

Copyright is owned by the author of this thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

# Assessing the Welfare of Pasture- Based Dairy Cows of New Zealand and Transhumance Chauris of Nepal

A thesis presented in partial fulfillment of the requirements for the  
degree of

Doctor of Philosophy

in Veterinary Science at

**MASSEY**  
**UNIVERSITY**  
RUNENGA POREHUROA

UNIVERSITY OF NEW ZEALAND

School of Veterinary Science  
Manawatu

SUJAN SAPKOTA

2023

DECLARATION

I hereby declare that I am the sole author of this thesis, entitled: "Assessing Welfare of Pasture-Based Dairy Cows of New Zealand and Transhumance Chauris of Nepal", submitted as partial fulfillment of the requirements for the degree of Doctor of Philosophy in Veterinary Science.

This research is an outcome of my scholarly endeavor, guided by the support of my supervisory committee. All collaborative inputs have been duly recognized and attributed.

This is the result of my own research, except where otherwise acknowledged, correctly and completely.

Sujan Sapkota

## **Abstract**

There is no industry-recognized welfare assessment protocol for pasture-based dairy cows of New Zealand. Also, the welfare assessment in yak/chaury raised under the transhumance system is at the preliminary stage. So, there is a strong necessity of a pastured-based welfare assessment protocol for pasture-based dairy cows in New Zealand and transhumance yak/chaury in Nepal. The aim of the research studies presented in this thesis were to develop a practical and time-limited welfare assessment protocol suitable to pasture-based dairy farms, and transhumance yak chaury focused on a single visit around milking. During the process, 84 different welfare measures were collected from six protocols and 4 welfare studies which were screened and trialed in two pasture-based farms to finalise 32 welfare measures including 5 additional measures specific to New Zealand. These measures were tested on 23 different dairy farms from the Waikato and Manawatu. All the measures were feasible except for the measure related to water availability and behavior. Testing of the repeatability and reliability should be performed for all the selected measures on more number of farms before taking this protocol for commercial use. Also, further subsampling-based locomotion scoring was done on five different pasture-based dairy farms to know if they could predict herd level prevalence. The findings were that there was a significant association between the order in which cows were milked and their susceptibility to lameness. However, the percentage of lame cows within the sub-sampled group was not uniform and was significantly influenced by the farm and the timing of the visit. For our yak/chaury protocol, 31 potential welfare measures were submitted to 120 Nepalese experts for evaluation identifying 13 measures, plus a new one (hematology) was deemed useful. The resulting protocol was tested in five chaury herds in northern Nepal, encompassing animal-based evaluations, mastitis and parasite sampling, and hematology. The protocol was found to be feasible and offers a valuable starting point for yak/chaury welfare assessment.

# Table of Contents

<u>Chapter One: General Introduction</u> .....	1
<u>References</u> .....	3
<u>Chapter Two: Literature Review</u> .....	5
2.0 <u>Welfare Assessment of Dairy Cows at Pasture</u> .....	5
2.1 <u>Welfare assessment and studies in dairy cattle</u> .....	6
2.1.1 <u>Foundations of the welfare assessment models</u> .....	6
2.1.2 <u>Purpose of welfare assessment in farm assurance</u> .....	7
2.2 <u>Welfare measures</u> .....	9
2.3 <u>Features of welfare measures used in farm assurance</u> .....	10
2.4 <u>Welfare assessment protocols in dairy cows</u> .....	11
2.5 <u>Need for welfare assessment system for farm assurance in pasture-based dairy cows</u> .....	24
2.6 <u>Practical challenges of welfare assessment in pasture-based farms of New Zealand</u> .....	27
2.7 <u>Conclusion</u> .....	28
<u>References</u> .....	29
<u>Chapter Three: Animal Welfare Assessment: Can We Develop a Practical, Time-Limited Assessment Protocol for Pasture-Based Dairy Cows in New Zealand?</u> .....	36
<u>Abstract</u> .....	37
3.1 <u>Introduction</u> .....	38
3.2 <u>Materials and Methods</u> .....	39
3.2.1 <u>Collection and Screening of Potential Assessments</u> .....	39
3.2.3 <u>Feasibility Testing</u> .....	39
3.2.4 <u>Finalisation Phase</u> .....	40
3.3 <u>Results</u> .....	40
3.4 <u>Discussion</u> .....	45
3.4.1 <u>Nutrition</u> .....	45
3.4.2 <u>Environment</u> .....	46
3.4.3 <u>Health</u> .....	47
3.4.4 <u>Behaviour</u> .....	47
3.5 <u>Conclusions</u> .....	48
<u>Appendix A</u> .....	49
<u>Appendix B</u> .....	52
<u>Appendix C</u> .....	52
<u>References</u> .....	54
<u>Statement of Contribution Doctrate with Publications/Manuscripts</u> .....	57

Chapter 4: <u>Practicability of a Time-Limited Welfare Assessment Protocol for Pasture-Based Dairy Farms, and a Preliminary Assessment of Welfare Outcome Thresholds</u> .....	58
<u>Abstract</u> .....	59
4.1 <u>Introduction</u> .....	59
4.2 <u>Materials and Methods</u> .....	60
4.2.1 <u>Methods and Categorisation of Welfare Measures</u> .....	60
4.2.2 <u>Data Collection</u> .....	64
4.2.3 <u>Data Analysis</u> .....	64
4.3 <u>Results</u> .....	64
4.3.1 <u>Animal-Based Measures</u> .....	65
4.3.2 <u>Resource-Based Measures</u> .....	66
4.3.3 <u>Track Assessment</u> .....	67
4.3.4 <u>Shelter and Shade</u> .....	67
4.3.5 <u>Record, Management, and Stockpersonship Based Measures</u> .....	67
4.4 <u>Discussion</u> .....	68
4.5 <u>Conclusions</u> .....	71
<u>References</u> .....	72
Chapter 5: <u>Can We Predict Herd Level Prevalence of Lameness by Subsampling the Herd ?</u> .....	75
<u>Abstract</u> .....	76
5.1 <u>Introduction</u> .....	77
5.2 <u>Materials and Method</u> .....	79
5.2.1 <u>Statistical methods</u> .....	79
5.3 <u>Results:</u> .....	80
5.3.1 <u>Descriptive Statistics</u> .....	80
5.3.2 <u>Limits of agreement</u> .....	82
5.4 <u>Discussion</u> .....	84
5.5 <u>Conclusion</u> .....	87
<u>References</u> .....	88
<u>Appendix 1</u> .....	89
<u>Statement of Contribution Docrate with Publications/Manuscripts</u> .....	90
Chapter 6: <u>Possible Consequences of Climate Change on Survival, Productivity and Reproductive Performance, and Welfare of Himalayan Yak (<i>Bos grunniens</i>)</u> .....	91
<u>Abstract</u> .....	92
6.1 <u>Introduction</u> .....	93
6.2 <u>Climate Change in the Himalaya</u> .....	94
6.2.1 <u>Temperature</u> .....	94

6.2.2 <u>Precipitation</u> .....	94
6.2.3 <u>Vegetation</u> .....	94
6.3 <u>Yak Population</u> .....	95
6.4 <u>Possible Consequences of Climate Changes on Yak</u> .....	95
6.4.1 <u>Climate Change and Yak Physiology</u> .....	96
6.4.2 <u>Climate Change and Reproductive Performance</u> .....	97
6.4.3 <u>Climate Change and Productivity</u> .....	97
6.4.4 <u>Climate Change and Infectious Disease Occurrence</u> .....	97
6.5 <u>Overall Welfare Status</u> .....	99
6.6 <u>Adaptation Strategies to Mitigate Adverse Effects of Climate Change on Yak</u> .....	100
6.7 <u>Conclusions</u> .....	100
<u>References</u> .....	101
Statement of Contribution Docrate with Publications/Manuscripts .....	105
<u>Chapter 7: Assessment of welfare in transhumance yak hybrids (chauri) in lower Himalayan region of Nepal</u> .....	107
<u>Abstract</u> :.....	108
<u>7.1 Introduction</u> .....	114
<u>7.2 Materials and Methods</u> .....	109
<u>7.2.1 Identification of measures for inclusion in the welfare assessment</u> .....	109
<u>7.2.2 Feasibility</u> .....	110
<u>7.3 Results</u> .....	116
<u>7.3.1 Survey results</u> .....	116
<u>7.3.2 Feasibility results</u> .....	117
<u>7.3.3 Resource and record-based measures</u> .....	122
<u>7.4 Discussion</u> .....	122
<u>7.5 Conclusions</u> .....	123
<u>Appendix 1</u> .....	128
<u>Appendix 2</u> .....	132
<u>Appendix 3</u> :.....	134
<u>References</u> .....	135
Statement of Contribution Docrate with Publications/Manuscripts .....	139
<u>Chapter 8: General Discussion</u> .....	140
<u>8.1 Selection of welfare assessment measures</u> .....	140
<u>8.1.1 Development of the New Zealand protocol</u> .....	140
<u>8.1.2 Simplifying lameness assessment</u> .....	144
<u>8.2 Development of the protocol for use in Yak/Yak hybrids in Nepal</u> .....	144

8.3 <u>Range of welfare measures</u> .....	145
8.4 <u>Representation of welfare outcomes</u> .....	146
8.5 <u>Threshold establishment, Welfare Categorisation and Welfare Outcomes.</u> .....	147
8.6 <u>Limitations of the study</u> .....	147
8.6.1 <u>Reliability and repeatability of welfare measures</u> .....	147
8.6.2 <u>Seasonality</u> .....	147
<u>References</u> .....	148
Chapter 9: <u>Future Perspectives and Conclusions</u> .....	151
<u>References</u> .....	152

## **Acknowledgments**

I would like to express my sincere gratitude to my supervisory team: Professor Richard Laven, Dr. Kristina Mueller, Dr. Nikki Kells, and Dr. Shanker Raj Barsila for their invaluable support and guidance throughout this research journey. Their guidance as supervisors, along with their constructive feedback and insightful advice, have played a crucial role in shaping this work. I extend my heartfelt thanks to the School of Veterinary Sciences and Prof Richard Laven for their financial support: this project would not have been possible without their support.

I am deeply grateful to my mother and my wife for their unwavering support at every step of this academic endeavor. Their encouragement and understanding have been my pillars of strength. A special mention goes to my son, Saman, who has been my constant source of joy and stress relief throughout this challenging journey. His presence has been a grounding force, reminding me of the importance of balance in life.

I would also like to acknowledge and appreciate the help from VetEnt, Waikato, and Dr Winston Mason during the farm visits. I would like to thank all the farmers from Nepal and New Zealand for allowing me to visit their farms and share their information with me. This has been pivotal to the success of this research. I would like to remember my friends and brothers Dr. Keshav Bhatt, Dr. Rockson Karmacharya, Dr. Bikash Giri, Dr. Nabin Shrestha, and Dr. Dhurba DC for their help and support during my study in Nepal.

I want to express my gratitude to the almighty for guiding me through the challenges of my PhD journey. I also ask his blessings for everyone who supported me in this journey knowingly or unknowingly. I hope the divine grace of the almighty reaches all these wonderful people, bringing them happiness and success. May their kindness and support come back to them in abundance. I'm grateful for their role in my academic journey and wish them all the best in their endeavours.

## Thesis Outline and Publications

This thesis has been prepared partly via publication. Thus chapters 1, 2, 5, 8, 9 were not written for publication. However, chapters 3, 4, 6, and 7 were written for publication and have been published.

Table 1: Thesis outline and publications

<b>Chapter</b>	<b>Status</b>
Chapter One: General Introduction	Not written for Publication
Chapter Two: Literature Review	Not written for Publication
Chapter Three: Animal Welfare Assessment: Can We Develop a Practical, Time-Limited Assessment Protocol for Pasture-Based Dairy Cows in New Zealand	Published (2019) <a href="https://doi.org/10.3390/ani10101918">https://doi.org/10.3390/ani10101918</a>
Chapter 4: Practicability of a Time-Limited Welfare Assessment Protocol for Pasture-Based Dairy Farms, and a Preliminary Assessment of Welfare Outcome Thresholds	Published (2022) <a href="https://doi.org/10.3390/ani12182481">https://doi.org/10.3390/ani12182481</a>
Chapter 5: Can We Predict Herd Level Prevalence by Sub-Sampling the Herd?	Not written for Publication
Chapter 6: Possible Consequences of Climate Change on Survival, Productivity and Reproductive Performance, and Welfare of Himalayan Yak (Bos Grunniens)	Published <a href="https://doi.org/10.3390/vetsci9080449">https://doi.org/10.3390/vetsci9080449</a>
Chapter 7: Development of Welfare Assessment Protocol for Yak/Yak hybrids in Nepal	Published <a href="https://www.mdpi.com/2673-933X/4/1/9">https://www.mdpi.com/2673-933X/4/1/9</a>
Chapter 8: General Discussion	Not written for Publication

Chapter 9: Future Studies and Conclusions	Not written for Publication
---	-----------------------------

## **Chapter One: General Introduction**

Demand for quality animal products has increased the concern for the welfare of animals used in food production (Alonso et al., 2020). This increasing social demand for transparency related to animal welfare has led to the development of many welfare assurance schemes (Webster, 2008). Such schemes have increased the bar for acceptable welfare standards. For dairy cows, there are many widely used welfare assessment protocols e.g., Welfare Quality (2009) but, most protocols are specifically designed to assess the welfare of indoor cows (Crossley et al., 2021). Therefore, existing protocols do not cover all the welfare issues/measures needed for pasture-based cows (Aubé et al., 2022). Measures used for welfare assessment in housed cows either have to be modified or replaced by other suitable measures to be implemented in pasture-based conditions (Laven & Fabian, 2016). These measures need to be feasible in terms of their applicability, conciseness, and time efficiency. Such attributes facilitate the smooth functioning of the welfare assessment and enable it to be implemented on a routine basis on pasture-based dairy farms. In addition, the impact of season and herd size on different welfare measures in the pasture based cows should also be considered for making the protocol more feasible.

The selection of suitable measures is an essential aspect of developing a system-specific welfare assessment protocol (Knierim & Winckler, 2009). Feasibility testing is a key step in the selection of practicable and achievable measures for systems (Battini et al., 2014). This is especially important in pasture-based dairy farming systems such as New Zealand due to the particular nature of the daily routine (e.g., walking at least daily from pasture to the milking parlour to get milked), the associated infrastructure (e.g., tracks, backing gate, collecting yard and related management practices (e.g., grazing management, and limited animal handling).

The time required to assess a specific welfare measure is a crucial factor in determining the feasibility and applicability of that measure (Knierim & Winckler, 2009). In New Zealand, milking time is the only time when cows are routinely restricted in a confined environment and animal-based measures can be relatively simply assessed. The limited time available around milking means that welfare assessment needs to be simplified and particular attention needs to be paid to time budgeting and management.

For any dairy farm assurance scheme, assessment of lameness is one of the most important welfare assessments, even on pasture-based dairy farms (Alawneh et al., 2011). However, although assessing the level of lameness across the entire herd can be advantageous for determining lameness prevalence, it should be time and resource-intensive (Hoffman et al., 2013), especially in a pasture-based system where lameness scoring can be difficult to achieve whilst also assessing other welfare measures (Laven & Fabian 2016). Sampling procedures can significantly reduce the time and resources needed (Beggs et al 2019) but may be limited in accuracy, especially in a pasture-based system.

Most of this interest in the systematic assessment of farm animal welfare has focused on commercially farmed livestock rather than livestock that are farmed on a subsistence or semi-commercial basis. This applies to yak and their hybrids which are reared on a subsistence or semi-commercial basis under the transhumance system in the Himalayan region, including Nepal. There are limited data on yak welfare, so we lack a good baseline, but it is apparent that they face various challenges, such as a shortage of forage, lack of access to water, parasites, and heat stress, which are exacerbated by climate change and competition for land (Krishnan et al 2016). Longer-term problems, such as a lack of proper treatment facilities, limited knowledge and skills of yak herders, and a lack of government support (especially in relation to pasture management and the development of infrastructure along the transhumance route) are also likely to contribute to negative yak welfare. To optimize the welfare of yak and ensure the sustainability of yak herding, an outcome-based welfare assessment program is needed. The program should consider the challenging geographical conditions of the Himalaya where yak and their hybrids are found. It should involve expert and stakeholder perspectives to select welfare assessments that are practicable and achievable as there are very few studies focused on the welfare assessment of yak. Further testing of those measures should be done to ensure their feasibility under the transhumance system.

Thus, the aim of this study was 1) to develop a time-limited welfare assessment protocol suitable for pasture-based dairy cows in New Zealand. 2) to test the feasibility and practicability of measures included in the protocol across various pasture-based dairy farms in New Zealand. 3) to determine thresholds for the selected measures and compare the results from the welfare assessment of dairy farms based on them. 4) to investigate whether sampling-based locomotion

scoring can predict the herd-level prevalence of lameness. 5) to identify the assessments that are likely to be useful for assessing the welfare of yak in Nepal with the help of local Nepalese experts, and then 6) to test those measures in yak and chauri in herds being grazed in the Himalayan region of Nepal.

## References

- Alawneh, J., Laven, R., & Stevenson, M. (2011). The effect of lameness on the fertility of dairy cattle in a seasonally breeding pasture-based system. *Journal of Dairy Science*, *94*(11), 5487-5493.
- Alonso, M. E., González-Montaña, J. R., & Lomillos, J. M. (2020). Consumers' concerns and perceptions of farm animal welfare. *Animals*, *10*(3), 385.
- Aubé, L., Mialon, M., Mollaret, E., Mounier, L., Veissier, I., & des Roches, A. d. B. (2022). Assessment of dairy cow welfare at pasture: measures available, gaps to address, and pathways to development of ad-hoc protocols. *Animal*, *16*(8), 100597.
- Battini, M., Vieira, A., Barbieri, S., Ajuda, I., Stilwell, G., & Mattiello, S. (2014). Invited review: Animal-based indicators for on-farm welfare assessment for dairy goats. *Journal of Dairy Science*, *97*(11), 6625-6648.
- Beggs, D., Jongman, E., Hemsworth, P., & Fisher, A. (2019). Lameness in Australian dairy farms: A comparison of farmer-identified lameness and formal lameness scoring, and the position of lame cows within the milking order. *Journal of Dairy Science*, *102*(2), 1522-1529.
- Hoffman, A., Moore, D., Wenz, J., & Vanegas, J. (2013). Comparison of modeled sampling strategies for estimation of dairy herd lameness prevalence and cow-level variables associated with lameness. *Journal of Dairy Science*, *96*(9), 5746-5755.
- Knierim, U., & Winckler, C. (2009). On-farm welfare assessment in cattle: validity, reliability and feasibility issues and future perspectives with special regard to the Welfare Quality® approach. *Animal Welfare*, *18*(4), 451-458.
- Krishnan, G., Paul, V., Hanah, S., Bam, J., & Das, P. (2016). Effects of climate change on yak production at high altitude. *Indian Journal of Animal Sciences*, *86* (6), 621-626.
- Laven, R., & Fabian, J. (2016). Applying animal-based welfare assessments on New Zealand dairy farms: Feasibility and comparison with United Kingdom data. *New Zealand Veterinary Journal*, *64*(4), 212-217.

- Temple, D., & Manteca, X. (2020). Animal welfare in extensive production systems is still an area of concern. *Frontiers in Sustainable Food Systems*, 4, 545902.
- Webster, J. (2008). *Animal Welfare: Limping towards Eden: A practical approach to redressing the problem of our dominion over the animals*: John Wiley & Sons.
- Welfare Quality (2009). Welfare Quality® assessment protocol for cattle. *Lelystad: Welfare Quality R Consortium*.

## **Chapter Two: Literature Review**

### **2.0 Welfare Assessment of Dairy Cows at Pasture**

Animal welfare is a complex and multi-faceted phenomenon (Lund et al., 2006), which is subject to a diverse array of interpretations and definitions (Carenzi & Verga, 2009). Despite this variance, it is generally acknowledged that the three fundamental components of animal welfare are biological functioning, affective state, and natural living (Fraser, 2003). There is also consensus among many animal welfare scientists that higher-order animals, including mammals and birds, are sentient beings with emotions and an awareness of their surroundings (Broom, 2014). As Webster (2005) states, this capacity for sentience goes hand-in-hand with a capacity to suffer, and therefore welfare matters to sentient animals. Thus it is important that, in animals that we manage, welfare is optimised. This is particularly important in farm animals because, especially in commercial farms, they are being used to produce products for consumption, remote from the farm, by people who have no direct control over the management of those animals.

Independent rigorous assessment of farm animal welfare is thus essential to enhance the standard of living of farm animals and to increase consumer transparency regarding animal-derived products (Grandin, 2014). This requires the development of protocols for the assessment of animal welfare that are valid (i.e., they need to actually measure animal welfare), accurate, comprehensive, and reliable (i.e. limited intra- and inter-observer variation) (Browning 2022). These protocols then need to be incorporated into farm assurance programmes that provide welfare assurance for purchasers of farm animal products, whether those purchasers be the end-consumer or intermediaries such as manufacturers, wholesalers, and retailers.

A wide range of welfare assessment protocols have been developed for dairy cattle, such as the Welfare Quality assessment protocol (Welfare Quality, 2009), and the Animal Needs Index (Bartussek et al., 2000). However, the vast majority of these have been developed for housed, or otherwise confined cattle. Their applicability to cattle which are kept permanently at pasture is limited (Laven & Fabian, 2016). There is thus a need to develop assessment protocols specifically designed for pasture-based cattle, which take account of the different

welfare issues such as cattle encounter and the differences in access that the observer will have to pasture-based rather than confined cattle.

This review aims to discuss various facets of welfare assessment protocols, including frameworks, purposes, and welfare measures, with a particular focus on welfare assessment as part of “Farm Assurance”. It will also provide a sound rationale for the need for a specific, pasture-based welfare assessment protocol by demonstrating the limitations of currently available welfare assessment protocols in terms of practicality, time, and resources required to implement them. Additionally, it will highlight the practical difficulties of conducting welfare assessments in the intensive pasture-based dairy farms of New Zealand.

## **2.1 Welfare assessment and studies in dairy cattle**

### **2.1.1 Foundations of the welfare assessment models.**

Although there is no fixed methodology or framework for evaluating animal welfare (Hewson, 2003), the Five Freedoms paradigm and the Five Domains model are widely accepted models that serve as the basis for developing assessment protocols (Mellor, 2017).

The Five Freedoms consist of four ‘freedom from’ conditions, i.e., freedom from hunger and thirst, from thermal and physical discomfort, from pain, injury, and disease, and from fear, and distress, along with one freedom to, i.e., freedom to express normal behavior (Webster 2016). These freedoms are matched against their respective “provisions” which describe how the five freedoms can be practically achieved (Mellor 2016). According to Webster (2016), the main strength of the Five Freedoms concept is that it provides a set of outcome measures that can be understood by non-specialists, and which can be used to develop quality control protocols for welfare assessment. Nevertheless, although the Five Freedoms approach has proved very successful and (especially if its “Five Provisions” are included as part of the approach) it underlies almost all subsequent welfare assessment programs used for farm assurance, there are multiple issues with the approach. In particular the phrase ‘freedom from’ can be misunderstood/misrepresented as meaning complete freedom from negative experiences, establishing the concept that such states are fully achievable, although, the Five Freedoms were intended to ensure that animals were ‘as free as possible’ from negative

experiences (Mellor, 2016). But, this still leaves the issue that the focus of the Five Freedoms on minimising negative effects does not address positive welfare. This was unequivocally accepted by Webster (2016) but he highlighted that the core principles of the Five Freedoms were not aimed at creating a comprehensive understanding of an animal's mental state, but rather as providing guiding principles for taking appropriate actions. He stated that "to animals our thoughts about them are inconsequential; it's our actions that truly matter".

In contrast, the Five Domains model, which encompasses the domains of nutrition, environment, health, behaviour, and mental state (Mellor, 2017), is more holistic and is aimed at both minimising negative experiences and promoting positive ones. Risks to welfare compromise and opportunities for welfare enhancement are evaluated in the first four physical/functional domains and are interpreted in terms of the animal's likely affective experiences in domain five (mental state). Overall welfare status may then be determined by the integrated outcome of all affective experiences in Domain five. The Five Domains model is more comprehensive, nuanced, and detailed than the Five Freedoms model, but in regard to developing welfare assessment protocols for farm assurance, which need to be outcomes and action-focussed, it is likely that both models, at least at present, will result in similar protocols. For example, direct assessment of mental state and many aspects of the behaviour domain are not really achievable during a single farm visit. As such, if a single-visit protocol is developed using the Five Domains approach, all the measurements are likely to be derived from the first four domains, and the protocol will be similar to those chosen based on the Five Freedoms approach.

### **2.1.2 Purpose of welfare assessment in farm assurance**

The evaluation of animal welfare for farm assurance has become a crucial aspect of modern livestock farming (Main et al., 2001), with on-farm welfare assessment being used as an integral part of various farm assurance programs (Webster, 2005, 2008; Whay, 2007). Welfare assessment in farm assurance programmes has multiple roles:

**a) Checking compliance against legal welfare requirements:** In most cases, there are mandatory legal requirements related to livestock farming and often Codes of Practice (e.g. New Zealand Code of Welfare for Dairy Cattle (Ministry of primary industries, 2019)) that define how legal requirements should be met. Assurance programs can check if the farm is meeting those legal standards (Rowe et al., 2021), with failure to comply with these requirements resulting in the farm no longer being applied to sell its products.

**b) Checking compliance against higher welfare standards:** Demand for higher standards of animal welfare by purchasers (often through pressure from consumers) can result in farms needing to demonstrate higher standards than legal requirements (Webster, 2008). Such standards can be used to identify a product as premium which can result in higher returns to the producer (e.g. Certified Humane Program (Certified Humane, 2023)). Again, a welfare assessment can be used to check that these higher standards are being met.

**c) Identification of welfare compromises and their mitigation strategies:** For all farm assurance programmes, whether their standards are equivalent to legal requirements or more stringent, welfare assessment can be used to identify the areas where on-farm welfare is close to the standards required and then help farmers to solve those issues, and thus improve overall wellbeing of their animals (Whay, 2007). This is built into and a key part of many programmes. For example, schemes like "ProAction" (ProAction, 2021) require that, when issues are identified, farmers develop action plans with expert involvement to address those issues within specific timeframes. Improvements in animal welfare are thus built into such programmes, rather than being a passive measurement of welfare.

**d) Benchmarking:** Across a scheme, welfare assessment outcomes can be used for benchmarking purposes. This allows an individual farm to be compared against other farms for all the measures included in the assessment. This, for example, is a particular focus of the UC Davis cow-calf health and handling assessment (University of California Davis, 2017). Such information helps to inform the farmer where they stand within the wider community for a particular welfare measure.

All of these roles have the underlying intention of building consumer confidence, by increasing the trust of the consumers that they are buying a product that comes from welfare-friendly farms (Webster, 2005). This increase in trust is dependent on an independent third-party assessment of welfare, which is supported by clear evidence of routine ongoing assessment rather than one-off assessments which are never followed up.

## **2.2 Welfare measures**

Measuring the welfare of an animal directly is not feasible, as animal welfare is a subjective state (Hawkins et al., 2011) and animals cannot self-report as humans can. However, animal welfare can be assessed by monitoring certain behavioural and physiological measures that serve as indicators of welfare state. It is crucial to establish and monitor the appropriate types and quantities of these measures for inclusion in farm-assurance-based welfare assessment protocols. An excessive number of indicators may result in a cumbersome and time-consuming process, while too few indicators may lead to inaccurate and misleading assessments of animal welfare (Hawkins et al., 2011). So, a comprehensive assessment of animal welfare on farm requires the utilization of a balanced and broad spectrum of welfare measures (Johnsen et al., 2011). Assessment measures can principally be divided into animal, resource, and management-based parameters. Animal-based measures, which focus on the health, physiology, and behaviour of the animals, are widely employed in farm assurance-based welfare assessment protocols (Spigarelli et al., 2020) and provide a direct evaluation of the animal's welfare state (Sevi, 2009; Webster, 2005; Whay et al., 2003). For instance, evaluating the lameness status of cows through locomotion scoring is a more meaningful indicator of their welfare than assessing the quality of the floor in the yard. However, certain animal-based measures may present challenges in implementation on a farm level, such as the need for laboratory examination to assess stress hormone levels or the difficulty in objectively quantifying behavioural measures that may require extensive time.

Resource-based parameters such as length of stalls, feeding and drinking infrastructures, space requirements, litter quality, and access to pasture are relatively easy and quick to measure. However, measuring the resources provided to animals is an indirect and less precise means of assessing welfare state (Linnet al., 2018). Nevertheless, in some circumstances where it might not be feasible to assess welfare using animal-based measures, resource-based measures can be used to predict the welfare status. For example, assessing

animals directly for thirst is difficult under field conditions so measures of water availability such as trough capacity may be a suitable proxy for herd-level assessment.

Management practices can also impact the welfare status of farm animals. For example, routine management practices such as dehorning, handling and restraint, record keeping, pain management, and noise management can impact the welfare of the animals in both the short and long term (Grandin, 2020; Stafford & Mellor, 2005). Assessment of management practices is a key part of welfare assessment as part of farm assurance. Similarly, stock person skills and knowledge can have a major impact on animals, particularly in regard to the prevention, detection, and treatment of disease, and animals' perception of humans (as reflected in the level of fear or anxiety in the presence of humans) (Rushen et al., 2008). Measures of stock person behaviour (e.g. shouting, use of sticks) and of animal-human interactions (e.g. flight distance) are thus critically important in farm assurance schemes.

### **2.3 Features of welfare measures used in farm assurance.**

For farm assurance, measures included in a welfare assessment protocol should be valid, feasible and reliable. In particular, they should not be too time-consuming so that the whole protocol can be undertaken within a short timeframe as much as possible. For example, the Welfare Quality protocol, known for its comprehensiveness, demands approximately 7.7 hours to assess a 200-cow herd, which is difficult to integrate into a farm assurance scheme (Heath et al., 2014; Lin et al., 2014). Farm assurance schemes typically favour a straightforward process of result interpretation, involving direct comparisons with requirements, making it less conducive for interpreting results based on welfare quality and ranking farms based on aggregated scores.

In terms of farm assurance, the validity (is the measure actually measuring what you think it is) and feasibility (can the measure be assessed efficiently in real-life conditions,) of welfare quality measures have been primarily established for housed cows, necessitating further evaluation in diverse farming systems. In New Zealand, adopting these measures may prove impractical for assurance purposes, particularly if the aim is to assess large-scale farms within a single day. Pasture-based systems introduce additional challenges, demanding concise assessment methodologies and efficient time utilization, considering that cows in such

systems spend most of their time grazing, making assessments more complex. In contrast, assessing housed cows is comparatively simpler, given the ease of access to animals and shorter observation periods.

Reliability stands as another crucial facet of welfare measures, encompassing inter-observer reliability, test-retest reliability, and predictive reliability. Inter-observer reliability implies that different assessors, with similar training, should yield consistent results when assessing the same subjects. Test-retest reliability measures consistency over time, especially important for certification purposes when frequent assessments are impractical. Predictive reliability requires assessment methods that accurately forecast outcomes over extended periods, even amidst minor on-farm variations, emphasizing the importance of strong test-retest reliability to ensure consistent results despite evolving conditions (Knierim & Winckler, 2009; Plesch et al., 2010; Windschnurer et al., 2009).

Another important feature of welfare measures, especially animal-based measures, is that they should be able to integrate the long-term consequences of past husbandry practices (Webster, 2005). For example, body condition reflects past nutrition rather than the current amount of available feed/grass in a day. This can prevent injustice in the assessment as the farmer is not penalised based only on conditions on the day, but also prevents from using short-term manipulation to hide their weak areas. As far as possible, the measures should be non-intrusive and cause minimal disturbance to the animal's natural behaviour (Webster, 2005).

## **2.4 Welfare assessment protocols in dairy cows**

There have been many studies on the development of welfare assessment systems for dairy cows. As there is no gold standard for the assessment of welfare in dairy cows, different countries and different programmes use and apply different welfare assessment protocols. The focus of the protocol depends on factors, such as the management system (e.g., pasture-based or indoor), and the key problems and legal requirements of the country or region in which they are being applied. Some of the major welfare assessment protocols/systems in use across the world are described below, in terms of their specific features and any identified limitations for their application in pasture-based systems.

Table 1: Summary of major dairy cow welfare assessment protocols, highlighting their features and any limitations for their application in farm assurance schemes of pasture-based systems.

Continent	Name of the protocol	Features	Limitations for use in pasture-based farming systems
Europe	Welfare Quality Assessment protocol for cattle (Welfare Quality, 2009)	<ul style="list-style-type: none"> <li>• <b>Purpose:</b> to scientifically assess welfare and integrate the information in a standardised way to categorize farms into different welfare categories.</li> <li>• <b>Developer:</b> Welfare Quality Project</li> <li>• <b>Method:</b> Assessed by the trained assessors from the Welfare Quality</li> <li>• <b>Framework:</b> Five Freedoms of animal welfare</li> <li>• <b>Range of measures:</b> Under four principles (good feeding, good housing, good health, appropriate behavior) there are 12 welfare criteria (e.g., the criteria “absence of prolonged hunger” under the welfare principle of good feeding). Altogether there are 31 welfare measures out of which 23 are animal-based measures, 4 of them are resource-based measure and the other 4 are management-based measures.</li> <li>• <b>Scoring mechanism:</b> Involves a combination of factors such as expert value judgment, empirical data, and</li> </ul>	<p><b>Irrelevant welfare measures:</b> Time needed to lie down, animals colliding with housing equipment during lying down, animals lying partly or completely outside the lying area, Hock injury</p> <p><b>Lagging welfare measures:</b> Important resource-based measures like access to water have not been clearly defined, measures for assessing thermal comfort are completely (Knierim &amp; Winckler, 2009).</p> <p><b>Time:</b> To assess a 200-cow dairy farm it takes more than 7 hours (Andreasen et al.,2014).</p>

		<p>stakeholder consultation for weighting of different subcriteria, criteria, and welfare principles.</p> <ul style="list-style-type: none"> <li>a) Point separation in the decision tree e.g., absence of prolonged thirst,</li> <li>b) Scale from worst to best, measurements provided with weighted sum and spline function transformed into severity index within the scale of 0 to 100. e.g. lameness</li> <li>c) determination of alarm threshold (%) between abnormal and normal.</li> </ul> <ul style="list-style-type: none"> <li>• Welfare score: All the sub-criteria scores of are combined to form a criterion score which is further combined to form a principle score and finally a total welfare score.</li> <li>• <b>Advantages:</b> Multidimensional inclusion of welfare measures across all areas of the five freedoms.</li> <li>• <b>Disadvantages:</b> Aggregation of scores can cause the problematic interpretation of weighted sums that may allow compensation between welfare</li> </ul>	
--	--	--	--

		<p>principles, i.e., non-appropriate environment can be counter-balanced by good health.</p> <ul style="list-style-type: none"> <li>• Time-consuming and a complex process (Andreasen et al 2014).</li> </ul>	
	<p>Animal Needs Index for Cattle, also known as ANI 35L/2000 (Bartussek et al., 2000).</p>	<ul style="list-style-type: none"> <li>• <b>Purpose:</b> To assess animal housing conditions based on what is known to be important for meeting animals' needs and ensuring their well-being.</li> <li>• <b>Developer:</b> Initially developed by Helmut Bartussek in 1985.</li> <li>• <b>Method:</b> Trained assessor (second party)</li> <li>• <b>Framework used:</b> No specific framework used.</li> <li>• <b>Range of welfare measures:</b> No direct assessment of animal-based measures. Five categories of housing conditions: locomotion, social interaction, flooring, light, air, and stockpersonship are assessed.</li> <li>• <b>Scoring mechanism:</b> During an assessment, points are awarded to each assigned measure to calculate</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Irrelevant welfare measures:</b> locomotion (lying down, lying and rising and boundary movement of tether) flooring, light and air quality.</li> <li>• <b>Irrelevant methods:</b> For pastured cows, it assesses locomotion and social interaction with the help of number of days spent in pasture/year (Bartussek et al., 2000). If this is used in pasture based dairy farms of New Zealand, every farm would get a full score on these categories which would not be true in all cases.</li> <li>• For assessment of floor in the pasture it uses measurement of pasture slope (Bartussek et al., 2000) which could vary</li> </ul>

		<p>an overall ANI score. Higher points indicate better housing conditions.</p> <ul style="list-style-type: none"> <li>• <b>Advantages:</b> Close investigation of the resources associated with housing.</li> <li>• <b>Disadvantages:</b> Possibility of compensating poor conditions within one component with a better situation in another component (Bartussek, 1999)</li> <li>• No animal-based measures.</li> </ul>	<p>largely within pasture-based farms as in New Zealand. This could be time-consuming to do multiple slope measurements for different pastures.</p> <ul style="list-style-type: none"> <li>• For assessing stockpersonship, it uses assessment of animal-based measures like animal health, hoof condition, cleanliness, integument condition and technopathies. But, this could be irrelevant and outdated approach if applied on New Zealand farms because health itself is one of the important domain among the Five Domains of animal welfare so they must be assessed for their main domain.</li> </ul>
	<p>AssureWel Dairy Cow Welfare Assurance Scheme (Assurewel, 2018)</p>	<ul style="list-style-type: none"> <li>• <b>Purpose:</b> To use welfare outcome assessments to their full potential to improve animal welfare</li> <li>• Deliver optimum welfare assurance within RSPCA Freedom Food and Soil association certification schemes.</li> <li>• To promote the uptake of outcome-based assurance within the UK and European farm assurance certificate</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Irrelevant methods:</b> The average herd size of New Zealand is 440 unlike the UK where the average herd size is just 150 (Agriculture and Horticulture Development Board, 2022). Only sampling 20 cows for measures like body condition, mobility and cleanliness might not be sufficient enough to provide clear</li> </ul>

		<ul style="list-style-type: none"> <li>• <b>Developer:</b> Jointly developed by the University of Bristol, RSPCA, Soil Association with the formation of AssureWel project.</li> <li>• <b>Method of assessment:</b> It can be used by anyone from farmers (for self-assessment) to farm assurance schemes, milk suppliers, producer groups and vets.</li> <li>• <b>Range of welfare measures:</b> All the assessment measures are animal-based welfare measures (total 11 measures). These include mobility, body condition, cleanliness, hair loss /lesions, swellings, broken tails, response to a stock person, cows needing further care, mastitis, calf/heifer survivability, and cull and casualty cows.</li> <li>• <b>Scoring mechanism:</b> Result expressed for a sample of 20 cows for animal-based measures such as BCS, mobility score and cleanliness, whereas whole herd count for broken tails and cows needing further care. There is no aggregation of welfare scores. The results of all individual measures are reported individually.</li> <li>• <b>Advantages:</b> It is quick; it can be completed within half an hour.</li> </ul>	<p>welfare status for those measures especially in larger herds as in New Zealand.</p>
--	--	--	--

		<ul style="list-style-type: none"> <li>• There is no aggregation of scores, therefore no loss of data. Individual measures are interpreted individually.</li> <li>• <b>Disadvantage:</b> It does not cover the assessment of disease/symptoms like coughing, hampered respiration, nasal discharge, ocular discharge, valvular discharge, dystocia etc.,</li> </ul>	
North America	UC Davis Cow-Calf Health and Handling Assessment, USA (UC Davis, 2017)	<ul style="list-style-type: none"> <li>• <b>Purpose:</b> To assess health, behaviour and stockperson handling.</li> <li>• <b>Developer:</b> University of California Davis</li> <li>• <b>Method:</b> It can be done by the producers for self-assessment and by an independent third party assessor as a part of supply chain process.</li> <li>• <b>Framework used:</b> Not specific (Measures are not arranged specifically according to five freedoms).</li> <li>• <b>Range of welfare measures:</b> It is mainly focused on animal-based observations (total 13) and handling measures (total 7 measures). The user of this system can start with the core assessment and then move ahead to the complete assessment.</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Irrelevant measures:</b> Measures like use of balk, miscatch might not be useful for New Zealand cows.</li> <li>• <b>Irrelevant methods:</b> Positioning of the assessors during scoring is based on infrastructure and design of the American ranches, which is different from the farm infrastructure found in pasture-based farms of New Zealand.</li> <li>• The comparison of results with benchmarked data is not suitable for New Zealand farms because the pre-recorded data set are from American farms. Also, benchmarking does not provide a clear</li> </ul>

		<ul style="list-style-type: none"> <li>• The core assessment involves <b>four</b> animal-based measures: abrasions, swelling, lameness, and thin cows. Similarly, the complete assessment involves <b>nine</b> more animal-based assessment measures: blind eye, bloated rumen, broken tail, diarrhea, dirty, hairless patch, nasal discharge, obesity, and ocular discharge.</li> <li>• It also includes 7 handling measures like the use of balk, fall, mis-catch, moving aid use, run, tail twist, and vocalize.</li> <li>• <b>Scoring mechanism:</b> All the observations are converted into percentages, evaluated and compared with pre-recorded data set. The conversion of percentage is from the number of cows successfully assessed.</li> <li>• <b>Advantages:</b> It is made simple and easy so that farmers can assess their herd themselves.</li> <li>• It can be accomplished in quick succession of time (around 2-2.5 hours).</li> <li>• <b>Disadvantages:</b> Assessment of important health measures like mastitis and reproductive abnormalities are not included.</li> </ul>	<p>indication of welfare unless it is a very big dataset.</p>
--	--	---	---

	<p>Farmers assuring responsible management (FARM) animal care evaluation.</p>	<p><b>Purpose:</b> To assure the standard of animal care on dairy farms.</p> <p><b>Developer:</b> a group consisting of academics specializing in animal health and well-being, veterinarians, dairy cooperative and processor staff, industry experts, and dairy farmers in the USA.</p> <p><b>Method:</b> Second-party evaluation and third-party verification.</p> <p>Framework used: Not applicable.</p> <p><b>Range of welfare measures:</b> Assessment is carried out by second- and third-party assessors. It involves 4 phases 1) review (educational records, signed veterinarian documentation, written protocols and annual treatment records). 2) observe (animals, facilities). 3) verify (observations compared with written documentation), 4) create (a corrective action plan).</p> <ul style="list-style-type: none"> <li>• <b>Review phase</b> includes 4 areas: Signed cow care agreement, veterinarian-client-patient relationship,</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Irrelevant welfare measures:</b> Calving area, exercise methods, space for lying and standing along with visual contact, quality of resting area, and facilities to prevent injuries.</li> <li>• <b>Time:</b> Not reported but review and observation likely to be lengthy processes</li> </ul>

		<p>continuing education records, permanent written or electronic drug treatment records.</p> <ul style="list-style-type: none"> <li>• <b>Observe phase:</b> It consists of animal- based assessments (total 6), resource-based assessments (total 6).</li> <li>• Animal-based measures included are BCS, Lameness, hock, knee condition, animal hygiene and broken tail.</li> <li>• Resource-based measures include detailed assessment of housing facilities like calving area, exercise methods, shelter against heat and cold, space for lying and standing, along with visual contact, quality of resting area, and facilities to prevent injuries.</li> <li>• <b>Scoring Mechanism:</b> More than 90% of the animals are assessed for all the animal-based measures with the help of individual animal tag number.</li> <li>• <b>Advantages:</b> It involves strict evaluation and verification process.</li> <li>• <b>Disadvantages:</b> It is a complex process which cannot be conducted by the farmers.</li> </ul>	
--	--	---	--

	<p>Animal care module, Canada</p>	<ul style="list-style-type: none"> <li>• <b>Purpose:</b> To measure animal care and wellbeing</li> <li>• <b>Developer:</b> Dairy Farmers Canada (DFC)</li> <li>• <b>Method:</b> Assessors from Holstein Canada</li> <li>• <b>Framework used:</b> Not applicable.</li> <li>• <b>Range of welfare measures:</b> Welfare framework: It has major emphasis on animal-based measures (total 5 measures). The observations are BCS, Hock condition, Knee condition, Neck condition, and mobility condition. This module also includes 4 resource-based measures (comfortable housing, clean water and nutritious diet, healthcare provision) and 2 management-based measures (pain control and appropriate handling).</li> <li>• <b>Scoring mechanism:</b> This module is principally focused on assessing animal-based measures based on sampling methods (For example every third cow assessed for a 100-cow farm, every 20<sup>th</sup> cow for 1000 animals). The report of the assessment is separated into four zones namely, green, yellow, red, and dark red. For any result that falls within the red and dark red zone, farmers should come up with strategies to improve it.</li> </ul>	<p><b>Irrelevant welfare measures:</b> Assessment of Knee, neck and Hock injuries is not important for pasture-based conditions of New Zealand (Laven &amp; Fabian, 2016).</p> <p><b>Missing welfare measure:</b> Assessment of Mastitis which is one of the important diseases in New Zealand dairy cows (Petrovski 2009), is not included as the part of routine assessment.</p> <p><b>Irrelevant methods:</b> Arbitrarily set thresholds for welfare measures might not be acceptable for everyone.</p>
--	---------------------------------------	--	--

		<ul style="list-style-type: none"> <li>• <b>Advantages:</b> No aggregation of score, each measure assessed individually.</li> <li>• At most 4 minutes is allocated for a cow so, for an assessment of 450 cow farms which requires a sample size of 40 (every twelve cows), it would require around 160 minutes.</li> </ul> <p><b>Disadvantages:</b> Arbitrary thresholds for welfare measures might not be applicable all the systems. For instance, pasture-based systems.</p>	
South America	Chilean Protocol of Animal Welfare for Dairy Farms (CPAWDF)(Danitza, 2016)	<ul style="list-style-type: none"> <li>• <b>Purpose:</b> To disseminate the concept of animal welfare through the dairy chain and increase the awareness about the importance of this issue in milk production.</li> <li>• <b>Developer:</b> Chilean Dairy Consortium</li> <li>• <b>Method:</b> Officials from Animal Welfare Program</li> <li>• <b>Framework used:</b> Five Freedoms of animal welfare.</li> <li>• <b>Range of welfare measures:</b> -Measures were selected from Welfare Quality and APROCAL and adjusted as per Chilean conditions.-It has 36 assessment indicators under 4 welfare principles namely, adequate food, adequate housing, adequate</li> </ul>	<p>Adopted for Chilean conditions which could be different to New Zealand conditions.</p> <p>Time: Not available</p>

		<p>health an appropriate behavior. Altogether there are 11 animal-based measures and 25 measures related to resources.</p> <ul style="list-style-type: none"><li>• <b>Scoring mechanism:</b> Not included</li><li>• <b>Advantages:</b> It is adjusted to suit the local farming conditions of Chile.</li><li>• <b>Disadvantages:</b> Only developed for a specific project rather than routine welfare assessment practice in Chile.</li></ul>	
--	--	--	--

## **2.5 Need for welfare assessment system for farm assurance in pasture-based dairy cows.**

Studies on the welfare of pasture-based dairy cows are increasing as demand for pasture-based dairy products is increasing. But the existing welfare assessment protocols for dairy cows such as Welfare Quality, AssureWel, and the Animal Need Index were designed for indoor use. Such protocols do not cover all the measures needed to assess the welfare of pasture-based cows (Aubé et al., 2022b). Many studies have found that existing protocols and measures cannot be directly applied to farm assurance schemes designed for pasture-based cows so they either have to be modified or replaced by other suitable measures (Laven & Fabian, 2016). For example, hock lesions are uncommon in pasture-based cows as these occur due to poor housing design or space allowance. Likewise, lying restrictions are not applicable to outdoor cows. Also, European protocols might not be suitable to assess the welfare of cows in other parts of the world due to differences in farming systems and infrastructure (Hernandez et al., 2017).

In outdoor systems, variables such as season could impact measures like shade, biomass quality and quantity, and track conditions (Aubé et al., 2022a). These variables possibly have lesser impact on indoor cows because of the controlled environment. But protocols and farm assurance schemes related to indoor cows have failed to include measures and methods to assess them. So, to capture all the major seasonal variations, measures to assess such variations should be included. Also, some measures which are already valid in indoor assessment schemes, such as disease prevalence, should further be tested in pasture-based conditions, as the severity of certain problems such as animal diseases may significantly vary between systems (Arnott et al., 2017; Loberg et al., 2004).

In the nutrition domain, welfare assessment considers the availability of nutritious feed and adequate clean drinking water. In New Zealand, assessment of nutrition would be more meaningful when there is a scarcity of grass during winter (Catalyst, 2021). Also, the desired body condition can vary significantly according to the lactation cycle in pastured-based conditions (pre-mating, pre-calving, post-calving) (DairyNZ, 2022). Therefore, dichotomization of measures (e.g., body condition score) to measure unacceptable welfare levels should be carefully selected to be included in a farm assurance schemes, and it needs to

be recognised that using a single time-point for such measures won't represent the year-round welfare situation. Measures used to assess adequate availability of drinking water in indoor systems, such as flow rate and trough capacity, might not be feasible to assess across multiple troughs in the pasture because of time constraints (Sapkota et al., 2020).

In the environment domain, the most significant area to be assessed in the pasture is the availability of shade and shelter, because cows spend most of their time outdoors (Iqbal et al., 2023). However, shade and shelter are complex to assess, and even established protocols such as Welfare Quality have not developed any measures or methods to assess these. As pasture-based cows have a higher chance of experiencing heat or cold stress due to exposure to adverse weather compared to housed cows (Moons et al., 2014; Tuytens, 2015), including measures of shade and shelter availability are of high importance for pasture-based dairy cows. There are many other benefits of shade and shelter, particularly in pasture-based cows which could promote better and positive welfare. Studies have shown that provision of shade and shelter in the pasture, e.g., trees, can lower the surrounding temperature and increase grazing time, resulting in higher dry matter intake and improved body condition score (Mancera et al., 2018; Pérez et al., 2008). Also, it has been found that the provision of trees at pasture improved affiliative interactions between the cows (Améndola et al., 2016). The presence of trees in the pasture reduced integument alterations in cattle (Mancera et al., 2018) by controlling the ectoparasites like ticks due to the higher presence of birds and insects (Murgueitio & Giraldo, 2009). Therefore, inclusion of measures to assess shade and shelter is important for pasture-based welfare assessment schemes.

Cleanliness (cow hygiene) is another area that could differ among production systems. Generally, indoor-housed cows are dirtier than pasture-based cows (Laven & Fabian, 2016). In indoor cows, this is primarily faeces, whereas pasture-based cows have more mud on their bodies (Laven & Fabian, 2016). Weather conditions will also influence cow cleanliness in pasture-based systems (Aubé et al., 2022b). In pasture-based cows, lower legs will commonly be dirtier if they have to walk on a muddy track, especially during wet weather. Clean cows with dirty lower legs may indicate that cows did not have a comfortable place to sit in the pasture (Laven & Fabian, 2016). Tail tuft trimming which generally improves the level of cleanliness in the herd (Hughes, 2001) may also influence cleanliness in pasture-based cows

in a different way. These things all need to be balanced before developing an appropriate method for assessing cleanliness in pasture-based cows.

The health domain is one of the most important welfare domains for pasture-based cows, even though they are less disease-prone compared to housed cattle, especially in relation to clinical mastitis and lameness (Mee & Boyle, 2020). However, the risk factors associated with diseases can vary between the systems. For example, a long walking distance to the milking parlour and poor track condition are risk factors for lameness in pasture-based cows (Ranjbar et al., 2016) but are less relevant for housed cows. Therefore, these factors should be included in assessment schemes for pasture-based cows. In addition, the exclusion of less important diseases adopted from indoor protocols would make the assessment less complicated and more time efficient.

Assessment of the behavioural domain can be more challenging in pasture-based systems, as it is more difficult to observe the entire herd. Even where behavioural observations included in indoor protocols are potentially suitable for assessing cows at pasture, the timing, location and methods of assessment needs to be adapted. For example, the Welfare Quality Assessment protocol for cattle (Welfare Quality, 2009) assesses the behaviour of cows in the barn areas in different segments. Such segmentation with an equal number of animals is difficult to create in a pasture-based setting. Also, if the stocking density of cows in the pasture is less than indoor-housed cows, there is a greater likelihood of no behavioural interactions being observed within the same time frame (Aubé et al., 2022b). These factors need to be taken into consideration.

Another area that needs to be well thought out during protocol development is the establishment of thresholds. Studies focused on welfare assessment of pastured cows to collect benchmarked datasets could help identify appropriate thresholds for each welfare measure (Crossley et al., 2021). Other approaches would be to use literature review, expert input and round table discussions involving stakeholders from various backgrounds such as animal welfare science, advisory bodies, animal welfare organizations, business operators, farmers, veterinarians etc. to establish robust thresholds (Schenkenfelder & Winckler, 2022).

It has been seen that it is difficult to get consensus on welfare assessment thresholds for indoor-housed cows (Whay et al., 2003) even among experts. So, it is important to use all available means to develop widely acceptable welfare thresholds for pasture-based systems such as in New Zealand.

## **2.6 Practical challenges of welfare assessment in pasture-based farms of New Zealand**

Pasture-based dairy farming is unique and offers comparatively better welfare conditions for cows than indoor farming (Arnott et al., 2017). However, there are several challenges in conducting a smooth welfare assessment in such conditions. These difficulties must be addressed if specific welfare assessment schemes are to be developed for New Zealand's pasture-based dairy farms.

In New Zealand, cows are at pasture for the majority of the day (Kilgour, 2012). Assessing measures such as BCS, rumen fill, or injuries will be more challenging in cows that are widely distributed and moving around than in housed cows. Therefore, appropriate timing should be considered for the assessment of each specific measure included. For example, it may only be feasible for some measures to be assessed during the milking period when cows are confined in the yards or the parlour.

**a) Large area:** Pasture-based farms are larger in area compared to indoor farms. So, assessment of infrastructure such as water troughs, trees, and shelter belts in every paddock will require a lot of time. Farm maps showing every detail of their infrastructure may be a time-saving alternative.

**b) Safety concern:** It might be unsafe for a single assessor to be in the middle of the moving cows in the paddock for welfare assessment. During pre-mating season, herd of cows are mixed with teaser bulls (Norton et al., 2008) which could be a big threat to the assessor if welfare assessment is to be performed in the pasture. Also, cows might be aggressive when they are with their newly born calf during calving season.

**c) Weather:** Weather could be another challenge in assessment of pasture-based dairy cows (Aubé et al., 2022b; Mee & Boyle, 2020) as they are exposed to rain, heat, wind and snow. Weather can influence both animal welfare and welfare assessment, so the assessment process needs to be able to account for the impact of the weather.

**d) Behavioural Observation:** Assessment of behaviour at pasture can be a difficult as animals keep moving. Also, there is a chance that there would be less interaction because of large available space.

## **2.7 Conclusion:**

Despite widely available welfare assessment schemes for indoor cows, there are no specific welfare assessment schemes designed for the pasture-based dairy farming conditions of New Zealand. Not all measures suitable for indoor cows are useful for pasture-based dairy cows because of feasibility issues, time constraints, and limited importance. In pasture-based cows factors such as routine practices, farming environment, and seasonal changes all make welfare assessment different at pasture compared to indoors. Thus, it is also essential to identify suitable welfare measures for pasture-based cows; including new specific pasture-based measures with specific pasture-based levels for defining acceptable welfare.

## References:

- Agriculture and Horticulture Development Board. (2022). New Zealand Farming Production System. Retrieved from <https://ahdb.org.uk/trade-and-policy-New-Zealand-farming-productionsystems dairy#:~:text=Cattle%20numbers%20and%20milk%20production&text=New%20Zealand%20produces%20around%2021,herd%20size%20of%20440%20cows>
- Améndola, L., Solorio, F., Ku-Vera, J., Améndola-Massiotti, R., Zarza, H., & Galindo, F. (2016). Social behaviour of cattle in tropical silvopastoral and monoculture systems. *Animal*, 10(5), 863-867.
- Andreasen, S. N., Sandøe, P., & Forkman, B. (2014). Can animal-based welfare assessment be simplified? A comparison of the Welfare Quality® protocol for dairy cattle and the simpler and less time-consuming protocol developed by the Danish Cattle Federation. *Animal welfare*, 23(1), 81-94.
- Andreasen, S. N., Wemelsfelder, F., Sandøe, P., & Forkman, B. (2013). The correlation of Qualitative Behavior Assessments with Welfare Quality® protocol outcomes in on-farm welfare assessment of dairy cattle. *Applied animal behaviour science*, 143(1), 9-17.
- Arnott, G., Ferris, C., & O'connell, N. (2017). Welfare of dairy cows in continuously housed and pasture-based production systems. *Animal*, 11(2), 261-273.
- Assurewel. (2018). Dairy Cattle Welfare Protocol. Retrieved from [http://www.assurewel.org/Portals/2/Documents/Dairy%20cows/AssureWel%20Dairy%20Welfare%20Outcome%20Assessment%20Protocol\\_2018.pdf](http://www.assurewel.org/Portals/2/Documents/Dairy%20cows/AssureWel%20Dairy%20Welfare%20Outcome%20Assessment%20Protocol_2018.pdf).
- Aubé, L., Mialon, M., Mollaret, E., Mounier, L., Veissier, I., & des Roches, A. d. B. (2022b). Assessment of dairy cow welfare at pasture: measures available, gaps to address, and pathways to development of ad-hoc protocols. *Animal*, 16(8), 100597.
- Aubé, L., Mialon, M.-M., Mollaret, E., Mounier, L., Veissier, I., & des Roches, A. d. B. (2022a). Assessment of dairy cow welfare at pasture: measures available, gaps to address, and pathways to development of ad-hoc protocols. *Animal*, 16(8), 100597.
- Bartussek, H. (1999). A review of the animal needs index (ANI) for the assessment of animals' well-being in the housing systems for Austrian proprietary products and legislation. *Livestock Production Science*, 61(2-3), 179-192.

Bartussek, H., Leeb, C., & Held, S. (2000). Animal Needs Index for Cattle (Ani 35 L/2000-cattle). *Federal Research Institute for Agriculture in Alpine Regions BAL Gumpenstein, Irdning, Austria*.

Battini, M., Vieira, A., Barbieri, S., Ajuda, I., Stilwell, G., & Mattiello, S. (2014). Invited review: Animal-based indicators for on-farm welfare assessment for dairy goats. *Journal of dairy science*, 97(11), 6625-6648.

Broom, D. M. (2014). *Sentience and animal welfare*: Cabi.

Broom, D. M., & Fraser, A. F. (2015). *Domestic animal behaviour and welfare*: Cabi.

Carenzi, C., & Verga, M. (2009). Animal welfare: review of the scientific concept and definition. *Italian Journal of Animal Science*, 8(sup1), 21-30.

Catalyst. (2021). Best Practice Winter Grazing Guide. Retrieved from [https://catalystag.co.nz/assets/P62421-Winter-Grazing-Guide\\_FA-WEB.pdf](https://catalystag.co.nz/assets/P62421-Winter-Grazing-Guide_FA-WEB.pdf)

Certified Humane. (2023). Retrieved from <https://certifiedhumane.org/>

Crossley, R. E., Bokkers, E. A., Browne, N., Sugrue, K., Kennedy, E., de Boer, I. J., & Conneely, M. (2021). Assessing dairy cow welfare during the grazing and housing periods on spring-calving, pasture-based dairy farms. *Journal of Animal Science*, 99(5), skab093.

DairyNZ. (2022). Body Condition Scoring Made Easy. Retrieved from [https://www.dairynz.co.nz/media/5790783/body-condition-score-made-easy\\_a6-field-guide\\_2022-final-web.pdf](https://www.dairynz.co.nz/media/5790783/body-condition-score-made-easy_a6-field-guide_2022-final-web.pdf)

Danitza, A. B. (2016). Animal Welfare Program of Chilean Dairy Consortiums. Retrieved from <https://www.icar.org/Documents/Puerto-Varas-2016-presentations/files/OL/OL%205/RDY/1%20Presentacion%20Programa%20de%20bienestar%20animal%20del%20Consorcio%20Lechero%20de%20Chile%20ICAR%202016%20D.%20ABARZUA.pdf>

De Passillé, A. M., & Rushen, J. (2005). Can we measure human–animal interactions in on-farm animal welfare assessment?: some unresolved issues. *Applied Animal Behaviour Science*, 92(3), 193-209.

- Edwards, J., Kuhn-Sherlock, B., Rue, B. D., & Eastwood, C. (2020). Technologies and milking practices that reduce hours of work and increase flexibility through milking efficiency in pasture-based dairy farm systems. *Journal of Dairy Science*, 103(8), 7172-7179.
- Fraser, D. (2003). Assessing animal welfare at the farm and group level: the interplay of science and values. *Animal Welfare*, 12(4), 433-443.
- Fraser, D. (2008). Understanding animal welfare. *Acta Veterinaria Scandinavica*, 50(1), 1-7.
- Grandin, T. (2014). Animal welfare and society concerns finding the missing link. *Meat science*, 98(3), 461-469.
- Grandin, T. (2020). *Improving animal welfare: A practical approach*: Cabi.
- Hawkins, P., Morton, D., Burman, O., Dennison, N., Honess, P., Jennings, M., . . . Wells, S. (2011). A guide to defining and implementing protocols for the welfare assessment of laboratory animals: eleventh report of the BVAAWF/FRAME/RSPCA/UFAW Joint Working Group on Refinement. *Laboratory Animals*, 45(1), 1-13.
- Heath, C., Lin, Y., Mullan, S., Browne, W., & Main, D. (2014). Implementing Welfare Quality® in UK assurance schemes: evaluating the challenges. *Animal Welfare*, 23(1), 95-107.
- Hernandez, A., Berg, C., Eriksson, S., Edstam, L., Orihuela, A., Leon, H., & Galina, C. (2017). The Welfare Quality® assessment protocol: how can it be adapted to family farming dual purpose cattle raised under extensive systems in tropical conditions? *Animal Welfare*, 26(2), 177-184.
- Hewson, C. J. (2003). Can we assess welfare? *The Canadian Veterinary Journal*, 44(9), 749.
- Hughes, J. (2001). A system for assessing cow cleanliness. *In Practice*, 23(9), 517-524.
- Iqbal, M. W., Draganova, I., Henry Morel, P. C., & Todd Morris, S. (2023). Variations in the 24 h temporal patterns and time budgets of grazing, rumination, and idling behaviors in grazing dairy cows in a New Zealand system. *Journal of animal science*, 101, skad038.
- Johnsen, P., Johannesson, T., & Sandøe, P. (2001). Assessment of farm animal welfare at herd level: many goals, many methods. *Acta Agriculturae Scandinavica, Section A-Animal Science*, 51(S30), 26-33.

- Kilgour, R. J. (2012). In pursuit of “normal”: A review of the behaviour of cattle at pasture. *Applied Animal Behaviour Science*, 138(1-2), 1-11.
- Knierim, U., & Winckler, C. (2009). On-farm welfare assessment in cattle: validity, reliability and feasibility issues and future perspectives with special regard to the Welfare Quality® approach. *Animal welfare*, 18(4), 451-458.
- Laven, R., & Fabian, J. (2016). Applying animal-based welfare assessments on New Zealand dairy farms: Feasibility and a comparison with United Kingdom data. *New Zealand Veterinary Journal*, 64(4), 212-217.
- Lin, Y.-C., Mullan, S., & Main, D. C. (2018). Use of welfare outcome information in three types of dairy farm inspection reports. *Asian-Australasian Journal of Animal Sciences*, 31(9), 1525.
- Loberg, J., Telezhenko, E., Bergsten, C., & Lidfors, L. (2004). Behaviour and claw health in tied dairy cows with varying access to exercise in an outdoor paddock. *Applied Animal Behaviour Science*, 89(1-2), 1-16.
- Lund, V., Coleman, G., Gunnarsson, S., Appleby, M. C., & Karkinen, K. (2006). Animal welfare science—Working at the interface between the natural and social sciences. *Applied Animal Behaviour Science*, 97(1), 37-49.
- Main, D., Webster, A., & Green, L. (2001). Animal welfare assessment in farm assurance schemes. *Acta Agriculturae Scandinavica, Section A-Animal Science*, 51(S30), 108-113.
- Mancera, K. F., Zarza, H., de Buen, L. L., García, A. A. C., Palacios, F. M., & Galindo, F. (2018). Integrating links between tree coverage and cattle welfare in silvopastoral systems evaluation. *Agronomy for Sustainable Development*, 38, 1-9.
- McCulloch, S. P. (2013). A critique of FAWC’s five freedoms as a framework for the analysis of animal welfare. *Journal of agricultural and environmental ethics*, 26(5), 959-975.
- Mee, J., & Boyle, L. (2020). Assessing whether dairy cow welfare is “better” in pasture-based than in confinement-based management systems. *New Zealand Veterinary Journal*, 68(3), 168-177.
- Mellor, D. J. (2015). Positive animal welfare states and reference standards for welfare assessment. *New Zealand Veterinary Journal*, 63(1), 17-23.

- Mellor, D. J. (2016). Updating animal welfare thinking: Moving beyond the “Five Freedoms” towards “a Life Worth Living”. *Animals*, 6(3), 21.
- Mellor, D. J. (2017). Operational details of the five domains model and its key applications to the assessment and management of animal welfare. *Animals*, 7(8), 60.
- Ministry of Primary Industries. (2019). Code of Welfare: Dairy Cattle. Retrieved from <https://www.mpi.govt.nz/dmsdocument/46024-Code-of-Welfare-Dairy-cattle>
- Moons, C. P. H., Sonck, B., & Tuytens, F. A. M. (2014). Importance of outdoor shelter for cattle in temperate climates. *Livestock Science*, 159, 87-101.
- Murgueitio, E., & Giraldo, C. (2009). Sistemas silvopastoriles y control de parasitos. *Revista Carta Fedegán*, 115, 60-63.
- Norton, C., Veterinarian, D. C., & Dunsandel, C. (2008). Canterbury teaser bull study. *Proceedings of the Society of Dairy Cattle Veterinarians*, 143-149.
- Pérez, E., Soca, M., Díaz, L., & Corzo, M. (2008). Comportamiento etológico de bovinos en sistemas silvopastoriles en Chiapas, México. *Pastos y Forrajes*, 31(2), 1-1.
- Petrovski, K., Heuer, C., Parkinson, T., & Williamson, N. (2009). The incidence and aetiology of clinical bovine mastitis on 14 farms in Northland, New Zealand. *New Zealand Veterinary Journal*, 57(2), 109-115.
- Plesch, G., Broerkens, N., Laister, S., Winckler, C., & Knierim, U. (2010). Reliability and feasibility of selected measures concerning resting behaviour for the on-farm welfare assessment in dairy cows. *Applied Animal Behaviour Science*, 126(1-2), 19-26.
- ProAction. (2021). Animal Care: Quick Guide to Animal-Based Measurement Protocol. Retrieved from <https://www.dairyfarmers.ca/proaction/resources/animal-care>
- Ranjbar, S., Rabiee, A., Gunn, A., & House, J. (2016). Identifying risk factors associated with lameness in pasture-based dairy herds. *Journal of Dairy Science*, 99(9), 7495-7505.
- Rowe, E., Rix, J., & Mullan, S. (2021). Rationale for Defining Recognition of “Higher Animal Welfare” Farm Assurance Schemes in a Global Food System: The GAWA Alliance. *Frontiers in Animal Science*, 2, 665706.
- Rushen, J., De Passillé, A. M., Von Keyserlingk, M. A., & Weary, D. M. (2008). Stockmanship and the Interactions between People and Cattle: *Springer*.

- Sapkota, S., Laven, R., Müller, K., & Kells, N. (2020). Animal Welfare Assessment: Can We Develop a Practical, Time-Limited Assessment Protocol for Pasture-Based Dairy Cows in New Zealand? *Animals*, 10(10), 1918.
- Schenkenfelder, J., & Winckler, C. (2022). To meet or not to meet welfare outcome thresholds: A case-control study in dairy cow herds. *Animal*, 16(3), 100461.
- Sevi, A. (2009). Animal-based measures for welfare assessment. *Italian Journal of Animal Science*, 8(sup2), 904-911.
- Spigarelli, C., Zuliani, A., Battini, M., Mattiello, S., & Bovolenta, S. (2020). Welfare assessment on pasture: A review on animal-based measures for ruminants. *Animals*, 10(4), 609.
- Stafford, K. J., & Mellor, D. J. (2005). The welfare significance of the castration of cattle: a review. *New Zealand Veterinary Journal*, 53(5), 271-278.
- Tuytens, F. A. (2015). *Detection, consequences and prevention of thermal discomfort for cattle kept outdoors in Belgium* [Doctoral dissertation, Faculty of Veterinary Medicine, Ghent University].
- University of California Davis. (2017). Cow-Calf Health and Handling Assessment: Learn how to access. Retrieved from <https://www.ucdcowcalfassessment.com/dirty.html>
- Webster, J. (2005). The assessment and implementation of animal welfare: theory into practice. *Revue Scientifique Et Technique-Office International Des Epizooties*, 24(2), 723.
- Webster, J. (2008). *Animal Welfare: Limping towards Eden: A practical approach to redressing the problem of our dominion over the animals*: John Wiley & Sons.
- Webster, J. (2016). Animal welfare: Freedoms, dominions and “a life worth living”. *Animals*, 6(6), 35.
- Welfare Quality. (2009). Welfare Quality® assessment protocol for cattle. Lelystad: *Welfare Quality R Consortium*.
- Whay, H. (2007). The journey to animal welfare improvement. *Animal welfare*, 16(2), 117-122.

Whay, H., Main, D., Green, L., & Webster, A. (2003). Assessment of the welfare of dairy cattle using animal-based measurements: direct observations and investigation of farm records. *Veterinary record*, 153(7), 197-202.

Windschnurer, I., Boivin, X., & Waiblinger, S. (2009). Reliability of an avoidance distance test for the assessment of animals' responsiveness to humans and a preliminary investigation of its association with farmers' attitudes on bull fattening farms. *Applied Animal Behaviour Science*, 117(3-4), 117-127.

### **Chapter 3: Animal Welfare Assessment: Can We Develop a Practical, Time-Limited Assessment Protocol for Pasture-Based Dairy Cows in New Zealand?**

**Foreword:** This chapter covers the selection of suitable welfare assessment protocols for pasture-based dairy cows in New Zealand. As a starting point, multiple measures were collected from different welfare assessment protocols across the world and from welfare studies that measured the welfare of pasture-based dairy cows. Measures that were irrelevant in pasture-based cows, which had limited applicability, or which took a long time to assess were screened out, and the remaining measures were taken for feasibility testing on two pasture-based dairy farms. All assessment measures were evaluated for practicability, time taken, best place for assessment, and ease of scoring. Based on the trial result measures that were not feasible were further screened out, and the measurement methods for some measures were modified for easy scoring and 5 additional measures suitable for pasture-based dairy farms were identified. Altogether 32 measures were identified for extensive feasibility testing across more New Zealand dairy farms.

Article

# Animal Welfare Assessment: Can We Develop a Practical, Time-Limited Assessment Protocol for Pasture-Based Dairy Cows in New Zealand?

Sujan Sapkota \*, Richard Laven , Kristina Müller and Nikki Kells 

School of Veterinary Science, Massey University, Palmerston North 4442, New Zealand;  
R.Laven@massey.ac.nz (R.L.); K.Mueller@massey.ac.nz (K.M.); N.J.Kells@massey.ac.nz (N.K.)

\* Correspondence: S.Sapkota1@massey.ac.nz; Tel.: +64-225165850

Received: 16 September 2020; Accepted: 16 October 2020; Published: 19 October 2020



**Simple Summary:** Systematic welfare assessment protocols are increasingly being used as a tool to demonstrate animal welfare and to drive improvements within the industry. Despite dairy products from New Zealand trading on the ‘green’ image of extensive pasture-based farms, dairy cattle welfare is not routinely assessed on most New Zealand farms, and there is no industry-recognised protocol for such assessment. Drawing on protocols and studies from across the world, this project aimed to create a science-based but practical assessment of dairy cow welfare that could be undertaken as a single one-day visit with a focus on assessment around milking time. After in-farm testing, this project identified 32 assessments which could form a part of such a protocol. Although further testing is required, this protocol could form the basis of a standardised assessment of dairy cow welfare on New Zealand dairy farms.

**Abstract:** Despite being a leading producer and exporter of dairy products, New Zealand has no industry-recognised welfare assessment protocol. A New Zealand-specific protocol is essential, as almost all dairy farms in New Zealand are pasture-based and housing is rarely used. Therefore, protocols developed for intensive cows are not suitable. The aim of this study was to develop a simple yet practical welfare assessment protocol that could be used to assess the welfare of a dairy herd during one visit timed to occur around milking. Six welfare assessment protocols and four studies of dairy cattle welfare assessments that had some focus on dairy cattle welfare at pasture were used, along with the New Zealand Dairy Cattle Code of Welfare, to identify potential assessments for inclusion in the protocol. Eighty-four potential assessments (20 record-based and 64 that needed assessing on-farm) were identified by this process of welfare assessments. After screening to exclude on-farm assessments that were not relevant, that had only limited practical application in pasture-based dairy cows or that required more time than available, 28 on-farm assessments remained, which were put together with the 20 record-based assessments and were tested for feasibility, practicality and time on two pasture-based dairy farms. Assessments were then identified as suitable, suitable after modification or not feasible. Suitable and modified assessments were then included in the final protocol alongside additional measures specific to New Zealand dairy farms. The final protocol included 24 on-farm assessments and eight record-based assessments. Further testing of these 32 assessments is needed on more dairy farms across New Zealand before the protocol can be used to routinely assess the welfare of dairy cows in New Zealand.

**Keywords:** welfare assessment; pasture-based dairy cows; New Zealand

## 1. Introduction

Social demand for quality animal products from welfare-friendly farms has led to the development of a myriad of welfare assurance schemes which set a higher benchmark for animal welfare than legislation, especially in Europe [1]. However, there is a growing need for robust and science-based welfare assessment systems all over the globe. Despite being the eighth largest producer of milk [2] and a leading nation in terms of milk exports [3], New Zealand still has no industry-standard welfare assessment scheme and routine welfare assessments are rare on New Zealand dairy farms. In contrast, the Red Tractor scheme, which requires regular independent assessment of animal welfare, certifies 95% of milk produced in the UK [4]. Having such a scheme could be a significant boon for the New Zealand dairy industry, as it would provide transparency regarding the general welfare status of cattle on New Zealand dairy farms, as well as benchmarking to drive continued improvements in animal welfare [5].

Starting with the development and codification of the Five Freedoms [6], through to the conceptualisation of the Five Domains model, a strong science-based foundation has been established for the development of systematic, structured, inclusive and logically consistent welfare assessments protocols [7]. In the Five Domains model, the first four physical/functional domains (nutrition, environment, health and behaviour) are concerned with biological functioning/physical wellbeing and the fifth domain, the mental state, is concerned with affective state or psychological wellbeing [8].

Most welfare assessment protocols amalgamate animal, resource and management-based assessments [9], along with assessments related to stockpersonship and farm records [10]. Much of the emphasis in such protocols is on outcomes (i.e., animal-based assessments) rather than inputs (resource- and management-based assessments), as animal-based assessments reflect the actual response of the animals to the inputs, rather than the potential response to those environments and management practices [8]. Nevertheless, input-based measures are still commonly used as part of farm-animal welfare assessment protocols because of the ease with which they can be measured and benchmarked [11]. They are also particularly useful as predictors of potential welfare issues when the welfare assessment protocol is being undertaken as part of a single visit rather than an ongoing repeated observation.

Welfare assessment protocols need to be relevant to the management system in which the animal is being kept [12]. This means that before protocols designed for welfare assessment in one system are used for assessment in a different farming system, they must be tested for their relevance, as protocols suitable for one system may not be suitable for a different system. For example, Laven and Fabian [13] studied the practicalities of using a welfare assessment designed for housed dairy cows [9] on dairy farms in New Zealand where cattle were permanently kept at pasture and concluded that significant refinements to the protocol were needed before it could be used on New Zealand dairy farms. However, the focus of that study was on determining lameness prevalence on those dairy farms, rather than welfare assessment, and the welfare assessment was limited to animal-based assessments that could be evaluated alongside whole herd locomotion scoring. No assessments of resources, animal handling or stockpersonship were included in their study.

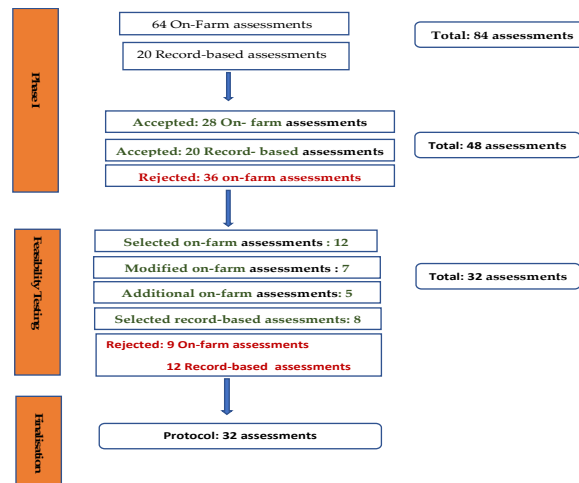
If an assessment protocol is to be used widely, it needs to include individual assessments that are practical to measure within the system being assessed, and it needs to be achievable within a reasonable time frame [14]. The latter is particularly important in a pasture-based system, as many animal-based assessments are only measurable while cattle are being milked, as this is the only time that they can be closely and systematically observed. As time during milking is limited, this means that even to collect data from a relatively small number of cows, animal-based assessments will require either two observers or observations during at least two milkings.

Thus, the aim of this study was to expand the assessment made by Laven and Fabian [13] and develop a welfare assessment protocol for dairy cows (based on a combination of animal-based, resource-based and stockpersonship-based assessments) that would be suitable for farms adopting the pasture-based dairy farming system which predominates in New Zealand. In addition, the protocol

needed to be achievable within a single day assessment period, in which one person collected data before milking (for a maximum of 2 h) and two people collected data during afternoon milking.

## 2. Materials and Methods

The research was undertaken in three phases (Figure 1).



**Figure 1.** Summary of identification, screening, and finalisation of welfare assessments included in the protocol for assessment of welfare in pasture-based dairy cows in New Zealand.

### 2.1. Collection and Screening of Potential Assessments

The base protocol used was the Welfare Quality protocol for dairy cows [13]. As this was not specifically designed for cattle kept permanently at pasture, additional potential assessments were identified from five assessment protocols which had some focus on cattle at pasture. This was a convenience-driven selection, designed to reflect welfare assessments used across the world, with two from Europe (AssureWel [15] and the Animal Need Index [16]); two from North America (the UC Davis Cow-Calf Health and Handling Assessment [17] and the Canadian Animal care module [18]) and one from South America (the Chilean Protocol of Animal Welfare for Dairy Farms [19]). This was then supplemented by data from four studies on dairy cattle welfare assessment—three from Europe [9,20,21] and one from South America [22].

The welfare assessments identified by this process (see Appendix A) were then screened by the authors to identify and exclude (a) assessments that were only relevant to non-pasture-based dairy farming systems, (b) assessments that had limited practical application in such a system, or (c) assessments that required significantly more time than would be available in a one-off single day assessment.

The remaining assessments were then used to create a protocol for feasibility testing. Prior to this testing the protocol was checked against the New Zealand Dairy Cattle Code of Welfare, to confirm that no potentially relevant areas of welfare covered by the code had been omitted.

### 2.2. Feasibility Testing

Feasibility testing of the test protocol was undertaken on two dairy farms in the Manawatu region of the North Island of New Zealand—one where cattle were milked on a rotary platform (Farm 1) and one where cows were milked through a herringbone (Farm 2).

The first feasibility test was undertaken in June 2019 on Farm 1 during the milking of 198 autumn-calving cows.

All resource-based assessments were tested before afternoon milking, whereas animal-based and stock skills-related assessments were assessed during the afternoon milking (see Appendices A

and B for selected assessments considered for feasibility testing). All assessments were evaluated for practicability, time taken, best place for assessment and ease of scoring. For animal-based assessments the intention was to score/assess all animals. In addition, the best site for recording those assessments was evaluated by two assessors; one who stood outside the parlour (in a good site for locomotion scoring) and one inside the parlour. The assessor outside the parlour attempted to record rumen fill, body condition, skin injuries, broken tail, cleanliness, coughing, nasal and ocular discharge and diarrhoea, alongside locomotion score, whereas the assessor inside the parlour attempted to record the same assessments without also recording the locomotion score.

Record-based assessments were collected after milking using a questionnaire (Appendix B) combined with a farmer interview if the farmer had time available. At the end of this first test the evaluated assessments were divided into three groups based on the consensus of the four authors: (i) assessments that were not suitable for inclusion as part of a one-off single day assessment; (ii) assessments which were suitable, but which needed modification (e.g., changes in the scoring system) and (iii) assessments which were identified as suitable for inclusion in the final protocol without change. Alongside this categorisation, additional assessments were identified of which the inclusion would increase the comprehensiveness of the assessment protocol. Finally, for all the suitable animal-based assessments, a conclusion was made as to whether they were best assessed while the cows were being milked or outside the milking parlour.

This revised assessment protocol was then tested again on Farm 1 in July 2019 (excluding the resource-based and record-based assessments, as their practicability had already been tested on this farm). At that time, 900 spring- and autumn-calving cows were being milked. The final trial of the protocol was undertaken on Farm 2 (milking ~300 cows; all assessments evaluated) in October 2019.

### 2.3. Finalisation Phase

After all three farm visits had been completed, a critical assessment was made of the assessments included in the protocol used for farm visits 2 and 3 and the final protocol was confirmed.

## 3. Results

During phase I, 84 potential assessments were identified (see Appendices A and B). Of these, 20 were assessments based on farmer records/recollection (see Appendix B) and were therefore to be collected using a questionnaire. This meant that there were 64 remaining assessments which would require active on-farm measurement, and therefore required screening during the first phase. Of these 64, 21 were excluded because they were irrelevant under New Zealand conditions, 13 because they had limited practical application under New Zealand conditions, and two because it was clear that they would be too time consuming to undertake alongside the other suggested measurements (see Appendix A). This meant that 48 assessments (28 of which required active on-farm measurement (see Appendix C for details of these assessments) and 20 of which were to be answered by questionnaire) were brought forward for feasibility testing (Figure 1).

During phase II (feasibility testing) 21 of these 48 assessments were identified as not being suitable for inclusion as part of a one-off single day assessment protocol where animal-based assessments were principally made during milking. The excluded assessments and the reasons for their lack of suitability are shown in Table 1.

In addition, seven assessments were modified and scores for animal-based assessment were dichotomised (Table 2). Five new assessments were added (Table 3). Of these five assessments, four were related to the handling of cattle before they were milked and are associated with cow flow and lameness risk [23], whereas the fifth, heifer mortality, was added to get better data on mortality before first calving. This left 32 assessments, which were taken to the final two farm trials (Figure 1). The final two farm trials confirmed that the 32 assessments were all suitable and practicable. The final protocol is summarised in Table 3.

**Table 1.** Dairy cow welfare assessments that were trialled on-farm but excluded from the final welfare assessment protocol and the rationale for their exclusion.

Rejected Assessment	Reason for Rejection	Rationale
<ul style="list-style-type: none"> <li>Nasal discharge</li> <li>Ocular discharge</li> </ul>	Difficult to observe	During milking (in both types of parlour) the assessor is behind the cows and cannot easily observe the nostrils or the eyes. Outside the parlour, observer needs to be distant from the cows (to avoid interfering with movement), so assessment of mild-moderate discharge was difficult.
<ul style="list-style-type: none"> <li>Diarrhoea</li> </ul>	Difficult to identify pathological diarrhoea	Lactating dairy cattle in New Zealand are fed a low dry matter, highly digestible diet [24], thus loose faecal consistency is normal.
<ul style="list-style-type: none"> <li>Heat stress indicators</li> <li>Cold stress indicators</li> </ul>	Occurrence depends on environmental conditions	Observing such symptoms on a one-off visit is unpredictable. Resource-based assessments, such as assessment shelter, will provide an estimate of the resources available to the cows should there be heat or cold stress.
<ul style="list-style-type: none"> <li>Slope before the entry and exit of the parlour</li> </ul>	Limited resources	Difficult to assess without specialised equipment. Limited impact where track quality is maintained.
<ul style="list-style-type: none"> <li>Milking behaviour</li> </ul>	Difficult to observe alongside other measurements	On an elevated platform in a rotary parlour, only a few cows are observable at any one time. In a herringbone parlour, it was difficult to assess alongside other assessments requiring scoring of individual cows.
<ul style="list-style-type: none"> <li>Orientation of the cows in the milking yard (facing or back to the parlour)</li> </ul>	Not suitable for all NZ farms	Suitable for rectangular yards only.
<ul style="list-style-type: none"> <li>Qualitative behaviour</li> </ul>	Difficult to assess during milking and insufficient time available during paddock visit	Assessment of qualitative behaviours is difficult and time consuming. In paddock Assessment was limited to agonistic and positive behaviours, which were thought to be more important [25].
<ul style="list-style-type: none"> <li>Disease records</li> </ul>	Record quality generally poor—farmer recollection rather than records	Only clinical mastitis and lameness cases were retained. For data collected by outside bodies (e.g., bulk milk somatic cell count), it was thought best to collect from those sources rather than from the farmer.

**Table 2.** Welfare assessment criteria that were modified before inclusion in the final protocol and rationale for their modification.

Assessment	Changes Made	Reason for Modification
<b>Scoring system (animal-based assessments)</b>	Only welfare-compromised animals (e.g., score $\geq 2$ for locomotion score, $\leq 2$ for rumen fill and $\leq 3$ for body condition score) recorded.	Categorisation made these assessments simpler and quicker.
<b>Cleanliness of the cow</b>	Three-category AHDB cleanliness scoring system [26] used rather than four-category Wisconsin Hygiene Scoring system [27]. Dirtiness on lower leg (below hock joint) and only dried dirt was recorded (fresh dirt was not included in score [17]). Udder, flank and upper leg scored separately. Proportion of cows with at least one score $\geq 1$ recorded.	AHDB scoring system and categorisation made assessment simpler and quicker.
<b>Fear behaviour</b>	Response of the cows towards the assessor, i.e., fearful, neutral and approach, was observed at the entrance to the parlour. Approximately 2% of cows were assessed.	Interpretation of aversion distance is uncertain in extensive systems [21]; in addition, measurement was not possible in the paddock alongside behavioural observation due to time restrictions.
<b>Body condition score (BCS)/Skin injury</b>	Change of site in herringbone parlour from inside to on immediate exit. No change for rotary, as all cows were assessable.	For BCS, only 50% of cows (left row) were assessable in the herringbone parlour. For skin injury, assessment was limited to the back of the cow and one observable side only.
<b>Maximum waiting time before entering the milking parlour</b>	Assessor standing outside the parlour recorded arrival times of cow groups/herds.	On farms with multiple herds, the assessor standing inside the parlour could not observe the arrival time of the second herd alongside other assessments.
<b>Ingrown horn/Blind eye</b>	Not included under main assessment but recorded if seen.	Difficult to observe systematically but needs to be recorded if observed.

**Table 3.** Final proposed assessment protocol for assessing welfare of pasture-based dairy cattle on New Zealand farms with respective site of assessment.

Welfare Domain [4]	Assessments	Assessment Types	Site of Assessment			
			Inside Parlour	Outside/Around Parlour/Collecting Yard	Paddock or Track	Questionnaire
<b>Nutrition</b>	Body condition score <sup>†</sup>	Animal-based	✓			
	Rumen fill Score	Animal-based	✓			
	Distance to water points	Resource-based			✓	
	Trough cleanliness	Resource-based			✓	

Table 3. Cont.

Welfare Domain [4]	Assessments	Assessment Types	Site of Assessment			
			Inside Parlour	Outside/Around Parlour/Collecting Yard	Paddock or Track	Questionnaire
Environment	Cow Cleanliness †	Animal-based	✓			
	Shelter availability	Resource-based			✓	
	Maximum waiting time in the collecting yard †	Resource-based		✓		
	Noise level	Resource-based	✓			
	Mixing of Cows	Management-based				✓
	Handling aids	Management-based				✓
	Handling during milking	Stockmanship-based	✓			
	Farthest paddock distance	Resource-based				✓
	Track condition	Resource-based			✓	
	Head position *	Animal-based		✓		
	Handling on track *	Stockmanship-based			✓	
	Yard space per cow *	Resource-based		✓		
	Backing gate speed *	Resource-based		✓		
Health	Pain relief	Record-based				✓
	Lameness	Animal-based		✓		
	Broken tail	Animal-based	✓			
	Coughing	Animal-based	✓			
	Skin Injury †	Animal-based	✓			
	Ingrown Horn †	Animal-based		✓		
	Blind eye †	Animal-based		✓		
	Vaccination record	Record based				✓

Table 3. Cont.

Welfare Domain [4]	Assessments	Assessment Types	Site of Assessment			
			Inside Parlour	Outside/Around Parlour/Collecting Yard	Paddock or Track	Questionnaire
	Lameness per year	Record-based				✓
	Mastitis per year	Record-based				✓
	Cow mortality per year	Record-based				✓
	Replacement heifer deaths before calving/year *	Record-based				✓
Behaviour	Agonistic behaviour	Animal-based			✓	
	Positive behaviour	Animal-based			✓	
	Fear behavior †	Animal-based	✓			

\* indicates assessments added to the final protocol during the trials (details on method of assessment in Appendix C) † indicates assessments which were modified before inclusion in the final protocol (see Table 2 for how they were modified). No superscript indicates assessments that remained unchanged from the initial test protocol to the final protocol.

#### 4. Discussion

The aim of this study was to develop a protocol that could be used to assess welfare on pasture-based dairy farms in New Zealand, where the amount of time available was limited to one person collecting data for up to 2 h before milking and two people collecting during afternoon milking.

The assessments initially included in the protocol were primarily based on the Welfare Quality protocol [11] with changes to reflect the pasture-based system which predominates on New Zealand dairy farms. Assessment protocols that adapt the Welfare Quality protocol to different systems often just use that protocol with some assessments removed and assessments added from another protocol (e.g., [22,28]). In our first phase, we used the same approach but added assessments from a convenience selection of protocols and studies of protocols from across the world, rather than relying on a single additional protocol. This process was not intended to identify all potential assessments but to identify a large range of assessments that could be practically assessed in a test protocol under New Zealand conditions.

Our initial test protocol had 48 assessments (20 record-based and 28 which required active on-farm assessment). Of those 48 assessments, 21 (12 record-based and 9 on-farm) were excluded during the farm trials. As five new assessments were identified during phase 2 (farm trial), the final protocol included 32 assessments, of which 8 were record-based and 24 required active on-farm measurement.

This protocol met the requirement of taking less than two hours to undertake the assessments to be done outside of milking time (paddock or track; see Table 3) and having milking time assessments that could be undertaken by a maximum of two people. However, these time limitations do mean that not all potentially useful assessments were included in the final protocol, which could have compromised the coverage of the assessment protocol.

Mellor (2017) [7] identified four functional domains (“Nutrition”, “Environment”, “Health” and “Behaviour”) as representing the key general foci of animal welfare management. These four domains all need to have sufficient depth and breadth of assessment if a welfare assessment protocol is to properly measure animal welfare status. It is thus critical to assess whether our final protocol meets these requirements.

##### 4.1. Nutrition

In this domain, body condition score (BCS) and rumen fill were the two assessments related to feed intake identified by the literature search that were kept after screening and feasibility testing. BCS is an effective measure of energy balance over the medium term [29,30], whereas rumen fill is a reliable measure of feed intake in the previous 24 h [31].

Generally, extreme BCS (too low or too high) is associated with compromised welfare, but there are no clear or simple thresholds for BCS which determine that welfare has been compromised [29]. For this study, we only used a single threshold for low BCS, because very high BCS  $\geq 7$  (1–10 score) [32] is very rare on New Zealand dairy farms [13]. The threshold we used for low BCS ( $\leq 3$ ) is the same as used previously [13] and is derived from the Dairy Cattle Code of Welfare [33] which states that when BCS is  $< 3$  urgent remedial action must be taken. This threshold is well below the optimum BCS for productivity [29].

Rumen fill has been shown to accurately reflect feed intake in the previous 24 h [31]. For this study, a score of  $\leq 2$  was determined as indicating poor welfare [26]. The main issue with rumen fill as a measure of nutrition-related welfare is that current health status can also affect it. However, when recorded at the herd level, poor rumen fill is much more likely to reflect feed availability, rather than individual cow health.

Nevertheless, although both BCS and rumen fill accurately reflect medium term energy balance and recent feed intake, respectively, their use in a single one-off assessment may not accurately reflect true welfare status within the nutrition domain. This is because the dependence on grazed grass of New Zealand dairy farms means the balance between feed supply (from pasture) and feed demand in New Zealand is highly seasonal [24]. Multiple measurements of BCS and rumen fill throughout

the year may thus be a useful addition to this protocol to take account of seasonal variation in feed supply. This may be particularly important in winter, when negative welfare related to feeding is most likely to occur, especially in dry cows where pasture intake may be restricted to minimise the impact of winter grazing on grass growth in the spring. This negative welfare is not likely to be reflected in BCS, as this will be at its nadir in early lactation rather than during the dry period [34], but it may be reflected in rumen fill if feed restriction is too great.

Assessment of water quality and availability is a crucial aspect of any welfare assessment scheme. For this protocol, average distance between water troughs within a paddock was chosen as the measure of water availability, whereas the cleanliness of water troughs was identified as a suitable measure of water quality. The latter is consistent with the Welfare Quality assessment protocol [11], in which the cleanliness of the water trough is the only measure of water quality. In contrast, water availability in the Welfare Quality assessment protocol includes more assessments, including water flow and size of drinking troughs. These were excluded during the screening process for this study on the basis of the time required. Measuring water flow would require measuring flow in multiple troughs across a farm (to account for distance from central supply); thus, it was excluded for being too time consuming. The distance between drinking troughs was chosen rather than the size of drinking troughs because it was thought to be more applicable to extensive systems [35] where cattle drinking behaviour is different from that of confined cattle [36]. Further research is required on drinking behaviour in cattle at pasture so that the impact of differing types of water provision on cattle welfare (both positive and negative) can be determined.

#### 4.2. Environment

The final protocol had twelve assessments in this domain. The majority of assessments (seven) related to cow handling before and during milking. This is a crucial time for the welfare of the pasture-based cow as most welfare issues are likely to arise during this period. Of the five added assessments, four were in this domain. All four were related to cow handling and are crucial assessments for identifying problems with cow flow (i.e., how well the herd moves into the collecting yard and through the milking parlour). Cow flow is crucial on pasture-based farms because it has significant effects on milking time, staff patience and cow welfare (both behavioural and health, especially lameness) [23].

Another measure included in the final protocol that was related to cow flow was the maximum waiting time before entering the milking parlour. This identifies the length of time spent standing on concrete and away from pasture. For small herds (e.g., 200 cows) this can be identified by simply recording the start and end of milking. However, on farms with more cows, cows are generally separated into multiple herds and these are all milked through the same parlour. In such herds (e.g., Farm 1 when it was examined the second time) it was not possible for the assessor inside the parlour to identify when the first herd finished and the next herd arrived. Thus, recording the maximum time waiting should be undertaken by the assessor recording the locomotion score.

Noise level during milking is also associated with cow flow, but is also a measure of the impact of the environment on the cow during milking, as excessive noise can have an adverse effect on an animal's physiological, behavioural and production aspects [37]. This may be especially important in pasture-based dairy cows as they generally only encounter loud background noises when they are being milked. In dairy cattle, research suggests that noise as high as 80 dB seems to have no effect on milk production [37]. As normal conversation is around 60 dB [38], using a simple categorical measure of noise based on the ease of having a conversation is able to identify when there is no risk of noise-related welfare effects (conversation easily heard) and a high risk (normal conversation not possible) without expensive equipment. However, we recommend that further research is carried out to better establish the effect of noise during milking, specifically in cows based at pasture.

Tracks are a critical part of a pasture-based farm's infrastructure. In this protocol we included assessments of track quality, length, width and camber, in addition to handling on the track, all of

which have been associated with lameness in New Zealand dairy cattle [39]. Track assessments were limited to tracks within 100 m of the milking parlour. These areas are the most used parts of the track on a farm and are thus the most likely to have an impact on lameness risk if they do not meet recommendations. Assessing all the tracks was not feasible within the timescale but would have added little to the 100 m selection and complicated welfare assessment (e.g., is a very poor quality track used once a month equivalent to a good section used daily?).

Two assessments were included which evaluated the environment in which the cows spend most of their time, i.e., the pasture. The cleanliness of the cow reflects the status of the pasture as a clean dry surface to stand and lie on. Compared to the assessment in the Welfare Quality protocol [11] (for housed cattle), there were two key modifications in this assessment. Firstly, measurement of cleanliness of the lower leg (below the hock) was not undertaken (as this not a good reflection of the acceptability of a pasture environment), and secondly, only dried dirt (which reflects persistent rather than one-off contamination) was considered. Both of these modifications were also recommended by the UC Davis Cow-calf handling assessment [17].

As cattle at pasture have an uncontrolled environment, exposure to extreme climatic conditions has been one of the welfare concerns in pasture-based dairy systems [40]. Heat and cold stress can be identified by behaviour, but as the risk of such stress on any individual day is low [41], identifying these behaviours is of very little value in a routine welfare assessment. The best assessment is thus a resource-based one which identifies the resources available should there be a problem. Measurement and assessment of shelter belts and shade provides such a resource-based assessment, but it is time consuming to do this. The major issue is that the availability of shelter does not necessarily indicate that it is used when needed. This information may be possible to collect via a questionnaire, but for such a question there is a clear risk of the owner giving the answer that they think the questioner wants to hear.

#### 4.3. Health

Nine animal-based health assessments were included in the feasibility testing, with six being included in the final protocol. Three assessments were excluded because they were not recordable during the examination (nasal and ocular discharge) or because normal could not be separated from abnormal (diarrhoea). Of the remaining six assessments, it was decided that two (blind eye and ingrown horn) would not be specifically counted, but would be recorded if observed (similar to the way that broken tails are assessed in many other assessment protocols [42]). The number of animal-based assessments in the final protocol is much lower than that used in other protocols and studies (e.g., [9,11]). Although some of this is related to limited time (and the requirement to examine cows during milking) (e.g., claw confirmation), the difference is mainly due to many animal-based health assessments used in previous protocols being irrelevant in pasture-based cattle (e.g., swollen and ulcerated hocks).

No sampling procedure was used in this protocol. The aim was to assess all cattle being milked. This is partly because no sampling protocols have been validated for use in pasture-based cattle, but also, in contrast to assessment in housed cattle where sampling significantly reduces the time taken for the assessment, when milking cows are being assessed the assessor still has to be present for the whole of milking, so no time is saved [41].

#### 4.4. Behaviour

Seven assessments in this domain were considered during feasibility testing. Four of these were assessments of cattle in the paddock (identifying (i) social agonistic behaviours, (ii) qualitative behaviours, (iii) positive behaviours and (iv) aversion distance) and the remainder were assessments made during milking.

It was in this domain that the time limitations had the most impact on our ability to assess welfare. The Welfare Quality assessment protocol [11] includes a large number of behavioural assessments which take a considerable amount of time to assess. In this protocol there was about 30 min available to

assess cow behaviour in the paddock. This limited the assessment to only two of the four in-paddock assessments: social agonistic behaviour and positive behaviours. Qualitative behaviour assessment was excluded because it takes considerably more time than assessing social agonistic and positive behaviours; for example, the Welfare Quality assessment [11] allocates 150 min to assessing this type of behaviour in housed cows. Measurement of aversion distance could not be undertaken alongside behavioural assessment. It was therefore modified and simplified so that it could be assessed during milking (fear, neutral or curious response to the assessor moving towards them at the entrance to the milking parlour).

The available time for in-paddock assessment could have been increased by having the second assessor start at the same time as the first one. However, as milking generally takes around two hours, having both assessors available from two hours before milking would mean that this protocol would take eight hours of assessor time (two times four hours), which is more time than the Welfare Quality assessment generally takes in housed cows [11]. In addition, it is unclear whether the increased time (which is still limited to <2 h) would significantly advance our understanding of welfare within the behaviour domain [25] and how much influence behaviour in the paddock has on a dairy cow's welfare status.

One key measure of cow behaviour which we were unable to include in the final protocol was cow behaviour during milking. This reflects cow welfare in terms of their mental state in relation to coming into the milking parlour, as well as whether there is current discomfort due to being milked. This did not prove possible to collect alongside other assessments during milking, especially in a rotary parlour. Cow behaviour during milking is related to cow flow (as cows that are not reluctant to be milked will enter the parlour without having to be coerced) and so measuring the response to the assessor and assessing cow handling during milking is likely to provide some of the information which records behaviour during milking.

## 5. Conclusions

The aim of this study was to develop a practical and feasible but science-based welfare assessment protocol for a one-off single day assessment for pasture-based dairy cows in New Zealand. We believe that within these constraints, we have succeeded in creating a protocol with good coverage of the four domains outlined by Mellor which will identify the key areas of welfare concern on a farm, which will be useful in benchmarking and in providing transparency in regard to the welfare of dairy cows on New Zealand farms. However, before this protocol can be used as a basis for welfare assessment on New Zealand dairy farms it needs further testing on more farms in multiple areas of New Zealand.

**Author Contributions:** S.S.—main researcher, conceptualisation, methodology, main writing; R.L.—main supervisor, conceptualisation, methodology, writing, review and editing; K.M.—co-supervisor, conceptualisation, review and editing; N.K.—co-supervisor, conceptualisation, review and editing. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by Post Graduate Research Fund, SoVS, Massey University.

**Acknowledgments:** Winston Mason, Vet Ent, Waikato for support and advice.

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

## Appendix A

Table A1. Welfare Assessments Identified during Phase I and Status after Screening.

Welfare Domain [4]	Measuring Standards Taken from Different Protocols Studies and Welfare Code	Status after Screening
Nutrition	Body condition score	Accepted
	Rumen fill score	Accepted
	Cleanliness of water points/troughs.	Accepted
	Average distance to water points from the pasture	Accepted
	Additional feeding sites in the pasture	Limited practical application
	Contamination of the feeding site	Limited practical application
	Feeding places per cow	Limited practical application
	Distance from the pasture to the feeding site	Not relevant at pasture
	Choice of water temperature	Not relevant at pasture
	Proper flow and functioning of the water points	Time consuming as part of assessment
Sufficient amount and size of drinking troughs	Time consuming as part of assessment	
Environment Health	Noise level (e.g., dogs/machineries)	Accepted
	Cleanliness of udder, lower hind legs (including the hock), hind quarters-upper hind leg, flank and rear-view including tail	Accepted
	Track condition: surface, width, slope	Accepted
	Shelter: Provision of shade, wind breaks and natural barriers during extreme weather.	Accepted
	Heat stress indicators (seeking shade, open mouth panting).	Accepted
	Cold stress indicators (shivering, huddling, facing away from wind or rain).	Accepted
	Slope before the entry and exit of the parlour	Accepted
	Maximum time waiting before entering the milking parlour	Accepted
	Slope of pasture	Limited practical application
	Milking hours aligned to climate	Limited practical application

Table A1. Cont.

Welfare Domain [4]	Measuring Standards Taken from Different Protocols Studies and Welfare Code	Status after Screening
Environment Health	Access to the pasture (days per year, average time spent on pasture per day).	Limited practical application
	Time taken to lie down	Not relevant at pasture
	Animals colliding with housing equipment while lying down	Not relevant at pasture
	Animals lying partly or completely outside the lying area	Not relevant at pasture
	Comfortable calving pen, separate pens for calves	Not relevant at pasture
	Walking of the cows related to the placement of the shafts	Not relevant at pasture
	Light and air quality of the lying area	Not relevant at pasture
	Position of animals in the cubicles (diagonal and lying, backward-forward standing, diagonal and standing, backward-forward and standing).	Not relevant at pasture
	Comfortable, safe and clean flooring.	Not relevant at pasture
	Run (after release from restraint.)	Not relevant at pasture
	Stumble, fall	Not relevant at pasture
	Building allowing mounting	Not relevant at pasture
	Access to outdoor loafing area	Not relevant at the pasture
	Lameness	Accepted
	Broken tail	Accepted
	Blind eye	Accepted
	Ingrown horn	Accepted
	Abrasions, injuries, integument alteration (hairless patches, lesions/swellings)	Accepted
	Coughing	Accepted
	Nasal discharge	Accepted
	Diarrhoea	Accepted
	Ocular discharge	Accepted
	Claw conformation	Limited practical application
Skin irritation	Limited practical application	

Table A1. Cont.

Welfare Domain [4]	Measuring Standards Taken from Different Protocols Studies and Welfare Code	Status after Screening
Environment Health	Signs of Facial eczema	Limited practical application
	Thick hocks	Not relevant at pasture
	Thick carpi	Not relevant at pasture
	Animals needing further care	Not relevant at pasture
	Lying down and standing difficulty	Not relevant at pasture
	Abnormal sitting position (dog sitting)	Not relevant at pasture
	Abomasal dislocations	Not relevant at pasture
	Bloated rumen	Not relevant at pasture
Behaviour	Social agonistic behaviour (headbutting, displacement, chasing, chasing up, fighting, pushing)	Accepted
	Fear behaviour towards human approach/Avoidance distance	Accepted
	Lapping behaviour/allogrooming	Accepted
	Milking behaviour (cow restlessness during milking; number kicking and stepping over a complete milking time)	Accepted
	Orientation in the collecting yard (facing towards the parlour, facing directly away from the parlour, not orientated towards the parlour,)	Accepted
	Qualitative behaviour (Active, Frustrated, Irritable, Relaxed, Friendly, Uneasy, Fearful, Bored, Sociable, Agitated, Playful, Apathetic, Calm, positively occupied, Happy, Content, Lively, Distressed, Indifferent, Inquisitive)	Accepted
	Animal handling during milking (vocal tone, hitting, tail pulling, etc.)	Accepted
	Leg stretching while standing in the pasture	Limited practical application
	Tail hanging straight and relaxed in pasture	Limited practical application
	Avoidance distance at the feeding rack	Limited practical application
Stockperson to animal ratio	Limited practical application	

## Appendix B

Record-based assessments identified as potentially useful as part of an on-farm welfare assessment protocol from six welfare assessment protocols, four studies of on-farm welfare assessment protocols and the New Zealand Dairy Cattle Code of Welfare.

- (1) What is the distance to the farthest paddock? ... ..
- (2) Do you mix the cows between the herds? Yes ... .. No ... ..
- (3) Do you use pain relief during routinely husbandry procedures? Yes ... .. No ... ..
- (4) How do you manage your vaccination record?
- (5) What do you use for cattle handling (e.g., prod, sticks, miscatch, tail twist, etc)?
- (6) Is your stockperson trained in animal handling, professionalism and knowledge of signs and symptoms of diseases?
- (7) How often do you cull your cows (planned/unplanned culls per year, enforced culls, e.g., TB (Tuberculosis))?

### Yearly Records

- (1) Number of mastitis/year
- (2) Number of lameness/year
- (3) Total mortality per year
- (4) Milk somatic cell count
- (5) Downer cow
- (6) Milk fever
- (7) Acetonemia
- (8) Abortions
- (9) Mortality at birth
- (10) Retention of placenta
- (11) Prolapse
- (12) Infertility
- (13) Dystocia

## Appendix C

Measurements included in the test protocol with method of assessment (and domain of coverage [6]).

### Appendix C.1 Nutrition

**Body Condition Scoring:** All animals will be scored using the Dairy NZ body condition score scale from 1 to 10 [32,43] (modified for final protocol; Table 2).

**Rumen Fill Score:** All animals will be scored using the Dairy Veterinary Consultancy Ltd. Rumen Fill Scorecard which scores rumen fill on a 1–5 scale [44] (modified for final protocol; Table 2).

**Average distance to water points:** Two paddocks near where the cows were being kept and which had two water troughs were examined and the average distance between the two paired troughs was calculated.

**Cleanliness of the trough:** (paddocks/feed pads): Visual observation in the paddocks and feed pads (if present). *Clean:* Transparent water, base easily visible, no apparent dirt/dead insects. *Marginal:* Base of the trough partly obscured, no floating dirt or dead insects. *Dirty:* Base of the trough not visible, dirt/insects may be observed. Note: Fresh green grass in trough does not affect category.

### Appendix C.2 Environment

**Cleanliness of the cows:** For all cows, dirtiness around flanks (including tail), lower and upper hind leg, udder and tails were scored using the four-point Wisconsin hygiene scoring system [27] (modified for final protocol; Table 2).

**Noise level inside milking parlour:** 0: No noise from the machinery/dogs. 1: Slight noise, conversation with milkers can be heard with concentration. 2: High noise, conversation cannot be heard.

**Availability of shelter:** A shelterbelt was defined as an area of trees where the size of the horizontal canopy radius was at least 12 times the height of the trees in the area. For farms with at least one group of trees which satisfied this condition (from a visual estimate), the main orientation of the shelterbelts was recorded using a compass.

The vertical canopy radius was estimated as per [45] for two representative areas of shelterbelt, and the protection provided by the shelterbelt was recorded separately for shelterbelts running north-south and east-west using three categories: 0, complete protection, 1, some protection, 2, no protection.

In addition, where individual trees had been planted for shade in more than 80% of paddocks, two representative paddocks were selected and the height (as per [45]) and the average horizontal radius (by pacing) of four trees per paddock were measured.

**Maximum waiting time before entering the milking parlour:** The start and end of the milking time will be assessed by the assessor inside the parlour (modified for final protocol, see Table 2).

#### Environment assessments removed during the second phase of the study

**Slope before entry and exit of the parlour:** Slope of the junction between the yard (both entry and exit) and the track will be assessed.

**Heat Stress indicators:** Symptoms like open mouth panting, laboured breathing, sweating and restlessness will be assessed.

**Cold stress symptoms:** Symptoms like huddling, shivering and facing away from wind or rain will be assessed.

#### Environment assessments added during the second phase of the study

**Space allowance in the collecting yard:** Yard area calculated from measurements of length and width (rectangular yards) and radius (circular yards). Space allowance was yard area/cow. Maximum herd size (from questionnaire).

**Proper use of the backing gate:** Speed of the backing gate measured at the end of milking, with the time taken for the backing gate to move a known distance (from one identifiable point to another (e.g., pair of railings) being measured).

**Head position of the cows in the collecting yard:** Proportion of cows standing in the collecting yard with their heads up, recorded immediately after one movement of the backing gate.

**Track condition:** Track surface condition, the slope of camber and the width of the track will be assessed as per [46]. All tracks within 100 m of the parlour will be assessed at ~20 m intervals. The score is the average for the width and camber and for surface condition the worst area is assessed.

### Appendix C.3 Health

**Lameness:** All cows will be locomotion scored using the (0-3 scale) DairyNZ locomotion score [43].

**Broken tail:** Visual assessment for broken tails (swelling and or deviation) while cows are standing to be milked.

**Skin injuries:** All cows will be observed during milking for abrasions, cuts, hairless patches and swellings and the proportion of cows with any such injury recorded (modified for final protocol, see Table 2).

**Coughing:** Number of cows coughing during milking will be recorded.

**Blind eye:** Number of cows with blind eye will be recorded (modified for final protocol, see Table 2).

**Ingrown horn:** Number of cows with ingrown horns will be recorded (modified for final protocol, see Table 2).

### Health assessments removed during the second phase of the study

**Nasal Discharge:** Proportion of cows with visible discharge from the nose will be recorded.

**Ocular discharge:** Proportion of cows with visible discharge from the eyes will be recorded.

**Diarrhoea:** Proportion of cows with faecal stains below the tail head on both sides of the tail will be assessed.

#### Appendix C.4 Behaviour

**Social agonistic and affiliative behaviour in the paddocks:** Cows will be observed for a total of 30 min in the paddock prior to milking. The number of observed behaviours will be recorded. Social agonistic behaviour: headbutting, chasing, displacement, fighting, pushing. Affiliative behaviour: Lapping behaviour/allogrooming.

**Avoidance distance:** Average distance between the assessor and the point of aversion by the cow will be recorded [11] (modified for final protocol, see Table 2).

**Handling of cows during milking:** Vocal tone and aggressive behaviour by farm staff towards the cows will be assessed. The number of behaviours such as shouting, threatening and hitting the cows will be recorded during milking.

**Handling of the cows on track:** Use of dogs or quad bikes to move the cows forcefully will be observed from behind the stockperson. Movement will be considered forceful if the quad bikes or dogs are used to pressure the cows on the tracks. Pressure will be identified when the cows being pressed lift their heads.

### Behavioural assessments removed during the second phase of the study

**Milking behaviour:** Cow restlessness during milking; number kicking and stepping over a complete milking time will be recorded.

**Orientation of the cows:** Orientation of the cows in the collecting yard (facing towards the parlour, facing directly away from the parlour, not orientated towards the parlour) will be recorded at the beginning of milking.

## References

1. Webster, J. *Animal Welfare: Limping Towards Eden: A Practical Approach to Redressing the Problem of our Dominion over the Animals*; John Wiley & Sons: Chichester, UK, 2008.
2. DCANZ. About the NZ Dairy Industry. Available online: <https://www.dcanz.com/about-the-nz-dairy-industry/> (accessed on 12 August 2019).
3. Workman, D. Top Milk Exporting Countries. Available online: <http://www.worldstopexports.com/top-milk-exporting-countries/> (accessed on 12 February 2020).
4. Red Tractor. Dig a Little Deeper. Available online: <https://redtractor.org.uk/dig-a-little-deeper/> (accessed on 3 May 2020).
5. Webster, A. The virtuous bicycle: A delivery vehicle for improved farm animal welfare. *Anim. Welf.* **2009**, *18*, 141–147.
6. FAWC. Farm Animal Welfare Council. Available online: <http://webarchive.nationalarchives.gov.uk/20121007104210/http://www.fawc.org.uk/pdf/fivefreedoms1979.pdf>; (accessed on 13 June 2018).
7. Mellor, D.J. Operational details of the five domains model and its key applications to the assessment and management of animal welfare. *Animals* **2017**, *7*, 60. [[CrossRef](#)] [[PubMed](#)]
8. Green, T.; Mellor, D.J. Extending ideas about animal welfare assessment to include ‘quality of life’ and related concepts. *N. Z. Vet. J.* **2011**, *59*, 263–271. [[CrossRef](#)] [[PubMed](#)]
9. Whay, H.; Main, D.; Green, L.; Webster, A. Assessment of the welfare of dairy cattle using animal-based measurements: Direct observations and investigation of farm records. *Vet. Rec.* **2003**, *153*, 197–202. [[CrossRef](#)] [[PubMed](#)]
10. Simon, G.; Hoar, B.; Tucker, C. Assessing cow–calf welfare. Part 1: Benchmarking beef cow health and behavior, handling; and management, facilities, and producer perspectives. *J. Anim. Sci.* **2016**, *94*, 3476–3487. [[CrossRef](#)] [[PubMed](#)]

11. Consortium, W.Q. *Welfare Quality® Assessment Protocol for Cattle*; Welf. Qual. Consort. Lelystad Neth.: Lelystad, The Netherlands, 2009.
12. Winckler, C.; Capdeville, J.; Gebresenbet, G.; Hörning, B.; Roiha, U.; Tosi, M.; Waiblinger, S. Selection of parameters for on-farm welfare-assessment protocols in cattle and buffalo. *Anim. Welf.* **2003**, *12*, 619–624.
13. Laven, R.; Fabian, J. Applying animal-based welfare assessments on New Zealand dairy farms: Feasibility and a comparison with United Kingdom data. *N. Z. Vet. J.* **2016**, *64*, 212–217. [[CrossRef](#)]
14. De Vries, M.; Engel, B.; Den Uijl, I.; Van Schaik, G.; Dijkstra, T.; De Boer, I.; Bokkers, E. Assessment time of the Welfare Quality® protocol for dairy cattle. *Anim. Welf.* **2013**, *22*, 85–93. [[CrossRef](#)]
15. AssureWel Dairy Welfare Outcome Assessment—ADF Pilots Protocol. Available online: [http://www.assurewel.org/Portals/2/Documents/Dairy%20cows/AssureWel%20Dairy%20Welfare%20Outcome%20Assessment%20Protocol\\_2018.pdf](http://www.assurewel.org/Portals/2/Documents/Dairy%20cows/AssureWel%20Dairy%20Welfare%20Outcome%20Assessment%20Protocol_2018.pdf) (accessed on 14 July 2019).
16. Bartussek, H.; Leeb, C.; Held, S. *Animal Needs Index for Cattle (Ani 35 L/2000-Cattle)*; Federal Research Institute for Agriculture in Alpine Regions BAL Gumpenstein: Gumpenstein, Austria, 2000.
17. University of California, Davis. Cow-Calf Health and Handling Assessment. Available online: <https://Ucdcowcalfassessment.com> (accessed on 15 June 2019).
18. proAction. Animal Care: Quick Guide to Animal-Based Measurement Protocols. Available online: <https://www.dairyfarmers.ca/proaction/resources/animal-care> (accessed on 25 September 2020).
19. Danitza, A.B. Animal Welfare Program of Chilean Dairy Consortiums. Available online: <https://www.icar.org/Documents/Puerto-Varas-2016-presentations/files/OL/OL%205/RDY/1%20Presentacion%20Programa%20de%20bienestar%20animal%20del%20Consorcio%20Lechero%20de%20Chile%20ICAR%202016%20D.%20ABARZUA.pdf> (accessed on 15 June 2019).
20. Napolitano, F.; Grasso, F.; Bordi, A.; Tripaldi, C.; Saltalamacchia, F.; Pacelli, C.; De Rosa, G. On-farm welfare assessment in dairy cattle and buffaloes: Evaluation of some animal-based parameters. *Ital. J. Anim. Sci.* **2005**, *4*, 223–231. [[CrossRef](#)]
21. Capdeville, J.; Veissier, I. A method for assessing dairy cows welfare in a loose housing herd focussing on animal observations. *Acta Agric. Scand. Suppl.* **2001**, *30*, 62–68.
22. De Wolf, A. *A Welfare Assessment System for Dairy Cows on Pasture and the Comparison to a Welfare Scoring System for Cows in Cubicles*; Research Project Medicine; University of Utrecht: Utrecht, The Netherlands, 2010.
23. DairyNZ. Preventing and Managing Lameness: A Farmer’s Guide to Lameness on New Zealand Dairy Farms. Available online: <https://www.dairynz.co.nz/mdia/5790786/preventing-and-managing-lameness-guide.pdf> (accessed on 23 July 2020).
24. Gibbs, J. Fibre in New Zealand pastures. *VetScript* **2012**, *25*, 43–45.
25. Foris, B.; Zebunke, M.; Langbein, J.; Melzer, N. Comprehensive analysis of affiliative and agonistic social networks in lactating dairy cattle groups. *Appl. Anim. Behav. Sci.* **2019**, *210*, 60–67. [[CrossRef](#)]
26. AHDB. Cleanliness Scoring Card. Available online: <https://dairy.ahdb.org.uk/resources-library/technical-information/health-welfare/cleanliness-score-card/#.XwUrTSgzbIU> (accessed on 8 July 2020).
27. University of Wisconsin—Madison. Hygiene Scoring Card. Available online: [http://www.infodairy.com/infodairy\\_upload\\_files/Cows\\_heifers\\_calves/Milk%20Quality/0111hygiene%20scoring%20card.pdf](http://www.infodairy.com/infodairy_upload_files/Cows_heifers_calves/Milk%20Quality/0111hygiene%20scoring%20card.pdf) (accessed on 8 July 2019).
28. Zuliani, A.; Mair, M.; Kraševc, M.; Lora, I.; Brscic, M.; Cozzi, G.; Leeb, C.; Zupan, M.; Winckler, C.; Bovolenta, S. A survey of selected animal-based measures of dairy cattle welfare in the Eastern Alps: Toward context-based thresholds. *J. Dairy Sci.* **2018**, *101*, 1428–1436. [[CrossRef](#)]
29. Roche, J.R.; Friggens, N.C.; Kay, J.K.; Fisher, M.W.; Stafford, K.J.; Berry, D.P. Invited review: Body condition score and its association with dairy cow productivity, health, and welfare. *J. Dairy Sci.* **2009**, *92*, 5769–5801. [[CrossRef](#)] [[PubMed](#)]
30. Klopčič, M.; Hamoen, A.; Bewley, J. *Body Condition Scoring of Dairy Cows*; Biotechnical Faculty, Department of Animal Science: Ljubljana, Slovenia, 2011.
31. Burfeind, O.; Sepúlveda, P.; Von Keyserlingk, M.; Weary, D.; Veira, D.; Heuwieser, W. Evaluation of a scoring system for rumen fill in dairy cows. *J. Dairy Sci.* **2010**, *93*, 3635–3640. [[CrossRef](#)]
32. DairyNZ. How to BCS. Available online: <https://www.dairynz.co.nz/animal/body-condition-scoring/how-to-bcs/> (accessed on 14 July 2019).
33. Ministry for Primary Industries (MPI). Dairy Cattle Code of Welfare. Available online: <https://www.dairynz.co.nz/media/5792347/dairy-cattle-code-of-welfare-dairy-cattle.pdf> (accessed on 22 June 2020).

34. Laven, R. Veterinary control of herd fertility in pastoral dairy herds. *Arthur's Vet. Reprod. Obstet. E Book* **2018**, 485–492. [[CrossRef](#)]
35. Kaurivi, Y.; Laven, R.; Hickson, R.; Stafford, K.; Parkinson, T. Identification of suitable animal welfare assessment measures for extensive beef systems in New Zealand. *Agriculture* **2019**, *9*, 66. [[CrossRef](#)]
36. Morris, C.; Hickey, S.; Thom, E.; Waugh, C. Daily water intake by individual dairy cows on a pasture diet during mid lactation. *N. Z. Soc. Anim. Prod.* **2010**, *70*, 257–260.
37. Brouček, J. Effect of noise on performance, stress, and behaviour of animals. *Slovak J. Anim. Sci.* **2014**, *47*, 111–123.
38. HealthLinkBC. Harmful Noise Levels. Available online: <https://www.healthlinkbc.ca/health-topics/tf4173> (accessed on 20 July 2020).
39. Chesterton, R.; Pfeiffer, D.; Morris, R.; Tanner, C. Environmental and behavioural factors affecting the prevalence of foot lameness in New Zealand dairy herds—A case-control study. *N. Z. Vet. J.* **1989**, *37*, 135–142. [[CrossRef](#)]
40. Zähler, M.; Schrader, L.; Hauser, R.; Keck, M.; Langhans, W.; Wechsler, B. The influence of climatic conditions on physiological and behavioural parameters in dairy cows kept in open stables. *Anim. Sci.* **2004**, *78*, 139–147. [[CrossRef](#)]
41. Laven, R.; Holmes, C. A review of the potential impact of increased use of housing on the health and welfare of dairy cattle in New Zealand. *N. Z. Vet. J.* **2008**, *56*, 151–157. [[CrossRef](#)]
42. Laven, R.; Jermy, M. Measuring the torque required to cause vertebral dislocation in cattle tails. *N. Z. Vet. J.* **2020**, *68*, 107–111. [[CrossRef](#)] [[PubMed](#)]
43. DairyNZ. Lameness Scoring. Available online: <https://www.dairynz.co.nz/animal/cow-health/lameness/lameness-scoring/> (accessed on 14 July 2020).
44. Dairy Veterinary Consultancy Ltd. Rumen Fill Scorecard. Available online: <https://dairyveterinaryconsultancy.co.uk/download/rumen-fill-scorecard/> (accessed on 14 July 2020).
45. Grewcock, M. How to Estimate the Height of a Tree Using a Stick. One Minute ID. Available online: [https://www.youtube.com/watch?v=\\_kKsp9R9Xb0](https://www.youtube.com/watch?v=_kKsp9R9Xb0) (accessed on 14 July 2019).
46. DairyNZLtd. DairyNZ Improving Cow Flow. Available online: <https://www.youtube.com/watch?v=XUnzfH9jPM&t=328s> (accessed on 14 July 2019).



**Publisher's Note:** MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



© 2020 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).

## STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the candidate and the candidate's Primary Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of candidate:	Sujan Sapkota
Name/title of Primary Supervisor:	Richard Laven
In which chapter is the manuscript /published work: Chapter 3	
Please select one of the following three options:	
<input checked="" type="radio"/> The manuscript/published work is published or in press <ul style="list-style-type: none"> <li>• <a href="https://doi.org/10.3390/ani10101918">https://doi.org/10.3390/ani10101918</a></li> </ul>	
<input type="radio"/> The manuscript is currently under review for publication – please indicate: <ul style="list-style-type: none"> <li>• The name of the journal:</li> <li>• The percentage of the manuscript/published work that was contributed by the candidate: 75%</li> <li>• Describe the contribution that the candidate has made to the manuscript/published work: main researcher, conceptualisation, methodology, main writing</li> </ul>	
<input type="radio"/> It is intended that the manuscript will be published, but it has not yet been submitted to a journal	
Candidate's Signature:	
Date:	05/01/24
Primary Supervisor's Signature:	
Date:	05/01/24

This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/publication or collected as an appendix at the end of the thesis.

#### **Chapter 4: Practicability of a Time-Limited Welfare Assessment Protocol for Pasture-Based Dairy Farms, and a Preliminary Assessment of Welfare Outcome Thresholds.**

This chapter covers the study that further tested the feasibility of the protocol finalised in Chapter 3. In this study, 23 different dairy farms of Manawatu and Waikato were tested for their feasibility. Measures that were not feasible were identified. The collected data for the rest of the measures were categorized into different welfare status (i.e., acceptable, marginal, and unacceptable) based on author-derived thresholds.

## Article

# Practicability of a Time-Limited Welfare Assessment Protocol for Pasture-Based Dairy Farms, and a Preliminary Assessment of Welfare Outcome Thresholds

Sujan Sapkota \*, Richard Laven , Kristina Ruth Müller and Nikki Kells 

School of Veterinary Science, Massey University, Tennent Drive, Palmerston North 4474, New Zealand

\* Correspondence: s.sapkota1@massey.ac.nz; Tel.: +64-225165850

**Simple Summary:** This study tested the feasibility and practicability of 32 welfare measures as a part of a time-limited protocol across 23 pasture-based farms. The study identified that one measure, maximum time waiting to enter the milking parlour, was required to be assessed alongside locomotion scoring (by an observer outside the milking parlour) and that our measures of water availability (distance between water points), and behaviour (30 min observation in paddock prior to milking) needed significant changes before inclusion in the protocol. Overall, the protocol was generally feasible, but further testing for repeatability and reliability of measures with multiple observers is needed.

**Abstract:** This study assessed a new time-limited protocol developed for pasture-based cows across 23 dairy farms. The process started prior to milking with a questionnaire, followed by an assessment of resources (16 farms only) and behavioural observation of cows at pasture. Remaining animal-based measures were assessed during milking, usually by two assessors (one parlour based and one outside). The protocol proved to be practical and feasible with limited changes needed, except for the assessment of water availability and behaviour. As most cows could access only one water trough, distance between troughs was not a measure of water availability, while the observation of a large numbers of cows at pasture for 30 min resulted in few observations and an uncertain denominator (effective number of observed cows). Further research is needed to determine the best way of assessing water availability and cow behaviour in a time-limited assessment of pasture-based cows. Three animal-based measures (broken tails, dirtiness, and coughing) had mean values higher than the author-determined acceptable thresholds, while <50% of farms met trough cleanliness and track condition targets, and none met the criteria for shelter and shade. This was a sample of farms based on convenience, so more data are required to establish the representativeness of these results. Such testing should involve assessment of the repeatability and reliability of the measures in our protocol.

**Keywords:** animal-based measures; welfare threshold development; locomotion scoring; paddock observation; milking cow



**Citation:** Sapkota, S.; Laven, R.; Müller, K.R.; Kells, N. Practicability of a Time-Limited Welfare Assessment Protocol for Pasture-Based Dairy Farms, and a Preliminary Assessment of Welfare Outcome Thresholds. *Animals* **2022**, *12*, 2481. <https://doi.org/10.3390/ani12182481>

Academic Editor: Umberto Bernabucci

Received: 20 July 2022

Accepted: 16 September 2022

Published: 19 September 2022

**Publisher's Note:** MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



**Copyright:** © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

## 1. Introduction

Changes and advancements in animal production have resulted in public concern regarding the treatment of animals on farm and their quality of life. In response to this, animal-focused welfare-assessment protocols have become increasingly common, especially in Europe [1–3]

All assessment protocols must address the management used on the farm and use measures selected after appropriate feasibility testing [4]. This approach is particularly important in systems such as the pasture-based dairy farming system which predominates in New Zealand, which are very different from the housed systems which are the principal focus of most welfare assessment schemes. This is because many parameters useful in housed systems are not relevant or useful in cows that are never housed [5]. As there

is currently no industry-standard welfare assessment scheme for dairy farms in New Zealand, we developed a welfare assessment protocol for use on pasture-based dairy farms in New Zealand [6]. This protocol was focused on being time-limited with measurements made during and around milking. It consisted of 32 on-farm measures, of which nine were resource-based, 13 were animal-based, six were record-based and two each were management- and stock person-based. The protocol required two people and took 2–3.5 h to complete (depending on the farm size). However, the feasibility and applicability of those measures needed further testing before the protocol could be recommended for use as a welfare assessment tool on New Zealand dairy farms.

One key challenge during the development of a protocol is the setting of thresholds for the measures used in the protocol. These thresholds can be used for a variety of purposes, from identifying farms not meeting compliance standards to identifying areas for action on farms that need to improve beyond the baseline, to identifying farms achieving high standards. However, for most measures, especially in understudied systems such as pasture-based dairy systems, there are no clearly defined thresholds indicative of acceptable and unacceptable welfare [7]. Indeed, it seems unlikely that universally agreed thresholds are feasible, as there are significant disagreements even between experts on what constitutes acceptable and unacceptable welfare [1,5]. Thus, any expert-set threshold will be a compromise, even if experts are carefully chosen [6]. However, there is increasing recognition that optimising animal welfare is a crucial part of farming's "social licence" and that this social licence is determined by people other than experts [8]. Consideration of stakeholder opinions, including all purchasers of dairy products such as dairy companies, retailers, and consumers is thus important when setting welfare thresholds as much of the assessment is targeted at the social licence to farm. However, including consumers in the process is likely to significantly increase the variability in what is considered to be acceptable and the potential identification of different areas of concern [9–11] making the process of deciding thresholds and identifying areas of concern more complex and time consuming.

The alternative to using thresholds based on opinion (expert or otherwise) is the use of benchmarking, where an individual farm's results for each indicator or measure can be compared to results from a larger group of farms (which may be national, local, or farm-type based). However, this seemingly simple approach requires a relatively large dataset, so that the benchmarking is robust [12]. Additionally, although benchmarking can drive industry change [13], it may fail to identify systemic problems, especially if thresholds are set using industry averages (e.g., broken tails on New Zealand dairy farms [14]).

Thus as a starting point, we created thresholds based on the authors' opinions as to what was acceptable and unacceptable welfare. This is the same approach used to determine thresholds for a protocol for assessing beef cow welfare in New Zealand [15].

The aims of this study were (i) to test our previously developed time-limited protocol [6] across more New Zealand dairy farms, and (ii) to assess the data collected on the included measures against author-determined thresholds for a provisional assessment of animal welfare status on these farms.

## 2. Materials and Methods

### 2.1. Methods and Categorisation of Welfare Measures

The measurement methods for each of the 32 measures are summarised in Tables 1–4, along with their threshold values. Due to the lack of established thresholds for welfare measures for pasture-based dairy cows [16], thresholds were set based on the authors' opinion, guided, when available, by published recommendations. We assigned three categories of welfare to most measures: acceptable welfare (represented by green), marginal welfare (represented by orange), and unacceptable welfare (represented by red) as in Kaurivi et al. [15], but where marginal welfare was thought to be an inappropriate category, e.g., for the question "do you use pain relief for disbudding", we assigned only two categories (red and green) (see Tables 1–4).

**Table 1.** Method of assessment for animal-based welfare measures from the pasture-based dairy cattle welfare assessment protocol, with categorisation based on author-determined thresholds. Note: all cows assessed for all measures, and no sampling used.

Measure	Basis of Scoring	Animal Welfare Categories		
		Acceptable	Marginal	Unacceptable
Body condition Percentage of cows $\leq 3.5$ .	1–10 score (See: Body Condition Scoring. <a href="http://www.dairynz.co.nz/animal/body-condition-scoring/how-to-bcs/">www.dairynz.co.nz/animal/body-condition-scoring/how-to-bcs/</a> (accessed on 1 December 2021)).	Green: 0–5%	Orange: >5–10%	Red: $\geq 10\%$
Rumen Fill Percentage of cows $\leq 2$ .	1–5 score (See: Rumen Fill Scorecard. <a href="https://dairyveterinaryconsultancy.co.uk/download/rumen-fill-scorecard/">https://dairyveterinaryconsultancy.co.uk/download/rumen-fill-scorecard/</a> (accessed on 1 December 2021)).	Green: 0–2%	Orange: >2–5%	Red: >5%
Cleanliness Percentage of very dirty cows.	Three-category cleanliness score: clean, dirty, and very dirty. Scored as <sup>a</sup> with modifications: only flank and hind quarters were observed with cow scored based on worst score [17].	Green: <10%	Orange: 10–20%	Red: >20%
Heads-up position	Assessment of cows standing in the collecting yard with their heads up <sup>a</sup> immediately after one movement of the backing gate.	Green: No heads up		Red: Any heads up
Lameness Percentage of cows score $\geq 2$	0–3 score (See: Lameness Scoring. <a href="https://www.dairynz.co.nz/animal/cow-health/lameness/lameness-scoring/">https://www.dairynz.co.nz/animal/cow-health/lameness/lameness-scoring/</a> (accessed on 1 December 2021)).	Green: 0–5%	Orange: >5–10%	Red: >10%
Broken Tail Percentage of cows.	Deviation/swelling of the tail visually assessed from within 2 m of the cow during milking. Any visible deviation or swelling in any region of the tail was recorded as a “broken tail”.	Green: 0–5%	Orange: >5–10%	Red: >10%
Coughing Percentage of cows.	Cows coughing while being milked.	Green: 0–1%	Orange: >1–2%	Red: >2%
Skin Injury Percentage of cows.	Visual assessment of abrasions, cuts, hairless patches, and swellings was assessed at a combined level, i.e., no separate scoring of abrasions, cuts, hairless patches, and swellings. Observed from behind in rotary and at exit in herringbone. Any visible injury was recorded as injured.	Green: 0–1%	Orange: >1–2%	Red: >2%
Ingrown horn Percentage of cows.	All cows with overgrown horns which could penetrate the skin in future were recorded, along with horns that had already penetrated the skin.	Green: 0–1%	Orange: >1–2%	Red: >2%
Blind eye Percentage of cows.	All cows that were blind in one eye or had visible eye damage were recorded.	Green: 0–1%	Orange: >1–2%	Red: >2%
Agonistic Behaviour Total number of agonistic behaviours observed.	A 30 min observation of all cows in the paddock (current grazing area). All social agonistic behaviours (head butting, chasing, displacement, fighting, pushing) were recorded (>1 s elapsed—new behaviour).	ND		
Positive Behaviour Total number of affiliative behaviours observed	A 30 min observation of all cows in paddock. All social affiliative behaviours (allogrooming, lapping) were recorded (>10 s elapsed—new behaviour).	ND		

<sup>a</sup> cows normally stand with their heads at the same level as shoulders, “heads up” indicates a cow is being pushed and space is limited [18]; ND, not determined.

**Table 2.** Method of assessment for resources and stockperson-based measures from the pasture-based dairy cattle welfare assessment protocol, with categorisation based on author-determined thresholds.

Basis of Scoring		Animal Welfare Categories		
		Acceptable	Marginal	Unacceptable
Distance to waterpoints	Distance between water points/troughs in the grazing area.	Green: $\leq 150$ m	Orange: $>150$ – $250$ m	Red: $> 250$ m
Shade availability Proportion (%) of cows with shade available if grazed by largest herd.	If $< 80\%$ of paddocks planted with trees, welfare was recorded as unacceptable. If $>80\%$ , paddock next to one being currently grazed was assessed for available shade at noon [19] (see appendix 3 for details). Required shaded area was set at of $6 \text{ m}^2/\text{cow}$ (See: Trees for Shade. Retrieved from <a href="https://www.dairynz.co.nz/media/5447835/Trees_for_shade.pdf">https://www.dairynz.co.nz/media/5447835/Trees_for_shade.pdf</a> (accessed on 1 December 2021))	Green: $>40\%$	Orange: $20$ – $40\%$	Red: $<20\%$ .
Shelter availability (against wind) Proportion of cows with shade available if grazed by largest herd.	Shelterbelts (trees at least $15$ m high and length of the belt at least 12 times the height of the trees) were recorded.	Green: Shelter for $100\%$ cows	Orange: Shelter for at least $50\%$ of cows	Red: Shelter for $<50\%$ cows.
Maximum waiting time in collecting yard	Time of arrival of each milking group and the time of exit of the last cow of each group from the milking parlour were recorded.	Green: $\leq 2$ h	Orange: $2$ – $2.5$ h	Red $\geq 2.5$ h
Trough cleanliness	Visual observation of where cows are grazing and one adjacent paddock. Troughs at the feed pad were assessed when present. The worst observation was recorded.	Green: Clear water, easily visible base, no apparent dirt/dead insects.	Orange: Base partly obscured, no floating dirt or dead insects.	Red: Base not visible, dirt/insects
Noise level	Subjective assessment of noise inside the milking parlour.	Green: Minimal noise, conversation can be easily heard	Orange: Some noise, conversation heard with concentration.	Red: High noise, conversation cannot be heard.
Furthest paddock distance	Farmer-estimated distance from the milking parlour to the furthest paddock.	Green: $<1$ km;	Orange: $1$ – $1.5$ km	Red: $>1.5$ km
Track condition	Assessment of width, camber, and surface quality of the track/s (See: Efficient tracks. <a href="https://www.dairynz.co.nz/milking/milking-efficiently/cow-flow/track-and-yard/efficient-tracks/">https://www.dairynz.co.nz/milking/milking-efficiently/cow-flow/track-and-yard/efficient-tracks/</a> (Accessed 1 December 2021)), (See: DairyNZ Improving Cow Flow. <a href="https://www.youtube.com/watch?v=XUnzfH9JpPM&amp;ab_channel=DairyNZ/">https://www.youtube.com/watch?v=XUnzfH9JpPM&amp;ab_channel=DairyNZ/</a> (Accessed 1 December 2021)) leading to the parlour ( $100$ m). If multiple tracks, the worst case was used for categorisation.	Green: All three track assessments good	Orange: Two track assessments good, must include track surface	Red: Two track measures poor/poor track surface
Yard space per cow	Available space/cow in the collecting yard. Note: was checked against the largest herd size of the farm (See: Yard Features. <a href="https://www.dairynz.co.nz/milking/milking-efficiently/cow-flow/track-and-yard/yard-and-handling-facilities/yard-features/">https://www.dairynz.co.nz/milking/milking-efficiently/cow-flow/track-and-yard/yard-and-handling-facilities/yard-features/</a> (Accessed 1 December 2021)).	Green: $>1.2 \text{ m}^2/\text{cow}$ ;		Red: $\leq 1.2 \text{ m}^2/\text{cow}$
Backing gate speed	Speed of the backing gate (See: Backing gates. <a href="https://www.dairynz.co.nz/milking/milking-efficiently/cow-flow/track-and-yard/yard-and-handling-facilities/backing-gates/">https://www.dairynz.co.nz/milking/milking-efficiently/cow-flow/track-and-yard/yard-and-handling-facilities/backing-gates/</a> (Accessed 1 December 2021)).	Green: $\leq 1 \text{ m}/5 \text{ s}$ for circular yard and $\leq 0.5 \text{ m}/5 \text{ s}$ for rectangular yard		Red: Gate speed greater than those limits
Handling on track	Observation from behind stockperson as cows were brought in for milking. Pressure identified when cows lifted their heads or ran in response to stockperson/dog.	Green: No pressure observed		Red: Pressure observed

**Table 3.** Method of assessment for record-based assessment measures from the pasture-based dairy cattle welfare assessment protocol, with the categorization based on author-determined thresholds.

Basis of Scoring		Animal Welfare Categories		
		Acceptable	Marginal	Unacceptable
Lameness incidence	Percentage of milking herd treated for lameness per year.	Green: 0–10%	Orange: >10–15%	Red: >15%
Mastitis incidence	Percentage of milking herd treated for mastitis per year.	Green: 0–10%	Orange: >10–15%	Red: >15%
Cow mortality	Percentage of milking herd that die on farm in a year.	Green: 0–1%	Orange: >1–2%	Red: >2%
Replacement heifer deaths before calving/year	Percentage of replacement heifers that die before calving for the first time.	Green: 0–0.5%	Orange: >0.5–1%	Red: >1
Vaccination record	Presence or absence of vaccination records.	Green: present		Red: absent
Pain relief	Use of pain relief before routine husbandry practices (disbudding, dehorning, castration, removal of supernumerary teats).	Green: use of pain relief in all calves for all procedures		Red: Pain relief not used for all calves/procedures

**Table 4.** Method of assessment for stockpersonship measures obtained from questionnaire, with the categorization based on author-determined threshold.

Basis of Scoring		Author's Welfare Categorisation		
		Acceptable	Marginal	Unacceptable
Mixing of Cows	Mixing of cows between herds if more than one herd on a farm or mixing of cows that are new to the farm (i.e., purchased cows). Does not include mixing of heifers after calving with lactating cows.	Green: No mixing of cows	Orange: Rare mixing of cows (up to two times per lactation)	Red: Frequent mixing of cows
Use of handling aids	Use of handling aids (during milking) such as prod, wooden/rubber pipe Note: if use is observed during the assessment, it will be prioritised over the farmer's questionnaire response.	Green: No use of mentioned handling aids		Red: Use of handling aids

## 2.2. Data Collection

In October and November 2019, 23 pasture-based dairy farms (seven in Manawatu and 16 in Waikato) selected based on convenience sampling were visited by the first author. Of the 23 farms, 10 farms had a rotary milking platform and 13 had milked cows in a herringbone parlour. The number of milking cows in these farms ranged from 166 to 900 (see Table S2, Supplementary Materials) on the assessment day. On all farms, cows were kept at the pasture throughout the year using rotational grazing, with the length of rotation being dependent on the rate of grass growth. Of the 23 farms, 20 milked cows twice a day. On the remaining three farms (all in the Manawatu) cows were milked once a day.

On the twice-a-day farms, the process started ~2 h before afternoon milking on 17/20 farms. The first author undertook a questionnaire-guided interview which included questions related to record and management-based measures (see File S2, Supplementary Materials) with a key worker (usually farm owner/manager), followed by the assessment of resources (Table 2) and then (Waikato herds only) behavioural observation of the milking herd at grass for ~0.5 h and, finally, recording of animal-based and stockpersonship measures (Tables 1 and 2) during milking. On these 17 farms, a second assessor arrived at milking to undertake locomotion scoring. The first author was inside the milking parlour for the whole of the milking, whereas the second assessor stayed outside the parlour. On the remaining three twice-a-day farms, a second assessor was not available, so the assessment was carried out by the first author alone, with measurements at morning (locomotion scoring) and afternoon milking (remaining assessments).

On once-a-day farms, the assessment process started with the assessment of animal-based measures alongside locomotion scoring followed by the assessment of resources and, finally, the questionnaire-guided interview.

Alongside data collection, we assessed whether our proposed protocol was suitable for collecting data on all 32 welfare measures, during the time available (from ~2 h before milking to the end of milking). Additionally, we assessed whether our measures provided useful data that were relevant to the assessment of animal welfare on a farm and allowed comparison between farms.

## 2.3. Data Analysis

Data were analysed using SPSS version 27 (IBM, Seattle, WA, USA). Descriptive statistics (mean, maximum value, minimum value, and 25th, 50th, and 75th percentiles) were calculated for all numerical animal-based measures (except where <0.5% of cattle were affected) and compared with their respective author-determined acceptable thresholds. The welfare category for each of those animal-based measures was then determined (Table 1) and a three-coloured heatmap was created. This comparison with author-determined thresholds and the creation of a heat map was then repeated for the categorical animal-based, resources-based, and stockpersonship-related measures.

## 3. Results

During the collection process, problems were identified with the collection of 3/32 measures included in the original protocol: maximum waiting time, distance to water points, and agonistic/positive behaviour assessment. Table 5 summarises the problems identified with each of these three measures and the changes needed for inclusion in the protocol. The only one of the three measures where data were collected on all farms where the collection was attempted were the counts of agonistic and positive behaviours. The results (raw counts) ranged from no behaviours observed (4/16 farms) to 26 behaviours observed. As these numbers were so low, no further analysis (e.g., calculation of behaviours observed/cow hour) was undertaken.

**Table 5.** Welfare measures found not to be feasible on all farms and reasons why they were not.

Measures	Issue Identified	Solution
Distance to waterpoints	Most paddocks only had a single trough, and on some farms, even though the paddocks had multiple troughs, the cows only had access to one trough because of temporary electric fencing.	Alternative method of measure of water availability is required. Further research is required to establish a valid but not time-consuming assessment method
Maximum waiting time in the parlour	Main assessor inside the parlour could not record the arrival of multiple herds if present.	The outside assessor can record the arrival of a new group at the collecting yard and when the last cow of a group leaves the milking parlour alongside locomotion scoring
Agonistic/positive behaviour	The 30 min allocated to this observation was insufficient, with no observations of agonistic or positive behaviour on many farms. Calculating the denominator (i.e., the number of cows being observed) was also difficult as it was not possible to observe all cows in a paddock simultaneously.	Further research is required to establish a more effective and valid method of identifying the behaviour of cows at pasture. Simply increasing observation time would be unlikely to provide useful data and would conflict with the aim of producing a time-limited protocol.

### 3.1. Animal-Based Measures

Descriptive statistics for the seven different animal-based parameters (with prevalence >0.5%, i.e., excluding blind eye and ingrown horn) are shown in Table 6, with a comparison to the author-derived acceptable thresholds (Figure 1). Overall mean percentage was above our acceptable range for broken tails, very dirty cows, and coughing during milking (observed percentages of 10, 17.3, and 1.2%, respectively, vs. acceptable thresholds of 5, 10, and 1%, respectively).



**Figure 1.** Heatmap representing welfare levels for eight animal-based measures from 23 dairy farms. All measures have three welfare levels (acceptable, green; marginal, orange; or unacceptable, red), except for the heads-up position which has only two levels (acceptable, green; and unacceptable, red). See Table 1 for further details of measurements and thresholds.

**Table 6.** Descriptive statistics for selected animal-based measures from 23 farms and their comparison with a predetermined acceptable threshold (see Table 1 for details of measurements).

Measure	Mean (%)	Max (%)	Min (%)	Percentiles			Acceptable (Green) Threshold
				25	50	75	
BCS ( $\leq 3.5$ )	4.8	14.2	1.2	2.5	4.1	5.7	$\leq 5\%$
RFS ( $\leq 2$ )	1.9	7.8	0.0	0.0	1.2	3.4	$\leq 2\%$
Lameness ( $\geq 2$ )	3.3	9.3	0.4	1.2	2.8	4.6	$\leq 5\%$
Broken tails	<b>10.0</b>	24.3	0.3	2.9	<b>9.2</b>	<b>17.8</b>	$\leq 5\%$
Dirtyness	<b>17.3</b>	38.8	2.7	<b>11.6</b>	<b>15.7</b>	<b>23</b>	$< 10\%$
Skin Injury	0.4	2.4	0.0	0.1	0.3	0.6	$\leq 1\%$
Coughing	<b>1.2</b>	2.2	0.0	0.8	<b>1.3</b>	<b>1.4</b>	$\leq 1\%$

BCS, body condition score; RFS, rumen fill score. Figures in bold where mean or percentiles exceed the upper green threshold.

### 3.2. Resource-Based Measures

The heatmap for these measures is presented in Figure 2. Of the 23 farms, 16 had more than our acceptable threshold of  $1.2 \text{ m}^2/\text{cow}$  in the collecting yard (range:  $1.25\text{--}2.12 \text{ m}^2$ ). For backing gate speed, in the farms with a circular yard (20/23 farms), eight farms had gate speeds above our  $\leq 1 \text{ m}/5 \text{ s}$  threshold (range:  $1.05\text{--}1.4 \text{ m}/5 \text{ s}$ ), seven farms had gate speeds of exactly  $1 \text{ m}/5 \text{ s}$ , and five farms had gate speeds below  $1 \text{ m}/5 \text{ s}$  (range:  $0.46\text{--}0.98 \text{ m}/5 \text{ s}$ ). In all three farms with a rectangular collecting yard, the backing gate speeds were above our  $\leq 0.5 \text{ m}/5 \text{ s}$  threshold (range:  $0.96\text{--}1.51 \text{ m}/5 \text{ s}$ ) (see Supplementary Table S3). Only (4/23) farms met our acceptable target for water trough cleanliness.



**Figure 2.** Heatmap representing welfare levels for six resource-based measures and two handling measures. All measures had three welfare levels (acceptable, green; marginal, orange; or unacceptable, red), except for yard space, backing gate speed, and the two handling measures which had two levels (acceptable, green; unacceptable, red). See Table 2 for further details of measurements and thresholds.

### 3.3. Track Assessment

On the 23 farms, a total of 48 tracks which ended at the collecting yard were identified and assessed for track width and surface. Of those 48 tracks, five tracks (on 5 farms) were recorded as having a poor surface. Only 45 tracks were assessed for camber (transverse slope) (three could not be assessed due to very poor track condition). Of these, 28 had a camber >8%. The minimum recommended track width varies by herd size (See: Efficient tracks. <https://www.dairynz.co.nz/milking/milking-efficiently/cow-flow/track-and-yard/efficient-tracks/> (accessed on 1 December 2021)). Table 7 summarises the measurement of track width, camber, and track surface based on the largest herd size.

**Table 7.** Measurement of width, camber, and surface of the tracks leading to the parlour based on the largest herd size of the farm.

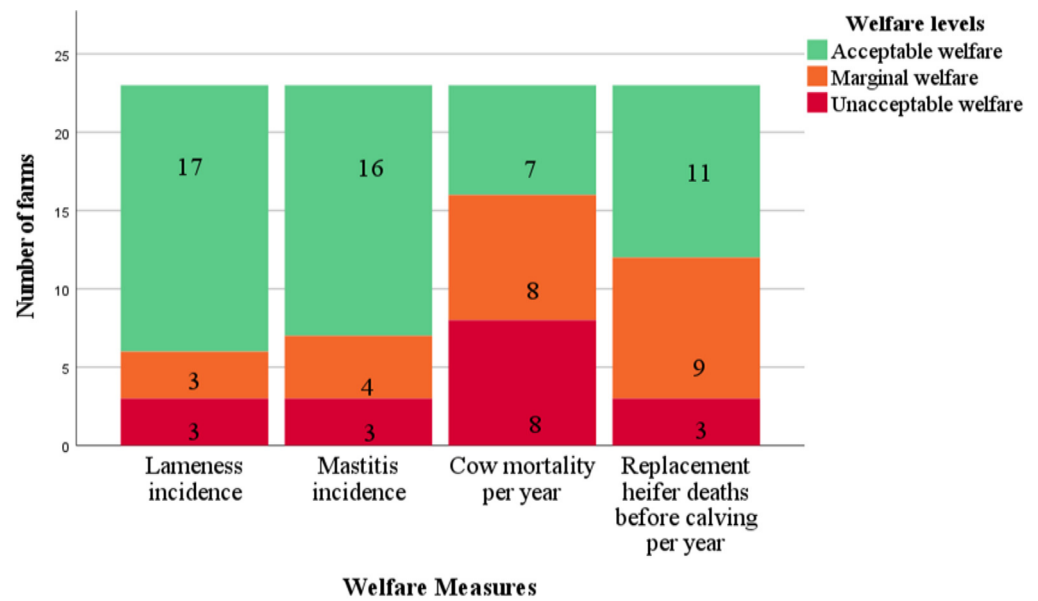
Farm No	Group of Herd Size	Largest Herd Size	Recommended Width (m)	Track(s) Width (m)	Camber (cm/m)	Bad Surface (in Number)
5		224		5.4, 4.2	4.6, 4.3	1
6		224		4.5	8.7	
8		210		5.5, 4.4	11, 8.5	
9		240		4.8, 4.1, 6.6	20.2, 22.5	1
12		178		5.8, 6	9.8, 11	
14	(120–250)	235	5.5	5.2, 5.3, 5.1	20.8, 17.1	1
18		240		6, 5.5	6.8, 6.6	
19		125		5.2, 5.5	7.6, 21	
21		216		8.2, 5.9	7.8, 6.2	
22		166		3, 4	8.2, 12	
1		305		4.6	6.7	
3		300		4.5, 3.9	5.7, 4	
4		257		4.5, 4.1	8.1, 8.6	
11	(251–350)	310	6.0	5.4	8.6	
16		350		7.8, 5	8.8, 5	
17		350		4.6, 5.5	7.8, 14, 1	
20		330		6.9, 6, 6	9.2, 5.2	
23		364		3, 4.3, 4.5	9.4, 8.4, 7.8	
13		350		5.2, 5.3, 5.1	8.6, 8.5, 7.2	
15		364		5.6, 4.6	9.8, 6.7	
10	(351–450)	360	6.5	6, 4.1, 4.5	12, 9.4, 8.4	1
7		450		8.2	10.25	
2		420		4.7, 5	9.5, 6.7	

### 3.4. Shelter and Shade

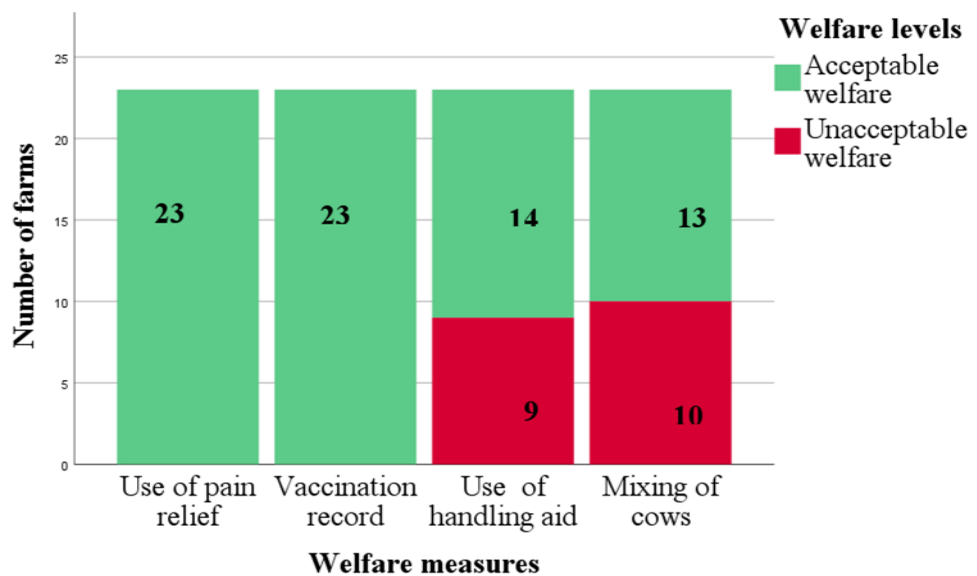
Of the 23 farms, only two had shelterbelts which met the criteria for an effective shelterbelt (i.e., height >15 m and length at least twelve times tree height). Both had one East–West and one North–South shelterbelt. Only three farms had >80% of paddocks (enclosed grazing areas) with trees. The proportions of the largest grazing group which could be protected in these farms were 12.7%, 32.5%, and 39.7%.

### 3.5. Record, Management, and Stockpersonship Based Measures

The welfare levels for each of these measures are presented as stacked bar charts (Figures 3 and 4). For stockpersonship-related measures, although 14/23 farms used some sort of handling aids to control their cows, handling of the cows on track by the stockperson was acceptable on all but two farms, where tail pulling and hitting were observed during milking.



**Figure 3.** Stacked bar chart for welfare levels of disease and mortality data for 23 pasture-based dairy farms.



**Figure 4.** Stacked bar chart for welfare levels of management data for 23 pasture-based dairy farms.

#### 4. Discussion

This study was an extension of a previous pilot study which developed a time-limited protocol for pasture-based dairy cows [6]. This study was designed to test the practicality and usefulness of that protocol on more farms across New Zealand. Three assessment measures (i.e., maximum waiting time, distance between waterpoints, and behavioural measures) were identified as having problems of feasibility or applicability. For maximum waiting time, this was because the in-parlour assessor had not been able to identify the time of arrival for all herds at the collecting yard on many of the farms assessed in the present study, although this was not the case in the pilot study [6]. This issue could be simply solved by ensuring that the outside assessor recorded herd arrival time and milking finish time alongside locomotion scoring. That assessor can record when a new group of cows enters the collecting yard and when the last cow of that group has finished milking. For the latter, the last cow in a group can be identified by the outside observer, as the farm staff

will have to change gates to ensure that the new group (if there is one) goes to a different paddock than the previous one.

The remaining two assessments (distance between waterpoints and behavioural measures) require significant modification before inclusion. Distance between waterpoints was used by Kaurivi et al. [20] as a simple proxy for water availability. However, it was not applicable on these farms, as the rotational grazing system meant that cows were grazed on relatively small fenced-off paddocks [21]. In this study, paddocks generally only had one water trough, so the distance between water troughs could not be measured. Even though the paddock had two troughs, they were partitioned by fencing for grass management, so only a single trough was available for drinking. However, water availability is a key welfare issue, so alternatives are required. One potential alternative is to estimate the water requirements of the largest herd on a farm and then measure whether the trough can supply water at a sufficient rate to meet those requirements. Measurement of the refilling rate can be time-consuming, especially if multiple troughs are assessed. Another alternative is to measure trough capacity and ensure trough volume is at least half of the hourly demand (See: Farm Water Quantity and Quality. [https://www.dairynz.co.nz/media/254175/5-15\\_Farm\\_water\\_quantit-and\\_quality.pdf](https://www.dairynz.co.nz/media/254175/5-15_Farm_water_quantit-and_quality.pdf) (accessed on 1 December 2021)). Water requirements are very variable on New Zealand dairy farms [22], but an estimate of 70 L/cow/day supplied over 5 h (i.e., 14 L/cow/h) is likely to cover most situations. A quicker alternative, based on a suggestion by [22], is that at least 10% of the cows in a herd should be able to drink at once—equivalent to 50 cm of available trough space per cow. However, as identified by Jensen et al. [23], further research on the effect of these recommendations on competition, drinking behaviour, and water intake in dairy cows at pasture is required to establish that these are truly optimal recommendations.

Assessment of agonistic and positive behaviours also requires significant modification. Thirty minutes were set aside to observe behaviour while the cows were in the paddock before milking. No behaviours were observed on 4/16 farms and the total number of behaviours recorded was low. Additionally, the maximum rate of observed agonistic behaviour was only  $\sim 0.1$  interaction/cow/h (assuming  $\sim 300$  cows in each group, which is  $\sim 1/10$  of the rate reported in cows at pasture by [24]). However, this rate calculation ignores the issue of identifying the true denominator when observing a group of 300 cows at pasture. One observer cannot simultaneously observe 300 cows, and it is likely that their attention will be principally drawn to cows that are nearer to the observer (i.e., close to the paddock exit). So the true denominator is likely to be less than  $300 * 0.5$  cow hours, but it is likely to vary depending on farm, paddock, and cow behaviour. One potential alternative is to simply record the number of cows that are easily observed and use that number as the denominator. However, it is likely that position within a field prior to milking is related to cow status [25], so simply recording behaviours of those cows may not reflect behaviour across the herd.

The low numbers observed may also in part be an issue of observation timing; [26] reported agonistic and grooming behaviour peaked when cattle returned to pasture after milking. However, even if the timing is changed, identifying differences between farms when the expected rate of behaviours is low [24,26] is likely to require a much longer observation period than used in this study. This would significantly add to the time required without necessarily adding value. The focus of the assessment of behaviours is to provide “indices of animals’ perceptions of their external circumstances” [27]. As such, it is unclear how useful assessment of behaviour at pasture when grass growth is at or near its peak (October/November in New Zealand [21]) is as an assessment of on-farm welfare. Measurement of behaviours when pasture availability is more likely to be restricted (e.g., in winter, which coincides with the late dry period and early lactation) is likely to be more useful, as feed restriction may be associated with increased aggression [28]. Such an assessment would thus need a separate visit in addition to the visit in October/November. However, even in such a situation measurement of the behaviour of cows at pasture for a short period just prior to milking is not a useful assessment. Further research is required on

how best to assess behaviour-related welfare in cows at pasture, in particular, to determine what indicators should be used to identify positive behaviours [29], as well as to determine the optimal timing of such observations (during the day and across the year), the required observation duration, and the best way to observe a representative proportion of the herd.

This protocol was designed to be a time-limited assessment of milking cattle, so it is not aimed to be a comprehensive welfare assessment. It is thus inevitable that there will be compromises. Some of these compromises involve reducing the time spent assessing a particular welfare measure. This is particularly clear in regard to behavioural assessment, but it also applies to two of the animal-based assessments included in the final protocol, visual assessment of injuries and broken tails.

Visual assessments of injuries were assessed at a combined level, i.e., no separate scoring of cuts, abrasions, or swellings, or recording of the site of injury. This approach, while simple, lacks potentially useful details, and does not distinguish between cows with one or multiple injuries. Similarly, rather than using palpation, broken tails were assessed using visual assessment. This is faster but may be less sensitive and specific than palpation. If visual assessment of broken tails is to be used, its specificity and sensitivity compared to palpation need to be estimated.

Another issue is that this protocol is based on a single assessment point. In contrast to non-seasonal herds where cattle are at different points in their lactation cycle at the same point in time, in seasonally calving herds cattle are all at the same lactation stage. Thus, for measures such as body condition score and lameness, which vary considerably with the lactation stage [30,31], measurement at a single time point may not capture a farm's true welfare status. Additionally, there are specific welfare challenges related to the season on New Zealand farms, such as cows self-feeding on root or leaf forages (e.g., fodder beet) during winter (See: End Intensive Winter Grazing. <https://www.youtube.com/watch?v=9sJZgQ3yNTA> (accessed on 1 December 2021)) or pasture restriction, which will be missed if the assessment is restricted to just one timepoint within a year.

Nevertheless, we believe that, given these constraints, this is a practicable and feasible protocol that can be used to provide a reasonable assessment of the welfare of pasture-based cows in a single visit. However, further testing on more farms with more assessors in order to provide details on repeatability and reliability of the measures included in our protocol are required.

The thresholds used in this study were based on the author's opinion and are not intended to be definitive, but rather a starting point for discussion. Additionally, this was a convenience sample of farms in two regions in New Zealand, so we do not know how representative the results from our study farms are of farms across New Zealand. Nevertheless, using our thresholds, it was clear that shelter and shade were issues on all the dairy farms examined, with none of the farms having acceptable areas of either shade or shelter. In a pasture-based system, it is recognised that shade and shelter are important for at least part of the year [32], but they seem to be a low priority on dairy farms in New Zealand. Comparing these results to those from [15] on beef farms on the North Island of New Zealand, it is instructive that the only farm that they recorded as having insufficient shelter was a farm that was being converted to beef from dairy.

The other resource-based assessments in which a high proportion of study farms were identified as being in either our marginal or unacceptable category were the cleanliness of drinking troughs and track condition. For the former, 11 out of 23 farms had at least one unacceptably dirty trough. This was principally because most farms which used a feed pad (a designated, usually concrete, area, for feeding supplementary feeds, e.g., concentrates, palm kernel extract, and/or silages) had dirty troughs, as animals eat the supplementary feed and then drink from and contaminate the troughs. Our data thus suggest that more attention needs to be paid to managing this issue. Track quality was marginal or worse on 21/23 farms. As a major factor associated with the development of lameness [33], it is disappointing that track quality was not better. However, it is possible that the high proportion of farms categorised as marginal or unacceptable reflects a very

rigorous assessment of track conditions. Despite the study being undertaken at the expected time of peak lameness prevalence in North Island dairy herds [30], all of the herds had <10% lameness with 20/23 having <5%. This reflects how animal-based measures indicate actual welfare problems and resource-based measures indicate potential welfare problems.

For the animal-based assessments, comparisons of percentiles and the author-imposed thresholds identified three conditions where mean and median percentages were outside our acceptable ranges (Table 6). These were dirtiness, coughing, and broken tails. Dirtiness was also identified by Fabian et al. [30] as an issue on the pasture-based dairy farms that they assessed in New Zealand. However, as those authors stated, in contrast to housed cows where dirtiness often reflects faecal contamination, under New Zealand's conditions dirtiness reflects soil contamination, which probably has less of a welfare impact than faecal contamination. Nevertheless, especially with the concern around winter grazing and mud (See: End Intensive Winter Grazing. <https://www.youtube.com/watch?v=9sJZgQ3yNTA> (accessed on 1 December 2021)), we need more data on the impact of cleanliness of New Zealand cows on other welfare outcomes (such as mastitis). For coughing, further research, particularly on the cause of the coughing, is required to better understand its welfare impact. This research could then be used to provide data for a more objective welfare threshold for coughing in pasture-based dairy cattle.

The final condition identified as having a median within-herd prevalence higher than the upper threshold of the acceptable welfare zone was broken tails. Despite tails being observed rather than palpated, which would miss non-deviated broken tails with small swellings, we still observed broken tails in ~10% of cows. These results are consistent with previous reports from New Zealand [14] and support their conclusion that more needs to be done to reduce the prevalence of broken tails in New Zealand dairy cattle.

This is a descriptive study undertaken on a convenience sample of farms. Thus, we need more data from a representative, preferably randomly sampled, sample of farms across New Zealand to better establish how our thresholds are reflected on dairy farms across New Zealand. Such a study could be undertaken alongside the assessment of the repeatability and reliability of the measures included in our protocol.

## 5. Conclusions

This study has shown that the time-limited protocol we developed in a previous study was generally feasible to use across a range of farms. We believe that after further testing for repeatability and reliability with multiple observers and further discussion and testing of thresholds for determining whether welfare is acceptable or not, this protocol can form the basis of a welfare assessment protocol for pasture-based dairy cattle in New Zealand and elsewhere.

**Supplementary Materials:** The following are available online at <https://www.mdpi.com/article/10.3390/ani12182481/s1>, Table S1: Percentage figure for animal-based measures recorded from 23 different pasture-based dairy farms of New Zealand, Table S2: Result for measures derived from questionnaire with the farmers from 23 different pasture-based dairy farms, File S1: Shade/paddock calculation, File S2: Questionnaires related to the records and management-related measures, Table S3: Results for gate speed and space available per cow in the collecting yard during milking.

**Author Contributions:** Conceptualization, S.S., R.L., K.R.M. and N.K.; methodology, S.S., R.L., K.R.M. and N.K.; software, S.S.; validation, S.S., R.L., K.R.M. and N.K.; formal analysis, S.S.; investigation, S.S.; resources, S.S.; data curation, S.S. and R.L.; writing—original draft preparation, S.S.; writing—review and editing, R.L., K.R.M. and N.K.; visualization, S.S.; supervision, R.L., K.R.M. and N.K.; project administration, R.L., K.R.M. and N.K.; funding acquisition, R.L., K.R.M. and N.K. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by the SoVS Post Graduate Research Fund.

**Institutional Review Board Statement:** Not applicable.

**Data Availability Statement:** Not applicable.

**Acknowledgments:** We appreciate the help from the staff of the Farm Services, Massey University, and VetEnt Waikato during data collection. Additionally, we would like to thank Winston Mason for his support in arranging the farm visits in Waikato. Special thanks to all the hard-working farmers who provided us the opportunity to conduct our study.

**Conflicts of Interest:** None of the authors has any financial or personal relationships that could inappropriately influence or bias the content of the paper.



## References

1. Whay, H.; Main, D.; Green, L.; Webster, A. Assessment of the welfare of dairy cattle using animal-based measurements: Direct observations and investigation of farm records. *Vet. Rec.* **2003**, *153*, 197–202.
2. Quality, W. Welfare Quality® Cattle Protocol without Veal Calves. 2012. Available online: <http://www.welfare-qualitynetwork.net/network/45848/7/0/40> (accessed on 16 July 2022).
3. EFSA Panel on Animal Health and Welfare. Statement on the use of animal-based measures to assess the welfare of animals. *EFSA J.* **2012**, *10*, 2767.
4. Winckler, C.; Capdeville, J.; Gebresenbet, G.; Hörning, B.; Roiha, U.; Tosi, M.; Waiblinger, S. Selection of parameters for on-farm welfare-assessment protocols in cattle and buffalo. *Anim. Welf.* **2003**, *12*, 619–624.
5. Laven, R.; Fabian, J. Applying animal-based welfare assessments on New Zealand dairy farms: Feasibility and a comparison with United Kingdom data. *N. Z. Vet. J.* **2016**, *64*, 212–217.
6. Sapkota, S.; Laven, R.; Müller, K.; Kells, N. Animal Welfare Assessment: Can We Develop a Practical, Time-Limited Assessment Protocol for Pasture-Based Dairy Cows in New Zealand? *Animals* **2020**, *10*, 1918.
7. Ferguson, D.; Colditz, I.; Collins, T.; Matthews, L.; Hemsworth, P. Assessing the welfare of farm animals: A review. In *Final report to the National Animal Welfare Research, Development & Extension Strategy Committee*; Australian Pork Limited: Canberra, Australia, 2013.
8. Hampton, J.O.; Jones, B.; McGreevy, P.D. Social license and animal welfare: Developments from the past decade in Australia. *Animals* **2020**, *10*, 2237.
9. Fraser, D. Assessing animal welfare at the farm and group level: The interplay of science and values. *Anim. Welf.* **2003**, *12*, 433–443.
10. Ventura, B.A.; Von Keyserlingk, M.A.; Wittman, H.; Weary, D.M. What difference does a visit make? Changes in animal welfare perceptions after interested citizens tour a dairy farm. *PLoS ONE* **2016**, *11*, e0154733.
11. Alonso, M.E.; González-Montaña, J.R.; Lomillos, J.M. Consumers' concerns and perceptions of farm animal welfare. *Animals* **2020**, *10*, 385.
12. Sandøe, P.; Hansen, H.O.; Rhode, H.L.H.; Houe, H.; Palmer, C.; Forkman, B.; Christensen, T. Benchmarking farm animal welfare—A novel tool for cross-country comparison applied to pig production and pork consumption. *Animals* **2020**, *10*, 955.
13. Shadbolt, N. DairyBase: Building a best practice benchmarking system. In *Benchmarking in Food and Farming*; Routledge: London, UK, 2016; pp. 53–62.
14. Laven, R.; Jermy, M. Measuring the torque required to cause vertebral dislocation in cattle tails. *N. Z. Vet. J.* **2020**, *68*, 107–111.
15. Kaurivi, Y.B.; Hickson, R.; Laven, R.; Parkinson, T.; Stafford, K. Developing an animal welfare assessment protocol for cows in extensive beef cow-calf systems in New Zealand. Part 2: Categorisation and scoring of welfare assessment measures. *Animals* **2020**, *10*, 1592.
16. Aubé, L.; Mialon, M.; Mollaret, E.; Mounier, L.; Veissier, I.; des Roches, A.d.B. Assessment of dairy cow welfare at pasture: Measures available, gaps to address, and pathways to development of ad-hoc protocols. *Animal* **2022**, *16*, 100597.
17. Kaurivi, Y.B.; Laven, R.; Hickson, R.; Stafford, K.; Parkinson, T. Identification of suitable animal welfare assessment measures for extensive beef systems in New Zealand. *Agriculture* **2019**, *9*, 66.
18. Ranjbar, S.; Rabiee, A.; Gunn, A.; House, J. Identifying risk factors associated with lameness in pasture-based dairy herds. *J. Dairy Sci.* **2016**, *99*, 7495–7505.
19. Armson, D.; Stringer, P.; Ennos, A. The effect of tree shade and grass on surface and globe temperatures in an urban area. *Urban For. Urban Green.* **2012**, *11*, 245–255.
20. Kaurivi, Y.B.; Laven, R.; Hickson, R.; Parkinson, T.; Stafford, K. Developing an animal welfare assessment protocol for cows in extensive beef cow-calf systems in New Zealand. Part 1: Assessing the feasibility of identified animal welfare assessment measures. *Animals* **2020**, *10*, 1597.
21. Holmes, C.W.; Wilson, G.F.; Mackenzie, D.; Flux, D.; Brookes, I.; Davey, A. *Milk Production from Pasture*; Butterworths of New Zealand Ltd.: Wellington, New Zealand, 1987.
22. Harrington, G.J. *Water consumption of sheep and cattle in New Zealand*; Project Report-New Zealand Agricultural Engineering Institute: Canterbury, New Zealand, 1980.
23. Jensen, M.B.; Vestergaard, M. Invited review: Freedom from thirst—Do dairy cows and calves have sufficient access to drinking water? *J. Dairy Sci.* **2021**, *104*, 11368–11385.
24. Miller, K.; Wood-Gush, D. Some effects of housing on the social behaviour of dairy cows. *Anim. Sci.* **1991**, *53*, 271–278.

25. Sauter-Louis, C.; Chesterton, R.; Pfeiffer, D. Behavioural characteristics of dairy cows with lameness in Taranaki, New Zealand. *New Zealand Vet. J.* **2004**, *52*, 103–108.
26. O’Connell, J.; Giller, P.; Meaney, W. A comparison of dairy cattle behavioural patterns at pasture and during confinement. *Ir. J. Agric. Res.* **1989**, *28*, 65–72.
27. Mellor, D.J.; Beausoleil, N.J.; Littlewood, K.E.; McLean, A.N.; McGreevy, P.D.; Jones, B.; Wilkins, C. The 2020 five domains model: Including human–animal interactions in assessments of animal welfare. *Animals* **2020**, *10*, 1870.
28. Schütz, K.; Cox, N.; Macdonald, K.; Roche, J.; Verkerk, G.; Rogers, A.; Tucker, C.; Matthews, L.; Meier, S.; Webster, J. Behavioral and physiological effects of a short-term feed restriction in lactating dairy cattle with different body condition scores at calving. *J. Dairy Sci.* **2013**, *96*, 4465–4476.
29. Keeling, L.J.; Winckler, C.; Hintze, S.; Forkman, B. Towards a positive welfare protocol for cattle: A critical review of indicators and suggestion of how we might proceed. *Front. Anim. Sci.* **2021**. [[CrossRef](#)]
30. Fabian, J.; Laven, R.; Whay, H. The prevalence of lameness on New Zealand dairy farms: A comparison of farmer estimate and locomotion scoring. *Vet. J.* **2014**, *201*, 31–38.
31. Pryce, J.; Harris, B. Genetics of body condition score in New Zealand dairy cows. *J. Dairy Sci.* **2006**, *89*, 4424–4432.
32. Laven, R.; Holmes, C. A review of the potential impact of increased use of housing on the health and welfare of dairy cattle in New Zealand. *N. Z. Vet. J.* **2008**, *56*, 151–157.
33. Chesterton, R.; Pfeiffer, D.; Morris, R.; Tanner, C. Environmental and behavioural factors affecting the prevalence of foot lameness in New Zealand dairy herds—A case-control study. *N. Z. Vet. J.* **1989**, *37*, 135–142.

## STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the candidate and the candidate's Primary Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of candidate:	Sujan Sapkota
Name/title of Primary Supervisor:	Richard Laven
In which chapter is the manuscript /published work:	Chapter 4
Please select one of the following three options:	
<input checked="" type="radio"/> The manuscript/published work is published or in press <a href="https://doi.org/10.3390/ani12182481">https://doi.org/10.3390/ani12182481</a>	
<input type="radio"/> The manuscript is currently under review for publication – please indicate: <ul style="list-style-type: none"> <li>• The name of the journal:</li> <li>• The percentage of the manuscript/published work that was contributed by the candidate: 75%</li> <li>• Describe the contribution that the candidate has made to the manuscript/published work:              main researcher, conceptualisation, methodology, main writing</li> </ul>	
<input type="radio"/> It is intended that the manuscript will be published, but it has not yet been submitted to a journal	
Candidate's Signature:	
Date:	05/01/24
Primary Supervisor's Signature:	
Date:	05/01/24

This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/publication or collected as an appendix at the end of the thesis.

## **Chapter 5: Can We Predict a Herd Level Prevalence of Lameness by Sub-Sampling the Herd?**

**Foreword:** The welfare assessment protocol developed in the chapter 3 and chapter 4 used an additional assessor just to perform whole herd locomotion scoring. So, the aim of this study was to determine whether sub-sampling-based locomotion scoring (first 100, middle 100, and last 100) could accurately predict the lameness prevalence of the whole milking herd.

## **Chapter 5: Can We Predict a Herd Level Prevalence of Lameness by Sub-Sampling the Herd?**

**Abstract:** When developing our time-limited welfare assessment focused on assessment during milking time for New Zealand dairy farms, an additional assessor was needed either outside the milking parlour solely to locomotion score, or to locomotion score at one milking and assess the remaining animals-based measures at a subsequent milking. The requirement to locomotion score thus significantly increases the cost of welfare assessment. The research aimed to assess whether scoring the first 100, middle 100, and last 100 cows during milking can predict the herd-level prevalence of lameness on New Zealand dairy farms. Six pasture-based dairy farms in the Manawatu district, New Zealand, were conveniently selected for study between October 15, 2021, and May 10, 2022. Visits occurred at approximately 6-week intervals, five visits in total for most farms (only 4 visits for the last farm). Cows were lameness-scored on a flat surface after leaving the milking parlour, where the assessor tallied the order of cows leaving the parlour and recorded those with a lameness score of  $\geq 2$ , along with their milking order. Of the 263 lame cow observations, 40.7% were in the last 100 cows, 25.9% in the middle 100, and 14.4% in the first 100. All interactions between the group, farm, and visit were statistically significant ( $P < 0.001$ ). While, overall, the last 100 cows showed the highest proportion of lame cows, this pattern varied across farms. For instance, on Farm 6, the last 100 had fewer lame cows than the middle 100, whereas on Farm 2, the first 100 had more lame cows than the middle 100. The limits of agreement plots showed that as the herd prevalence increased for all three groups, the agreement between group prevalence and the overall herd prevalence decreased. However, when the mean prevalence exceeded 5%, it was only the middle 100 group that exhibited a difference between overall and group prevalence with clearly less than 5%. This suggests that there will be variations across farms and seasons in the proportion of lame cows identified by sampling and thus variations in the accuracy of predicting overall lameness from such a sample. We need more research on a larger number of farms to better characterise the accuracy of scoring the middle 100 cows, and to test strategies using scoring the middle 100 cows as a screening test followed by whole herd lameness scoring.

## 5.0 Introduction

Lameness in dairy cattle is a critical concern affecting the global dairy industry, with detrimental effects on fertility (Alawneh et al., 2011) and milk production (Green et al., 2002) resulting in increased management and treatment costs (Ózsvári, 2017). Moreover, it also poses a significant welfare issue, causing pain and distress that can impact the health, and behaviour of the affected animals (Whay & Shearer, 2017).

In New Zealand, the most commonly used method for actively detecting lameness is locomotion scoring, with the Dairy NZ 4-point lameness score (DairyNZ, 2017), being the industry-recognised system. Typically, cows are locomotion-scored after they are released from the milking parlour as they walk along a flat, usually concrete, surface (Fabian et al., 2014). Thus, to locomotion score the whole herd necessitates an observer who is present outside the milking parlour for the whole of the milking. This may be difficult to achieve on a routine basis on many New Zealand farms because of the high ratio of cows-to-staff (DairyNZ, 2022). In addition, estimating the herd prevalence of lameness by locomotion scoring is an essential part of the welfare assessment of dairy cows (Laven & Fabian, 2016). This meant that when developing a time-limited welfare assessment focused on assessment during milking time for New Zealand dairy farms, an additional assessor was needed either outside the milking parlour solely to locomotion score, or to locomotion score at one milking and assess the remaining animals-based measures at a subsequent milking (Sapkota et al., 2022). The requirement to locomotion score thus significantly increases the cost of welfare assessment.

Alternatives to whole herd locomotion scoring are required. One possible alternative is in-parlour scoring (Werema et al., 2022), which could allow a single assessor to record lameness alongside other animal-based welfare measures. However, it needs further development and testing before it can be recommended as an alternative to locomotion scoring. The same applies to automatic scoring and recording of lameness. O'Leary et al. (2020) suggested that any automatic recording system would need to have greater than 90% sensitivity and 99% specificity to be of significant value on most farms for lameness management. No systems with proven accuracy that exceed these targets are currently available in New Zealand. A lower specificity (such as 95%) might be thought to be acceptable for welfare assessment but,

using a system with 90% sensitivity and 95% specificity would significantly increase the apparent prevalence of lameness on New Zealand farms. Based on the results from Sapkota et al. (2022) where the interquartile range (IQR) for lameness prevalence (from whole herd locomotion scoring) across the 23 study farms was 1.2 to 3.8%; the IQR of the apparent prevalence using an automatic system with 90% sensitivity and 95% specificity would have been 6 to 8.2%, i.e. >75% of all farms would have had an apparent prevalence greater than our acceptable threshold of 5%, when the figure based on whole herd locomotion scoring was <25%.

One method used in welfare assessment to reduce the time taken for locomotion scoring during welfare is using a sampling strategy (Sørensen et al., 2007). In housed cows, random sampling of a herd can be used as individual cows can be easily selected and locomotion scored alongside other welfare assessments (Van Os et al., 2019), but this process is more difficult in cows at pasture, at least in part because they need to be moved away from pasture to be locomotion scored. Scoring after milking greatly simplifies the random sampling process, but still means that the assessor has to be present outside the milking parlour for the whole of the milking. An alternative to random sampling is targeted sampling of a specific subgroup.

According to Main et al. (2010), sampling a maximum of 100 cows from the middle of the milking order in 36 herds with over 100 cows resulted in an estimated prevalence that was within 5% of the actual prevalence on 83% of farms (i.e., 30 out of 36 farms). Thus, they (Main et al., 2010) suggested that a viable approach to sampling could involve observing up to 100 cows from the middle of the milking sequence. In a subsequent study, Beggs et al. (2019) found that the prevalence of lameness in the last 200 cows in the milking order was always within 5.4% of the overall prevalence. However, no similar study has been undertaken under New Zealand conditions. The objective of the present study was to build on the sub-sampling locomotion scoring strategy used by Main et al. (2010) and assess whether scoring the first 100, middle 100 and last 100 cows in the milking order could be used to predict the herd-level prevalence of lameness on New Zealand dairy farms.

## 5.1 Materials and Method

A convenience selection was made of six spring-calving pasture-based dairy farms (see Appendix 1) in the Manawatu district of the North Island of New Zealand. Between October 15, 2021 (early lactation, and May 10, 2022 (late lactation), the study farms were visited five times at ~ 6-week intervals, except for one farm where the last visit did not occur.

Cows were scored for lameness on a flat hard surface, immediately on leaving the milking parlour after being milked. Cows' locomotion was scored by the first author, using the DairyNZ Lameness Score (DairyNZ, 2017). The number of cows scored was tallied and if any cows had a lameness score of  $\geq 2$ , the number on the tally was recorded as the number of that cow in the milking order. In farms where multiple milking herds were present (total 2 farms), only the first herd to be milked was included in the study and lame cow mob was not considered in this study. Data from visits where  $< 200$  cows were scored were excluded from all analyses.

## 5.2 Statistical methods

The effect of farm, visit, and sampled group (first, middle, or last 100) on the proportion of lame cows identified was analysed using repeated measures generalised estimating equation with the proportion of all lame cows identified in the group as the outcome variable and farm visit and group as the predictor variables. The model included all main effects (farm, visit, and sampled group) and all 2-way interactions. For this analysis, all visits (total of 3) where no lame cows had been identified were excluded.

To determine the level of agreement between the overall lameness prevalence as determined by whole herd locomotion scoring (%) and lameness prevalence identified through locomotion scoring of the first 100, middle 100, and last 100 cows milked, three limits of agreement plots were created using R (R Foundation for Statistical Computing, Vienna, Austria), with regression analysis used to account for any association between the mean and difference of the two methods and between the mean and the variance of that difference as per Bland & Altman (1999).

### 5.3 Results:

Farm details are summarised in Table S1. Of the six farms three milked their cows twice daily through a rotary platform, while the remaining three milked their cows once a day through a herringbone parlour (See Appendix 1).

#### 5.3.1 Descriptive Statistics

Across the 28 visits on six farms, 8872 lameness scores were recorded, of which 263 (3.29%) were recorded as lame (lameness score  $\geq 2$ )

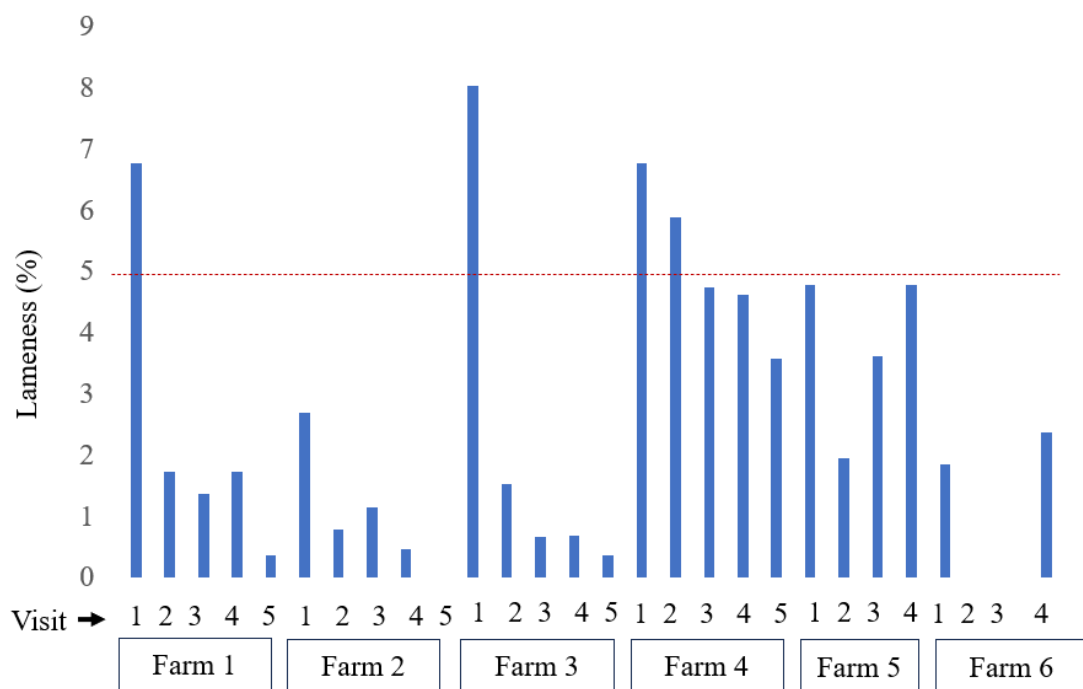


Figure 1: Proportion of total lame cows by farm and visit on dairy farms in the North Island of New Zealand (~6 weekly visits from mid-October to mid-May). Red line represents an acceptable welfare threshold for Lameness (%) in New Zealand set by Sapkota et al. (2020).

Of the 28 farm visits, herd lameness prevalence was greater than 5% (the threshold set for acceptable welfare set by Sapkota et al. (2022) on four occasions (see Figure 1). Of those four occasions all but one was observed on the first visit for a farm (i.e., in mid-October to mid-November (see Figure 1).

Of the 263 lame cow observations, 107 (40.7%) were made in the last 100 cows in the milking order, with 68 (25.9%) and 38 (14.4%) in the middle 100 and first 100, respectively. All interactions were statistically significant ( $P < 0.001$ ), i.e., the proportion of lame cows identified within a milking order group by farm, and by visit. This is illustrated for the interaction between group and farm. Although, overall, observing the last 100 cows in the milking order identified the highest proportion of lame cows (estimated marginal mean from the model (EMM) 0.5; 95%CI 0.48-0.52), observing the middle 100 the next highest proportion (EMM 0.26; 95%CI 0.25-0.28) and observing the first 100 the lowest (0.14; 95% CI 0.12-0.17), this pattern was only seen on 3/6 farms (see Figure 2). For example, a lower proportion of lame cows was observed in the last 100 (compared to the middle 100) on farm 6 (EMM 0.79; 95% CI 0.74 -0.84 vs 0.58; 95% CI 0.56 - 0.61, respectively), while on Farm 2 lame cows were more likely to be observed in the first 100 than the middle 100 (EMM 0.22; 95% CI 0.20-0.25 vs 0.07; 95% CI 0.07-0.08).

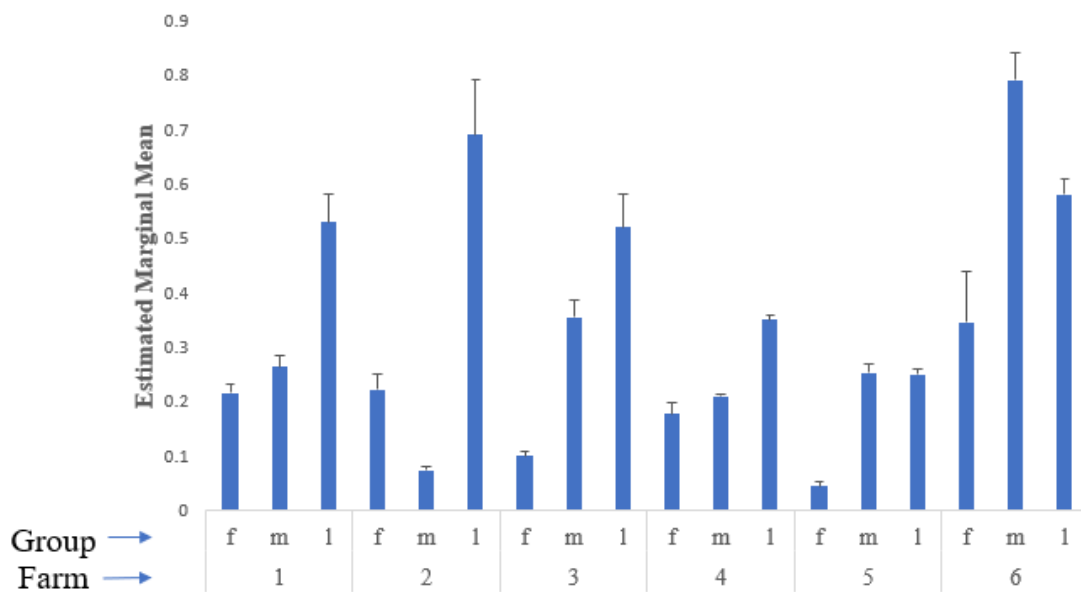
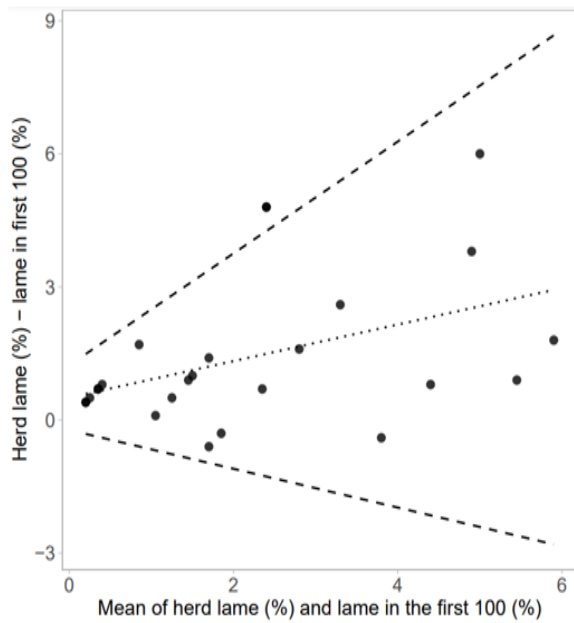


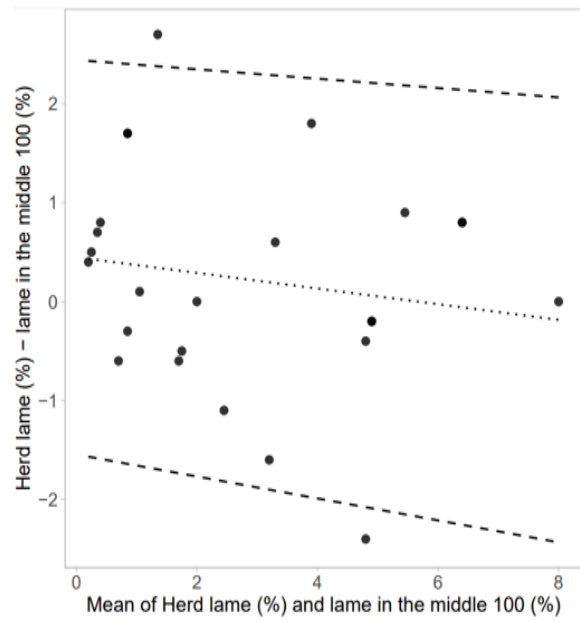
Figure 2: Estimated marginal mean (95%CI) of the proportion of total lame cows observed the first 100 (f), middle 100 (m), and last 100 (l) cows in the milking order for individual farms.

### 5.3.2 Limits of agreement

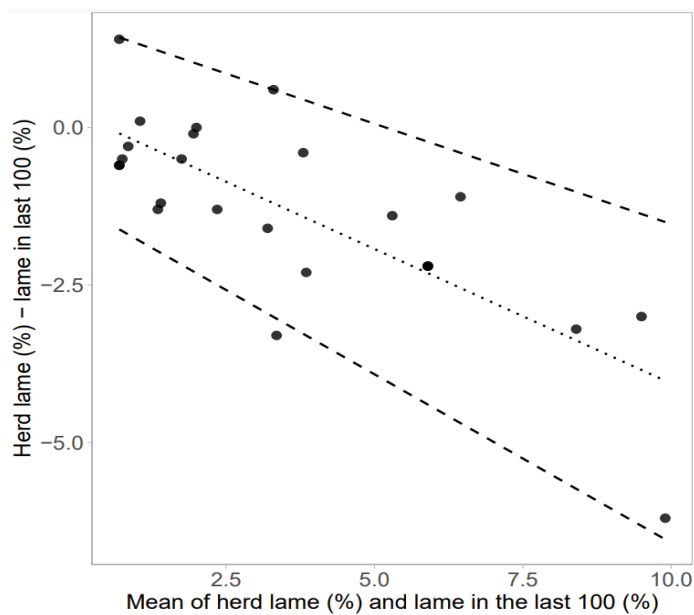
Figure 3 shows the limits of the agreement plot for overall herd lameness percentage and percentage lame in each milking order group. In all three cases, adjustment for association between mean and difference and mean and the variance of that difference improved the fit of the model. The equations for the limits of agreement along with the estimated limits of agreement for a mean prevalence of 1% and 6% are presented in Table 1.



(a)



(b)



(c)

Figure 3: Regression-based Bland-Altman plots showing the relationship of mean and difference for a) % lame overall and % lame in first 100 cows in milking order, b) % lame overall and % lame in middle 100 cows in milking order, and c) % lame overall and % lame in last 100 cows in milking order. Dotted (....) line; line of best fit, dashed (---)limits of agreement.

For all three groups, the width of the limits of agreement increased as the mean of total lame and group lame increased (see Table 1); i.e. as herd prevalence increased, the agreement between group and whole herd prevalence decreased.

Table 1: Limits of Agreement (LOA) equation for all three sub-sample groups and the predicted LOA at mean of 1% and 6% respectively.

Sample groups	LOA equation	Predicted LOA* at 1%	Predicted LOA* at 6%
First 100	$0.4143 * \text{mean} + 0.493 \pm 1.96$ ( $0.4374 + 0.3941 * \text{mean}$ ).	-0.7 to 2.5	-3 to 8.8
Middle-100	$(-0.0772 * \text{mean} + 0.4346) \pm 1.96$ ( $0.0147 * \text{mean} + 1.020$ )	-1.7 to 2.4	-2.2 to 2.1
Last 100	$(-0.4248 * \text{mean} + 0.1889) \pm 1.96$ ( $0.055 * \text{mean} + 0.7389$ ).	-1.8 to 1.3	-4.5 to 0.3

\*Interpretation of predicted LOA: At the mean percentage, 95% of differences between total lameness % and lameness % in the sample group will be between the LOA, i.e., at a mean of 1% for first 100 and total lameness, it is expected that 95% of the time, the percentage of lame cows in the first 100 in the milking order will be between 0.7% lower than total lameness % and 2.5% higher.

#### 5.4 Discussion

The aim of this study was to assess whether a sampling strategy (based on scoring a specific group of 100 cows within the milking order) could reliably predict herd level prevalence of lameness on New Zealand dairy farms, with the aim of eliminating the need for an additional assessor to lameness score during a time-limited welfare assessment.

This study sampled three groups of cows: the first 100, the middle-100 and last 100 in the milking order, building on the study by Main et al. (2010.) Our initial analysis identified that, although overall the proportion of lame cows identified in each group was significantly different ( $P < 0.001$  for all comparisons), the effect of group varied markedly by farm and by visit. Consequently, even within a farm, there was no consistent proportion of lame cows that were found in each sample group. Thus, although our results are consistent with those of (Sauter-Louis et al., 2004) who reported that cows which became lame were more likely to be observed in the last quarter of the walking order after milking (milking order). They also showed that farm level and seasonal factors seem to affect the position of lame cows within the milking order. Both Sauter-Louis et al. (2004) and the current study are small studies (10 and 6 farms, respectively), so our results highlight the need for further larger studies of lameness and milking order. In particular, we need to study the impact, in cows permanently based at pasture, of lameness on milking order, as it is likely that farms in which lameness has less impact on milking order are managing their cows better between pasture and parlour than farms where lameness has more impact. This is because cows have a relatively narrow range of preferred positions within the milking order (Sauter-Louis et al 2004), and therefore if lameness is having less impact on milking order, this means that cows are able to maintain their preferred position within the herd.

Our limits of agreement showed that the difference in all sample group was within Main et al.'s (2010) target of estimating prevalence ( $\pm 5\%$ ) when mean prevalence was low ( $< 5\%$ ) but at a mean prevalence  $> 5\%$ , it is only the middle 100 where the difference between overall and group prevalence is clearly  $< 5\%$ . These results thus suggest that we can achieve Main's target of being within 5% of overall prevalence by lameness scoring the middle 100 in the milking order prevalence.

However, we question whether this 5% target is suitable for New Zealand. In a recent study, Mason et al. (2023) conducted lameness assessments on 120 farms during two distinct periods, once in the spring and once in the summer. Out of the 240 total assessment occasions, they identified instances where more than 10% of cows were lame on only 14 occasions.

Thus, simply assuming a constant 5% lameness prevalence on every farm (and not scoring any cattle) would have been within 5% of the true prevalence on over 95% of occasions. Similarly, in the survey from which the data used in this analysis came (Sapkota 2022) we scored 23 farms and found no farms with >10% prevalence.

Secondly, Sapkota et al.'s (2020) recommended acceptable welfare threshold for lameness of 5%, is much lower than that used in other countries with well-developed welfare assessment schemes (e.g. UK; 15% annual average prevalence (RSPCA, 2018), Netherlands; (<33% moderately lame cows) (Vries, 2013), Canada;  $\leq 10\%$ , (Code of Practice for the Care and Handling of the Dairy Cattle, 2023). Thus, setting a target accuracy of within  $\pm 5\%$  of the true value will not allow us to distinguish between farms with very low levels of lameness and ones with lameness prevalence equivalent to Sapkota et al.'s (2022) unacceptable threshold.

We thus need more accurate measurement of lameness than suggested by either Main et al. (2010) or Begg et al. (2019). Our data suggest that measuring the middle 100 would give us a measure of lameness within  $\sim 2\%$  of the true value 95% of the time. However, this is based on data from only 6 farms; we need far more data to confirm whether our finding is accurate. Secondly, 2% may not be sufficient to accurately categorise farms as having adequate welfare, based on the data from Mason et al (2023) using a sampling strategy with a 2% accuracy would have identified  $\sim 33\%$  of farms as within 2% of our adequate threshold, potentially leading to a significant proportion of farms being mischaracterised if sampling the middle 100 cows in the milking order was used. These studies also suggest that we need lower thresholds for assessing acceptable welfare thresholds. Thus, it may be better to use a sampling strategy as a screening test rather than an absolute measure of lameness prevalence. We believe that there are two potential strategies.

- 1) Score middle 100 cows and mark any farm with < 3 lame cows in that group as acceptable welfare and > 11 lame as unacceptable. For herds in between those thresholds, a whole herd lameness score would be used.

2) Score middle 100 cows and mark any farm with  $<3$  lame cows in that group as acceptable. However, in contrast to strategy 1, as soon as  $>2$  lame cows are identified in the middle 100, scoring is stopped and a whole herd lameness score arranged.

These strategies need to be tested, alongside better estimation of the accuracy of scoring only the middle 100 in the milking order, on a large number of farms, to determine which strategy combines optimal accuracy with minimal time requirement. Once the best strategy is identified, we need to determine how best to integrate into our time-limited welfare assessment protocol.

## **5.5 Conclusion**

The study showed that although, as expected, there was a significant association between milking order and risk of lameness, the proportion of lame cows identified within a particular group within that order (i.e., first 100, middle 100, and last 100) is not consistent and was significantly affected by farm and by timing of the visit. This suggests that there will be variations across farms and seasons in the proportion of lame cows identified by sampling and thus variations in the accuracy of predicting overall lameness from such a sample. This was confirmed using the limits-of-agreement analysis which showed that, consistent with Main et al. (2010), of the three milking order groups only scoring of the middle 100 cows in New Zealand pasture-based herds could predict whole herd prevalence within a 5% margin. Furthermore, even the  $\pm 2\%$  accuracy, for scoring the middle 100 cows, identified by our study may be insufficient for properly categorising farms based on their lameness prevalence. We need more research on a larger number of farms to better characterise the accuracy of scoring the middle 100 cows, and to test strategies using scoring the middle 100 cows as a screening test followed by whole herd lameness scoring when results are equivocal.

## References

- Code of Practice for the Care and Handling of Dairy Cattle (2023). Retrieved from <https://www.nfacc.ca/codes-of-practice/dairy-cattle/code2023#section5>
- Alawneh, J., Laven, R., & Stevenson, M. (2011). The effect of lameness on the fertility of dairy cattle in a seasonally breeding pasture-based system. *Journal of Dairy Science*, *94*(11), 5487-5493.
- Beggs, D., Jongman, E., Hemsworth, P., & Fisher, A. (2019). Lameness on Australian dairy farms: A comparison of farmer-identified lameness and formal lameness scoring, and the position of lame cows within the milking order. *Journal of Dairy Science*, *102*(2), 1522-1529.
- DairyNZ. (2017). Lameness field guide. Retrieved from [https://www.dairynz.co.nz/media/5787958/lameness\\_field\\_guide\\_july\\_2017\\_v2\\_web.pdf](https://www.dairynz.co.nz/media/5787958/lameness_field_guide_july_2017_v2_web.pdf)
- DairyNZ. (2022). Latest Dairybase Benchmarks. Retrieved from <https://www.dairynz.co.nz/business/dairybase/benchmarking/latest-dairybase-benchmarks/>
- Fabian, J., Laven, R., & Whay, H. (2014). The prevalence of lameness on New Zealand dairy farms: A comparison of farmer estimate and locomotion scoring. *The Veterinary Journal*, *201*(1), 31-38.
- Green, L., Hedges, V., Schukken, Y., Blowey, R., & Packington, A. (2002). The impact of clinical lameness on the milk yield of dairy cows. *Journal of Dairy Science*, *85*(9), 2250-2256.
- Heath, C., Lin, Y., Mullan, S., Browne, W., & Main, D. (2014). Implementing Welfare Quality® in UK assurance schemes: evaluating the challenges. *Animal Welfare*, *23*(1), 95-107.
- Heath, C., Main, D., Mullan, S., Haskell, M., & Browne, W. (2016). Sequential sampling: A novel method in farm animal welfare assessment. *Animal*, *10*(2), 349-356.
- Laven, R., & Fabian, J. (2016). Applying animal-based welfare assessments on New Zealand dairy farms: Feasibility and a comparison with United Kingdom data. *New Zealand Veterinary Journal*, *64*(4), 212-217.
- Main, D., Barker, Z., Leach, K., Bell, N., Whay, H., & Browne, W. (2010). Sampling strategies for monitoring lameness in dairy cattle. *Journal of Dairy Science*, *93*(5), 1970-1978.
- Mason, W., Müller, K., Huxley, J., & Laven, R. Prevalence of Lameness on Pasture-Based New Zealand Dairy Farms; An Observational Study. Available at SSRN 4527032.
- Ózsvári, L. (2017). Economic cost of lameness in dairy cattle herds. *J. Dairy Vet. Anim. Res*, *6*(2).
- Royal Society for the Prevention of Cruelty to Animals (2018). RSPCA welfare standards for dairy cattle. Retrieved from <https://science.rspca.org.uk/documents/1494935/9042554/RSPCA+welfare+standards+for+dairy+cattle+%28PDF+7.76MB%29.pdf/41638530-20de-c6cc-5e9c-7b73f9c8f4b7?t=1557731468543>

Sapkota, S., Laven, R., Müller, K. R., & Kells, N. (2022). Practicability of a Time-Limited Welfare Assessment Protocol for Pasture-Based Dairy Farms, and a Preliminary Assessment of Welfare Outcome Thresholds. *Animals*, 12(18), 2481.

Sauter-Louis, C., Chesterton, R., & Pfeiffer, D. (2004). Behavioural characteristics of dairy cows with lameness in Taranaki, New Zealand. *New Zealand Veterinary Journal*, 52(3), 103-108.

Vries, M. d. (2013). Assuring dairy cattle welfare. Retrieved from <https://edepot.wur.nl/258787>

Whay, H. R., & Shearer, J. K. (2017). The impact of lameness on welfare of the dairy cow. *Veterinary Clinics: Food Animal Practice*, 33(2), 153-164.

## Appendix

### Appendix 1 : Details of farm used for the study

Farm	Mob	Predominant breed	Milking Parlour	Milking frequency
1	Single	Holstein/Cross Breed	Herringbone	OAD
2	Single	Holstein/Cross Breed	Herringbone	OAD
3	Two	Jersey/Cross breed	Rotary	TAD
4	Single	Holstein/Cross Breed	Rotary	TAD
5	Single	Holstein/Cross Breed	Rotary	TAD
6	Single	Holstein/Cross Breed	Herringbone	OAD

Note: OAD: ONCE A DAY milking, TAD: TWICE A DAY milking

## **Chapter 6: Possible Consequences of Climate Change on Survival, Productivity and Reproductive Performance, and Welfare of Himalayan Yak (*Bos Grunniens*)**

Foreword: Climate change is a global issue that is likely to have significant impacts on yak and yak hybrids living in the Himalaya and are likely to be affected by it. This chapter reviews the possible impacts of climate change on the survival, welfare, production, and reproductive performance of yak in the Himalayan region and some potential solutions to these issues. The information collected in this chapter will help develop a deep insight into how the yak and yak hybrids are reared in the Himalaya using transhumance systems and the key areas that are likely to affect their welfare. This information will be helpful in the preparation of the welfare assessment protocols for transhumance yak and yak hybrids in Nepal.

Review

# Possible Consequences of Climate Change on Survival, Productivity and Reproductive Performance, and Welfare of Himalayan Yak (*Bos grunniens*)

S. Sapkota <sup>1,\*</sup>, K. P. Acharya <sup>2,3,\*</sup>, R. Laven <sup>1</sup> and N. Acharya <sup>4</sup><sup>1</sup> School of Veterinary Science, Massey University, Palmerston North 4442, New Zealand<sup>2</sup> Animal Quarantine Office, Department of Livestock Services (DLS), Kathmandu 44600, Nepal<sup>3</sup> Department of Veterinary Medicine, University of Cambridge, Madingley Road, Cambridge CB3 0ES, UK<sup>4</sup> Department of Pharmacology and Toxicology, The University of Texas at Austin, Austin, TX 78712, USA

\* Correspondence: s.sapkota1@massey.ac.nz (S.S.); kriaasedu@gmail.com (K.P.A.)

† These authors contributed equally to this work.

**Simple Summary:** Climate change is a global issue, with a wide range of ecosystems being affected by changing climatic conditions including the Himalaya. Yak are exquisitely adapted to the high-altitude conditions of the Himalaya and are thus highly likely to be affected by climate change. This paper reviews the evidence of how the reported impacts of climate change on the environment and ecosystem of the Himalaya are affecting the survival, productivity and welfare of Himalayan Yak. This review identified that we do not know how big the impact of climate change is on yak as very few papers have measured that impact and, in many cases, potentially climate-change-related effects (such as changes in feed supply) are principally driven by human factors.



**Citation:** Sapkota, S.; Acharya, K.P.; Laven, R.; Acharya, N. Possible Consequences of Climate Change on Survival, Productivity and Reproductive Performance, and Welfare of Himalayan Yak (*Bos grunniens*). *Vet. Sci.* **2022**, *9*, 449. <https://doi.org/10.3390/vetsci9080449>

Academic Editor: Adele M. Turzillo

Received: 20 July 2022

Accepted: 19 August 2022

Published: 22 August 2022

**Publisher's Note:** MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



**Copyright:** © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

**Abstract:** Yak are adapted to the extreme cold, low oxygen, and high solar radiation of the Himalaya. Traditionally, they are kept at high altitude pastures during summer, moving lower in the winter. This system is highly susceptible to climate change, which has increased ambient temperatures, altered rainfall patterns and increased the occurrence of natural disasters. Changes in temperature and precipitation reduced the yield and productivity of alpine pastures, principally because the native plant species are being replaced by less useful shrubs and weeds. The impact of climate change on yak is likely to be mediated through heat stress, increased contact with other species, especially domestic cattle, and alterations in feed availability. Yak have a very low temperature humidity index (52 vs. 72 for cattle) and a narrow thermoneutral range (5–13 °C), so climate change has potentially exposed yak to heat stress in summer and winter. Heat stress is likely to affect both reproductive performance and milk production, but we lack the data to quantify such effects. Increased contact with other species, especially domestic cattle, is likely to increase disease risk. This is likely to be exacerbated by other climate-change-associated factors, such as increases in vector-borne disease, because of increases in vector ranges, and overcrowding associated with reduced pasture availability. However, lack of baseline yak disease data means it is difficult to quantify these changes in disease risk and the few papers claiming to have identified such increases do not provide robust evidence of increased diseases. The reduction in feed availability in traditional pastures may be thought to be the most obvious impact of climate change on yak; however, it is clear that such a reduction is not solely due to climate change, with socio-economic factors likely being more important. This review has highlighted the large potential negative impact of climate change on yak, and the lack of data quantifying that impact. More research on the impact of climate change in yak is needed. Attention also needs to be paid to developing mitigating strategies, which may include changes in the traditional system such as providing shelter and supplementary feed and, in marginal areas, increased use of yak–cattle hybrids.

**Keywords:** yak; climate change; temperature; heat stress; diseases; welfare

## 1. Introduction

Domestic yak (*Bos (Poephagus) grunniens*) and their hybrids with domestic cattle (both *B. taurus taurus* and *B. t. indicus*) are hardy animals that are most commonly found in the highland regions of Asia including the Himalaya [1,2]. Yak are usually found in areas that are 3000 to 6000 m above sea level, and are adapted to extremely cold, harsh environments with low atmospheric oxygen concentrations and high levels of solar radiation [3]. They are used for a huge range of purposes including producing milk and milk products (cheese, butter, and whey), fuel (yak dung), meat, blood, fat, hair, and skins [4]. Yak are also used as a pack of animals, being able to travel up to 15 km per day in high-altitude areas [5] and carry loads of up to 100 kg in weight [5].

Like all *Bos* species, yak is a strict herbivore. They can graze/browse a wide range of vegetation from grass to small shrubs, grazing short forage like sheep (using their incisor teeth and lips), and browsing longer material like cattle (using their tongues to grasp plant material) [6]. Yak usually rely on natural vegetation as their feed source as supplementary feeding (other than wilted forages) is limited in most yak herding regions, including the Himalayas [7].

However, in traditional yak-farming areas, the growing season for natural vegetation is very short (e.g., 90–120 days on the Qinghai-Tibetan plateau) [8]. Temperature is the key factor limiting herbage growth, but rainfall during the warmer months also plays a crucial role [9]. This short grazing season has resulted in the main farming method used by traditional yak herders being transhumance pastoralism [10,11] with yak using high-altitude alpine pastures during summer and migrating to lower altitudes during winter. This migration also allows yak to encounter a relatively consistent ambient temperature throughout the year [3].

Despite this migration, from October to March, feed shortages are common due to thick snow layers over the winter pastures. During these shortages, wilted vegetation may be fed to yak, but, at best, this supplementary feeding is sufficient for maintenance only [12]. Thus during winter, yak usually lose body weight (up to 17–25%) and body condition and have an increased risk of mortality [13].

Yak are extremely well adapted to intense cold. They can survive ambient temperatures of  $-40^{\circ}\text{C}$ , and they perform best when the average annual temperature lies below  $5^{\circ}\text{C}$  and the average temperature in the hottest month is less than  $13^{\circ}\text{C}$  [6]. The key adaptations of yak to cold are: (1) a compact body shape with a short neck, limbs, and tail along with small ears resulting in a small surface area for heat loss; (2) a long thick fleece of outer hairs on the chest, legs, and flanks which traps air against the body; and (3) a thick but fine undercoat of downy hairs [12,14]. The outer hairs are produced by the primary hair follicles and the downy coat by secondary follicles; the balance between the two is highly seasonal, with significantly more secondary follicles being present in the cold seasons [14]. It is important to note that all of these adaptations are designed to reduce heat loss rather than increase heat production (which would be energetically difficult to achieve from winter forage). These adaptations, even with the seasonal loss of downy hair from secondary hair follicles, mean that yak are intolerant to heat stress. This is exacerbated by the lack of functional sweat glands with functional sweating being restricted to the muzzle region [15].

The reproductive performance of yak has a close relation to climate and season [16]. Although oestrus behaviour can be observed at most times of the year [7,17], yak are best considered as seasonal breeders (especially in areas such as the Himalaya) with conception and mating generally occurring during the warmer months of the year [16]. The start and end of the breeding season is determined by ambient temperature and relative humidity. These influence the availability of feed and fodder and thus the nutritional status of the yak. Nutrition is also the main factor influencing ovarian function (alongside a minor role for photoperiod) [18]. The timing of the breeding season has a close relationship with factors that determine climate, i.e., the latitude, longitude, and altitude of the pastures where yak are kept, with breeding season varying markedly across the Himalaya [7,19].

The following three issues mean that yak are likely to be exquisitely sensitive to climate change (especially increasing temperatures in both warm and cold months): (1) adaptation to cold environments; (2) reliance on alpine herbage for nutrition; (3) the close link between climate and fertility. Thus, the aim of this review was to identify the possible impacts of climate change on survival, welfare, production, and reproductive performance of yak in the Himalayan region and some potential solutions to these issues.

## 2. Climate Change in the Himalaya

The Himalayan ecosystem has been significantly affected by climate change [20]. The rise in temperature has altered climate patterns, destabilized the patterns/forms of water resources [21], and increased the risk of natural hazards [22] as well as affecting the growing cycle of plants, and the migratory pattern of animals [23].

### 2.1. Temperature

Based on data from 478 meteorological stations across the Hindu-Kush Himalayan region collected between 1961 and 2015, there had been a significant decrease in the number of extreme cold events (cold nights, cold days, and frost days) and a concomitant increase in the number of extreme warm events (warm nights, warm days, and summer days) (see Table 1 below) [24]. Similar trends have been reported in the western Himalaya [25].

**Table 1.** Trends of extreme temperature indices over the Hindu-Kush Himalaya region in the period 1961–2015. Source: Sun et al. [24].

Indicator Name	Definition	Trend (d/10 Years)
Cold nights	Days when $T_{\min} < 10$ th percentile	−0.977
Cold Days	Days when $T_{\max} < 10$ th percentile	−0.511
Warm nights	Days when $T_{\min} > 90$ th percentile	1.695
Warm days	Days when $T_{\max} > 90$ th percentile	1.239
Frost days	Annual count when $T_{\min} < 0$ °C	−3.636
Summer days	Annual count when $T_{\max} > 25$ °C	6.741

This increase in temperature is most marked in the winter season. Shrestha et al. [26] reported that, between 1982 and 2006, across multiple ecoregions in the Himalaya, there was a warming trend of 0.07 °C per year in the winter and 0.03 °C per year during the summer season. Current projection models suggest that this warming will continue; Shrestha et al. [27] estimated that, between 2020 and 2050, the average temperature across the Hindu-Kush Himalayan region will increase by 1–2 °C (and in some areas by 4–5 °C).

### 2.2. Precipitation

Average annual precipitation across the Himalaya increased by 163 mm (6.52 mm per year) between 1986 and 2006 [26]. This increase has been very seasonal, with an increase of 187 mm (7.48 mm per year) during the summer months but a decrease of 17 mm (−0.68 mm per year) during the winter months. Climate models suggest that precipitation will increase by an average of 5% (maximum 25%) between 2020 and 2050, with a longer and more erratic monsoon season with fewer but more intense extreme rainfall events [27]. This is likely to be particularly pronounced in the Eastern Himalaya, while the southern part will show a slightly decreasing trend in extreme rainfall events [27]. This shows that extremes of both rain and drought could potentially bring a challenge to the Himalayan ecosystem.

### 2.3. Vegetation

Temperature changes have meant that high-altitude, cold-adapted plant species have shifted to higher altitudes and been replaced by species that are better adapted to warmer temperatures [28]. This is evident in the shifting in the treeline by up to 0.37 m/year across the central Himalaya [29]. These changes have resulted in alterations in vegetation type,

with alpine meadows and herbs being replaced by shrubs [30–32]. This trend is predicted to continue, with higher CO<sub>2</sub> scenarios being associated with greater replacement of herbs by shrubs [32]. Shrub encroachment is probably the major climate-change-associated factor decreasing the availability and quality of grazing vegetation in the Himalaya [30,31].

The changes in precipitation patterns are also crucial. Variation in precipitation between years greatly influences the production of vegetation [33], with accumulated precipitation playing a key role in seasonal vegetation production in the Himalaya [33]. Although biomass reduction induced by insufficient precipitation will reverse after good rainfall/snowfall [34], the ability of the land to recover after water scarcity will gradually decrease over time [33]. The processes responsible for this decline in responsiveness include soil erosion, a decline in infiltration or moisture-holding capacity of the soil, loss of seed banks, and shrub encroachment [35]. These changes will result in a long-term continued decrease in forage biodiversity, availability, and quality, with Yang et al. [36] reporting that increasing shrub cover was associated with reduced total herbaceous forage production and with reduced crude protein intake by yak.

Extreme weather events such as floods, droughts, and high temperatures, the risks of which are increased by climate change, increase the likelihood of outbreaks of pests and other diseases in alpine vegetation, because they affect plant defence mechanisms and make them more susceptible to pests and pathogens [37].

The changes in temperature and rainfall patterns have resulted in an earlier start of the growing season and earlier bud outbreaks as well as increased germination rates [26]. The impacts are not solely beneficial. The changes in temperature and timings are especially beneficial for weed species which have become much more invasive, thus crowding out useful forage plants. Additionally, many of the forage species relied on by yak need snow cover to insulate them from the winter cold, so have been hit hard by the loss of that cover even though winter air temperatures have increased, while other species that require winter chilling for bud break may not get sufficiently low temperatures over a sufficiently long period for that to occur [38]. Even if we account for changes due to increased shrub cover, increased weed growth, and loss of forage during winter has meant that in many cases, the main impact of climate change on alpine yak pastures has been a reduction in yield and productivity, despite the apparent increase in the length of the growing season [39].

### 3. Yak Population

There is a lack of precise statistics in regard to the current population of domestic yak. According to Weiner [12], there are around 13–14 million domestic yak population in the world with majority of them being in China (Table 2). Outside of China domestic yak populations are declining in many countries, e.g., India, Bhutan, and Nepal [40–42]. In addition, increasing hybridisation has made it difficult to identify the population of pure domestic yak population.

**Table 2.** Recent estimates of domestic yak populations in Himalaya.

Country/Region	Yak Population (Year)	Reference
Tibet	4.9 million (not dated)	Song et al. [43] cited Zhang [44]
Bhutan	38,642 (2021)	[41]
India	57,570 (2019)	[40]
Nepal	65,406 (2020)	[42]
Pakistan	25,900 (2013)	[45]
Afghanistan	4600 (2015)	[46]

#### 4. Possible Consequences of Climate Changes on Yak

The thermo-neutral zone of yak ranges from 5–13 °C [6]. The risk of heat stress in yak can be assessed by measuring the temperature-humidity index (THI), which combines temperature and relative humidity. The yak's physiological focus on reducing heat loss means that, compared to cattle, the THI threshold above which yak are likely to begin experiencing heat stress is much lower (52 vs. 72 for yak and cattle, respectively) [47]. If the relative humidity is 65%, then air temperatures >13 °C will result in a THI > 52. The change in climate in the Himalaya has meant that this THI threshold is being increasingly exceeded even during winter [48], thus putting yak at higher risk of becoming heat stressed.

The pastoral nature of yak farming, especially in its traditional transhumance form, means that artificial heat stress mitigating strategies, such as providing shelters, are difficult to provide in many circumstances. This means that heat stress due to climate change could potentially have severe impacts on the health and welfare of farmed yak. However, to date, there have been no published studies that have directly evaluated the effect of this heat stress on the productivity, disease risk, and immune functions of yak. However, the results of previous studies on yak and related domestic species, especially cattle, have suggested that the increase in the number of days where the THI of yak is exceeded is likely to have negative impacts on physiology, production, immune function, and disease risk.

##### 4.1. Climate Change and Yak Physiology

The main effects of climate change on yak physiology are likely to be principally mediated through environmental temperature. Increased temperature leads to an increase in respiration rate as that is the yak's main method of heat dissipation [6]. If this increased temperature continues, pulse rate and, eventually, the rectal temperature will rise [49,50].

Another significant physiological change associated with environmental temperature is plasma cortisol concentration. In yak, plasma cortisol concentrations are lower in warmer months than in cooler seasons [51]. The physiological significance of this cortisol reduction is not clear, but it suggests that one of the adaptive mechanisms of the yak to prolonged elevated heat loads is decreasing adrenal cortical output as found in cattle [52–54]. Alongside this decrease in cortisol concentrations, lower blood glucose, and volatile fatty acid concentrations are also observed during the warm-humid seasons compared to the cold-humid seasons [50]. These changes in blood metabolites are consistent with the findings in cattle that cold exposure causes blood glucose concentrations to rise in response to increases in circulating thyroid and adrenal hormones which contribute to metabolic heat production [55].

One crucial physiological response to heat stress is the response of the reproductive system. Yak reproduction is affected by temperature, as yak are much more likely to come into oestrus during the early morning or evening than in the hotter parts of the day, and they are more likely to be seen in oestrus on overcast rather than clear days [56]. However, the underlying physiology of this effect is unclear, as there have been no published studies on reproductive physiology in yak and heat stress.

Studies in cattle may provide some guidance as to the likely effect of heat stress on reproductive physiology in yak. In cattle, heat stress has been shown to have effects across the whole of the oestrus cycle, for example, decreasing luteinising hormone concentrations and depressing the LH surge [57,58], while also stimulating premature luteinisation and increasing progesterone production [58]. Heat stress also impairs oocyte development and disrupts normal follicular function [59,60]. If these effects also occur in yak, it is unlikely that they will be simple to ameliorate once they occur.

##### 4.2. Climate Change and Reproductive Performance

Thus, the physiological changes associated with heat stress are likely to result in reduced reproductive performance. These impacts are likely to be exacerbated by the impacts of climate change on yak nutrition. As discussed earlier, nutrition is critically associated with yak reproduction. As the grass starts growing in May, the body condition

of yak begins to improve, and in June, dry females begin to exhibit oestrus peaking around July–August. Lactating yak have a delayed return to good body condition and, thus, tend to show oestrus later (September to November) than dry yak, and are more likely to be non-pregnant at the end of the breeding season [56]. The changes in forage availability and quality as a result of climate change are likely to delay the recovery of body condition in both dry and lactating yak, increasing the proportion that is non-pregnant at the end of the breeding season (especially lactating yak). It is also important to note that a reduction in forage quality and availability is also likely to impact the onset of puberty which is closely linked to nutrition [61]. Thus, climate change is likely to have long-term effects on yak fertility unless there is greatly increased use of supplementation.

It has also been suggested that abortion in yak may be related to heat stress [62], but this suggestion was based on data from one farm where ~40% of abortions occurred in May/June. This farm had a much higher rate of abortion than is normal for yak, so it is unclear how representative it is, and the conclusion was based only on the timing of the abortions, and no investigation of the cause of the abortions seems to have been undertaken. More research is needed to properly evaluate the effect of heat stress on yak fertility.

#### 4.3. Climate Change and Productivity

The changes in forage quantity and quality described earlier are likely to have a significant negative effect on yak productivity. Yang et al. [36] reported that the changes in forage quantity and quality associated with shrub encroachment led to reduced growth in yak. Similar results are not available for milk production and reproductive performance, but the impacts are likely to be similar.

The evidence of an impact of heat stress on the milk production of yak is limited, with no long-term studies of comparative production under different temperature and humidity conditions. Shikui et al. [63] reported that over the short term, yak produced more milk (~0.1 to 1 kg/day) on cloudy, cool days (6.7 to 9.3 °C) than on the preceding and following warmer, clear sunny days (12.5–13.5 °C). This was a small study (only 19 animals) over an approximately two-week period in June, on one farm, so much more data are required to properly establish the likely impact of heat stress on milk production by yak. Furthermore, the underlying cause of these changes is unclear, but it might be related to dry matter intake, which is negatively related to THI in cattle [64], although this reduction in food intake may not be the sole reason for the reduction in milk yield. In cattle, Gao et al. [65] reported that despite similar dry matter intake, heat-stressed cows produced less milk than pair-fed cows kept in thermoneutral conditions. They [65] suggested that THI-related impacts on mammary blood flow could be responsible for some of this reduction. The cattle data thus suggest that milk production will reduce in yak suffering from heat stress but as impact on cattle is dependent on the level of productivity, with higher-yielding cows being more susceptible to heat stress [66], yak-specific data are needed to properly assess the likely range of losses.

#### 4.4. Climate Change and Infectious Disease Occurrence

Yak are susceptible to a large number of infectious diseases, most of which are also present in local cattle or sheep [6,67]. Losses from infectious diseases can be high in individual herds [67], but it is likely that the literature is biased toward investigations in problem herds as there are few studies on the prevalence and economic impact of infectious diseases across multiple herds and multiple regions.

On first principles, it is likely that climate change is increasing the exposure of yak to disease. Firstly, increased temperatures may increase contact between yak and cattle, particularly during the winter period. As a large proportion of the infectious disease recorded in yak is likely to come from cattle [6], this increased contact is likely to increase the exposure of yak to cattle diseases. Secondly, climate change may affect vector-transmitted disease prevalence by shifting the geographical range of vectors, increasing their reproductive efficiency, and by altering vector–host interactions [68,69]. These changes could increase

the incidence of diseases that are already established and/or result in the introduction of new diseases. Finally, the increased periods of nutritional stress caused by the impact of climate change on forage quality and quantity are likely to increase the susceptibility of yak to disease. Nevertheless, the lack of baseline data on disease prevalence in yak means that it is likely to be difficult to identify whether climate change is actually altering disease prevalence. Koirala et al. [70] surveyed in the Mustang district of Western Nepal, interviewing 71 households on the effects of climate change on livestock, particularly their perception of the impact of climate change on livestock disease. Although yak is common in the Mustang district, most of the respondents did not have a yak, so the survey does not provide direct evidence of changes in the perception of disease risk in yak herders. However, many of the households did have Jhopa (yak/cattle cross) and because disease transmission from cattle to yak is likely to be a key source of disease in yak, increased disease in Jhopa is likely to be reflected in yak.

Koirala et al. [70] claimed that there was “strong evidence to suggest that climate change has affected the occurrence, distribution, and prevalence of livestock disease in Nepal”. However, of their 71 respondents, 38 reported that either livestock disease patterns had not changed or had decreased. This is despite 60/71 respondents reporting that they had observed climate changes. Additionally, Koirala et al. [70] stated that mixed feeding (i.e., feeding supplements or by-products in housed animals) had become much more common and that free grazing had reduced, changes which would have been expected to increase disease occurrence.

Increases in the prevalence of parasitic diseases have been commonly linked to climate change. For example, Li et al. [71] linked increases in besnoitosis on the Tibetan plateau to climate change. However, they did not report a consistent increase in seroprevalence between 2012 and 2017 (the highest prevalence was recorded in 2014) and as seropositive animals were very rare, the study lacked the power to detect a true trend. Thus, their suggestion of a link between climate change and besnoitosis was not based on the data from their study. Another parasitic disease, babesiosis, which is a prime cause of mortality of young and adult yak in native yak herding regions, seems to be spreading in the yak population, with He et al. [72] highlighting climate change as a potential cause of this spread (principally because it was increasing the area of yak habitat that was suitable to the tick species that are the vectors of the pathogenic *Babesia* spp.). However, they also identified nutrition, animal movement, human activities, and the change from local resistant *Bos indicus* cattle to exotic susceptible *Bos taurus* breeds as potential risk factors which could increase the spread of babesiosis. So as with besnoitosis, for babesiosis, we lack both good quality prevalence data and data linking increases in prevalence to climate change.

A more data-based study was that provided by Khanyari et al. [73], who modelled the dynamics of gastrointestinal nematodes in trans-Himalayan pastures. They concluded that more than 30 years of climate change in the region had not resulted in an increase in the transmission potential of gastro-intestinal nematodes on pasture but that, relative to rainfall, temperature had become a more important determinant of pasture infectivity. The results of this modelling process highlight the complexity of determining the impact of climate change on disease prevalence, especially in a data-poor environment.

One particular area where climate change may be affecting the prevalence of parasites in yak is through its impact on medicinal plants. Yak herders rely on medicinal plants found in the Himalayan pastures for controlling parasitic infestations (both ecto- and endoparasites) [74]. However, these naturally occurring medicinal plants have become less common in the Himalaya [32,75], due to previously discussed climate-change-induced effects such as increases in plant pests, changes in the flowering season, geographical range shifts and shrub invasion [28,30,31,37].

The effect of climate change on the prevalence of non-parasitic diseases, such as brucellosis and foot-and-mouth disease, is even less clear with very limited data. Most analyses of climate change and yak diseases suggest that climate change will lead to increased disease (e.g., [15,23]) without providing data, while most datasets of disease

prevalence, e.g., Mortenson et al. [76] are single timepoint studies which provide no data, on their own, as to disease patterns in yak. As far as the authors are aware, the only published systematic study of temporal patterns in non-parasitic disease in yak is the meta-analysis undertaken by Zhao et al. [77] who analysed the prevalence of brucellosis in Chinese yak. They reported that the “incidence of brucellosis was higher”, with the pooled prevalence being higher after 2012 than before. However, while suggestive of an increase, this study is not conclusive. Zhao et al. [77] separated their pooled prevalence over time into three categories—before 2012, 2012 to 2016, and 2016 or later—with the three pooled prevalences being 5.8, 11.5, and 7%, respectively. Thus, the changes in prevalence over time were relatively small, and there was no clear pattern of a continuous increase. Additionally, their modelling did not rule out there being no effect of time on the prevalence of brucellosis (95%CI of their regression coefficient being  $-0.01$  to  $0.205$ ;  $p = 0.075$ ). Zhao et al. [77] suggested that the National Brucellosis Control Plan which was issued in 2016 was responsible for the decrease seen after that year, but their dataset is too small to make such a conclusion, and it is too small to allow their model to distinguish between the pre-2012 prevalence and the prevalence in the 2012–2016 time period. Thus, their [77] conclusion that “in China, yak brucellosis is reviving” seems to be based more on their perception of disease risk than on their data. They [77] linked the increase in brucellosis to increased stocking density (and thus increased exposure to brucellosis). They linked the increased stocking density to degradation of grazing areas, a change which has been clearly linked to climate change [78,79]. However, overgrazing has also been shown to occur because of human activity driving changes in land use, and it is likely that if degradation of grazing is causing an increase in brucellosis in yak, then these socio-economic changes are currently more important in driving change in disease risk than climate change [23,80].

The lack of data on disease in yak makes it very difficult to assess whether disease prevalence is increasing, let alone relating any such changes to climate change. This does not mean that significant changes in disease prevalence are not happening, rather that we lack the data to identify such changes. We strongly agree with the conclusion by Zhao et al. [77] that extensive epidemiological investigations need to be conducted on brucellosis in yak, except that we would extend that to include all of the key diseases in yak.

In this discussion about climate change, it is important to stress that the lack of access to proper veterinary facilities, advice and medications is currently having a major effect on the prevalence and impact of disease in yak in the Himalayan region. If climate change is changing disease risk (or is going to), this lack of access to veterinary care will significantly increase the impact of such changes, so improving access to veterinary support needs to be a key part of any plan to mitigate the impact of climate change on yak.

## 5. Overall Welfare Status

The impact of climate change on yak welfare is difficult to assess because there is a paucity of information on yak welfare. As far as the authors are aware, there are no peer-reviewed papers on the assessment of yak welfare, and there is only one non-peer-reviewed conference abstract [81] which reported the results of an assessment of yak welfare in three regions of Bhutan using an assessment program derived from the Welfare Quality system [82]. The paucity of studies on yak welfare assessment means we cannot directly assess the impact of climate change on yak welfare. Nevertheless, potential impacts of climate change, such as the rise in extreme weather conditions, increases in parasitic and other diseases, and increasing difficulty accessing water sources are all likely to have reduced welfare [6,15,22]. The climate-change-related issue that is likely to have the most impact on yak welfare is shortage of forage in yak rangelands, which has been recognised as a major concern in yak farming region [83]. However, forage shortages are a result of a complex range of factors, some of which may be related to climate change (e.g., reduced snow cover and increased grazing by cattle) and some of which are probably not (e.g., bans on burning rangelands and increased collection of *Cordyceps* (caterpillar fungus)). As the

key causes of forage shortages vary across regions within the same country [83], it is likely that determining how much of the impact of such shortages on yak welfare is due to climate change rather than socio-economic factors will be difficult. In addition, although climate change is likely to be having a deleterious impact on yak welfare, other key issues such as lack of proper treatment facilities and effective medicines, limited knowledge and skill of stockpeople, continuation of traditional farming practices, and limited support from the governments to uplift and promote sustainable yak farming are likely to be as, if not more, important in determining yak welfare.

There is thus a clear need for more welfare assessments in yak. In particular, we need a robust, internationally recognised protocol for such assessment, and, using that protocol, we need to collect data on yak welfare on an ongoing basis in yak herding regions across the Himalaya, alongside the collection of data on the impact of climate change on yak's environment and its resources.

## 6. Adaptation Strategies to Mitigate Adverse Effects of Climate Change on Yak

Increasing ambient temperatures, more erratic precipitation patterns, higher rates of natural disasters, growing disease risk, and disruption of food plant ecosystems are all likely to bring more challenges to yak in the Himalaya. Addressing such effects is likely to take significant global effort and require substantial research. So, in the short to medium term, developing strategies to mitigate the effects of climate change are likely to be an essential step in helping yak to adapt to their changing environmental circumstances. Table 3 summarises some potential mitigation strategies, but this is clearly a very large area of research that deserves more space than is available in the current review.

**Table 3.** Summary of some potential strategies to mitigate the effect of climate change on Himalayan yak.

Type of Modification	Mitigation Strategies
Physical modification	<ul style="list-style-type: none"> <li>➤ Planting trees to provide shelter and shade [83] could be utilised wisely by avoiding forest degradation.</li> <li>➤ Mud pens and other temporary pens used during winter [84] could be modified and used in summer.</li> <li>➤ Concept of water collection tanks used for agriculture and household in the Himalaya can be utilised for yak drinking [82,85] during water shortage.</li> </ul>
Breeding selection	<ul style="list-style-type: none"> <li>➤ Hybridization with hill cattle can produce an animal that is better adapted the rising ambient temperature and can utilise rangelands that are too high for cattle and too low for pure yak [86].</li> <li>➤ Dimjo chauri (hybrids from mating cattle bulls with female yak) adapt well to both high and low-altitude areas and are more adaptable than Urang chauri (hybrids from mating yak bulls with local female cattle) [87,88].</li> <li>➤ Selection of heat-tolerant yak will aid the identification of genes related to thermotolerance which, if incorporated into breeding programs, will produce more resilient genotypes [89].</li> </ul>
Nutritional modification	<ul style="list-style-type: none"> <li>➤ Increased use of supplements would replace the reduced quantity and quality of the forage available improving productivity and performance. Suggested feed sources include feed blocks, concentrates and silage as well as mineral blocks to tackle potential mineral deficiencies [90], with particular attention being paid to feeding during the winter season [91].</li> <li>➤ More active management of alpine pastureland is also likely to be beneficial. Renovation with high-quality forages (20–30% legumes and 70–80% grass is likely to be a cost-effective strategy [92]. This can either be achieved through re-seeding or through transplanting of roots and stems. This is likely to be most effective if it is combined with regular weed control and well-regulated rotational grazing [88,92].</li> <li>➤ Planting of tree fodder alongside pasture grasses will increase the availability of feed when pasture growth is limited [93]. Increased research on local forage and pasture species could be extremely valuable as it would allow the development of high-yielding and nutritious local plant varieties.</li> </ul>

## 7. Conclusions

This review has highlighted the clear effects of climate change on temperature, precipitation, and vegetation in the Himalayan ecosystem. Climate change has destabilised the ecosystem by increasing the ambient temperature, altering seasonal and climatic patterns (increasing extreme hot and cold events), causing erratic rainfall events, increasing natural disasters such as landslides and flood, and causing the replacement of native forages with

unpalatable shrubs. These climate-change-induced events have clearly affected the traditional transhumance farming system of Himalayan yak. It is clear that there is an increased risk of heat stress in yak because of the increase in the number of days in both summer and winter where maximum THI is above the optimal THI of yak, and that this heat stress is likely to negatively affect welfare, productivity, and performance. The alteration in feed supply resulting from climate change is also likely to be negatively affecting welfare, productivity, and performance, as is the increase in disease risk. However, we lack the data to quantify these effects, and for some of the changes (particularly in relation to feed supply), it is difficult to distinguish between changes occurring due to climate change and changes driven by socio-economic factors. Additionally, non-climate-related issues such as lack of infrastructure (including veterinary facilities,) and poor management are possibly more important causes of poor welfare, productivity, and performance than climate change, and if not improved will act to exacerbate any future impact of climate change. Some immediate steps such as building temporary sheds, using water sprinklers, increased planned use of supplements, improved breeding practices, more effective rangeland management including rejuvenation and controlled grazing, should be implemented on the ground level. However, these steps can only slow down the impact of climate change on yak. On the broad spectrum, climate change is a global issue and must be addressed globally.

**Author Contributions:** Conceptualization, S.S., K.P.A., R.L. and N.A.; methodology, S.S., K.P.A., R.L. and N.A.; software, S.S.; validation, S.S., K.P.A. and R.L.; formal analysis, S.S. and R.L.; investigation, S.S., K.P.A. and R.L.; resources, S.S., K.P.A. and R.L.; data curation, S.S., K.P.A. and R.L.; writing—original draft preparation, S.S., K.P.A. and R.L.; writing—review and editing, R.L. and N.A.; visualization, S.S.; supervision, R.L. and N.A.; project administration, S.S.; funding acquisition, S.S., K.P.A., R.L. and N.A. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Not applicable.

**Acknowledgments:** We would like to thank Krishna Kaphle, Tribhuvan University (TU) and Philips Thorton (ILRI) for their valuable suggestions to improve the manuscript.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References

1. Qiu, Q.; Zhang, G.; Ma, T.; Qian, W.; Wang, J.; Ye, Z.; Cao, C.; Hu, Q.; Kim, J.; Larkin, D.M. The yak genome and adaptation to life at high altitude. *Nat. Genet.* **2012**, *44*, 946–949. [[CrossRef](#)] [[PubMed](#)]
2. Shi, Q.; Guo, Y.; Engelhardt, S.C.; Weladji, R.B.; Zhou, Y.; Long, M.; Meng, X. Endangered wild yak (*Bos grunniens*) in the Tibetan plateau and adjacent regions: Population size, distribution, conservation perspectives and its relation to the domestic subspecies. *J. Nat. Conserv.* **2016**, *32*, 35–43. [[CrossRef](#)]
3. Krishnan, G.; Paul, V.; Biswas, T.; Chouhan, V.; Das, P.; Sejian, V. Adaptation strategies of yak to seasonally driven environmental temperatures in its natural habitat. *Int. J. Biometeorol.* **2018**, *62*, 1497–1506. [[CrossRef](#)]
4. Rhode, D.; Madsen, D.B.; Brantingham, P.J.; Dargye, T. Yaks, yak dung, and prehistoric human habitation of the Tibetan Plateau. *Dev. Quat. Sci.* **2007**, *9*, 205–224.
5. Feroze, S.M.; Ray, L.I.; Singh, K.J.; Singh, R. Pastoral yak rearing system is changing with change in climate: An exploration of North Sikkim in Eastern Himalaya. *Clim. Chang.* **2019**, *157*, 483–498. [[CrossRef](#)]
6. Wiener, G.; Han, J.; Long, R. *The Yak*; FAO Regional Office for Asia and the Pacific: Bangkok, Thailand, 2003.
7. Krishna, G.; Ramesh, K.; Chakravarty, P.; Chouhan, V.; Jayakumar, S. Effect of environment on reproductive traits in yaks. *Indian J. Anim. Sci.* **2010**, *80*, 123–124.
8. Long, R.; Ding, L.; Shang, Z.; Guo, X. The yak grazing system on the Qinghai-Tibetan plateau and its status. *Rangel. J.* **2008**, *30*, 241–246. [[CrossRef](#)]
9. Miao, F.; Guo, Z.; Xue, R.; Wang, X.; Shen, Y. Effects of grazing and precipitation on herbage biomass, herbage nutritive value, and Yak performance in an alpine meadow on the Qinghai-Tibetan Plateau. *PLoS ONE* **2015**, *10*, e0127275. [[CrossRef](#)]
10. Namgay, K.; Millar, J.; Black, R.; Samdup, T. Transhumant agro-pastoralism in Bhutan: Exploring contemporary practices and socio-cultural traditions. *Pastor. Res. Policy Pract.* **2013**, *3*, 13. [[CrossRef](#)]



11. Paul, V.; Maiti, S.; Krishnan, G.; Medhi, D.; Deb, S. Yak rearing on high altitude pastures of northeastern Himalaya of India: Their utilization strategies and rejuvenation. In Proceedings of the XXIII International Grassland Congress Proceedings, New Delhi, India, 1 April 2020.
12. Wiener, G. The yak, an essential element of the high altitude regions of Central Asia. *Etudes Mongoles et Siberienne* **2013**. [[CrossRef](#)]
13. Zou, H.; Hu, R.; Wang, Z.; Shah, A.M.; Zeng, S.; Peng, Q.; Xue, B.; Wang, L.; Zhang, X.; Wang, X. Effects of nutritional deprivation and re-alimentation on the feed efficiency, blood biochemistry, and rumen microflora in yaks (*Bos grunniens*). *Animals* **2019**, *9*, 807. [[CrossRef](#)] [[PubMed](#)]
14. Bao, P.; Luo, J.; Liu, Y.; Chu, M.; Ren, Q.; Guo, X.; Tang, B.; Ding, X.; Qiu, Q.; Pan, H. The seasonal development dynamics of the yak hair cycle transcriptome. *BMC Genom.* **2020**, *21*, 355. [[CrossRef](#)]
15. Krishnan, G.; Paul, V.; Hanah, S.; Bam, J.; Das, P.; Indian, J. Effects of Climate Change on Yak Production at High Altitude. *Indian J. Anim. Sci.* **2016**, *86*, 621–626.
16. Wangdi, J.; Wangchuk, K. Productive and reproductive traits of yak types in Bhutan: Characteristics and comparisons. *J. Appl. Anim. Res.* **2018**, *46*, 893–897. [[CrossRef](#)]
17. Sarkar, M.; Meyer, H.; Prakash, B. Is the yak (*Poephagus grunniens* L.) really a seasonal breeder? *Theriogenology* **2006**, *65*, 721–730. [[CrossRef](#)]
18. Xu, S.-R.; Wei, P.; Yang, Q.-L.; Jia, G.-X.; Ma, S.-K.; Yang, Q.-E.; Jun, Z.; Zhang, R.-N. Transcriptome analysis revealed key signaling networks regulating ovarian activities in the domestic yak. *Theriogenology* **2020**, *147*, 50–56. [[CrossRef](#)] [[PubMed](#)]
19. Shrestha, B.; Khatri Chhetri, K.; Shrestha, N.; Serchan, L. Morphological characteristics and productive reproductive performance of Yak/Nak. In Proceedings of the 1st National Workshop on Livestock and Fisheries Research in Nepal, Khumaltar, Lalitpur, Nepal, 7–9 May 1996.
20. Shukla, R.; Agarwal, A.; Sachdeva, K.; Kurths, J.; Joshi, P. Climate change perception: An analysis of climate change and risk perceptions among farmer types of Indian Western Himalayas. *Clim. Chang.* **2019**, *152*, 103–119. [[CrossRef](#)]
21. Gautam, M.R.; Timilsina, G.R.; Acharya, K. Climate change in the Himalayas: Current state of knowledge. In *Policy Research Working Paper*; World Bank: Washington, DC, USA, 2013.
22. Eriksson, M.; Xu, J.; Shrestha, A.B.; Vaidya, R.A.; Santosh, N.; Sandström, K. *The Changing Himalayas: Impact of Climate Change on Water Resources and Livelihoods in the Greater Himalayas*; International Centre for Integrated Mountain Development (ICIMOD): Lalitpur, Nepal, 2009.
23. Sherpa, Y.D.; Kayastha, R.B. A study of livestock management patterns in Sagarmatha National Park, Khumbu Region: Trends as affected by socio-economic factors and climate change. *Kathmandu Univ. J. Sci. Eng. Technol.* **2009**, *5*, 110–120.
24. Sun, X.-B.; Ren, G.-Y.; Shrestha, A.B.; Ren, Y.-Y.; You, Q.-L.; Zhan, Y.-J.; Xu, Y.; Rajbhandari, R. Changes in extreme temperature events over the Hindu Kush Himalaya during 1961–2015. *Adv. Clim. Chang. Res.* **2017**, *8*, 157–165. [[CrossRef](#)]
25. Pant, G.B.; Kumar, P.P.; Revadekar, J.V.; Singh, N. *Climate change in the Himalayas*; Springer: Berlin/Heidelberg, Germany, 2018.
26. Shrestha, U.B.; Gautam, S.; Bawa, K.S. Widespread climate change in the Himalayas and associated changes in local ecosystems. *PLoS ONE* **2012**, *7*, e36741. [[CrossRef](#)]
27. Shrestha, A.B.; Agrawal, N.K.; Alfthan, B.; Bajracharya, S.R.; Maréchal, J.; Oort, B.V. The Himalayan Climate and Water Atlas: Impact of climate change on water resources in five of Asia's major river basins. In *The Himalayan Climate and Water Atlas: Impact of Climate Change on Water Resources in Five of Asia's Major River Basins*; International Centre for Integrated Mountain Development (ICIMOD): Lalitpur, Nepal; GRID-Arendal, Arendal, Norway and the Centre for International Climate and Environmental Research-Oslo (CICERO): Oslo, Norway, 2015.
28. Padma, T. Himalayan plants seek cooler climes: Race is on to record mountain biodiversity before it is lost. *Nature* **2014**, *512*, 359–360. [[CrossRef](#)] [[PubMed](#)]
29. Sigdel, S.R.; Wang, Y.; Camarero, J.J.; Zhu, H.; Liang, E.; Peñuelas, J. Moisture-mediated responsiveness of treeline shifts to global warming in the Himalayas. *Glob. Chang. Biol.* **2018**, *24*, 5549–5559. [[CrossRef](#)] [[PubMed](#)]
30. Dalle, G.; Maass, B.L.; Isselstein, J. Encroachment of woody plants and its impact on pastoral livestock production in the Borana lowlands, southern Oromia, Ethiopia. *Afr. J. Ecol.* **2006**, *44*, 237–246. [[CrossRef](#)]
31. Brandt, J.S.; Haynes, M.A.; Kuemmerle, T.; Waller, D.M.; Radeloff, V.C. Regime shift on the roof of the world: Alpine meadows converting to shrublands in the southern Himalayas. *Biol. Conserv.* **2013**, *158*, 116–127. [[CrossRef](#)]
32. Manish, K.; Telwala, Y.; Nautiyal, D.C.; Pandit, M.K. Modelling the impacts of future climate change on plant communities in the Himalaya: A case study from Eastern Himalaya, India. *Modeling Earth Syst. Environ.* **2016**, *2*, 92. [[CrossRef](#)]
33. Paudel, K.P.; Andersen, P. Assessing rangeland degradation using multi temporal satellite images and grazing pressure surface model in Upper Mustang, Trans Himalaya, Nepal. *Remote Sens. Environ.* **2010**, *114*, 1845–1855. [[CrossRef](#)]
34. Bai, Z.; Dent, D.L.; Olsson, L.; Schaepman, M.E. *Global Assessment of Land Degradation and Improvement: 1. Identification by Remote Sensing*; ISRIC-World Soil Information: Wageningen, The Netherlands, 2008.
35. Bastin, G.; Pickup, G.; Chewings, V.; Pearce, G. Land degradation assessment in central Australia using a grazing gradient method. *Rangel. J.* **1993**, *15*, 190–216. [[CrossRef](#)]
36. Yang, C.; Yan, T.; Sun, Y.; Hou, F. Shrub cover impacts on yak growth performance and herbaceous forage quality on the Qinghai-Tibet Plateau, China. *Rangel. Ecol. Manag.* **2021**, *75*, 9–16. [[CrossRef](#)]
37. Rosenzweig, C.; Iglesias, A.; Yang, X.-B.; Epstein, P.R.; Chivian, E. *Climate Change and Extreme Weather Events-Implications for Food Production, Plant Diseases, and Pests*; NASA Publications: Washington, DC, USA, 2001.

38. Cannone, N.; Sgorbati, S.; Guglielmin, M. Unexpected impacts of climate change on alpine vegetation. *Front. Ecol. Environ.* **2007**, *5*, 360–364. [[CrossRef](#)]
39. Negi, G.; Samal, P.; Kuniyal, J.; Kothiyari, B.; Sharma, R.; Dhyani, P. Impact of climate change on the western Himalayan mountain ecosystems: An overview. *Trop. Ecol.* **2012**, *53*, 345–356.
40. Livestock Census, Department of Animal Husbandry and Dairying, India. Available online: <https://dahd.nic.in/documents/statistics/livestock-census> (accessed on 19 July 2022).
41. Livestock Statistics Report, National Statistics Bureau, Bhutan. Available online: <https://www.nsb.gov.bt/livestock-statistics-report/> (accessed on 19 July 2022).
42. Agriculture Statistics, Ministry of Agriculture and Livestock Development, Nepal. Available online: <https://moald.gov.np/publication-types/agriculture-statistics/> (accessed on 19 July 2022).
43. Song, Q.; Chai, Z.; Xin, J.; Zhao, S.; Ji, Q.; Zhang, C.; Ma, Z.; Zhong, J. Genetic diversity and classification of Tibetan yak populations based on the mtDNA COIII gene. *Genet. Mol. Res.* **2015**, *14*, 1763–1770. [[CrossRef](#)]
44. Zhang, C. Study on Superovulation of Tibetan Yak. Master Thesis, Chinese Academy of Agricultural Sciences, Beijing, China, 2012.
45. Jasra, A.W.; Hashmi, M.M.; Waqar, K.; Ali, M. Traditional yak herding in high-altitude areas of Gilgit-Baltistan, Pakistan: Transboundary and biodiversity conservation challenges. In *Yak on the Move*; International Centre for Integrated Mountain Development (ICIMOD): Lalitpur, Nepal, 2016; Volume 40, pp. 41–51.
46. Ali, A.; Shaoliang, Y.; Nazarbekov, A.; Joshi, S. Survival in the Frontiers: Yak husbandry of Kyrgyz communities in the Pamir region of Afghanistan. In *Yak on the Move*; International Centre for Integrated Mountain Development (ICIMOD): Lalitpur, Nepal, 2016.
47. Krishnan, G.; Ramesha, K.; Sarkar, M.; Chakravarty, P.; Kataktalware, M.; Saravanan, B. Modified temperature humidity index for yaks. *Indian J. Anim. Sci.* **2009**, *79*, 788–790.
48. Krishnan, G.; Paul, V.; Biswas, T.; Chouhan, V.; Das, P.; Sejian, V. Diurnal variation and oscillatory patterns in physiological responses and HSP70 profile in heat stressed yaks at high altitude. *Biol. Rhythm. Res.* **2018**, *49*, 782–796. [[CrossRef](#)]
49. Chetri, D.; Karki, D.N.; Sah, R.; Devkota, N. Transhumance effect on husbandry practices and physiological attributes of Chauri (Yak-Cattle) in Rasuwa District. *Our Nat.* **2011**, *9*, 128–137. [[CrossRef](#)]
50. Sarkar, M.; Das, B.; Mondal, D.; Chatterjee, A. Physiological responses of yak under different environments. *Yak Prod. Cent. Asian Highl.* **2002**, *388*, 271–272.
51. Sarkar, M.; Bandyopadhyay, S.; Krishnan, G.; Prakash, B. Seasonal variations in plasma glucocorticoid levels in yaks (*Poephaqus grunniens* L.)(*Bos grunniens*). *Trop. Anim. Health Prod.* **2010**, *42*, 421–424. [[CrossRef](#)] [[PubMed](#)]
52. Correa-Calderon, A.; Armstrong, D.; Ray, D.; DeNise, S.; Enns, M.; Howison, C. Thermoregulatory responses of Holstein and Brown Swiss heat-stressed dairy cows to two different cooling systems. *Int. J. Biometeorol.* **2004**, *48*, 142–148.
53. Gwazdauskas, F. Effects of climate on reproduction in cattle. *J. Dairy Sci.* **1985**, *68*, 1568–1578. [[CrossRef](#)]
54. Wise, M.; Armstrong, D.; Huber, J.; Hunter, R.; Wiersma, F. Hormonal alterations in the lactating dairy cow in response to thermal stress. *J. Dairy Sci.* **1988**, *71*, 2480–2485. [[CrossRef](#)]
55. Weekes, T.; Sasaki, Y.; Tsuda, T. Enhanced responsiveness to insulin in sheep exposed to cold. *Am. J. Physiol. Endocrinol. Metab.* **1983**, *244*, E335–E345. [[CrossRef](#)]
56. Zhang, R. Effects of environment and management on yak reproduction. In *Recent Advances in Yak Reproduction*; International Veterinary Information Service: New York, NY, USA, 2000.
57. Abilay, T.; Johnson, H.; Madan, M. Influence of environmental heat on peripheral plasma progesterone and cortisol during the bovine estrous cycle. *J. Dairy Sci.* **1975**, *58*, 1836–1840. [[CrossRef](#)]
58. Bridges, P.; Brusie, M.; Fortune, J. Elevated temperature (heat stress) in vitro reduces androstenedione and estradiol and increases progesterone secretion by follicular cells from bovine dominant follicles. *Domest. Anim. Endocrinol.* **2005**, *29*, 508–522. [[CrossRef](#)] [[PubMed](#)]
59. Lenz, R.; Ball, G.; Leibfried, M.; Ax, R.; First, N. In vitro maturation and fertilization of bovine oocytes are temperature-dependent processes. *Biol. Reprod.* **1983**, *29*, 173–179. [[CrossRef](#)] [[PubMed](#)]
60. Collier, R.; Renquist, B.; Xiao, Y. A 100-Year Review: Stress physiology including heat stress. *J. Dairy Sci.* **2017**, *100*, 10367–10380. [[CrossRef](#)] [[PubMed](#)]
61. Zi, X.-D. Reproduction in female yaks (*Bos grunniens*) and opportunities for improvement. *Theriogenology* **2003**, *59*, 1303–1312. [[CrossRef](#)]
62. Deori, S.; Bam, J.; Paul, V.; Baruah, K. Epidemiology of abortion in yaks (*Poephaqus grunniens*) under farm conditions. *Indian J. Anim. Res.* **2013**, *47*, 178–180.
63. Shikui, D.; Ruijun, L.; Muiyi, K. Milking performance of China yak (*Bos grunniens*): A preliminary report. *Afr. J. Agric. Res.* **2007**, *2*, 052–057.
64. Chang-Fung-Martel, J.; Harrison, M.; Brown, J.; Rawnsley, R.; Smith, A.; Meinke, H. Negative relationship between dry matter intake and the temperature-humidity index with increasing heat stress in cattle: A global meta-analysis. *Int. J. Biometeorol.* **2021**, *65*, 2099–2109. [[CrossRef](#)]
65. Gao, S.; Guo, J.; Quan, S.; Nan, X.; Fernandez, M.S.; Baumgard, L.; Bu, D. The effects of heat stress on protein metabolism in lactating Holstein cows. *J. Dairy Sci.* **2017**, *100*, 5040–5049. [[CrossRef](#)]

66. Tao, S.; Rivas, R.M.O.; Marins, T.N.; Chen, Y.-C.; Gao, J.; Bernard, J.K. Impact of heat stress on lactational performance of dairy cows. *Theriogenology* **2020**, *150*, 437–444. [CrossRef]
67. Dubal, Z.; Khan, M.; Dubal, P. Bacterial and viral zoonotic diseases of yak. *Int. J. Bioresour. Stress Manag.* **2013**, *4*, 288–292.
68. Patz, J.A.; Epstein, P.R.; Burke, T.A.; Balbus, J.M. Global climate change and emerging infectious diseases. *JAMA* **1996**, *275*, 217–223. [CrossRef] [PubMed]
69. Gale, P.; Drew, T.; Phipps, L.; David, G.; Wooldridge, M. The effect of climate change on the occurrence and prevalence of livestock diseases in Great Britain: A review. *J. Appl. Microbiol.* **2009**, *106*, 1409–1423. [CrossRef] [PubMed]
70. Koirala, A.; Shrestha, K. Effects of climate change on the livestock population in Mustang District, Nepal. *Asian J. Agric. Dev.* **2017**, *14*, 37–49.
71. Li, K.; Zhang, L.; Luo, H.; Mehmood, K.; Shahzad, M.; Naseer, M. Besnoitiosis: An emerging parasitic disease in yaks (*Bos grunniens*) and tibetan sheep (*ovies aries*) on the qinghai tibetan plateau, China. *Pak. Vet. J.* **2019**, *39*, 447–450. [CrossRef]
72. He, L.; Bastos, R.G.; Sun, Y.; Hua, G.; Guan, G.; Zhao, J.; Suarez, C.E. Babesiosis as a potential threat for bovine production in China. *Parasites Vectors* **2021**, *14*, 460. [CrossRef]
73. Khanyari, M.; Suryawanshi, K.R.; Milner-Gulland, E.; Dickinson, E.; Khara, A.; Rana, R.S.; Rose Vineer, H.; Morgan, E.R. Predicting Parasite Dynamics in Mixed-Use Trans-Himalayan Pastures to Underpin Management of Cross-Transmission Between Livestock and Bharal. *Front. Vet. Sci.* **2021**, *8*, 1108. [CrossRef]
74. Gyawali, R.; Paudel, H. Plant bio-resources used in ethno-veterinary practices in Jumla District. *Nepal. Vet. J.* **2017**, *34*, 128–134. [CrossRef]
75. Kunwar, R.M.; Lamichhane Pandey, M.; Mahat Kunwar, L.; Bhandari, A. Medicinal plants and ethnomedicine in peril: A case study from Nepal himalaya. *Evid. Based Complement. Altern. Med.* **2014**, *2014*, 792789. [CrossRef]
76. Mortenson, J.; Khan, E.; Ali, I.; Manzoor, S.; Jamil, A.; Abubakar, M.; Afzal, M.; Hussain, M. Evaluation of foot and mouth vaccination for yak (*Bos grunniens*) in Pakistan. *Trop. Anim. Health Prod.* **2017**, *49*, 691–695. [CrossRef]
77. Zhao, B.; Gong, Q.-L.; Feng, H.-F.; Wang, Q.; Shi, J.-F.; Song, Y.-H.; Liu, F.; Shi, K.; Zong, Y.; Du, R. Brucellosis prevalence in yaks in China in 1980–2019: A systematic review and meta-analysis. *Prev. Vet. Med.* **2022**, *198*, 105532. [CrossRef] [PubMed]
78. Fort, M. Natural hazards versus climate change and their potential impacts in the dry, northern Himalayas: Focus on the upper Kali Gandaki (Mustang District, Nepal). *Environ. Earth Sci.* **2015**, *73*, 801–814. [CrossRef]
79. Mipam, T.-D.; Zhong, L.-L.; Liu, J.-Q.; Mieke, G.; Tian, L.-M. Productive overcompensation of alpine meadows in response to yak grazing in the eastern Qinghai-Tibet Plateau. *Front. Plant Sci.* **2019**, *10*, 925. [CrossRef]
80. Garrard, R.; Kohler, T.; Price, M.F.; Byers, A.C.; Sherpa, A.R.; Maharjan, G.R. Land use and land cover change in Sagarmatha National Park, a world heritage site in the Himalayas of Eastern Nepal. *Mt. Res. Dev.* **2016**, *36*, 299–310. [CrossRef]
81. Dorji, N.; Derks, M.; Koerkamp, P.G.; Bokkers, E. Welfare and management practices of free-ranging yaks in Bhutan. In Proceedings of the 8th International Conference on The Assessment of Animal Welfare at Farm and Group Level, Cork, Ireland, 16–19 August 2021; p. 155.
82. Dorji, N. Transhumant Pastoralism in a Changing World: Challenges and Opportunities to Sustainable Yak Farming in Bhutan. Ph.D. Thesis, Wageningen University, Wageningen, The Netherlands, 2020.
83. Dorji, T.; Facelli, J.M.; Norbu, T.; Delean, S.; Brookes, J.D. Tree shelters facilitate brown oak seedling survival and establishment in a grazing-dominant forest of Bhutan, Eastern Himalaya. *Restor. Ecol.* **2020**, *28*, 1145–1157. [CrossRef]
84. FAO. Management of Yak. Available online: <https://www.fao.org/3/AD347E/ad347e0j.htm#TopOfPage> (accessed on 19 July 2022).
85. Vaidya, R.A. Governance and management of local water storage in the Hindu Kush Himalayas. *Int. J. Water Resour. Dev.* **2015**, *31*, 253–268. [CrossRef]
86. Maiti, S.; Jha, S.K.; Garai, S.; Nag, A.; Chakravarty, R.; Kadian, K.; Chandel, B.; Datta, K.; Upadhyay, R. Adapting to climate change: Traditional coping mechanism followed by the Brokpa pastoral nomads of Arunachal Pradesh, India. *Indian J. Tradit. Knowl.* **2014**, *1313*, 752–7610114.
87. Barsila, S.; Kreuzer, M.; Devkota, N.; Ding, L.; Marquardt, S. Adaptation to Himalayan high altitude pasture sites by yaks and different types of hybrids of yaks with cattle. *Livest. Sci.* **2014**, *169*, 125–136. [CrossRef]
88. Barsila, S.R.; Devkota, N.R.; Kreuzer, M.; Marquardt, S. Effects of different stocking densities on performance and activity of cattle × yak hybrids along a transhumance route in the Eastern Himalaya. *SpringerPlus* **2015**, *4*, 398. [CrossRef]
89. Osei-Amponsah, R.; Chauhan, S.S.; Leury, B.J.; Cheng, L.; Cullen, B.; Clarke, I.J.; Dunshea, F.R. Genetic selection for thermotolerance in ruminants. *Animals* **2019**, *9*, 948. [CrossRef]
90. Kang, K.; Ma, J.; Wang, H.; Wang, Z.; Peng, Q.; Hu, R.; Zou, H.; Bao, S.; Zhang, W.; Sun, B. High-energy diet improves growth performance, meat quality and gene expression related to intramuscular fat deposition in finishing yaks raised by barn feeding. *Vet. Med. Sci.* **2020**, *6*, 755–765. [CrossRef] [PubMed]
91. Medhi, D.; Hannah, S.; Sarmah, P.; Karmu, T.; Ali, E.; Das, P.; Deb, S. Performances of lactating yaks on silage and complete feed block based feeding regiments. *Indian J. Anim. Res.* **2016**, *86*, 203–205.
92. Das, P.; Deori, S.; Deb, S. *Arunachali Yak*; ICAR-NRCY Publication: Dirang, India, 2016.
93. Katoch, R. Tree fodder for mitigating the forage requirement in Himalayan region. *Range Manag. Agrofor.* **2019**, *40*, 173–180.

## STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the candidate and the candidate's Primary Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of candidate:	Sujan Sapkota
Name/title of Primary Supervisor:	Richard Laven
In which chapter is the manuscript /published work: Chapter 6	
Please select one of the following three options:	
<input checked="" type="radio"/> The manuscript/published work is published or in press	
<ul style="list-style-type: none"> <li>• <a href="https://doi.org/10.3390/vetsci9080449">https://doi.org/10.3390/vetsci9080449</a></li> </ul>	
<input type="radio"/> The manuscript is currently under review for publication – please indicate:	
<ul style="list-style-type: none"> <li>• The name of the journal:</li> </ul>	
<ul style="list-style-type: none"> <li>• The percentage of the manuscript/published work that was contributed by the candidate: 75%</li> </ul>	
<ul style="list-style-type: none"> <li>• Describe the contribution that the candidate has made to the manuscript/published work: main researcher, conceptualisation, methodology, main writing</li> </ul>	
<input type="radio"/> It is intended that the manuscript will be published, but it has not yet been submitted to a journal	
Candidate's Signature:	
Date:	05/01/24
Primary Supervisor's Signature:	
Date:	05/01/24

This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/publication or collected as an appendix at the end of the thesis.

## **Chapter 7: Development of Welfare Assessment Protocol for Yak/Yak hybrids in Nepal**

**Foreword:** This chapter is focused on the development of an assessment protocol for transhumance yak/yak hybrids amid a scarcity of relevant studies on yak/yak hybrids compared to dairy cattle. The study was in two parts – firstly identification of potential measures and collation of expert opinion on those measures, followed by a feasibility study in 5 different yak hybrid herds in Nepal.

*Article*

## Assessment of welfare in transhumance yak hybrids (chauri) in lower Himalayan region of Nepal

Sujan Sapkota <sup>1</sup>, Richard Laven <sup>1, \*</sup>, Shanker Raj Barsila <sup>2</sup>, Nikki Kells <sup>1</sup>, Kristina Ruth Mueller <sup>1</sup>, Dhurba DC <sup>3</sup>

<sup>1</sup> School of Veterinary Sciences, Massey University, Palmerston North 4442, New Zealand

<sup>2</sup> Faculty of Animal Science, Veterinary Science and Fisheries, Agriculture and Forestry University, Nepal,

<sup>3</sup> Veterinary Hospital and Livestock Service Expert Centre, Dolakha, Nepal

\*Correspondence: [R.Laven@massey.ac.nz](mailto:R.Laven@massey.ac.nz)

**Abstract:** In order to develop a yak/chauri-specific welfare assessment protocol, we sent a set of 31 potential welfare measures to 120 Nepalese experts and asked them to identify measures they thought would be useful, and to propose additional useful measures. Eighty-three experts responded, with 13 measures being identified by >50% of respondents as likely to be useful. These 13 measures plus one new measure (hematology) were included in an assessment protocol which was tested in the second phase in five chauri herds in two districts in northern Nepal. Animal-based evaluations along with sampling for mastitis, intestinal parasites, and hematology were undertaken during or just after morning milking. Resource and record-based measures were assessed through structured interviews, with verification on-site where possible. No chauri exhibited poor body condition, skin injuries, significant locomotion issues, or significant subclinical mastitis. Fecal testing suggested a high prevalence of intestinal parasites at the herd level, while blood testing suggested no evidence of haematological abnormalities. However, for both of these results we need more data to use these effectively as measures of welfare. Resource-based assessment revealed significant challenges across all, and veterinary services were reported as inadequate. A high estimated annual mortality rate (10–21%) needs further investigation. This protocol provided an useful start towards developing welfare assessment in yak/chauri and identified issues which need addressing to optimise chauri welfare.

Keywords: yak, chauri, welfare assessment protocol, welfare measures

## 7.1 Introduction

Consumer concerns about animal welfare have driven increasing interest in systematically assessing the welfare of livestock, particularly intensively reared animals such as permanently housed dairy cattle [1], cage-housed layer chickens [2], and pigs farrowing in crates [3]. There has been less interest in less intensive systems such as pasture-based dairy and beef cattle [4,5]. This is, in part, because of the perceived naturalness of those systems, but it is increasingly being recognized that the natural environment can result in poor welfare conditions and that we need to systematically assess the welfare of pasture-based livestock in order to provide evidence that claims of higher animal welfare are robust [6,7]. Furthermore, most of this interest in the systematic assessment of farm animal welfare has focused on commercially farmed livestock rather than livestock that are farmed on a subsistence or semi-commercial basis, even though increasing commercialisation may actually be positively associated with welfare outcomes [8].

Almost all yak (*Bos grunniens*) and their hybrids; chauri (Types: *Bos taurus* ( $\sigma$ ) $\times$ *B. grunniens* ( $\varphi$ ) (Dimjo chauri) and *B. grunniens* ( $\sigma$ ) $\times$ *Bos indicus* ( $\varphi$ ) (Urang chauri)) are reared under a transhumance system [9] and farmed on a subsistence or semi-commercial basis [10]. So it is not surprising that there are few published studies on the systematic assessment of yak welfare [11,12]. This lack of systematic assessment is accompanied by a general lack of information on yak welfare. The latter is likely to be due to their limited economic importance resulting from their semi-commercial/communal status and, in most areas outside of Tibet, their small numbers relative to other livestock. For example in Nepal there are ~50000 yak/chauri but more than 64 million cattle and 30 million buffalo [13]. Furthermore, in all areas, including Tibet, the remote locations in which yak are kept and the transhumance system that is used to access seasonal grazing mean that access to yak (and even chauri) is often difficult. Nevertheless, yak do play a significant role in the economy and sustainability in regions where they are common, and yak products can be an important part of the local experience for tourists [14], so assessing yak welfare and ensuring that it is optimal is likely to be of benefit in such areas.

Although we have limited data on yak welfare, it is clear that they face increasing challenges in many areas including nutrition, access to water, parasite burden and heat stress [11]. Perhaps the most important of these is shortage of forage in their rangelands [15] which is due

to both climate change (which alters growth rates of traditional forage and competing weeds; [11] and competition for land with other uses [11,16].

The welfare of yak is closely linked with the wellbeing of yak herders [17]. Socioeconomic changes in the prestige associated with yak herding as well as its profitability [18,19] have significantly decreased herder wellbeing and are thus likely to have had negative impacts on yak welfare. However, it is not just climatic and socioeconomic changes that are likely to be negatively affecting yak welfare. Longer term problems such as a lack of proper treatment facilities, limited knowledge and skill of yak herders combined with traditional farming practices, and a lack of support from governments [19] are also likely to be negatively impacting yak welfare.

We thus need more data on the welfare of yak and their hybrids, so that we can optimise their welfare (and the wellbeing of yak herders) and ensure the sustainability of yak herding for the future. To do this on an ongoing basis will require the development of an outcome-based welfare assessment programme. The first step in developing such a programme is to get expert and stakeholder perspectives on the key issues around yak welfare [20]. This approach should provide comprehensive information regarding the key welfare challenges that yak and chauri are likely to encounter and, thereby help to select welfare measures that are likely to be practicable and achievable in the challenging geographical conditions in which yak and chauri are found. The second step in developing the programme is to take the selected welfare measures and test their practicability and feasibility on farm.

The two aims of this study were thus to: 1) identify, with the help of local Nepalese experts, the measures that are likely to be useful for assessing the welfare of yak/yak-hybrids in Nepal, and then 2) test the practicality and feasibility of assessing those measures in a selection of chauri herds being grazed in the lower Nepalese Himalaya.

## **7.2 Materials and Methods**

### *6.2.1. Identification of measures for inclusion in the welfare assessment*

This process was undertaken in two phases. The first phase identified assessment measures to be included in our survey of local Nepalese experts. As the welfare assessment was intended for use during milking and immediately afterwards, animal-based measures for in-

clusion in the survey were principally sourced from our previous time-limited welfare assessment of dairy cattle in New Zealand [4]. Of the 13 measures included in our dairy protocol, all except ingrown horn and blind eye (not known to be a problem in yak/chaury) and heads up (not relevant in a transhumance system) were put forward. These measures were supplemented with material from a study which is, as far as the authors are aware, the only published peer-reviewed welfare assessment of yak [12]. That material came from a thesis on the challenges and opportunities to sustainable yak farming in Bhutan [21]. Additional material from this thesis was also used in the identification process, particularly that published in a paper on the future of yak farming [22], as was material collected during our recent review of the impact of climate change on yak [11] which included a section on the likely welfare impact of climate change. This resulted in 31 measures being included in the survey (15 animal-based, eight resource-based, six record-based, and two management-related measures; Table 1).

An online survey (See Appendix 1) was sent using Google Forms to a convenience sample of 120 Nepalese veterinarians and animal scientists. All invitees had at least four years of experience in the field and were known to the first author and were linked to him via a social media page. Invitees were contacted via Facebook Messenger. Response was voluntary and only the first author knew the identity of the invitees (and who had responded). The online survey was available for 3 months, with at least three reminders (follow-up messages and Messenger calls). For each of the 31 proposed measures, respondents were asked whether they would include it in a welfare assessment. Each individual measure was assessed on its own merit. The proportion of respondents who included a measure was calculated and measures were incorporated into the assessment protocol used for the feasibility study if >50% of respondents indicated that they would include it in a welfare assessment. Participants were also given the opportunity to suggest additional measures that were not included in the lists. Once the survey period was completed, all the additional measures suggested by the respondents were examined by the authors and if the authors thought they would be useful, potentially achievable, likely to provide further information on yak welfare, and could be incorporated into a time-limited assessment protocol they were included.

### 7.2.2. *Feasibility study*

For logistical reasons, unrelated to the study, the measures identified in phase one were evaluated for feasibility on-farm in November 2022. The timing of this assessment meant that yak could not be easily reached as they were still being kept on pastures at around 4000 m. In contrast, in November, chauri herds have moved down from their high-altitude summer pastures to their more accessible lower winter pastures. The preliminary welfare protocol was therefore assessed in a convenience selection of five chauri herds in two regions of Nepal (Dolakha and Rasuwa). In Dolakha, the committee members of the Yak/Chauri Farmers Association were contacted with the help of the district veterinary office, and herd owners grazing within 2 hours travel of the district veterinary office were identified. In Rasuwa, local farmer leaders were contacted directly by the authors themselves who identified target farms based on a farmer's willingness to participate and the location of the herd being accessible within 2 hours of travel from the local town. Three herds were selected in Dolakha and two in Rasuwa.

The assessment process began during morning milking, as soon as the chauris were tied to a pole for milking. Animal-based assessments were principally made during milking, with milk sampling for mastitis assessment when the chauris were being milked by the farmers followed by faecal sampling for evaluation of intestinal parasites. Once milking was complete, ~5 mL of blood was collected from the jugular vein into EDTA tubes (K3EDTA, Sanli Medical, Liuyang, China). These tubes were gently mixed, placed in an icebox and then transported to the laboratory for testing using a ProCyte Dx Haematology analyser (Idexx, Bangalore, India) within 12 hours of collection. The cattle algorithm was used for the analysis. For the mastitis, blood and faecal examinations we aimed to collect samples from at least 50% of the milking herd size. The final animal-based assessment was lameness scoring which was undertaken once the chauris were released after milking. Details of the method of assessment for these assessments are provided in Table 1.

Resource-based and record-based measures were then assessed using a questionnaire-guided interview (Appendix 2) with the farmers. All the interviews were conducted by the first author. For resource measures, the farmer response was cross-checked by the assessor if

the resource was accessible. For example, on the Dolakha farms the measure 'access to water' was assessed via questionnaire only as the chauris were being milked deep inside the forest, whereas in Rasuwa the sources of drinking water were visible and accessible.

Table 1: List of welfare measures included in the survey with the vote obtained from the survey respondents for inclusion (%) and the study they were selected from. Selected welfare measures in bold (obtaining > 50% vote) are only provided with their method of assessment.

	<b>Welfare measures<sup>†</sup></b>	<b>Assessment method*</b>	<b>Respondents (total n=83) recommending inclusion (%)</b>	<b>Selected from</b>
<b>Animal-based measures</b>	<b>Body condition Score</b>	using [23]. Poor BCS $\leq$ 3.5	70 (84%)	[4], [12]
	<b>Skin Injury/swellings</b>	Presence/absence of visible abrasions, cuts, hairless patches, and swellings	53 (63%)	[4], [12]
	<b>Endoparasite burden</b>	Qualitative fecal examination (present/absent) using simple fecal floatation method [24].	50 (60%)	[12], [25]
	<b>Lameness score</b>	>1 recorded as lame [26].	45 (54%)	[4], [12]
	<b>Mastitis</b>	California Milk Test. Score >1 mastitis [27].	42 (51%)	[12]
	Rumen fill score		27 (33%)	[4]
	Body cleanliness		26 (31%)	[4]
	Positive behaviours		25 (30%)	[4],[12]
	Nasal discharge		22 (27%)	[12]
	Ocular discharge		20 (24%)	[12]

	Agonistic behaviour		17 (21%)	[4], [12]
	Coughing		13 (16%)	[12]
	Diarrhoea		10 (12%)	[12]
	Avoidance distance		9 (11%)	[12]
	Broken tails		1 (1%)	[4]
<b>Resource-based measures</b>	<b>Access to drinking water at pasture.</b>	Farmer response at interview. Crosschecked if water source present within 500 m of milking site.	70 (84 %)	[4], [12]
	<b>Protection from climate extremes</b>	Farmer response at interview: Cross-checked if shelter /shade present within 500 m of milking site.	61 (74%)	[4], [11], [12]
	<b>Availability of veterinary services</b>	Farmer response at interview.	53 (64%)	[28]
	<b>Availability of sufficient forage at pasture</b>	Farmer response at interview	52 (63%)	[28]
	Cleanliness of water-points		34 (41)	[28]
	Distance between grazing pastures		29 (35)	Author selection
	Tracks/ & terrains condition		23 (28)	Author selection
	Availability of bridges		17 (21)	Author selection

<b>Management based measure</b>	Stockperson handling (during milking)		24(29)	[4]
	Any training on yak/chaury farming and handling?		19 (23)	[28]
<b>Record-based measures</b>	<b>Number of yak that die in a herd per year (any cause)</b>	Farmer response at interview (incidence calculated using current herd size estimate)	60 (73)	[4], [28]
	<b>Number of yak that die in a herd per year (extreme weather and accidents)</b>	Farmer response at interview (incidence calculated using current herd size estimate)	60 (73)	[28]
	<b>Number of yak that die in a herd per year (diseases and plant poisonings)</b>	Farmer response at interview (incidence calculated using current herd size estimate)	55 (67)	[28]
	<b>Are you satisfied with the veterinary support?</b> (accessibility vets/technicians; medicine availability)	Farmer response at interview	42 (51)	[28]
	Do you routinely vaccinate your herd?		36 (44)	Author selection
	Number of mastitis cases per year.		31 (38)	Author selection

## 7.3 Results

### 7.3.1. Survey results

Of the 120 Nepalese experts invited to complete the survey, 83 (69%) responded. Table 1 lists the measures included in the survey. Of the 15 suggested animal-based measures only five were selected by more than 50% of the respondents (i.e., >41/ 83) (see Table 1). For resource-based measures the equivalent figures were 4/8 and for record-based measures it was 4/6. Neither of the management-related measures were selected.

A total of 15 different additional measures were suggested by the local experts (see Table 2). The most suggested measure was assessment of hoof condition/foot lesions, but even this measure was suggested by only 5/83 respondents. After author discussion, measurement of complete blood count was added to the list of welfare measures. Therefore, the feasibility study included a total of 14 measures.

**Table 2:** Additional welfare measures suggested by survey respondents.

<b>Suggested animal-based measures (n)</b>	<b>Suggested non-animal-based measures (n)</b>
Wound score and size (1)	Stocking density (1)
Complete blood count (2)	Amount of concentrate/day (2)
Blood parasites (1)	Milk production (1)
Mineral status (1)	Separate walking route (2)
Hydration status (2)	Recent change in productivity (2)
Hoof condition/ foot lesions (5)	Breeding record (2)
Ectoparasites (1)	
Limb swellings (1)	
Body weight (2)	

n = number of respondents suggesting measure

### *7.3.2 Feasibility study results*

The location of the selected herds within Nepal are shown in Figure 1 and their demographics are summarised in Table 3. In our study, herds in Dolakha were at around 2800-2900 metre altitude range whereas herds in Rasuwa were at around 2200 metre altitude.

**Figure 1:** Map showing location within Nepal of farms where the welfare of chauri was assessed.



**Table 3:** Herd demographic information and number of samples collected per herd.

	Dolakha			Rasuwa	
	Herd 1	Herd 2	Herd 3	Herd 4	Herd 5
Herd size	18	20	20	14	16
Milking herd size	7	12	9	5	5
Mastitis check	7	8	4	5	5
Faecal collection	7	7	6	5	5
Blood sample	5	5	5	4	4

#### 7.3.2.1. Animal-based measures

In Dolakha the herds were mixed Urang and Dimjo whereas in Rasuwa the chauri were all Urang. In all the herds assessed there were no chauris with poor body condition (i.e. score  $\leq 3.5$ ), skin injuries, or poor locomotion score (score  $>1$ ).

The number of samples collected for faecal examination, mastitis test and haematology are shown in Table 2. On the two Rasuwa farms, all samples were collected from all milking animals, whereas in Dolakha it did not prove possible to do that (see Table 3). In addition across the three Dolakha farms we were unable to sample  $\geq 50\%$  of the milking herd for mastitis on one farm (Herd 3) and for haematology on another (Herd 2).

#### *7.3.2.2. Mastitis testing*

Across the five herds, 29/38 were tested for subclinical mastitis. None of the tested chauri had a CMT $>1$ , although five (three in Dolakha and two in Rasuwa), had a score of 1 (all in just one quarter).

#### *7.3.2.3. Parasite prevalence*

Of the 20 faecal samples collected from milking chauris in Dolakha, 12 were positive for gut parasites (giving a prevalence of 60%) whereas all faecal samples from the 2 herds in Rasuwa were positive (see Appendix C) giving a prevalence of 100%.

#### *7.3.2.4. Haematology*

The mean and approximate 95% prediction limits (mean  $\pm$  2 standard deviations) of the results from the ProCyte Dx Haematology analyser are presented in Table 4. As far as the authors are aware, there have been no published full haematology analyses from chauri, so our results are presented alongside equivalent results from four previous studies in yak and reference data from cattle obtained using a similar haematology analyser [29]. The data from these previous yak studies are too limited for statistical comparison, but except for total leucocyte count and haemoglobin concentration, the mean values from the current study are within the range of mean results found in yak. (The approximate prediction intervals are appreciably different in many cases but this is likely to be related to the small size of the yak studies cited in Table 4). Compared to reference data in cattle, there were marked differences, with many of the mean values observed in the current study close to or outside the reference limits identified by Herman et al [29].

**Table 4:** Haematological values obtained in the study and their comparison with previous studies on yaks and reference data from cattle obtained using a similar analyser.

	<i>Current (n=23)</i>	<i>Yak<sup>1</sup> (n = 7)</i>	<i>Yak<sup>2</sup> (n=7)</i>	<i>Yak<sup>3</sup> (n=7)</i>	<i>Yak<sup>4</sup> (n=6)</i>	<i>Cow<sup>5</sup> (n=152)</i>
<b>Measure</b>	<b>Mean (95%PI)</b>	<b>Mean (95%PI)</b>	<b>Mean (95%PI)</b>	<b>Mean (95%PI)</b>	<b>Mean (95%PI)</b>	<b>Mean (95%PI)</b>
Red blood cells (10 <sup>12</sup> /L)	4.9 (3-6.8)	6.4 (4.6-8.2)	4.7 (3.6-5.8)	6.9 (3-10.9)	7.6 (0-16.3)	6.2 (4.7-7.7)
Haemoglobin (g/l)	106 (66-146)	137 (103-171)	111 (85-138)	111 (101-121)	120 (51-188)	106 (80-132)
Haematocrit (%)	28.2 (15.7-40.6)	38 (30-46)	27.2 (20.6-33.9)	35.7 (29.3-42)	N/A	30 (20-40)
Mean corpuscular volume (fl)	57.8 (43.2-72.4)	N/A	58.2 (44.7-71.8)	52.2 (33.2-71.2)	N/A	50 (41.4-58.6)
Mean corpuscular hemoglobin (pg)	22 (15.4-28.8)	N/A	23.7 (19.4-28)	16.4 (7.5-25.3)	N/A	17.1 (14.3-19.9)
MCHC (g/l)	384 (275-492)	N/A	408 (359-458)	313 (250-376)	N/A	343 (324.4-361.6)
Total leucocyte count (10 <sup>9</sup> /l)	10.5 (1.8-19.4)	6.6 (4.2-9)	9.7 (6-13.4)	7.1 (4.7-9.5)	6.7 (4.5-8.9)	7.2 (4-10.4)
Neutrophil (%)	27.7 (9-48.6)	42 (18-66)	31.8 (18-45.7)	27.8 (24.4-31.1)	29.2 (2.7-55.7)	2.7 (0.5-4.9)
Lymphocyte (%)	62.3 (33.7-90.7)	46 (26-66)	52.1 (40.8-63.4)	60 (55.2-64.8)	60.7 (36.2-85.2)	3.1 (1.5-4.7)
Monocyte (%)	3.7 (0-5.7)	N/A	6.9 (0-14.1)	1.3 (0-3.8)	3.8 (0-8.6)	0.6 (0.2-1)
Eosinophil (%)	9.4 (1-17.3)	N/A	8.2 (0-16.4)	10.5 (2.3-18.7)	6 (0-14.7)	0.7 (0-1.7)

Basophil (%)	0.8 (0-1.6)	N/A	0.4 (0-1.2)	0.5 (0-2)	N/A	0.1 (0.1-0.1)
Platelets (K/ $\mu$ l)	101.5 (42-160.8)	N/A	N/A	N/A	N/A	N/A

Yak<sup>1</sup>: [30]; Yak<sup>2</sup>: [31]; Yak<sup>3</sup>: [32]; Yak<sup>4</sup>: [33], Cow<sup>5</sup>: [29]; 95% PI: Approximate 95% prediction interval calculated as mean $\pm$ 2SD

#### 7.4 Resource and record-based measures

The assessment of resource-based measures showed that there were significant issues in all herds (See Table 5). Herds in Dolakha were situated deep within the forest, which provided some protection from heat, wind, rain, and snow. In contrast, the herds in Rasuwa were situated in an open area, making them more vulnerable to such weather. However, none of the herds, regardless of location, had the use of proper shelters which could safeguard them from the adverse effects of extreme weather conditions.

In both districts, farmers reported the availability of veterinary services was poor as the veterinary facilities (hospital and manpower) were concentrated in the district headquarters. Four of the 5 respondents stated that they were not satisfied with current veterinary support, with the fifth stating they did not want such support. Farmers reported that 10–21% of their chauris died every year (See Table 5), although no deaths were reportedly due to extreme weather, or, despite all reporting a lack of availability of sufficient forage, starvation.

**Table 5:** Summary of welfare assessment outcomes for resource and record-based measures on transhumance chauri from five herds.

Measures	Dolakha			Rasuwa	
	Herd 1	Herd 2	Herd 3	Herd 1	Herd 2
Access to drinking water in the pasture	No	No	No	No	No
Availability of sufficient forage	No	No	No	No	No
Availability of veterinary services	Poor	Poor	Poor	Poor	Poor
Protection from extreme climate	For-est	Forest	For-est	None	None
Proportion of deaths per year (any cause) (%)	17	15	10	21	13
Proportion of deaths per year (accident) (%)	11	5	5	7	0
Proportion of deaths per year (weather-related) (%)	0	0	0	0	0

---

Satisfied with current veterinary support?	No	Don't want	No	No	No
--	----	------------	----	----	----

## 7.5 Discussion

The aim of this study was to select potentially useful welfare measures which could be applied in a time-limited welfare assessment of hybrid yaks (chauris) and to then test their feasibility and applicability in transhumance chauri herds in Nepal.

The process to achieve this faced several challenges. The most important of these was the limited information available related to the welfare of yaks. We thus took a mixed approach towards identifying suitable welfare assessment measures, combining measures from the limited literature on yak welfare, with measures used in a similar programme in pasture-based dairy farms [4], along with the authors' knowledge of yak/chauri farming. We then consulted with local Nepalese experts to identify which of our suggested measures they thought were appropriate to the assessment of yaks raised in a transhumance system.

Our approach to expert consultation was a simplified single stage process, differing from the Delphi process, which employs multiple stages to achieve consensus, both at an overall and individual measure level [34]. In addition, unlike the approach taken by Whay et al. [35], we did not ask our experts to rank measures based on their perceived importance, but just to select potentially suitable welfare measures from a list along with some suggested measures. We used this simplified approach because we had limited time for consultation and because our principal aim was to feasibility test a limited protocol. This also meant that we only chose measures for which there was >50% support from our experts.

This selection process resulted in a limited set of measures. Compared to the dairy protocol developed for New Zealand which had 32 measures and Dorji et al. [12] which had 18 measures, we had only 14 in our yak/chauri protocol. This meant that the protocol was

---

achievable within the time limits set (milking time) but limited the comprehensiveness of the welfare assessment (especially of resources) compared to the New Zealand system. One key difference between our dairy protocol and our yak/chaury protocol was the inclusion of animal-based sampling (milk, faeces, and blood) in the latter. This added considerably to the time which meant that although herd size was very small compared to that of New Zealand, assessment time was similar. Approximately half the assessment time was taken up by blood sampling, mainly due to the poor handling facilities available. Nevertheless, we believe that this animal sampling is likely to be an extremely useful part of the assessment for yak and chaury farmers who have very limited access to veterinary services, providing useful information on general animal health.

Traditional herding practices limit the ease of undertaking a welfare assessment, with chaury being milked early in the day and returned to their pastures before dawn (with milking being completed before 6:30 am when temperatures begin to increase). This constraint is similar to that in New Zealand on farms which milk once-a-day, with most such farms milking early in the morning to avoid the heat of the day. However, the additional challenge for yak/chaury is that the herd location is often a significant distance from infrastructure. For example, Dolakha, herds were camped at the grassland patches deep inside the forest, which meant it required a 30–40-minute walk to reach the herd from the road (in the dark). The welfare assessment could have been carried out during the afternoon milking, when the time pressure to set the chaury free and back to pasture is less pronounced, but this creates logistical problems for the laboratory testing, especially for the haematology. Sampling in the afternoon means that blood samples have to be stored and kept cool overnight, as reaching even local laboratories before they close is unlikely to be possible. An alternative to travelling in the early morning would be for the welfare assessor to stay the night with the herd so that assessment can be completed relatively easily during morning milking.

---

Farmers were concerned about the assessment interrupting their daily routine. Webster [36] stated that welfare assessment measures and processes should be as non-intrusive as possible. Our process aligned with this suggestion, as our assessment started with the least intrusive animal-based measures, such as observation of injuries, but our sampling did interfere with their routine, even we left the most intrusive sample (i.e. blood) until after milking. The initial attempt was to obtain as many samples as possible (at least 50% of the milking herd). However, the lack of handling facilities prolonged the sample collection process, which resulted in owners, especially in Dolakha, being worried about our assessment disrupting the normal daily routine of the animals particularly returning to pasture. Further feasibility testing and working with herders is required to establish how we can sample at least 50% of the milking herd without concerns about disrupting the daily routine.

This was a small-scale feasibility study with only 5 farms being assessed at a time of year that was not chosen based on likely presence of welfare issues, so it is important not to over-interpret the findings. For example, all chauri observed on all 5 farms were well-conditioned. It is likely that this is because they had just come down from their high summer pastures which generally have reasonable quantities of nutritious grass and herbs. A more appropriate time to assess BCS would just be late winter to early spring (February to April) when body condition is typically poorer due to feed scarcity over winter [11,37]. This timing presents an opportunity to evaluate their susceptibility to ailments due to reduced immunity [31,38], while also allowing for easier access to the herds [31].

We found no evidence of clinical lameness in any of the chauri. This is consistent with the findings of Dorji et al. [12] who reported a lameness prevalence of 0.5% in female yak, but needs further confirmation in more chauri herds, especially those which use shelters. This is likely because they do not walk long distances on a routine basis, unlike the male yak used in transporting goods in local towns and tourist destinations.

---

Assessment of mastitis by visual examination combined with the California Mastitis test (see Table 1) revealed that none of the chauri assessed had mastitis. This was not an unexpected result because yak and their hybrids traditionally have lower incidence of mastitis compared to cattle [39], however a recent study Biswas et al. [40] identified subclinical mastitis in 16% of quarters. The significant impact of mastitis on milk quality and safety combined with the importance of milk and products to yak herders [40] suggests that the benefits of testing when there are issues may more than justify the high proportion of tests where no problems are identified.

Endoparasites are known to be a significant and increasing problem in yak and chauri [11]. Our testing identified a high proportion of positive faecal samples, so supports that conclusion. It would have been better if we could have performed a quantitative parasitological test (eggs per gram) that would have determined the severity of infection, however, qualitative assessment of faecal samples is the common standard approach of the laboratory to which we sent our samples. Our data strongly suggest that we need more quantitative data to better understand endoparasite burdens in yak and chauri.

This is as far as the authors are aware the first published report of haematology in chauri. Our haematology data show that chauri haematology is much more similar to yak than to cattle. Unfortunately, as Table 4 shows haematological studies on yak are very limited so we lack data to properly use haematology to monitor and identify health problems in both chauri and yak. We need more baseline data, which takes account of season and altitude, as well as chauri type. Barsila et al. [9] showed that haemoglobin concentration in chauri and yak changed with altitude and with time at that altitude and Dimjo chauri had higher haemoglobin than Urang chauri). Furthermore, the analyser we used has not been validated for either yak or chauri. Our data shows that the differences between chauri and cattle are large enough to require specific validation.

---

Our resource assessment relied on subjective evaluations and questionnaires, limiting the scope of our investigation. However, we included key resource-based measures. Our findings indicate inadequate access to water, pasture, and veterinary services across all herds. In transhumant systems, these resources fluctuate with seasonal movements. During our assessment, as chauris descended to lower altitudes in preparation for winter, we noted a decrease in pasture abundance and natural water sources compared to summer levels. Addressing these resource deficits is crucial for maintaining chauri welfare, particularly in terms of supplying alternative sources of water and feed. Proximity to local towns during descent did not significantly improve access to veterinary services as the available services was still inadequate.

Record-based measures, such as an annual herd mortality rate of at least 10%, reflect poor welfare conditions. However, these records, primarily based on farmers' recollections, may be biased, and also include deaths from non-welfare-related causes like leopard attacks, highlighting the challenges in accurate welfare assessment in natural settings.

## **7.6 Conclusions**

Overall, the 15 welfare measures selected endorsed by Nepalese experts provided some useful information on yak welfare, and the protocol was feasible to carry out as a single time-limited welfare assessment, at least on lowland pastures. However, the protocol needs to be tested at different altitudes of the transhumance journey across different points in time before it can be recommended as a convenient welfare assessment tool in yak / yak hybrids.

In the small sample assessed, animal-based measures such as BCS, injury, lameness and mastitis were satisfactory at the time of assessment. However parasitic infestation was a welfare concern in all the herds assessed. It was clear that yak farmers are in need of better and more accessible veterinary services. The feasibility of providing mobile veterinary services with regular health check-up camps should be investigated, as should the provision of alternative winter-feeding strategies and pasture reseeded. Yak are particularly sensitive to climate change effects, especially wildfire in the pastures and forests, so addressing climate

---

change is likely to improve yak welfare (though it will take a global effort rather than a purely local one).

**Author Contributions:** Conceptualization, S.S. and R.L.; methodology, S.S., R.L., S.R.B., D.DC.; software, S.S.; validation, S.S., R.L.; formal analysis, S.S.; investigation, S.S., S.R.B., D.DC; resources, S.S., S.R.B., D.DC; data curation, S.S.; writing—original draft preparation, S.S.; writing—review and editing, R.L., N.K., KM; S.R.B, visualization, S.S.; supervision, R.L., N.K., K.M., S.RB; project administration, R.L.; funding acquisition, R.L. All authors have read and agreed to the published version of the manuscript.”

**Funding:** This research was funded by the SoVS Post Graduate Research Fund.

**Institutional Review Board Statement:** It has been judged as a minimal risk (AFU-FWA00031653/2022) for both animals and humans by the Institutional Review Board (IRB) of Agriculture and Forestry University (AFU), Nepal.

**Informed Consent Statement:** Verbal consent was obtained from the participants involved in this study.

**Data Availability Statement:** All data generated and analyzed during this study are included in this published article.

**Acknowledgments:** We extend our heartfelt gratitude to the farmers who generously permitted us to assess their herds. Our special appreciation goes to Dr. Keshav Bhatt for his instrumental role in connecting us with the farmers and to Dr. Rockson Karmacharya for his invaluable assistance in the hematological analysis. We also express our sincere thanks to the veterinary technician students whose logistical support was crucial to our endeavor.

**Conflicts of Interest:** The authors declare no conflict of interest.

**Appendix A :** Questionnaire survey on selection of suitable welfare assessment measures for a single visit welfare assessment of Yaks reared under the Transhumance system.

---

Name:..... Job position:.....

Experience(in Years):.....

Questions:

1. In your opinion, which of the following animal-based measures should be selected for a single visit welfare assessment of Yaks/Chauris reared under transhumance system? (Note: You can select multiple options.)

1. *Body condition Score*
2. *Rumen Fill Score*
3. *Skin injury/swellings*
4. *Ocular discharge*
5. *Nasal discharge*
6. *Coughing*
7. *Mastitis*
8. *Gait condition*
9. *Parasitic infestation*
10. *Diarrhoea*
11. *Avoidance distance*
12. *Agonistic behaviour*
13. *Positive behaviour (allogrooming, rubbing/scratching, playing, self-licking, tail wagging)*
14. *Body cleanliness*

---

15. *Broken tails*

2. In your opinion, which of the following resource and stockpersonship based measures should be selected for single visit welfare assessment of Yaks reared under transhumance system? (Note: You can select multiple options.)

1. *Access to drinking water in the pasture.*
2. *Cleanliness of waterpoints*
3. *Availability of sufficient forage at the pasture*
4. *Distance between grazing pastures*
5. *Protection from extreme climatic events like rainfall, hailstorm, heat and cold.*
6. *Availability of bridges*
7. *Availability of veterinary services*
8. *Tracks/Terrains Condition*
9. *Stockperson handling (stockpersonship-based measure)*

3. In your opinion, which of the following record-based measures (farmers estimate) should be selected for single visit welfare assessment of Yaks reared under transhumance system? (Note: You can select multiple options.)

1. *Number of yaks that die in a herd per year.*
2. *Number of yaks that die due to diseases and plant poisonings.*

---

3. *Number of yaks that die from extreme weather events and accidents (hailstone, flood, landslide, falling from the tracks and cliffs).*

4. *Number of mastitis cases per year.*

5. *Do you vaccinate your Yaks?*

4. Are you satisfied with the veterinary facilities?.....

5. Any trainings on yak farming?.....

6. Any animal-based measures you would like to add which is not in the list?.....

7. Any resource-based measures you would like to add which is not in the list?.....

8. Any management -based measures you would like to add which is not in the list?.....

**Questionnaire interview:**

1. Do you have a provision/source of drinking water within 500m of the milking site?

2. Do you have a provision of shade/shelter for protection against extreme climatic events like rainfall, hailstorm, heat and cold?

3. Do you have a veterinary hospital/treatment centre nearby?

4. Do you have sufficient availability of forages at the pasture?

5. Proportion of yaks that die in a herd per year (any cause)

.....

6. Proportion of yaks that die in a herd per year (extreme weather events and accidents)

.....

7. Proportion of yaks that die in a herd per year (diseases and plant poisonings)

.....

8. Are you satisfied with the government veterinary facilities (timely accessibility of veterinarians or veterinary technicians and availability of medicine, and vaccinations, when needed)?

Appendix B: Summary of rapid on- field test (California Mastitis test) of mastitis in 5 Chauri herds of Dolakha and Rasuwa district

		Mastitis rapid test				
		Quarters				
Place	S.N.	Herd	FR	FL	BR	BL
D	1	1	0	0	0	0
D	2	1	0	0	0	0
D	3	1	0	1	0	0
D	4	1	0	0	0	0
D	5	1	0	0	0	1
D	6	1	0	0	0	0
D	7	1	0	0	0	0
D	8	2	0	0	0	0
D	9	2	0	0	0	0

D	10	2	0	0	0	0
D	11	2	0	0	0	0
D	12	2	0	0	0	0
D	13	2	0	0	0	0
D	14	2	0	0	0	0
D	15	2	0	0	0	0
D	16	3	0	0	0	0
D	17	3	0	0	0	0
D	18	3	0	0	0	0
D	19	3	0	0	0	0
R	20	1	0	0	0	0
R	21	1	0	1	0	0
R	22	1	0	0	0	0
R	23	1	0	0	0	0
R	24	1	0	0	0	0
R	25	2	0	0	0	0
R	26	2	1	0	0	0
R	27	2	0	0	0	0
R	28	2	0	0	1	0
R	29	2	0	0	0	0

---

**Appendix C:** Summary of fecal examination using floatation method for to determine the presence/absence of parasites in Chauris.

S.N.	District	Herds	Result	Parasites
1	Dolakha	1	p	strongyle
2	Dolakha	1	p	strongyle
3	Dolakha	1	n	
4	Dolakha	1	n	
5	Dolakha	1	p	strongyle
6	Dolakha	1	n	
7	Dolakha	1	p	strongyle
8	Dolakha	2	n	strongyle
9	Dolakha	2	n	
10	Dolakha	2	p	trichuris
11	Dolakha	2	p	trichuris
12	Dolakha	2	n	
13	Dolakha	2	n	
14	Dolakha	2	p	trichuris
15	Dolakha	3	p	strongyle

16	Dolakha	3	n	
17	Dolakha	3	p	strongyle
18	Dolakha	3	p	trichuris
19	Dolakha	3	n	
20	Dolakha	3	p	stongyle
21	Rasuwa	1	p	Moneiza, tricostrongylus
22	Rasuwa	1	p	Monizia
23	Rasuwa	1	p	Trichostongylus
24	Rasuwa	1	p	strongyle
25	Rasuwa	1	p	Monizia
26	Rasuwa	2	p	Monizia+strongylus
27	Rasuwa	2	p	strongyloid
28	Rasuwa	2	p	Monoiza
29	Rasuwa	2	p	Trichostongylus
30	Rasuwa	2	p	Monizia

Note: P means positive for parasites, n means no presence of parasites

## References



- 
1. Arnott, G.; Ferris, C.; O'connell, N. Welfare of dairy cows in continuously housed and pasture-based production systems. *Animal* **2017**, *11*, 261-273.
  2. Hartcher, K.M.; Jones, B. The welfare of layer hens in cage and cage-free housing systems. *World's Poultry Science Journal* **2017**, *73*, 767-782.
  3. Tonsor, G.T.; Olynk, N.; Wolf, C. Consumer preferences for animal welfare attributes: The case of gestation crates. *Journal of Agricultural and Applied Economics* **2009**, *41*, 713-730.
  4. Sapkota, S.; Laven, R.; Müller, K.; Kells, N. Animal Welfare Assessment: Can We Develop a Practical, Time-Limited Assessment Protocol for Pasture-Based Dairy Cows in New Zealand? *Animals* **2020**, *10*, 1918.
  5. Kaurivi, Y.B.; Laven, R.; Hickson, R.; Parkinson, T.; Stafford, K. Developing an animal welfare assessment protocol for cows in extensive beef cow-calf systems in New Zealand. Part 1: Assessing the feasibility of identified animal welfare assessment measures. *Animals* **2020**, *10*, 1597.
  6. Dawkins, M.S. Natural Behaviour Is Not Enough: Farm Animal Welfare Needs Modern Answers to Tinbergen's Four Questions. *Animals* **2023**, *13*, 988.
  7. Spigarelli, C.; Zuliani, A.; Battini, M.; Mattiello, S.; Bovolenta, S. Welfare assessment on pasture: A review on animal-based measures for ruminants. *Animals* **2020**, *10*, 609.
  8. Kaurivi, Y.B.; Laven, R.; Parkinson, T.; Hickson, R.; Stafford, K. Assessing extensive semi-arid rangeland beef cow-calf welfare in Namibia: part 1: comparison between farm production System's effect on the welfare of beef cows. *Animals* **2021**, *11*, 165.
  9. Barsila, S.; Kreuzer, M.; Devkota, N.; Ding, L.; Marquardt, S. Adaptation to Himalayan high altitude pasture sites by yaks and different types of hybrids of yaks with cattle. *Livestock Science* **2014**, *169*, 125-136.
  10. Ning, W.; Oli, K.P.; Gilani, H.; Joshi, S.; Bisht, N. Yak raising challenges: transboundary issues in far eastern Nepal. *Yak on the Move* **2016**, 53.
  11. Sapkota, S.; Acharya, K.; Laven, R.; Acharya, N. Possible Consequences of Climate Change on Survival, Productivity and Reproductive Performance, and Welfare of Himalayan Yak (*Bos grunniens*). *Veterinary Sciences* **2022**, *9*, 449.
  12. Dorji, N.; Derks, M.; Koerkamp, P.G.; Bokkers, E. Welfare and management practices of free-ranging yaks (*Bos grunniens*) in Bhutan. *Animal Welfare* **2022**, *31*, 467-481.
  13. Shingh, S.; Kalwar, C.S.; Poudel, S.; Tiwari, P.; Jha, S. A Study on Growth and Performance of Dairy Sector in Nepal. *International Journal of Environment, Agriculture and Biotechnology* **2020**, 5.
  14. Gurung, L. Exploring links between tourism and agriculture in sustainable development: A case study of Kagbeni VDC, Nepal: A thesis submitted in partial fulfilment of the requirements for the Degree of Master of Tourism Management at Lincoln University. Lincoln University, 2012.
  15. Krishnan, G.; Paul, V.; Hanah, S.; Bam, J.; Das, P. Effects of climate change on yak production at high altitude. **2016**.
  16. Tiwari, P.C.; Joshi, B. Natural and socio-economic factors affecting food security in the Himalayas. *Food Security* **2012**, *4*, 195-207.
  17. Pinillos, R.G.; Appleby, M.C.; Manteca, X.; Scott - Park, F.; Smith, C.; Velarde, A. One Welfare - a platform for improving human and animal welfare. *Veterinary Record* **2016**, *179*, 412-413.

- 
18. Sherpa, Y.D.; Kayastha, R.B. A study of livestock management patterns in Sagarmatha National Park, Khumbu Region: trends as affected by socio-economic factors and climate change. *Kathmandu University Journal of Science, Engineering and Technology* **2009**, *5*, 110-120.
  19. Joshi, S.; Shrestha, L.; Bisht, N.; Wu, N.; Ismail, M.; Dorji, T.; Dangol, G.; Long, R. Ethnic and cultural diversity amongst yak herding communities in the Asian highlands. *Sustainability* **2020**, *12*, 957.
  20. Main, D.; Whay, H.; Green, L.; Webster, A. Preliminary investigation into the use of expert opinion to compare the overall welfare of dairy cattle farms in different farm assurance schemes. *Animal Welfare* **2003**, *12*, 565-569.
  21. Dorji, N. Transhumant pastoralism in a changing world: Challenges and opportunities to sustainable yak farming in Bhutan. Wageningen University and Research, 2020.
  22. Dorji, N.; Derks, M.; Groot Koerkamp, P.W.; Bokkers, E.A. The future of yak farming from the perspective of yak herders and livestock professionals. *Sustainability* **2020**, *12*, 4217.
  23. DairyNZ. Body Condition Scoring Made Easy. Available online: [https://www.dairynz.co.nz/media/5790783/body-condition-score-made-easy\\_a6-field-guide\\_2022-final-web.pdf](https://www.dairynz.co.nz/media/5790783/body-condition-score-made-easy_a6-field-guide_2022-final-web.pdf) (accessed on 2021).
  24. Burton, E. Introduction to Common Fecal Diagnostic Procedures **2021**.
  25. Sapkota, S.; Laven, R.; Müller, K.R.; Kells, N. Practicability of a Time-Limited Welfare Assessment Protocol for Pasture-Based Dairy Farms, and a Preliminary Assessment of Welfare Outcome Thresholds. *Animals* **2022**, *12*, 2481.
  26. DairyNZ. Lameness field guide. **2017**.
  27. AHDB. California milk test for dairy cows. Available online: <https://ahdb.org.uk/knowledge-library/california-milk-test-for-dairy-cows> (accessed on 29/05/2023).
  28. Dorji, N. Transhumant pastoralism in a changing world: Challenges and opportunities to sustainable yak farming in Bhutan. *PQDT-Global* **2020**.
  29. Herman, N.; Trumel, C.; Geffré, A.; Braun, J.-P.; Thibault, M.; Schelcher, F.; Bourguès-Abella, N. Hematology reference intervals for adult cows in France using the Sysmex XT-2000iV analyzer. *Journal of Veterinary Diagnostic Investigation* **2018**, *30*, 678-687.
  30. Hawkey, C.; Ashton, D.; Hart, M.; Cindery, R.; Jones, D. Normal and clinical haematology in the yak (*Bos grunniens*). *Research in Veterinary Science* **1983**, *34*, 31-36.
  31. Barari, S.; Biswas, D.; Pal, R. Normal hemogram of yak (*Bos grunniens*). *Journal of Applied Animal Research* **1995**, *7*, 99-103.
  32. Wadhwa, D.; Prasad, B. A note on haematological profile of yaks (*Bos grunniens*). *Indian veterinary journal* **1996**, *73*, 330-332.
  33. Singh, S.; Sharma, K.; Rastogi, S.; Narang, M. A FEW PHYSIOLOGICAL-PARAMETERS OF YAKS. **1989**, *59*, 1108-1109.
  34. Campos-Luna, I.; Miller, A.; Beard, A.; Leach, M. Validation of mouse welfare indicators: a Delphi consultation survey. *Scientific reports* **2019**, *9*, 1-11.
  35. Whay, H.; Main, D.; Green, L.; Webster, A. Assessment of the welfare of dairy cattle using animal - based measurements: direct observations and investigation of farm records. *Veterinary record* **2003**, *153*, 197-202.

- 
36. Webster, J. The assessment and implementation of animal welfare: theory into practice. *Revue Scientifique Et Technique-Office International Des Epizooties* **2005**, *24*, 723.
  37. Barsila, S.R.; Devkota, N.R.; Kreuzer, M.; Marquardt, S. Effects of different stocking densities on performance and activity of cattle× yak hybrids along a transhumance route in the Eastern Himalaya. *SpringerPlus* **2015**, *4*, 1-12.
  38. Iqbal Yattoo, M.; Shabir, M.; Kubrevi, S.S.; Dar, R.A.; Angmo, K.; Kanwar, M.S.; Bhat, R.A.; Muheet; Parray, O.R. A study on biological rhythms of Himalayan yaks. *Biological Rhythm Research* **2020**, *51*, 1087-1094.
  39. Tashi Dorji, W.R., Yu Sijiu. DISEASE IN THE YAK Available online: <https://www.fao.org/3/ad347e/ad347e0k.htm> (accessed on
  40. Biswas, S.; Mukherjee, R.; Chakravarti, S.; Bera, A.K.; Bandyopadhyay, S.; De, U.K.; Datta, S. Influence of pathogens specific subclinical mastitis on oxidative status and mineral metabolism of yak. *Emerging Animal Species* **2023**, 100028.

## STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the candidate and the candidate's Primary Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated below in the *Statement of Originality*.

Name of candidate:	Sujan Sapkota
Name/title of Primary Supervisor:	Richard Laven
In which chapter is the manuscript /published work:	Chapter 6
Please select one of the following three options:	
<input type="radio"/> The manuscript/published work is published or in press	
<input checked="" type="radio"/> The manuscript is currently under review for publication – please indicate:	
<ul style="list-style-type: none"> <li>• The name of the journal: Ruminants</li> </ul>	
<ul style="list-style-type: none"> <li>• The percentage of the manuscript/published work that was contributed by the candidate: 75%</li> </ul>	
<ul style="list-style-type: none"> <li>• Describe the contribution that the candidate has made to the manuscript/published work: main researcher, conceptualisation, methodology, main writing</li> </ul>	
<input type="radio"/> It is intended that the manuscript will be published, but it has not yet been submitted to a journal	
Candidate's Signature:	
Date:	05/01/24
Primary Supervisor's Signature:	
Date:	05/01/24

This form should appear at the end of each thesis chapter/section/appendix submitted as a manuscript/publication or collected as an appendix at the end of the thesis.

## **Chapter 8: General Discussion**

The main objectives of this research were to develop a streamlined protocol for evaluating the welfare of dairy cows kept permanently at pasture in New Zealand, and to then adapt that process to create a welfare assessment protocol that was suitable for use in yak and yak hybrids in the challenging conditions of the Himalaya.

The key issue for developing an efficient assessment protocol for cows in New Zealand is the limited time available when cows can be closely observed and their relationship with farm staff assessed. Milking time is the only time that this can occur without requiring either significant changes in farm practice (such as bringing cows in simply to be assessed) or limiting when assessments can be undertaken (e.g., assessing cows during pregnancy diagnosis, a process that only occurs 2-3 times a year in summer/autumn). Thus, the assessment protocol developed for this research needed to be practical and comprehensive, while also being achievable during the limited time available around milking. Interestingly, despite the differences between commercial dairy farms in New Zealand and transhumance yak/yak hybrid farms in Nepal, the same key issue was also apparent during the development of the welfare assessment protocol of yak and their hybrids, as again milking time was the only suitable time for much of the welfare assessment, as this is the only time when the animals are restrained.

### **8.1 Selection of welfare assessment measures.**

For both protocols, the first step was developing a list of potential welfare measures that could be used for welfare evaluation purposes.

#### **8.1.1 Development of the New Zealand protocol**

The initial measures included in the protocol were mainly based on the Welfare Quality protocol for dairy cows (Welfare Quality, 2009). However, this protocol was principally designed for dairy cows which spend a significant proportion of their time indoors. To address this issue, additional assessments were identified from five assessment protocols which had some cattle at pasture. These were selected from different protocols across the world so that our protocol would reflect a global approach to welfare assessment. Two protocols from Europe (Asurewel, 2018) and the Animal Needs Index (Bartussek et al., 2000), two from North America (the UC Davis Cow-Calf Health and Handling Assessment; (UCDavis, 2017) and the Canadian Animal care module (proAction, 2021), were selected

along with one from South America (the Chilean Protocol of Animal Welfare for Dairy Farms (Danitza, 2016)). This approach was then supplemented by analysis of data from four studies on dairy cattle welfare assessment; three from Europe (Capdeville & Veissier, 2001; Napolitano et al., 2005; Whay et al., 2003) and one from South America (De Wolf, 2009). This process was influenced by and similar to the approach used by (Kaurivi et al, 201) to select suitable welfare measures for beef cattle kept at pasture in New Zealand.

The goal of our procedure was not to include all potential measures but rather to pinpoint a spectrum of assessment measures that would cover the key welfare areas (Nutrition, Environment, Health, Behaviour) in ways that are relevant to cattle kept in the pasture-based conditions that are predominant on New Zealand dairy farms.

An iterative process was used to screen potential measures for relevance, practicality, and required time and thereby to eliminate measures that in the authors' opinion did not meet those targets, without significantly reducing coverage of the key welfare areas. Once the final protocol had been agreed it was taken to two farms for a feasibility study. Feasibility (i.e., achievability and practicality within the constraints of welfare assessment) is an important aspect of welfare assessment (Knierim & Winckler, 2009); our aim in the feasibility study was to test the practicality, time requirements, optimal assessment location, and ease of scoring of our measures. The objective of this process was to identify those measures which needed modification and those measures which were not suitable as well as to identify useful measures that had not been included in the study protocol. The process was constrained by it having to be time-limited with animal-based assessments being principally made during milking-time. Thus, the protocol we developed was a simplified protocol designed for the purposes of farm assurance rather than a systematic comprehensive assessment of dairy cattle welfare.

With a simplified protocol, it is essential to ensure that the main welfare areas have been covered, and that the time-limited nature of the assessment which necessitates that simplification has not resulted in a protocol with major welfare gaps. In regard to the nutrition domain, we used body condition scoring to evaluate long to medium-term energy balance and rumen fill to assess feed intake over the previous 24 hours. The former is commonly used in welfare assessment frameworks such as Welfare Quality (2009), but the latter is less commonly used (although Whay et al. (2003) did include it in their study). We feel that both methods are needed to effectively assess feed intake, especially as our protocol did not directly assess feed availability. Under New Zealand conditions this is principally a

measure of grass availability, which can be time consuming to assess and is of limited value as a single snapshot in time as it is very seasonally dependent. The seasonality of feed availability highlights the need of routine assessment nutrition domain using outcome based measures like BCS and rumen fill from the farm management staffs alongside the routinely planned independent assessment throughout the year. Another critical aspect in the nutrition domain is water availability. Assessing water flow and functionality of water points, as done in Welfare Quality (2009), is challenging in pasture settings as it is difficult to record water intake, flow rate because of outdoor settings with number of troughs to be assessed at different surface levels. Also, the drinking behaviour of the pasture-based cows is different from the housed cows which needs further studies (Jensen & Vestergaard, 2021). So we used distance to water points as a proxy as done by Kaurivi et al (2019), which proved impractical in many farms with fencing for grass management meaning that cows only had access to a single trough. Thus our protocol currently lacks a direct measure of water availability, although we did have a measurement of water quality (trough cleanliness assessment). A quick alternative could be at that available trough space is always at least 50 cm per cow as suggested by (Harrington, 1980) who concluded that if there was such space at least 10% of the herd should be able to drink water at the same time. However, it is clear that we need more data on the use of water troughs by dairy cattle under New Zealand conditions to identify what the cows want and need and how that varies over the season.

A major part of assessing welfare in the environment domain is cleanliness. However, assessing the impact of cleanliness on the welfare of cows in a pasture-based setting presents a significant challenge (Laven and Fabian) prompting our focus on refining this measure in a way that suits pasture-based cows. Thus, a strategic exclusion of the lower leg (below hock) in the assessment was implemented, and we concentrated solely on dry dirt accumulation. This methodological refinement was also employed by the UC Davis Cow-Calf Health and Handling Assessment (University of California Davis, 2017) protocol.

One key environmental area for pasture-based cows, which is not explicitly assessed in housed cows (Welfare Quality 2009), is shade and shelter. This involved, for shade, measuring the height of the tree, and canopy radius and then calculating the shade using Monteith and Unsworth's (1990) equation, while for shelter recorded the proportion of the examined area covered by shelter belts. Both of these approaches only covered a small amount of the farm, but we identified that most farms did not have enough shade or shelter. This issue needs to be prioritised and taken to the farm level. Information from drones

combined with machine learning algorithms could rapidly and inexpensively be used to audit farms on a yearly basis, saving time during the yearly assessment for other assessments such as positive welfare outcomes. Another environmental factor area which is not commonly assessed in housed cow programs is the examination of walking tracks. The assessment specifically concentrated on the initial 100 meters of the walking track. This minimises the time spent assessing tracks by focusing on the area of track that is most used and thus most likely to wear and be damaged, and, if damaged, likely to have the most impact on cow welfare.

Other measures added to our protocol for pasture-based dairy cows included head positioning in the yard, yard space per cow, and the speed of backing gates. These all record the impact of the environment on cow welfare during milking – crucial for assessing pasture-based cows which have limited interaction with people and the built environment.

The health domain comprised an equal number of animal and record-related measures (six each). This combination was important as measures that could not be assessed during milking but were still important for welfare could be assessed with the help of the records. Established welfare protocols like Welfare Quality (2009) give more weight to the animal-based measures in assessing this domain compared to record-based measures as they provide more accurate reflection of welfare. But Welfare Quality is a comprehensive welfare assessment protocol which is not time limited. We focussed on observing health issues such lameness, broken tails, and skin injuries which we thought were particularly relevant in a pasture-based system. Laven & Fabian, (2016) reported that recording of health-related issues was often poor on New Zealand farms. But other record-based measures like the annual incidence of lameness, mastitis, and mortality (replacement heifer deaths, total deaths) were included as they were expected to be recorded or at least remembered as an estimate.

The behavioural interaction domain included three measures focussed directly on behaviour (agonistic behaviour, positive behaviour, and fear behaviour). However, our feasibility study identified that fear behaviour was not feasible to measure alongside other measurements during milking, while for the other behavior measures there were insufficient behaviours observed in a 30 minute period prior to milking for them to be a useful assessment. We need more studies on behaviour in pasture-based dairy cows in order to determine the optimal timing of observations throughout the day and across seasons and to define the most effective approach to observe a representative proportion of the herd.

Nevertheless, we were able to cover key areas of the behavioural interaction domain, as we observed handling of animals on the track while bringing them from the paddock to milking and handling of the cows during milking which are key human-animal interactions in pasture-based cows.

### **8.1.2 Simplifying lameness assessment.**

Although we developed a simplified welfare assessment protocol, it still required whole herd lameness scoring. This necessity to score the entire herd demanded either two assessors at a single milking or assessments at two separate milkings by a single assessor, incurring higher costs and time. We therefore explored sampling strategies. Random sampling was a priori determined to be impractical, as it still required a separate focus on locomotion scoring throughout milking. Thus, we experimented with sub-sampling specific cow groups in the milking order (e.g., first 100, middle 100, last 100). Our findings aligned with Main et al.'s (2010) results, indicating that assessing the middle 100 cows could approximate herd prevalence within a 5% margin. However, given New Zealand's lower lameness prevalence (Mason et al 2023), and our target threshold for acceptable welfare of 5% we need a more precise estimate. Thus, our conclusion was that we needed to more data from more farms to more precisely characterise the accuracy of scoring the middle 100 cows in the milking order and to test screening strategies based around the middle 100 cows in order to identify it was possible, under New Zealand conditions for a single observer to assess all welfare measures during one milking.

## **8.2 Development of the protocol for use in Yak/Yak hybrids in Nepal**

In contrast to dairy cattle where there are many farm-assurance-based welfare assessment schemes and a significant amount of published data on welfare assessment in general, the amount of material available relating to yak welfare assessment is much more limited. As far as the authors are aware there is only one peer-reviewed welfare assessment programme for yak (Dorji et al., 2022). This was a part of a thesis (Dorji, 2020) which also looked at other areas like development, challenges and future perspectives of Yak farming in Bhutan. This

lack of material on yak welfare assessment is clearly linked to the more limited nature of yak farming both in commercial terms and in the number of countries where it is an important part of livestock farming, but it meant that we needed a different approach to identify potential measures for a yak welfare assessment. The key part of this approach was to collate views from experts in Nepal to guide the choice of measures. Such an approach has been implemented in multiple studies related to welfare assessment where the amount of information has been thought to be insufficient to make robust conclusions (Campos-Luna et al., 2019) and was, in simplified form, similar to the approach used by (Whay et al., 2003) in the first welfare assessment protocol of dairy cattle which was focussed principally in terms of animal-based welfare outcomes.

For our yak/chaury protocol, we adopted the process of assessing the animals during milking for a limited time from our dairy protocol. We did not aim to ensure that all four domains were appropriately covered but to develop a protocol that could be built on to create a feasible but comprehensive yak/chaury welfare assessment. The key difference between our yak and dairy protocols was the inclusion in the former of sampling. We believe that including sampling alongside observations provides a health check for farmers, who have very little health information as well as providing with data in those areas where there is a paucity of information related to yak/chaury (e.g., haematology of yak/chaury). For the welfare assessment, perhaps the biggest missing area was in the behavioural interaction domain as we did not record any measures related to animal handling which needs to be added for its comprehensiveness.

### **8.3 Representation of welfare outcomes**

In New Zealand, our objective was to assess dairy cow welfare, categorizing measures into distinct welfare levels through author-assigned thresholds. However, in Nepal limited information on yak/chaury welfare assessment, meant that the establishment of thresholds posed a challenge.

This highlights the difference between the two protocols. In New Zealand our dairy protocol could be relatively simply integrated into commercial farm assurance programs (after determining efficient lameness assessment strategy). However, we need to significantly improve our knowledge about and understanding yak/chaury welfare remains a prerequisite before advancing in protocol development useful for auditing.

#### **8.4 Threshold establishment, Welfare Categorisation and Welfare Outcomes.**

Establishment of thresholds for welfare measures is a must if we are to implement welfare protocols on farms. Thresholds help to define and categorise target, caution, and alert ranges and can act as a valuable means of comparing welfare outcomes. So, they are an integral part of the protocol development process, although developing welfare threshold is a complicated process (Sørensen & Fraser, 2010; Whay et al., 2003).

As our aim during the New Zealand phase of this thesis was focused on feasibility testing, we choose not to use expert consensus to establish the thresholds for different welfare measures as done by many others (Whay et al., 2003). Our initial strategy involved employing our own judgement and utilizing relevant literature, where available, to aid in our feasibility study. The aim was to categorise the results into three distinct levels: acceptable, marginal, and unacceptable. The inclusion of the marginal level serves to clearly differentiate between acceptable and unacceptable welfare and thus the marginal range represents a cautionary zone. Further deterioration in a measure could potentially result in crossing into the unacceptable zone, while improvement could elevate it to the acceptable zone. We did not aggregate our results. We believe that representing outcomes on individual measure basis and excluding the mathematical calculations involved in the aggregation process will be more able to easily convey the outcomes of our assessment to a wide audience (Hampton et al., 2019). This approach avoids the limitations of compensating for a low welfare area with higher scores. This approach is similar to the methodology employed to establish thresholds in a protocol used for assessing beef cow welfare in New Zealand (Kaurivi et al., 2020).

In contrast, the study in yak was just a small-scale study designed to kickstart the development of an assessment process, so we simply reported the data rather than trying to develop welfare levels and thresholds. The process of threshold development for yak/chauri needs more data alongside a mixed approach of expert advice, literature reviews and discussions (Schenkenfelder & Winckler, 2022). Combining the two approaches uses the advantages of the benchmarking approach where the top x% of herds are identified as having acceptable welfare, and the last y % as unacceptable welfare, with independent expert advice which will prevent 'normal' being misinterpreted as 'acceptable'.

## **8.5 Limitations of the study**

### **a) Reliability and repeatability of welfare measures**

Interobserver reliability (comparison of results across observers) and test-retest reliability (consistency overtime) along with repeatability (consistency of measurements with the same method under identical conditions) determines the utility of the measures included in a protocol and are fundamental to effective welfare assessment (Kirchner et al., 2014; Knierim & Winckler, 2009). To ensure the consistency and accuracy of the data collected, it is essential to evaluate the reliability the measures used (Harley et al., 2021, Stack et al., 2021; Knierim & Winckler, 2009). Without reliability, uncertainty remains as to the robustness of conclusions drawn from the data obtained during the welfare assessment. In our study, even though the measures we selected from other protocols for our dairy cow protocol had all been tested for reliability in housed cows, many are yet to be tested in pasture-based cows. In addition, measures included after the initial trial phase (for instance, backing gate speed, Yard space per cow, heads up, and noise level) have all been related to welfare significance but have yet to be tested in terms of reliability and repeatability. For our yak protocol, we principally used measures based on our dairy protocol (Sapkota et al., 2020) and the Bhutanese welfare assessment studies (Dorji et al., 2022). As in our New Zealand protocol, most of the measures used in our yak/chaury protocol have been demonstrated to be repeatable and reliable in housed dairy cows but not in yak or chaury (like us, Dorji et al. (2022) did not assess repeatability or reliability). This validation needs to be done as part of the development process.

### **b) Seasonality**

Though this protocol could be used at any time of the year, it was only applied in a single season. Specific welfare issues (Fleming et al., 2021) faced by the cows during winter in New Zealand (e.g. pasture restriction, extensive fodder beet feeding), would be missed if the assessment is restricted to just a one-time point within a year. Therefore, it is important to keep these limitations in mind when using the protocol. In contrast, for yak/chaury welfare is probably poorest at the end of the winter season, so targeting that season may identify the key welfare challenges.

## References

- Armson, D., Rahman, M. A., & Ennos, A. R. (2013). A comparison of the shading effectiveness of five different street tree species in Manchester, UK. *Arboriculture & Urban Forestry*, 39(4), 157-164.
- Assurewel. (2018). Dairy Cattle Welfare Protocol. Retrieved from [http://www.assurewel.org/Portals/2/Documents/Dairy%20cows/AssureWel%20Dairy%20Welfare%20Outcome%20Assessment%20Protocol\\_2018.pdf](http://www.assurewel.org/Portals/2/Documents/Dairy%20cows/AssureWel%20Dairy%20Welfare%20Outcome%20Assessment%20Protocol_2018.pdf)
- Bartussek, H., Leeb, C., & Held, S. (2000). Animal Needs Index for Cattle (Ani 35 L/2000-cattle). *Federal Research Institute for Agriculture in Alpine Regions BAL Gumpenstein, Irnding, Austria*.
- Campos-Luna, I., Miller, A., Beard, A., & Leach, M. (2019). Validation of mouse welfare indicators: A Delphi consultation survey. *Scientific reports*, 9(1), 1-11.
- Capdeville, J., & Veissier, I. (2001). A method for assessing dairy cows welfare in a loose housing herd focussing on animal observations. *Acta Agriculturae Scandinavia, Suppl*, 30, 62-68.
- Danitza, A. (2016). Animal Welfare Program of Chilean Dairy Consortium. Retrieved from <https://www.icar.org/Documents/Puerto-Varas-2016-presentations/files/OL/OL%205/RDY/1%20Presentacion%20Programa%20de%20bienestar%20animal%20del%20Consortio%20Lechero%20de%20Chile%20ICAR%202016%20D.%20ABARZUA.pdf>
- De Wolf, A. (2009). A welfare assessment system for dairy cows on pasture and the comparison to a welfare scoring system for cows in cubicles. *Research Project Veterinary Medicine, University of Utrecht*.
- Dorji, N. (2020). *Transhumant pastoralism in a changing world: Challenges and opportunities to sustainable yak farming in Bhutan*. Wageningen University and Research,
- Dorji, N., Derks, M., Koerkamp, P. G., & Bokkers, E. (2022). Welfare and management practices of free-ranging yaks (*Bos grunniens*) in Bhutan. *Animal Welfare*, 31(4), 467-481.

- Fleming, A., Edwards, G., Bryant, R., & Gregorini, P. (2021). Feeding fodder beet to grazing dairy cows: Is it a paradigm for reduced animal welfare and increased economic and environmental risk? *Applied Animal Science*, 37(3), 294-305.
- Hampton, J. O., MacKenzie, D. I., & Forsyth, D. M. (2019). How many to sample? Statistical guidelines for monitoring animal welfare outcomes. *PLoS One*, 14(1), e0211417.
- Harley, J. J., Stack, J. D., Braid, H., McLennan, K. M., & Stanley, C. R. (2021). Evaluation of the Feasibility, Reliability, and Repeatability of Welfare Indicators in Free-Roaming Horses: A Pilot Study. *Animals*, 11(7), 1981.
- Harrington, G. J. (1980). Water consumption of sheep and cattle in New Zealand. *Project Report-New Zealand Agricultural Engineering Institute (New Zealand)*.
- Jensen, M. B., & Vestergaard, M. (2021). Invited review: Freedom from thirst—Do dairy cows and calves have sufficient access to drinking water? *Journal of Dairy Science*, 104(11), 11368-11385.
- Kaurivi, Y. B., Hickson, R., Laven, R., Parkinson, T., & Stafford, K. (2020). Developing an animal welfare assessment protocol for cows in extensive beef cow-calf systems in New Zealand. Part 2: Categorisation and scoring of welfare assessment measures. *Animals*, 10(9), 1592.
- Kaurivi, Y. B., Laven, R., Hickson, R., Stafford, K., & Parkinson, T. (2019). Identification of suitable animal welfare assessment measures for extensive beef systems in New Zealand. *Agriculture*, 9(3), 66.
- Kells, N. (2022). The Five Domains model and promoting positive welfare in pigs. *Animal*, 16, 100378.
- Kirchner, M., Westerath, H. S., Knierim, U., Tessitore, E., Cozzi, G., & Winckler, C. (2014). On-farm animal welfare assessment in beef bulls: consistency over time of single measures and aggregated Welfare Quality® scores. *Animal*, 8(3), 461-469.
- Knierim, U., & Winckler, C. (2009). On-farm welfare assessment in cattle: validity, reliability and feasibility issues and future perspectives with special regard to the Welfare Quality® approach. *Animal Welfare*, 18(4), 451-458.
- Laven, R., & Fabian, J. (2016). Applying animal-based welfare assessments on New Zealand dairy farms: Feasibility and a comparison with United Kingdom data. *New Zealand Veterinary Journal*, 64(4), 212-217.

- Lievaart, J., & Noordhuizen, J. (2011). Ranking experts' preferences regarding measures and methods of assessment of welfare in dairy herds using Adaptive Conjoint Analysis. *Journal of Dairy Science*, *94*(7), 3420-3427.
- Mason, W., Müller, K., Huxley, J., & Laven, R. (2023). Prevalence of lameness on pasture-based New Zealand dairy farms; an observational study. *Preventive veterinary medicine*, 106047.
- Napolitano, F., Grasso, F., Bordi, A., Tripaldi, C., Saltalamacchia, F., Pacelli, C., & De Rosa, G. (2005). On-farm welfare assessment in dairy cattle and buffaloes: evaluation of some animal-based parameters. *Italian Journal of Animal Science*, *4*(3), 223-231.
- ProAction. (2021). Animal Care: Quick Guide to Animal-Based Measurement Protocol. Retrieved from <https://www.dairyfarmers.ca/proaction/resources/animal-care>
- Sapkota, S., Laven, R., Müller, K., & Kells, N. (2020). Animal Welfare Assessment: Can We Develop a Practical, Time-Limited Assessment Protocol for Pasture-Based Dairy Cows in New Zealand? *Animals*, *10*(10), 1918.
- Schenkenfelder, J., & Winckler, C. (2022). To meet or not to meet welfare outcome thresholds: A case-control study in dairy cow herds. *Animal*, *16*(3), 100461.
- Sørensen, J. T., & Fraser, D. (2010). On-farm welfare assessment for regulatory purposes: Issues and possible solutions. *Livestock Science*, *131*(1), 1-7.
- University of California Davis. (2017). Cow-Calf Health and Handling Assessment: Learn how to access. Retrieved from <https://www.ucdcowcalfassessment.com/dirty.html>
- Welfare Quality, R. (2009). Welfare Quality® assessment protocol for cattle. *Lelystad: Welfare Quality R Consortium*.
- Whay, H., Main, D., Green, L., & Webster, A. (2003). Assessment of the welfare of dairy cattle using animal-based measurements: direct observations and investigation of farm records. *Veterinary record*, *153*(7), 197-202.

## **Chapter 9: Future Perspectives and Conclusion**

### **9.1 Future Perspectives**

New Zealand does not have any large-scale established welfare assessment programs or quality assurance schemes. Our objective in this thesis was to push start the development of such a programme by demonstrating that welfare can be assessed in a limited amount of time (around milking time) in pasture-based dairy farms in New Zealand, with minimal to no use of advanced technologies. Even though the study successfully developed a time-limited welfare assessment protocol, for this protocol to become a widely acceptable welfare assessment program, several steps need to be implemented. Some of them are mentioned below.

#### **I. Development of protocols based on Positive welfare measures.**

Our current protocol was focused on the assessment of negative welfare outcomes ('absence of ...'). But the development of welfare science has established the importance of positive welfare outcomes (Yeates & Main, 2008). Such a concept may be particularly useful in the pasture-based dairy cows of New Zealand as there is already consumer perception that welfare is inherently better (Billones, 1999), as it would be an opportunity for the New Zealand dairy farmers to showcase the welfare status of their dairy cows by demonstrating not just the absence of problems but also positive outcomes.

#### **II. Involvement of farmers**

Farmer involvement and buy-in is essential for a welfare assessment program. Such a strategy is commonly utilized by established protocols like AssureWel Dairy Cow Welfare Assurance Scheme (Assurewel, 2018) and animal care module. These programs are designed in such a way that the initial assessment is done by the farmers and is further checked by the independent assessors. Another alternative is identifying a separate group of farmers who are ready to uplift and promote farmers (e.g Arlagarden) (Arlagarden, 2021). This group could assess the welfare using the protocol or measures which they think are important and still

participate in an assessment program. For e.g arla group of farmers running their own assessment and yet participating in the red tractor welfare assessment scheme.

Whatever approach is used, it is crucial to make farmers feel that the assessment of welfare is there to help them lift up welfare rather than make them feel that assessment is being implemented to make their task harder.

### **III. Development of a prototype online system for welfare assessment**

An online system that supports the farmer to meet the goals of the assessment programme is likely to be extremely valuable. Similar programmes are part of the Animal Care Module (Proaction, 2018) by keeping the farmer and the programme up to date in terms of availability, assessments and outcomes.

#### **9. 2 Conclusions**

Overall, the time-limited welfare assessment protocol for dairy cows provided reasonable coverage in relation to the first three domains (Nutrition, Physical Environment and Health). As such, with limited further modification we believe that our protocol could form as the basis of a tool to assess a welfare of pasture based dairy cows during milking. In regard to yak and chauri., we successfully developed a preliminary version of a feasible welfare assessment protocol. However, this programme is only and initial step towards the development of a welfare assessment protocol for yak and chauri.

#### **References**

Arlagarden. (2021). Farm Management Programme. Retrieved from <https://www.arla.com/4a54d6/globalassets/arla-global/arlagarden/arlagardenrcatalogue.pdf>.

Assurewel. (2018). Dairy Cattle Welfare Protocol. Retrieved from [http://www.assurewel.org/Portals/2/Documents/Dairy%20cows/AssureWel%20Dairy%20Welfare%20Outcome%20Assessment%20Protocol\\_2018.pdf](http://www.assurewel.org/Portals/2/Documents/Dairy%20cows/AssureWel%20Dairy%20Welfare%20Outcome%20Assessment%20Protocol_2018.pdf)

Billones, R. G. (1999). Consumer and farmer perceptions of the New Zealand dairy industry's image. Unpublished master's thesis, Massey University, Palmerston North, New Zealand.

ProAction. (2021). Animal Care: Quick Guide to Animal-Based Measurement Protocol.

Retrieved from <https://www.dairyfarmers.ca/proaction/resources/animal-care>

Yeates, J. W., & Main, D. C. (2008). Assessment of positive welfare: A review. *The Veterinary Journal*, 175(3), 293-300.