farming systems. Thirty-two commercial sheep farms in Victoria, Australia were involved in this study. Of the 32 farms involved, 30 were visited twice (at mid-pregnancy and weaning), and 2 farms only once (both at weaning). In total, 62 visits were conducted and 6,200 ewes (aged 2–5 years) were examined using six animal-based indicators: body condition score (BCS), fleece condition, skin lesions, tail length, dag score and lameness. In addition, the number of ewes that needed further care (such as sick or injured sheep) was recorded and reported to the farmers. Generalised linear mixed models were conducted to investigate associations between welfare outcomes and visit, ewe breed and location, with all three, and their interactions, as fixed factors. In all instances, farm was set as a random factor to account for specific variation between farms. Overall, the welfare of the ewe flocks, based on the six indicators measured, was considered good. A total of 86.9% of the ewes were in adequate BCS (2.5–3.5), 91% had good fleece condition, 69.2% had no skin lesions, 97.1% had low dag scores, and overall lameness was 4.7%. An important and prevalent risk to welfare identified across farms was short tail length; with 85.7% of ewes having tails docked shorter than the third palpable joint. While the welfare of the flock was good, ewes in need of further care were identified at all farms. There were 185 (3.0%) cases needing further care, and the extent of welfare compromise of these animals was considered significant. Main reasons for further care were moderate/severe lameness or foot-related issues, $BCS \leq 2$ and active dermatophilosis or broken wool. To our knowledge, this study constitutes the largest assessment of ewes conducted in Australia, and the findings provide valuable insight into the main welfare issues likely to be encountered in extensive sheep farming enterprises. Future studies should develop practical technologies that can assist in the detection of the welfare issues identified in this study. In addition, the thresholds identified here could be used for future comparison and sheep welfare benchmarking programs to assess farm performance and measure continuous improvements.

OPEN ACCESS

Citation: Munoz CA, Campbell AJD, Hemsworth PH, Doyle RE (2019) Evaluating the welfare of extensively managed sheep. PLoS ONE 14(6): e0218603. <https://doi.org/10.1371/journal.pone.0218603>

Editor: Edna Hillmann, Humboldt-Universität zu Berlin, GERMANY

Received: December 14, 2018

Accepted: June 5, 2019

Published: June 19, 2019

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Data Availability Statement: All relevant data are within the manuscript and its Supporting Information files.

Funding: The research was funded by Meat & Livestock Australia Ltd (MLA), which represents funding from the red meat producers and the Australian Commonwealth Government. The funders had no role in the study design, data collection and analysis, decision to publish or preparation of the manuscript.

Competing interests: This research was funded by Meat & Livestock Australia Ltd (MLA), and we

declared that this does not alter our adherence to PLOS ONE policies on sharing data and materials.

Introduction

There are many types of extensive sheep production systems in the world, but some shared characteristics of extensive systems are that they rely mainly on pasture feeding as animals are managed outdoors all year round, or at least for most of their lives, with limited monitoring and human intervention [1]. These are typical production systems in the UK and the southern hemisphere, including Australia, New Zealand, South Africa, Argentina, Chile and Uruguay [1]. Extensive sheep farming systems create opportunities for sheep to live a ‘natural life’. Sheep have a free choice and control over a number of aspects of their life, including grazing, exploration, rumination, social interaction and maternal behaviours [2]. These characteristics of extensive systems fit with one of the three conceptual frameworks used to assess animal welfare, ‘natural living’ [3], and also has clear links to similar concepts in the ‘five freedoms’—*freedom to express normal behaviours* [4] and the ‘five domains’—*behavioural or interactive restriction* [5].

While the welfare of sheep is largely positive when assessed according to natural living, extensive systems create a different set of welfare issues to those that are seen in intensive (or behaviourally restrictive) production settings. There is limited research, however, investigating welfare issues in extensively managed sheep [6], and the research that does exist has largely been conducted in European countries [2,7–11]. Although there may be similarities in welfare issues between sheep farming systems in Europe and the southern hemisphere, different locations, the scale of production and weather conditions can create a different set of welfare concerns which warrants further investigation.

Sheep farms in the southern hemisphere are quite typically large-scale farms with a considerably low sheep:labour ratio when compared with European countries. In Scotland for instance, there are 2.6 million breeding ewes, with the majority in flock sizes of 500 sheep [12]. In contrast, countries such as Australia and New Zealand have 37.2 and 17.8 million breeding ewes respectively, with the majority of the Australian ewes in flocks of more than 2,800 sheep [13]. Lamb and ewe mortality, poor nutrition, intestinal parasites, lameness, provision of water and shelter, flystrike and mastitis have been identified as important welfare concerns for Australian sheep producers by survey studies [14–16] and one on-farm study [17]. While some issues likely to be encountered in these extensive systems have been identified, the extent of the issues remains unknown and needs further investigation. In this study, animal welfare assessments were conducted on 32 commercial Australian sheep farms with the aim of identifying the main welfare compromises and risks. This present study is part of a larger research investigating farmer attitudes and sheep welfare outcomes. This paper reports on the main welfare issues likely to be encountered in extensive sheep farming systems and examines opportunities to safeguard the welfare of sheep. The work reported in Munoz et al., [18] (under review by PLOS ONE) builds on this present paper and reports on the relationship between farmer attitudes, management behaviour and sheep welfare.

Material and methods

Farms and visits

Thirty-two commercial sheep farms, located in the high rainfall (> 600 mm) and wheat-sheep zones (300–600 mm) of Victoria, Australia were involved in the study. Farmers were recruited through advertisements in industry magazines, by engaging with local consultants and their groups, by advertising in industry conferences or through nomination by neighbours. Eligible farms had to have a self-replacing ewe flock and spring lambing and contain a minimum of 400 breeding ewes. This cut-off number was based on preliminary results from focus group discussions with Victorian farmers [19]. Wherever possible, visits were arranged to coincide

with ultrasound pregnancy diagnosis ('scanning' in mid-pregnancy) and weaning 2016/17. These periods were selected because mid-pregnancy and weaning are critical periods when many welfare challenges can arise due to fluctuation in environmental and climatic conditions combined with physiological demands due to the sheep reproductive cycle [9,10,17]. Of the 32 farms involved in the study, 30 were visited twice (at mid-pregnancy and weaning), and two farms only at once (both at weaning). Mid-pregnancy visits were not conducted on two farms because either the animals or the farmers were unavailable at the right time.

Animals and welfare assessment protocol

This study was approved by the University of Melbourne Animal and Human Ethics Committees, ethical review numbers 1613838 and 1646392 respectively. Sixty-two farm visits were conducted, and 6,200 ewes were assessed in total. Sixty-one visits were conducted by the lead researcher (C.A.M), and one visit was conducted by the principal researcher (R.E.D) who was also trained by C.A.M. At each visit, farmers were asked to provide a random sample of 100 ewes, aged from 2 to 5 years. The sample size was selected based on a power calculation to estimate a trait's prevalence, assuming a design prevalence of 50%, a 95% confidence interval and desired precision of $\pm 10\%$. This number was supported by the AWIN sheep protocol which recommends a sample of 92 sheep when the farm size is greater than 2000 breeding ewes [20]. Sheep were managed under extensive commercial conditions, in year-round outdoor systems. The assessments were performed using a holding pen and a single-file race within the farms' regularly-used sheep yards. At each visit, we recorded the prevalence of adequate/inadequate body condition according to [21], adequate/inadequate fleece condition [20], prevalence and severity of skin lesions, adequate/inadequate tail length according to [20], low/high dag score [22] and lameness [20]. The assessment criteria of the welfare indicators are reported in Table 1. These indicators were selected because they proved to be valid, reliable and feasible for extensive sheep farming conditions [17,23], and they address main welfare concerns for sheep, covering freedom from hunger, pain, injury or disease. In addition, the number of ewes that required further care was recorded and reported back to the farmer. Further care was defined as any sick or injured ewe that would benefit from further inspection and/or intervention. This included, but was not limited, to poor body condition, poor fleece condition, severe injuries (e.g. fresh, bleeding and ≥ 10 cm) and severe lameness (e.g. score 2 or more). Further interventions may have included: further treatment, drafting the animal from the main flock or culling. If indicated by the farmer, the ewes classed as 'further care' were drafted to a holding pen for further inspection by farm staff. The course of action, or intended course of action, taken by the farmer was recorded. During the visits, farmers also had to complete a questionnaire on general information about the farm (e.g. main farming enterprise, flock size, etc) and demographic information.

Statistical analyses

Descriptive analyses were performed in Excel (Microsoft) and in R statistical package 2.13.1 (R Development Core Team, 2008). Statistical analyses were based on prevalence data. To assess ewe welfare, the data was checked for normal distribution (Kolmogorov-Smirnov test; Q-Q, scatter and box plots) and generalised linear mixed models were conducted to investigate the associations of time of assessment (mid-pregnancy and weaning), ewe breed (meat or wool breeds) and location (high rainfall or sheep-wheat zones) on welfare outcomes, with all three and their interactions as fixed factors. In all instances, farm was set as a random factor to account for specific variation between farms. In addition, t-test was used to compared differences in flock sizes between high rainfall and wheat-sheep zones.

Table 1. Animal-based welfare indicators used to assess ewe welfare.

Welfare indicators	Assessment criteria
Body condition score	Scored on a 5-point scale, using a quarter-unit precision [24,25] (1) Emaciated. Dorsal spinous and transverse processes are sharp and prominent. (2) Thin. Dorsal spinous processes are still prominent, but not as sharp. Transverse processes rounder on edges. (3) Average. Spinous and transverse processes are smoother and less prominent. (4) Fat. Considerable pressure is needed to feel dorsal spinous processes. Transverse processes cannot be felt (5) Obese. Dorsal spinous and transverse processes cannot be felt. The BCS classification was also based on recommendations from [21].
Fleece condition	Scored on a 3-point scale: (0) Good fleece condition, when parted, the fleece has no lumpiness or signs of ectoparasites (1) Some fleece loss, small shedding or bald patches ≤ 10 cm diameter. When parted, the fleece may have some lumpiness or scurf, little evidence of ectoparasites (2) Significant fleece loss with bald patches of greater than 10 cm in diameter, clear evidence of ectoparasite [20]
Skin lesions	Assessed by recording number, location and severity of the skin lesions. Lesions were classified as cuts, open wounds, old wounds or scars and abscesses.
Tail length	Scored on a 2-point scale: (0) The ventral tip of the vulva is covered by the docked tail when held down (1) The tail is over-shortened or almost not present, or if the vulva and anus cannot be covered [20]
Dag score	Scored on a 6-point scale: (0) No evidence of faecal soiling (1) Very light soiling on the breech area (2) Moderate dag on the breech area extending ventrally (3) Severe dag predominantly on the breech area, extending ventrally and dorsally over the tail some soiling and dag around the anus (4) Excessive dag on the breech area and on the hind legs (5) Very severe dag on the breech area and on the hind legs or below the level of the hocks [22]
Lameness	Scored on a 4-point scale: (0) Not lame (1) Clear shortening of stride with obvious head nodding or flicking as the affected limb touches the floor (2) Clear shortening of stride with obvious head nodding and not weight-bearing on affected limb whilst moving (3) Reluctant to stand or move [20]

<https://doi.org/10.1371/journal.pone.0218603.t001>

The results from ewes classed as ‘further care’ were grouped into quartiles, and the 25% top performing farms, that is, farms in the lower quartile for this ‘summary measure’ were identified at both time periods.

Relationships between the different welfare indicators were examined by Spearman’s Rank correlation using SAS statistical package. Correlation values were classified as moderate if between 0.3 and 0.59 or strong if ≥ 0.60 . (Statistical Analysis System, Release 9.4 2012; SAS Institute Inc., Cary, NC, USA). Only those correlations significant at $P \leq 0.05$ are reported.

Results

From the 32 farms in the study, the majority of farmers were male ($n = 30$). The average age was 51 (ranged from 25 to 87) and the average years working with sheep was 26.7 years (ranged from 2 to 67). A total of fourteen farms (44%) were classed as meat-focused enterprises, as the primary source of income was the production of lambs for slaughter. Twelve farms (38%) were classed as dual purpose (meat-wool) enterprises, defined here as enterprises which at least 25% of income was derived each from wool and meat, and six farms (18%) were classed

Table 2. Farm demographics according to enterprise, flock size and breed. The range of the ewe flock sizes is presented in parentheses.

Enterprise	Farms	Average flock size	Breed
Meat	14	2,770 (500–9000)	*Composite, Poll Dorset Highlander, Corriedale
Meat-wool	12	2,246 (431–4411)	Merino, Merino first-cross, Composite, Dohne
Wool	6	2,091 (1075–9400)	Merino

*Composite breeds were mainly Coopworths (Border- Romney, F3 generation progeny). Merino first-cross ewes refer to the offsprings of Merino ewes with Border Leicester rams.

<https://doi.org/10.1371/journal.pone.0218603.t002>

as wool-focused enterprises as the primary source of income was wool production. The average ewe flock size was 2,771, however, there was a wide range in flock sizes (431–9,400) and breeds used across the 32 farms which are summarised in Table 2. On average, there were significantly more ewes on farms in the high rainfall zones ($n = 3,555$) compared to the wheat-sheep zones ($n = 1,624$, $t = 2.86$, $P = 0.008$).

Assessment of ewes' welfare

The results of the welfare assessment at both visits are presented in Table 3. Overall, 185 (3.0%) ewes were reported to farmers for further care. Considering both visits, there was at least one ewe reported for further care on each farm. On average, 2.6% of ewes required further care at mid-pregnancy and 3.3% of ewes required further care at weaning. The highest percentage of ewes requiring further care on a farm was 11% ($n = 11$) which was at weaning time. There was no influence of breed type or visit on the number of ewes that needed further care, however, location had a significant effect ($F = 1.87$, $P = < 0.001$). Ewes on wheat-sheep zones were more commonly in need of further care than ewes in high rainfall zones ($n = 97$ (6%) vs. $n = 88$ (2.5%)).

Nine farms (30%), out of the 30 farms assessed at mid-pregnancy, were classed in the lower quartile for the measure 'further care' (1% or fewer ewes in need of further care), and thirteen farms (40.6%), out of the 32 assessed, were classed in the lower quartile at weaning (2% or fewer ewes required further care). However, only six farms (20%), out of the 30 farms visited twice, were consistently in the lower quartile for this 'summary measure'. In contrast, eleven farms (36%) were consistently classed in the upper quartile. At both visits, these farms had 3% or more ewes that required further care.

Some common causes of further care were moderate/severe lameness or foot-related issues, BCS of 2 or below and active dermatophilosis or broken wool. Other afflictions included severe skin lesions, active pink eye, clinical mastitis, flystrike and vulva bleeding. In 51% of the cases, ewes in compromised welfare were experiencing multiple issues. Farmers took action in 40 (20%) of the 185 cases of ewes needing further care reported. Action taken by the farmer during the researcher presence involved drafting the ewes to be checked later ($n = 29$) or immediately addressing the issue. Immediate actions taken were hoof trimming to correct hoof overgrowth ($n = 6$), draining abscesses ($n = 2$), treating for flystrike ($n = 2$) and removing ingrown horns ($n = 1$). Issues where no immediate action was taken include cases of moderate and severe lameness, low condition score ewes, severe injuries, active pink eye and mastitis.

Lame ewes were found on all 32 farms. A total of 68% ($n = 198$) of all observed lameness cases were mild (score 1) while 32% ($n = 93$) of all cases were moderate or severe (scores 2 and 3). Lameness was affected by visit and location ($F = 5.87$, $P = 0.014$) with ewes in the wheat-sheep zones having more incidents of lameness at weaning compared to mid-pregnancy.

Table 3. Percentage, standard deviation (SD), minimum and maximum number scored in each category according to time of assessment; raw numbers presented in parentheses.

Animal Welfare Indicators	Pregnancy				Weaning				Total
	Percentage	SD	MIN	MAX	Percentage	SD	MIN	MAX	Percentage
	(n = 3,000)				(n = 3,200)				(n = 6,200)
BCS									
Thin ≤ 2.25	8.4 (253)	± 9.8	0	45	12.7 (407)	± 11.3	0	43	10.6 (660)
Adequate 2.5–3.5	90 (2701)	± 9.6	55	100	84 (2688)	± 10.1	56	100	86.9 (5389)
Fat ≥ 3.75	1.5 (46) ^a	± 2.8	0	12	3.3 (105) ^b	± 3.7	0	13	2.4 (151)
Fleece condition									
Score 0	91.6 (2748)	± 11.6	54	100	90.3 (2891)	± 16.4	23	100	91 (5639)
Score 1–2	8.4 (252) ^a	± 11.6	0	46	9.7 (309) ^b	± 16.4	0	77	9.0 (561)
Ewes with skin lesions	30.1 (904)	± 23.5	0	94	31.5 (1011)	± 28.6	1	100	30.8 (1915)
Total skin lesions	1637 ^a				2624 ^b				4261
Head/neck	10.8 (177)	± 16.9	0	91	19.4 (508)	± 50.2	0	283	16.1 (685)
Ear	35.9 (588)	± 18.5	0	54	24.4 (639)	± 19.2	0	64	28.8 (1227)
Eye	1.2 (19)	± 1.1	0	3	0.3 (8)	± 0.5	0	2	0.4 (27)
Body	17.9 (293)	± 38.1	0	206	29.5 (773)	± 100.1	0	560	25.0 (1066)
Rear	29.8 (488)	± 45.3	0	219	19.4 (508)	± 43.6	0	228	23.4 (996)
Legs	4.4 (72)	± 9.7	0	53	7.0 (188)	± 17.2	0	85	6.1 (260)
Dag score									
Score 0–3	98.9 (2967)	± 2.2	91	100	95.4 (3054)	± 12.7	31	100	97.1 (6021)
Score 4–5	1.1 (33) ^a	± 2.2	0	9	4.6 (146) ^b	± 12.7	0	69	2.9 (179)
Tail length									
Score 0	11.9 (356)	± 16.2	0	67	16.4 (526)	± 21.7	0	78	14.2 (882)
Score 1	88.1 (2645)	± 16.2	15	100	83.6 (2674)	± 21.7	22	100	85.8 (5318)
Lameness									
Score 0	95.7 (2872)	± 3.2	85	99	94.8 (3034)	± 2.6	90	99	95.3 (5909)
Score 1	2.9 (86)	± 2.8	0	11	3.5 (112)	± 1.8	0	7	3.2 (198)
Score 2–3	1.3 (40)	± 1.0	0	4	1.7 (53)	± 1.3	0	4	1.5 (93)
Further Care	2.6 (77)	± 1.4	0	5	3.3 (108)	± 2.3	0	11	3.0 (185)

^{a,b} Values within a row with different superscripts differ significantly at $P < 0.05$. The BCS classification was based on recommendations from [21].

<https://doi.org/10.1371/journal.pone.0218603.t003>

Most ewes examined (85.7%) had short docked tails, with 2645 (88.1%) at mid-pregnancy and 2674 (83.6%) at weaning. No differences were found between breed type, visit or location. While less frequent, adequate tail lengths were present across 30 out of the 32 farms assessed and ranged between 1 to 67 ewes with adequate tail length at mid-pregnancy, and from 1 to 78 at weaning.

Most of the ewes were within the BCS range of 2.5 and 3.5. However, a total of 10.6% ($n = 660$) of the ewes were classed 'thin' (BCS of 2.25 or below). Out of these 660 ewes, 36 (5.4%) cases had a BCS of 2 or below. On the other hand, a total of 2.4% ($n = 151$) of the ewes were classed 'fat' (BCS of 3.75 or above) which were more often observed at weaning than at mid-pregnancy ($F = 4.11$, $P = 0.04$).

A total of 30.8% ($n = 1915$) of the ewes examined presented skin lesions, and the rate of lesions was higher at weaning (0.5 lesions per ewe; $F = 200.46$, $P < 0.001$) than at mid-pregnancy (0.29 lesions per ewe). Most common lesions were ear lesions related to sunburn (17.5%, $n = 1086$). Affected ears were irritated, the skin was red and presented scabs, and the extent of the lesion usually compromised 50% of the ears or more. Other common lesions

Table 4. Spearman's Rank correlations between the welfare indicators.

Welfare indicators		r	P-Value
Mid-pregnancy			
BCS ≤ 2.25	BCS 2.5–3.5	-0.88	< .0001
BCS ≥ 3.75	Skin lesions	-0.67	< .0001
	High dag scores	-0.46	0.011
	Lameness (score 1–3)	0.41	0.023
Skin Lesions	High dag scores	0.36	0.053
	Lameness (score 1–3)	-0.37	0.044
High dag scores	BCS ≥ 3.75	-0.46	0.011
Weaning			
BCS ≥ 3.75	BCS ≤ 2.25	-0.47	0.007
	Lameness (score 2)	0.45	0.009
Inadequate fleece	Skin lesions	0.35	0.052
Skin lesions	High dag scores	-0.44	0.011

<https://doi.org/10.1371/journal.pone.0218603.t004>

were cuts to the body and rear. Eye lesions were the least with 27 ewes affected in total (0.4%). Nine of these were active pink eye and a maximum rate recorded on a farm was 2%. Skin lesions were more common in wool breeds at both mid-pregnancy and weaning visits. Five merino flocks were visited following shearing or crutching, which significantly affected the number of injuries observed per ewe ($F = 1128.7$, $P < 0.001$). During the visits after shearing, 86.8% of the ewes assessed ($n = 434$) had at least one lesion to their body, legs, rear, ears or head. The average number of skin lesions per ewe was 5.4 (range 0 to 26) and most of these lesions were to the body.

Fleece issues were observed in 9% ($n = 561$) of the ewes. They were more common in meat breeds than they were in wool breeds ($F = 5.67$, $P = 0.02$), and were more common at weaning than at mid-pregnancy ($F = 5.50$, $P = 0.02$). Incidents were under 5% in wool breeds, but up to 15% in meat breeds at weaning. Common fleece issues were related to fleece rot, that is, matted band of wool with either, yellow, green or brown discolouration due to bacterial growth ($n = 507$). Other issues were active or old lesions of dermatophilosis ($n = 32$) and wool loss ($n = 22$). Overall, only 2.9% of ewes had high dag scores (score 4 and 5), but they were found on 17 out of the 32 farms, and they were more frequently observed at weaning than at mid-pregnancy ($F = 29.19$, $P < 0.001$).

Table 4 shows the significant correlations observed between the different welfare indicators. At both visits, there was a moderate positive correlation between 'fat' ewes (BCS equal or above 3.75) and lameness. In addition to these correlations, at mid-pregnancy there was a significant negative correlation between skin lesions and 'fat' ewes ($r = -0.67$, $P < 0.001$). At weaning, there was a significant negative correlation between skin lesions and high dag scores ($r = -0.44$, $P = 0.014$).

Discussion

Thirty-two farms in the high-rainfall and wheat-sheep zones of Victoria were involved in this study and 6,200 ewes were examined in total. To our best knowledge, this study constitutes the largest evaluation of the welfare of ewes conducted in Australia. While results in this study may be more representative of welfare problems in large-scale sheep farms, such as those in the southern hemisphere, the findings of this study are a sound basis for future research,

providing valuable insight into the main welfare issues likely to be encountered in extensive sheep farming enterprises.

Overall, the welfare of the ewe flocks, based on the six indicators measured, was considered good. A total of 86.9% of the ewes were in adequate BCS, 91% had good fleece condition, 69.2% had no skin lesions, 97.1% had low dag scores and 95.3% of the ewes were not lame. For the proportion of ewes that needed further care (3.0%), the extent of welfare compromise was significant and, in many cases, involved multiple issues. The most common causes of further care were severe lameness or foot-related issues, low body condition and active dermatophilosis or broken wool. These results are in agreement with previous on-farm studies conducted in the UK [10,26], suggesting that the welfare issues identified in this study are also relevant to some extent to sheep managed extensively worldwide. While cases of further care were identified in all farms, there were six farms (20%) that at both visits were classed in the lower quartile for the summary measure 'further care'. These farms consistently had 2% or fewer ewes in need of further care during the assessments, performing better for this measure than the rest of the studied group. To our knowledge, this is the first study quantifying the number of ewes in need of further care on farms and we propose that a target of 2% for animals in need of further care could be a useful starting point to encourage continuous improvement for the welfare of extensively managed ewes. Future benchmarking programs could use this threshold to assess/compare farm performance and measure improvements.

In all cases of ewes classed as in need of further care, none of these cases were previously identified or treated by farm staff or the farmer, even though all ewes were recently in the yards for other husbandry procedures (e.g. ultrasound pregnancy diagnosis and weaning). We believe this highlight two issues: 1) the difficulty of identifying individual welfare compromise in large-size flocks and 2) the difficulty of decision-making about when and how to manage ewes that need further attention. While the number of ewes requiring further care was low, a limited number of ewes were immediately treated or drafted for further treatment, which does not necessarily guarantee that corrective actions were taken. Management of sick animals involves decision-making and planning, and therefore, a number of factors may be influencing farmers' willingness to address farm issues [27]. Possible reasons for not providing immediate care, or why some cases were treated more promptly than others, may include: the issue may not have been perceived to be important by the farmer, a perceived difficulty in treating certain health issues (e.g. draining abscesses vs clinical mastitis), or time constraints. Possibly, this lack of intervention is driven by the low economic value of an individual ewe, which has been previously identified as a contributing factor to low levels of intervention [28].

A valuable and practical way that could help farmers to identify sheep at risk or in compromised welfare could be to perform close examination ('hands-on' inspection) of a representative sample of the flock around times where sheep are in the yards for other husbandry procedures (e.g. vaccinations, internal parasite control, weaning). Close examination of sheep should be performed more than once throughout the year to obtain accurate results as seasonal variation needs to be accounted for. Assessing welfare at critical times, such as mid-pregnancy and weaning, concentrate observations on those periods when many welfare challenges can arise [9,10,12]. In addition, providing farmers with easily accessible and practical solutions to common welfare issues could help increase the frequency with which sheep in need of further care are treated. Methods would need to be applied when ewes are in the yards or implement relatively easily in the paddock. For example, tools like decision trees and checklists that are simple to follow and readily available could be effective ways to help farmers in the management of sheep in need of further care. Another alternative could be the use of sensor technology. Currently, GPS tracking devices have been developed to assist farmers with flock

monitoring and the identification of sick animals [29–31]. However, further research is required to improve the practicality of this technology in order to increase its applicability.

Lame ewes were found across all farms and while moderate and severe lameness were notified to farmers, it is difficult to assure that corrective measures were taken in all cases. Lameness was affected by visit; there was an average of 4.2% of lame ewes at mid-pregnancy and 5.2% of lame ewes at weaning. This is consistent with the normal pattern of lameness affecting sheep mostly over the winter and spring months when the soil has more moisture, predisposing sheep to footrot, foot abscess and hoof overgrowth [32,33]. In extensive sheep farming conditions, where sheep may walk on average 17 km daily [34], and there is limited monitoring of individuals, the potential for lameness to impact animal welfare is of particular concern [7]. In this study, it was not practical to always identify the cause of lameness, which was a limitation of the study. However, from an animal welfare perspective, whilst the incidence and cause of lameness are important to identify, so is how rapidly lame sheep are identified and treated. Only a few cases of mild or moderate lameness were immediately treated by the farmers of this study, and the immediate action taken was hoof trimming to correct some cases of hoof overgrowth. While treatment of lameness may be influenced by cost and labour, further studies examining other key drivers that might influence this behaviour such as time constraints, knowledge and skills of farmers are needed to develop adequate strategies to promote behavioural change and safeguard sheep welfare.

A high number of ewes (85.7%) had tails docked too short, indicating that farmers tail docking behaviour present an important risk to welfare. These results are in agreement with an interview study from South America [35] that reported that most farmers in Chile (55.9%) docked lambs' tails shorter than recommended. Tail docking is an important management practice used to reduce the risk of flystrike. However, if the tail of the lambs is docked too short (less than the third palpable joint) sheep have a higher risk of rectal prolapse [36], flystrike [37] and bacterial arthritis [38]. Even though the negative impacts of docking tails too short have been well established, short tails were found across all farms. As tail docking is a common husbandry practice, it is possible that other classes of stock on the farms assessed also had short docked tails and the associated welfare risks. Further studies assessing different classes of sheep on farms may be valuable to clarify this issue.

Most of the ewes in this study were within recommended body condition at both mid-pregnancy and weaning, which suggests that farmer nutritional management of the whole group was good overall. However, thin ewes were observed within flocks, suggesting that some farmers in this study were not identifying/treating individual thin ewes. Maintaining ewes in adequate body condition correlates positively with most production traits, including numbers of lambs born and weaned and both, lamb and ewe survival [39]. However, ensuring that all sheep in a flock meet their nutritional requirements is not easily achievable in extensive systems [7]. While animal welfare issues can occur at both high and low body condition, thin sheep face more immediate risks to welfare generally. They have higher feeding motivation than ewes with higher BCS, have reduced ability to adapt to cold challenges [40] and are at greater risk of developing pregnancy toxemia [41]. Body condition scoring is a simple and low-cost management practice that can help farmers to identify animals in low BCS. Further studies, however, need to assess farmers' engagement and barriers for adoption of this practice. In addition, further research in the development of sensor technologies to identify thin and fat sheep in extensive farming systems are required to assist farmers with this issue, and therefore, mitigate the welfare compromise or risks associated with inadequate body condition.

The number and severity of skin lesions were variable, however, ear lesions due to sunburn were commonly observed. Possible reasons for these findings may be associated with lack of shelter in the paddocks and/or inadequate nutrition e.g. ingestion of toxin plants or cobalt

deficiencies [42]. This suggests that other stock classes in the farms may also be affected. Further examination on nutritional management and farm resources e.g. presence, quality and type of shelter may be valuable. While body lesions were not very common, the number and severity of them increased significantly following shearing. Although only very large and open cuts were referred to the farmers, there were many instances where cuts were >5 cm in length but healed. Shearing is a stressful procedure for sheep [34], and injuries sustained during wool removal contribute significantly to this stress while also creating a risk of infection and other diseases [43]. The data collected in this study would serve as groundwork for future comparison. However, further research is needed on the short and long-term impact of shearing injuries on the welfare and productivity of extensively managed sheep.

This study's results may not necessarily represent the welfare of ewes within the flocks of the study farms or ewes throughout Australia. While the study visits were conducted during key periods of the reproduction cycle of sheep, the population studied was robust. The ewes examined in this study were the easiest to manage and an economically valuable group in the farms; that is, single-bearing ewes (if known), from 2 to 5-year-old. Age and mortality have a parabolic relationship, with the risk being higher in younger and older animals. As a result, it is possible that the level of welfare compromise reflected on this study may be the lowest it would be across each farm. Ewes were also brought into the yards by the farmers so that the welfare assessment could be conducted. It is possible that this process may have favoured healthier animals, due to farmers bias, but also because more compromised ewes (e.g. severe lame, lethargic) are less able to move [44], and thus seriously compromised ewes were less likely to be mustered to the yards. Further on-farm research examining whole flocks and, obviously, differences between stock classes need to be conducted to validate these findings. Furthermore, although there was an adequate representation of farm enterprises and location according to the national statistics of the sheep industry [13,45], we used voluntary recruitment, which may have introduced a participation bias into the study skewed towards more 'proactive' farmers or farmers more engaged with industry or research activities. Further studies could develop a nation-wide survey to collect information on demographic data, farm management and farm health records from a wide variety of farmers to broaden the reach and increase the likelihood of a more accurate representation to compare these findings.

Further refinement of the welfare assessment protocol is necessary to achieve a more comprehensive assessment. The welfare assessment of this study mainly evaluated the biological functioning of ewes, addressing important welfare issues identified by producers, industry, specialist and general public [10,14,20]. While animal-based indicators are the most important to consider, as they are direct indicators of the welfare of the animal, some relevant management- and resource-based indicators may also need to be incorporated in future assessments (such as nutrition management or provision of shelter). When combining the information gathered by animal-, management- and resource-based indicators it is possible to assess, more comprehensively, where actions need to be taken to correct or mitigate the issue or potential risks to welfare. Reduction in the number of animal-based indicators could also make this on-farm welfare assessment even more practical, and thus more likely to be implemented. Overall, there were consistent and significant associations between some welfare indicators in this study. At both visits, positive correlations were found between lameness and 'fat' ewes, possibly because fat sheep walk less, which predispose them to foot problems [46]. Correlations are useful in understanding associations between welfare indicators, but these associations are usually complex and not straightforward. Further examination of these relationships is necessary to determine the potential of lameness and/or BCS to act as proxy measures for a larger suite of welfare indicators. Another aspect that needs to be considered in future assessments is the evaluation of the affective state of ewes. Flight distance and qualitative behaviour assessment

are two potential measures that can be used to assess emotional state in these animals [47]. How flight distance and the behaviour of sheep during routine handling may differ across farms, and how they may be associated with farmer handling behaviour and attitudes to sheep could provide further insights on the affective state of sheep and the farmer-sheep relationship in extensive systems.

Conclusion

We conservatively conclude that the flocks assessed in this study were in good welfare, however, welfare compromise to the individual animal can be significant. The most common causes of further care were severe lameness or foot-related issues, low body condition and active dermatophilosis or broken wool. In addition, an important and prevalent risk to welfare identified across all farms was short tail length. While less prevalent, other risks to welfare such as poor fleece condition, ear lesions due to sunburn, shearing cuts and fat ewes were also identified. Overall, the issues identified in this study can arise from, and be treated or mitigated by, management practices. While results in this study may be more representative of welfare problems in large-scale sheep farms, such as those in the southern hemisphere, the findings of this study are groundwork for future research, providing valuable insight into the main welfare issues likely to be encountered in extensive sheep farming enterprises. Future studies should develop practical technologies that can assist in the detection of the welfare issues identified in this study. For example, practical GPS tracking sensors to monitor the flock and identify sheep at risk or in compromised welfare are much needed. Finally, understanding the prevalence of welfare issues is the first step to determining acceptable thresholds for the industry. Therefore, the thresholds and prevalence data identified in this study could be used for future comparison and sheep welfare benchmarking programs. For instance, a target of 2% for animals in need of further care could be a useful starting point to encourage continuous improvement in extensive sheep farming enterprises.

Supporting information

S1 Data. Supporting information.
(XLSX)

Acknowledgments

The authors would like to thank all farmers that kindly participated in this project and the research team of the Animal Welfare Science Centre for their great assistance during fieldwork.

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Main findings/implications of Chapter 4:

- The welfare of the ewe flock was good overall. However, individual welfare compromise can be significant.
- Farmers ability to identify individual welfare compromise was limited.
- The number of ewes requiring further care per farm was relatively low, however, farmer intervention was limited.
- A target of 2% for animals in need of further care could be a useful starting point to encourage continuous improvement for the welfare of extensively managed ewes.

Chapter 5: Positive attitudes, positive outcomes:

This chapter examines the relationships of ewe welfare outcomes and the attitudes and management practices of the 32 farmers that manage the sheep. This chapter provides insight into the underlying beliefs that underpin farmers' management behaviour and how management behaviours may influence ewe welfare outcomes.

This chapter has been published as:

Munoz CA, Coleman GJ, Hemsworth PH, Campbell AJD, Doyle RE. Positive attitudes, positive outcomes: The relationship between farmer attitudes, management behaviour and sheep welfare. Hillmann E, editor. PLoS One. Public Library of Science; 2019;14: e0220455. doi:10.1371/journal.pone.0220455



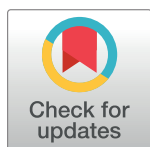
RESEARCH ARTICLE

Positive attitudes, positive outcomes: The relationship between farmer attitudes, management behaviour and sheep welfare

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OPEN ACCESS

Citation: Munoz CA, Coleman GJ, Hemsworth PH, Campbell AJD, Doyle RE (2019) Positive attitudes, positive outcomes: The relationship between farmer attitudes, management behaviour and sheep welfare. PLoS ONE 14(7): e0220455. <https://doi.org/10.1371/journal.pone.0220455>

Editor: Edna Hillmann, Humboldt-Universitat zu Berlin, GERMANY

Received: January 31, 2019

Accepted: July 16, 2019

Published: July 31, 2019

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Data Availability Statement: All relevant data are within the manuscript and its Supporting Information files.

Funding: This research was funded by Meat & Livestock Australia Ltd (MLA), and by red meat producers and the Australian Commonwealth Government. The funder had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing interests: This research was funded by Meat & Livestock Australia Ltd (MLA), and we

Abstract

This study examined the relationships between the attitudes and the management behaviour of the farmer and the on-farm welfare of their ewes. To our knowledge, this is the first study investigating these relationships in extensive sheep farming systems. Thirty-two sheep farmers and 6200 ewes were sampled across Victoria, Australia. Questionnaire interviews and on-farm animal welfare assessments were conducted. The ewes were assessed at two-time points, mid-pregnancy and weaning. To examine relationships between farmer and ewe variables, categorical principal component analyses, correlations and logistic regressions were used. The main findings of this study indicate relationships between farmer attitudes and management behaviour, consistent with findings from other more intensive livestock industries. Farmers were more likely to check the body condition of their ewes (Odds ratio = 2.37, $P = 0.03$), perform ultrasound pregnancy diagnosis (Odds ratio = 1.16, $P = 0.02$) and test for egg count before deworming sheep (Odds ratio = 2.88, $P = 0.01$) if they perceived these activities were important/valuable. In addition, farmers that performed these activities had a more active management style, and ewes in better welfare: fewer lame ewes at mid-pregnancy ($r = -0.38$, $P = 0.04$), and fewer ewes in need of further care at mid-pregnancy and weaning respectively ($r = -0.47$, $P = 0.01$; $r = -0.50$, $P = 0.01$). When combining the qualitative and quantitative analyses, behavioural attitudes (attitudes towards specific management behaviours) and perceived behavioural control (perceived barriers to performing the behaviour) emerged as the two main drivers underpinning farmer management behaviour. The results of this study indicate that the way farmers manage their ewes influences welfare outcomes, and management decisions are influenced by attitudes towards management practices. These findings demonstrate the opportunity to create change in farmer management behaviour and improve sheep welfare via targeted education programs.

declared that this does not alter our adherence to PLOS ONE policies on sharing data and materials.

Introduction

Extensive sheep production systems allow sheep to live in a more natural environment and to perform an extensive amount of natural behaviours. Under these systems, and when resources are available, sheep have more choice in, and control over their day to day activities, such as grazing, ruminating and socially interacting with conspecifics [1,2], all of which can be indicative of good sheep welfare [3]. Although behaviour is not restricted, extensive farm systems create other environmental risks to welfare such as the possibility of predation, variable quantity and quality of feed and water and climatic extremes [2]. While welfare issues in extensive systems can be exacerbated by the environment, management practices play a significant role in mitigating these risks [4].

Improved management practices to increase sheep welfare and productivity are widely available for farmers [5–8]. However, farmer adoption of best practice is limited and warrants further investigation. For example, survey data suggest that despite training only 32% of farmers either measure the body condition of their ewes or would be willing to do so, and only 47% of farmers did or would be willing to allocate pregnant ewes to different groups according to nutritional needs [9]. More recently, a broad industry survey on 600 sheep farmers identified that only half of producers use ultrasound pregnancy diagnosis regularly, with only 31% of them separating ewes into different mobs according to nutritional needs [10]. Farmers are the key players in improving sheep welfare and farm productivity because they provide the actual care of animals and make the management decisions on their farm. Thus, a better understanding of farmer attitudes towards sheep and sheep management and barriers to best practice is imperative.

Training and education programs for farmers usually focused on knowledge transfer (e.g. nutrition management, pasture management, etc.), however, it has been demonstrated that programs should also focus on generating change in the beliefs and attitudes that underpin behaviours to create a long-term change [11]. This present study examined how farmer attitudes influence their management behaviour, and how management influence welfare outcomes for the animal. In order to do this, we used the Human-Animal Relationship Model (HAR) by Hemsworth and Coleman [12]. It was hypothesised that farmer attitudes will relate to management behaviour and management behaviour will influence the on-farm welfare of extensively managed ewes.

The HAR Model (Fig 1), is based on the Theory of Planned Behaviour [13], and establishes that stockperson behaviour is likely to be determined by three 'key drivers' (1) attitudes towards the behaviour, which refers to a person's beliefs of the outcome (favourable or unfavourable) of a specific behaviour, (2) subjective norms, which refers to a person's beliefs about other people expectations (e.g., parents, spouse, friends) or social pressures to perform a specific behaviour and (3) perceived behavioural control, which refers to a person's beliefs about the control they have (ease or difficulty) of performing a specific behaviour [11,14]. According to this model, human attitudes formed by behavioural attitudes, subjective norms and perceived behavioural control, determine intention and influence human behaviour (interactions, husbandry and management) which has been showed, in other livestock industries, to have implications for animal behaviour, productivity and welfare [12,15–21].

Understanding the underlying beliefs that underpin farmers' management behaviour, as well as main barriers for adoption, have the possibility to create broad industry impact. With this information, it is possible to develop adequate educational programs to promote attitudinal change, and thus increase the implementation of improved welfare practices with the goal of achieving sustained practice change in the sheep industry. This present study is part of a larger research investigating farmer attitudes and sheep welfare outcomes. This paper reports

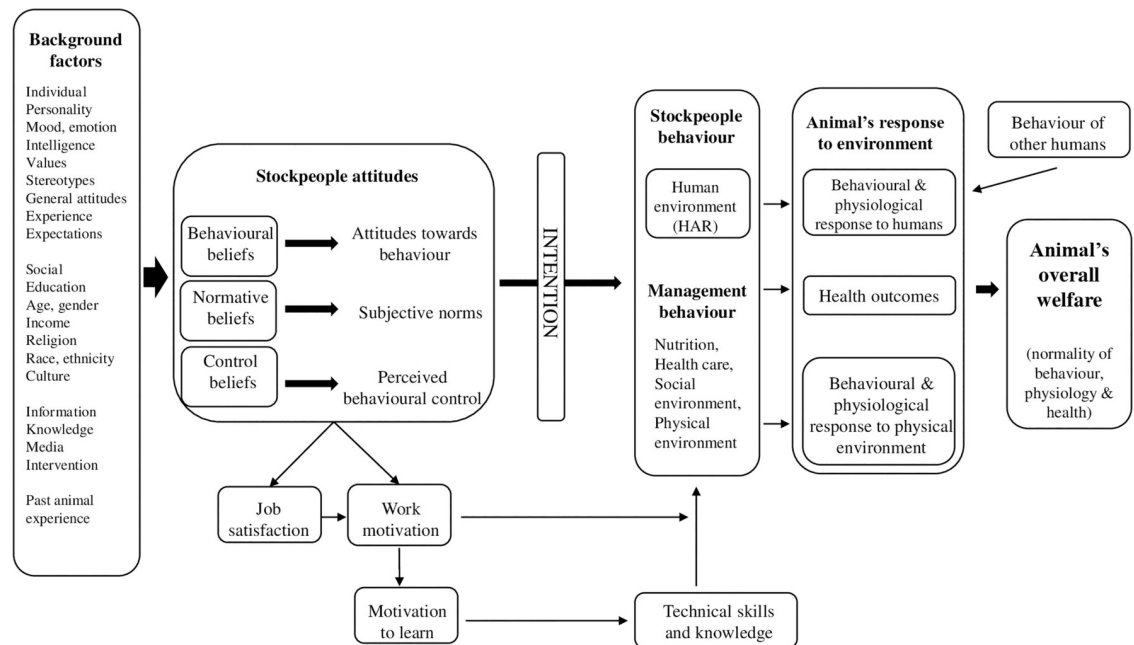


Fig 1. The Human-Animal Relationship Model based on the Theory of Planned Behaviour adapted from [14].

<https://doi.org/10.1371/journal.pone.0220455.g001>

on the relationship between farmer attitudes, management behaviour and sheep welfare and builds on a published study by Munoz et al., [22] that reports details on the on-farm welfare of extensively managed sheep.

Materials and methods

Farms and visits

To determine relationships between farmer attitudes, management behaviour and ewe welfare, questionnaire interviews with sheep farmers and two visits to their property to perform animal welfare assessments were conducted. This study was approved by the University of Melbourne Animal and Human Ethics Committees, ethical review numbers 1613838 and 1646392 respectively. In total, 32 commercial sheep farms, located in the high rainfall (> 600 mm) and wheat-sheep regions (300–600 mm) of Victoria, Australia were involved in this study. Farmers were recruited through advertisements in industry magazines, by engaging with local consultants and their groups, by advertising in industry conferences or through nomination by other farmers. Eligible farms had to have a self-replacing ewe flock, spring lambing and contain a minimum of 400 breeding ewes. This lower limit was based on preliminary results from focus group discussions with Victorian farmers [23].

Questionnaires

Two questionnaires were used; a farmer attitude questionnaire and a management questionnaire, both completed by the main person in charge of the animals, either the owner or the farm manager. The attitude questionnaire measured general attitudes towards sheep, sheep management and husbandry practices, using three types of attitude statements, based on attitudes towards the behaviour, subjective norms and perceived behavioural control. The questionnaire contained 88 statements in total and was developed based on results from two focus group discussions [23]. Using a five-point Likert scale, farmers were asked to indicate their

level of agreement to the statements, the level of importance or perceived difficulty of performing and activity e.g. score 1 = not at all agree/not at all important/not at all difficult to score 5 = strongly agree/very important/very difficult. Questions were both positive and negative, but responses were re-coded so that a high score indicated that the farmer held a positive attitude towards sheep and sheep management. Several statements on a specific topic were used to measure consistent beliefs, which allows the identification of a person's attitude towards a specific topic [12]. Thus, the attitudes that farmers held regarding sheep and management practices were used to establish their attitudes towards these aspects.

The management questionnaire involved a total of 51 questions on demographics, farm characteristics, animal numbers, labour units, production type, self-reported sheep husbandry and management practices, and perceived 'barriers' to best practice. Specifically, farmers were asked if they performed the following management practices: daily monitoring of the ewe flock, monitoring of feed on offer, body condition scoring of ewes, ultrasound pregnancy diagnosis annually, keep mortality records, keep productive records, perform internal parasite egg count before deworming sheep, provide sheep with some sort of shelter (e.g. trees) and whether they manage ewes according to their nutritional needs. This section was conducted in an interview-style, where the lead researcher (CAM) and the farmer discussed the questions. This allowed the farmer to clarify anything he/she was uncertain of, and for the researcher to follow up with any questions for clarification. The completion of the questionnaires took from 90 to 180 min, depending on the level of discussion that occurred, both questionnaires were conducted a day before the first welfare assessment. Farmers were also asked to complete a stock tally form to provide details on their sheep numbers from 1st of July 2016 to 30th of June 2017.

Animals and welfare assessments

Welfare assessments were conducted at two-time points. Visits were arranged to coincide with mid-pregnancy and weaning 2016/17. Sheep were managed under extensive commercial conditions, in year-round outdoor systems.

The assessments were performed using a holding pen and a single-file race within the regularly-used sheep yards of each farm. At each visit, farmers were asked to provide a random sample of 100 ewes, aged from two to five years. The ewes were examined using five animal-based welfare measures: body condition, fleece condition, number of skin lesions, faecal soiling and lameness. The assessment criteria for the welfare measures are presented in Table 1. In addition, the number of animals in need of further care (e.g. such as injured or sick sheep) were recorded at each farm at both time periods. Further care was defined as any sick or injured ewe that would benefit from further inspection and/or intervention. This included, but was not limited, to poor body condition, poor fleece condition, severe injuries (e.g. fresh, bleeding and ≥ 10 cm) and severe lameness (e.g. score 2 or more). Further details on the on-farm welfare of the ewes is reported in [22].

Resource-based measures were collected by assessing the farms' yards. The quality of the yards was subjectively scored from 0 to 7 by the lead researcher. Measures taken into consideration were; yard design (the ease of moving sheep from pens to the race), condition of the construction materials, quality of gates (ease of closing and opening gates), quality of floor (even floor), presence of roof, adequate wide and adequate length of the race to work with sheep.

Statistical analysis

The survey was analysed using qualitative and quantitative analysis. The questionnaires consisted of continuous data (e.g. farm hectares, sheep numbers, labour units, etc) and categorical,

Table 1. Animal-based welfare measures used to assess ewe welfare.

Welfare measures	Assessment criteria
Body condition score	Scored on a 5-point scale, using a quarter-unit precision [24,25] (1) Emaciated. Dorsal spinous and transverse processes are sharp and prominent. (2) Thin. Dorsal spinous processes are still prominent, but not as sharp. Transverse processes rounder on edges. (3) Average. Spinous and transverse processes are smoother and less prominent. (4) Fat. Considerable pressure is needed to feel dorsal spinous processes. Transverse processes cannot be felt (5) Obese. Dorsal spinous and transverse processes cannot be felt.
Fleece condition	Scored on a 3-point scale: (0) Good fleece condition, when parted, the fleece has no lumpiness or signs of ectoparasites (1) Some fleece loss, small shedding or bald patches ≤ 10 cm diameter. When parted, the fleece may have some lumpiness or scurf, little evidence of ectoparasites (2) Significant fleece loss with bald patches of greater than 10 cm in diameter, clear evidence of ectoparasite [26]
Skin lesions	Assessed by recording number, location and severity of the skin lesions. Lesions were classified as cuts, open wounds, old wounds or scars and abscesses.
Dag score	Scored on a 6-point scale: (0) No evidence of faecal soiling (1) Very light soiling on the breech area (2) Moderate dag on the breech area extending ventrally (3) Severe dag predominantly on the breech area, extending ventrally and dorsally over the tail some soiling and dag around anus (4) Excessive dag on the breech area and on the hind legs (5) Very severe dag on the breech area and on the hind legs or below the level of the hocks [27]
Lameness	Scored on a 4-point scale: (0) Not lame (1) Clear shortening of stride with obvious head nodding or flicking as the affected limb touches the floor (2) Clear shortening of stride with obvious head nodding and not weight-bearing on affected limb whilst moving (3) Reluctant to stand or move [26]

<https://doi.org/10.1371/journal.pone.0220455.t001>

ordinal (attitude statements using a five-point Likert scale) and binomial data (management questions where farmers responded yes/no). Fisher's exact tests (FET) were used to compare differences between management practices and ewe breeds (wool breeds vs meat breeds) and locations (high rainfall vs wheat-sheep regions).

Farmers' self-reported management behaviour and responses to the attitude statements were analysed by categorical principal component analysis, which is the non-linear equivalent of PCA. This procedure is available in SPSS as CATPCA. As with PCA, this technique reduces a set number of variables to a small number of new variables, known as principal components (or dimensions). Overall, CATPCA and PCA are very similar in objective, method, results, and interpretation. However, one of the main advantages of CATPCA is that can be used for nominal and ordinal variables. Likert-type scale values are not truly numeric, because intervals between consecutive categories cannot be assumed to be equal. Thus, to obtain the component scores, CATPCA analysis iteratively computes the component scores from the data itself, using an optimal scaling process to quantify the variables according to their analysis level [28].

Spearman's Rank correlation analyses were subsequently used on the CATPCA components scores to examine relationships between management and welfare outcomes and farmers general attitudes to sheep and welfare outcomes. Correlation analyses were also used to examine relationships between farm characteristics and welfare outcomes and to examine relationships between the attitude subscales (attitude towards the behaviour, subjective norms and perceived behavioural control). Correlation values were classified as strong if coefficients were ≥ 0.6 and moderate if between 0.3 and 0.59 [29]. Corrections to P values such as the

Bonferroni correction were not conducted in this study to minimise the risk of type II errors [30–33].

Logistic regression analyses (stepwise selection) were used to determine which of the independent variables (attitudes towards the behaviour, subjective norms and/or perceived behavioural control) had a statistically significant effect on farmer management behaviour. In addition, ordinal logistic regression analyses were performed to determine which of the background factors; age, work experience and level of education (independent variables) were significant predictors of the attitude subscales; attitudes towards the behaviour, subjective norms and/or perceived behavioural control (dependent variables). Data were analysed using the statistical programs SPSS 16.0 and SAS 9.4 statistical package.

Results

Relationship between management behaviour and sheep welfare

From the 32 farms in the study, fourteen farms were meat-focused enterprises (44%), twelve were meat-wool enterprises (38%), and six were wool focused enterprises (18%). Overall, common practices among sheep farmers were visual monitoring of both the ewe flock and feed on offer. All farmers reported that monitoring of the flock was done visually, from a distance while driving around the farm, and/or when feeding or moving sheep. However, the frequency of monitoring varied depending on the reproductive stage of the ewes. During lambing periods, 87.5% of farmers monitored their flocks twice daily ($n = 20$) or daily ($n = 8$). During non-lambing periods, farmers monitored their flock once weekly (66%, $n = 21$), every second day (16%, $n = 5$), fortnightly (16%, $n = 5$) or monthly (3%, $n = 1$). There was no statistical difference between meat-breed farmers and wool-breed farmers. Visual monitoring of feed on offer was a common activity and did not differ between meat-breed farmers and wool-breed farmers or across regions. While less common, a total of 19% ($n = 6$) of the farmers reported the use of more technical approaches such as industry guidelines, rulers/sticks or the advice of agronomists to measure pasture availability and quality. When asked about why some farmers did not monitor their flock or pasture every day (during the lambing period), the most common response was to not cause mismothering (31%). When asked about why some farmers did not monitor their flock or pasture every day (outside the lambing period), the most common responses were that they were busy with other activities or had other priorities (34%).

A total of 23 (72%) farmers self-reported that they checked the body condition of their ewes, and this was most commonly among meat-breed farmers than wool farmers ($P = 0.02$, FET). However, when asked to describe how they checked the body condition of their ewes, 14 (61%) farmers out of the 23 reported that they did this by physically touching the back of the ewes, while nine (39%) out of the 23 only did so visually from the distance. The latter group of farmers were re-coded as 'not performing this activity' for further analysis. Lack of time or not enough labour were cited as the most common reasons farmers did not physically condition score their ewes. Other descriptive reasons included farmers not wanting to do it or not appreciating the value of it.

Deworming sheep was usually performed once a year (41%, $n = 13$) or twice a year (34%, $n = 12$) and most commonly before lambing (44%) or during summer (41%), but most farmers (72%) agreed this activity was highly influenced by environmental conditions. A total of 66% ($n = 21$) of farmers performed egg count before deworming sheep. No differences were observed between flock type or region. Ultrasounds pregnancy diagnosis was more commonly performed on meat-breed flocks than wool flocks ($P = 0.02$, FET). Overall, a total of 22 (69%) of farmers scanned for pregnancy every year, six farmers (19%) scanned only in particular

years and four farmers (13%) had never scanned. The main reason farmers decided not to perform ultrasound pregnancy diagnosis annually was cost (25%, $n = 8$). Other reasons listed were; poor facilities, another activity to do, farmers not appreciating the benefits or not willing to change their practices, not being considered a priority and 'indolence'.

Record keeping was a less common activity and not influenced by flock type or region. Farmers were more likely to keep records of marking (50%) and conception rates (47%), than weaning (44%) and mortality records (41%). While 41% of farmers ($n = 13$) self-reported to keep mortality records, only 34.4% ($n = 11$) of farmers provided accurate, or close to accurate, stock tally records. Although mortality records were not usually accurate, a total of 47% ($n = 15$) of farmers reported that the main cause of ewe mortality was dystocia. Other causes were related to low body condition, internal parasites and age. Farmers estimated that their annual ewe mortality was 2.7% (range from 1 to 5%). However, according to the stock tally records, annual ewe mortality rate was 4.7% (ranged from 0.2 to 14.4%). Comparing farmer responses in the questionnaire and the stock tally data, six farmers overestimated their mortalities while 16 (50%) underestimated their mortality rates. Lack of time was the most common reason for not keeping records. Other reasons focused on the difficulty of measuring, not wanting to know the answer, not interested or not seeing the value in knowing mortalities rates, some quotes included 'it's difficult to keep accurate records', 'it's difficult to work in the office when you are tired from working sheep', 'you don't want to keep remembering how much you have lost', 'The information doesn't change my operation', and '(you) can't make a dead sheep alive'.

Overall, industry engagement in the study group was high. A total of 69% ($n = 22$) of farmers were active members of industry groups. The most common industry group membership was to BestWool/BestLamb (Australian sheep farmers industry network) with 50% of the farmers registered. Attendance to workshops or field days was even more common among these farmers as 81% ($n = 26$) of participants reported that they attended at least one workshop within 12 months prior to this study.

Five specific questions on management were used for analyses between self-reported management behaviour and ewe variables. The questions were reduced to one component using CATPCA. The component accounted for 48% of the variance (Cronbach's alpha 0.73) and included the following questions 'Do you perform egg count before deworming?', 'Do you perform ultrasound pregnancy diagnosis annually?', 'Do you manage ewes according to nutritional needs?' 'Do you condition score ewes?' 'Do you measure feed on offer?' This component reflects active sheep management and was labelled accordingly. The CATPCA component score was subsequently used to examine relationships between management and welfare outcomes at mid-pregnancy and weaning with results presented in Table 2. Results disclosed moderate negative relationships between *Active Management* and lameness and ewes that needed further care at mid-pregnancy. Also, moderate negative relationships were observed between *Active Management* and skin lesions and ewes that needed further care at weaning. Overall these results indicate that farmers that performed more management activities had fewer lame ewes at mid-pregnancy, fewer ewes with skin lesions at weaning and fewer ewes that needed further care after both assessments.

Relationship between farm characteristics and sheep welfare

There was large variation in the study group in relation to farm characteristics. The average ewe flock size was 2,771 (± 2770 , $n = 32$), however there was a wide range in ewe numbers (431–9,400) and farm sizes (200–3200 hectares). Details on farm flock sizes and sheep breeds are presented in Table 3.

Table 2. Spearman's rank correlations between management and welfare outcomes.

Welfare measures	Active Management	
	Mid-pregnancy	Weaning
BCS		
≤ 2.25 (low)	-0.05	-0.04
2.5–3.5 (adequate)	0.07	0.05
≥ 3.75 (fat)	-0.01	0.03
Fleece condition		
score 1–2	-0.03	-0.02
Skin lesions		
(count)	0.16	-0.44
Dag score		
score 4–5	0.01	0.12
Lameness		
score 1–3	-0.38*	-0.23
Further Care		
(count)	-0.47**	-0.50**

*Correlation significant at $p \leq 0.05$,

** Correlation significant at $p \leq 0.01$.

<https://doi.org/10.1371/journal.pone.0220455.t002>

Labour units averaged 1.7 Full-time employees (FTE) and ranged between 0.5 to 3.5 FTE. The quality of the yards also varied significantly with an average score of 4.5 (± 1.8 , $n = 32$) and ranged from 1 to 7. Results disclosed that *yards*, *hectares*, *flock size* and *sheep:labour ratio* were correlated with welfare outcomes. As presented in Table 4, moderate negative relationships were found between *yards*, *hectares* and *flock size* and fat ewes and ewes that needed further care at weaning. *Flock size* also showed moderate negative relationships with lameness at weaning. At mid-pregnancy, *sheep:labour ratio* had a moderate negative relationship with inadequate fleece condition. While not statistically significant, *sheep:labour ratio* tended to be negatively associated with ewes that needed further care at weaning ($r = -0.33$, $P = 0.06$). Moderate positive relationships were also disclosed between *yards* and *flock size* ($r = 0.58$, $P = 0.000$), between *yards* and *hectares* ($r = 0.50$, $P = 0.001$) and between *yards* and *sheep:labour ratio* ($r = 0.46$, $P = 0.001$).

Relationship between general attitudes towards sheep and sheep welfare

All farmers considered themselves to be responsible for the welfare of their animals and 84% recognised that how people handle ewes will affect their fearfulness. In the attitude questionnaire, there were six statements focused on general attitudes about sheep. These were reduced

Table 3. Farm demographics according to enterprise, flock size and breed. The range of the ewe flock sizes is presented in parentheses.

Enterprise	Farms	Average flock size	Breed
Meat	14	2,770 (500–9000)	[#] Composite, Poll Dorset Highlander, Corriedale
Meat-wool	12	2,246 (431–4411)	Merino, [^] Merino first-cross, Composite, Dohne
Wool	6	2,091 (1075–9400)	Merino

[#]Composite breeds were mainly Coopworths (Border- Romney, F3 generation progeny).

[^]Merino first-cross ewes refer to the offsprings of Merino ewes with Border Leicester rams

<https://doi.org/10.1371/journal.pone.0220455.t003>

Table 4. Spearman's rank correlation between farm characteristics and welfare outcomes.

Welfare measures	Yards	Hectares	Flock size	Sheep:labour
MID- PREGNANCY				
BCS				
≤ 2.25 (low)	-0.23	-0.11	-0.09	-0.10
2.5–3.5 (adequate)	0.22	0.23	-0.02	-0.08
≥ 3.75 (fat)	-0.04	-0.27	0.02	0.15
Fleece condition				
score 1–2	-0.12	-0.23	-0.32	-0.36*
Skin lesions				
(count)	0.13	0.31	0.09	-0.19
Dag score				
score 4–5	-0.05	0.18	0.19	0.07
Lameness				
score 1–3	-0.04	-0.20	0.01	0.25
Further Care				
(count)	-0.05	-0.27	-0.05	-0.02
WEANING				
BCS				
≤ 2.25 (low)	0.21	0.31	0.22	0.09
2.5–3.5 (adequate)	-0.08	-0.14	-0.03	0.09
≥ 3.75 (fat)	-0.34*	-0.42*	-0.47**	-0.44*
Fleece condition				
score 1–2	0.09	0.03	0.29	0.32
Skin lesions				
(count)	-0.07	-0.13	0.13	0.22
Dag score				
score 4–5	-0.08	0.08	-0.01	-0.09
Lameness				
score 1–3	-0.28	-0.29	0.37*	-0.29
Further Care				
(count)	-0.51**	-0.40*	-0.52**	-0.33

*Correlation significant at $p \leq 0.05$,**Correlation significant at $p \leq 0.01$.<https://doi.org/10.1371/journal.pone.0220455.t004>

to two components using CATPCA and varimax rotation. Component one included the statements 'ewes are NOT stubborn' 'ewes are NOT frustrating to work with' and 'I think ewes are NOT annoying'. This component accounted for 40.0% of the variance (Cronbach's alpha 0.70) and was labelled 'Positive attitudes towards sheep'. The second component included the statements, 'Farm animals have feelings like people have feelings', 'Ewes have a gentle nature' and 'Ewes are intelligent'. This second component accounted for 33.6% of the variance (Cronbach's alpha 0.61) and was labelled 'Positive attitudes towards sheep as sentient animals.' Spearman's Rank correlation analyses between the CATPCA components scores and welfare outcomes disclosed moderate, negative relationships between *Positive attitudes towards sheep* and lameness and ewes that needed further care at weaning (Table 5). Moderate positive correlations were observed between *Positive attitudes towards sheep* and fat ewes at mid-pregnancy. In addition, moderate negative relationships were found between *Positive attitudes towards sheep as sentient animals* and ewes with low body condition and skin lesions. In general, these

Table 5. Spearman's rank correlations between general attitudes towards sheep and welfare outcomes.

Welfare measures	Positive Attitudes Towards	
	Sheep	Sheep as sentient animals
MID-PREGNANCY		
BCS		
≤ 2.25 (low)	-0.23	-0.38*
2.5–3.5 (adequate)	0.14	0.18
≥ 3.75 (fat)	0.41*	0.33
Fleece condition		
score 1–2	0.01	-0.05
Skin lesions		
(count)	-0.34	-0.40*
Dag score		
score 4–5	-0.15	-0.09
Lameness		
score 1–3	0.21	0.23
Further Care		
(count)	-0.04	0.02
WEANING		
BCS		
≤ 2.25 (low)	-0.01	0.19
2.5–3.5 (adequate)	0.07	-0.18
≥ 3.75 (fat)	-0.24	-0.09
Fleece condition		
score 1–2	-0.07	0.02
Skin lesions		
(count)	-0.15	0.07
Dag score		
score 4–5	-0.09	0.07
Lameness		
score 1–3	-0.42*	-0.18
Further Care		
(count)	-0.36*	-0.24

*Correlation significant at $p \leq 0.05$ <https://doi.org/10.1371/journal.pone.0220455.t005>

results indicate that farmers with more positive attitudes towards sheep had fewer lame ewes and fewer ewes in need of further care at weaning. Also, farmers with more positive attitudes towards sheep had fewer thin ewes, more fat ewes and fewer ewes with skin lesions at mid-pregnancy. No significant correlations were found between positive attitudes towards sheep and active management, although a tendency of a moderate positive relationship was disclosed at weaning ($r = 0.33$ $p = 0.07$).

There were nine statements on farmers general attitudes relating to handling and moving sheep. These were reduced to two components using CATPCA and varimax rotation. The first component accounted for 31.8% of the variance (Cronbach's alpha 0.74) and included the following statements: 'The way people handle sheep impact ewes' fearfulness', 'Moving sheep is an easy task', 'Sheep are easy to train to a routine', 'If someone is roughly handling my sheep, I would intervene', 'The best way to move sheep is by not rushing them' and 'I am good at handling sheep'. This component was labelled as 'Positive attitudes towards handling

and moving sheep'. The second component accounted for 28.2% of the variance (Cronbach's alpha 0.68) and included the statements: 'Using dogs is the best way to move sheep', 'Using dogs is not stressful for sheep' and 'Sheep are easy to handle'. This second component was labelled as 'Positive attitudes towards using dogs'. Spearman's rank correlation analyses between the CATPCA component scores and welfare outcomes showed moderate negative relationships between *Positive attitudes towards handling and moving sheep* and lameness at weaning (Table 6). Moderate positive relationships were also observed between *Positive attitudes towards using sheep dogs* and lameness at mid-pregnancy. While not statistically significant, *Positive attitudes towards using sheep dogs* tended to be negatively associated with adequate BCS at mid-pregnancy ($r = -0.31$, $P = 0.09$). These results indicate that farmers with more positive attitudes towards handling and moving sheep, and with less positive attitudes towards using sheep dogs, had fewer lame ewes and tended to have more ewes in adequate body condition.

Table 6. Spearman's rank correlations between general attitudes towards handling sheep and welfare outcomes.

Welfare measures	Positive Attitudes Towards	
	Handling and moving sheep	Using sheep dogs
MID-PREGNANCY		
BCS		
≤ 2.25 (low)	-0.14	0.08
2.5–3.5 (adequate)	0.16	-0.31
≥ 3.75 (fat)	0.04	0.23
Fleece condition		
score 1–2	0.25	-0.33
Skin lesions		
(count)	-0.10	-0.22
Dag score		
score 4–5	0.07	-0.05
Lameness		
score 1–3	-0.04	0.39*
Further Care		
(count)	-0.24	0.30
WEANING		
BCS		
≤ 2.25 (low)	0.24	-0.04
2.5–3.5 (adequate)	-0.27	-0.09
≥ 3.75 (fat)	-0.09	0.01
score 1–2	-0.04	-0.01
Skin lesions		
(count)	0.01	0.17
Dag score		
score 4–5	-0.08	-0.07
Lameness		
score 1–3	-0.57**	0.10
Further Care		
(count)	-0.26	0.06

*Correlation significant at $p \leq 0.05$,

**Correlation significant at $p \leq 0.01$.

<https://doi.org/10.1371/journal.pone.0220455.t006>

Table 7. Logistic regression analysis for farmer attitudes about management and farmer self-reported management behaviour (n = 32).

Management behaviour	Attitude Variable	β coefficient	Standard error	P-value	Odds ratio	95% C.I for odds ratio	
						Lower	Upper
Condition scoring ewes	Attitude	0.86	0.39	0.03	2.37	1.12	5.04
Ultrasound pregnancy diagnosis	Attitude	1.16	0.5	0.02	3.19	1.21	8.41
Mortality records	SN	1.13	0.44	0.01	3.04	1.28	7.24
Egg count before deworming	Attitude	1.06	0.4	0.01	2.88	1.31	6.29
Provision of shelter at winter	SN	2.13	0.98	0.03	8.41	1.24	57.29
Manage according to nutritional needs	PBC	-1.35	0.55	0.01	0.26	0.09	0.76

The variable 'Attitude' refers to attitudes towards the behaviour, 'SN' refers to subjective norms and 'PBC' refers to perceived behavioural control. Example of questions concerning attitudes towards the behaviour: How important is it to (e.g. condition score ewes)? Example of questions concerning subjective norms: How important does your trusted advisor believe it is to (e.g. body condition score ewes)? Example of questions regarding perceived behavioural control: How difficult is it for you to (e.g. body condition score ewes)?

<https://doi.org/10.1371/journal.pone.0220455.t007>

Relationships between farmer attitudes and farmer self-reported management behaviour

Only a few attitude subscales were significantly associated with farmer management behaviour (6 out of 18 variables analysed). However, the relationships observed tended to be in the expected direction. A positive self-evaluation of the behaviour (attitude towards behaviour, labelled as 'attitude'), a perceived positive evaluation of the behaviour by others (subjective norms, labelled as 'SN') or the belief that the behaviour can be realised (perceived behavioural control, labelled as 'PBC') were predictive of management behaviour by sheep farmers. Only results significant at $p \leq 0.05$ are reported in Table 7. Condition scoring ewes, ultrasound pregnancy diagnosis and testing for egg count before deworming sheep were all positively predicted by the attitude towards the behaviour, which refers to the importance/value farmers place on these management practices. Keeping mortality records and provision of shelter were both positively predicted by subjective norms. Managing ewes according to nutritional needs was negatively predicted by perceived behavioural control (Odds ratio = 0.26, $P = 0.01$), which indicates that when farmers perceived this activity to be difficult, they were less likely to perform this activity.

Overall, there was a low perceived difficulty for all management practices, with farmers usually rating the activities 'not at all difficult' or 'slightly difficult'. However, while management practices were usually perceived as not difficult, most farmers agreed with the statement 'No matter how hard I try, a constant number of ewes will always die' (72%) and 'Weather will influence lamb survival more than any management decisions I make' (53%).

Significant inter-correlations between some attitude subscales were found across the behaviours. Strong to moderate positive correlations were found between positive attitude towards managing ewes according to nutritional needs and positive attitudes towards ultrasound diagnosis ($r = 0.62$, $P \leq 0.01$), and between positive attitudes towards monitoring feed on offer and keeping mortality records ($r = 0.55$, $P \leq 0.01$). Similarly, positive correlations were obtained between perceived difficulty of performing ultrasound diagnosis annually and perceived difficulty of managing ewes according to nutritional needs ($r = 0.63$, $P \leq 0.01$), and between perceived difficulty of monitoring feed on offer and monitoring the flock ($r = 0.47$, $P \leq 0.01$). Significant negative correlations were also observed between perceived difficulty of managing ewes according to nutritional needs and (1) positive attitudes towards managing ewes according to nutritional needs ($r = -0.48$, $P \leq 0.01$), (2) positive attitudes towards performing egg count before deworming sheep ($r = -0.42$, $P = 0.02$), (3) positive attitudes towards monitoring

Table 8. Ordinal logistic regression analyses for farmer attitudes about management behaviour and farmers background factors (n = 32).

Management behaviour	Attitude Variable	Background factor	β coefficient	P-value	Odds ratio	95% C.I for odds ratio	
						Lower	Upper
Condition scoring ewes	PBC	Age	-0.16	0.00	0.85	0.76	0.95
		WE	0.13	0.01	1.14	1.03	1.26
		Education	-3.57	0.01	0.03	0.01	0.42
Ultrasound pregnancy diagnosis	SN	Education	1.99	0.08	7.38	0.78	70.14
Mortality records	PBC	Age	-0.10	0.05	0.90	0.81	1.00
		WE	0.13	0.01	1.14	1.03	1.26
		Education	-2.44	0.03	0.87	0.01	0.79
Provision of shelter at winter	PBC	WE	0.09	0.02	1.09	1.01	1.19
		Age	-0.08	0.07	0.93	0.85	1.00
Manage according to nutritional needs	Attitude	WE	-0.10	0.04	0.90	0.82	0.99

The variable 'Attitude' refers to attitudes towards the behaviour, 'SN' refers to subjective norms and 'PBC' refers to perceived behavioural control. Age refers to the farmers or farm managers age. Work experience (WE) refers to the years of experience working with sheep of the farmers or farm managers. Education refers to the level of education of the farmers or farm managers.

<https://doi.org/10.1371/journal.pone.0220455.t008>

feed on offer ($r = -0.41$, $P = 0.02$) and (4) positive attitudes towards ultrasound pregnancy diagnosis ($r = -0.38$, $P = 0.03$).

Relationships between background factors and farmer attitudes

Most farmers/managers in this study were male ($n = 30$) and their average age was 52 ($16.5 \pm \text{SD}$) years. The educational level in the study group ranged from 'secondary school' (22%, $n = 7$) to 'university degree' (56%, $n = 18$) and the average number of years working with sheep was 26.7 ($17.7 \pm \text{SD}$) years.

The ordinal logistic regression analyses showed that farmers' background factors had some role in predicting farmers attitudes concerning sheep management (Table 8). *Work experience* (WE) predicted perceived behavioural control concerning condition scoring ewes, keeping mortality records and provision of shelter at winter. All these relationships were positive, which mean that farmers with more years of work experience perceived condition scoring of ewes, keeping mortality records and provision of shelter at winter to be more difficult activities. *Work experience* also predicted behavioural attitudes towards managing ewes according to nutritional needs. This relationship was negative meaning that farmers with more years of work experience tended to perceive this activity to be less important. *Level of education* predicted perceived behavioural control concerning condition scoring ewes and mortality records. The direction of these relationships was negative meaning that farmers with higher the level of education perceived condition scoring of ewes and keeping mortality records to be less difficult activities. While not statistically significant, *level of education* also tented to predict subjective norms concerning ultrasound pregnancy diagnosis (the direction of the relationship was positive). *Age* predicted perceived behavioural control concerning body condition scoring of ewes, keeping mortality records and tended to predict provision of shelter at winter (Odds ratio = 0.93, $P = 0.07$). The direction of these relationships was negative which means that older farmers perceived the aforementioned activities to be less difficult. No background factors were predictive of farmers attitudes concerning performing egg count before deworming sheep. Results significant at $p \leq 0.05$, or close to significant, are reported in Table 8.

Discussion

This study hypothesised that farmer attitudes relate to management behaviour and management behaviour relates to the on-farm welfare of extensively managed sheep. To our knowledge, this is the first study investigating these relationships in extensive sheep farming systems. The main results of this study indicate relationships between farmer attitudes and management behaviour, as well as relationships between management behaviour and ewe welfare outcomes, consistent with the Theory of Planned Behaviour and the HAR model [12,13] and in agreement with previous studies in the pig, poultry and dairy industries [21,34–37].

When combining the qualitative and quantitative analyses, behavioural attitudes (attitudes towards specific management behaviours) and perceived behavioural control (perceived barriers to performing the behaviour) emerged as the two main drivers underpinning farmer management behaviour. While the results from the regression analyses indicated that effect of perceived behavioural control in farmer management behaviour was limited, the fact that most farmers ranked management practices as being ‘not at all difficult’ or ‘slightly difficult’ may have influenced these results. When participants were further asked about why they or other farmers did not perform improved practices, comments were mainly focused on not having enough time to perform the activity or practices not being able to influence the outcome. This suggests that the perceived difficulty of performing an activity was, indeed, an important barrier to farmers. This also indicates that sometimes there was a disconnect between specific management practices and the impact or value they can have on sheep welfare. Overall, these results demonstrate the potential to alter farmer behaviour by modifying the key attitudes and barriers that underpin these behaviours.

By modifying one key behaviour it may be possible to modify other farm management practices. Significant inter-correlations between some of the attitude subscales (attitudes towards the behaviour and perceived behavioural control) were observed in this study, which may represent a general farmer attitude towards the performance of management behaviours [34]. Consistency of attitudes towards management behaviours suggests that if farmers have a positive attitude towards one key management behaviour (e.g. ultrasound pregnancy diagnosis), they are likely to have positive attitudes towards similar behaviours (e.g. manage ewes according to nutritional needs). These findings are consistent with the HAR model [12] and add to the existing literature for other livestock industries in which some consistent patterns of correlations between the attitude subscales and several stockperson behaviours have been identified [15,18,20,38,39]. Practically, this suggests that by modifying one key behaviour it may be possible to modify other practices. This could be used to encourage change in management, however, there is a risk of a reverse relationship: if a farmer does not believe in the value of one management practice, they may stop believing in the value of performing others as well.

Active management was associated with positive sheep welfare outcomes, as indicated by fewer ewes with skin lesions, fewer lame ewes and fewer ewes in need of further care. Overall, visual monitoring of the flock and feed on offer were common management practices among farmers, while body condition scoring, performing internal parasite egg count before deworming sheep, ultrasound pregnancy diagnosis and records keeping were less common activities. It is important to consider that while most farmers reported that they checked the body condition of their sheep, 39% of farmers misunderstood how to effectively perform this activity reporting that body condition scoring was performed visually from the distance. For records keeping, engagement was limited and the accuracy with which farmers could estimate issues on the farm was low, with stock tally data usually not corresponding with the estimated ewe mortality rates provided by the farmer, and mortality rates were frequently underestimated. If data are not recorded and not reliable, then it is difficult to

estimate the productivity, health and welfare issues of the farm to make interventions accordingly. Thus, improved methods to monitor the flock and keep accurate records are needed. Providing farmers with easily accessible and practical alternatives to improve data collection, such as the use of electronic identification (EID) systems, would be a valuable and relatively low-cost alternative to benefit welfare and productivity. However, the implementation of any strategy should be combined with programs targeting farmer attitudes in order to achieve a sustained change in farmer behaviour.

Welfare compromise did not necessarily increase with farm size. Larger farms in this study had yards in better condition and had fewer fat ewes, fewer lame ewes and fewer ewes in need of further care at weaning. While not tested in this study, previous studies have demonstrated that larger farms (>5,000 head) have the ability to access more resources (e.g. veterinary assistance) [40] and stockpeople are more likely to have formal training [41]. These relationships were more evident at weaning as these welfare outcomes were probably exacerbated by seasonal and physiological variation at this period [4,42].

General attitudes towards sheep were associated with welfare outcomes. Positive attitudes towards handling and moving sheep were associated with fewer lame ewes. However, it is important to consider that direct evidence on the effects of handling and moving sheep were not measured in this study. In addition, the attitudes and the behaviours of farm contractors, who often handle sheep during routine husbandry procedures, were not examined. For further studies, it would be valuable to assess both farmer and contractors' attitudes and behaviour during routine husbandry procedures such as lamb marking, weaning or ultrasound diagnosis, to better understand the human-animal relationship in extensive systems.

The relationship observed between level of education and farmers attitudes towards management behaviour demonstrates a key role for education in farmer behaviour. This is further supported by previous research that has demonstrated that education programs designed to promote attitudinal change have been successful in the pork [12,39] and dairy [43] industries. Overall, the main findings of this study indicate relationships between farmer attitudes and management behaviour, relationships between management behaviour and ewe welfare outcomes and relationships between background factors and farmer attitudes. Based on our main findings, and the HAR Model [12], Fig 2 illustrates the proposed farmer-sheep relationships in extensive farming conditions.

Although this present study does not permit causal inferences to be made, if education programs are able to improve farmer attitudes and behaviour as well as sheep welfare, then causality could be investigated. Based on our findings, a potential intervention in the sheep industry may involve the implementation of an education program intended to improve

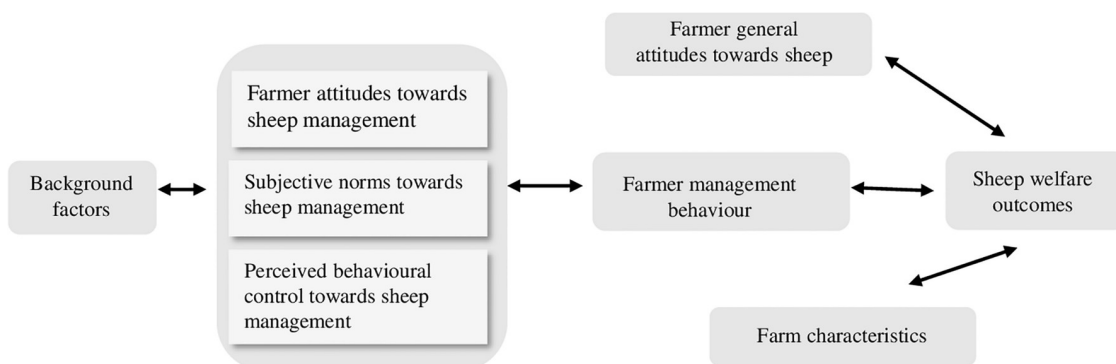


Fig 2. Proposed farmer-sheep relationships in extensive farming conditions.

<https://doi.org/10.1371/journal.pone.0220455.g002>

farmer self-evaluation of the behaviour (behavioural attitudes) and their perceived control regarding the behaviour. The focus should be put on flock monitoring, BCS and records keeping as these management practices influence welfare and productivity despite location and type of enterprise.

Conclusions

The main results of this study indicate relationships between farmer attitudes and management behaviour, as well as relationships between management behaviour and ewe welfare outcomes. Overall, farmers that held more positive attitudes towards sheep management were more likely to have an active management style and had fewer ewes in need of further care at mid-pregnancy and weaning. Both behavioural attitudes and perceived behavioural control were predictive of farmer behaviour, and these key attitudes should be addressed in future education strategies aimed at promoting practice change. Further research needs to provide evidence of causal relationships and determine the effectiveness of education programs in achieving attitudinal and sustained practice change in the sheep industry.

Supporting information

S1 Appendix. CATPCA components data supporting information.
(XLSX)

S2 Appendix. Regression analyses data supporting information.
(XLSX)

Acknowledgments

The authors would like to thank all the farmers that kindly participated in this study. We also thank Professor Ian Gordon, Director of the statistical Consulting Centre of The University of Melbourne and Dr David McGill, academic of the Faculty of Veterinary and Agricultural Sciences, The University of Melbourne for their advice on the statistical analyses of this manuscript.

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Main findings/implications of Chapter 5:

- There is an opportunity to create change in farmer management behaviour and improve sheep welfare via targeted education programs.
- Farmers were more likely to perform an activity (management behaviour) if they perceived the activity was valuable and if they perceived the activity could be realised.
- Farmer management behaviour influences ewe welfare outcomes.
- Welfare compromise did not necessarily increase with farm size.

6: General Discussion

The aim of this thesis was to examine the relationships between the attitudes and the management behaviour of farmers and the on-farm welfare of their ewes. To achieve this aim, it was first necessary to develop a valid, reliable and practical welfare assessment for extensively managed ewes, as a protocol that suited the extensive Australian environment was not available (Chapter 2). This component of the thesis was conducted on one flock of 100 ewes that were individually identified and assessed during mid-pregnancy, mid-lactation and weaning. Secondly, two focus groups with farmers were conducted in regional Victoria, Australia to gather farmers' opinions and concerns about ewe welfare and management (Chapter 3). This information was used to develop two farmer questionnaires; an attitude questionnaire and a management questionnaire. The examination of the farmer-ewe relationship, which is the core aim of this thesis, is then presented in the two following chapters. Chapter 4 presents the results of the welfare assessment of 6,200 ewes and identifies main welfare issues likely to be encountered in large-scale extensive farms. Chapter 5 examines the relationships of ewe welfare outcomes and the attitudes and management practices of the 32 farmers that manage the sheep. This chapter provides insight into the underlying beliefs that underpin farmers' management behaviour. To the best of the author's knowledge, this is the largest study investigating the on-farm welfare of ewes in Australia and the first study assessing the farmer-sheep relationship in extensive sheep farming systems. While the results of this thesis are from Victoria, Australia, they are relevant to some extent to sheep managed extensively worldwide as many of the welfare issues, management practices and farmer attitudes are broadly applicable.

Main findings and implications

There is opportunity to create change in farmer management behaviour and improve sheep welfare via targeted education programs.

Main results of this thesis indicate that farmer management behaviour was associated with favourable attitudes towards the behaviours in question. When evaluating the results from the two focus groups (Chapter 3) and the 32 questionnaire interviews (Chapter 5), behavioural attitudes and perceived behavioural control emerged as the two main drivers underpinning farmer management behaviour. Both sets of results show that farmers in this study were more likely to perform an activity (management behaviour) if they perceived the activity was valuable and if they perceived the activity could be realised. These results are in agreement with the Theory of Planned Behaviour and the HAR model (1,2) and are consistent with previous findings in the pig, poultry, horse and dairy industries (3–7).

In addition, the relationships observed in Chapter 5 between the level of education and farmers attitudes towards management behaviours demonstrate a key role for education in farmer behaviour. This is further supported by previous education programs, in other livestock industries, that have been successful in achieving change in human attitudes and behaviour (8–10). The results of this thesis indicate that similar education strategies could generate sustained change in farmer management behaviour and welfare improvements in the sheep industry.

Farmer management behaviour influences ewe welfare outcomes.

The welfare of the ewe flock, based on the six animal-based measures assessed; body condition, fleece condition, skin lesions, tail length, dag score and lameness, was considered good overall. However, while prevalence was relatively low, when an individual animal's welfare was compromised, the issue was considered important. In total, there were 185 (3.0%) cases of ewes in need of further assessment or care and the extent of welfare compromise for this group was significant, and in many cases, involved multiple issues (Chapter 4). Common causes of ewes classed as 'further care' were severe lameness or foot-related issues, low body condition and active dermatophilosis or broken wool. These results are in agreement with previous on-farm studies conducted in the UK (11,12) which suggests that welfare issues identified in this thesis are also relevant to some extent to sheep managed extensively elsewhere.

Most welfare issues identified in this thesis (Chapter 2 and 4) can arise from or can be treated or mitigated by management practices. While welfare issues can be exacerbated by location, the season and the reproductive state of the ewe, improved management practices are important to mitigate welfare problems. Results in Chapter 5 indicated that farmers that had an active management style, that is, performed egg counts before internal parasite control, used ultrasound pregnancy diagnosis annually, performed condition scoring (hands-on), managed ewes according to nutritional needs and measured feed on offer with technical approaches had fewer lame ewes and fewer ewes in need of further care after both welfare assessments (mid-pregnancy and weaning). While a number of other factors may be playing an important role in these relationships, it is clear that improved management practices are fundamental to ensure good

standards of animal welfare. Still, widespread adoption of these practices is somewhat low (13) (Chapter 3 and 5), which needs to be further addressed.

Farmers ability to identify individual welfare compromise was limited. In this thesis, all the ewes classed as in need of further inspection/care were not previously identified by the farmer even though the ewes had recently been in the yards for other husbandry procedures. This highlights the difficulty of identifying individual welfare compromise in large-size flocks. Consistent with the focus groups, most farmers interviewed in this thesis relied on visual monitoring of the flock, from a distance, while close inspection or other improved management practices such as body condition scoring sheep were less common activities (Chapter 3 and 5). Clearly, visual observations of large-size flocks risk missing animals in compromised welfare but with less obvious signs of poor welfare such as sheep with major injuries under the fleece, flystrike (early stages), mastitis, eye wounds and animals of low body condition but in fleece. Close examination ('hands-on' inspection) of a representative sample of the ewe flock around times where sheep are in the yards for other husbandry procedures (e.g. ultrasound pregnancy diagnosis or weaning) is a valuable and practical way for farmers to monitor the flock and concentrate observations on those periods when many welfare challenges can arise. Certainly, improved methods to monitor the flock are needed and the implementation of new technologies can also provide great assistance to flock inspection. For example, fixed and on-farm tracking technologies, where farmers can receive real-time information on the health and welfare of their flock (14–16) may be a valuable strategy to improve monitoring, and at the same time, could assist farmers in demonstrating good standards of animal welfare.

While the number of ewes requiring further care was low, farmer intervention was limited. Although farmers feel they are self-sufficient to deal with sheep health issues (17,18), the participants involved in this study only took immediate action in 40 (20%) of the 185 cases reported, which highlights the difficulty of decision-making about when and how to manage ewes that need further attention. Possible reasons for not providing immediate care, or why some cases were treated more promptly than others, may include: the issue may not have been perceived to be important by the farmer, perceived difficulty in treating certain health issues (e.g. draining abscesses vs clinical mastitis), time constraints or labour availabilities. Providing farmers with easily accessible and practical solutions to common welfare issues could help increase the frequency with which animals in need of further care are treated. Methods would need to be applied when ewes are in the yards or implemented relatively easily in the paddock. Tools like decision trees and checklists that are simple to follow and readily available could be effective ways to communicate this, such as the 'fit to load' guide (19). These tools could also increase farmers' awareness of the impact of welfare issues on farm performance and productivity.

A prevalent issue identified across farms was short docked tails. In total, 85.7% of the ewes assessed had tails docked shorter than the tip of the vulva. Tail docking is an important management practice used to reduce the risk of flystrike. However, if the tail of the lambs is docked too short (less than the third palpable joint or equivalent to the length of the vulva) sheep have a higher risk of rectal prolapse (20), flystrike (21) and bacterial arthritis (22). While the negative impacts of docking tails too short have been well reported, short tails were found across all of the farms visited, indicating that farmers tail docking behaviour present an important risk to sheep welfare. These results

are in agreement with national survey data that reported that nearly half of sheep producers (47%) dock lambs' tails shorter than the third palpable joint. Similarly, Larrondo, Bustamante and Gallo, (2018) reported that 55.9% of the farmers in the South of Chile dock lambs' tails shorter than what is recommended, and the main reasons giving were: to improve mating (33.8%), to improve animal sanitary conditions (18.4%), traditional farming (12.2%) and aesthetic reasons (10.2%). Further studies should examine main drivers behind Australian farmers tail length docking decisions to develop adequate intervention programs to encourage the adoption of improved tail docking behaviour.

The accuracy with which farmers could estimate issues on the farm was low.

When evaluating the results from the focus groups and the questionnaire interviews, it was evident that record keeping was not a common activity. Although farmers have to report stocking rates for tax purposes every year, the accuracy with which farmers could estimate mortality on their farm was low, with stock tally data usually not corresponding with the estimated ewe mortality rates provided by the farmer in the management questionnaire, and mortality rates were frequently underestimated. If data are not recorded and not reliable, then it is difficult to estimate the productivity, health and welfare issues of the farm to make interventions accordingly. Improved methods to collect accurate records on the farm are needed and solutions to this issue need to be valuable and practical for farmers. For example, the implementation of Radio Frequency Identification Devices (RFID) such as EID ear tags, which is currently mandatory in the state of Victoria for sheep and goats (24), could be used to track animals on property and could assist farmers with collecting more accurate mortality records.

Six animal-based welfare measures are proposed for on-farm use in welfare assessments of extensive sheep production systems.

Body condition, fleece condition, skin lesions, tail length, dag score and lameness are proposed for on-farm use in welfare assessments of extensive sheep production systems. These six animal-based welfare measures address important welfare issues identified by producers, industry, specialists and the general public (25–27), and can be reliably and feasibly measured in the field.

Although animal-based measures are direct measures of the welfare of the animal, some valuable management- and resource-based indicators may need to be incorporated in future assessments. When combining the information gathered by animal-, management and resource-based indicators it is possible to further assess where actions need to be taken to correct or mitigate welfare issues. In addition, to get an accurate representation of the welfare status of sheep, farms need to be assessed more than once throughout the year. Pregnancy, lactation and weaning have been previously identified as key times to conduct welfare assessments as concentrate observations on those periods when many welfare challenges can arise (12,28). In agreement with previous findings by Phythian (2011) and Dwyer *et al.* (2014) results in this thesis showed that significant variation in the welfare of sheep occurs between these periods which needs to be accounted for when assessing farms (Chapter 2). With this in consideration and taking into account practicality, mid-pregnancy and weaning are likely the most feasible and useful times to conduct assessments. At mid-lactation, lambs are mustered to the yards for lamb marking which disturbs the ewes and makes mustering and handling of ewes more time-

consuming. The consistent participation of farmers in this project (62 of 64 visits were conducted) further supports that mid-pregnancy and weaning were valuable and convenient times to conduct the farm visits.

Limitations

The sample studied may not represent the attitudes of Australian farmers or the welfare of ewes throughout Australia.

The study visits were conducted during key periods of the reproduction cycle of sheep, there was variation within the study population in terms of welfare outcomes and farmer attitudes and there was good representation of farm enterprise, location, flock sizes, farm hectares, farmers' age and gender according to the national statistics of the sheep industry (30,31). However, the fact that we used voluntary recruitment may have introduced a participation bias into the study skewed towards more 'proactive' farmers. Farmers involved in this study had, in general, positive attitudes towards sheep and management and they had high engagement with industry activities. Considering the focus group participants in Chapter 3 described themselves as being the top 20% of the industry for these reasons, it can be reasoned that most farmers in this study may have also been above the industry norm. This limitation of sample bias is not unique to this body of work. A number of studies have used a voluntary recruitment process to conduct on-farm welfare research (12,28,32–35). One alternative to overcome this issue could be to develop a nation-wide phone survey to collect information on management and farm health issues and mortality records from a wide variety of farmers. This would not guarantee that results are not skewed towards more proactive farmers, as farmers would

still have to participate in the survey, but at least it would likely broaden the reach, increasing the likelihood of a more accurate improve industry representation, albeit at the risk of introducing reporting bias.

The welfare status reported in this thesis may be a conservative estimate of welfare across stock classes on participating farms. The ewes assessed in this thesis were the easiest to manage and an economically valuable group; that is, single bearing ewes (if known), from 2 to 5-year-old. Age and mortality have a parabolic relationship, with risk being higher in younger and older animals. As a result, it is possible that the level of welfare compromise reflected on this thesis may be the lowest it would be across each farm. Ewes were also brought to the yards by the farmers so that the welfare assessment could be conducted. There is a possibility that this process may have favoured healthier animals, due to farmers bias, but also because more compromised ewes (e.g. severe lame, lethargic) are less able to move (36), and therefore, were less likely to been mustered to the yards for assessment. Another important consideration is that data collection was conducted during the 2016-17 season in Victoria, Australia, which was a particularly good year in terms of rainfall and feed availability, which suggests that the ewes assessed in this thesis may have been in better condition than during less favourable seasons. It is possible that the results of this thesis could be an 'iceberg scenario', and thus, farmer attitudes, engagement and sheep welfare might be lower than currently identified. With this in consideration, it is possible that a target of 2% for animals in need of further care may not be achieved by a large number of farms. However, by having a target, it may be possible to encourage some improvements for the welfare of extensively managed ewes.

Relationships were observed, but causal inferences cannot be made

Another issue that needs consideration is that, while relationships were observed between farmer attitudes and management behaviour, and between management behaviour and ewe welfare outcomes, this present thesis does not permit causal inferences to be made. Controlled trials to assess if education programs or other interventions are able to improve farmer attitudes and management behaviour, as well as sheep welfare, would allow causality to be investigated and would be a valuable next research step following on from the current work.

Implications for further research

One of the outcomes of this thesis was the identification of main ewe welfare issues likely to be encountered in large-scale extensive farms (Chapter 4). These results are a sound basis for future comparison, and future research could use this information to develop technologies that can assist farmers in the detection of the welfare issues identified in this thesis. Nevertheless, further on-farm research is necessary to examine differences between stock classes particularly weaners/hoggets and older ewes, to obtain a more comprehensive snapshot of the on-farm welfare of sheep under extensive systems. There is great potential for the recommended animal-based measures (Table 4.1) to be applied within farm assurance and certification schemes or industry benchmarks. The indicators used in this thesis mainly assessed the biological functioning of sheep, and therefore future assessments may need to examine the affective state of these animals. For example, how the behaviour of sheep during routine handling may differ across farms, and how it may be associated with sheep welfare, farmer management and attitudes towards sheep

handling could provide further insights on the affective state of sheep and the farmer-sheep relationship in extensive systems.

Further research is required to evaluate whether interventions targeting farmers' attitudes, behaviour and management improve sheep welfare, as assessed by the measures described in this thesis. Similarly, the implementation of these interventions, including farmer acceptance, and efficiency and sustainability of changed management practices could be assessed through prospective monitoring and evaluation studies to determine their value and efficacy. For example, programs designed to benchmark welfare and production, at a local and national level, may be a valuable strategy to increase farmer awareness of how management practices can influence their enterprise and the welfare of their sheep. Improved sheep monitoring, 'hands-on' inspection, treatment of animals in need of further care and data recording are likely required to support the implementation of new management to reduce the risk of compromised ewe welfare.

Conclusions

This is the first study examining farmer attitudes, management behaviour and ewe welfare in extensive farming systems. Results in this thesis indicate that the way farmers manage their ewes influences ewe welfare outcomes, and management decisions are influenced by positive attitudes towards sheep management. Specifically, farmers are more likely to perform an activity if they can see the value of the activity and if they perceived the activity is feasible under extensive farming conditions. These results demonstrate that there is an opportunity to create change in farmer management

behaviour and potentially improve sheep welfare via education programs targeting attitudinal change. I conservatively conclude that the welfare of the ewe flocks, based on the six welfare indicators measured, was good but individual welfare compromise can be significant. While improved management practices are fundamental to ensure good standards of animal welfare, farmer adoption of improved practices is low which needs to be addressed further to ensure the sustainability of the industry and to maintain its current 'social license to farm sheep'. Overall, sheep monitoring, 'hands-on' inspection, treatment of animals in need of further care and data recording needs improving to reduce the risk of compromised ewe welfare. For instance, easily accessible decision trees or checklist could be used to facilitate farmer decision-making about how and when to intervene in cases of animals in need of further care. The implementation of new technologies may also be of great value to assist farmers with flock monitoring and the identification of sick/injured sheep. However, any implementation should be combined with programs targeting farmer attitudes in order to achieve a sustained change in farmer management behaviour. Further research is required to provide evidence of causal relationships between farmer attitudes, behaviour and sheep welfare and to determine the effectiveness of education programs in achieving attitudinal and sustained practice change in the sheep industry.

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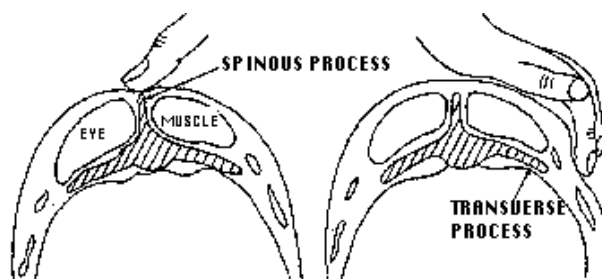
Appendix 1

Individual welfare assessment

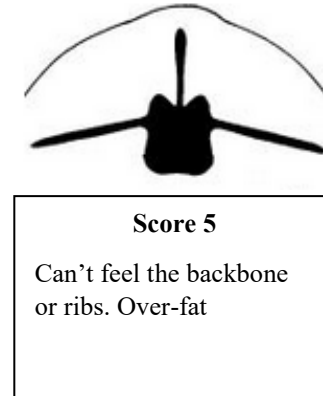
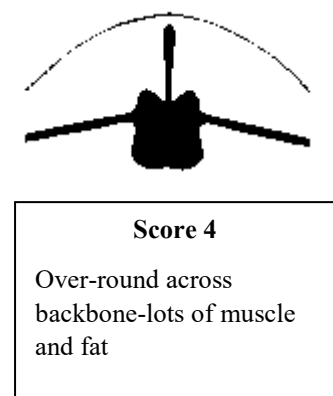
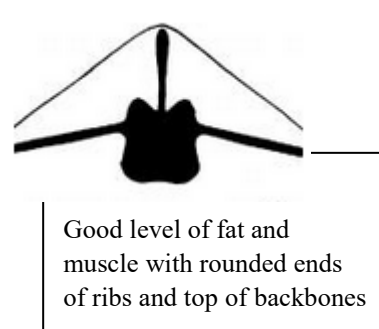
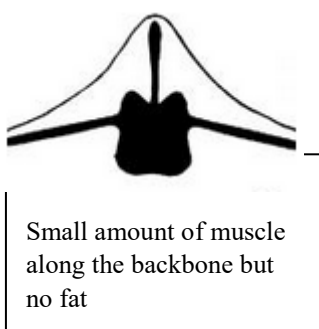
1. Body Condition Score (1-5).

Scored on a 5 point scale from 1 (thin) to 5 (obese), using a quarter-unit precision [14,21]. Sheep were assessed by palpation of the backbone, muscle and short ribs [20,22].

How to assess?



How to score?



2. Fleece condition

Fleece condition	Scored on a 3 point scale: (0) Good fleece condition, when parted, the fleece has no scurf or lumpiness or signs of ectoparasites (1) some fleece loss, small shed or bald patches of no more than 10 cm diameter. When parted, the fleece may have some lumpiness or scurf, little evidence of ectoparasites, and (2) significant fleece loss with bald patches of greater than 10 cm in diameter, clear evidence of ectoparasites [10].
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How to score?



Score (0)



Score (1)



Score (2)

Good condition:
Sufficient fleece for breed and time of the year. No evidence of ectoparasites.

Some fleece loss: Loose fleece in some areas. Shed or patches no more than 10 cm diameter. Some lumpiness or scurf, little evidence of ectoparasites.

Significant fleece loss: Loose fleece and shed areas or pulls with bald patches of greater than 10 cm. Evidence of ectoparasites.

3. Body injuries and wounds

How to assess?

Count the numbers of lesions in the head/neck, ears, eyes, body, rear and legs and categorized them. Assess both sides of the body.

How to score?

Minor

Hairless patches or scratches or haled lesions, or open wounds less than 10 cm.

Severe

Open wound greater than 10 cm and/or reaches the muscles layer.

4. Tail Length

Tail length	Scored on a 2 point scale: (0) The tip of the vulva is covered by the tail when held down (1) the tail is over-shortened or almost not present, or if the vulva and anus cannot be covered [25,26].
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Score (0)

The tip of the vulva is covered by the tail when held down.



Score (1)

Tail is over-shortened or almost not present, the vulva and anus cannot be covered by remaining tail

5. Dag score

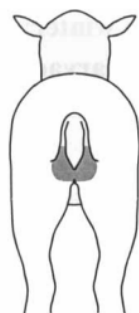
Dag score	Scored on a 6 point scale: (0) No evidence of fecal soiling, (1) very light soiling on the breech area, (2) moderate dag on the breech area extending ventrally, (3) severe dag predominantly on the breech area, extending ventrally and dorsally over the tail some soiling and dag around anus, (4) excessive dag on the breech area and on the hind legs (5) Very severe dag on the breech area and on the hind legs or below the level of the hocks [16].
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How to score?



Score (0)

No
faecal
soiling



Score (1)

Very
light
soiling



Score (2)

Light
soiling
& dags
around
anus



Score (3)

some
soiling
& dags
around
anus



Score (4)

excessiv
e soiling
& dags
around
anus



Score (5)

severe
soiling &
dags
around
anus

6. Gait/Lameness

Lameness	Scored on a 4 point scale: (0) Not lame, (1) clear shortening of stride with obvious head nodding or flicking as the affected limb touches the floor, (2) clear shortening of stride with obvious head nodding and not weight-bearing on affected limb whilst moving, (3) reluctant to stand or move [10].
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How to score? Ewes will be gently encouraged to walk along the race.

Not Lame

Minor lameness

Lame

Severe lameness

Score (0)

Movement is smooth, and weight is borne equally on all four feet. No shortening of stride.

Score (1)

Clear shortening of stride with obvious head nodding or flicking as the affected limb touches the floor.

Score (2)

Clear shortening of stride. Obvious head nodding and not weight-bearing on affected limb whilst moving

Score (3)

Reluctance to stand or move.

Appendix 2

Questionnaire

Thank you for agreeing to participate in this research project. This study is funded by Meat and Livestock Australia and is being conducted by Carolina Munoz (PhD student), Dr Rebecca Doyle (University of Melbourne), Dr Angus Campbell (University of Melbourne), Professor Paul Hemsworth (University of Melbourne) and Professor Grahame Coleman (University of Melbourne).

This questionnaire complements the on-farm assessment performed in your farm, therefore your participation is very important and appreciated. The questionnaire is completely anonymous, and has been approved by the Human Research Ethics Committee of the University of Melbourne.

SECTION A. Sheep management and husbandry. There are no right or wrong answers. All we want is your honest answer. Please read each question and then indicate using the following scale: 'not at all important', 'slightly important', 'moderately important', 'important' and 'very important'.

	Not at all important	Slightly important	Moderately Important	Important	Very important
	1	2	3	4	5
A.1 How important is to daily check:					
Dry ewes					
Pregnant ewes					
Ewes with lambs at foot					
A.2 How important is monthly checking of body condition for:					
Dry ewes					
Pregnant ewes					
Ewes with lambs at foot					
A.3 How important is it to measure pasture <u>availability</u> ?					
A.4 How important is it to measure pasture <u>quality</u> ?					

A.5 How important is it to allocate pregnant ewes in different groups according to their nutritional needs?					
--	--	--	--	--	--

	Not at all important	Slightly important	Moderately Important	Important	Very important
	1	2	3	4	5
A.6 How important is it to perform pregnancy scans annually?					
A.7 How important is it to assist ewes with dystocia?					
A.8 How important is it to provide ewes with shelter during winter?					
A.9 How important is it to provide ewes with shelter during summer?					
A.10 How important is it to have the ewes annually checked by a veterinarian?					
A.11 How important is it to have a written health plan in the farm?					
A.12 How important is it to treat ewes for parasites?					
A.13 How important is it to test ewes for parasites before drenching sheep?					
A.14 How important do you think mulesing is to prevent flystrike?					

A.15 How important is it to provide local anaesthesia or pain relief at mulesing?					
A.16 How important is it to calculate annual disease rates in your farm?					
A.17 How important is it to calculate annual mortality rate in your farm?					
A.18 How important is it to calculate annual culling rate in your farm?					

There are no right or wrong answers. All we want is your honest answer. Please read each question and then indicate using the following scale: 'Strongly disagree', 'Disagree' 'Neither agree nor disagree', 'Agree', 'Strongly agree'.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
	1	2	3	4	5
A.19 I'm responsible for the welfare of my animals					
A.20 Farm animals have feelings like people have feelings					
A.21 Farm animals experience physical pain as humans do					
A.22 Farm animals generally aren't affected by the way they are treated					
A.23 Ewes are intelligent					
A.24 The way how people handle ewes will impact ewes' fearfulness					
A.25 Ewes are stubborn animals					
A.26 Ewes have a gentle nature					
A.27 Ewes are frustrating to work with					
A.28 Ewes are easy to train to a routine					
A.29 Moving sheep is an easy task					
A.30 The best way to move sheep is by not rushing them					
A.31 Using sheepdogs is the best way to move the ewes					
A.32 Using trained sheepdogs is not stressful for ewes					
A.33 Ewes are easy to handle					
A.34 Ewes do not require a great deal of care					
A.35 Mulesing is not painful for sheep					
A.36 I think ewes can be annoying					
A.37 Shearing is not stressful for ewes					

There are no right or wrong answers. All we want is your honest answer. Please read each question and then indicate using the following scale: 'Strongly disagree', 'Disagree' 'Neither agree nor disagree', 'Agree', 'Strongly agree'.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
	1	2	3	4	5
A.38 I really like being a sheep farmer					
A.39 I look forward to the days I have to work sheep in the yards.					
A.40 I am good at handling sheep					
A.41 If someone is roughly handling my sheep, I would intervene					
A.42 It is really important for me to try hard at work.					
A.43 I am the type of person who gets over-involved with my job.					
A.44 It is important to me that I do a good job.					
A.45 I get bored easily in my job.					
A.46 I do not like having a lot of responsibility at work.					
A.47 I feel respected for the work I do.					

A.48 I'm able to do things that don't go against my morals					
A.49 I do not have the chance to do something that makes use of my abilities					
A.50 I feel rewarded from this job					
A.51 No matter how hard I try, a constant number of ewes will always die					
A.52 Weather will influence lamb survival more than any management decisions I make					

SECTION B: There are no right or wrong answers. All we want is your honest answer.

When faced with a difficult situation on your farm, who would you seek advice/guidance from? Please indicate using the following scale: I **never, rarely, occasionally, frequently** or **always** seek advice/guidance from him/her.

	Never	Rarely	Occasionally	Frequently	Always
	1	2	3	4	5
Veterinarians					
More experienced farmers					
Closest family members (e.g. spouse, parents, siblings, etc.)					
Friends					
Other (please specify)					

Please answer the following questions thinking of the person you always or frequently seek advice/guidance from. How do you think your trusted advisor would rate these issues? Read each question and then indicate using the following scale: 'not at all important', 'slightly important', 'moderately important', 'important' and 'very important'.

	Not at all important	Slightly important	Moderately important	Important	Very important
	1	2	3	4	5
B.1 How important does your trusted advisor believe it is to check daily:					
Dry ewes					
Pregnant ewes					
Ewes with lambs at foot					
B.2 How important does your trusted advisor believe it is to check monthly the body condition of:					
Dry ewes					
Pregnant ewes					
Ewes with lambs at foot					
B.3 How important does your trusted advisor believe it is to measure pasture <u>availability</u> ?					
B.4 How important does your trusted advisor believe it is to measure pasture <u>quality</u> ?					

	Not at all important	Slightly important	Moderately Important	Important	Very important
	1	2	3	4	5
B.5 How important does your trusted advisor believe it is to allocate pregnant ewes in different groups according to their nutritional needs?					
B.6 How important does your trusted advisor believe it is to pregnancy scan annually?					

B.7 How important does your trusted advisor believe it is to assist ewes with dystocia?					
B.8 How important does your trusted advisor believe it is to provide ewes with shelter during winter?					
B.9 How important does your trusted advisor believe it is to provide ewes with during summer?					
B.10 How important does your trusted advisor believe it is to have the ewes annually checked by a veterinarian?					
B.11 How important does your trusted advisor believe it is to have a written health plan of the farm?					
B.12 How important does your trusted advisor believe it is to treat ewes for parasites annually?					
B.13 How important does your trusted advisor believe it is to test ewes for parasites before drenching?					
B.14 How important does your trusted advisor believe it is mulesing to prevent flystrike?					
B.15 How important does your trusted advisor believe it is to provide local anaesthesia or pain relief at mulesing?					
B.16 How important does your trusted advisor believe it is to calculate annual disease rates?					
B.17 How important does your trusted advisor believe it is to calculate annual mortality rate?					
B.18 How important does your trusted advisor believe it is to calculate annual culling rate?					

SECTION C: There are no right or wrong answers. All we want is your honest answer. Please read each question and then indicate using the following scale: 'not at all difficult', 'slightly difficult', 'moderately difficult', 'difficult' and 'very difficult'.

	Not at all difficult	Slightly difficult	Moderately Difficult	Difficult	Very difficult
	1	2	3	4	5
C.1 How difficult is it for you to perform daily checking of:					
Dry-ewes					
Pregnant ewes					
Ewes with lambs at foot					
C.2 How difficult is it for you to monthly check body condition of:					
Dry-ewes					
Pregnant ewes					
Ewes with lambs at foot					
C.3 How difficult is it for you to measure pasture <u>availability</u> ?					
C.4 How difficult is it for you to measure pasture <u>quality</u> ?					
C.5 How difficult is it for you to allocate pregnant ewes in different groups according to their nutritional needs?					
C.6 How difficult is it for you to perform pregnancy scan annually?					
C.7 How difficult is it for you to assist ewes in case of dystocia?					
C.8 How difficult is it for you to provide ewes with a form of shelter during winter?					
C.9 How difficult is it for you to provide ewes with a form of shelter during summer?					

C.10 How difficult is it for you to have the ewes annually checked by a veterinarian?					
C.11 How difficult is it for you to have a written health plan for the farm?					

	Not at all difficult	Slightly difficult	Moderately Difficult	Difficult	Very difficult
	1	2	3	4	5
C12. How difficult is it for you to test ewes for parasites before drenching?					
C13. How difficult is it for you to annually treat ewes for parasites?					
C.14 How difficult is it for you to provide any form of local anaesthesia or pain relief at mulesing?					
C.15 How difficult is it for you to calculate annual disease rates					
C.16 How difficult is it for you to calculate annual mortality rate.					
C.17 How difficult is it for you to calculate annual culling rate?					
C.18 How difficult is it for you to be prepared for a bad season?					

SECTION D: CHARACTERISTICS OF THE PROPERTY.

This section contains general questions about your farm. If you don't know the answer to any question, please give your best estimate.

D.1 How long have you farmed sheep? _____ Years

D.2 What is the approximate size of the property? _____ Hectares

D.3 What is your main farming enterprise? (Please tick a box)

Activity	Percentage of land used
----------	-------------------------

Sheep (wool)	
Sheep (prime lamb)	
Cattle	
Pigs	
Poultry	
Crop	
Other	

D.4 Rainfall for the area? Average annual rainfall ____ mm

D.6 What is the number of full-time labour units (workers) on the farm? (Including yourself, family members and employees) _____

SECTION E: EWE MANAGEMENT

This section contains general questions about your ewes. If you don't know the answer to any question, please give your best estimate.

E.1 How often are the ewes checked throughout the year (not including during lambing)?

- ☐ Daily
- ☐ Every 2nd day
- ☐ Weekly
- ☐ Fortnightly
- ☐ Monthly
- ☐ Never

E.2 How are the ewes checked? _____

E.3 How often are ewes checked during lambing?

- ☐ Daily
- ☐ Every 2nd day
- ☐ Weekly
- ☐ Fortnightly
- ☐ Monthly
- ☐ Never

E.4 How are the ewes checked during this time? _____

E.5 what do you think is the main reason why people do not perform regular surveillance? (Please tick ONE box)

- ☐ Size of the farm
☐ Labour
☐ Cost
☐ Lack of time
☐ Other _____

E.6 Do you body condition score your ewes?

1 ☐ Yes 2 ☐ Sometimes 3 ☐ No

How? _____

When? _____

E.7 What do you think is the main reason why people do not body condition score their ewes? (Please tick ONE box)

- ☐ Size of the farm
☐ Labour
☐ Cost
☐ Lack of time
☐ Other _____

E.8 Do you measure pasture availability?

1 ☐ Yes 2 ☐ No

E.9 How? _____

E.10 Do you measure pasture quality?

1 ☐ Yes 2 ☐ No

E.11 How? _____

E.12 What do you think is the main reason why people do not measure pasture availability/quality? (Please tick ONE box)

- ☐ Size of the farm
☐ Labour
☐ Cost
☐ Lack of time
☐ Other _____

E. 13a What was the average amount of supplement feed provided to your ewe flock over last 12 months (kg/head/week)? _____

E. 13b How long have you supplement? _____

E.14a Do you pregnancy scan annually?

1 ☐ Yes 2 ☐ Sometimes 3 ☐ No

E.14b What percentage of your ewes do you pregnancy scan annually? _____%

E14.c Do you keep 'singles' and 'twins' separate?

☐ Yes 2 ☐ Sometimes 3 ☐ No

E.15 When do you pregnancy scan? _____

E.16 What has been the average conception rate in the last three years? _____

E.17 Do you keep records of conception rate?

1 ☐ Yes 2 ☐ Sometimes 3 ☐ No

E.18 What has been the marking percentage in the last three years? _____%

E.19 Do you keep records of marking percentage?

1 ☐ Yes 2 ☐ Sometimes 3 ☐ No

E.20 What has been the weaning percentage in the last three years? _____%

E.21 Do you keep records of weaning percentage?

1 ☐ Yes 2 ☐ Sometimes 3 ☐ No

E.22 What do you think is the main reason why people do not maintain records?

(Please tick ONE box)

- ☐ Size of the farm
- ☐ Labour
- ☐ Cost
- ☐ Lack of time
- ☐ Other _____

E.23 What do you think is the main reason why people do not scan for pregnancy?

- ☐ Size of the farm
- ☐ Labour
- ☐ Cost
- ☐ Lack of time

☐ Other _____

E.24 Are ewes assisted during lambing in case of dystocia?

1 ☐ Yes 2 ☐ Sometimes 3 ☐ No

E.25 Do the ewes have access to shade/shelter during adverse weather conditions?

1 ☐ Yes 2 ☐ Sometimes 3 ☐ No

If yes, please specify _____

E.26 Before drenching sheep, are ewes tested for parasites?

1 ☐ Yes 2 ☐ Sometimes 3 ☐ No

E.27 How are the ewes tested? _____

E.28 How often are the ewes treated for parasites?

- ☐ Never
- ☐ Once a year
- ☐ Twice a year
- ☐ Three times a year
- ☐ More than 3 times per year

E.29 When are ewes treated for parasites? _____

E.30 What is the average greasy wool production per head? _____

E.31 What was the average carcase price that you received (for/if animals sold $\leq$ 1 year old) the last 12 months (\$/kg CWT)? _____

E.32 Does the farm have a written health plan?

1 ☐ Yes 2 ☐ No

E.33 Are annual disease rates recorded and calculated on the farm?

1 ☐ Yes 2 ☐ Sometimes 3 ☐ No

E.34 What is the average mortality rate per year of adult ewes on the farm? _____

E.35 Is annual ewe mortality rate recorded and calculated on the farm?

1 ☐ Yes 2 ☐ Sometimes 3 ☐ No

E.36 What do you think is the main reason why people do not record mortality rates? (Please tick ONE box)

- ☐ Size of the farm
☐ Labour
☐ Cost
☐ Lack of time
☐ Other _____

E.37 Which do you think is the most significant cause of mortality in your farm? (Please tick ONE box)

- ☐ Disease (if yes, please specify: _____)
☐ Fly strike
☐ Predation
☐ Nutritional (e.g. under nutrition, deficiencies, etc.)
☐ Other _____

E.38 What is your culling rate of ewes? _____

E.39 What is your main reason for culling? (Please tick ONE box)

- ☐ Age
☐ Reproductive failure
☐ Fly strike
☐ Other _____

Do you cull 1-2 years ewes? _____ Why? _____

E.40 Are male lambs on the farm usually castrated?

1 ☐ Yes 2 ☐ No

E.41 If yes, what method is used to castrate lambs:

- ☐ Rubber rings (elastration)
☐ Burdizzo or other form of clamp
☐ Knife/surgical castration
☐ Banding
☐ Other (specify)

E.42 Is any form of local anaesthesia or pain relief given at castration?

1 ☐ Yes 2 ☐ Sometimes 3 ☐ No

E.43 Do you perform mulesing to prevent flystrike?

1 ☐ Yes 2 ☐ Sometimes 3 ☐ No

E.44 If yes, who performs this procedure on the farm?

E.45 Is any form of local anaesthesia or pain relief given at mulesing?

1 ☐ Yes 2 ☐ Sometimes 3 ☐ No

E.46 Have you or any of your staff members attended an animal handling course?

1 ☐ Yes 2 ☐ No

E.47 Have you or any of your staff members attended any workshop or training sessions on how to improve productivity/welfare in the last 12 months?

1 ☐ Yes 2 ☐ No

If yes, please specify _____

E.48 Are you a member of any industry-based organisations?

1 ☐ Yes 2 ☐ No

If yes, please list _____

SECTION F: Demographic characteristics.

This section contains general questions about you. Please note that your individual responses will remain **strictly confidential**. Only average results for the entire sample will be used and reported.

F.1 Are you? (Please tick box)

1 ☐ Male 2 ☐ Female

F.2 What year were you born? _____

F.3 What is your highest level of education? (Please tick one box)

☐ No formal schooling

- ☐ Primary school
- ☐ Secondary school
- ☐ Technical or further education institution (including TAFE College)
- ☐ University or post-graduate degree
- ☐ Other educational institution (please specify) _____

Appendix 3: ISAE 2016**Assessment of human-animal relationship in extensively managed ewes**

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The quality of the human-animal relationship is a key factor affecting the welfare of farm animals, however, methods for its practical assessment in extensively managed sheep are lacking. The current exploratory study investigated some measures to assess the human-animal relationship in extensively managed ewes. The responsiveness of 100 Merino ewes (2 to 4 years old) to the presence of a human was tested at three-time points: late-pregnancy (LP), mid-lactation (ML) and weaning (W). Ewes were tested in the yard using a group pen and a race. A single observer, always the same person, quietly entered the pen (9m x 8m), walked around the perimeter and stood opposite the entry point. From here, 'time to settle' (time taken for the group to stop moving) was recorded. Subsequently, approach distance (AD) was then measured in 20 ewes (randomly selected from the mob) per reproduction stage. To measure AD the observer waited for a ewe to be orientated towards her before approaching the animal in a standardised way (i.e. slowly, at one step per second). The test ended whenever the ewe withdrew, defined as taking steps away from the observer, and the avoidance distance was estimated. A count of the number of vigilant sheep in the group (defined as having their head above shoulder height) was recorded. Ewes were then moved to a single file race and vigilance was again recorded. The mean AD were 5.1 m (LP), 6.2 m (ML) and 4 m (W), and significantly different over time LP vs. ML ($T_{(19)}=2.8$ $P=0.010$), LP vs. W ($T_{(19)}=4.3$ $P=0.000$) and ML vs. W ($T_{(19)}=5.4$ $P=0.000$). Analysis of vigilance also showed a significant difference. At all time points and in both scenarios, the majority of the ewes were vigilant; however, the number of vigilant animals decreased significantly over time (the number of vigilant ewes in groups: 100, 83 and 61 at each three-time points respectively; $X^2_{(2)}=45.8$, $P=0.000$, in the race: 84, 77 and 61 at each three-time points respectively; $X^2_{(2)}=11.3$, $P=0.003$). While only one flock at one farm was assessed, the variation observed in AD and vigilance suggests that these measures may be influenced by the reproduction stage of the ewes, the presence of lambs at foot, and/or their familiarity with the test/experimenter. The test performed in this study is consistent with other human-approach tests for livestock; however, our results indicated that the repeatability of the measures needs to be assessed comprehensively and caution may be required when interpreting results at different reproductive stages.

Appendix 4: ISAE 2016**Farmers' opinions about sheep management and welfare**

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Two focus groups were conducted to collect quantitative and qualitative information on the opinion and concerns of sheep farmers. These discussions were conducted with the purpose of identifying the underlying beliefs that influence farmers' behaviour, and the consequences for the productivity and welfare of their sheep. Both focus group discussions ran for approximately 60 min, followed semi-structured agenda, and comprised of eight and seven farmers respectively, ranging from 35 to 65 years of age. In general, monitoring was usually performed visually, without approaching the mob; all farmers agreed that they visually assessed behaviour and body condition as indicators of individual sheep welfare, but did not assess either in close proximity. Farmers also only visually assessed pasture quality and availability. Perceived barriers to more frequent/detailed management included time and labour availabilities. There was strong acknowledgement that behaviour and attitudes towards moving sheep dictated a farmer's success, with direct quotes including 'if you say sheep are stupid and you are getting angry at them, it is probably because you are doing something wrong', and 'the worst you can do it is to set a time... do not put a time on it, do not rush and everybody would be happy'. It was consistently acknowledged that the treatment of sheep by contractors was something that they had little control over. Farmers acknowledged that some husbandry procedures may be painful, and believed that the use of pain relief makes a 'huge difference' in how the sheep recover. Some diseases like foot abscess and eye injuries were identified as likely to cause pain, but conditions like lameness and dystocia were not raised, and veterinary intervention was rare, reserved only for particular diseases or to assess rams before mating. Farmers did engage with workshops and training courses however, indicating a desire for further education. In summary, farmer attitudes to sheep were positive and welfare was expressed as an important consideration; however, the extensive farming conditions and a perceived lack of behavioural control are likely barriers to welfare monitoring and improvement. This qualitative study will be used to inform a longitudinal study measuring the welfare of sheep in relation to farmer attitudes.

Appendix 5: ASAP 2016

Reliability and feasibility of animal-based indicators to assess the welfare of extensively managed ewes.

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Summary

The reliability and feasibility of 10 animal-based indicators of ewes welfare (body condition score (BCS), rumen fill, fleece cleanliness, fleece condition, skin lesions, tail length, dag score, foot-wall integrity, hoof overgrowth and lameness) were examined for on-farm use in extensive sheep production systems. The indicators were independently examined on 100 Merino ewes (from 2 to 4 years old) during late-pregnancy (LP), mid-lactation (ML) and weaning (WN) by a pool of nine trained observers. Levels of observer agreement were determined by Kendall's coefficient (W) and Kappa statistics. Overall, good agreement (from 'moderate' to 'almost perfect' agreement) were found for the indicators BCS, fleece condition, skin lesions, dag score and lameness, and the inter- and intra-observer agreement of these indicators increased from LP through to WN. This study presents five valid, reputable and feasible indicators for on-farm assessments of extensively managed ewes.

Introduction

Welfare assessments can be a useful way to demonstrate compliance with national and international legal welfare standards and for on-farm monitoring and benchmarking by farmers and veterinarians (Phythian et al., 2013). Thus, studies have recently started to examine indicators that could be used in welfare protocols for sheep (Stubsj  en et al., 2011; Phythian et al., 2013). Animal-based indicators are seen as the outcome of resource inputs and management practices, and therefore there is increasing interest in the incorporation of these indicators

in welfare assessments, as they provide an integrative and direct measurement of the welfare state of animals.

Welfare problems that affect sheep are mainly influenced by the farming system, production cycle and geographical location (Phythian, 2011). Thus, not all animal-based indicators identified for sheep can be broadly applied. Indicators need to be examined in terms of their validity (meaningful with respect to animal welfare), reliability (repeatable outcomes when applied by different observers), and feasibility (practical under farm conditions). The aim of the present study was to identify if 10 animal-based indicators were both reliable and feasible, and therefore appropriate for inclusion in welfare protocols for extensively managed ewes.

Materials and methods

Animals and management

A longitudinal on-farm study was performed in Victoria, Australia from July to December 2015. The reliability and feasibility of 10 welfare indicators extensively used in research, (BCS, rumen fill, fleece cleanliness, fleece condition, skin lesions, tail length, dag score, foot-wall

integrity, hoof overgrowth and lameness), were examined on 100 Merino ewes (2-4 years old) by a pool of nine trained observers. Ewes were marked within a large flock of approximately 3000 sheep and examined during late-pregnancy (LP) (July), mid-lactation (ML) (November) and weaning (WN) (December). These periods were selected because they are critical times in the concerns for ewe welfare (Stubsj  en et al., 2011). The ewes were managed under extensive

conditions, in a year-round outdoor system, grazing annual pastures, and managed under commercial conditions. The indicators were assessed in all animals individually, and the assessment was performed in a raceway.

The validity of these indicators was established by a literature review of indicators commonly used in research, by consultations with an expert group and from European-based protocols for sheep, so they were assumed to be valid.

Animal based-Indicators and reliability assessment

Nine observers, all with animal science backgrounds, with different levels of expertise of working with sheep, were recruited. Prior to individual assessments, observers were provided with an assessment protocol, and an on-farm training session using on average 25 ewes. Thereafter, each observer independently evaluated the 10 indicators on each sheep. The protocols were taken from Phythian (2011) and AWIN (2015). Reliability was assessed by evaluating test agreement between different observers, in line with previous studies of welfare indicators for sheep (Phythian et al., 2013). This is done by comparing the score given by each observer against a reference or 'test standard observer' (TSO). In the present study, observer 1 (CM), a veterinarian who developed the list of the indicators and provided training to the other observers was nominated as the TSO. From the pool of nine observers, combinations of four observers performed the assessments on each observation period, but the TSO performed the assessment in all the observation periods. To assess intra-reliability (the degree to which measurements taken by the same observer are consistent), all sheep were reassessed by the observers within a 15-day period in late-pregnancy, and within 24 hours at both mid-lactation and weaning. The observers subjectively evaluated the feasibility of assessing these indicators after the farm visits.

Statistical analysis

Reliability data were analysed using SAS statistical package (Statistical Analysis System, Release 9.4, 2012). The overall level of inter-observer reliability for multiple observer assessments was determined by Kendall's coefficient of concordance (W) for ordinal data (BCS, fleece cleanliness, fleece condition, skin

lesions, dag score, wall integrity, wall overgrowth and lameness) and Fleiss's Kappa for binary data (rumen fill and tail length). The level of pair agreement (agreement between the TSO and observers 2 to 9) and intra-observer agreement was analysed by Kendall's (W) and Weighted Cohen's k for ordinal data and Simple Cohen's K for binary data. All W and k results were interpreted according to Landis and Koch (1977), therefore values ≥ 0.81 suggested 'almost perfect' agreement, values from 0.61 to 0.80 indicated 'substantial' agreement, values from 0.41 to 0.60 suggested 'moderate' agreement, values from 0.21 to 0.40 suggested 'fair' agreement and values ≤ 0.20 indicated 'slight' to 'poor' agreement.

Results and Discussion

Overall, good observer agreements were found for the majority of the indicators, and the inter- and intra-observer agreement increased from LP through to WN. The indicators fleece cleanliness, fleece condition and dag score obtained 'moderate' to 'almost perfect' agreement during the three observation periods. Similarly, the indicators BCS and skin lesions increased from 'moderate' agreement at late-pregnancy to 'substantial-almost perfect' agreement at weaning (BCS W=0.60 (LP) 0.74 (ML) 0.80 (WN) skin lesions W= 0.41 (LP) 0.75 (ML) 0.93 (WN). Lameness was not assessed for inter-observer reliability because all the observers assisted with the identification of lame animals, but showed good intra-observer agreement (W= 0.53 (LP) 0.79 (ML) 0.86 (WN)). On the other hand, rumen fill, tail length, foot-wall integrity and hoof overgrowth were the indicators with only 'poor' to 'moderate' agreement. The difficulties of assessing these indicators (as numerous ewes were gathered in a race), along with the number of scoring categories and the descriptive terms used, may have adversely affected the levels of observer agreement in this study.

Rumen fill, fleece cleanliness, foot-wall integrity and hoof overgrowth were considered not very relevant for assessing welfare under extensive management conditions, even though some of these measures were repeatable and reliable. For example, fleece cleanliness had good reliability and feasibility. However, this indicator may be more valuable for indoor conditions to assess the cleanliness of the pens but might provide less

information on the condition of paddocks, and associated sheep welfare, in extensive settings. On the other hand, the indicator rumen fill showed low reliability and feasibility. This indicator is heavily influenced by how long sheep have been yarded, and although it could provide short-term information of food access, its inclusion in assessment protocols may be more valuable and feasible in lambs rather than ewes (Pythian et al., 2013). In the same way, the assessment of foot-wall integrity may be less relevant and feasible than the assessment of other indicators that are broader and thus provide an integrative assessment such as lameness (Kaler et al., 2011). In general, the indicators tested proved to be feasible, requiring 2 to 4 min to assess an individual ewe.

Conclusion

The outcomes of this study indicate that BCS, fleece condition, skin lesions, dag score and lameness are valid, reliable and feasible indicators for on-farm use in welfare protocols for extensively managed ewes. When combined, these indicators provide a snapshot of the current welfare status of ewes, as well as evidence of previous or potential welfare issues. Further research examining the effectiveness of these indicators in assessing seasonal variation and between-farm differences will provide additional evidence of their usefulness for incorporation into on-farm welfare assessments for extensively managed ewes.

Acknowledgement

This research was funded by MLA and by red meat producers and the Australian Commonwealth Government

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Appendix 6: ISAE regional 2016

Indicators to examine sheep welfare

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This study investigated whether nine animal-based measures of ewe welfare (body condition score (BCS), fleece cleanliness, fleece condition, skin lesions, tail length, dag score, foot-wall integrity, hoof overgrowth, and lameness) were reliable, feasible and able to detect seasonal variation in the welfare of sheep, and therefore appropriate for on-farm use in welfare assessments of extensive sheep production systems. The measures were examined on 100 Merino ewes (aged 2-4) during mid-pregnancy (MP), mid-lactation (ML) and weaning (WN) by a pool of nine trained observers. The ewes were marked within a flock of 3000 sheep, and they were managed under commercial conditions, in a year-round outdoor system. Good inter-observer agreement existed for the measures BCS, fleece condition, skin lesions, tail length, faecal soiling and lameness, determined by percentage of agreement, Kendall's coefficient (W) and Kappa (k) values, with inter- and intra-observer agreement increasing from MP ('moderate') through to WN ('almost perfect'). This study presents six valid measures that proved to be reputable and feasible measures for on-farm use, and they can also detect variation in the welfare of sheep in key periods of the production cycle, whereas three of the measures -fleece cleanliness, foot-wall integrity and hoof overgrowth- are more suited to more intensive sheep production systems. More measures such as practical on-farm assessment of fear of humans and the incorporation of different technologies such as infrared thermography for practical assessment of mastitis and lameness, and global positioning system (GPS) to track grazing behaviour and sheep movement to detect sick/lame animals may need to be developed if the welfare of extensively managed ewes is going to be assessed effectively.

Appendix 7: WAFL 2017**On-farm ewe welfare and its relationship with farmer management styles**

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This study investigated the relationship between on-farm ewe welfare and farmer management styles in 25 sheep flocks in Victoria, Australia. One hundred ewes (aged 2-5) were assessed at each farm. Animals were managed extensively in a year-round outdoor system and farm visits were conducted after weaning (spring/summer 2016). The ewes were assessed by six valid animal-based measures: body condition score (BCS), fleece condition, skin lesions, tail length, dag score and lameness. Management-based measurements were collected through an interview with the farmers or farm managers. All measurements were collected by a single observer. To examine the relationship between ewe welfare and management, farmers were classified as having a 'passive' or 'proactive' management style. Farmers who do not measure the body condition of their ewes, do not maintain mortality records and do not scan for pregnancy, or scan but do not manage single and multiple ewes differently were classified as passive. Flock sizes ranged from 430 to 9400 (2714 ± 2147). Overall, 56% (n=14) of the farmers were classified as passive and 44% (n=11) as proactive. No differences were found in the average BCS of passive (2.9 ± 0.25) and proactive flocks (2.8 ± 0.19). However, a binomial generalized linear model showed that passive farmers had more ewes in inadequate BCS (too thin or too fat according to industry recommendations) ($P=0.004$), and more ewes needed further care in passive flocks (due to flystrike, severe lameness, etc.) compared to proactive flocks ($P=0.017$), indicating that farmers with passive management style have more ewes at risk of welfare compromise. This study constitutes the first investigation of sheep welfare and its relationship with management styles in Australia. These data will be further investigated to develop an intervention strategy to improve sheep welfare and productivity, with the ultimate goal of ensuring sustainability for the sheep industry.

Appendix 8: ISAZ 2018**Farmer attitudes and its relationship with sheep welfare**

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Introduction:

Human-animal relationships may markedly affect the welfare and productivity of farm animals. This project aimed to address this knowledge gap by examining the relationship between farmer attitudes and on-farm ewe welfare.

Methodology:

Farmer attitudes and its relationship with sheep welfare was investigated using an attitude questionnaire and an on-farm welfare assessment of breeding ewes. A total of 32 commercial sheep farms in Victoria, Australia were studied. In the questionnaire, farmers rated a set of statements on their attitudes towards sheep, sheep management, job satisfaction, and perceived difficulty in conducting best practice. For the welfare assessment, 100 ewes were randomly selected and assessed at each farm after weaning (spring/summer 2016). Seven measures were used for the assessment: body condition score (BCS), fleece condition, skin lesions, tail length, dag score, lameness and animals needing further care. Data were analysed by principal component analyses (PCAs) and Pearson correlations.

Main Results:

The farms studied consisted of 13 (41%) prime lamb enterprises, 12 (38%) meat/wool enterprises and 7 (21%) wool enterprises. Flock sizes ranged from 430 to 9400 ewes (2714 ± 2147). PCAs on the questionnaire identified four main components (Kaiser-Meyer-Olkin value >0.60 , Barlett's test of sphericity $p < 0.05$). Based on semantic content, the components were labelled subjectively as: 'positive attitudes towards parasite control', 'positive job satisfaction', 'negative attitudes towards sheep' and 'perceived difficulties to sheep management'. Overall, farmers that had more ewes in adequate BCS had 'positive attitudes towards parasite control' ($r = 0.35$, $p = 0.04$), 'positive job satisfaction' ($r = 0.41$, $p = 0.01$) and 'perceived sheep management to be easy' ($r = 0.38$, $p = 0.03$). Furthermore, farmers that had more lameness 'perceived sheep management to be difficult' ($r = 0.40$, $p = 0.02$), and farmers that had more ewes needing further care had more 'negative attitudes towards sheep' ($r = 0.35$, $p = 0.05$).

Principal Conclusions and Implications for Field:

These results suggest that farmer attitude and perceived behavioural control may be two key drivers behind the behaviour of sheep farmers. Understanding the underlying beliefs that underpin farmer behaviour provides the opportunity, through targeted education and training, to improve the key human-animal interactions and subsequently farmer-ewe relation and animal welfare.

Appendix 9: ISAE 2018**Using qualitative behaviour assessment and flight distance to examine the farmer-ewe relationship in extensively managed ewes.**

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The quality of the human-animal relationship (HAR) is a key factor affecting animal behaviour and welfare. However, methods for practically assessing the HAR in sheep are limited. This study investigated the use of qualitative behaviour assessment (QBA) and flight distance (FD) as tools to examine the HAR in extensively managed ewes. It was hypothesized that ewes will be more reactive (e.g. alert and agitated) towards human stimulus and will have greater FD during a standardized FD test if they are managed by a farmer with negative attitudes towards sheep and sheep handling. Thirty-two sheep farms in Victoria, Australia were involved in this study, and visits were conducted after weaning (Oct-Dec 2016). Farmers answered an attitude questionnaire and ewes went through a QBA and FD test. In the questionnaire, farmers rated a set of statements on their attitudes towards sheep and sheep handling. To conduct the QBA and the FD test, at each farm 100 ewes were allocated in four groups of 23-27 ewes. The test was performed using a holding pen within the farms' regularly-used sheep yards. A single unfamiliar human stimulus (female), quietly entered the pen (holding one of the four groups of ewes), and walked around the perimeter at 1-step per second. During this procedure, the behaviour of the group was continuously recorded for 1 min by a GoPro camera. After this, FD was measured in 5 ewes randomly selected from each of the four groups of ewes (n=20 ewes tested per farm). The test ended whenever the ewe stepped away from the experimenter, and the FD was estimated. Using the video footage, one observer (not involved in the on-farm data collection) conducted the QBA. The attitude questionnaire and QBA data were each analysed by Principal Component Analysis (PCA), and Spearman rank correlations were performed between the PCA data and the FD data to examine relationships. PCA distinguished three main dimensions of farmer attitudes: PC1 (explained 26% of the variation) summarised as 'positive attitudes towards sheep', PC2 (24%) 'positive attitudes towards sheep handling' and PC3 (14%) 'positive perceived control of sheep handling'. Regarding QBA, one dimension of sheep expression was found: PC1 (77%) ranging from vigorous/agitated/fearful/alert/aggressive to calm/relax/quiet, summarised as 'mood'. Overall, FD ranged from 1.6 to 6.8 m (SD $\pm$ 1.1), and a significant positive correlation was obtained between 'mood' and FD ($r=0.49$ $P=0.004$), indicating that ewes that are more reactive towards human stimulus (vigorous/agitated/fearful/alert/aggressive) also presented greater FD. However, no relationships were found between 'mood' and farmers attitudes or between FD and farmer attitudes. These results suggest a moderate relationship between 'mood' and FD, and no clear relationships between 'mood' or FD and farmer attitudes towards sheep and sheep handling. Further research on farmer attitudes and behaviour specifically during routine husbandry is required to understand the farmer-ewe relationship in extensive systems.

Appendix 10: ISAE Regional 2018**La actitud de los agricultores y su relación con el manejo y bienestar ovino.**

Carolina A. Munoz¹, Grahame J. Coleman, Paul H. Hemsworth¹, Angus J. D. Campbell² and Rebecca E. Doyle¹

Estudios en el área de relación humano-animal han demostrado que la actitud tiene una relación directa en cómo las personas interactúan con los animales y en las decisiones de interacción y manejo que adoptan, lo cual a su vez afecta el comportamiento y bienestar animal y vice versa. Sin embargo, no existen estudios en ovinos manejados extensivamente, los cuales no están usualmente expuestos al contacto humano y muchas veces el contacto es asociado a manejos estresantes como castración y corte de cola. El presente estudio evaluó la actitud de los agricultores ovinos y la asociación con el estilo de manejo (pasivo o activo) y el bienestar de sus ovejas. Para esto, se realizaron cuestionarios y evaluaciones de bienestar animal en 32 granjas del estado de Victoria, Australia. En el cuestionario, los agricultores respondieron a una serie de preguntas relacionadas al manejo, actitud frente a trabajar con ovejas, satisfacción laboral, influencia de otros agricultores y dificultad percibida frente a mejoras en el manejo. Para la evaluación de bienestar animal, se visitaron las granjas en dos ocasiones; durante la preñez (abril/junio) y al destete (octubre/noviembre). En cada visita, se seleccionó aleatoriamente una muestra de 100 ovejas y se evaluó condición corporal (CC), calidad de la lana, lesiones, presencia de fecas, cojera y el número de ovejas que requerían cuidados más específicos (ej. ovejas con heridas severas, mastitis clínica, etc.). Los cuestionarios fueron analizados usando regresión logística (RL) y análisis de componentes principales (ACP). Los resultados del ACP y de la evaluación de bienestar se utilizaron para examinar la relación entre manejo y bienestar animal a través de correlación de Spearman. Todos los análisis se realizaron en SPSS. En total, se evaluaron 6200 ovejas y 32 granjas, 13 (41%) granjas de carne, 12 (38%) doble propósito (carne/lana) y 7 (21%) de lana. El tamaño de los rebaños fue de entre 430 y 9400 ovejas (2714 ± 2147). Los resultados de RL mostraron que la actitud influencia el estilo de manejo de los agricultores ($P=0.01$). Los agricultores con actitudes positivas frente al manejo ovino adoptan un estilo activo, es decir, revisan CC, detectan preñez, manejan registros, entre otras. A su vez, los agricultores con actitudes negativas adoptan un estilo más pasivo. Los resultados también indicaron que los agricultores con manejo más activo tenían ovejas en mejor CC ($r=0.38$ $p=0.03$), menos cojera ($r=-0.47$ $P=0.01$) y menor número de animales que necesitaron cuidados específicos ($r=-0.58$ $P=0.01$). Estos resultados indican primero, que la actitud cumple un rol importante en el estilo de manejo que adoptan los agricultores, y segundo, que existe una relación directa entre la actitud, el manejo y el bienestar de las ovejas. Este estudio se utilizará para desarrollar estrategias de educación con el objetivo de impulsar estilos de manejo activo en el sector ovino y así promover la sustentabilidad de la industria.

Appendix 11: UFAW 2018**Investigating the effect of pen size and pen shape on group flight distance of extensively managed ewes**

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A stockperson's attitudes and behaviours has a direct impact on animal fear, stress, welfare and productivity. Extensive environments that sheep are kept in result in infrequent handling, and can be coupled with aversive interactions and social isolation, all of which can lead to significant fear responses in sheep. Flight distance test is a valid indicator of this relationship, but a test of this nature for use on-farm has not been validated for use in extensively managed sheep. One key limitation to being able to develop this is between-farm differences in pens, making direct comparisons difficult. This study aimed to assess the effect of different pens on the flight distance of ewes and to trial a method to adjust for this.

A flock of 200 single-bearing Merino ewes (2-4 years) in early pregnancy was randomly selected. From this group, eight groups of 25 animals were created and six animals were selected to be focal animals (total=48). Ewe flight distances were tested in four pens: rectangle (4.8m x 5.8m), small rectangle (3.3m x 7.2m), large rectangle (11m x 19.6m) and curved pen (31.5m perimeter). Once a group of 25 were in the pen, the observer entered and approached each focal ewe in a standardised way to measure flight distance. For four days, this was repeated for each ewe until each group had been tested in each pen.

Group flight distance ranged from 1.1 m to 14.8 m (mean 4.7 m) and there was a significant Day x Pen interaction ($F = 2.58$, $P = 0.008$). Post-hoc tests revealed a clear difference across pens, but no clear relationship across days. Flight distances were then divided by the largest dimension of each pen. This modification resulted in flight distance proportions ranging from 0.15 m to 0.66 m (mean 0.36 m). There was still a statistically significant interaction of Day x Pen ($F = 3.01$, $P = 0.002$), but no clear pattern across pens or days was evident.

Pen size and shape clearly affects flight distance of ewes, but by adjusting for pen dimension flight distances can be made comparable. This is the first step in developing a flight distance test that allows for comparisons across farms. There was no evidence of habituation on the ewes, as indicated by a change in distance over days, suggesting that this test could be repeatable.

Appendix 12: UFAW 2018

Too short: understanding farmer knowledge of and attitudes towards appropriate lamb tail length

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A recent study identified that 84% of the ewes on 32 farms in Victoria, Australia had tails too short despite research linking health and welfare issues in sheep with tails shorter than the length of the vulva, or equivalent. Two focus groups were conducted with the aim to collect qualitative data on the opinions, knowledge and attitudes that underpin tail docking practice and decisions of tail length.

The discussions ran for approximately 60 mins, followed a semi-structured agenda and comprised of 13 and 10 sheep farmers respectively, ranging from 26 to 70 years of age, 21 males and two females. Voice recordings were collected, and qualitative content analysis was conducted in NVivo software using a thematic framework.

Overall, it was consistently acknowledged that tail docking was a method of flystrike prevention. Sixty percent of participants docked using rubber rings, which were described as 'easier' and 'quicker'. The remaining participants used the gas knife and those from the first group shared comments around the reduced stress of this method, one stating '[they] run away a lot happier' comparatively. Regardless of the method, the procedure was described as 'basic', often given less priority than other procedures at marking and is commonly carried out by labourers and farmers without formal training. In general, farmers were aware of the standards and guidelines regarding tail length; however, in most cases, the tail length was determined visually without measurement, based on experience and having 'your eye in'.

Some participants in the second group agreed there is '[a lot] of variation' between farms 'everywhere' in Victoria. Health concerns related to tail length were not viewed as common; in fact, most participants were aware of research around short tails being a risk factor of perineal cancers, prolapses and/or arthritis, although most were sceptical of the associations. Potential factors determining the choice of tail length included recognised breed conventions and ease of shearing. Farmers agreed 'it's easier to crutch' sheep with shorter tails, some reporting shearer complaints regarding tail lengths equivalent to the length of the vulva.

In summary, although tail docking is considered a simple procedure, there is an apparent deviation from the recommended length, significant length variation and a failure to consider health and welfare issues when deciding the tail length. This study will be used to develop a survey that will be delivered to 32 Victorian sheep farmers with the aim to understand key drivers behind farmer choice of lambs' tail length.

Appendix 13: Abstract of the manuscript submitted to Applied Animal Behavioural Science.

Investigating the effect of pen shape and pen size on group flight distance of extensively managed ewes

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Abstract

This study investigated the effect of pen shape and pen size on the group flight distance of extensively managed ewes, and how group results compared to isolated flight distances. Two hundred Merino ewes were randomly selected and evenly divided into eight groups. Over four days, the group flight distance of each group was tested in four different sized and shaped pens: rectangle 4.8 m x 5.8 m, small rectangle 3.3 m x 7.2 m, large rectangle 11 m x 19.6 m and curved with 31.5 m perimeter. Flight distance (m) and environmental noise levels (dB) were recorded for the same six focal animals in each group (total observed animals = 48). Flight distance (m) was also recorded when focal sheep were physically isolated from conspecifics, following a previously validated protocol.

The raw group flight distance ranged from 1.1 m to 14.8 m (Mean (M) = 4.67 m +/- 3.18 m). A linear model was run to compare pen effects. Pen design had a statistically significant effect on group flight distance ($P < 0.05$). When in large pens, sheep had greater flight distances, whilst flight distances were smaller in small pens. To account for these pen effects, group flight distance was adjusted and analysed as a proportion of the largest dimension of each pen. The adjusted group flight distance ranged from 0.15 to 0.66 (M = 0.36 +/- 0.11). A linear mixed model was run to compare the adjusted flight distance across the pen, day and decibel maximum effects. Day x Pen and Pen x Decibel Maximum interactions were statistically significant ($F_{9,169} = 4.17$, $P < 0.05$, $F_{3,169} = 4.73$, $P < 0.05$). Post-hoc pairwise comparisons showed no clear pattern across days or pens, however, when accounting for decibel maximums, adjusted flight distance increased for Pens A and C and decreased for Pens B and D. There was no association between the isolated flight distance scores and the adjusted group flight distance averages of all focal animals ($n = 48$, $r(46) = 0.11$, $P > 0.05$).

The application of a simple mathematical adjustment and statistical modelling made our data comparable. Pen size and environmental noise need to be measured and adjusted in future welfare assessments if human-sheep relationships are to be compared within and between farms. There were no relationships between a focal animal's isolated and group test results, suggesting that these tests are incomparable and highlighting the need for situation-specific tests.

Keywords: animal welfare assessment; animal-based indicator; fear; flight zone; human-animal relationship