Assessing Animal Welfare of Extensively Reared Beef Cows in New Zealand and Namibia

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

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DECLARATION

I hereby declare that I am the sole author of this thesis, entitled: "Assessing Animal Welfare of Extensively Reared Beef Cows in New Zealand and Namibia", submitted as partial fulfillment of the requirements for the degree of Doctor of Philosophy in Veterinary Science.

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

The cows were not handled or yarded for a longer duration because of the study and there was no additional induced activity/yarding/handling, and there was no manipulation. Hence, ethics approval was not required.

Yolande Baby Kaurivi

Time period of entire research: September 2017- December 2020

ABSTRACT

There is currently no standardised validated animal welfare assessment protocol for beef cattle production systems in New Zealand or Namibia. In both countries beef cattle are reared extensively, and beef is exported to high-value markets. These markets require high production and welfare standards. The aims of the research described in this thesis were to: 1) develop a feasible, effective protocol for assessment of welfare in extensive pasture-based beef cattle in New Zealand, and modify it to be suitable for use on semi-arid rangeland farms in Namibia; 2) use that protocol to assess welfare on beef farms in New Zealand and Namibia.

A protocol based on the Welfare Quality and the University of California (UC) Davis Cow-Calf protocols, with some additional indicators specific to New Zealand was trialled on one farm and 50 measures were identified as potential welfare indicators on beef farms. The protocol was then tested on 25 farms (3366 cows) in the Waikato district and a 32-measure protocol was created which was suitable for assessing animal welfare. For each measure, categorical thresholds were created for acceptable and unacceptable welfare, to provide guidance for when intervention was needed at the individual measure level rather than create an aggregated 'score' for each farm. These imposed thresholds were compared to thresholds derived from farm data. After this comparison, most of the imposed thresholds were retained. This excluded thresholds for dirtiness and faecal staining (as they were thought to have limited welfare implications for pasture-based cattle) and fearful/agitated and running behaviours, which were thought to be higher than expected because of the unfamiliarity of extensively reared stock with yarding.

The New Zealand protocol was tested in one semi-commercial Namibian village farm composed of 5 separate herds. This test excluded one non-relevant measure (tail fecoliths) and identified nine additional measures (40 measures in total). The protocol was tested on 55 beef farms in three different production systems (17 commercial farms, 20 semi-commercial and 18 communal village farms), and found to be both feasible and applicable. Assessment of the data from this test found better welfare standards on commercial farms than village farms. Commercial farms in Namibia were generally able to meet the thresholds identified in the New Zealand part of the study but many semi-commercial and communal

herds were not. This was thought to be due, at least in part to the severe drought occurring in Namibia at the time of the study. It was thus suggested that for measures related to good feeding and mortality thresholds should be changed to reflect drought conditions with the original New Zealand-created thresholds retained under "normal conditions". Further work validating this protocol with more assessors on more farms across Namibia is needed, but this protocol can form the basis for beef cow welfare assessment to demonstrate and support good welfare standards across the beef production chain in Namibia.

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PREFACE

Namibians have been practicing reasonable animal welfare standards for generations without specifically categorising it as "animal welfare" but as a key component of animal health. As a member of World Animal Health Organization (OIE), the country is obligated to work for promotion and implementation of animal health and welfare standards. Hence, Namibia is in the process of revamping sectorial legislative acts, regulatory and policy frameworks in order to govern animal health and welfare for improvement in the production and reproduction of its livestock.

This Ph.D. thesis research was inspired by findings of a pilot project of artificial insemination of beef cows that was done in rural Namibia in Otjinene village farms (RAEIN AFRICA project, 2012). Out of three sites of insemination, the site with better care and management of cows obtained better pregnancy and calving rates than the two with poor management of cows. I realised there was a need for sustainable interventions to address constraints in the cattle value chain in order to improve cattle production and reproduction in communal areas. This became my mission to research more on how animal welfare affects reproductive performance of beef cattle, in order to advocate for better animal welfare standards in Namibia.

Hence, this passion for advocating better standards of animal health and welfare has led me on a journey to New Zealand beef farms. What a better way to show that "if you take care of your cow, it will give you better calves and meat"!

Dr Baby the traditional Herero vet preparing to inject cows. Note: there is no crush or race, and the cattle have big horns and branding marks - all welfare challenges that most communal farmers in Namibia are faced with

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simply the best; she raised me up to be a medical doctor, but I preferred animals. And to my beloved dad Jerry and kleinpa Collin Usurua- sincere gratitude! It will be an injustice not to aknowlegde the love and support of my " fathers" Bob Vezera Kandetu, Hiskia Karumendu, Benii Murangi and the late Mati Ndjoze.

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ABBREVIATIONS

AU	African Union
AWI	Animal Welfare Index
BSE	Bovine Spongiform Encephalopathy
BCS	Body Condition Score
CBRLM	Community-Based Rangeland and Livestock Management (Namibia)
CBPP	Contagious Bovine Pleuropneumonia
EU	European Union
FAN MEAT	Farm Assured Namibian Meat Scheme
FMD	Foot and Mouth Disease
MAWF	The Ministry of Agriculture, Water and Forestry (Namibia)
MPI	Ministry of Primary Industries (New Zealand)
NAIT	National Animal Identification Tracking (New Zealand)
NAMLITS	Namibia Livestock Identification and Traceability System
NCA	Northern Communal Areas (Namibia)
NZVA	New Zealand Veterinary Association
OIE	World Organisation for Animal Health
PCA	Principal Components Analysis
RFS	Rumen Fill Score
RNZSPCA	Regional New Zealand Society for The Protection of Animals
UK	United Kingdom
UC DAVIS	University of California Davis
VCF	Veterinary Cordon Fence

THESIS OUTLINE AND PUBLICATIONS

This thesis has been prepared partially through publication. As such, Chapters 1-2 and 6-7 were not written for publications while Chapters 3-5 were either published or were under review. The latter chapters have been prepared in the style and format of the journal they were submitted to or accepted in.

Chapter	**Write-up/Publication**	**Status**
Chapter 1 Introduction	General introduction	Not written for publication
Chapter 2 Literature Review	2.1 Animal Welfare Research and Assessment of Cattle 2.2 Animal Welfare Association with Reproductive Performance of Cattle 2.3 New Zealand Beef Cattle Systems 2.4 Namibia Beef Cattle Systems 2.5 Conclusion and research relevance	Not written for publication
Chapter 3 New Zealand Beef Cattle Welfare Assessment of Cow-Calf Systems	3.1 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(3), 66.	Published (March 2019)
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	3.3 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.	Published (September 2020)
Chapter 4 Namibia Animal Welfare Assessment of Cow-Calf Systems	4.1 Kaurivi, Y. B.; Laven, R.; Hickson, R.; Parkinson, T.; Stafford, K. Assessing Extensive Cow-Calf Welfare in Namibia: Feasibility of adapting a New Zealand beef cow welfare assessment protocol. *Applied Animal Welfare Journal*. 2020. Under review. https://doi.org/10.1080/10888705.2021.1937168	Accepted for publication (May 2021)
	4.2 Kaurivi, Y. B.; Laven, R.; Hickson, R.; Parkinson, T.; Stafford, K. Assessing Extensive Semi-Arid Rangeland Beef Cow-Calf Welfare in Namibia: Part 1: Comparison of farm production system effects on the welfare of beef cows. *Animals* ***2021***, *11(1), 165;* ***https://doi.org/10.3390/ani11010165***	Published (January 2021)
	4.3 Kaurivi, Y. B.; Laven, R.; Hickson, R.; Parkinson, T.; Stafford, K. Assessing Extensive Semi-Arid Rangeland Beef Cow-Calf Welfare in Namibia. Part 2: Categorisation and scoring of welfare assessment measures. *Animals* ***2021***, *11(2), 250;* ***https://doi.org/10.3390/ani11020250***	Published (January 2021)
Chapter 5 General Discussion	Comparison of cow-calf system welfare in New Zealand and Namibia.	Not written for publication
Chapter 6 Conclusion and Future research	Main conclusory remarks and future recommendations	Not written for publication
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Other Publication:

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List of Conference Papers and Posters:

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2. Categorising Welfare Assessment Measures for Extensive Pasture-based Beef Cattle Systems in New Zealand. Y. Baby Kaurivi, R Laven, S Sapkopta, R Hickson, T Parkinson, K Stafford. Conference of the New Zealand Society of Animal Production, Lincoln, New Zealand. 1-4 July2019
3. Identification of suitable animal welfare assessment measures for extensive beef systems in Namibia. Y. Baby Kaurivi, R Laven, R Hickson, T Parkinson, K Stafford. Massey University, New Zealand. The Universities Federation for Animal Welfare Advancing animal welfare science: How do we get there? – Who is it good for? UFAW International Symposium 2019 3 -4 July 2019, Bruges, Belgium.
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Chapter 1 GENERAL INTRODUCTION

Consumers require reassurance about food availability and food safety, and similar concerns are being increasingly expressed regarding the welfare of production animals (Grandin, 2014a). Animal welfare quality, based on basic health and biological function, natural living as well as affective states (positive and negative emotions; (Fraser, 2008b; Mellor, 2017) is recognised as an important component in the production and trade of farm animals and their products. In addition, poor welfare is often associated with adverse health and productivity of animals, and consequently can have important economic implications for farm animal operations (Gibson & Jackson, 2017; Stafford & Mellor, 2005). Hence, ensuring good welfare of livestock has progressively become a crucial concept on livestock farms. Achieving good welfare requires responsible husbandry and provision of appropriate care, and is dependent on many management factors, including health and nutritional management, environmental management, animal handling facility designs and stockpersonship (Fraser et al., 2013).

The increasing importance of animal welfare means there is an increasing need for independent assessment of on-farm animal welfare. This need has led to the development of animal welfare assessment protocols for animal species in specific production systems (Webster, 2005a). One weakness of these assessment protocols is that their outcomes, are system focused. For assessing animal-welfare in extensive systems, this is an issue, as almost all the currently widely used protocols are directed at measuring animal welfare in intensive systems because of the perception that these lacks 'naturalness' (Webster, 2005b; Fraser 2008b). Many measures which are important in intensive systems are not necessarily important in more extensive systems. Laven and Fabian (2016) studied the practicability of using a European-developed protocol for dairy cows on pasture-based dairy farms in New Zealand but rejected the use of the protocol on such farms unless the protocol was refined to better reflect the New Zealand system. This is consistent with the conclusion by Hernandez et al. (2017b) that the Welfare Quality protocol (developed and used as a gold standard in Europe) needed significant modification before it could be used on tropical Mexican farms with dual purpose cattle.

Similar issues apply for extensive beef farms as the Welfare Quality protocol (Welfare Quality, 2009) for beef cattle focuses on intensive growing cattle systems, which are completely different to extensive cow-calf operations. However, there are welfare assessment protocols that focus on extensive beef cattle, for example, the rangeland-based UC Davis Cow–Calf Health and Handling assessment protocol (UC Davis, 2017). However, this protocol is limited as unlike the Welfare Quality protocol, it does not consider resource-based measures. Thus, a comprehensive system is needed to assess extensive cow-calf operations, of which an amalgamation of the above two protocols could form a basis for a fitting and practicable animal welfare assessment protocol.

Such protocols need testing across different extensive systems in different countries, to confirm that they are suitable for a range of systems. A validated welfare assessment protocol that can be used across a range of extensive beef systems would be a highly valuable tool for demonstrating welfare standards to the end consumer. This would be especially valuable for beef cattle systems as different as the pasture-based system in New Zealand and the semi-arid rangeland beef cattle systems in Namibia, as both countries export beef to profitable markets such as the European Union (EU) and North America, which demand high production standards.

The aims of the research described in this thesis were to: 1) develop a feasible, effective protocol for assessment of welfare in extensive pasture-based beef cattle in New Zealand, which with a small number of modifications would also be suitable for use on semi-arid rangeland farms in Namibia; and 2) use that protocol to assess welfare on beef farms in New Zealand and Namibia.

Chapter 2 LITERATURE REVIEW

Many welfare assessments protocols for cattle have been developed but this review will focus on two such programs: Welfare Quality and UC Davis cow-calf. The aim of the thesis was to merge these two protocols and develop a modified protocol suitable for the New Zealand pasture-based beef system and the semi-arid rangeland beef systems in Namibia. The Welfare Quality protocols are the best-known and most comprehensive research-based animal welfare assessment protocols. They are the largest integrated research tool for on-farm animal welfare, with extensive research interest and applications (Hernández et al., 2017a; Knierim & Winckler, 2009; Sandøe et al., 2019). However, they are generally focused on intensively reared livestock. I contrast the UC Davis program is designed for extensive systems being used as a tool for self-assessment ranch management and as an assurance scheme on such farms (Simon et al., 2016a). It may thus be more relevant to the extensive beef production systems which predominate in New Zealand and Namibia. This review will also assess the association between animal welfare and reproduction efficiency in cattle, in order to investigate the application of the welfare assessment outcomes with reproductive key performance indicators (KPIs). Furthermore, the New Zealand and Namibia beef production industries and their respective beef cattle welfare, health and reproduction overview will be briefly reviewed.

2.1 Animal Welfare Research and Assessment of Cattle

Much of the research on welfare assessment in cattle has focused on cattle in intensive production systems because of the perception, especially in Europe, of a lack of 'naturalness' of confined systems (Fraser, 2008b), with confinement being criticised for its impact on the natural behaviour of confined animals (Fraser et al., 2013). For example, in dairy operations, housing designs and comfort when cattle are lying and rising indoors (Bartussek, 2001; Charlton et al., 2016) and behaviour (Fraser, 2008a; Mellor et al., 2009) have all been major focuses of research, as have diseases associated with housing such as digital dermatitis (Evans et al., 2012; Laven et al., 2014), claw horn lameness (Fabian et al., 2014; Laven & Holmes, 2008) and mastitis (Barkema et al., 1999; Ivemeyer et al., 2011) and the association between welfare and milk production (Coignard et al., 2014; Pragna et al., 2017). For intensive beef cattle, the research focus has been on housing, behaviour and health issues

(e.g. Brscic et al. (2014) as has meat quality in relation to welfare especially in feedlot cattle (Petherick et al., 2002; Warner et al., 2007).

In beef cattle in extensive production system, the research focus has been on environmental stressors such as heat stress (Gaughan et al., 2009; Polsky & von Keyserlingk, 2017), pain caused by management procedures (Stafford & Mellor, 2011), stockpersonship (Hemsworth, 2003; Simon et al., 2016b), animal handling facilities (Grandin, 2014b; Simon et al., 2016a) and animal welfare at slaughter plants (Grandin, 2010).

The increasing acceptance of animal welfare as an essential concept, stimulated the need for assessing animal welfare and the development of assessment protocols (Webster, 2005b). In early cattle welfare assessments protocols, the focus was on measurement of resources and housing design (Bartussek, 2001) but current protocols emphasize the use of animal based welfare measures such as health and behaviour (Welfare Quality, 2009; Whay et al., 2003) as well as human-animal interaction (Simon et al., 2016a; UC Davis, 2017). This is consistent with the definition of animal welfare by Fraser (2008b) that the combination of an animal's emotional and physical states as assessment at the animal level provides a direct measure of these states, while measurement of resources provides an indirect assessment of welfare.

2.1.1 The Purpose and Features of an Ideal Animal Welfare Assessment protocol for Cattle

An animal welfare assurance protocol has several purposes. At the farm level, the assessment can be used to identify welfare problems affecting animals on the farm. The results of the assessment can be used to design remedial action plans to improve the identified welfare problems, with follow-up assessments being used to review the effectiveness of those plans (Webster, 2005a; Whay, 2007). Thus at an individual farm level, assessments can provide the basis for advising farmers on how to change their animal management or their environment, in order to improve animal welfare, and, potentially, the health and productivity of their animals (Broom & Fraser, 2007; Webster, 2005a). Animal welfare assessment protocols may also be used at the purchaser level as tools to ensure compliance with certification schemes and product labelling, and as baseline indicators to demonstrate that farms are complying with animal welfare legislation (Botreau et al., 2007a; Webster, 2005a). For exporting countries, welfare assessment protocols can be used to certify

that standards are being met, minimising the need for expensive and time-consuming visits by overseas purchasers.

An on-farm animal welfare assessment protocol needs to be practicable, valid, reliable, feasible and easily conducted by trained operators within as short a time possible necessary to meet the goals of that assessment (Blokhuis et al., 2013; Knierim & Winckler, 2009; Whay et al., 2003). Consistency over time is another important feature of an animal welfare assessment protocol, i.e. getting comparable scores from different observers on the same farm under the same management situation (Blokhuis et al., 2013; Kirchner et al., 2014). However, consistency may only be attained if measures are assessed in the same season, as it is difficult to obtain consistency in measures taken at different times, due to changes in the climate and environment (Can et al., 2017; Kirchner et al., 2014). One cannot assume consistent validation of animal welfare assessments for labelling and certification if assessments are not repeated. For example, the validity of a single animal welfare assessment tool for certification purposes was challenged as significant variation the welfare state of beef bulls found after re-testing 6 months later (Kirchner et al., 2014).

2.1.2 Indicators for Cattle Welfare Assessments

The basic animal welfare assessment indicators were based on the Five Freedoms[1]. Thus, the emphasis was on good feeding, appropriate housing/ environment, good health and animals being free from injuries, and naturalness of behaviour (Botreau et al., 2007c; Webster, 2005b). More recently, Mellor (2017) described the Five Domains Model in order to facilitate "structured, systematic, comprehensive and coherent animal welfare assessment". However, the model was criticised (see Mellor and Webster (2014) as being merely a replication of the Five Freedoms, as the model also reflects good feeding, housing, health and appropriate behaviour. However, the Five Domains Model was developed to focus on both physical states and affective states ("mental wellbeing"), so provides a better basis for

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

assessing animal welfare, especially when the aim is to enhance welfare rather than just avoid negative welfare impacts. As such it is an appropriate base for an animal welfare assessment on farms (Mattiello et al., 2019; Mellor & Beausoleil, 2015).

For the assessment of animal welfare on farm operations, there are three main groups of measures on which animal welfare protocols are based: animal-based; resource-based, and management-based.

2.1.2.1 Animal-based measures

Most animal welfare assessment protocols focus on animal-based measures. The range of animal-based measures is large; for example 45 different animal-based measures have been included in welfare assessments of ruminants on pasture (Spigarelli et al., 2020), and the choice of indicator varies between studies whether the focus is on health and behaviour of cattle (Welfare Quality, 2009; Whay et al., 2003) or human-animal interactions (focusing on restraint and handling techniques; (Simon et al., 2016a; UC Davis, 2017).

Animal-based welfare assessments are outcome-based so directly provides information on basic health and function as well as affective state, whereas resource-based measures identify potential impacts on welfare (Webster, 2005a), which may necessarily affect welfare (Blokhuis et al., 2010). However, this separation is not clear cut, as input-based measures may influence the outcome of animal-based measures. For example, the physical environment (input-based) where an animal spends time for any activities such as resting, and grazing can influence its health and behaviour (animal-based). Unsuitable environments pose the risk of injuries: for instance, hock injuries in confined dairy cows are attributed to pressure sores caused from injuries from concrete floors (Fabian et al., 2014; Fjeldaas et al., 2011; Laven & Holmes, 2008) and injuries such as slipping and the risk of lameness are also more prominent in these unsuitable environments (Flower et al., 2007; Laven & Holmes, 2008). Similarly, an unclean environment may impact on the transmission of pathogens such as bacteria which cause mastitis and digital dermatitis (Evans et al., 2012).

2.1.2.2 Resource-based measures

Despite the general suitability of animal-based measures for animal welfare quality assessment, resource-based measures which are basically input-based are still commonly

used as part of farm-animal welfare assessment protocols. This may be because of the ease with which they can be measured and benchmarked. In the Welfare Quality protocol, prolonged thirst is not assessed by animal-based welfare measures but is rather a resource-based measure (i.e. the 'quantity of water' provided to cattle: Welfare Quality (2009). The quantity of water may be difficult to assess during rainy days on extensive pasture-based system (i.e. in New Zealand) where water is sourced naturally (Laven & Fabian, 2016). Similarly, 'access to water' is a resource-based measure but is assessed via indirect measures like 'space at water troughs' or 'cleanliness of water' (De Graaf et al., 2017a). Scoring the 'water flow' was also criticised by De Vries et al. (2013a) and Heath et al. (2014) as this parameter has poor validity (de Graaf et al., 2017b) due to the difficulty of assessing water intake of individual animals in a herd. As yet, there are probably no valid measures for assessing the actual state of prolonged thirst (De Graaf et al., 2017a; Knierim & Winckler, 2009). This emphasises the need for further research to improve criteria for measuring this aspect of welfare, more so in semi-arid and arid rangeland systems (i.e. in Namibia) with variable water sources and availability.

The difficulties in assessing some resource-based provisions have been recognised, and now are being determined through animal-based measures wherever possible (Botreau et al., 2007b; Knierim & Winckler, 2009). For example, the resource-based measuring of 'absence from prolonged hunger' with indirect, un-validated measures such as 'centimeters of feeding trough per cow' has been replaced by measuring body condition score (BCS) of animals rather than measuring the feed consumed (Blokhuis et al., 2010; De Graaf et al., 2017a; Webster, 2005a). Thus, provision of adequate food is interpreted via BCS, which is more practical than keeping records of quantity of feed given to group or individual cattle (Webster, 2005a).

2.1.2.3 Management-based measures

The identification of management practices as indicators of animal welfare is crucial because management procedures such as dehorning and castration that are commonly performed in cattle operations tend to facilitate good management, safety of personnel, as well as the welfare and productivity of cattle (Johnsen et al., 2001). On the other hand, these procedures cause pain and compromise the welfare of cattle (Stafford & Mellor, 2005b). Even if

performed with anaesthetics or analgesics, cattle may end up with post-surgical infection, swelling and myiasis (OIE, 2017); hence, the management of such procedures needs to be included in welfare assessment protocols.

Other management procedures that need to be included in welfare assessment protocols include animal handling and restraint techniques. These indicate stockpersonship and can significantly impact the welfare of cattle (Coleman & Hemsworth, 2014; Hemsworth, 2003; Simon et al., 2016b; Stafford, 1997). The need for restraint for animal management was viewed as a major constraint in extensive systems where cattle are not often handled (Spigarelli et al., 2020). For a positive human-animal relationship it is important that handlers do not cause injury, panic, lasting fear and stress to animals. Harsh handling such as the use of excessive force, electric prodders, rapid movements and excessive noise are all indicators of compromised welfare of cattle (Hemsworth & Coleman, 2010; Stafford, 2013).

2.1.3 Welfare Assessment Protocols for Cattle

2.1.3.1 The Welfare Quality Assessment Protocol for Cattle

The Welfare Quality program was designed to develop European welfare standards for farm animals (Blokhuis, 2008; Blokhuis et al., 2010; Whay et al., 2003) and mainly focuses on intensive livestock farming systems. The protocols are emphasised as being principally animal-based but also include resource-based and management-based welfare measures (Andreasen et al., 2014; Kirchner et al., 2014). Researchers had considerable challenges to overcome using the protocols both in intensive and extensive cattle production systems (Andreasen et al., 2013; De Vries et al., 2013a; Heath et al., 2014; Hernandez et al., 2017b; Sandøe et al., 2019) and the protocols clearly need adjustment before they can be applied to pasture-based and semi-arid rangelands such as those in New Zealand and Namibia, respectively.

For beef cattle, the focus of the Welfare Quality assessment protocol is for finishing beef cattle with welfare research in Europe being focused on housing (Kirchner et al., 2014) especially the effect of floor surface and behaviour of housed cattle (Brscic et al., 2014; Brscic et al., 2015; Keane et al., 2017). Thus, the focus in assessment of extensive beef herds needs to be different from that of the Welfare Quality protocol for finishing beef cattle.

The applicability of the Welfare Quality protocol for cattle has been verified under tropical conditions in Brazil (Franchi et al., 2014) Costa Rica (Hernández et al., 2017a) and Mexico (Hernandez et al., 2017b) albeit with some limitations. Hernández et al. (2017a) used an adapted version of the original Welfare Quality protocols to suit the predominant conditions encountered by extensive dual-purpose cattle. However, several indicators such as housing and access to pasture were clearly not relevant for extensively kept cattle. A similar conclusion was reached by Laven and Fabian (2016) based on applying a similar protocol on New Zealand pasture-based dairy farms.

One key issue in tropical extensive systems was assessing 'absence of prolonged thirst'. This measure has not been clearly defined and has been heavily criticised, and proved challenging to assess in extensive tropical systems where water may be obtained from natural resources such as dams, rivers, ponds or from water troughs in the open (Franchi et al., 2014; Hernández et al., 2017a). In addition, since a valid measure of 'thermal comfort' measure had not been fully developed in the Welfare Quality protocol, thermal comfort was modified to environmental comfort with access to shade or shelter as a measure, with a recommendation that cattle were always able to access and lie in shade during warmer months and the hottest part of the day (Hernandez et al., 2017b).

The Welfare Quality protocol has been criticised for poor correspondence between results from different assessors looking at the same groups of cows (de Graaf et al., 2017b), with differences in opinion even between Welfare Quality-trained users. This is particularly an issue with qualitative measures such as 'mental state', which is based on subjective behaviours that are translations of the body language of cattle into qualitative scores of overall welfare (Andreasen et al., 2013). Trained users found that using subjective descriptions such as 'frustration' or 'content' was not a very reliable method of describing how animals behave and interact (de Graaf et al., 2017b). A particular issue is that these subjective measures can be influenced by observers' personal feelings towards the animals they are assessing, which may be one of the causes of the low inter-observer reliability of these qualitative measures reported by Bokkers et al. (2012). Nevertheless, several studies have argued for the validity of qualitative behavioural assessments in dairy cows and sheep (Phythian et al., 2016; Rousing & Wemelsfelder, 2006; Serrapica et al., 2017; Wemelsfelder et

al., 2009). Notwithstanding that conclusion, further scrutiny of the validity and practicality of behavioural assessments on extensive systems is required.

For example, since cows on pasture and rangeland spent most of their time grazing and ruminating, Hernandez et al. (2017b) observed that social behavioural interactions would be likely to be rare or less noticeable when groups of cows are grazing together without the presence of bulls or calves. Indeed, it has been suggested that, under extensive conditions, positive status behavioural indicators may need to be lumped together in an assessment such as 'content, happy, or relaxed', unless the presence of aggressive behaviours is noted. Another potential issue is undertaking behavioural assessments in cattle in paddocks without disturbing those cattle (Hernandez et al., 2017b), which might, in many cases, be a lengthy and impractical process. One potential assessment of behaviour which may be more important in extensively kept animal is interaction with other species such as horses and dogs. As the presence and noise of other animals can affect cattle behaviour (Petherick et al., 2009; Phillips, 1993), interaction with other animals should be included in the assessment of animal welfare in extensive systems.

One of the key roles of a welfare assessment protocol is to set targets for welfare (Mellor & Webster, 2014) but different protocols use different methods and scales to categorise and/or score on-farm animal welfare outcomes. In the Welfare Quality protocol, data collected from farms are integrated via a sequential transformation and aggregation, and the farms final welfare score is presented on a scale of 0-100, and farms are ranked as excellent, improved, acceptable and not classified (Botreau et al., 2007b; de Graaf et al., 2017b). The expression of data as ordinal scores makes the summation into overall scores difficult (Botreau et al., 2007b; Mellor, 2017; Veissier et al., 2011), but, even without this caveat, aggregation of scores is a complex process and controversy emanates from the problematic interpretation of weighted sums that may tolerate compensation between welfare principles, i.e. whether a non-appropriate environment can be counter-balanced by good health (Botreau et al., 2007b; Sandøe et al., 2017). Attempts to remove all compensation between welfare aspects in the Welfare Quality were not successful (Sandøe et al., 2017; Veissier et al., 2010). As a result, the aggregation used in the Welfare Quality system has been criticised as illogically allowing

important welfare problems to be covered up, as not being in line with expert opinion and as not being ethically robust (de Graaf et al., 2017b; Sandøe et al., 2019; Sandøe et al., 2017).

The aggregation controversy increases doubt in the validity, reliability and feasibility of the Welfare Quality protocol as a "gold standard" for assessing animal welfare. Nevertheless the discussion highlights that grading animal welfare compromise is not an easy task (Botreau et al., 2007b; Mellor, 2017; Sandøe et al., 2019). This is likely to be even more so in extensive systems where there is less basic research of welfare compromise. Thus, trying to emulate Welfare Quality scoring system is probably not a good approach (at least at the start) when developing a protocol for extensively reared cattle.

One of the main criticisms of the Welfare Quality protocol in dairy cattle is that it is time consuming and not economically viable. It takes more than 7 hours to conduct an assessment on 200 on-farm dairy cattle (Andreasen et al., 2014; Heath et al., 2014). This could be because the dairy cow protocol contains many measures that need to be assessed (Blokhuis et al., 2010; De Vries et al., 2013b; Welfare Quality, 2009). Time may be even more of an issue for extensive beef systems, especially when the only suitable time for assessing animals is during yarding where there is only limited time to adequately assess each criterion. Thus, welfare measures, particularly animal-based measures, need to be carefully scrutinised for practicability and feasibility in extensive systems, not just simply copied over from protocols designed for intensive systems.

2.1.3.2 The UC-Davis Cow- Calf Health and Handling Assessment Protocol

The UC Davis Cow-Calf protocol was designed at the University of California Davis and it is principally being implemented on North American cattle ranches (Simon et al., 2016a). This protocol was created to increase the confidence of consumers in the beef production industry (Grandin, 2014a; Wognum et al., 2011), and is based on a health and handling assessment of cattle while they are being worked in the chute. Unlike the Welfare Quality protocol, it does not consider management and resource-based measures. Thus, information from measures (i.e. resource- based measures or animal health records) that could be obtained from resource evaluation, a questionnaire or farmers records are not considered. Similarly, painful procedures and conditions (e.g. castration, dehorning/disbudding,

dystocia), disease incidences and mortality rate are overlooked. This incompleteness in measures could be why the protocol is used as a tool for self-assessment ranch management more than an assurance scheme (Simon et al., 2016a).

Another critique of this system is that it calculates the percentage of a herd that showed a welfare compromise (on a yes/no basis), without giving thresholds for determining welfare compromise. Hence, the authors who peer reviewed this system on California ranches used minimum recommended standards from the Beef Quality Assurance (BQA) scheme to assess whether stockpersonship was good enough (Simon et al., 2016a). Any assessment system that does not use thresholds to define welfare compromise has only a limited capacity to identify welfare compromise or to be a driver to change (Sandøe et al., 2019). Another issue with the UC Davis protocol is the vagueness of some of the assessments. For example, the protocol grades the use of moving aids and discusses the different impacts of the force used and the area hit (Pajor et al., 2000), but does not clearly define inappropriate use which reduces repeatability across operations under the UC Davis protocol (Simon et al., 2016b).

However, one area where the protocol has an advantage compared to Welfare Quality is that it allows the selection of "core" assessments (Winckler, 2018), which indicate areas of major welfare concern. This resonates with the findings of Botreau et al. (2007b) who highlighted that in a multidimensional discipline such as animal welfare, all important issues of animal welfare for that specific system should be highlighted before those which are indicative of marginal compromise. Thus, the UC Davis approach provides a template for determining which welfare assessments to undertake when time is limited.

2.2 New Zealand Beef Cattle Sector

2.2.1 Beef cattle industry

Livestock farming forms the backbone of the country's export economy, which mainly comes from milk products, meat (beef and lamb), and wool and hides (Peterson, 2016). Although the beef production industry has been less important than the sheep and dairy industry to the New Zealand economy in the past, the beef production industry export 80% of the beef it produces, to the approximate value of NZ$3 billion per year which accounts for 10% of agricultural exports (Morris, 2017).

The estimated number of beef cattle in New Zealand is over 3.7 million, of which 71% are in the North Island and are farmed complimentarily with sheep on hill or high country (Morris (2017); Figure 1). The distribution of beef-producing cattle in New Zealand can be divided based on topography and elevation into 3 main categories, namely, high country, hill country and flat-to-rolling grassland. The high country is characterized by lower stock units per hectare because of lower pasture production, whilst the hill country has moderate stock carrying capacity dependent upon moderate-to-good pasture production. The flat-to-rolling areas have all year-round good pasture production with the highest livestock units per hectare (Morris, 2017).

On average, the smallholder farms keep 50-60 breeding cows that are extensively reared on pasture, whilst big commercial farms keep over 500 head of beef cattle (Morris, 2017). The beef production industry is mainly farmed complimentarily with sheep. The predominant breeds are Angus and Hereford and their crosses. Some of these beef breed cows are also mated with European beef bulls to maximize muscle mass. Some beef farms raise animal to laughter others use the traditional weaner production system where calves are weaned at about 6-7 months and sold to be finished elsewhere (Geenty & Morris, 2017; Smeaton, 2007). In addition, there is also significant crossover from the dairy industry with beef x dairy calves and dairy steers and bulls all being reared to produce beef as are unwanted dairy heifers and cull cows (Geenty & Morris, 2017; Morris, 2017).

Grass pasture-based production largely contributes to the success of the beef cattle production in New Zealand. This is a cattle production system that is viewed as being "organic" and "natural" especially compared to the feedlot system (Morris, 2017). Consequently, consumers are willing to pay a high price for New Zealand livestock exports because of the trusted history of natural grazing. Under the guidance of the Ministry of Primary Industries (MPI), animal products are certified to be of a high standard and produced following world-leading welfare regulations. Additionally, New Zealand has a generally low rate of disease, because major trade barrier diseases such as foot and mouth disease (FMD) and bovine spongiform encephalopathy are absent (MPI, 2013).

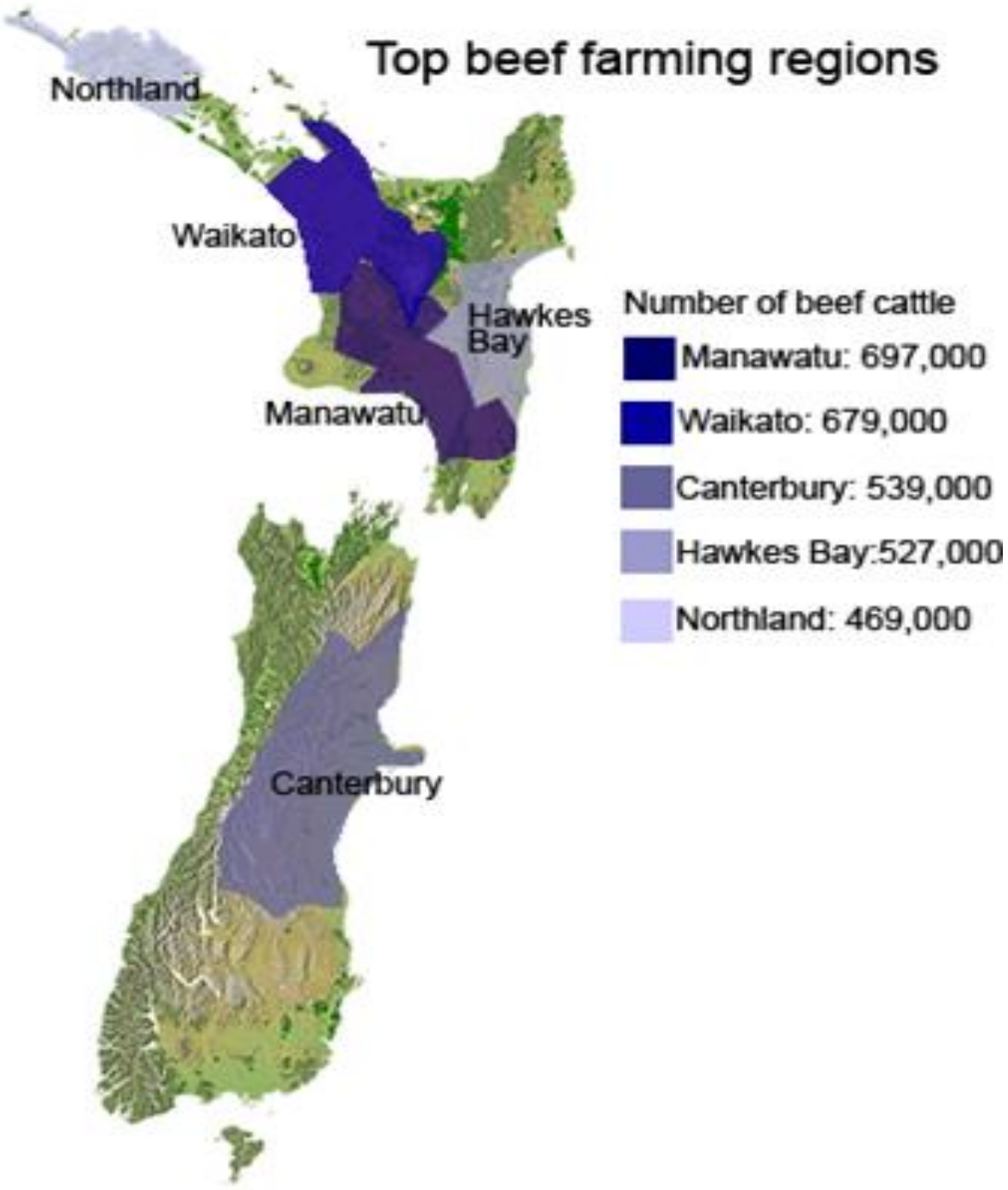

Figure 1. Top farming beef regions in New Zealand (based on 2012/2013 lic and dairy NZ surveys; (Morris, 2017).

The country is, however, not yet free of bovine tuberculosis which could be a major hindrance to the success of the beef production industry. Currently, only cattle from certified tuberculosis-free farms are slaughtered for the local and export markets (Geenty & Morris, 2017).

2.2.2 New Zealand animal welfare legislation and beef cattle welfare

New Zealand has laws, regulations, and codes for animal welfare. The Animal Protection Act (1960) was not necessarily based on animal welfare but rather on protecting animals against cruelty and neglect (Mellor and Webster, 2014). Following amendments and consultations, the subsequent Animal Welfare Act (1999) emphasized good management of animals and maintaining good welfare standards rather than preventing animal cruelty. The current animal welfare laws were developed because of public concern about animal production as well as trading partners having requirements for the export of animal products (Mellor & Bayvel, 2008; O'Connor & Bayvel, 2012; O'Connor & Littin, 2011). This has resulted in a legislative environment that is conducive to welfare laws, regulations and enforcement (O'Connor & Bayvel, 2012; Stafford, 2013).

With the Animal Welfare Act (1999), obligations that are to be followed by people in charge of animals were amalgamated in the Codes of Animal Welfare. In these codes, details are provided on how animal owners and handlers should establish minimum standards in the management of animal health and behaviour in the best practicable ways. For example, the Code of Welfare for Sheep and Beef Cattle (2018) restricted dehorning only to cattle that are "under the influence of an appropriately placed and effective local anaesthetic" (MPI, 2018). The codes can easily be modified while it is a lengthy and complicated process to revise the acts, and thus changes can be instituted in these codes without any amendment of the act (O'Connor and Bayvel, 2012, Stafford, 2013). The codes also provide a legal support evidence for prosecution for an offense under the act, although they were designed to encourage voluntary compliance (O'Connor and Bayvel, 2012).

The regulation and enforcement of animal welfare is the responsibility of the MPI officials (farm animals), as well as the New Zealand Police force. Additionally, the Royal New Zealand Society for the Prevention of Cruelty to Animals (RNZSPCA), the New Zealand Veterinary Association (NZVA) and the Animal Welfare Institute of New Zealand (AWINZ) are also approved to enforce welfare laws under the current animal welfare act (Stafford, 2013). Currently there is no cohesion between the various local farm assurance schemes and certification as they are private and not government regulated. The various farm assurance schemes have different farm assurance certification protocols of which some are

comprehensive whilst others are very modest.

Cattle welfare research in New Zealand gives a priority to dairy cattle although there is synergy in raising dairy and beef cattle mainly on pasture (Laven & Fabian, 2016; Sapkota et al., 2020). Due to the extensive management of beef cattle in New Zealand, the industry has not received as much criticism for the welfare of beef cattle as other livestock sectors such the dairy, pig and chicken industries. In fact, concerns over welfare measures such as housing, feeding and expression of natural behaviour have been minimal, because beef cattle are extensively reared on pastures with minimal interventions (Stafford, 2013). Cattle in this production system are well adapted to seek shelter or shade for protection when in need and are accustomed to winter conditions (Fisher & Stafford, 2007; Morris, 2017). Thus, the welfare concerns may arise mainly with poor stockpersonship and management procedures. With new regulations prohibiting disbudding without the use of anaesthesia, the farm management operations concerns relate to castration, and management during calving (Stafford & Mellor, 2005b) as well as limitations imposed by variations in climate and terrain (Fisher & Stafford, 2007).

2.3 Namibia Beef Cattle Sector and Welfare

The Namibian economy is heavily dependent on the livestock sector, which supports about 70% of the population directly and indirectly. The livestock industry remains the largest source of employment in the country and contributes about 75% to the national agricultural income, mostly because Namibia is one of the very few African countries that are geared towards exporting red meat, both from sheep and cattle. The country has been able to maintain export status to the lucrative EU, Norway and South African markets and recently also gained export access to other markets, notably the United States of America (USA), China and Russia (MAWF, 2017).

In 2018, the cattle population in Namibia was more than 3.28 million. The beef cattle industry is predominantly influenced by the demarcation of the country into two main parts; namely the northern and the southern parts, by the veterinary cordon fence (VCF; see Figure 2). The VCF is an important biosecurity measure for transboundary animal disease control for cattle across the northern communal regions, particularly for contagious bovine pleuropneumonia

(CBPP) and foot and mouth disease (FMD; endemic in parts of the north-eastern areas due to presence of free roaming buffaloes) (MAWF, 2017).

The northern part of the country is further demarcated into an FMD protection zone comprising of the central and western northern areas, whilst the north eastern part is called the FMD infected zone. Currently, all the northern areas are allocated to communal farmers with customary tenure (Mendelsohn, 2008). Most households in northern communal areas (NCA) are subsistence-based and labour intensive, with limited livestock and livestock-product marketing channels and inadequate access to technology (FAO, 2016). Namibia has developed strategies towards securing transboundary animal disease like FMD and CBPP freedom in the NCA through a policy document that was approved by the OIE in 2016. The policy strategies aim to include the protection zone as part of the free zone with consequent access to lucrative markets in beef, lamb and mutton (MAWF, 2017).

The vast southern part of Namibia below the VCF is referred to as the FMD free zone and has the advantage of access to profitable livestock markets since it was declared FMD free by the OIE (MAWF, 2017). In the FMD free zone, beef cattle farming occurs partly in commercial lands with freehold tenure that are privately owned purely for commercial beef production (Olbrich et al., 2016; Sweet & Burke, 2006). The other part of beef cattle farming

land in the free zone is principally in communal land (herein referred to as "semi-commercial' village farms) with customary tenure like in the NCA, but with access to lucrative livestock and livestock product markets similarly to the commercial farms (Mendelsohn, 2008; Siegmund-Schultze et al., 2012). Of the total number of cattle in the country, about 70% are found in communal areas and semi-commercial areas (MAWF, 2017).

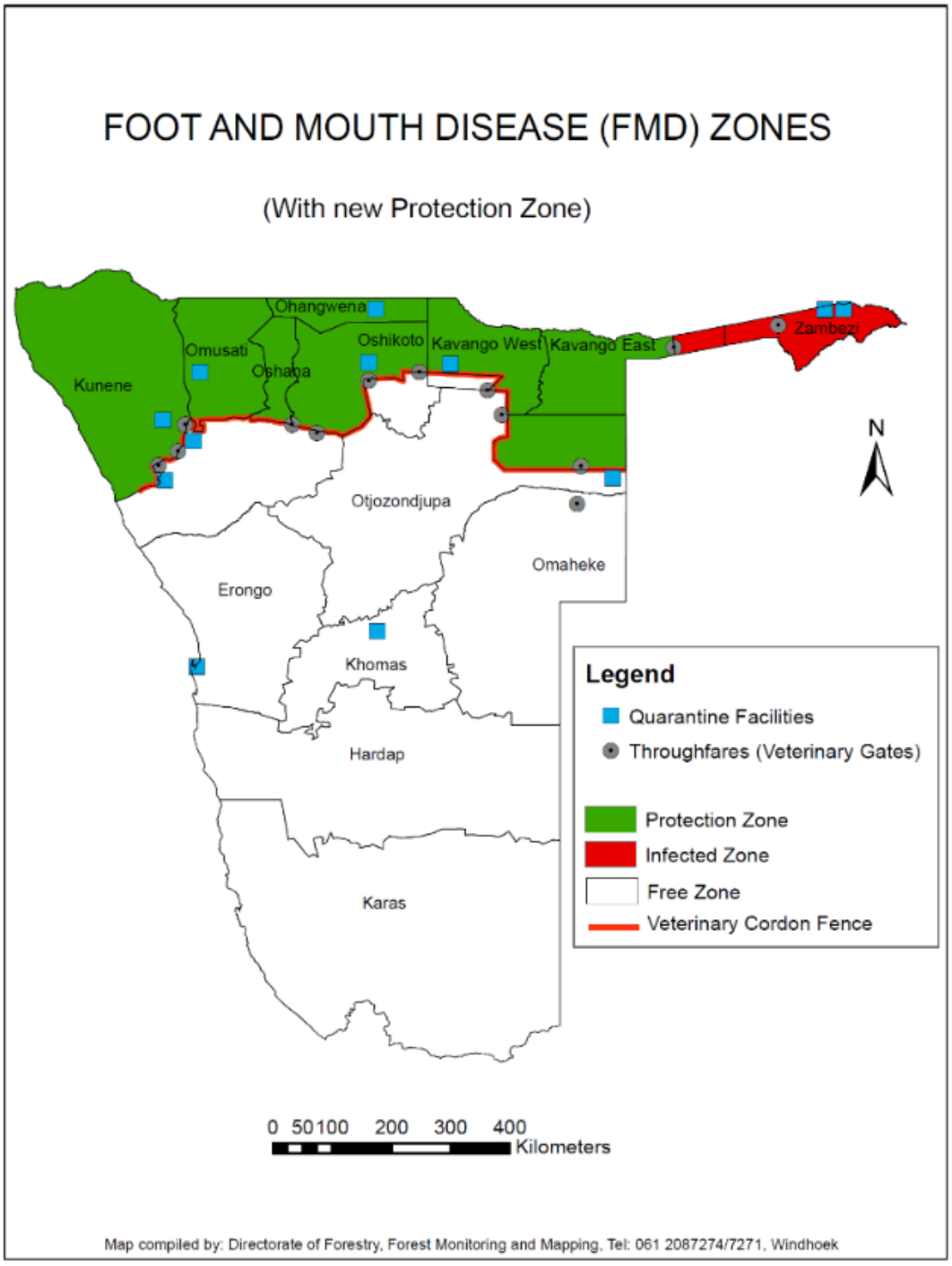

Figure 2. The FMD Zones and Fences with Regional Demarcation in Namibia (MAWF, 2017).

Namibia is still lacking concrete animal welfare legislation, despite its outstanding track record of gaining and maintaining access to lucrative markets. The Animal Protection Act (1962) is outdated and was inherited from the colonial South African era and does not cater to current developments in global animal welfare trends since it was based more on animal protection rather than upon the concept of animal welfare. The current Animal Health Act (2011) is inadequately based on the improvement of animal health in Namibia and does not include animal welfare per se, but rather the humane standard of keeping animals healthy. The Meat Safety Act (2000) also lays the ground rules for the registration of red meat abattoirs, hygiene slaughter of livestock, ante- mortem and post-mortem meat inspection, amongst others. Most importantly, animal welfare officers are in place at export abattoirs daily to perform inspections for compliance with animal welfare standards (MAWF, 2017).

The interests of the meat industry of Namibia are managed and promoted by the Meat Board of Namibia. The Farm Assured Namibian Meat (FAN Meat) scheme was set as a consumer-oriented, meat quality assurance scheme that functions as an independent body but with attachment to the government (Meat Board, 2017). The use of the FAN Meat logo confirms that Namibian export meat is produced according to standards laid down by its trading partners in a single scheme. Livestock producers are expected to adhere to the FAN Meat standards in order to qualify for export of meat of high quality sourced from livestock that are mainly naturally reared extensively on semi-arid vegetation without addition of growth hormones (Bowles et al., 2005; FAN Meat, 2019). These meat standards outline correct practices for livestock husbandry, animal health and welfare, with special emphasis on animal handling and transport, environmental management, pasture and feed management, record keeping, as well as livestock identification and traceability through the Namibian livestock identification and traceability system (NamLITS; FAN Meat (2019). However, the standards and guidelines mainly focus on correct practices; thresholds that indicate

unacceptable welfare are only for limited practices i.e. castration and disbudding at less than 2 months of age, and prohibited transport of pregnant cows over 8 months. The weakness of the FAN Meat scheme is that it is a voluntary scheme and is mainly utilised by producers for export purposes and not all livestock farmers are included.

Significant progress in the improvement of animal welfare standards in Namibia has been made through the inclusion of an animal welfare course and practical training in relevant tertiary education. Generally, apart from an inadequate legislative environment, the most pertinent concerns regarding animal welfare in Namibia include recurrent drought, transport of livestock, cattle branding and earmarking, livestock husbandry procedures, and poor animal handling facilities (DVS, 2016).

Despite the success of the Namibian beef cattle industry particularly in terms of beef export, cattle reproductive performance has been reported as suboptimal (Lepen, 1996; Samkange et al., 2019; Siegmund-Schultze et al., 2012). Apart from drought influences, the reproductive efficiency of beef cattle in the country is challenged by various factors including animal health, especially venereal diseases such as campylobacteriosis, trichomonosis, brucellosis, and BVD. Reproductive conditions such as dystocia, vaginal/uterine prolapse and retained fetal membranes are also common occurrences in beef herds. In addition, abortion ranks high on the list of poor fertility problems in cattle in the semi-commercial and communal areas of the country (DVS, 2016; Kaurivi, 2014a). Moreover, poor bull fertility and inadequate genetic materials also contribute to challenges of the overall reproductive performance in beef cattle herds (Kaurivi, 2014b).

2.4 Conclusion and justification of research

2.4.1 Concluding remarks

Consumers are demanding high animal welfare standards on farms from which their animal products are sourced and, hence, farm assurance that includes animal welfare assessment has become an essential component for certification and product labelling (Knierim & Winckler, 2009). Despite this desire for animal welfare certification, there is currently no standardised animal welfare protocol in the world. Even though the Welfare Quality protocol is extensively used for farm animal welfare assurance and product labelling in

Europe for intensively managed cattle, it has many limitations, especially in regard to assessment of welfare in extensive systems, while the UC Davis cow and-calf health and handling protocol, although designed for use in extensive systems, has limitations especially in the coverage of resources and management practices. Nevertheless, we believe that an amalgamation of these two protocols could pave the way to a fitting and practicable animal welfare assessment protocol for extensively reared beef cattle, such as those predominant in New Zealand and Namibia extensive cow-calf systems.

2.4.2 Objectives of this thesis

i. Develop and assess an animal welfare assessment protocol suitable for New Zealand extensive pasture-based cow-calf systems (Chapter 3).
    a. Identify suitable animal welfare assessment measures for extensive beef cow systems in New Zealand by selecting and merging the most practicable animal-based, resource-based and management-based measures in the Welfare Quality protocol for cattle and UC Davis Cow-Calf Health and Handling assessment protocol.
    b. Assess the feasibility of identified animal welfare assessment measures at commercial farms.
    c. Use the same data to validate potential categorisation thresholds of welfare measures for the assessment of beef cow herds.

ii. Develop an animal welfare assessment protocol for cow-calf systems in Namibia by adapting and assessing the practicability of using the proposed animal welfare assessment protocol for the New Zealand beef production system to the extensively semi-arid rangeland beef production systems in Namibia, namely, commercial beef farms, semi-commercial and communal village farms (Chapter 4).
    a. Assess the feasibility of adapting a New Zealand beef cow welfare assessment protocol on extensive cow-calf systems in Namibia and identify suitable measures.
    b. Apply the protocol on beef farms and comparison of farm production system effects on the welfare of beef cows.

c. Use the same data to validate potential categorisation thresholds of welfare measures for the assessment of beef herds.

iii. Compare and examine the animal welfare of cattle reared on pasture in New Zealand for beef production with those raised in Namibia on semi-desert rangelands (Chapter 5).

2.4.3 Research significance

The present study was undertaken as relevant, for the results are foreseen to fill a gap in the knowledge of how:

i. To develop an animal welfare assessment protocol that could pave the way to a more fitting and validated protocol for use in extensive beef farming systems. This is the first study to evaluate welfare in extensive beef systems using a comprehensive assessment protocol.

ii. To provide a baseline data with which veterinarians and farmers can compare their results to identify significant patterns on specific farm types, which will suggest specific causal factors for welfare concern on those farms and thus better guide prevention programme.

iii. In Namibia, the current assessment results and welfare measures thresholds could also be used as a basis for the welfare status of village farms to prioritise intervention areas of welfare compromise to either attain or maintain beef markets.

Chapter 3 New Zealand Animal Welfare Assessment Protocol Development And Assessment Of Cow-Calf Systems

Preface: **This chapter consist of 3 published papers that build on each other.**

Chapter 3.1: In order to develop an animal welfare assessment protocol for assessment of cow-calf systems in New Zealand, suitable measures were selected from the Welfare Quality protocol and the rangeland-based UC Davis Cow–Calf Health and Handling assessment protocol. After testing the applicability of selected measures at one farm, additional measures that were deemed to be practical to undertake in New Zealand were identified and incorporated, resulting in a protocol of 50 potential measures.

Chapter 3.2. This protocol required testing for practicability and feasibility of measures across multiple beef farms before it can be used more widely. In this chapter, the protocol was evaluated on 25 cow–calf farms during routine pregnancy testing, farm resource evaluation and a questionnaire guided interview. Judgements were made as to whether measures were feasible to record, required modification, were already adequately captured by another measure or were not practical to measure in a commercial setting. At the end of the process, a robust, achievable protocol with 32 measures for use on pasture-based extensive cow–calf farms was created.

Chapter 3.3: The application of the protocol on the farms showed that categorisation of identified animal welfare measures into scores that indicate a threshold of acceptable and non-acceptable welfare standards was necessary. In this chapter, the aim was achieved through the setting and comparing of imposed categorisation thresholds with derived thresholds to see, in a commercial setting, which was the most appropriate to the range of observations and the significance of the welfare implications of the measure. These thresholds provide indicators to farmers and farm advisors regarding the levels at which intervention and remediation is required.

3.1 Identification of suitable animal welfare assessment measures for extensive beef systems in New Zealand

This paper has been published and is presented in the journal format and style. This is the first chapter in the series of developing an animal welfare assessment protocol for extensive beef systems in New Zealand. This paper describes the measures that were selected from Welfare Quality and UC Davis protocols and tested at one farm resulting in a protocol of 50 potential measures.

agriculture

MDPI

Article

Identification of Suitable Animal Welfare Assessment Measures for Extensive Beef Systems in New Zealand

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Abstract: Farm animal welfare assessment protocols use different measures depending on production systems and the purpose of the assessment. There is no standardized validated animal welfare protocol for the assessment of beef cattle farms in New Zealand, despite the importance of beef exports to the country. The aim of this study was therefore to identify welfare measures that would be suitable for an animal welfare assessment protocol for use in extensive pasture-based cow–calf beef cattle systems in New Zealand. The proposed animal welfare assessment measures were selected from the Welfare Quality protocol and the rangeland-based UC Davis Cow–Calf Health and Handling assessment protocol. Measures that were deemed impractical and/or unsuitable were excluded from the protocol. After testing the applicability of selected measures at one farm, additional measures that were deemed to be practical to undertake in New Zealand were identified and incorporated into the protocol. The intention was to identify animal welfare indicators that were assessable in the yard during a single farm visit, a questionnaire guided interview, and a farm resource assessment visit that evaluated cattle health and management. Further testing of the 50 measures that were identified as being appropriate will be undertaken on commercial beef farms to develop a practicable welfare protocol for extensive pasture-based beef systems.

Keywords: welfare assessment; extensive beef; New Zealand

1. Introduction

High animal welfare standards are increasingly being requested by consumers of animal products [1], so farm assurance schemes that include animal welfare are being used in many systems. This led to the development of animal welfare assessment protocols for a range of farm animal species in a range of production systems [2]. Developing an appropriate and practicable animal welfare assessment protocol requires the identification and selection of suitable welfare measures for each production system. The chosen measures need to be relevant, repeatable, and comparable across farms with similar production systems [3,4]. Critically, not all measures (whether animal or input-based) are applicable to all production systems. For example, in the New Zealand dairy system, measures such as hock lesions and rising restrictions when cows are standing up in stalls (both of which are essential measures in welfare assessments of housed cattle) are generally irrelevant because New Zealand dairy cattle are not normally housed [5]. Similar issues apply in regard to assessing welfare on extensive cow–calf beef farms in New Zealand, as the focus of many welfare assessments (e.g., welfare quality) is on growing cattle managed in intensive beef production systems, which are completely different to extensive operations [6]. On the other hand, although the rangeland-based UC Davis Cow–Calf Health and Handling assessment is based on an extensive system [7], it does not entirely fit the pasture-based

system in New Zealand. For example, this protocol is limited to the observation of cows in the handling chute only, and had limited ability to measure the human–animal relationship [4,8].

Thus, the aim of the current study was to utilize the Welfare Quality and UC Davis assessment protocols as the basis for identifying animal welfare assessment measures. It was hoped that this would form the basis of a practicable and credible animal welfare assessment protocol for the extensively reared pasture-based beef cow–calf systems in New Zealand.

2. Materials and Methods

The aim of this study was to identify valid measures that could be practically assessed on pasture-based beef farms in New Zealand, using a process of expert opinion and review followed by pre-trialing on one farm. In order to identify suitable animal welfare assessment measures that would suit the extensive pasture-based cow–calf beef systems which predominate in New Zealand, the Welfare Quality [6] and UC Davis [7] protocols were scrutinized by the authors, and measures that were deemed not suitable for New Zealand were excluded.

The remaining measures were then pre-tested by the authors along with an experienced technician (expert opinion) on one New Zealand beef farm to identify which of these measures could be practically assessed while cows were being handled for other purposes. In addition, further parameters that were not included in either the Welfare Quality or UC Davis protocols, but that were deemed relevant and practicable on the basis of the farm evaluation, were also identified.

The pre-testing of the potential protocol was undertaken in November (spring) on one beef farm in the Manawatu region in the south of the North Island of New Zealand (latitude 40.4° S). The climate is temperate, with a monthly average temperature range of 8 to 18 °C and an average rainfall of 900 mm/year. The farm was a 500 Ha mixed sheep and beef farm with river flats and hill country. The principal beef breed was Angus, with some Hereford and dairy-beef crosses. The cows were observed in the yard during weighing in a chute and hoof confirmation scoring in a holding pen. Additionally, a questionnaire-guided interview and farm resource visit captured health and management of cattle over the previous 12 months.

3. Results

Unsuitable criteria and measures that were excluded as not fit for an animal welfare protocol for New Zealand beef farming systems, with reasons for their exclusion, are presented in Table 1.

Of the 60 cows presented for observation at the farm, 50 cows were assessed in the yard. In total, 50 indicators (Table 3) were assessable during the yard observation, questionnaire guided interview, and farm resource visit. The selected measures were shown to be feasible and practicable on this farm, with the whole process taking 3 h. The measures identified as suitable and the methods of assessment are shown in Table 2. Additional parameters that were not in the Welfare Quality [6] and UC Davis [7] protocols, but were deemed relevant and practicable from the farm evaluation, are shown in Table 3.

Table 1. Excluded welfare assessment criteria and measures (from Welfare Quality [6] and UC Davis [7] protocols) and reasons for exclusion as unsuitable for extensive pasture-based beef systems in New Zealand.

Welfare Principles	Criteria	Measures	Reasons of Exclusion
Good feeding		Space at water troughs, cleanliness of water troughs, number and size of water points	Water provision on New Zealand beef farms is typically plentiful and is sourced mainly from natural resources such as streams and rivers. In semi-intensive and intensive systems, the 'provision of water' at 'clean water points' might be an easy task to accomplish, but in extensive systems as shown by Franchi [9] and Hernandez [10] in the tropics, water may be obtained from natural resources and, hence, challenging to assess. In the Welfare Quality protocol, the measure of 'absence of prolonged thirst', is indicated by the 'number and size of water points', but these measures have proved challenging to assess in tropical extensive systems [10], and thus were rejected as not suitable for extensive pasture-based systems as well. This measure was therefore replaced by access to clean and safe water and distance to water supply
Good environment	Access to pasture, housing, rising restrictions, hazards in indoor environment		Cattle in New Zealand are already extensively reared on pasture and, as in accordance with Laven [5] and Hernandez [11], the 'access to pasture' criterion was not relevant. Another significant change to the Welfare Quality protocol was the replacement of 'good housing' with 'good environment'. With an absence of infrastructure or indoor obstacles in extensive systems where cattle might collide, the criteria of 'good housing' and 'rising restrictions' were thus excluded. Similarly, the absence of 'hazards in the indoor environment' was maintained but changed to capture hazards in extensive environments.
Good health		Bloat	Bloated rumens in beef cattle on pasture are rare, therefore this measure was regarded as not suitable as it is more associated with grain-fed cattle [8].
		Hock lesions	Hock lesion evaluation was rejected by Laven [5] as a measure of extensive based dairy cattle and there is even less likelihood that they will be an issue in permanently grazed beef cattle on pasture.
		Tail docking	Tail docking is prohibited by law [12] and thus not practiced in New Zealand beef cattle production systems.
Appropriate behavior	Expression of other behavior	Idling behavior	'Expression of other behavior' is a subjective measure and may vary with assessors and in this study, this measure was discarded, as in agreement with Laven [5] and Hernandez [11] as a feature only assessable in confined cattle. Idling behavior was also found by Laven [5] to be unsuitable to be included for pasture-based dairy cattle as cattle spend more time grazing than idling and, hence, it has been excluded for beef cattle in the same environment.

Table 2. Identified suitable measures and methods of assessment.

Method of Assessment	Measures Assessed
Observation from an elevated platform next to the race while cattle were in the race	Body condition score, rumen fill score, broken tails, short tail integument alterations (abrasions, swelling, hair loss), tail twist, striking/hitting cattle with moving aids, cleanliness of the animals (flank, hind, udder, dirty tail (fecal soiling), coughing, hampered respiration, nasal discharge, ocular discharge, diarrhea, hoof condition
Observation on exit from chute	Lameness, exit speed (running or walking), stumble or fall, mis-catch
Video behavioral observation of cattle in holding pens for 20 min before animals were put in the race as a back-up for visual observation	Agonistic behaviors (head butting, displacement, fighting, chasing), cohesive behaviors (social licking, horning), qualitative behavior assessment (fearful, frustrated, bored, agitated, irritable, uneasy, distressed, tense, uncomfortable, etc.)
Noise observation around the yard	Noise of handlers, noise of equipment /machinery, presence/noise of dogs at yards
Yard design assessment; if it allowed easy movement of cattle from holding pens into forcing pens, the race, the chute, and exiting.	Handling facility design
Questionnaire guided interview with the farm manager to assess health and management of cattle in the last 12 months.	Castration and disbudding procedures, ear-tagging, frequency of yarding cows/year, disease history, animal health checks frequency, accidents/misadventures, mortality, vaccination, reproductive conditions (abortions, dystocia, prolapse)
Cattle in paddocks observation	Avoidance distance, overall body condition and any signs of health problems, behavioral observations.
Farm observation	Access and type of water supply, distance to water points, availability of shade in paddocks, feed/pasture condition, absence of hazardous objects/terrain

Table 3. All potential measures identified as suitable (selected measures amalgamated from Welfare Quality [6] and UC Davis [7] assessment protocols and additional measures fit for New Zealand extensive pasture-based beef cattle farms).

Welfare Principles		Welfare Criteria	Combined Measures from Welfare Quality and UC Davis Assessment Protocols	Additional Measures Fit for New Zealand Beef Farms
Good feeding	1	Absence of prolonged hunger	Body condition score	Rumen fill score
	2	Absence of prolonged thirst	Access to safe and clean water	Distance to water points
Good environment	3	Comfort around resting	Cleanliness of the animals (flank, hind, udder)	Dirty tail
	4	Thermal comfort		Availability of shade in paddocks
	5	Ease of movement		Absence of hazardous objects/terrain
Good health	6	Absence of injuries	Lameness, integument alterations (abrasions, swelling, hair loss) broken tail	Short tail
	7	Absence of disease	Coughing, hampered respiration, nasal discharge, ocular discharge, diarrhea, hoof condition, mortality, reproductive conditions (abortions, dystocia, prolapse),	Disease history, animal health checks frequency, accidental misadventures (accidents where cattle fall in tomos (sinkholes) or roll off hills)
	8	Absence of pain induced by management procedures	Disbudding/dehorning, castration,	Ear-tagging
Appropriate behavior	9	Expression of social behaviors	Agonistic behaviors, cohesive behaviors	Handling facility design, noise of handlers, noise of equipment/machinery, presence/noise of dogs at yards, frequency of yarding cows/year
	10	Negative emotional state	Qualitative behavior assessment (fearful, frustrated, bored, agitated, irritable, uneasy, distressed, tense, uncomfortable, etc.)	
	11	Good human–animal relationship (stockmanship)	Avoidance distance, handling measures (mis-catch, tail twist, striking/hitting cattle with moving aids, stumble, fall or run exiting	

4. Discussion

4.1. Excluded Measures

It was evident during the study that not all measures (whether animal- or input-based) were applicable to the production system under study. The exclusion of measures (Table 1) was based on eliminating animal welfare criteria and measures that were not applicable to the extensive beef production system in New Zealand. The main criteria and measures that were rejected were largely those that had previously been rejected or questioned by Laven [5] as not practicable to apply for dairy cattle animal welfare assessment in extensive pasture grazing systems in the country. These measures were primarily those that were relevant to intensively-managed, housed cattle; including access to pasture, idling behavior, housing and rising restrictions. These measures were also irrelevant for assessment of beef cattle reared on extensive pasture.

Another consideration used to exclude certain measures such as cleanliness and 'space at water troughs' was based on the applicability of the Welfare Quality [6] protocol that has been verified under tropical conditions [9–11]. Moreover, [4,8], who also evaluated the UC Davis system in extensively-managed cattle, also rejected bloating.

4.2. Suitable Welfare Assessment Measures Identified from the Selected Protocols

The applicability of selected measures (Table 2) was based on the Welfare Quality [6] and UC Davis [7] protocols. A few adjustments were required to produce a practicable assessment on extensive commercial beef farms. For example, time limitation did not permit locomotion score or body condition score (BCS) beyond lame or not, and fat, good or thin, respectively.

4.3. Feeding

BCS has been regarded as the preferred indicator for good feeding in most on-farm welfare assessments [13]. The resource based measuring of 'absence from prolonged hunger' with indirect, non-validated measures such as 'centimeters of feeding trough per cow' or measuring the feed consumed by a group or individual cattle [13,14] has largely been replaced by measuring the BCS of the animals. In the present study it was more practical, with the limited time available per animal, to scale the BCS to good condition, fat or thin animals than to assess them based on the New Zealand beef cattle scale of 1 to 10 [15], or even the European/North American scale of 1 to 5.

Assessment of 'water availability' especially determining space, cleanliness, number, and size of water points is difficult to assess in extensive systems, so this was simplified to a simple yes/no regarding access to clean fresh water and the distance that cattle had to walk to access such water. This adjustment of distance is valuable in extensive systems, as the longer the distance that livestock travel to water the lower the rate of pasture utilization [16,17]. In extensive systems this definition is simpler and easier to use than the range of measures included in 'water availability' and is also supported by scientific evidence.

4.4. Environment

The key criteria for good environment were identified as 'thermal comfort' and 'ease of movement'. However, the concept of 'thermal comfort' was not developed nor assessed in the Welfare Quality [6] protocol, so this criterion was amended to 'comfort with access to shade or shelter', as was proposed by Hernandez [11]. Heat stress reduces the comfort and performance of cattle [18,19] which led Hernandez [11] to suggest replacing 'lying outside the lying area' with 'lying in the shade' as more suitable for application to extensive pastured cattle. However, this indicator is difficult to assess in the field, as beef cattle at pasture lie down mostly at night and are more likely to be found standing than lying when resting during daylight hours [20]. However, availability of shade for grazing cattle, for example from trees, shrubs, galleys, and man-made canopies, does have a significant effect

on animal productivity and well-being [21] and is thus likely to be a useful alternative to animal observation of lying behavior in extensive pasture-beef systems.

The assessment for 'comfort around environment' in the Welfare Quality protocol evaluates the cleanliness of the hind and lower legs, flank, and udder [6]. However, in the current study, the term was adjusted to 'dirtiness of cows' as it was deemed a better fit for this criterion. Laven and Fabian [5] included dirty flanks, hindlimbs, and udders in their assessment of the physical condition of pasture-based dairy cattle, but commented that the impact of dirtiness on welfare was likely to be different in pasture-based cattle and housing-based systems. This is consistent with the common finding in beef cattle in New Zealand, that beef cattle commonly have dirty lower limbs (particularly after wet weather) without significant consequences [22,23]. Therefore, in the present protocol only the dirtiness of the upper hind limbs was recorded.

4.5. Cattle Health

The relevant indicators for good health were selected as: 'absence of injuries and disease', 'management of painful procedures', and 'mortality'. To demonstrate absence of injuries and disease, animal-based measures were typically selected as described in the Welfare Quality [6] and UC Davis [7] protocols. For painful procedures, welfare assessment is influenced by countries' laws and societal expectations. In the European-based Welfare Quality protocol, data are collected about the method used for procedures such as castration, as well as the use of anesthetics and analgesics. However, in many countries which have extensive farming systems, (including New Zealand at the time of the on-farm examination: November 2017) painful procedures, including disbudding, could legally be performed without analgesics or anesthetics in young animals less than 9 months old [12]. However, it is clear that, irrespective of legislation, procedures such as castration and disbudding are painful, and that this pain can be mitigated by using anesthetics and analgesics [24]. Thus, in a welfare assessment it is important to assess pain management during and after painful procedures, even if pain management is not required by legislation. Welfare assessment should reflect our understanding of animal welfare science and not be controlled by it. For example, the regulations in New Zealand have recently changed, so that as of October 2019 disbudding without local anesthetic will be prohibited.

The Welfare Quality protocol assesses overall mortality, only recording the percentage of animals which died whatever the cause (for example whether it was disease or accident and whether the animal died or was euthanized) [6]. However, in New Zealand the hazards posed by the topography of hill farms and rolling country mean beef cattle are prone to misadventure. Thus, instead of collectively assessing overall mortality, cases of misadventure deaths on the farm during the last 12 months were separated from death due to disease or euthanasia for health issues.

4.6. Cattle Behavior in the Yard

Hernandez [11] suggested that the 'expression of social agonistic behavior' which includes head-butting, displacement, chasing, and fighting should be observed remotely (i.e., using binoculars) so as not to disturb pasture-based cattle. However, social agonistic behavior probably accounts for <5% of the time budget of grazing beef cattle [20]. Thus, in order to observe sufficient agonistic behavior at pasture to make a reasonable assessment of behavior, cattle would have to be observed for a prolonged period. It was decided to assess social behavior in the yard where agonistic behavior is likely to be more frequent [25].

'Positive emotional behaviors' were initially combined as 'calm/content' in this study as was recommended by Hernandez [11], even though these authors were unconvinced that the assessment of positive behaviors would be worthwhile (i.e., that such observations might be both practicable and of limited value). In the present study, it was difficult to quantify and assess these behaviors during the welfare assessment at the one farm. This criterion was rejected in favor of only focusing on assessing negative behaviors.

It was still difficult to follow the Welfare Quality protocol in order to quantify and assess 'negative qualitative behaviors' (fearful, frustrated, bored, agitated, irritable, uneasy, distressed, tense, uncomfortable, etc.) [6], during the farm visit. All of these behaviors can only be deduced subjectively from the body language of cattle [26] and are difficult to assess accurately. Thus, 'negative emotional behaviors' were merged into 'negative behavior', as a way of recording to describe general negative body language and behavior. For example, negative behavior (in the holding pens) could describe those cattle with tails swishing in agitation, shuffling feet, pawing, running away, and bellowing, pacing, head-shaking, and kicking. Each individual action was rare, so the data were amalgamated to create a measure which was the total count of negative behaviors as a percentage of observed cattle.

4.7. Appropriate Stockmanship

Cattle handling measures that indicate stockmanship in and out of the chute (vocalizing, stumbling, balking, falling or, running) were according to their description in the UC Davis [7] protocol. 'Tail twisting' and 'mis-catching' of cattle in the race and chute, respectively, were also identified as practicable measures. However, assessment of the 'use of moving aids' was challenging, as the definition was not clear. Simon [4] also disregarded 'moving aids touches' as a measure in an ideal comparable welfare measuring protocol because of its unclear definition. For example, some handlers would gently touch cattle with a moving aid as an extension of their arm while others used it more aggressively and on sensitive points. Thus, in the present study, hitting cows with moving aids was adjusted to evaluate the collective percentage of cows hit or poked regardless of the position on animals that were hit.

Measuring avoidance behavior was changed from the method used in the Welfare Quality [6] protocol because unlike dairy cattle and intensively reared beef cattle that are in daily contact with humans; extensive beef cattle tend to have a longer flight distance [25,27,28]. Therefore, this individual measure was replaced by the withdrawal distance when approaching a herd of cows in a paddock. However, although measurement of this distance is feasible, its interpretation in extensively-reared beef cattle may be problematic.

4.8. Additional Measures Identified as Suitable for New Zealand Extensive Pasture-Based Cow–Calf Beef Farming Systems

The extra measures that were deemed necessary for New Zealand pasture-based beef systems were based on the peculiarities of this system. For example, the topography of New Zealand hills and high country pose the risk of cattle falling downhill. Additionally, cattle may fall into tomos (natural underground holes), gullies, and bogs in some areas of New Zealand [23]. The 'ease of movement' was thus assessed by considering the absence of hazardous objects or risky areas.

Another peculiar practice of extensive beef farming where cattle are predominantly raised on hills in New Zealand is herding cattle with dogs and motorbikes. Herding cattle into the yards with other animal species like dogs or horses may cause them distress and thus, as observed by Hernandez [11], such farms should be recorded. Similarly, herding cattle on motorbikes can cause fearful behavior in cattle and thus both measures were noted as potentially useful indicators of extensive beef cattle welfare.

Sudden exposure to loud noise can stress cattle and may result in a stampede and other fear reactions [27]. Therefore, the noise made by handlers, equipment, and dogs during cattle handling were considered as potential welfare assessment measures. This opinion is supported in the measures of beef cattle welfare indicators developed by the World Organisation for Animal Health (OIE) that indicated that, extensively-managed cattle should be herded and handled calmly with minimal noise and at a slow pace to avoid stress [29].

The herding of cattle into the yards is known to influence the behavior of cattle in the yard during handling and restraining [25]. Thus, for extensively-managed cattle that are rarely yarded and handled, the 'yarding frequency per year' might serve as an indicator of welfare on beef farms. Moreover, the

number of times farmers inspect extensive-based cattle is crucial to their health. Therefore, 'health check frequency', particularly during the calving season, was identified as a valuable potential indicator for extensive beef farms welfare assessment. In New Zealand, the welfare concern for the traditional weaner production and finishing beef production farming is mainly due to limited inspection of cows and calves, and thus dystocia cases and injured or sick cattle might not receive immediate attention [23,30,31].

The design of yards and handling infrastructure can easily affect the flow and behavior of cattle in the yard [25,32]. 'Facility design' was added to evaluate any negative impact it might have on animal handling and flow in the holding pens and the race. Another added measure was, 'agitation and/or fearful behavior' of individual cattle in the race such as climbing on other cattle or attempting to escape. Such behaviors were recorded as indicators of negative behavior in the chute and as a measure of stockmanship.

Dirtiness in the Welfare Quality protocol focuses on dirt on the udder, hindlimbs, and flanks, but not the tail. In New Zealand, it is not unusual to see a ring of hardened feces on the tail of cattle. This ring can constrict the circulation to the distal part of the tail and, if it persists for long enough, it can result in necrosis and sloughing off and shortening of the tail predominantly in beef cattle. The risk factors for this condition are poorly understood, but it is thought to be associated with the production of large volumes of soft feces (typical of cattle on improved pasture). Thus, 'dirty tails' and 'short tails' were added to the list of potential measures to be recorded as measures of good environment and health respectively.

The 'disease history' measure was also added to the questionnaire for the New Zealand protocol to capture health and welfare of beef cattle in the last 12 months. This was deemed a more comprehensive approach than just performing a physical evaluation of the cows. Despite disease status of beef cattle in New Zealand being generally good, at least partly because of the absence of major diseases [23], the health and welfare status of an individual beef farm will be significantly influenced by the prevalence of diseases, such as bovine viral diarrhoea (BVD), facial eczema and milk fever, and reproductive problems like dystocia.

'Ear tagging' was not included in the original Welfare Quality protocol. However, it does cause pain and can lead to complications such as ear infection. Hernandez et al. [11] suggested inclusion of ear tagging in a cattle welfare assessment, but their study did not indicate a suitable measure for assessment. One potential method of assessment could be to determine the age at which tagging takes place. Some farmers ear-tag calves at a later stage, potentially causing more pain than if placed in younger animals. Younger animals are also easier to handle and quicker to recover than older animals [24].

In housed cattle, feed supply and access are crucial measures of animal welfare. In the extensive pasture system, these are more difficult to assess. A potential alternative is the scoring of rumen fill, which responds more quickly to insufficient feed than body condition score, as there are individual differences in rumen fill between cows (indeed these were observed on the trial farm), rumen fill provides an individualized measure of short-term feed intake. It has been commonly used as an indicator of the nutritional status of cattle [33,34], though commonly in dairy rather than beef cattle. To facilitate scoring the 5 point 'rumen fill score' was simplified to empty, normal, and distended.

5. Conclusions

The identification of suitable animal welfare measures is crucial for any valid and practicable welfare assessment across different production systems as all measures are not necessarily applicable to all systems and regions. The purpose of the current study was to identify suitable animal welfare assessment measures for extensive cow–calf beef systems in New Zealand. It was important to select valid measures with limited subjectivity that can be practically assessed across beef farms. Additional measures, such as presence of short tail in cows, deaths due to misadventure, yarding frequency, and herding of cattle with dogs and bikes were also identified as potentially valuable measures for

the assessment of extensive beef farms. Although the current study was based on a single farm, the 50 measures that were identified are anticipated to be relevant to other beef farms in the country. Thus, the next step is to test the practicability of applying these measures on representative commercial beef farms with the aim of paving the way to a validated animal welfare assessment protocol for extensive beef farming enterprises such as those in New Zealand.

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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*.

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Name/title of Primary Supervisor:	**Prof Richard Laven**
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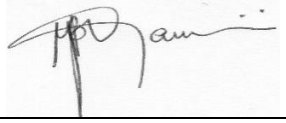
Candidate's Signature:	
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3.2 Developing an Animal Welfare Assessment Protocol for Cows in Extensive Beef Cow–Calf Systems in New Zealand. Part 1: Assessing the Feasibility of Identified Animal Welfare Assessment Measures

This paper has been published and is presented in the journal format and style. This is the second chapter in the series of developing an animal welfare assessment protocol for extensive beef systems in New Zealand. This paper describes the testing of the protocol for practicability and feasibility of measures across 25 cow-calf beef farms before wider recommendation. This resulted in a more robust protocol with 32 measures for use on pasture-based extensive cow–calf farms.

animals

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Article

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

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Simple Summary: It is not feasible to transfer animal welfare assessment protocols developed for intensive systems to extensive systems or from rangeland- to pasture-based cattle because each system needs a different protocol. In a previous study, we combined selected measures from the Welfare Quality protocol for beef cattle and the UC Davis Cow-Calf Health and Handling protocol with additional measures specific to New Zealand to create a welfare assessment protocol for pasture-based cow–calf systems that had 50 measures. In this study, the feasibility of this protocol was assessed during routine yardings of cows and a questionnaire. Individual measures that were deemed unsuitable were eliminated or modified. At the end of the process, a robust, achievable protocol with 32 measures for use on pasture-based extensive cow–calf farms was created.

Abstract: Potential measures suitable for assessing welfare in pasture-based beef cow–calf systems in New Zealand were identified from Welfare Quality and UC Davis Cow-Calf protocols. These were trialled on a single farm and a potential protocol of 50 measures created. The aim of this study was to assess the feasibility of the measures included in this protocol on multiple farms in order, to develop a credible animal welfare assessment protocol for pasture-based cow–calf farms systems in New Zealand. The assessment protocol was trialled on 25 farms over two visits and took a total of 2.5 h over both visits for a 100-cow herd. The first visit in autumn included an animal welfare assessment of 3366 cows during pregnancy scanning, while the second visit in winter included a questionnaire-guided interview to assess cattle management and health, and a farm resource evaluation. Through a process of eliminating unsuitable measures, adjustments of modifiable measures and retaining feasible measures, a protocol with 32 measures was created. The application of the protocol on the farms showed that not all measures are feasible for on-farm assessment, and categorisation of identified animal welfare measures into scores that indicate a threshold of acceptable and non-acceptable welfare standards is necessary.

Keywords: welfare assessment; beef cows; extensive systems; New Zealand

1. Introduction

Good animal welfare is increasingly recognised as an important component in the trade of farm animals and their products [1,2]. This has resulted in the development of welfare assessment protocols for specific production systems [3] which support trade, farm assurance, and product labelling.

Properly planned assessments can identify risk factors for poor welfare, aid in the development of interventions, and be used to monitor and evaluate changes in practice [2,4,5].

Most protocols are based on a mixture of animal- and input-based assessments [6,7], along with assessments of stockpersonship [8]. Almost all widely used protocols are directed at intensive systems, due to the perception, especially in Europe, that confined systems lack the 'naturalness' [1] of pasture-based systems. It is not possible to just transfer protocols developed for intensive systems to extensive systems. For example, measures such as hock lesions and rising restrictions, both of which are essential measures in welfare assessments of housed cattle, are generally irrelevant to New Zealand because cattle are not normally housed [9]. This means that to assess the welfare of beef cattle in New Zealand, the assessment must be designed for the extensive pasture-based beef system which predominates there.

In New Zealand, most farms that have breeding cows are on hill or high country and are also sheep farms. On many farms, the main purpose of beef cattle is to maintain good-quality pasture for the sheep. On most farms grazing policies are not consistent throughout the year with paddocks being set stocked in spring but rotationally grazed in the rest of the year. The predominant cow breeds are Angus and Hereford and their crosses. On commercial beef farms, herd sizes range from 50–60 breeding cows to over 500. Cows calve in spring (August to October) with steers and non-replacement heifers sold in September to November [10].

A protocol that combined selected measures from the Welfare Quality beef cow protocol [7] and the UC Davis Cow-Calf Health and Handling protocol [11] with additional measures specific to New Zealand was recently created [12]. This protocol required testing for practicability and feasibility across multiple beef farms before it can be used more widely. The aim of this study was to evaluate the practicability and feasibility using the protocol for welfare assessment on 25 cow–calf farms during routine pregnancy testing. This aim was achieved through the application of measures on commercial farms and making judgements as to whether they were feasible to record, required modification, were already adequately captured by another measure or were not practical to measure in a commercial setting. The scope of the current assessment protocol included replacement heifers and cows at pregnancy testing and excluded calves, steers and bulls.

2. Materials and Methods

2.1. Farms

The study was carried out on 25 extensive pasture-based cow–calf herds in the Waikato region of the North Island of New Zealand. This was a sample of the clients of a veterinary practice (VetEnt, Te Awamutu, New Zealand) who used that practice for routine pregnancy diagnosis in autumn. Herd details are summarised in Table 1. All farms were mixed sheep and beef enterprises and used rotational grazing as their main means of feeding cattle, with supplementary hay or silage fed during winter. No housing or off-pasture feeding was used.

Table 1. Details of farms, cow herds presented for pregnancy testing and percentage of cows assessed for animal-based welfare measures in the study.

	Topography	Breed	Age	Total Herd	Number Assessed	% Assessed
Farm 1	Hill	Angus	Mixed	253	176	70
Farm 2	Hill	Angus and Charolais	Mixed	410	209	51
Farm 3	Hill	Hereford	Heifers	33	25	76
Farm 4	Hill	Devon and Angus	Mixed	97	67	69
Farm 5	Hill	Angus and Simmental	Mixed	123	78	63
Farm 6	Hill	Hereford	Mixed	212	163	77
Farm 7	Hills rolling	Belted Galloway	Young	18	18	100
Farm 8	Hills rolling	Angus	Mixed	318	272	86
Farm 9	Hills	Angus × Simmental	Mixed	305	239	78

Table 1. *Cont.*

	Topography	Breed	Age	Total Herd	Number Assessed	% Assessed
Farm 10	Hills	Angus and Hereford	Mixed	241	180	75
Farm 11	Hills	Angus and Friesian	Mixed	103	101	98
Farm 12	Hills	Angus	Mixed	154	133	86
Farm 13	High	Angus and Devon	Mixed	145	113	78
Farm 14	Hill	Angus	Young	162	133	82
Farm 15	Flat to rolling	Angus × Hereford	Mixed	96	61	64
Farm 16	Flat to rolling	Angus × dairy breed	Mixed	30	28	93
Farm 17	Flat to rolling	Hereford	Mixed	81	52	64
Farm 18	High	Angus	Mixed	293	155	53
Farm 19	High	Angus	Mixed	98	62	63
Farm 20	High	Angus and crosses	Mixed	464	308	66
Farm 21	Hill to high	Angus and crosses	Mixed	174	124	71
Farm 22	Hill	Angus	Mixed	232	137	59
Farm 23	Hill rolling	Angus and crosses	Mixed	541	304	56
Farm 24	Hill	Mixed Angus with Devon	Mixed	306	171	56
Farm 25	High	Angus and crosses	Mixed	67	57	85
			Total	4956	3366	
	'Mixed': heifers and cows		Average	196	135	73
	'Young': heifers and yearlings		Median	162	133	71

2.2. Welfare Assessment and Data Collection

The protocol development process involved two phases. Phase 1 took place in March/April 2018 (autumn) at the time of pregnancy diagnosis and Phase 2 in winter 2018 (July) at a time when their natural environment is likely to be at its worst. Following the identification of suitable measures at one farm by three of the authors and an experienced technician where inter observer reliability was assured [12], the assessments in Phases 1 and 2 of the current study were undertaken by only one of the authors.

Phase 1

All assessments were undertaken when cattle were brought in for pregnancy diagnosis. Farms varied in how cattle were brought in for pregnancy diagnosis. Some cows were brought in from a nearby paddock when the veterinarians arrived, some were put in the holding pen in the early morning for pregnancy testing in the late morning or afternoon, and some were kept overnight in holding pens. All but one farm used herding dogs and bikes to bring the cows in (one farm had no dogs). Pregnancy diagnosis was done in a full race, using ultrasound with occasional manual examination for confirmation). Once all the cows in the race were tested, cows were let out into the holding pen or paddock, and the race refilled. Observations were made of cows in the holding pens and in the race during pregnancy diagnosis. Whilst in the holding pens, the cows were observed for physical health, body condition, rumen-fill, and behaviour. Video recordings (2 × 15–20 min) were also made of the herd in the holding pens for qualitative behavioural evaluations and as a back-up tool and were transcribed at the end of each farm visit.

Observations of cows in the race included the interaction between the stockperson and the cows, as the latter entered, were handled and exited the race, and the effects of race design (including the transition from holding pen to race) upon cow behaviour. As animals exited the race, their exit speed (running or walking), whether they fell or stumbled, and lameness signs were all recorded. The design and quality of handling facilities were concurrently assessed. Information was collected on yard accessibility and yard design, with emphasis on flooring, shape and size of forcing pens, race structure and the presence/absence of solid-sided walls. The position of the observer was constrained by the design of the race but observations of cows exiting the race were made by the assessor standing as close to the exit as possible without interfering with cow flow. All other observations were made

in single-file races. All animal-based assessments were made in the race, following the veterinarian who was doing pregnancy diagnosis. In some cases, the veterinarian started at the front of the race, others at the back. As many animals were assessed per race as possible without slowing the pregnancy diagnosis process, with a target of observing more than 50% of cows in a herd (Table 1). All assessments took place between 9:00 and 16:00. Phase 1 visits typically lasted 1 h per 100 cows in the herd.

Phase 2

A questionnaire-guided interview (see Appendix A) was conducted with the farm manager to assess health and management of each herd in the last 12 months. The general management and key health aspects on the farm (dehorning/disbudding, castration, vaccination, diseases or disease symptoms seen in cattle, cattle deaths, access and type of water supply, feed/pasture condition, wintering practices) were recorded.

A visit to observe cows at pasture (in at least one paddock per farm) was made to assess provision of grazing, access to water and shade in the paddocks, pasture hazards (e.g., steep hills and sinkholes), and to get a general overview of cow body condition. In addition, the flight zone was assessed when the assessor (with the farmer) moved closer to where the cows were in the paddock. Phase 2 visits typically lasted 1.5 h.

See Tables 2–4 for details on how each measure was recorded.

2.3. Data Analysis

Data were analysed using SPSS version 24 (IBM). Spearman's rank correlation was used to identify measures with a strong association ($\rho \geq 0.8$).

Following the visits, after consideration of farms variations and data analysis, the feasibility of the individual measures was divided by four of the authors into:

- Measures that were retained unchanged in final protocol;
- Measures that were not feasible on all farms but were considered necessary and suitable for keeping in an adjusted form in the final protocol;
- Measures that were significantly ($\rho \geq 0.8$) correlated with other measures, which could be rationalised into a single measure;
- Measures that were not feasible across all farms and or which were deemed to be unnecessary or unsuitable. These measures were removed from the final protocol.

Specific reasons for categorising each measure in these four groups are described in the results section (Tables 2–4). Broadly, the exclusion or modification of measures from the protocol was mainly due to the difficulty of measurements across all farms, questionable or unclear welfare implications to the production system, time and space limitation, measure requiring specialized assessments and adjustments of location of measuring to where it was more achievable.

Table 2. Measures assessed as feasible for inclusion in the final protocol without change (observations in and around the race were done in Phase 1, and questionnaire assessments in Phase 2).

Principle	Welfare Criteria	Welfare Measures	Method of Assessment (Observation in and Around Race Unless Otherwise Stated)
Good feeding	Absence of hunger	Body condition Score	% thin cows in the herd, based on score ≤4/10 on 1–10 scale [13].
		Rumen Fill	% of cows with hollow/empty rumen [14]
Appropriate Environment	Thermal comfort	Shade	Subjective assessment of shade in the paddocks (presence of trees, shrubs, galleys, human-made canopies) as enough or insufficient.
	Comfort around resting place	Short tail	% of cows with short tail (sloughed-off tails)
Good Health	Absence of injuries/physical impairment	Abrasions	% of cows with abrasions/fresh scratches or cuts extending >1 cm.
		Swelling	% of cows with swellings of >1 cm in diameter.
		Hair loss/hairless	% of cows with hairless patches of >1 cm.
		Blindness	% of cows with "affected eye (s)" by visual assessment and/or testing with hand.
	Absence of disease and pain	Ocular discharges	% of cows with evidence of ocular discharges extending 2 cm.
		Nasal discharges	% of cows with evidence of nasal discharges extending 2 cm.
		Dystocia	% as reported by the famers during questionnaire-guided interview.
	Absence of pain from management procedures	Ear tagging, Castration, Disbudding	Record age and use of local anaesthetic during questionnaire-guided interview.
Stockpersonship	Animal handling stockpersonship and resource-based measures	Noise of handlers	Subjective categorical assessment of handler noise: (1) none; (2) some but not frequent; (3) loud and repeated shouting.
		Noise of Equipment/machinery	Subjective categorical assessment of noise of equipment: (e.g., race or chute gate) and machinery (e.g., generators): (1) no noise, (2) minor audible noise or (3) unpleasantly noisy.
		Dogs herding cattle and noise around the yard	Categorical subjective assessment: (1) no dogs, (2) quiet dogs or (3) noisy/repeatedly audible dogs.
		Health checks	Record frequency of health checks on cows during winter/pregnancy (in questionnaire)
		Yarding frequency	Record frequency (number of times) of yarding of cows per year (in questionnaire).
		Yard design flow	Subjective categorical assessment: (1) easy movement and flow; (2) effective movement with minor problems (e.g., more gates needed) and (3) poor flow and difficult handling (e.g., forcing pen with too many corners or gate too big).

Table 3. Measures included in the protocol after adjustments, including the rationale for change and the changes that were made (observations in and around the race were done in Phase 1, and questionnaire assessments in Phase 2).

Welfare Principles	Measures	Method of Assessment Q: Questionnaire, D: Direct Observation	Reason for Difficulty	Adjustment of Measures and Outcome and Recommendation
Good feeding	Access to water	Q: How far cattle had to walk to access water	Difficult to estimate due to farm terrain.	Adjusted to a categorical measure based on average distance to water source (<250; 250–500 m and >500 m).
Appropriate Environment	Hazards	D: Identify pasture hazards (e.g., steep hills, cliffs, gullies, and sinkholes), and presence of dangerous objects/garbage.	Required a categorical scale.	Adjusted to a 3-point scale: 1; No hazards, 2; ≤two hazards; 3; >2 hazards or animals dying in any hazard.
Good Health	Disease history	Q: Occurrence of diseases of minor (e.g., warts), major (e.g., theileriosis) or variable (e.g., fasciolosis) significance to welfare	There were no common diseases on these farms which can act as proxies for disease control in general (as could, for example, cases of respiratory disease on beef finishing units).	Disease data collection kept in the protocol but not used as part of an individual farm's assessment (except dystocia and mortality)
	Mortality	Q: % of cows which died on the farm or were culled due to disease or accidents during the last 12 months.	Farmers did not discriminate between cow deaths and all animal deaths. Culling data did not differentiate between voluntary and involuntary.	Numbers of accidental deaths and deaths/slaughter (either on-farm or sent off-farm) due to disease were combined.
	Lameness	D: % of cattle with uneven weight-bearing on a limb that is immediately identifiable and/or obviously shortened stride).	It was often not possible to observe individual cows as they exited the race into a holding pen with other cows.	Adjusted so that lameness was also assessed as cows exited from the holding pen to the paddock.
	Diarrhoea	D: 'Diarrhoea' was defined as the % of cows with presence of symmetrical wet or dry patches of faeces below the tail head which were at least the size of a hand.	Watery faeces are extremely common in grass-fed cattle in New Zealand because of the high-water content of pasture, so could not be differentiated from a pathological condition.	Re-categorised as a measure of appropriate environment as "faecal soiling" alongside other related measures (i.e., short tail and dirtiness).
Appropriate Behaviour	Negative behaviour	D: Video recording agonistic behaviours, and signs of agitation or fearfulness	In most holding pens there was insufficient space for cows to display those behaviours.	Video records were not used and replaced by recording only observed fearful/agitated behaviour (i.e., persistent pushing, climbing on others, or trying to climb over the fence/rails) in the race.
Stockpersonship	Running and stumbling	D: Running or stumbling was defined as % of cows taking ≥2 strides at a gait faster than a trot, or their knees/hocks contacted the ground, on exiting the race.	Where cows exited from the race into a holding pen, stumbling or running could not be observed as they were usually moving into a group of cows.	Assessment changed so that stumbling or running when cows exit the holding pen to the paddocks was included.
	Fall	D: Falling was defined to capture % of cows whose torso contacted the ground on exiting the race.	No falling was observed. This may have been due to many farms moving cows into holding pens from the race rather than directly into a paddock.	Replaced by recording cows falling or lying down while in the race and forcing pen.
	Hitting cows	D: The % of individual cows aggressively hit or poked with force or repeatedly while in the race was to be recorded.	Most hitting occurred when drafting cattle into the forcing pen from the holding pens than within the race.	Changed to a subjective categorical observation of hitting of the group rather than the individual cow: no hitting; occasional hitting (≤10% of cows); frequent hitting (>10% of cows) into the forcing pen and race.
	Mis-catching	D: % animals mis-caught in the head gate	The head gate was not used routinely on most farms	Changed to a categorical estimate of the proportion of cows that were mis-caught on any part of the body while gates were closed into or within the race (<1% versus ≥1% mis-caught).

Table 4. Welfare measures removed from the protocol after feasibility testing on 25 Waikato beef farms (observations in and around the race were done in Phase 1, and Questionnaire assessments in Phase 2).

Welfare Principles	Measures	Method of Assessment:	Reasons for Removal
Good Environment	Udder dirtiness	>25% of an udder covered with dirt or manure	Difficulty of observing udders of cows in the race. Dirt on udders is more likely to be mud (low welfare risk) than faeces (high risk).
Good Health	Hoof problems	Presence of overgrown, abnormally shaped or cracked hooves in individual cows.	Difficulty of observing hoof confirmation of cows in the race, or in holding pens (individual assessment in a crowd) or when exiting the race (exiting into a crowd or straight into paddocks). Furthermore, the main link between hoof confirmation and welfare is likely to be its impact on lameness, thus measuring an additional criterion seems unnecessary especially when it would require a specific examination.
	Hampered respiration or coughing	Number of coughs or hampered respirations over 15–20 min for 20 cows in pens (video).	It was not possible to determine whether coughing and related signs were due to disease or to the environment of the yards.
	Broken tails	Observations of abnormal tails (misaligned or broken at the tail head).	Broken tails were not observed in the race nor reported (questionnaire) on any of the farms.
Stockpersonship	Baulking	Cows which refuse to move forward, or which move backwards, when the route is clear in front in the race.	Pregnancy testing was performed with a full race, i.e., all cows were lined up in the race, pregnancy tested and then released all at once. There was thus no opportunity to observe baulking
	Vocalisation	Cows which make an audible sound after restraining but before procedure takes place.	On the study farms vocalisation occurred when the cows were brought in, they either saw calves that had been weaned a month or two earlier or were separated from their calves before the cows were put in the holding pen.
	Flight distance	Cows in a group are approached slowly and distance is estimated when withdrawal start to occur. As this requires that they are free to move, this was assessed during Phase 2 of the study.	On some farms, the cattle could only be observed after they had been drafted with bikes and/or dogs which meant they were agitated before observation. On other farms, the presence of the farmer meant cattle were anticipating being moved to a new break of grass and thus approached the observer rather than moved away. it was therefore not possible to make valid determinations of flight distance
	Herding cattle on motorbikes and quadbikes	Recording those farms where cattle were herded on motorbikes and quadbikes.	All farms used motorbikes or quadbikes to herd cows, and it was not possible to apply criteria to assess the 'quality' of their use. Assessing handling in races was therefore considered as a more reliable proxy for assessing herding skills.

3. Results

A total of 4956 cows were presented for pregnancy diagnosis, with yard observations made on 3366 animals (Table 1). Measures included in the final protocol without adjustment are shown in Table 2. Twelve measures were modified before inclusion in the final protocol. These measures are shown in Table 3, along with the reason for modification and the suggested modification. Correlations of animal welfare measures with a Spearman's correlation coefficient of $\rho \geq 0.5$ and confidence interval are shown in Table 5. Only three measures were highly ($\rho > 0.8$) correlated: dirty tails and dirty hind quarters ($\rho = 0.85$), dirty tails and dirty flanks ($\rho = 0.86$), and dirty hind quarters and dirty flank ($\rho = 0.89$). These measures were combined for welfare assessment into one measure of "dirtiness" by averaging the three measures per farm. Other significant correlations were between; thin cows and poor rumen fill ($\rho = 0.76$), dirty tail and diarrhoea ($\rho = 0.75$), hit and noise of handlers ($\rho = 0.73$), fall and fearful ($\rho = 0.64$) and yarding frequency/year and fearful ($\rho = 0.50$). Eight measures were excluded as it was not feasible to assess them during a pregnancy diagnosis visit and they were not necessary to keep in an adjusted form. These measures are shown in Table 4, along with rationale for their removal.

Table 5. Correlations of animal welfare measures with a Spearman's correlation coefficient of > 0.5 and confidence interval.

				Confidence Interval	
Welfare Criteria	**Correlated Measures**		**Correlation Coefficient**	**Lower Bound −1.96**	**Upper Bound +1.96**
Feeding	Thin cows	Poor rumen fill	0.76	0.52	0.92
Environment and "Diarrhoea"	Dirty tail	Dirty hind	**0.85**	0.73	0.92
	Dirty tail	Dirty flank	**0.86**	0.73	0.93
	Dirty flank	Dirty hind	**0.89**	0.74	0.95
	Dirty tail	Diarrhoea	0.75	0.51	0.87
	Dirty hind	Diarrhoea	0.65	0.36	0.83
	Dirty flank	Diarrhoea	0.6	0.26	0.82
Stockpersonship	Hit	Noise Handler	0.73	0.49	0.87
	Yard flow	Noise Handlers	0.62	0.39	0.79
	Fall	Fearful	0.64	0.33	0.80
	Yarding/yr	Fearful	0.50	0.19	0.75
Stockpersonship and Others	Stumble	Abortion	0.69	0.21	0.94
	Run	Short tail	0.57	0.20	0.78

Bolded measures had a correlation coefficient of > 0.8.

The final protocol included 32 measures, as summarised in Figure 1. Three measures were related to good feeding, four to appropriate environment, 16 to health measures and 13 to stockpersonship. The data collected (summary statistics) will be reported and discussed in Part 2 (Kaurivi submitted).

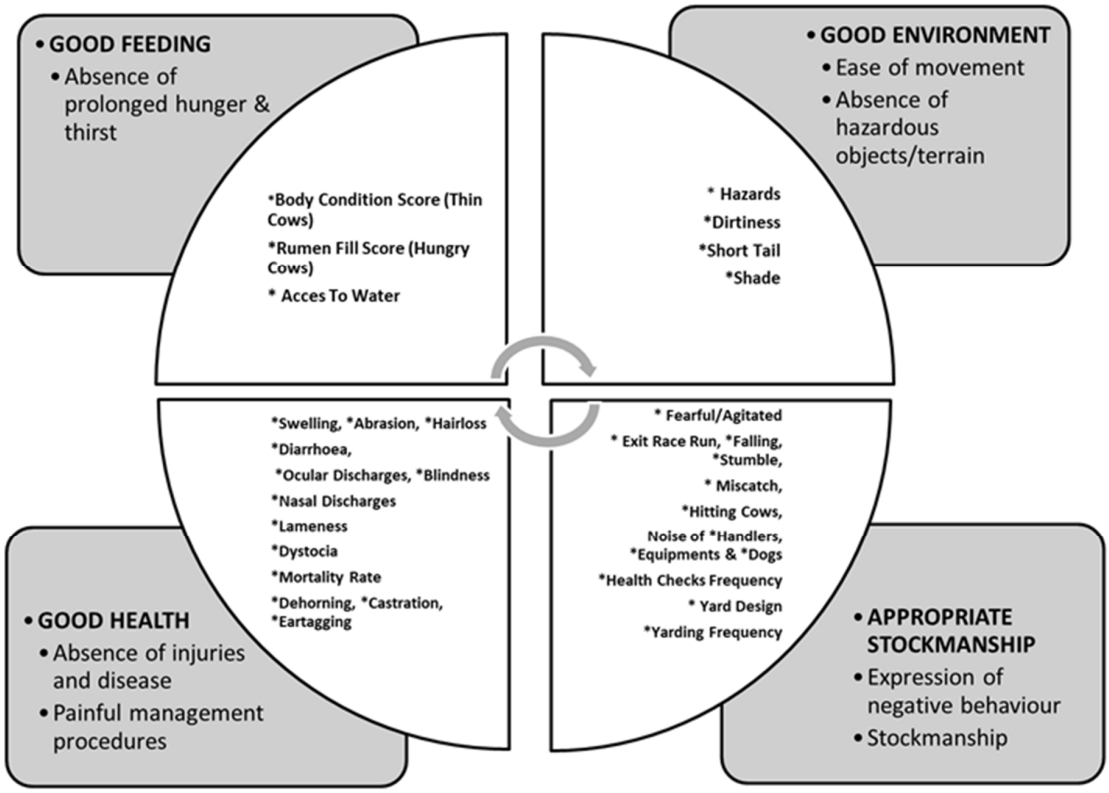

Figure 1. Summary of the 32 measures determined as being suitable for inclusion in a welfare assessment protocol for extensively reared pasture-based beef cattle in New Zealand.

4. Discussion

The aim of this study was to create a protocol in which most of the animal-based measures could be made in cattle that were being handled for purposes other than the assessment itself. To this end, the study evaluated the feasibility of applying 50 potential measures of welfare [11] in extensively managed beef cattle during routine yarding for pregnancy diagnosis and during a paddock observation; on the basis that there is limited value in recording measures that require a specific separate examination [9]. Of the 50 initial measures, 8 were excluded because it was not feasible to collect them across all farms during yarding and it was not worth routinely recording the prevalence of broken tails but if they are observed their presence should be noted. Three highly correlated measures ($\rho > 0.8$) were amalgamated into one combined measure. Avoidance distance was the only animal-based assessment made at pasture as it was not feasible to observe this during yarding. However, it is known that this can be difficult to assess in cows at pasture [15]. This proved to be the case in this study as, on many farms, cows associated the arrival of people with being moved to fresh grazing and so this measure was deemed unfeasible.

Moreover, the process of making the observations should not, of itself, impinge upon the welfare of the cattle. Thus, beef cattle that are managed in extensive systems are infrequently yarded and probably associate yarding with bad experiences and become stressed in them [16–18]. Conversely, cattle that are frequently yarded show fewer signs of agitation, such as vocalisation and stumbling [8] in handling facilities [17,19] than do those that are seldom yarded. Thus, the number of yardings is itself a determinant of the welfare of the cows, so setting thresholds of yarding of cows per year (e.g., 3–6 times per year in this study) should reflect the impact of yarding on the welfare of the animals. Further research is required to validate these thresholds and determine the effect of handling frequency itself on welfare of beef cows in New Zealand.

Measures should not be excluded from a protocol simply because they are absent, as their absence does demonstrate the lack of a welfare problem. Broken tail was excluded because it was not observed

on any farm and farmers were not observed twisting or manipulating cows' tails (probably the main cause of broken tails outside of accidental injury [20]). However, in this case, the exclusion does not mean it will not be observed, as broken tails can be easily observed if they are common.

Many measures can potentially be used to assess the welfare of cattle at pasture (e.g., [21]). However, if a measure is to be used in an assessment programme it must be repeatable and comparable across operations in similar production systems [5,22] and it must be achievable within a limited time frame alongside other assessments [5,6,23]. This requirement to undertake most of the assessments alongside a routine handling process has the benefit that the measures of stock handling reflect a real process but has the disadvantage that some animal-based measures are difficult or impossible to achieve. Hence, of the measures that were removed from the final protocol in this study, most were excluded primarily because they were difficult to assess in a single-file race from an elevated platform next to the race. These include recording baulking and assessing hoof problems and udder dirtiness. Similarly, the requirement that cattle were going through a routine handling process meant that, even with video cameras, complex behaviours could not be assessed as there was insufficient space and time [24] in the collecting pens for cattle to show such behaviours. Additionally, management practices during the handling limited the applicability of some measures. This was particularly so for vocalisation which can be a useful measure of stockpersonship, but on most farms was simply a measure of separation anxiety of cows from calves [25]. The requirement for measures to be repeatable and comparable across operations means that this protocol need to be tested on more farms by more assessors to validate whether measures are repeatable across assessors and whether differences between farms affect feasibility.

Of the original 50, 11 measures required modification based on the feasibility of making those observations during routine yarding. Many of these modifications were relatively trivial, commonly involving changing the position of the observer whilst the assessments were being made, and usually dictated by the design of the handling facilities. Thus, it proved more practical to assess mis-catching of cows with gates on any part of the body in the race instead of the head bale; hitting of cows in forcing pens versus in the race, and observing falling down while drafted into the race rather than only on exiting. The assessment of measures such as running, stumbling and lameness designed for cows exiting the race to paddocks also required adjustments to include those exited from holding pens to paddocks.

Conversely, other measures proved more amenable to converting to a categorical basis than originally envisaged. The provision of water is seen as a fundamental criterion of animal welfare, but in New Zealand, where it is sourced naturally, water is abundant, and is universally provided to cattle in water troughs, so devising an appropriate assessment criterion was challenging. The final criterion, namely, whether there was water available within 500 m, was based on the literature showing that 250 m is the optimum distance for cows to walk to water in terms of the ideal distance for optimum productivity [26,27]. Likewise, provision of shade is a critical criterion in terms of maintaining an animal thermal comfort [15,28]; however, in the present study, it was rarely an issue given the presence of trees and terrain shadows in paddocks on the beef farms under study.

It was difficult to make a useful assessment of dirtiness as a criterion of animal welfare. Dirt over the flank, hind and tail were highly correlated ($\rho > 0.8$) with each other, so were converted into a combined measure in the final protocol, as cows which are dirty in one place are usually dirty in the others. Dirtiness can be a useful measure of welfare in intensive dairy cows [29,30] and housed beef cows [31,32] where faecal contamination of the environment have a higher chance of udder, hoof and skin infections. However, it is probably not meaningful to equate the faecal contamination of housed cattle with the muddiness of pastured cattle [9,33]. The impact of this measure on the welfare of pastured cattle is, at best, ambiguous and may really only be of significance in terms of the risk of meat contamination when cattle are slaughtered [34]. Assessment of the presence of diarrhoea, again an important criterion for housed cattle, was also difficult in the present study. In New Zealand, most pasture-fed beef cows have watery faeces for most of the year, leading to a high level of faecal

soiling [35,36]. Even in rangeland systems, the importance of diarrhoea and faecal soiling as measures of welfare have been questioned: for example, Simon [22] observed a high rate of faecal soiling at most California beef cattle ranches. Faecal soiling of the tail may result in "short tails". Short tails are tails that have been sloughed off as a result of constriction of blood supply to the distal tails by hardened faecal rings [12,37]. Since this undoubtedly causes pain to the animal, short tail is an important indicator of adverse effects from faecal soiling. Measures that require complicated assessment need feasibility evaluation to be included in assessment protocols. For example, disease history requires considerable detail to establish the impact of a disease on cattle welfare. Such detail was not available on most farms. Similar restrictions meant that we recorded overall mortality rate and there was no differentiation than between voluntary and involuntary culling [38]. Such a differentiation would have provided further information in addition to the mortality rate, by identifying the rate at which health problems necessitated the culling of cows, but it was not possible in this study.

Nonetheless, despite the aforegoing caveats, most of the measures proposed by Kaurivi [12] proved to be both feasible and useful. The use of body condition score (BCS) as a means of identifying the adequacy of feeding is, of course, well documented. In the present study, BCS was assessed against the New Zealand scale of 1–10 [13], with scale of 1–4 taken as thin cows. However, from a production point, BCS 4 could be acceptable [39], but from an animal welfare perspective may be regarded as low and unacceptable. Moreover, there was a strong positive correlation ($\rho = 0.76$) between BCS (thin cows) and poor rumen fill scores (RFS). However, although both measures are good indicators of nutritional status of cows, they provide different information: BCS about the medium-term nutritional status of the animals, RFS about their recent intake [14,40]. Therefore, for large extensive beef farms where cattle are commonly yarded the day before any management procedure, the use of RFS by itself as a valid indicator of welfare is questionable. Nonetheless, poor RFS over a period could be a good indicator for farmers to monitor specific individual animals closely, adjust the herd's feed intake, or investigate problems that could be causing the prolonged poor RFS [41]. Taken together, such arguments justified retaining RFS as well as BCS in the final protocol.

Although the assessment of body injuries was regarded as feasible, setting the thresholds at which they would be regarded as abnormal required careful consideration. Various criteria have been set for skin alterations, varying from >5 cm [42] and >2 cm [22] to >1 cm in the present study. Generally, such determinations represent a compromise between what is likely to represent a negative effect upon the animal and what can be repeatedly assessed within the constraints of the situation in which the observations are made. A similar situation might arise in ranking the severity of body integument alterations, differentiating animals or farms with small or few lesions on the body of animals from those with big or many severe lesions [43]. This was not considered in this study for practical reasons.

Likewise, careful consideration was also given to categorise measures (e.g., stockpersonship measures) into three tiers to reflect severity. In the evaluation of noise at the yards, subjective thresholds were used to indicate severity, i.e., no noise to moderate/minimal noise versus very noisy handlers/equipment and no dogs at the yards *vs* quiet to constant noisy dogs. The grading developed in the present study aligns with Petherick [44] that sudden exposure to noise is stressful to cattle and may result in stampeding. A similar conclusion from Waynert [45] was that the reduction of metal clicking, and human shouting could reduce fear in cattle. Cattle respond to vocalisations of other species [46,47] and noisy dogs are likely to affect the behaviour of cattle [48], e.g., agitation and running on exit from race. Hence, the subjective weighing to indicate severity of this measure was necessary for a welfare assessment protocol.

The final assessment related to the design of yards and handling facilities. The difficulty in achieving optimal design is reflected in the many recommendations that are extant for facility design and handling infrastructure [22,49–51]. Consequently, various farmers opt for different yard designs, resulting in variable effectiveness of cattle flow. In the present study, it was clear that facilities fell into three categories: those that were associated with easy flow of cattle, those whose cattle flow could be

improved with minor adjustments, and those that would require major remediation to allow effective cattle flow.

5. Conclusions

This study has taken a series of measures that appear intrinsically suitable to the assessment of welfare of beef cows and has evaluated the feasibility of assessing those measures in cows during routine yardings and questionnaire on cattle and farm management. Whilst the 25 farms in this study do not necessarily represent the welfare conditions of beef cows throughout New Zealand and inter observer reliability was not assured, they were suitable for developing and validating feasible welfare measures for an assessment protocol. Through elimination of measures that were unsuitable for use, or required modification for use under those circumstances, or which yielded information that proved to be of little value, a robust, achievable protocol of 32 measures has been developed for use on pasture-based extensive cow–calf farms in New Zealand. The proposed protocol is envisioned as being suitable for use at farm level for benchmarking and certification of welfare standards on farms. Further research is required to establish this protocol with more observers and more farms across New Zealand.

The next immediate step of the research is to categorise identified feasible animal welfare measures into scores that indicate a threshold of acceptable versus unacceptable welfare standards, in order to explore the development of an animal welfare assessment protocol for extensive beef systems in New Zealand. These thresholds will provide indicators to farmers and farm advisors regarding the levels at which intervention and remediation is required. This will be addressed in a companion paper to this one (https://www.mdpi.com/2076-2615/10/9/1592).

Author Contributions: Y.B.K.—main researcher who did the project proposal and data collection, analysis and main write up. R.L.—main supervisor who did conceptualisation, methodology, funding acquisition, review and editing. R.H.—conceptualization and formal analysis. K.S.—conceptualization, methodology and editing and validation. T.P.—review and editing. All authors have read and agreed to the published version of the manuscript.

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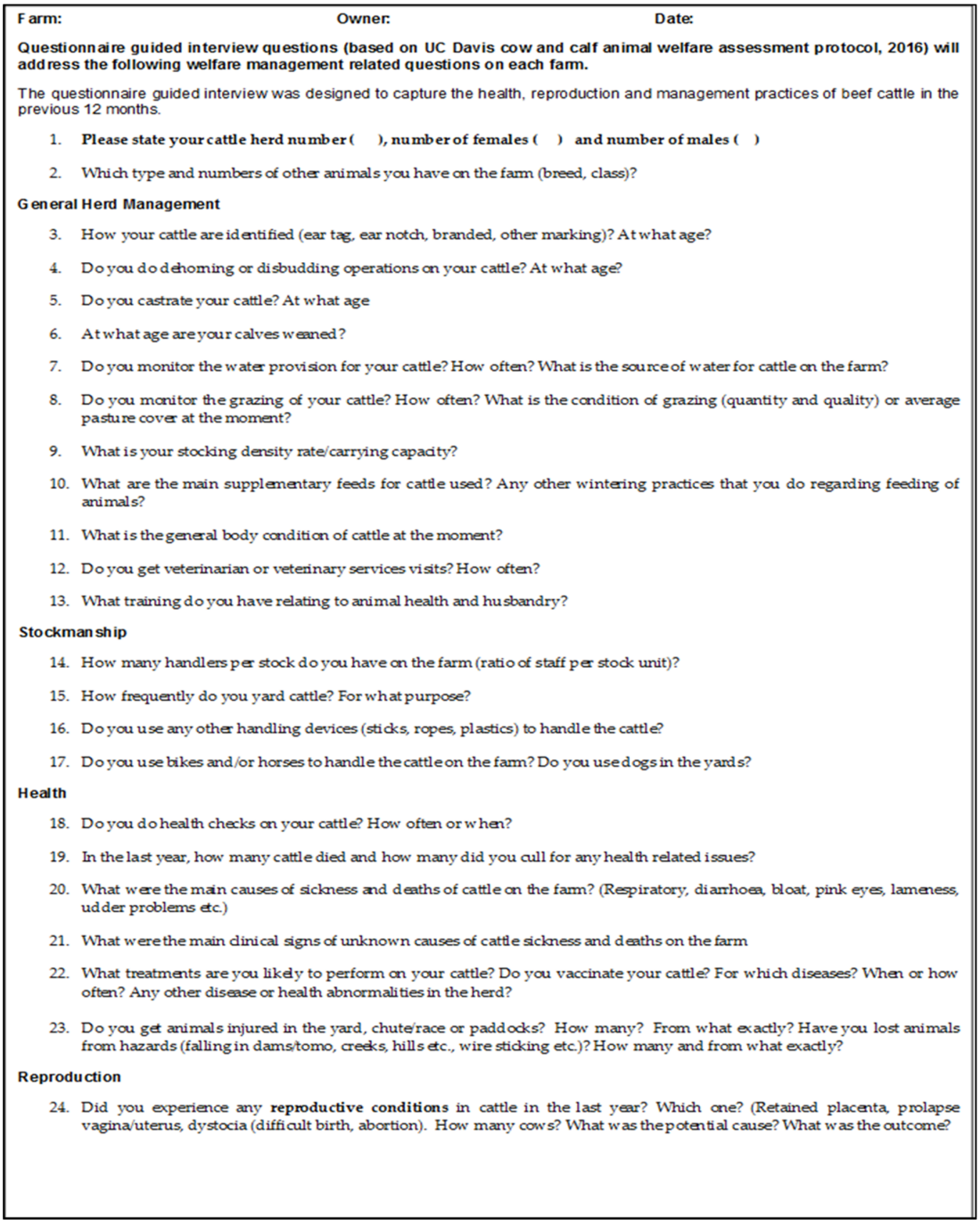
Conflicts of Interest: The authors declare no conflict of interest.

Appendix A



Farm: **Owner:** **Date:**

Questionnaire guided interview questions (based on UC Davis cow and calf animal welfare assessment protocol, 2016) will address the following welfare management related questions on each farm.

The questionnaire guided interview was designed to capture the health, reproduction and management practices of beef cattle in the previous 12 months.

1. **Please state your cattle herd number ( ), number of females ( ) and number of males ( )**
2. Which type and numbers of other animals you have on the farm (breed, class)?

General Herd Management

3. How your cattle are identified (ear tag, ear notch, branded, other marking)? At what age?
4. Do you do dehorning or disbudding operations on your cattle? At what age?
5. Do you castrate your cattle? At what age
6. At what age are your calves weaned?
7. Do you monitor the water provision for your cattle? How often? What is the source of water for cattle on the farm?
8. Do you monitor the grazing of your cattle? How often? What is the condition of grazing (quantity and quality) or average pasture cover at the moment?
9. What is your stocking density rate/carrying capacity?
10. What are the main supplementary feeds for cattle used? Any other wintering practices that you do regarding feeding of animals?
11. What is the general body condition of cattle at the moment?
12. Do you get veterinarian or veterinary services visits? How often?
13. What training do you have relating to animal health and husbandry?

Stockmanship

14. How many handlers per stock do you have on the farm (ratio of staff per stock unit)?
15. How frequently do you yard cattle? For what purpose?
16. Do you use any other handling devices (sticks, ropes, plastics) to handle the cattle?
17. Do you use bikes and/or horses to handle the cattle on the farm? Do you use dogs in the yards?

Health

18. Do you do health checks on your cattle? How often or when?
19. In the last year, how many cattle died and how many did you cull for any health related issues?
20. What were the main causes of sickness and deaths of cattle on the farm? (Respiratory, diarrhoea, bloat, pink eyes, lameness, udder problems etc.)
21. What were the main clinical signs of unknown causes of cattle sickness and deaths on the farm
22. What treatments are you likely to perform on your cattle? Do you vaccinate your cattle? For which diseases? When or how often? Any other disease or health abnormalities in the herd?
23. Do you get animals injured in the yard, chute/race or paddocks? How many? From what exactly? Have you lost animals from hazards (falling in dams/tomo, creeks, hills etc., wire sticking etc.)? How many and from what exactly?

Reproduction

24. Did you experience any **reproductive conditions** in cattle in the last year? Which one? (Retained placenta, prolapse vagina/uterus, dystocia (difficult birth, abortion). How many cows? What was the potential cause? What was the outcome?

Figure A1. Questionnaire-Guided Interview Questions Used for Welfare Assessment at 25 Waikato Beef Farms.

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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:	**Yolande Baby Kaurivi**
Name/title of Primary Supervisor:	**Prof Richard Laven**
Name of Research Output and full reference:	
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In which Chapter is the Manuscript /Published work:	**Chapter 3.2**
Please indicate: The percentage of the manuscript/Published Work that was contributed by the candidate:	**70%**
and Describe the contribution that the candidate has made to the Manuscript/Published Work:	
Main researcher who did the project proposal and data collection, analysis and main write up.	
Candidate's Signature:	
Date:	**10 December 2020**
Primary Supervisor's Signature:	
Date:	**10 December 2020**

DRC 16

3.3 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

This paper has been published and is presented in the journal format and style. This is the third chapter in the series of developing an animal welfare assessment protocol for extensive beef systems in New Zealand. This paper described protocol application on the farms and how categorisation of identified animal welfare measures into scores that indicate a threshold of acceptable and non-acceptable welfare standards was required. The thresholds allowed indicators to farmers and farm advisors regarding the levels at which intervention and remediation was required.

animals

MDPI

Article

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

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Simple Summary: Animal welfare assessment protocols use different methods to categorise and score animal welfare. This study has demonstrated the feasibility of developing standards for a welfare assessment protocol of cow-calf farms in New Zealand by validating potential categorisation thresholds for measures of assessment on 25 beef farms. Imposed thresholds of categorisation and derived thresholds based upon the poorest 15% and best 50% of farms for each measure were compared to see which was the most appropriate to the range of observations and the significance of the welfare implications of the measure. For measures with significant welfare implications, the stricter threshold was retained, while derived thresholds appeared more appropriate for commonly occurring traits but of less welfare importance for the production system at hand.

Abstract: The intention of this study was to develop standards for a welfare assessment protocol by validating potential categorisation thresholds for the assessment of beef farms in New Zealand. Thirty-two measures, based on the Welfare Quality and the University of California (UC) Davis Cow-Calf protocols, plus some indicators specific to New Zealand, that were assessed during routine yardings of 3366 cattle on 25 cow-calf beef farms in the Waikato region were categorised on a three-point welfare score, where 0 denotes good welfare, 1 marginal welfare, and 2 poor/unacceptable welfare. Initial categorisation of welfare thresholds was based upon the authors' perception of acceptable welfare standards and the consensus of the literature, with subsequent derived thresholds being based upon the poorest 15% and best 50% of farms for each measure. Imposed thresholds for lameness, dystocia, and mortality rate were retained in view of the significance of these conditions for the welfare of affected cattle, while higher derived thresholds appeared more appropriate for dirtiness and faecal staining which were thought to have less significant welfare implications for cattle on pasture. Fearful/agitated and running behaviours were above expectations, probably due to the infrequent yarding of cows, and thus the derived thresholds were thought to be more appropriate. These thresholds provide indicators to farmers and farm advisors regarding the levels at which intervention and remediation is required for a range of welfare measures.

Keywords: categorisation; welfare assessment; extensive beef cows; New Zealand

1. Introduction

An on-farm assessment of animal welfare requires a summation of measures which indicate the overall welfare status of farms. One key element of animal welfare assessment is the benchmarking of welfare measures across similar production operations and a summation of these measures [1]. Benchmarking farm animal welfare can be used to identify welfare problems and remediate them, and to allow follow-up assessments [2–4].

There is no simple way of measuring animal welfare [5–7] and grading animal welfare compromise is not easy [1,8,9]. The consensus for providing an overall judgement of animal welfare on a farm where different welfare measures are aggregated and weighted [8,10,11], is still contested [1,9]. The controversy emanates from the challenging interpretation of weighted sums that may tolerate compensation between welfare principles, such as an inappropriate environment being countered by good health [8,11]. Attempts to remove all compensation between welfare aspects in the Welfare Quality Assessment [12] were not achieved [11,13] and aggregation in this system was criticised as illogically allowing the cover up of important welfare problems [1].

In most welfare assessment protocols data are collected in various scales. The expression of data as ordinal scores makes the summation into overall scores difficult [8,9,14]. In the Welfare Quality protocol, data collected from the farms are integrated in a sequential transformation and aggregation, where the final welfare score result is presented on a scale of 0–100, ranking farms as excellent, improved, acceptable, and not classified [8,15]. This aggregation of scores is a complex process, and it has been criticised as not being in line with expert opinion [11,15].

The aggregation of welfare assessments may impact animal welfare decisions when schemes are applied on-farm. Indeed, the goal of achieving a transparent, yet practicable-to-compute system [1], may be unattainable. Hence, the splitting of measures into classes differing in severity has been recommended to give meaningful interpretation of scores on-farms [8]. Grading in the Five Domain Model comprises a five-tier scale grading from 'no compromise' to 'extreme compromise' [9]. The same author however, consented to the use of a simpler grading in cases of sparse or compromised data. The problem of having five-point grading systems on farm is that it is laborious and time consuming, which can reduce the feasibility of making such assessments [3,16]. This is even more impractical for extensive systems, or where animals are assessed during yarding where they may be moving fast in and out of the race with barely enough time to adequately assess each criterion. Hence, using an ordinal categorical score and computing the number of scores on a three-tier level (i.e., 0–2) might be an easier approach. A three-tier scale of severity was also endorsed by other authors [17,18].

Kaurivi [19] combined measures from the Welfare Quality protocol for beef cattle with the University of California (UC) Davis Cow-Calf Health and Handling protocol [20] and additional New Zealand-specific measures, to identify measures suitable for creating a welfare assessment protocol for extensively reared pasture-based beef cattle in New Zealand. Following the formulation phase, the protocol was then applied on 25 cow-calf farms in the Waikato region of New Zealand [21] to further test the protocol for completeness and on-farm feasibility. Through a process of eliminating unsuitable measures, adjustments of modifiable measures and retaining feasible measures, a protocol with 32 measures was created. However, the study did not attempt to categorise or rank welfare scores and welfare status of farms. The present study used the data collected by Kaurivi [21] to evaluate the best method to categorise animal welfare measures into scores that indicate a threshold of acceptable and non-acceptable welfare standards, as part of the development of an animal welfare assessment protocol for extensive beef systems in New Zealand. This aim was achieved through the setting and comparing of imposed categorisation thresholds with derived thresholds to see, in a commercial setting, which was the most appropriate to the range of observations and the significance of the welfare implications of the measure.

2. Materials and Methods

2.1. Protocol Used

The protocol was developed and trialled by Kaurivi [19] to create a robust, achievable suite of 32 measures which were usable on pasture-based extensive cow-calf beef farms in New Zealand [21]. Briefly, the protocol involved assessing measures combined from the Welfare Quality cattle protocol and the UC Davis Cow-Calf protocol, with additional New Zealand-specific measures. The assessment was trialled on 25 mixed sheep and cow-calf farms over 2 visits, with the first during routine yarding for pregnancy testing and the second using a questionnaire and observations of the herd at pasture during winter. In the first visit, a total of 4956 cows were presented for pregnancy diagnosis, with yard observations made on 3366 animals (see [19] for herd details). Observations were made of cows in the race regarding body condition, rumen-fill, behaviour and physical health. Stockpersonship was evaluated as cows entered and exited the race by observing how cows were handled. The yard design and handling facilities were also evaluated for ease of handling of cows. In the second visit, a farm resource evaluation and a questionnaire guided assessment of health and management of the herd was undertaken.

2.2. Categorisation of Measures

Categorisation of scores was based on the authors' experience and perception of what good welfare would be in extensive pasture-based beef cattle in New Zealand, together with a consensus developed from relevant literature. For each farm, the welfare impact of each of the 32 measures was categorised separately into 3 categories (Table 1). All discrete data were measured according to the proportion of cases and given an ordinal score of welfare on that 3-point category score. For example, the mean percentages of poor body condition (BCS; thin cows) and poor rumen fill (RFS; hungry cows) were given an ordinal score to indicate acceptable and unacceptable welfare in the herds.

Table 1. Categorisation of welfare scores.

Category Score	Welfare Assessment	Required Actions
0	Good/Acceptable	No intervention needed but keep monitoring
1	Marginal	Assess and plan for intervention. Increase monitoring
2	Poor/Unacceptable	Intervention needed immediately

For consistency, thresholds of measures across welfare principles were kept constant where reasonable. For example, for good health, absence of injuries or physical impairment welfare categories were kept the same at 2% threshold. Painful conditions (dystocia and short tail) were also given a similar category to the health issues. Ordinal data (i.e., age of castration) and subjective measures (i.e., handlers' noise) were similarly given a categorical score to indicate severity of marginal and unacceptable welfare in the herds. Finally, the categorisation of measures such as yarding frequency and health check frequency were moderated with respect to findings during the assessment visits. The categorisation and details on how each of these 32 measures were assessed are summarised in Tables 2–4.

Table 2. Categorical ranking of good feeding and appropriate environment measures in the New Zealand cow-calf protocol.

Welfare Principles	Welfare Criteria	Animal Welfare Measure/Indicator	Scoring Description	Categorical Ranking
Good feeding	Absence of hunger	Body condition score (thin cows)	% thin in herd of score (score 1–4 on 1–10 scale; [22])	0: 0–5.0% 1: 5.1–10% 2: >10%
		Rumen fill score (hungry cows)	% of animals with hollow/ empty rumen observed in the race	0: 0–20.0% 1: 20.1–50% 2: >50%
	Absence of thirst	Distance and availability of water	Average distance to access water	0: 0–250.0 m 1: 250.1 ≤500 m 2: >500 m.
Appropriate environment	Comfort around resting	Short tail	% of observed cows with shortened tail	0: 0.0% 1: 0.1–2% 2: >2%
		Dirty body	Total number of animals assessed as having dirty tail, hind and flank	0: 0–10.0% 1: 10.1–20% 2: >20%
	Thermal comfort	Shade	Subjective assessment of shade in the paddocks (presence of trees, shrubs, galleys, man-made canopies)	0: sufficient 2: insufficient
	Ease of movement	Absence of hazardous objects/environment	Hazardous objects observed in the yard and paddocks (i.e., tomos *, sharp objects lying around)	0: no hazards 1: 1–2 hazards 2: 3 or more hazards or animals dying in any hazard)

* Tomos are underground caverns usually containing a watercourse, with small openings to the surface into which cattle can fall and die (animals dying in tomo was given a score 2 hazards).

Table 3. Categorical ranking of health-related measures in the New Zealand cow-calf protocol.

Welfare Criteria	Animal Welfare Measure/Indicator	Scoring Description	Categorical Ranking in New Zealand Study
Absence of injuries/physical impairment	Swelling Hair loss/hairless Abrasions	% of observed cows with swelling, hairless patches or abrasions/fresh scratches (>1 cm)	0: 0.0% 8 81: 0.1–2% 2: >2%
Absence of disease	Lameness	% of observed cows with uneven weight weight-bearing on a limb that is immediately identifiable and/or obviously shortened strides	0: 0.0% 1: 0.1–2% 2: >2%
	Blindness Ocular discharges Nasal discharges	% of observed cows with ocular or nasal discharges extending 2cm, and those blind in one or both eyes	0: 0.0% 1: 0.1–2% 2: >2%
	Diarrhoea	% of observed cows with evidence of diarrhoea (more than a hand wide on both sides from base of tail)	0: 0–10.0% 1: 10.1–20% 2: >20%
	Dystocia	% of cows recorded with difficult births	0: 0.0% 1: 0.1–2% 2: >2%
	Mortality rate	% of accidental deaths, cattle which died due to disease, and those killed as a result of disease/accidents on the farm in the last 12 months	0: 0.0% 1: 0.1–2% 2: >2%
	Ear tagging/notching	Specify no tag or use of anaesthetics regardless of tagging or notching procedure and with/without the use of anaesthetic).	Ear tagging 0: no tag or use anaesthetics 1: tag with no anaesthetics 2: notching/cutting with no anaesthetics
Painful procedures	Castration Disbudding	Specify age at castration and use of anaesthetics Specify age at disbudding and use of anaesthetics	0: No castration/disbud 1: ≤2 months 2: >2 months

Table 4. Categorical ranking of appropriate stockpersonship measures in the New Zealand cow-calf protocol.

Welfare Criteria	Animal Welfare Measure/Indicator	Scoring Description	Categorical Ranking in New Zealand Study
Stockpersonship animal-based measures on entering and exiting the race	Fearful/agitated Fall	% cows fearful/agitated in the race/forcing pen (climbing on others or attempting to escape) % cows lying in or falling in race/forcing pen or on exiting	0: 0.0% 1: 0.1–2% 2: >2%
	Stumble	% cows stumbling when exiting the race/holding pens into paddocks	0: 0–2.0% 1: 2.1–5% 2: >5%
	Run	% cows running out of the race/holding pens into paddocks	0: 0–5.0% 1: 5.1–10% 2: >10%
Animal handling stockpersonship and resource-based measures	Mis-catch (in chute/race)	% cows mis-caught with gates on any part of the body either in the race or chute head bale	0: no mis-catch 1: mis-catch ≤1% 2: mis-catch >1%
	Hitting	% of cows hit or poked with moving aids	0: no hitting 1: occasional/few hit 2: frequent hit/poke (>10% cows)
	Noise of handlers Noise of equipment/machinery Dogs noise around the yard	Evaluate noise of handlers, noise of equipment (race or chute gate) and machinery (generators etc.) and observe the presence and noise frequency of dogs around the yard	0: no noise/dogs 1: minor audible/occasional noise 2: unpleasantly/ persistent noisy handlers/equip/dogs
	Health checks	Frequency of health checks on cows during pregnancy	0: daily 1: once-twice/week 2: less than weekly
	Yard flow of cattle	Yard flow of cattle influenced by handling facilities design/quality	0: very effective cattle flow 1: effective but with flaws 2: difficult flow
	Yarding frequency	Frequency of yarding of cows per year	0: >4 times 1: 3–4 times 2: 0–2 times

2.3. Data Analysis

Data were analysed using SPSS version 24 (IBM). Descriptive statistics for continuous measures were used to capture central tendency (mean and median), dispersion of data (standard deviation), range (minimum and maximum), variance and percentiles. Qualitative methods were used to analyse the frequency of ordinal measures. The Shapiro–Wilk test was used to test for normality, and log10(n + 1) was used to transform those variables that were not normally distributed. An alternative approach to applying pre-determined value judgements is to determine the threshold from the data, so that an arbitrary 15% of farms were considered poor and 50% good derived thresholds were determined based on z scores to result in approximately 50% of farms falling into a good welfare band ('green') and 15% of farms into a poor welfare band ('red'). Farms not in the green or red band were classified as orange. The arbitrary 15% was chosen to fit with the '15% rule' where animals (in this case farms) below this point are considered as worse-off in terms of animal welfare compromise [12,18]. Farms were not given an 'overall' welfare score [9]. For each non-categorical measure, the derived red threshold and the imposed score 2 threshold were then compared by dividing the derived threshold by the imposed threshold.

3. Results

3.1. Welfare Assessments Summary Statistics

Consolidated data for the welfare observations made using the final protocol are shown in Tables 5 and 6.

Table 5. Descriptive statistics (from 25 Waikato beef farms) for measures that were included in the final protocol and which were recorded as percentage of observed animals.

Welfare Principles	Measures	Mean (%)	Min (%)	Max (%)	Percentiles		
					25	50	75
Good Feeding	Thin cows	10.7	0	61	2.6	5.7	10.0
	Poor rumen fill	30.6	0	68	15.5	29.9	45.7
Good Environment	Short tail	4.2	0	21	0.6	3.0	6.0
	Dirtiness	21.3	4	50	10.7	20.6	29.4
	Watery faeces	39.6	15	87	24.0	35.7	48.5
Good Health	Swelling	0.7	0	5	0.0	0.0	1.1
	Hair loss	0.1	0	1	0.0	0.0	0.0
	Abrasion	0.1	0	2	0.0	0.0	0.0
	Lameness	2.7	0	12	0.5	1.5	3.6
	Blindness	0.4	0	4	0.0	0.0	0.0
	Ocular discharge	1.5	0	8	0.0	0.0	3.2
	Nasal discharge	1.2	0	13	0.0	0.0	1.3
	Accidental deaths	0.6	0	2	0.0	0.4	1.2
	Deaths from health	2.0	0	7	0.9	1.6	2.9
	Culling for health	1.2	0	6	0.0	0.8	2.0
Stockpersonship	Fearful/Agitate	2.7	0	7	1.3	2.3	4.1
	Fall/lie	0.9	0	8	0.0	0.0	0.8
	Stumble	1.6	0	21	0.0	0.0	1.7
	Run exit	13.0	0	51	2.6	7.8	15.1

Table 6. Observed frequencies from the 25 Waikato beef farms for handling/stockpersonship categorical measures. See Table 4 for description of assessments used to create these figures.

Measure	Categories and Number of Farms in Each Category		
Mis-catch	No mis-catch 18	<1% of cows mis-caught 4	>1% of cows 3
Hitting	No hitting 18	Few cows hit 4	>10% hit (frequent hit) 3
Noise of handlers	No noise 4	Minor audible noise 18	Noisy handlers 3
Noise of Equipment/machinery	No noise 9	Minor audible noise 6	Very noisy 10
Dogs noise around the yard	No dogs around yard 7	Quiet dogs 8	Noisy dogs 10
Health checks	Daily inspection 11	Once or twice a week 9	Longer than once/week 5
Yarding frequency	>4 times/year 5	Between 3–4 times/year 20	Below 3 times/year 0
Yard design flow	Effective 13	Minor problems 7	Significant problems 5

For painful management procedures, castration was performed with rubber rings on 20 of the 25 farms (mode and median two months of age; range 1–4 months). Calves were disbudded only on two farms, at three and four months respectively. Ear-tagging was performed without the use of anaesthesia on all farms at median and mode of two months. None of the farms reported high levels of diseases in the last 12 months (based on 2017 herd size). Of the diseases reported, only lameness (which was reported on 18 out of 25 farms), abortion (13 out of 25 farms), and dystocia (21 out of 25 farms) had a mean recorded incidence across all farms of greater than 1% (1.1%, 1.5%, and 2.6%, respectively). On individual farms, the highest recorded incidences of lameness, abortion and dystocia per herd were 4.1% (five out of 155 cattle), 8.8% (20 out of 226 and seven out of 80 cows) and 16.7% (two out of 12 cows), respectively. The mean incidence of all other diseases was < 0.5%, and of those diseases, only eye cancer (three out of 125; 2.4%), theileriosis (10 out of 470; 2.1%), vaginal prolapse (one out of 35; 2.9%), and Mg deficiency (10 out of 470; 2.1%) had maximum recorded incidences in an individual herd of >2%. (See Appendix A for the main diseases recorded as per farmers' recollection in the questionnaire assessment at the 25 Waikato beef farms).

3.2. Categorisation of Measures

Categorised observational data are illustrated in Figure 1 (measures of feeding and environmental factors), Figure 2 (health determinations and frequencies of painful procedures), and Figure 3 (stockpersonship scores).

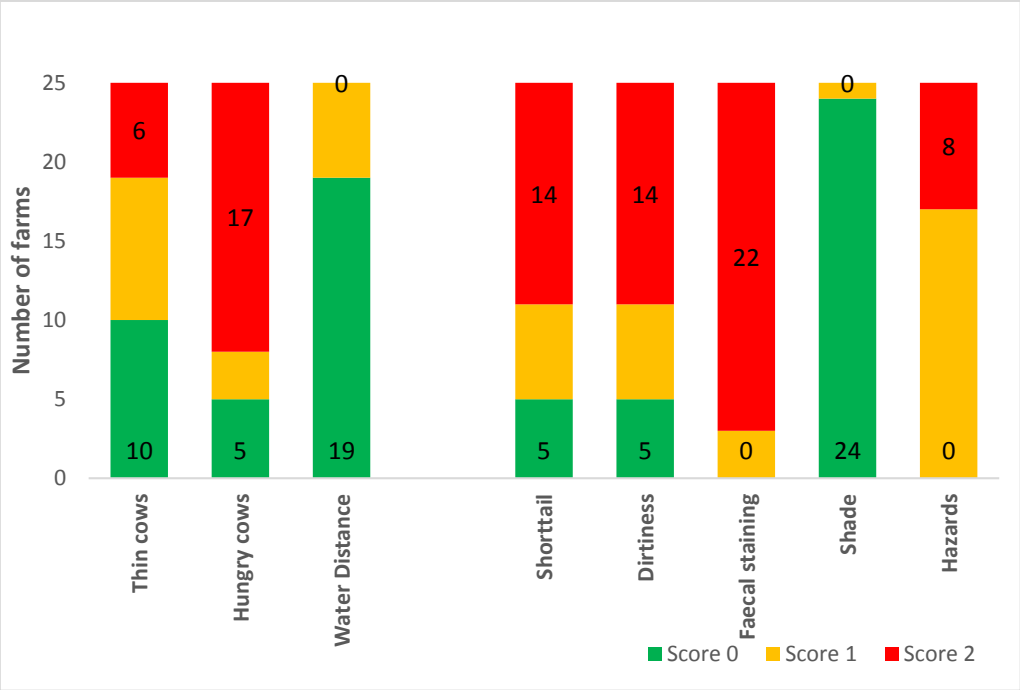

Figure 1. Frequency analysis of categorised good feeding and environment measures on the 25 Waikato beef farms, for which scores were assigned as either 0: good, 1: marginal, or 2: poor welfare. See Table 2 for further information on how each measure was categorised into a score of 0, 1 or 2.

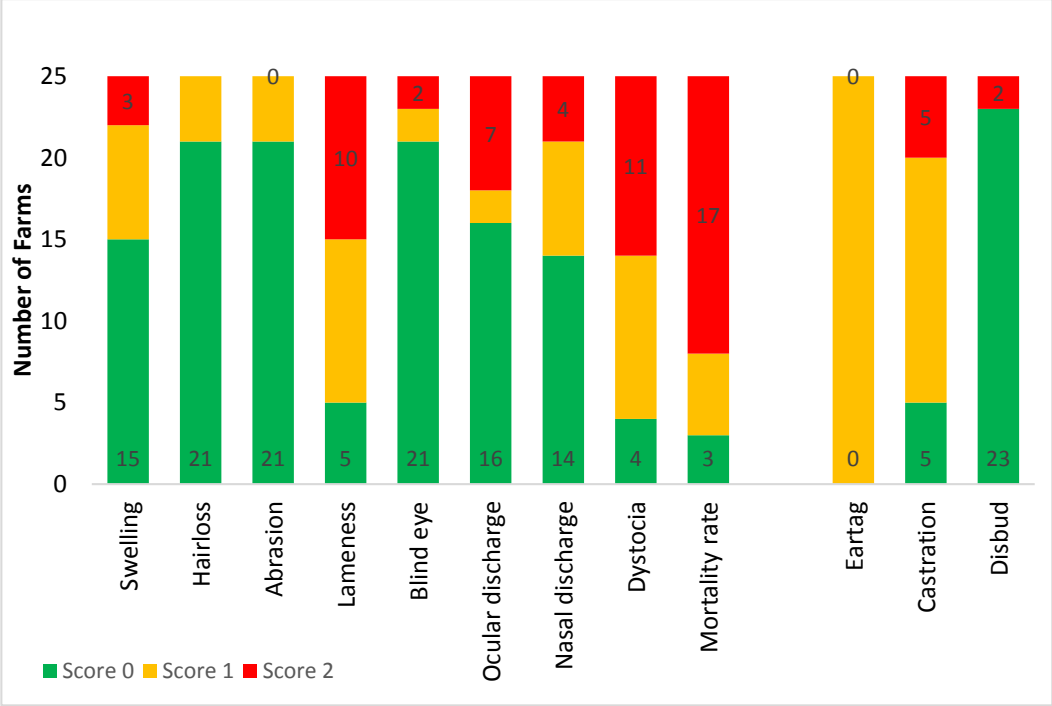

Figure 2. Frequency analysis of categorised good health measures on the 25 Waikato beef farms, for which scores were assigned as either 0: good, 1: marginal, or 2: poor welfare. See Table 3 for further information on how each measure was categorised into a score of 0, 1 or 2.

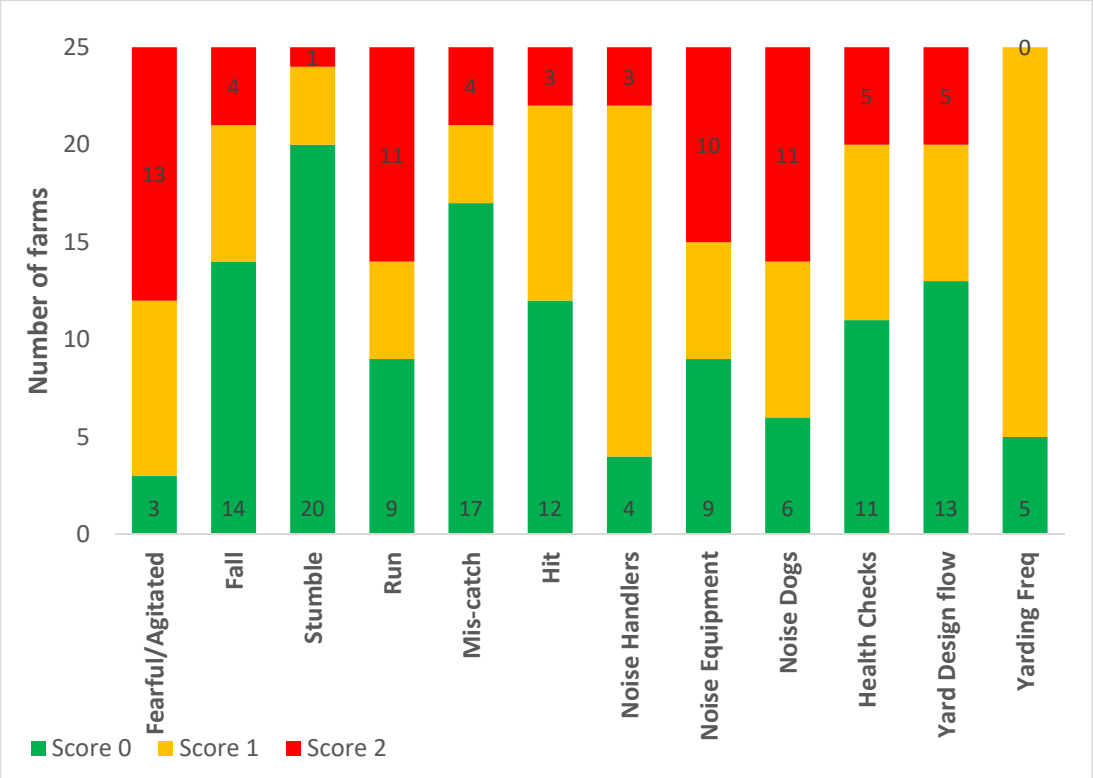

Figure 3. Frequency analysis of categorised appropriate stockpersonship measures on the 25 Waikato beef farms, for which scores were assigned as either 0: good, 1: marginal, or 2: poor welfare. See Table 2 for further information on how each measure was categorised into a score of 0, 1 or 2.

Most farms (17 out of 25) scored poorly for rumen fill, whereas no farms had poor welfare for distance to water. Poor welfare scores for short tails and dirtiness were reported at 14 out of 25 farms, whilst 22 out of 25 farms had faecal soiling ('diarrhoea'). All farms except one obtained good welfare score for shade and no farms had a good score for environmental hazards. Most farms scored poorly for mortality rate followed by lameness. No farm was scored as having poor welfare associated with hair loss or abrasions. Only two farms disbudded calves and both did so after two months, which gave a poor welfare score. The rest had calves that were genetically polled. A poor welfare score was noted at five out of 25 farms for castration, and all farms received a marginal welfare score for ear tagging (tagging without local anaesthesia). No farm scored poorly for mis-catching, hitting cows and handling noise whereas 10 and 11 out of 25 farms were placed in category 2, for equipment noise and dog noise, respectively. Most yarding frequency scores were in category 1, and cattle were generally fearful and agitated in the yards.

The accumulated welfare score according to the 3-point scores for each farm is shown in Figure 4, with farms ordered from most poor scores to fewest (range 14–3). The highest number of good scores was 22 out of 32 and lowest was six. For marginal scores, the range was 6–17.

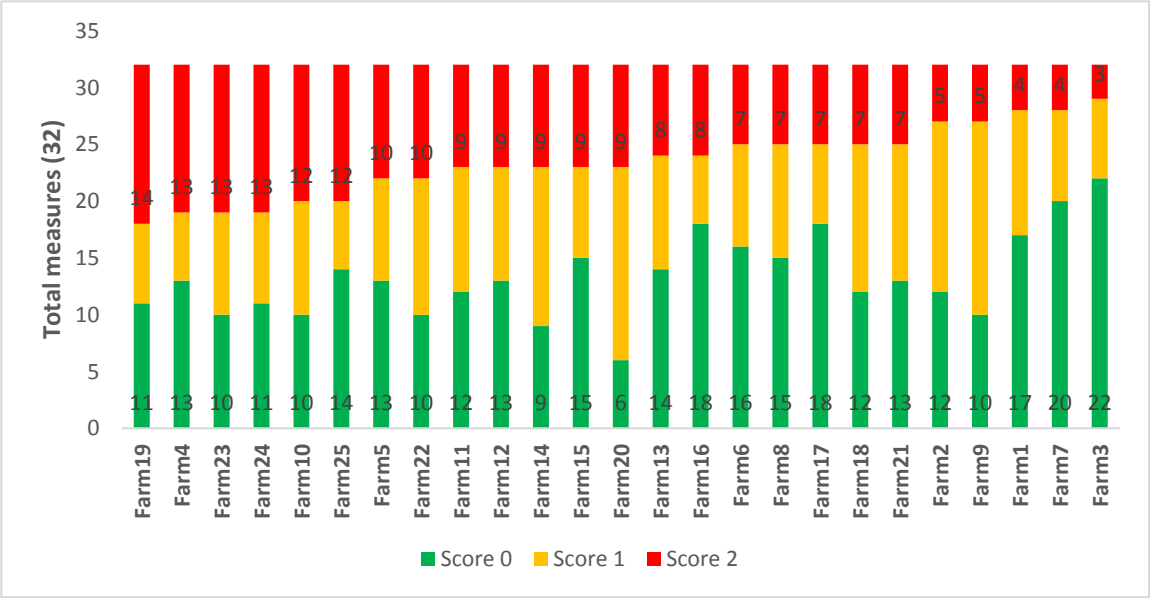

Figure 4. Accumulated categorised scores of the 32 measures according to the 3-point scores for the 25 Waikato beef farms, sorted from the most to the fewest score 2.

3.3. Refined Thresholds

Derived threshold values are shown in Table 7. Measures that were normally distributed were hungry cows, dirtiness, diarrhoea (faecal soiling), mortality rate and fearful/ agitated cows. Seven measures had a derived red threshold that was >2 times the threshold imposed by categorisation: short tail, diarrhoea, lameness, dystocia, mortality rate, fearful/ agitated, and cows running on exit.

Table 7. Normally distributed and log-transformed traits indicating multiples of the standard deviation with a 15% cut-off thresholds at the 25 Waikato beef farms showing thresholds of 50% of farms in "green" (good welfare), those in orange and 15% of farms in the "red" (poor welfare).

Welfare Principles	Measures	Mean	Orange Thresholds	Red Threshold (for the Bottom 15% Farms)	Thresholds Imposed by Categorisation for Poor Welfare Score (Score 2)	Ratio of Red Threshold Over the Imposed Categorisation Value
Feeding	* % thin cows	10.7	5.3	19.3	>10%	1.9
	% hungry cows	30.6	19.1	75.3	>50%	1.5
Environment	* Short tail	4.2	2.6	8.1	>2%	**4.1**
	Dirtiness	21.3	17.5	36.1	>20%	1.8
	Diarrhoea	39.6	35.6	58.6	>20%	**2.9**
Health	* Swelling	0.7	0.4	1.5	>2%	0.8
	* Hair loss	0.1	0.1	0.4	>2%	0.2
	* Abrasion	0.1	0.1	0.4	>2%	0.2
	* Lameness	2.7	1.7	5.0	>2%	**2.5**
	* Blindness	0.4	0.2	0.9	>2%	0.5
	* Ocular discharge	1.5	0.9	3.1	>2%	1.6
	* Nasal discharge	1.2	0.6	2.2	>2%	1.1
	Dystocia	2.6	1.8	4.9	>2%	**2.5**
	Mortality rate	3.9	3.3	6.4	>2%	**3.2**
Stockpersonship	Fearful/Agitated	2.7	2.2	4.9	>2%	**2.5**
	* Fall	0.9	0.5	1.8	>2%	0.9
	* Stumble	1.6	0.7	2.8	>5%	0.6
	* Run	13.0	7.7	24.4	>10%	**2.4**

* Normally distributed measures. Figures emphasized in bold/red font are measures where the ratio of derived threshold: imposed threshold was >2.

4. Discussion

Kaurivi [21] identified 32 measures of animal welfare that were feasible to assess during routine yarding of pasture-based beef cattle. This study categorised these animal welfare measures into scores that indicate a threshold of acceptable and unacceptable welfare, to provide guidance for when intervention was needed [8]. The thresholds that have been imposed or derived in this study are based on individual measures, rather than an aggregated 'score' for each farm [9].

Cattle were in good body condition at the time of assessment, with an average of 10.7% of cows having a BCS ≤ 4. The range of thin cows across farms was wide (0–60.7%). The imposed threshold for categorisation as poor welfare was 10% of the herd, whilst the derived threshold, based upon the poorest 15% of farms, was 19% of thin cows. In terms of identifying the need for nutritional intervention, the lower threshold seemed more appropriate, even though cows' productivity is not impaired in the short term, at BCS 4 [23]. Other studies have suggested that a threshold for the proportion of thin cows that is deemed unacceptable could be set at 5–15% [24] and 6.7% [16]. The BCS data in the present study were largely correlated with rumen fill score (RFS) data, although, whilst a poor RFS can reflect long-term underfeeding it can also occur during short term feed deprivation [25], such as when cows are drafted a day before pregnancy testing. Hence, the derived threshold of ≤19% of the herd with a low RFS may not be more appropriate for the detection of poor nutrition than the original imposed figure of 50%.

Assessing the dirtiness of cattle was both difficult and unrewarding. Kaurivi [21] concluded that all sites of dirt (tail, hindquarters and flank) should be amalgamated to provide a single 'dirtiness' score. They also noted the confounding of faecal staining of the tail head as a sign of infectious/parasitic diarrhoea with its very common occurrence in normal cattle that are being fed lush pasture. Hence, whilst in housed cattle, dirtiness and diarrhoea are rightly interpreted as signs of poor housing and/or health control, these interpretations may not be relevant to the study population. Rather, dirtiness and diarrhoea probably reflect the degree of muddiness of the paddocks and/or the lushness of the pasture which, in turn, are largely dependent on the season of the year. A point may be reached when the level of dirt in a pasture-based system does represents a welfare compromise [26], so creating standards for interpretation of dirtiness is therefore difficult [9,27]. The interpretation of dirtiness as a measure of welfare might require the setting of seasonal thresholds, e.g., finding dirty cows in January (summer lush pasture) is different to finding dirty cows in July (winter muddy terrain). Taken together, such considerations suggest that the derived threshold for red score of 36% of the herd being dirty seems more appropriate than the original imposed threshold of 20%. Likewise, the ubiquitousness of faecal staining due to the fluid nature of the cows' normal faeces means that the derived threshold of close to 60% is probably more realistic than the imposed threshold of 20%. It could in fact be argued that, whatever threshold is used for faecal staining, it may represent the imposition of a characterisation of a trait that is poorly related to welfare compromise; rather, it is merely a sign of cows having plenty of grass. On the other hand, faecal soiling may contribute to a risk of disease [25], so perhaps adopting the re-categorised threshold of >60% (or 50%) may indeed provide a meaningful measure of welfare. Perhaps a qualitative determination may also need to be made of whether watery faeces are simply the result of the pasture diet or whether some identifiable disease process is causing abnormally loose faeces. Finally, there are economic implications associated with dirtiness in cases of cattle destined for slaughter [28] so, again, the scoring that is imposed might vary with the circumstances and/or purpose for which it is being undertaken.

Assessing the incidence of short tails may help to determine whether faeces on tails does, or does not, represent compromised welfare, given that the aetiology of short tails is, in most cases, constriction of blood supply to the tails by hardened faecal rings. Short tails were present in 4.6% of cows, which compares unfavourably with the imposed standard of >2% of affected cows representing poor welfare. It seems reasonable to assume that the condition is associated with a significant level of pain to the cow, probably like that associated with tail docking with a rubber ring [29]. This is a good example of setting thresholds based on what should be achieved on-farm and not based on the status

quo, and the envisioned scale could be used as a tool to caution farmers about the state of tail soiling, so that remedial actions can be taken to curb or prevent the occurrence of this condition (i.e., washing off the dirt or clearing the hardened faecal balls before the tail sloughs or breaks off).

No farm in extensive hill or high-country in New Zealand is without any risk of hazards (i.e., steep hills, cliffs, streams, gullies and tomos). Farms (n = 8) that lost animals in tomos were considered as having major welfare compromise without considering the presence of the other hazardous terrains. Otherwise, the ranking of this measure was influenced by the prevailing conditions of the beef farms. Potential threats of the environment can never be eliminated, thus the application of strategies to minimise or bring accidents to tolerable levels would be more achievable [9]. The issue might be controlling the access of cows to these hazards rather than the presence of these hazards, so linking welfare compromise to good environmental management, such as preventing access to hazards, could provide a useful focus for reducing accidental death.

For most health-related measures, the welfare impacts were small on most farms. The exceptions were lameness, dystocia and mortality rate, for which the derived threshold was more than twice the imposed threshold. Importantly, whilst relatively low incidences of these conditions probably have relatively limited impact upon herd productivity per se, they have a very significant impact upon the individual cow. Thus, lameness is a critical welfare compromise indicator, as it is both a painful condition, and affects productivity [30,31]. The mean incidence of lameness in this survey was 2.7% (range 0–11.5%), but the incidence on the worst 15% of farms (derived threshold) was ≥4.8%, indicating that it has the potential to be a significant welfare issue. Consequently, the original imposed threshold of 2% is probably more appropriate than the derived threshold: particularly as the lower threshold would have the benefit of increasing the awareness of farmers to the need for intervention [31]. Whether it is appropriate to use a single 'catch all' criterion for lameness might be questioned [1,11]. For example, should lameness be differentiated into severe (non-weight-bearing) and non-severe lameness, with thresholds of 1% and 3% of the herd, respectively. On the other hand, in the circumstances in which observations were made in the present study, it was probably more accurate to use the catch all than to try to differentiate between levels of degrees of lameness. Dystocia similarly has a very significant impact upon the welfare of animals affected (and upon calves born/stillborn as a result of dystocia), and, at high incidences, can markedly impair the productivity of the farm [5]. Although the mean incidence, 2.6%, was close to the imposed limit, the derived limit was 4.9%, which indicates that dystocia is probably a relatively common trait on the beef farms. Again, given the significance of the condition for affected individuals, the 2% threshold seems more appropriate than the derived 5% limit. A threshold of 2% could aid in benchmarking for monitoring and correction of this condition. Finally, the average mortality rate was 3.9%, which is rather higher than the New Zealand industry standard for beef cattle (2–3% [32]). Similar figures have also been reported by international studies of pasture-based cow-calf units [33–35]. The threshold for the worst 15% of farms was 6.3%: given that mortality represents the total economic loss of the cow, mortality has the potential to be both common and economically serious on beef farms. Hickson [36] found a death rate of 2.1% per year in New Zealand beef herds, which is close to the imposed 2% threshold of the present study. Therefore, the 2% categorisation threshold appears to be a rational figure to trigger investigation of underlying contributing factors to reduce mortality rate.

The threshold for the ages above which performing painful management procedures (castration, removal of the horn bud) were considered as unacceptable welfare were set at >2 months. New regulations in New Zealand prohibit disbudding/dehorning without local anaesthesia, whilst the New Zealand Veterinary Association [37] advocates that these procedures should be undertaken at 2–6 weeks of age, and in conjunction with the use of analgesia [38]. For castration, this painful procedure can be mitigated using analgesia [39] and animals which are castrated early cope and recover faster than if this is done at an older age [39,40]. Ear notching is more painful than tagging, but the adverse effects can be mitigated using vapo-coolant [41] which provides a local cooling of the skin and

thereby reduces pain perception. Hence, performing notching without the use of any anaesthetic was deemed to be a significant welfare compromise.

Stockpersonship was categorised using ordinal measures related to the behaviour of the cattle in the yards and race, and categorical measures based upon observations of the stock handling. The ordinal measures 'fearful/agitated' and 'run' had derived thresholds that were more than twice the imposed threshold. Running was a common behaviour, for which the derived threshold (23.4%) was much higher than the imposed threshold (10%). Stumbling and falling were less common, with the derived and imposed thresholds being very similar at ~2%. Many of the stumbling cattle appeared to have been merely correcting their stance and hence might not warrant a stricter threshold. However, if extensiveness per se is the underlying cause, strategies such as more yarding events could be implemented to ascertain and prevent the welfare compromise. On the other hand, yarding is itself associated with stresses upon the cattle, so there are benefits to avoiding yarding cattle more often than is essential. In the present study, most farms (20/25) yarded the cattle 3–4 times per year, with the remainder of the farms yarding 5–6 times. A similar study of California ranches recorded an average of 3.4 yardings per year [42], but with a significant reduction in cattle vocalisation, stumbles and hitting with additional yardings per year [43]. This indicates an association of infrequent yarding and handling with difficult handling, restraining and fearfulness [44,45]. Concern around the infrequent yarding of cattle in extensive beef systems is supported by the finding in our study (Kaurivi Part 1) that yarding per year was correlated with fearful behaviour ($\varrho = 0.50$).

In the present study, the derived threshold for fearful/agitated behaviour was 4.9%, versus the imposed threshold of 2%. It is likely that the commonness of fearful/agitated behaviour may primarily be an indication of the lack of familiarity of extensively managed cattle with yarding and handling; as also found by Simon [43]. Taken together, it appears that the benefits of more frequent yarding (>4 times per year, for example) may be more compatible with acceptable welfare when cows are handled than yarding <3 times per year. Fortunately, the proportion of cows that were mis-caught during restraint when gates were closed into or within the race was low: even setting the threshold at 1% of cows mis-caught, only 4/25 farms exceeded that threshold. One explanation is that beef farmers do not routinely use a head bail for mass management procedures including pregnancy diagnosis (except on 8 out of 25 farms where the first cow was caught in the single-file race). Another explanation for this could be awareness of welfare compromise of this practice at New Zealand beef farms; a lower risk of mis-catching was reported if farmers undergo training in cattle handling techniques [43].

The frequency of health checks of cows by farmers during winter/pregnancy was based on the findings at the 25 beef farms, where health check frequency was regular with 20/25 farms inspecting at an interval of ≤1 week and 11/25 farms doing daily checks. Frequent health checks are expected to coincide with a good health status [43] and low mortality [46]. The limitation of health checks on extensive systems is that it is an overall inspection of cows at pasture, with rare close inspection to detect early health problems and injuries [47]. Thus, just recording health checks, without consideration of what health checks entailed while looking at individual cows versus the whole herd might influence the findings and hence categorisation of this measure [48].

This study was undertaken in only one region (Waikato) of New Zealand, thus the derived thresholds may reflect beef farming in that region rather than across the country. We concluded in our previous study that before the protocol was used widely it needed further testing on more farms across New Zealand with more assessors. This process should also include the calculation of derived thresholds for each of the measures in the protocol where data were collected on a continuous basis. These thresholds should, ideally, be calculated at a regional rather than a national level, so that, if present, differences between regions, can be highlighted. Only once this process is completed can we finalise the categorisation process started in this study. This finalisation process should involve beef farmers, beef exporters, animal welfare experts, veterinarians, consumers, and ideally, animal welfare advocacy groups.

5. Conclusions

This study has demonstrated the feasibility of developing standards for a welfare assessment protocol of cow-calf beef farms in New Zealand. Initial welfare thresholds were based upon the authors' perception of acceptable welfare standards and the literature, with subsequent derivation of thresholds based upon the poorest 15% and best 50% of farms for each category. Imposed and derived thresholds were compared to see which was the most appropriate to the range of observations and the significance of the welfare implications of the measure. Some of the derived thresholds were much higher than those originally imposed, with lameness, dystocia, and mortality rate being between two and three times higher than the imposed threshold. Nonetheless, in view of the significance of these conditions for the welfare of affected cattle, the original threshold appeared the more appropriate. The proportion of cows with low BCS or RFS evoked similar considerations. On the other hand, measures of dirtiness and faecal staining were more common, but less significant than originally envisaged, so the derived thresholds appeared more appropriate. Similarly, measures of cow behaviour during handling were above expectations. Again, due to the infrequent yardings that these animals experienced, the derived threshold appeared to be the more appropriate. Taken together, these thresholds provide indicators to farmers and farm advisors regarding the levels at which intervention and remediation is required. Findings during the assessments that were supported by national and international standards also rationalised the categorisation of measures such as yarding frequency/year and health checks frequency. Further data are required from more assessments across the country in order to finalise the categorisation process started in this study.

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Appendix A

Table A1. Main diseases (per percentage) recorded as per farmers' recollection in the questionnaire assessment at the 25 Waikato beef farms.

Farms	Total Cattle Herds	Mated Cows	Wooden Tongue	Lameness	Bovine Viral Diarrhoea	Theileriosis	Mg Deficiency	Liver Flukes	Warts	Cancer Eye/Problem	Milk Fever	Skin Eczema	Vaginal Prolapse	Dystocia	Abortion
Farm 1	850	160	0.6	0	0	0	0	0.7	1.2	0	0	0	0	0	0
Farm 2	2040	489	0	0	0	0	0	0	0.3	0	0	0	0.2	0.4	0
Farm 3	189	35	0	0	0	0.5	0	0.5	0	0.5	0	0	2.9	2.9	0
Farm 4	70	100	1.4	2.9	0	0	0	0	0	0	0	0	0	0	0
Farm 5	293	80	0.3	0.7	0	0	0	0	0	0.3	0	0.3	0	3.8	0
Farm 6	468	328	0.4	3	0	0	0	0	0	1.3	0	0	0	1.8	0.6
Farm 7	55	12	0	1.8	0	0	0	0	0	0	0	0	0	16.7	0
Farm 8	470	300	0	0.4	0	2.1	2.1	0	0	0	0	0	0	0.3	0
Farm 9	580	320	0	0.9	0	0	0	0	0	0.3	0	0	0	1.3	0.9
Farm 10	241	156	0	2.1	0	0	0	0	0	0	0	0	0	1.9	0.6
Farm 11	125	124	0	0	0.8	0	0	0	0	2.4	0	0	0.8	0.8	0.8
Farm 12	350	122	0	0.3	0	0	0	0	0	0	0	0	0.8	2.5	0
Farm 13	181	153	0.6	0.6	0	0	0	0	0	1.1	0	0	0	2.6	0
Farm 14	554	243	0.2	0	0	0	0	0	0	0	0	0.2	0	4.1	0
Farm 15	167	114	0	0	0	0	0	0	0	0	0.6	0	0	3.5	0
Farm 16	113	28	0	0.9	0	0	0	0	0	1.8	0	0	0	0	3.6
Farm 17	113	59	0	2.7	0	0	0	0	0	0	0	0	0	1.7	0
Farm 18	900	273	0	0.3	0	0	0	0	0	0	0.1	0	0	5.5	1.8
Farm 19	185	80	0	0	0	1.1	0	0	0	0	0	0	0	5.0	8.8
Farm 20	799	400	0.1	1.4	0	0	0	0	0	0.1	0	0.5	0	2.5	4.8
Farm 21	554	140	0	0.5	0	0	0	0	0	0.2	0	0	0	0.7	0.7
Farm 22	465	217	0	1.5	0	0	0	0	0	0	0	0	0.9	0	2.3
Farm 23	1585	412	0	0.4	0	0	0.4	0	0	0	0	0	0	1.5	1.7
Farm 24	244	226	0	2	0	0	0	0	0	0	0	0	0	2.2	8.8
Farm 25	122	66	1.6	4.1	0	0	0	0	0	0.8	0	0	0	4.5	1.5
Sum	11713	4637.0	5.2	26.5	0.8	3.7	2.5	1.2	1.5	8.8	0.7	1.0	5.7	66.1	37.0
Average	468.52	185.5	0.2	1.1	0.0	0.1	0.1	0.0	0.1	0.4	0.0	0.0	0.2	2.6	1.5
Max	2040	489.0	1.6	4.1	0.8	2.1	2.1	0.7	1.2	2.4	0.6	0.5	2.9	16.7	8.8
Stdev	468.3531	128.0	0.4	1.1	0.2	0.5	0.4	0.2	0.2	0.6	0.1	0.1	0.6	3.3	2.5

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STATEMENT OF CONTRIBUTION
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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:	**Yolande Baby Kaurivi**
Name/title of Primary Supervisor:	**Prof Richard Laven**
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In which Chapter is the Manuscript /Published work:	**Chapter 3.3**
Please indicate: □ The percentage of the manuscript/Published Work that was contributed by the candidate:	**70%**
and Describe the contribution that the candidate has made to the Manuscript/Published Work:	
Main researcher who did the project proposal and data collection, analysis and main write up.	
Candidate's Signature:	
Date:	**10 December 2020**
Primary Supervisor's Signature:	
Date:	**10 December 2020**

DRC 16

Chapter 4 NAMIBIA ANIMAL WELFARE ASSESSMENT PROTOCOL DEVELOPMENT FOR COW-CALF SYSTEMS

Preface: **This chapter consist of 3 submitted papers that build on each other**.

Chapter 4.1: To develop an animal welfare assessment protocol for assessment of extensive semi-arid cow-calf systems in Namibia, the feasibility of adapting a New Zealand beef cow welfare assessment protocol was tested on one semi-commercial village on 5 herds. The protocol provided a good basis for welfare assessment, but additional measures and modifications were needed to reflect specific challenges of the Namibian system, resulting in a protocol of 40 achievable measures.

Chapter 4.2. After testing the applicability of selected measures at one farm, the protocol needed full validation through widespread testing across the range of beef production systems used in Namibia. The aim was to apply this protocol and make a comparison between farm production system's effect on the welfare of beef cows across 55 cow–calf herds (17 commercial, 20 semi-commercial and 18 communal) during routine pregnancy testing, farm resource evaluation and a questionnaire guided interview.

Chapter 4.3: The application of the protocol on the farms showed that categorisation of identified animal welfare measures into scores that indicate a threshold of acceptable and non-acceptable welfare standards was necessary. The final protocol was refined after categorisation and scoring of welfare assessment measures based on the New Zealand thresholds and authors opinion of good welfare. These thresholds provide indicators to farmers and farm advisors regarding the levels at which intervention and remediation is required for use on extensive semi-arid cow–calf farms under Namibian conditions.

4.1 Assessing Extensive Cow-Calf Welfare in Namibia: Feasibility of adapting a New Zealand beef cow welfare assessment protocol

This paper has been presented in the journal format and style. The paper has since the thesis submission been reviewed and was acceptance for publication (May 2021; see Appendix 3 of the additional thesis appendices for the accepted manuscript version). This is the first chapter in the series of developing an animal welfare assessment protocol for extensive beef systems in Namibia. This study reports on the feasibility of adapting a New Zealand beef cow welfare assessment protocol on one semi-commercial village of five herds in an extensive semi-arid region of Namibia. It was concluded that the protocol needed additional measures and modifications to reflect specific challenges of the Namibian system, resulting in a protocol of 40 measures. The paper describes a discussion of the comparison of measure suitable for farm assessment on New Zealand and Namibia. This included the need to add additional country specific measures such as the varied reasons for mortality, use of electric prodders (which reflects stockpersonship), the number of brands on the animals, and horn length.

Assessing Extensive Cow-Calf Welfare in Namibia: Feasibility of adapting a New Zealand beef cow welfare assessment protocol

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Assessing Extensive Beef Cow-Calf Welfare in Namibia: Feasibility of adapting a New Zealand beef cow welfare assessment protocol

Namibia needs a robust welfare assessment protocol for beef cattle for purposes of benchmarking and trade. As there is presently no such protocol, one was developed for Namibian conditions based on one designed for extensive beef cattle in New Zealand. The original protocol had been derived from the Welfare Quality and the UC Davis Cow-Calf protocols, with additional criteria relevant to extensively managed beef cattle. The modified protocol was evaluated in a semi-commercial farming village in Namibia during the pregnancy testing of 141 cows from 5 herds of different households. Animal- and stockperson-based measures were assessed directly, cows were observed at grazing, and a questionnaire-guided interview was conducted. The protocol provided a good basis for welfare assessment, but additional measures and modifications were needed to reflect specific challenges of the Namibian system. Specifically, these were the effects of recurrent drought, predation, plant poisoning, external parasites, walking long distances to water and grazing, compulsory hot-iron branding, extraneous cattle marking, and variable standards of handling facilities. The protocol was modified to incorporate these changes, resulting in a total of 40 measures. It now needs full validation through widespread testing across the range of beef production systems used in Namibia.

Keywords: welfare assessment, extensive beef cows, Namibia, New Zealand

Introduction

The Namibian economy is heavily dependent on the agriculture sector which contributes around 7.1% of the GDP, of which 70% represents the output of the livestock sector. The beef industry is important not only in terms of GDP (1-2%) but also in terms of employment (~6% of total employment) (Olbrich, Quaas, & Baumgartner, 2016). Much of the value of beef to the Namibian economy is derived from ensuring that beef production is of a sufficiently high standard to be exported to high value markets such as Europe and North America (MAWF, 2017; Meat Board,

2019). The development of the Farm Assured Namibian (FAN) Meat scheme has provided assurance to consumers that Namibian meat for export is healthy, safe, of good quality, and traceable according to standards laid down by its trading partners ((FAN Meat, 2019). However, providing assurance for animal welfare remains a challenge, as the FAN Meat scheme is used on a voluntary basis, the country is in the process of updating animal welfare legislation (last updated in 1971), and there is no routine assessment of beef cattle welfare(Meat Board, 2019).

Namibia could adapt welfare protocols created for beef systems in developed countries. But animal welfare assessment protocols are systems-based (Mellor & Webster, 2014; Winckler, 2018) and it is impractical to simply impose a protocol developed for one system on another (Hernández et al., 2017a; Laven & Fabian, 2016). Moreover, most of the existing welfare assessment protocols are focused on intensive, rather than extensive, beef production systems. Because of the unique beef production systems in Namibia, with its preponderance of semi-commercial and communal village farms in semi-arid rangeland systems, a specific assessment protocol is needed for the country.

A welfare assessment protocol for extensive pasture-based beef cows in New Zealand, which used measures from Welfare Quality (Welfare Quality, 2009) and the University of California (UC Davis) Cow-Calf protocol (UC Davis, 2017), with additional measures specific to New Zealand was recently created (Kaurivi et al, 2019; 2020a,b) . The aim of the current study was to adapt this New Zealand protocol for use in extensively semi-arid rangeland-based beef cow systems in Namibia. This aim was achieved through the application of measures on 5 herds in one semi-commercial village farm and making judgements as to whether the measures the New Zealand protocol were suitable for inclusion, suitable after modification or not suitable for

inclusion, and by identifying additional measures that were not included in the New Zealand protocol but which were required on Namibian beef farms.

Material and Methods

Location

The protocol developed by Kaurivi et al., (2020a, b) for use in beef herds in New Zealand was tested in a semi-commercial farming village in Namibia. Semi-commercial villages are communal livestock farming setups, in which multiple families own livestock but use the same communal land, with common grazing and water supply points (Mendelsohn, 2008). Thus, each village has several herds that are under partially common management. The village chosen for the present study, Welgeluk, in the Otjombinde constituency, Omaheke region, eastern Namibia (~21.8 S latitude, 20.65 longitude), was situated in the foot and mouth disease (FMD) free zone of Namibia and therefore had access to high-value beef export markets. Welgeluk had ~6000 hectares of flat, sandy land with open savanna-type vegetation predominating. Annual rainfall in the area is between 100 and 300 mm (~2/3 in January-March) and temperatures range from <0°C in winter to 35°C in summer (Climate-data, 2020). At the time of the protocol testing (February 2019) there had been no significant rainfall since March 2018 and the region was under threat of drought. Farming of sheep, goats and cattle is the predominant economic activity in the village. The principal beef breed was Brahman, and their crosses with Simmental, Bonsmara, Nguni and Sanga.

Welfare assessment

The welfare assessment was undertaken by the same assessor who performed the assessments on New Zealand beef farms during the development of the protocol. Welfare observations were made during manual pregnancy testing of herds from five different households. These herds varied in

size from 50 to 200 cows. The number of cows that were pregnancy tested per herd ranged from 17 to 50 (a total of 141 cattle across all five herds). For each herd, the assessor took a general view of the cows in holding pens, observing health issues and behaviours before cows entered the race. The cows were observed in the race during pregnancy testing, except for the one herd which did not have a race. On that herd, cows were captured with ropes (as if for milking) and pregnancy tested whilst standing in a holding pen. A questionnaire-guided interview and farm resource visit captured health and management of cattle over the previous 12 months. The measures and methods of assessment are shown in Table 1. The visits typically lasted 2 hours per 20 cows in the herd.

Table 1: Measures developed for use in New Zealand beef herds (Kaurivi et al., 2020a) and tested in Namibia, and their methods of assessment

Measures assessed	**Method of assessment**
Body condition score (BCS), rumen fill score (RFS), integument alterations (abrasions, swelling, hair loss), dirtiness of cows, diarrhoea/faecal soiling, nasal discharge, ocular discharge	Observation next to the race or in holding pens where there was no race.
Lameness, exit speed (running or walking), stumble or fall, mis-catch, fearful/agitated, hitting cattle with moving aids	Stockpersonship observation in race or on exit from race or holding pen.
Noise of handlers, noise of equipment /machinery, presence/noise of dogs at yards	Subjective noise evaluation around the yard.
Handling facility design and quality, handling effectiveness	Yard design assessment if it allowed easy movement of cattle from holding pens into forcing pens and the race and exiting.
Castration and dehorning/disbudding procedures, ear-tagging and notching, frequency of yarding cows/year, disease history, animal health checks frequency, dystocia, mortality (causes of deaths), vaccination, distance to water and grazing	Questionnaire guided interview with the farm manager to assess health and management of cattle in the last 12 months.
Access and type of water supply, distance to water points, availability of shade in paddocks, feed/pasture condition, absence of hazardous objects/terrain, overall body condition	Farm observation and cattle in paddocks observation.

Additional measures were identified for use in Namibia based on two criteria: i) welfare issues identified at the time of assessment that were not covered by the New Zealand protocol, that ii)

were feasible to assess either during pregnancy testing or from farmer's recollection. Data on these measures were gathered to guide their future incorporation into the protocol. Following the herd visits, the measures tested during the herd assessments were divided into (i) measures that were not relevant for the Namibia systems and which were excluded; (ii) measures that were feasible and were retained unchanged in final protocol; (iii) measures that were kept in an adjusted form in the final protocol; and (iv) additional measures that were deemed necessary for welfare assessment of Namibia beef cattle on semi-arid rangeland.

Results

Most of the measures that had previously been identified for the assessment of beef cow welfare by Kaurivi et al., (2020a) were retained in the modified protocol after it was evaluatied under Namibian conditions. Measures that were retained unchanged or which had relatively minor modifications are shown in Table 2.

Short tails, which are sloughed tails resulting from constriction of blood supply to the tails by hardened faecal rings (faecoliths), were excluded from the final protocol. This abnormality is common in pasture-based Angus cows in New Zealand but was not present in semi-arid rangeland-based cattle of Namibia, so the measure was excluded. Other types of damage to the tail, such as stumpy or broken tails, were incorporated into the protocol as 'injury' (Table 3).

An additional nine measures were incorporated into the final protocol, as shown in Table 2. These largely expanded the existing measures to address potential welfare compromises that occurred during observations. Thus, the principle of 'good feeding' was modified to include the proportion of emaciated animals and had the additional criterion of 'distance to grazing' added. Additional measures related to the presence of sharp horns (which are almost entirely absent in

New Zealand beef cattle), the presence of branding marks and wounds, and the use of hot-iron branding, tail twisting and electrical goads (prodders).

Table 2: Measures assessed as feasible for inclusion in a welfare protocol without change and those modified to suit Namibia conditions

Welfare Principle	**Welfare criteria**	**Welfare measures**	**New Zealand assessment method** Observations made in the race	**Adjustments to suit Namibia assessment** Observation in the race or in holding pens if no race
Good Feeding	Absence of hunger	Body condition score (BCS)	% thin cows in the herd, based on score ≤4/10 on 1-10 scale (Hickson, Morris, & Thomson, 2017).	% thin cows in the herd based on score 1-2.5 on the 5-point BCS scale (Hulsen, 2005; Roche, Dillon, Stockdale, Baumgard, & VanBaale, 2004) that is commonly used in Namibia. Due to the drought conditions, another score of severity was added to differentiate between thin (>2-2.5 scale) and very thin/emaciated (1-2 scale) cows.
		Rumen fill score	% of cows with hollow/empty rumen (Hulsen, 2005).	Retained
	Absence of thirst	Distance to water	Average distance to water source.	Distance to water was estimated as the distance to grazing as water points are close to yards and cattle come to drink after grazing.
Appropriate Environment	Comfort around environment	Dirtiness	"Dirtiness" recorded by averaging the three measures of dirty tails, dirty hind quarters and dirty flanks	Retained
	Ease of movement	Hazards	Identify pasture hazards (e.g. steep hills, cliffs, gullies, and sinkholes), and presence of dangerous objects/garbage, and loss of animals to such hazards.	Retained to capture prevailing hazards.
	Thermal comfort	Shade	Subjective assessment of shade in the paddocks (presence of trees, shrubs, galleys, man-made canopies) as enough or insufficient.	Retained
Good Health	Absence of injuries/ physical impairment	Abrasions, Swelling and Hair loss	% of cows with abrasions/fresh scratches or cuts, swellings and hairless patches extending >1 cm.	Retained
		Blindness	% of cows with affected eye(s) by visual assessment and/or testing with hand.	Retained
	Absence of disease and pain	Ocular discharges	% of cows with ocular discharges extending 2 cm.	Retained
		Nasal discharges	% of cows with nasal discharges extending 2 cm.	Retained
		Lameness	% of cows with unsteady gait exciting the race to paddocks or from the holding pen to the paddocks	Retained
		Diarrhoea	% of cows with diarrhoea. Watery faeces are extremely common in grass-fed in New Zealand cattle because of the high-water content of pasture, so could not be differentiated from a pathological condition and was assessed with environmental measures.	Watery faeces are not common in Namibia (especially during the dry season) and diarrhoea was retained as a health measure.
		Dystocia	% reported by famers during questionnaire guided interview.	Retained

		Mortality	% of cattle which had accidental deaths and deaths/slaughter on-farm due to disease were combined.	It was emphasised that mortality rate included deaths due to predators, toxic plants and snake bites.
	Painful management procedures	Castration, Disbudding, Ear tagging/notch	Record age and use of local anaesthetic.	Retained
Stockpersonship	Animal handling stock-personship and resource-based measures	Fearful/agitated	% cows fearful/agitated in the race/forcing pen (climbing on others	Retained
		Running	% of cows running (taking ≥2 strides at a gait faster than a trot) when cows exit from the race or holding pen to the paddocks.	Retained
		Stumbling	% of cows stumbling was defined as cows with their knees/hocks contacted the ground, on exiting the race or if moving into a group of cows include assessment from holding pen to the paddocks.	Adjusted to also include those cattle stumbling in the holding pens when being drafted for restraint in the absence of a race.
		Falling	% of cows falling (torso contacted the ground) or lying down while in the race and forcing pen were recorded.	Adjusted to also include those cattle falling in the holding pens when being drafted for restraint in the absence of a race.
		Hitting cows	Subjective categorical observation of the group rather than the individual cow: no hitting; occasional hitting (≤10% of cows); frequent hitting (>10% of cows) into the forcing pen and race.	Included proportion of cattle hit in pens when being drafted for restraining in the absence of a race.
		Mis-catching	Estimate of the proportion of cows that were mis-caught on any part of the body while gates were closed into or within the race.	If no race, available mis-catch was recorded if more than one attempt was made to capture/restrain an individual animal with ropes or if a cow did not stand still when a rope was secured around the legs.
		Noise of Handlers Noise of Equipment/ machinery	Subjective categorical assessment of handlers' noise (e.g. shouting) and equipment noise (e.g. race or chute gate) and machinery (e.g. generators etc.): 1) no noise, 2) minor less frequent audible noise or 3) repeated, unpleasantly noisy.	Retained
		Dogs noise around the yard	Categorical subjective assessment: 1) no dogs; 2) quiet dogs; 3) Noisy or repeatedly audible dogs.	Retained
		Health checks	Record frequency of health checks on cows during winter/pregnancy.	Retained
		Yarding frequency	Record frequency (number of times) of yardings per year.	Retained and emphasised cattle yardings that only involve restraining (e.g. vaccinations and tagging).
		Yard design flow	Subjective categorical assessment: 1) easy movement and flow; 2) effective movement with minor problems (e.g. more gates needed) and 3) poor flow and difficult handling (e.g. forcing pen with too many corners or gate too big).	In the absence of a race, assessment included farmers' cattle handling skills and movement: 1) effective handling (manual restraint of cows was easily achieved), 2) minor issues with flow and/or restraint/ of cattle, 3) major issues with flow and/or restraint (e.g. lengthy periods of running behind cows while trying to capture and restrain them).

Table 3: Additional measures fit for a Namibia animal welfare assessment protocol and assessment methods

Welfare principles	**Welfare criteria**	**Welfare measures**	**Assessment method (in race unless otherwise stated)**
Good feeding	Absence of hunger	Distance to grazing	The questionnaire asked how far cattle had to walk to access grazing.
Good Health	Absence of injuries	Extraneous brands/wounds/cuts	Observation of brand mark wounds (>2cm) or more than once branded/marked (i.e. stock brand, initials or name of a farmer branded) and extraneous cuts (i.e. dew-lap skin cuts)
		Long/sharp horns	Number of observed cows with sharp/long horns (> 5cm in length, sharp and forward facing to pose a risk of injuring others).
		Broken tails	Observations of abnormal tails (misaligned or broken at the tail head).
	External parasites burden	Fly burden Tick burden	Separate impression of more than 20 number of flies (i.e. horse flies) and ticks on any part of the body of a cow.
	Absence of pain (from management procedures)	Hot-iron branding	Record age of branding and use of local anaesthetic (in questionnaire).
Stockmanship	Animal handling stockpersonship	Use of electrical prodders	Estimate the proportion of cows that were prodded with an electrical goad on any part of the body while drafted or standing in the race, pens or yards.
		Tail twisting	Estimate the proportion of cows with tail twisted while drafted or standing in the race or pens.

The final protocol, after modification, included 40 measures (Appendix A). Four measures were related to good feeding, three to appropriate environment, 18 to health measures and 15 to stockpersonship. The main welfare measures observed with considerable variations across the herds or with high occurrence were poor body condition (range 0- 29%; BCS 1-2.5/5 scale) and poor rumen fill (range 0-15%; hollow rumen/'hungry cows'). Dirtiness was only seen in one herd and then only in 3.8% of cows. The prevalence for all health measures that had been included in the New Zealand protocol was <8%, on all herds except for nasal discharge which was 18% in one herd. The poorest performance for stockpersonship was in the proportion of cows hit, with hitting of >10% of cows occurring in 3/5 herds. No hitting of cows was observed on the one herd without a race. Results for the four health measures which were added to the protocol are shown for each of the five herds in Figure 1. The main issue in all herds was the presence of sharp or long horns (prevalence range: 18 to 62%) (Figure 2a). Extraneous brand marks, although less common (prevalence range 0 to12%), represented a significant welfare concern (Figure 2b).

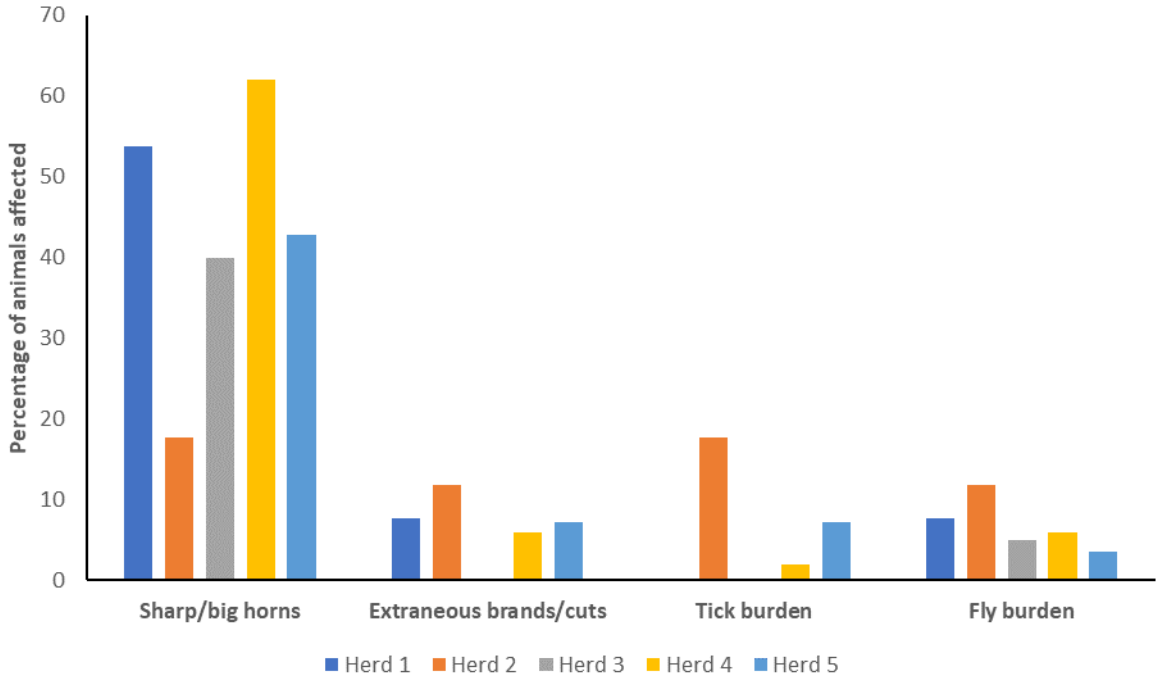

Figure 1: Additional health related welfare measures incorporated into the New Zealand protocol (Kaurivi et al., 2020b) to make it fit for use in semi-commercial Namibian beef herds, based upon observations of 5 herds in a semi-commercial farming village.

(a) (b)

Figure 1: Additional measures fit for Namibia included: (a) long/ sharp horns and (b) extraneous hot-iron brands/wounds

Discussion

The original protocol used in this study was designed for beef cows in New Zealand where reasonable grass growth occurs throughout the year. It formed a good basis for cattle welfare assessments in Namibian system where grass growth is much more variable throughout the year and between years. Only one measure (short tails due to fecoliths) from the original protocol was deleted from this study. This measure was specifically identified as being required for New Zealand conditions (Kaurivi et al., 2019) as beef cattle there have a high rate of fecoliths because they produce watery faeces because of the high-water content of pasture (Gibbs, 2012) which can accumulate and then dry on the tail. As the diet of Namibian beef cattle does not result in watery faeces it was unsurprising that this New Zealand-specific measure was not required in Namibia.

When developing the New Zealand protocol used in this study, 12/50 welfare assessment measures, identified from amalgamating the Welfare Quality and the UC Davis Cow-Calf protocols, were identified as not relevant for pasture-based beef cattle (Kaurivi et al., 2019). These results suggest that although welfare assessment protocols need to reflect the system they are being used in (Hernandez et al., 2017b; Hernández et al., 2017a; Laven & Fabian, 2016) the changes required when moving from assessing welfare in a confined (housed or feedlot) system to assessing it in an extensive system are likely to be greater than the changes required when moving from one extensive system to another.

Cattle managed in extensive systems are often assumed to have good welfare because of naturalness (Fraser, 2008). The counter argument is that these production systems are faced with threats to their welfare, including predation, inadequate water and grazing, toxic plants, a harsh topography and environmental challenges (Barrell, 2019; Petherick, 2005). Under New Zealand conditions, these welfare threats were almost

entirely limited to environmental hazards. But these threats are all present on Namibian beef farms. For example, predators (mostly cheetahs, leopards, hyenas and lions), snake bites and poisonous plants can all cause losses of livestock in Namibia (MAWF, 2017). Provision of grazing and access to water is significantly affected by environmental conditions, especially drought (Rothauge, Smit, & Abate, 2007). These threats affected the protocol principally through modifications of assessments rather than their removal. For example, in New Zealand, recording of herd mortality focused on deaths due to disease and accident, while in Namibia it had to be specified that it included deaths due to predators, snake bite and toxic plants. Similarly, the measurement of BCS remained a key part of the assessment, but whereas in New Zealand, the focus was on moderately compromised animals (≤4 on 1-10 BCS scale; (Hickson et al., 2017), in Namibia an additional category of very thin animals; 1 to 2 on 1-5 scale (Hulsen, 2005; Roche et al., 2004) had to be included to reflect the greater compromise associated with drought conditions.

Additionally, the semi-arid environment of Namibia is commonly associated with ectoparasite infestations. These parasites are of negligible welfare significance on most New Zealand beef farms (Heath, 1994); however, on Namibian beef farms they can be a major irritant (Davis, Blair, Ramirez, & French, 2014) and transmit significant disease e.g. lumpy skin disease, theileriosis, babesiosis, anaplasmosis and sweating sickness (Mashebe, Lyaku, & Mausse, 2014; Pascucci et al., 2017), so it was considered important that ticks and flies burden should be reflected in the welfare protocol. It was impractical to count ticks and flies on individual animals, thus an impression of more than 20 number of flies or ticks on any part of the body of a cow was regarded as abundance to signify a burden.

Another area which required modifications to the protocol was stockpersonship. In the New Zealand protocol, many of the measures were related to handling and

behaviour of cows in a race and/or chute. Many farms in the semi-commercial and communal areas of Namibia do not have these facilities. This meant that measures such as stumbling, falling, fearful/agitated behaviours and hitting of cows all had to be modified to account for this. Interestingly, in creating the New Zealand protocol, similar modifications had to be made to account for cows being handled as a group in the race, as the UC Davis protocol focused on cows being restrained in a head bail (which rarely happened during pregnancy diagnosis on New Zealand beef farms)(Kaurivi et al., 2019).

Development of a protocol for use in Namibia required the addition of nine measures that were specific to the country. The first of these, which was related to feeding, was distance to grazing. This measure was excluded from the New Zealand protocol because cows remain at grazing except for handling. In contrast, Namibian cattle on most farms in semi-commercial and communal villages are grazed separately from their calves during the day and at night but return in the morning to drinking points close to the yards. Suckling cows then meet with their calves for suckling in the yards (without restraint) or for milking (with restraint). This practice ensures the return of cows for daily monitoring. In the dry season, especially, this can mean that cattle must walk long distances to access feed, resulting in longer distance walking to and returning from grazing. An earlier research reference was for rangeland cattle in rough country not to walk more than 1.6km to water, and on flat topography a 3.2km distance was specified to attain more value for grazing ((Hart, Bissio, Samuel, & Waggoner Jr, 1993; Heady, 2019; Holechek, Thomas, Molinar, & Galt, 1999).

Two handling assessments were added to the protocol: tail twisting and use of electrical prodders (goads). Both are rarely used on New Zealand beef farms (Kaurivi et al., 2020a), in contrast to Namibia where tail twisting was observed in the current study. The use of electrical prodders was not noted on the five herds but should be validated on

multiple farms. The use of the electric prodder highlights the differences between New Zealand and Namibia in animal welfare legislation. In New Zealand, the use of the electric prodder is constrained by legislation (New Zealand Dairy Cattle Code of Welfare; MPI, 2019). In contrast, in Namibia there are no such regulations, although the FAN Meat scheme advises on the avoidance of the use of electric prodders on livestock (FAN Meat, 2019). This painful practise is associated with undesirable cattle behaviours (Pajor, Rushen, & De Passillé, 2000; Simon, Hoar, & Tucker, 2016).

Another aspect of animal welfare concern of cattle in Namibia arises from legislation. This is the compulsory requirement for hot-iron branding. Under the Stock Brand Act (1995), all cattle must be branded clearly with a hot-iron by 6 months of age and all cattle taken to auction or slaughter should be clearly branded with the brand mark of their current owner; thus, rebranding when animals change owner is also a legal requirement (FAN Meat, 2019). In addition, farmers in communal and semi-commercial areas opt for multiple hot-iron brands (i.e. letters, names, certain signs) in an attempt to reduce stock theft. Hot-iron branding causes considerable, long-lasting pain (Schwartzkopf-Genswein, Stookey, & Welford, 1997; Tucker et al., 2014), so needs to be included as a management procedure which causes pain. However, in addition to simply recording whether branding is undertaken, the number of brands per cow and the presence of extraneous wounds associated with hot-iron brands need to be included. There is also an issue with other painful identification measures used on communal and semi-commercial farms especially ear marking and cutting, as well as cutting of the dewlap-flap skin. The presence/absence of these were therefore recorded in addition to hot-iron branding.

The final additional measure was the size and shape of horns. In New Zealand, almost all commercial beef cattle are either genetically polled or disbudded soon after

birth. In most African countries, including Namibia, there are strong cultural preferences towards keeping cattle with long horns. For example, some customs (e.g. of OvaHerero people) in Namibia require cattle used for paying a bride price (lobola) and for slaughter at weddings and funerals to be horned. This has meant that breeding polled cattle is not common and that until recently calves in many herds were not disbudded or dehorned. Dehorning cattle improves human safety and improves cattle welfare as dehorned cattle cause fewer injuries to other cattle, and other animals (Stafford & Mellor, 2005). Thus, the size, length and shape of horns was added to the welfare assessment, so that this welfare risk could be identified

Conclusion

The animal welfare assessment protocol developed for pasture-based beef cattle in New Zealand provided a good foundation for a protocol to assess welfare in rangeland beef cattle in Namibia, with only one measure being excluded, the New Zealand-specific measure of short tails due to fecoliths. However, several measures needed minor modification to reflect differences between the New Zealand and Namibian environment, e.g. the inclusion of predators and toxic plants as causes of mortality in addition to accident and disease and identifying handling issues on farms where a race is not available. There was also a need for additional measures, because of differences between the Namibian and the New Zealand systems in feeding practice (distance to grazing), cattle identification (use of hot-iron branding), and horn management and relative importance of ectoparasites. The adoption of validated welfare protocols such as this will be to the advantage of Namibia and other developing countries to provide benchmarking and transparency. However, before it is used more widely it needs to be tested across multiple commercial, semi-commercial and communal beef farms.

Authors Contributions

Author Contributions: Y.B.K.—main researcher who did the project proposal and data collection, analysis and main write up. R.L.—main supervisor who did conceptualisation, methodology, funding acquisition, review and editing. R.H.— editing and validation. K.S.—conceptualization, methodology and editing. T.P.—review and editing. All authors have read and agreed to the published version of the manuscript.

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Appendices

Appendix A. A summary of all 40 potential measures identified as suitable (selected measures amalgamated from Welfare Quality & UC Davis assessment protocols and additional measures fit for New Zealand extensive pasture-based beef cattle farms plus additional measures fit for Namibia)

Welfare Principles	Welfare Criteria		New Zealand Assessment Protocols suitable measures for Namibia	Additional Measures Fit for Namibia Beef Farms
Good feeding	1	Absence of prolonged hunger	body condition score, rumen fill score	distance to grazing points
	2	Absence of prolonged thirst	distance to water points	
Appropriate environment	3	Comfort around environment	dirtiness (flank, hind, tail)	
	4	Thermal comfort	availability of shade in paddocks	
	5	Ease of movement	absence of hazardous objects/terrain	
Good health	6	Absence of injuries	swelling, hair loss, abrasions	broken tail, size and shape of horns, extraneous brands/wounds/ cuts (e.g., 2 or more brands, dew-lap cuts)
	7	Absence of disease	blindness, ocular discharge, nasal discharge, diarrhoea, lameness, dystocia, mortality (deaths, accidents and culling for health), disease history*	ticks burden, flies burden, mortality to include predators, poisoning plants and snake bite, deaths,
	8	Absence of pain induced by management procedures	disbudding/dehorning, castration, ear-tagging/notching	hot-iron branding
Appropriate Stockpersonship	9	Negative emotional state	fearful/agitated behaviour	
	10	Animal handling stockpersonship	stumbling, falling or running exiting, mis-catching, hitting cattle	use of electrical prodders, tail twisting
	11	Management-based stockpersonship	noise of handlers, noise of equipment /machinery, presence/noise of dogs at yards, frequency of yarding cows/year animal, health checks frequency	
	12	Resource-based stockpersonship	flow of handling affected by facility design/quality	

*Disease history data collection was kept in the protocol but not used as part of an individual farm's assessment

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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:	**Yolande Baby Kaurivi**
Name/title of Primary Supervisor:	**Prof Richard Laven**
Name of Research Output and full reference:	
Kaurivi, Y. B.; Laven, R.; Hickson, R.; Parkinson, T.; Stafford, K. Assessing Extensive Cow-Calf Welfare in Namibia: Feasibility of adapting a New Zealand beef cow welfare assessment protocol. *Applied Animal Welfare Journal*. 2020. Under review. The paper was since reviewed and was acceptance for publication (Additional thesis appendices: Appendix 3, https://doi.org/10.1080/10888705.2021.1937168)	
In which Chapter is the Manuscript /Published work:	**Chapter 4.1**
Please indicate: ☐ The percentage of the manuscript/Published Work that was contributed by the candidate:	**80%**
and Describe the contribution that the candidate has made to the Manuscript/Published Work:	
Main researcher who did the project proposal and data collection, analysis and main write up.	
Candidate's Signature:	
Date:	**10 May 2021**
Primary Supervisor's Signature:	
Date:	**10 May 2021**

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4.2 Assessing Extensive Semi-Arid Rangeland Beef Cow-Calf Welfare in Namibia: Part 1: Comparison of farm production system effects on the welfare of beef cows

This paper is presented in the journal format and style, and was under journal review by thesis submission, and was since then published in January 2021 (see Additional thesis appendices: Appendix 4). This is the second chapter in the series of developing an animal welfare assessment protocol for extensive beef systems in Namibia. This study applied the new protocol developed in the previous paper and compared farm production system's effect on the welfare of beef cows across 55 cow–calf herds in 3 systems (17 commercial, 20 semi-commercial and 18 communal) during routine pregnancy testing (2529 beef cows), farm resource evaluation and a questionnaire guided interview. Using the protocol in the context of these farm systems indicated that the standards of welfare differed across production systems; with commercial farms achieving the best standard of welfare, followed by semi-commercial, then communal village farms.

animals

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Article

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

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Simple Summary: Namibia is in the process of updating animal welfare legislation. This needs to include an assessment protocol for beef cattle production systems that is sufficiently rigorous for the country to gain and maintain access to high-value beef export markets. Beef is produced in commercial and semi-commercial systems and in communal village farms. Privately owned commercial farms allow maximum herd and rangeland management to ensure optimum productivity and profitability. Village farms (semi-commercial and communal) have limited grazing land, with consequent challenges of grazing and water management, as well as traditional customs of cattle management. A protocol was developed to assess the welfare of beef cattle in the context of these production systems. The application of the welfare assessment protocol indicated that the standards of welfare differed across production systems; with commercial farms achieving the best standard of welfare, followed by semi-commercial, then communal village farms. The greatest opportunity for change exists within the semi-commercial village farms, which need to attain to the requirements imposed by international markets to maximise their returns; hence herd management and welfare status is better than in the purely communal farms. This suggests that commercialisation of communal farming may have benefits for animal welfare.

Abstract: A proposed animal welfare assessment protocol for semi-arid rangeland-based cow-calf systems in Namibia combined 40 measures from a protocol developed for beef cattle in New Zealand with additional Namibia-specific measures. Preliminary validation of the protocol had been undertaken with five herds in one semi-commercial village. The aim of the current study was to apply this protocol and compare animal welfare across three cow-calf production systems in Namibia. A total of 2529 beef cows were evaluated during pregnancy testing in the yards of 17 commercial, 20 semi-commercial and 18 communal (total: 55) herds followed by an assessment of farm resources and a questionnaire-guided interview. Non-parametric tests were used to evaluate the difference in the welfare scores between the production systems. The results indicated a discrepancy of animal welfare between the three farm types, with a marked separation of commercial farms from semi-commercial, and communal village farms in the least. The differences in these production systems was mainly driven by economic gains through access to better beef export market for commercial farms and semi-commercial villages, as well as by the differences in the available grazing land, facility designs/quality and traditional customs in the village systems. The results indicate an advantage of commercialisation over communalisation.

Keywords: animal welfare assessment; beef cow systems; semi-arid rangelands; Namibia

1. Introduction

Namibian beef farming is dependent on extensive grazing under semi-arid, rain-fed conditions [1, 2]. The beef cattle industry is predominantly driven by the demarcation of Namibia into two parts (northern and southern) by the veterinary cordon fence (VCF; see Figure 1). The VCF is an important biosecurity measure for animal disease control, particularly for contagious bovine pleuropneumonia and foot and mouth disease (FMD). North of the VCF, livestock and livestock products are not eligible for overseas export because of the risk of FMD which is endemic in north-east Namibia [3, 4]. All farming rangeland north of the VCF is allocated to communal farmers with customary tenure [5, 6]. Most households in these areas are subsistence-based and labour intensive, with inadequate access to technology (FAO, 2016).

The southern part of Namibia (below the VCF) was declared FMD free by the World Organisation for Animal Health (OIE) and can export beef to overseas markets [4]. In this zone there are two types of farms; privately-owned commercial farms [2] and communally owned village farms with customary tenure. The latter "semi-commercial" village farms are set-up in the same way as communal village farms north of the VCF but have access to high-value commercial and overseas markets [6, 7]. The line of these two systems is also blurred by the resettlement freehold farms where the Namibian government buys farms from commercial farmers and resettle people mostly from communal areas.

These three different beef farming systems, commercial, semi-commercial and communal, have different management styles, income streams and levels of productivity. These differences are likely to have a significant effect on cattle welfare, although there are no data on beef cattle welfare on Namibian beef farms. In part, this dearth of information is because there is no standardized system of independent assessment of animal welfare under Namibian production systems. However, welfare assessment is commonly demanded by the type of markets to which Namibian farm animal products are exported. Importing countries commonly have welfare assessments that are applied to their domestic beef production, but such assessments are focused upon the species and production systems that pertain in those countries [8-10], and do not take into consideration the conditions that pertain in (for example) the semi-arid conditions of countries such as Namibia. Thus, as different systems need different welfare assessment protocols [11, 12], the value of developing a system of welfare assessment that was relevant to Namibian conditions became evident.

As part of a project to create welfare assessment protocols for extensively reared beef cattle in the semi-arid conditions of Namibia, Kaurivi [13] assessed the use of a protocol that was originally developed for New Zealand semi-intensive temperate pastoral beef production systems (based on the Welfare Quality protocol [14] and University of California Davis protocol [15]). The protocol was validated on five herds in one semi-commercial village in Namibia. That preliminary study identified nine further Namibian-specific measures that could be incorporated into the protocol to make it suitable for use on Namibian beef farms. By using the protocol on commercial, semi-commercial and communal beef farms in Namibia, the aim of this study, was to confirm that conclusion and to determine the impact of farm system on the welfare of Namibian beef cows.

2. Materials and Methods

Three areas were selected for inclusion in the study based on being representative of their farm type within Namibia. The herds included in the study were a convenience selection based on the willingness of the farmers to be involved. A total of 55 farms were enrolled, 17 commercial farms, 20 semi-commercial herds and 18 communal farming enterprises. Details of these herds are given in Table 1.

Table 1: Study areas for commercial, semi-commercial and communal farming areas showing number of herds, farms/villages and number of cows assessed.

Beef cattle system	Area	No. of herds assessed	No. of farms/ villages	Total Cattle	Average cattle /herd	Total Cow/ heifers/ herd	No of cows/ heifers assessed			
							Average	Min	Max	Total
Commercial	Gobabis	17	17	5887	346	3923	76.7	34	141	1305
Semi-commercial	Okakarara	20	8	2196	110	1590	29.7	11	55	593
Communal	Opuwo	18	8	4563	254	2485	35.1	8	78	631

2.1 Description of the study areas

Commercial farming system: (Gobabis area, Omaheke region, eastern Namibia). Commercial farms are large farms (range 3000-10000 ha) that have a boundary fence and fenced grazing paddocks [16]. On most farms (every farm represents one herd), the owners are full-time farmers or employ managers [2]. On the study farms, beef cattle farming was the predominant economic activity of interest, supplemented by small stock (sheep and goats) farming and wildlife ranching. Horses were commonly used for cattle mustering on most farms. The principal beef breed was Brahman, alongside pure breeds or crosses of Simmental, Charolaise, Bonsmara, Afrikaner and Nguni. The area is a flat sandy thorn bush highland with predominant open acacia savannah-type vegetation [17]. Annual rainfall in the area ranged between 200–400 mm (~2/3 in January-March) and average annual temperature is 19.3°C; ranging from <0°C in winter to 33°C in summer [18].

Semi-commercial farming system: (Okakarara area, Otjozondjupa region, central Namibia).

In a semi-commercial village farm, multiple families use the same permanent communal land for grazing and water. The land is government-owned with limited or no internal and external border fencing and animals roam freely [5, 19]. Semi-commercial village farmers in Okakarara are mainly dependent on livestock production (multi-purpose cattle, sheep and goats) for their livelihood. In the study area, the village farm size ranged from ~3000 to 6000 ha, with ~10-30 families/households per farm (called a village). Of these families' cattle herds, a selection of 1-5 herds from eight different villages were included in the study (total n= 20 herds; Table 1). In one of the eight study villages, government-built, village-maintained, common cattle handling facilities (yard with a race) were available; in the other villages, farmers were responsible for erecting their own facilities. Some households, without adequate handling facilities, took their cattle to yards with better facilities on days of mass handling. The principal beef breed was Brahman, alongside crosses with Simmental, Hereford, Nguni and Sanga. The area is a sandy thorn-bush highland acacia savannah [7]. Annual rainfall in the area ranged between 100–430 mm (~2/3 in January-March) and average annual temperature was 19.6°C; ranging from <0°C in winter to 32°C in summer [18].

Communal farming system: (Opuwo/Kaokoland area, Kunene region, north-western Namibia). As in semi-commercial villages, in communal villages, animals of different households graze together on the same government-owned communal land with limited or no internal and external border fencing. The small cattle herds are mainly for subsistence and mostly multi-purpose; i.e. milk, meat as well as manure for fire and building houses. Cattle farming is supplemented by herds of goats and some sheep. In the study area, farmers tend to be semi-nomadic with livestock being moved from permanent structures (yards and water troughs) to temporary ones in seasons of limited grazing (e.g. winter or drought). The government had constructed community crush pens (forcing pen and race only) within ~3 km of each village. These were completed and maintained by the villagers. The main breed in the area was indigenous Sanga cattle alongside Nguni and Brahman

crosses. Average cattle herd size was ~ 254 cattle, ranging from 30-548 cattle (one herd with 1900 cattle was owned by multiple members of the same family but managed as one group). From the selected eight villages, a selection of 2-5 herds per village farm was included in the study (total n= 18 herds; Table 1). The area vegetation is classified as mopane savannah with shrubland-woodland mosaic vegetation partly with rocky and bare mountains [20]. Annual rainfall in the area ranged between 50–320 mm (~2/3 in January-March) and average annual temperature was 21.6 °C; ranging from 10°C in winter to 30°C in summer [18].

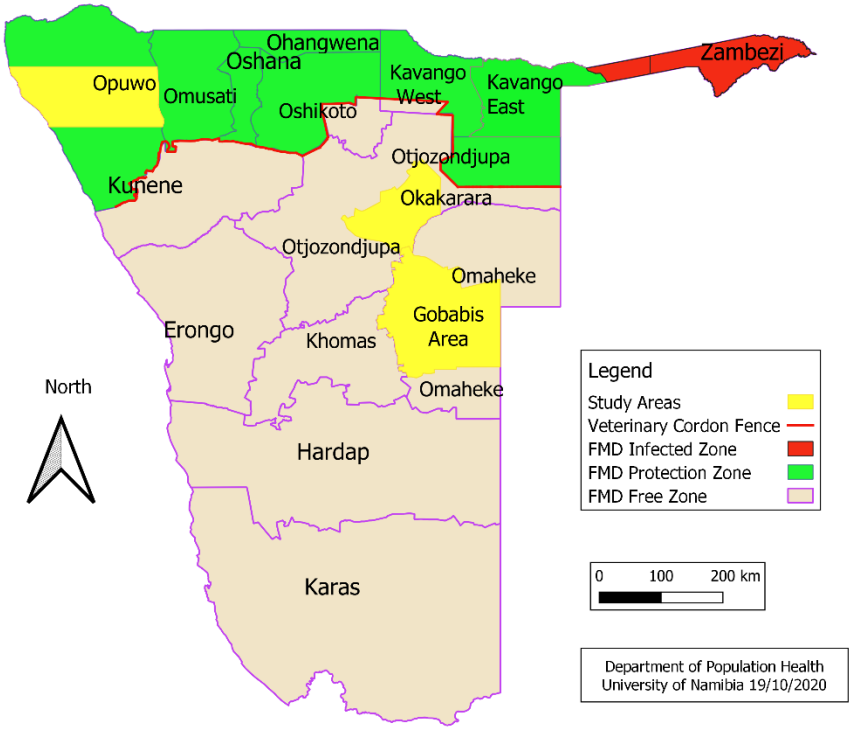

Figure 1. Namibia regional map showing the foot and mouth disease (FMD) zones and fences and study areas for commercial (Gobabis area), semi-commercial (Okakarara area) and communal farming (Opuwo area) [4](source Dr Alec Bishi).

2.2. Welfare assessment and data collection

The welfare assessments took place in March/April 2019 (autumn). The protocol was used on 55 herds with animal-based measures being assessed on 2529 cows (Table 1). (See Appendix A for protocol and description of measures). All animal-based and handling assessments were made during pregnancy testing, with all cows presented for pregnancy testing being assessed on each herd. On farms where a race was present, pregnancy testing was undertaken in the race. In the absence of a race, cows were captured with ropes (as if for milking) and pregnancy tested whilst standing (or lying) in a holding pen.

All observations were made by the same observer (first author). For each herd, the observer took a general overview of the cows in holding pens, before observations of body condition, rumen-fill, behaviour and physical health were made in single-file races (or in pens where there were no races). Stockpersonship was evaluated as cows entered, were handled and exited the race or the pens. Information was collected on yard design and accessibility (i.e. shape and size of forcing pens, race structure as well as cow flow and effective handling from pens to race). As animals exited the race (or pens), their exit speed (running or walking), whether they fell or stumbled, and lameness signs were all recorded. Depending on accessibility and race design, the position of the assessor varied from standing on the side of the race or in pens as cattle moved around. For observation of

cows exiting the race/pens the observer stood as close to the exit as possible without interfering with cow flow.

A farm resource visit and a questionnaire-guided interview were conducted to assess health and management of each herd over the last 12 months. These included records of dehorning/disbudding, castration, vaccination, diseases or disease symptoms seen in cattle, cattle deaths, access to water and grazing and wintering practices. (See Appendix B for questionnaire).

2.3. Data analysis

All data were analysed using SPSS version 24 (IBM). Descriptive statistics for continuous measures were used to capture central tendency (median), and range (minimum and maximum). The effect of farm type on continuous measures of welfare was analysed by using the Kruskal-Wallis test, and on categorical measures using the Fisher's exact test. Where the p value was <0.2 for either test, post-hoc testing was used for pairwise comparisons (Dunn test for continuous measures, and Fisher's exact for categorical). Holm-Bonferroni correction was used to account for multiple comparisons. For this analysis α was set at 0.05.

3. Results

The proposed protocol took on average 2.5 hours for a 100-cow herd at commercial farms (yard assessment - 1 hour and questionnaire and farm resource visit - 1.5 hours) and 2.5 hours for a 50-cow herd at the village farms (semi-commercial + communal)..

3.1. Continuous measures

The median and range for the 30 continuous indicators included in the assessment are shown in Table 2 (mean ranks for these measures are shown in Appendix C). Of those measures, only one, broken tails, had no recording on any farm of any type. Five measures (dirtiness, blindness, ocular and nasal discharge and poisoning deaths) had medians of 0 on all three farm types. Of the other 24 measures, commercial herds had the lowest median for 15 (including one tie) and the highest median for seven (including one tie). Semi-commercial herds had the lowest median for 9 (including three ties) and highest median for two. In contrast communal herds had the lowest median for three measures (including two ties) and highest median for 16 measures (including one tie).

Table 2: Descriptive analysis (median and range in percentage) of continuous welfare indicators in three Namibian beef production systems.

Measure	Commercial (N=17)	Semi-commercial (N=20)	Communal (n=18)
Thin cows	2.5 (0-46.9)	78.3 (25-100)	**100** (83.3-100)
Emaciated cows	0	7.3 (0-40)	**83.9** (52.5-100)
Poor rumen fill	0 (0-45.2)	48.1 (14.3-100)	**78.9** (39.3-100)
Dirtiness	0 (0-8.8)	0	0 (0-16.7)
Swelling	1.7 (0-8.2)	**3.7** (0-37.1)	2.3 (0-13.3)
Hair loss	0 (0-2.8)	2.8 (0-16.7)	**5.3** (0-20)
Abrasion	2.8 (0-12.5)	5.6 (0-27.3)	**19** (1.8-40)
Multiple brands/wounds/cuts	0.8 (0-3.6)	2.8 (0-44.4)	**5.3** (0-87.5)
Broken tail	0	0	0
Long/sharp horns	2.5 (0-37)	40.5 (10-96.6)	**61.8** (13.1-85)
Blindness	0 (0-2.5)	0	0 (0-1.3)
Ocular discharge	0 (0-1.4)	0	0 (0-1.3)

Nasal discharge	0 (0-1.4)	0	0 (0-1.3)
Diarrhoea	0.9 (0-12.9)	0 (0-1.8)	**4.3** (0-25)
Lameness	0 (0-3.9)	0 (0-3.3)	**3.4** (0-16.7)
Dystocia	0.8 (0-3.3)	1 (0-10.0)	**1.4** (0-6.7)
Tick burden	0 (0-6.8)	1.4 (0-81.3)	**4.4** (0-35)
Fly burden	0 (0-12.3)	1.4 (0-61.5)	**4.5** (0-55)
Deaths from diseases	**0.7** (0-4.1)	0 (0-2)	0.4 (0-7.9)
Accidental deaths	**0.2** (0-1.6)	0 (0-3)	0.1 (0-16)
Culling for health	**0.2** (0-2.3)	0 (0-3.1)	0 (0-3.3)
Predation/snake bite deaths	0.4 (0-9)	0 (0-4.1)	**4** (0-20)
***Nutritional deaths**	0 (0-3.2)	**6.6** (0-50)	1.1 (0-10)
***Poisoning deaths**	0	0 (0-2.4)	0 (0-0.3)
***Reproduction deaths**	**0.2** (0-0.8)	0 (0-4)	**0.2** (0-2.6)
Annual mortality rate	2.4 (0-15.5)	11.3 (0-26.9)	**11.7** (2.2-26)
Fearful/Agitate	3 (0-25)	6.2 (0-19.4)	**7.7** (0-17.5)
Fall/lie	**5.8** (0-17.7)	3.4 (0-26.7)	5 (0-17.5)
Stumble	**1.4** (0-4.9)	0 (0-40)	0 (0-14.3)
Run exit	**3.8** (0-16.9)	1 (0-20)	0.8 (0-15)

Highest median(s) for each category is in red/bold (if >0). See Appendix A for description of how each measure was assessed. *Nutritional deaths included weight loss and mineral deficiency (e.g. phosphate) deaths. *Poisoning deaths were plant poisonings and other poisonings (e.g. urea). *Reproduction related deaths included dystocia, retained placenta and vaginal prolapse complications.

No effect of farm type was found on the numbers of cattle affected with 14/24 measures (swelling, blindness, ocular and nasal discharges, dystocia, fly burden, deaths from disease, accident, culling or poisoning, fearful behaviour, falling/lying, stumbling or running ($p \geq 0.35$). Of the measures where the Kruskal-Wallis test returned a p-value of 0.05 to 0.2 (i.e. blindness, fly burden, run and excess branding/wounds), none could be separated by farm category using the Dunn test. The lowest adjusted p-value for a pairwise comparison was >0.0167 for the analysis (the lowest p-value has to be >0.05/ 3 farm types).

For the remaining measures, grouping by farm category using the Dunn test is shown in Table 3. The analysis separated the three farm types for proportion of emaciated cows and proportion of cows with poor rumen fill. In both cases, the median was lowest on commercial herds (0%) and highest in communal herds (83.9% and 78.9%), with semi-commercial herds (13% and 48.1%) in between the two. For long/sharp horns, hair loss, tick burden and mortality, commercial herds were separated by the analysis from semi-commercial and communal herds, but the analysis did not separate the village farms. In all cases, the median was lowest on commercial herds (see Table 2).

The analysis for dirtiness showed no separation between commercial and semi-commercial herds or between commercial and communal herds but separated semi-commercial from communal herds. Although in all farm types, the median was 0, semi commercial herds had a lower mean rank than communal herds. The comparison of farm effects for diarrhoea and reproduction deaths separated semi-commercial from commercial and communal herds but did not separate commercial from communal herds. In both cases, semi-commercial had the lowest median value and communal had the highest (Table 2).

There was an effect of farm type on the proportion of cows with skin abrasion and lameness, and the number of reported predator deaths. The analysis separated commercial and semi-commercial herds from communal herds, but not commercial from semi-commercial herds. In both these cases the median was highest in communal herds (Table 2). For deaths associated with nutritional deficiency, the analysis separated semi-commercial herds (which had the highest median) from commercial and communal herds but did not separate communal and commercial herds.

Table 3: Groupings by farm category (1: Commercial (N=17), 2: Semi-commercial (N=20), 3: Communal (n=18)), using the Dunn test (i.e. lowest adjusted p-value for a pairwise comparison was >0.0167).

Farm grouping	Measures
1<2<3	Emaciated, poor rumen fill
1 <2, 1<3, 2=3	Thin, horns, hair loss, ticks, mortality rate
2<3, 1=2, 1=3	Dirtiness
1<3, 2<3, 1=2	Abrasion, lameness, predator deaths
2<3, 2<1, 1=3	Diarrhoea, reproduction deaths
1<2, 3<2, 1=3	Deficiency (nutritional) deaths

3.2. Categorical measures

Shade (natural savannah-type rangeland trees) was sufficient on all the farm types. The remaining frequencies of ordinal measures by farm type in each welfare category are shown in Appendix D. Commercial herds had the highest frequency of farms in the poor welfare category for 4/17 measures (dog noise, equipment noise, mis-catch and use of electric prodders). Semi-commercial village herds had the highest frequency of farms in the poor welfare category for 4/17 measures (late castration and dehorning, hazards and poor flow of cattle during handling). Communal herds had the highest frequency of farms in the poor welfare category for 8/17 measures (distance to water/grazing, ear tagging, hitting and tail twisting in the yards, handler noise and yarding frequency).

Of the categorical measures, no effect of farm type was found on 4/17 measures (hazards, hitting, equipment noise and health checks; p >0.2 in the initial analysis). The p-values for the multiple comparisons and direction of the difference for the remaining measures are shown in Table 4. Although the overall p-value was <0.2 for mis-catch and dog noise, the analysis did not separate these measures by farm (lowest adjusted p-value >0.0167).

Electrical prodders were only used on commercial farms, so the analysis separated commercial herds from communal and semi-commercial herds, but not communal from semi-commercial. For distance to water/grazing, dehorning, castration, ear tagging, tail twisting and yard/handling flow, the analysis separated commercial from semi-commercial and communal herds, but not semi-commercial from communal herds. For all these measures, commercial herds had the lowest frequency of herds with poor welfare and communal the highest frequency.

For hot-iron branding, semi-commercial herds had the highest frequency of poor welfare. The analysis separated them from commercial and communal herds but did not separate communal from commercial herds. For noise of handlers, the analysis separated commercial and communal herds (with the latter having a higher proportion of farms with poor welfare than the former) but did not separate semi-commercial herds from communal or commercial herds. For yarding/handling frequency the analysis separated communal from commercial and semi-commercial herds, but not commercial from semi-commercial herds. For this measure communal herds had the highest of herds with poor welfare

Table 4: Pairwise comparisons for the Fishers exact test for the frequency of categorical measures at the production systems herds in Namibia (1- Commercial (n=17), 2-Semi-commercial (n=20), 3- Communal (n=18)

Ordinal measures	**Fishers exact p-value**			**Pairwise**
	1 vs 2	1 vs 3	2 vs 3	**outcomes**
Water distance	<0.001	<0.001	1	1<2, 1<3, 2=3
Grazing distance	<0.001	<0.001	1	1<2, 1<3, 2=3
Dehorning	0.001	<0.001	0.468	1<2, 1<3, 2=3
Castration	0.005	<0.001	0.135	1<2, 1<3, 2=3
Ear tagging	<0.001	<0.001	0.526	1<2, 1<3, 2=3
Hot-iron branding	<0.001	0.466	<0.001	1<2, 1=3, 3<2
Mis-catch	0.094	0.019	0.526	1=2=3
Electrical prodders	0.019	0.015	1	2<1, 3<1, 2=3
Tail twisting	0.013	0.005	0.639	1<2, 1<3, 2=3
Handlers noise	0.068	0.005	0.028	1=2, 1<3, 2=3
Dog noise	0.270	0.019	0.027	1=2=3
Yarding/handling freq.	0.363	<0.001	<0.001	1=2, 1<3, 2<3
Yard/ handling flow	<0.001	<0.001	0.512	1<2, 1<3, 2=3

Painful management procedures: Castration was performed on 9/17 commercial herds (mode and median 2 months of age; range 1week to 8 months), 8/20 semi-commercial herds (mode and mean 6 months) and on all 18 communal herds (all after 6 months). Disbudding was performed at all commercial herds (mode 2 months; 1week to 8 months), 17/20 semi-commercial and 12/18 communal herds (mode 6 months at the villages; range 4 months to 12 months). Ear tagging was performed on all herds with median and mode of 2 months at the commercial herds and mode and median of 6 months in both types of village herds. Ear notching (cutting with a knife) was routinely performed on all village herds as a form of identification but not on the commercial herds. Skin cutting (dewlap cuts) was performed on 7/20 and 4/18 herds in the semi-commercial and communal herds, respectively. Cattle branding with hot-iron was used on all herds; secondary branding (i.e. letters, marks) was routinely performed on commercial stud farms (5/17 commercial farms) and on all the village herds. No anaesthesia was used for any procedure.

4. Discussion

The current study confirmed the findings of Kaurivi [13] that a 40 measure protocol developed for use on extensive cow-calf farms in New Zealand was, with the addition of nine Namibian-specific measures, feasible for use during yarding on all classes of Namibian beef farms. The use of this protocol has identified marked differences between production systems in animal welfare. For 25 of the total 47 indicators (30 continuous + 17 categorical) included in the protocol, the analysis separated welfare outcome by system. For 16/25 measures, the welfare outcome was better on commercial herds than semi-commercial herds, and for 19/25 it was better on commercial herds than communal herds (Tables 3 and 4). For 9/25 measures, semi-commercial herds had a better welfare outcome than communal herds, while communal herds had better outcomes overall than semi-commercial herds for only two measures.

The most obvious difference between farm systems was related to feeding. For proportion of emaciated cattle and proportion with poor rumen fill, commercial farms performed better than the village farms, and semi-commercial farms performed better than communal farms. This is likely to be because commercial farms have more control over cattle feed supply than village farms. Village systems also have limited fencing, which limits the ability of farmers to manage grazing [1, 19, 21]. Moreover, social obligations and customary factors contribute to a widespread failure of village

296 farmers to undertake timely reductions of stock numbers, even when feed is scarce [7]. Nevertheless,
297 despite these challenges, semi-commercial farmers were able to maintain cattle in better BCS than
298 their communal counterparts. This may be due to the better feeding, herd management and genetics
299 associated with the cash income from beef sales. On the other hand, it may reflect differences
300 between the selected regions rather than farm system. Siegmund-Schultze [7] reported that the
301 average BCS was higher on communal than semi-commercial village farms (3.0 vs 2.5 respectively;
302 1-5 scale), concluding that this was related to feed supply, as the communal farms in northeast
303 Namibia had significantly more rainfall than the semi-commercial farms in central Namibia (550 vs
304 350 mm/year, respectively). Similar considerations may pertain to the present study, the communal
305 farms were in northwest Namibia (Opuwo area), which has a much drier environment than the
306 region (Kavango West) studied by Siegmund-Schultze [7]. Thus, the differences of BCS in the
307 present study may, at least partly, reflect the effect of rainfall on feed availability rather than system
308 differences.
309 The distances that animals had to walk to grazing may also have exacerbated pressures upon
310 BCS [22]. Distances are characteristically shorter on commercial farms (2-4km) than on
311 semi-commercial (3-6km) or communal farms (4-8km). The distance to grazing also had an impact
312 on distance to water. In village farms, water is provided in or around the yards, so distance to water
313 is strongly related to distance to grazing, whereas in commercial farms, water troughs are in the
314 grazing paddocks. The relationship between BCS and lameness may therefore be of interest,
315 inasmuch as lameness was rare on commercial and semi-commercial herds (median 0% on both,
316 max. 3.9% and 3.3%, respectively), but more common on communal herds (median 3.3, max 17%).
317 The association between the prevalence of lameness and distance walked is well recognised [23, 24]
318 and cattle on communal village farms walked the longest distances. Lameness rates could be also
319 related to handling facilities, which could cause injury and acute lameness. However, there was no
320 difference between semi-commercial and communal herds in yard handling/flow (Table 4), despite a
321 difference in the prevalence of lameness prevalence. The older age of cattle at communal farms could
322 also have contributed to lameness. Finally, BSC itself can affect the risk of lameness, as poorer BCS
323 has been associated with increased risk of lameness [25]. There is clearly a need for further research
324 to unravel these relationships.
325 Differences between systems were also noted in relation to animal health. Skin
326 abrasions/injuries were more common in communal than semi-commercial and commercial herds,
327 probably because the quality of handling facilities on communal farms were poorer (i.e. greater use
328 of thorny bushes and tree poles tight with wires), and thus the risk of accidental injury higher.
329 Hairless patches were less common in commercial than semi-commercial/communal farms,
330 although this may be a reflection of the prevalence of lumpy skin disease than of welfare *per se.*
331 Relatively few animals were assessed as having diarrhoea, although the prevalence was highest in
332 communal than other herds (4.3 % vs 0% and 0.9% at semi-commercial and commercial
333 respectively).
334 There was a large difference between the median of mortality rates on commercial (2.4%) versus
335 semi-commercial (11.3%) and communal (11.7%) herds. It was likely that underlying differences
336 between systems were exacerbated by the impact of the prevailing drought. Deaths due to
337 predation, dystocia (reproduction) and nutrition varied between farm systems. Interestingly, death
338 due to predation was higher in communal herds but there was no difference between commercial
339 and semi-commercial herds. This may reflect the value of internal fencing and the ability of
340 commercial farmers to control where cattle go (such as calving in calving camps in areas not
341 frequented by cheetahs; [26]. Risk of death due to predation may also reflect changes in the
342 population of wild prey associated with drought conditions [27, 28]. Opuwo communal area borders
343 the Etosha National Park where livestock are at a risk from predators. Deaths due to dystocia
344 (reproduction deaths) were lowest in semi-commercial herds, but there was no difference between
345 commercial and communal herds. However, the risk of deaths due to dystocia was not significantly
346 related to the reported incidence of dystocia per se. There is no clear explanation for this, except to

note that the rate of dystocia and reproduction deaths in communal herds was probably related to the lower plane of BCS [29].

Deaths reported as nutritional were far higher in semi-commercial than communal or commercial herds. Again, the reasons for this pattern are not clear, although the lower prevalence in commercial herds is consistent with better body condition and the use of supplementary feeding. Conversely, the lower prevalence on communal herds is not consistent with the higher proportion of emaciated cattle in those herds. It may be that the discrepancy lies in the effects of phosphate deficiency [30], which is widespread, but whose distribution and severity varies between the different areas included in the present study. For example, sandy soil around Okakarara areas has significantly lower phosphate than that at the harder and drier sand around Opuwo area (3.35 mg P/kg; [17], vs 12.4 ± 1.7 mg P/kg; [20]), while the available soil phosphorus threshold is intermediate (≤10mg kg -1 DM; [30]). A comprehensive investigation in the suspected phosphate deficiency related deaths of cattle is warranted and would help to unravel this question.

No effect of farm system on fly burden was found, but tick burdens were lowest on commercial farms. It is likely that this reflects parasite management with commercial farms using external parasite control as a key part of herd health management, whereas semi-commercial farmers treat cattle for ticks when necessary to do so (i.e. when preparing them for sale, when there are high tick burdens or in response to tick-borne diseases). No difference was found between semi-commercial and communal herds in tick burden, despite communal farmers rarely, if ever, using tick control. These data suggest that the limited use of tick control in semi-commercial herds is not having any impact on ticks.

There are issues with painful management procedures on all farm types. No anaesthesia was used for any procedure on any farm. On commercial farms, dehorning/castration is generally performed when calves are younger than on village farm types (mode 2 vs 6 months respectively). The FAN Meat scheme [31] requires that these operations are performed on calves younger than 2 months of age to ensure reduced pain and faster healing [32]. However, the FAN Meat is a voluntary scheme, and farmers in the villages have a traditional but erroneous conviction that late castration allows faster growth and muscle gain [33].

Keeping of horned cattle is traditional in the villages, but there is clear evidence of long horns injuring other animals and hampering handling flow in the race. There is increasingly strong advocacy for keeping polled cattle (which would also eliminate the need for dehorning: [34]). However, horns are natural defense tools against predators' attacks [35] and imposing such restrictions in areas that lose livestock to predators may hinder the sustainability of farming.

Hot-iron branding and ear tagging are compulsory for cattle identification and traceability in Namibia. Analgesia was not provided on any farm for cattle during or after hot-iron branding, so hot iron branding was a significant welfare concern on all farms. However, on many farms additional painful methods were used to permanently identify cattle in addition to the statutory brand. On commercial farms, stud breeders (n= 5/17) used an extra brand on stud cattle, while on village farms additional brands (e.g. letters, names, certain signs) as well as markings (e.g. dewlap skin-flap cutting; see Appendix E) were used for security and easy identification. Rebranding of cattle that change ownership was also common. Branding was also used on village farms for treatment of musculoskeletal problems (e.g. hip tendon slipping), with cattle being branded over the affected site. Branding for security reasons was most common in semi-commercial areas, due to the high levels of stock theft in such areas. Furthermore, on village farms, ear notching (with knives), was used in addition to compulsory ear tagging because of the perception that ear tags were easily lost or dislodged. Thus cattle identification, for whatever reason, was a welfare issue on all farms, especially village farms. On the other hand, the national traceability system (NamLITS) benefits cattle movement control[36], which is itself a critical underpinning of the Namibian beef industry. There would be great value in reducing the need to use painful methods for such identification.

There were differences between systems in measures related to stock handling. Only 6% of commercial herds had poor cattle flow/handling, compared to 50% and 70% in communal and semi-commercial herds respectively. The effects of farm type on cattle handling were determined by

differences in yard design and quality. For commercial farms with marginal flow, the main issues were related to yard design (e.g. oversized holding pens, sharp corners and poor accessibility of the forcing pen). The problems on village farms were more fundamental, notably lack of gates, races and forcing pens. In semi-commercial village farms yards were well constructed (usually) with wooden poles, whereas some communal villages yards were partially, or fully, constructed using thorny bushes. Thus, on village farms, poor construction and poor design of yards resulted in poor cow flow and subsequently increased handling times, frequency of hitting and tail twisting, and noise of handlers.

Despite differences across farm types in facilities and stock handling behaviour, there was no farm type effect on behaviour related to handling (fearful/agitated, fall/lie, stumble and run). This may be related to the "flighty" temperament of the Brahman breed which was predominant across all farm types [37]. For example, Brahman cattle and their crosses lay down in the race more commonly than other breeds, contributing to the high proportion of fall/lie cows in this study across all farm types.

Importantly, however, not all issues related to cow handling were worse on village farms. Electric prodders were only present on commercial farms (5/17); and all these farmers were using prodders on more than the 1% recommended by Grandin [38]. The use of prodders was related to cow flow in the yards with marginal designs and cattle lying in the race. The data from this study on stock handling suggest that improvements are needed across all farm types. In particular, training on alternatives to sticks, whips, pipes and prods, such as flags on sticks [39, 40] is needed. It also reinforced the value of a race in reducing stress during handling [41, 42], especially for extensively reared cattle that are not frequently restrained [43].

5. Conclusions

The study evaluated the welfare of beef cattle in the various extensive beef production systems of Namibia. It showed that the welfare of cows varied between farm types: 25 of the 44 criteria in the present study varied across systems. Of those 25 measures, the welfare outcome was better on commercial herds than semi-commercial herds in 16 and better than communal in 19. The main reason for the better performance of commercial herds were better nutrition and management of grazing land, better cattle handling infrastructure, and preventative disease control. Despite the similar animal welfare challenges facing semi-commercial and their communal counterparts, of the 25 measures found to be affected by farm type, 9 were better on semi-commercial herds than communal herds and only 2 were better on communal than semi-commercial herds. This suggests that even limited commercialisation of communal farming may have benefits for animal welfare. However, this conclusion needs testing on more farms in more areas of Namibia. There is an immediate need however, to categorise measures across the farm production systems in order to indicate thresholds of acceptable and unacceptable welfare, to give guidance regarding the levels at which intervention and remediation is required. This will be addressed in a companion Part 2 paper of the current study.

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animals

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453 **Appendix A. Description of welfare measures included in the assessment protocol for cow-calf welfare in Namibia (Kaurivi et al., 2020c).**

Welfare Principle	Welfare criteria	Welfare measures	Assessment method Observations made in the race or in holding pens if no race
Good Feeding	Absence of hunger	Body condition score (BCS)	% thin cows in the herd based on score 1-2.5 on the 5-point BCS scale that is commonly used in Namibia. Due to the drought conditions, another score of severity was added to differentiate between thin (>2-2.5 scale) and very thin/emaciated (1-2 scale) cows.
		Rumen fill score (RFS)	% of cows with hollow/empty rumen.
		Distance to grazing	The questionnaire asked how far cattle had to walk to access grazing (≤ 1.6kmm, 1: 1.6km-3.2km and > 3.2km).
	Absence of thirst	Distance to water	Average distance to water source. Distance to water in semi-commercial and communal villages was estimated as the distance to grazing as water points are close to yards and cattle come to drink after grazing (≤ 1.6kmm, 1: 1.6km-3.2km and > 3.2km).
Appropriate Environment	Comfort around environment	Dirtiness	"Dirtiness" recorded by averaging the three measures of dirty tails, dirty hind quarters and dirty flanks
	Ease of movement	Hazards	Identify pasture hazards (e.g. steep hills) and presence of dangerous objects/garbage, and loss of animals to such hazards: 1) no hazards, 2) 1or 2 hazards and 3) 3 or more hazards or animals dying in any hazard.
	Thermal comfort	Shade	Subjective assessment of shade in the paddocks (presence of trees, shrubs, galleys, man-made canopies) as enough or insufficient.
Good Health	Absence of injuries/ physical impairment	Abrasions, Swelling and Hair loss	% of cows with abrasions/fresh scratches or cuts, swellings and hairless patches extending >1 cm.
		Extraneous (multiple) brands/wounds/cuts	Observation of brand mark wounds (>2cm) or more than once branded/marked (i.e. stock brand, initials or name of a farmer branded) and extraneous cuts (i.e. dew-lap skin cuts)
		Long/sharp horns	Number of observed cows with sharp/long horns (> 5cm in length, sharp and forward facing to pose a risk of injuring others).

		Broken tails	Observations of abnormal tails (misaligned or broken at the tail head).
	Absence of disease and pain	Blindness	% of cows with affected eye(s) by visual assessment and/or testing with hand.
		Ocular discharges	% of cows with ocular discharges extending 2 cm.
		Nasal discharges	% of cows with nasal discharges extending 2 cm.
		Lameness	% of cows with unsteady gait exciting the race to paddocks or from the holding pen to the paddocks
		Diarrhoea	% of cows with diarrhoea.
		Dystocia	% reported by famers during questionnaire guided interview.
		Mortality	% of cattle which had accidental deaths and deaths/slaughter on-farm due to disease were combined. It was emphasised that mortality rate included deaths due to predators, toxic plants and snake bites.
	External parasites	Fly burden Tick burden	Separate impression of more than 20 number of flies (i.e. horse flies) and ticks on any part of the body of a cow.
	Painful management procedures	Castration, Disbudding, Ear tagging/notch	Record age and use of local anaesthetic on a 3-point level: 1) No disbud/castration, 2) ≤2 months and 3) >2 months. For ear tagging/notching the scoring was: no tag or use anaesthetics; tag with no anaesthetics and notching/cutting with no anaesthetics.
		Hot-iron branding	Record age of branding and use of local anaesthetic (in questionnaire) on a 3-point score: 1) no branding or use anaesthetics, 2) one brand (compulsory) and 3) more than 1 brand.
Stockpersonship	Animal handling stock-personship and resource-based measures	Fearful/agitated	% cows fearful/agitated in the race/forcing pen (climbing on others.
		Running	% of cows running (taking ≥2 strides at a gait faster than a trot) when cows exit from the race or holding pen to the paddocks.
		Stumbling	% of cows stumbling were cows with their knees/hocks contacted the ground, on exiting the race or if moving into a group of cows include assessment from holding pen to the paddocks. Also included those cattle stumbling in the holding pens when being drafted for restraint in the absence of a race.
		Falling	% of cows falling (torso contacted the ground) or lying down while in the race and forcing pen were recorded. Also include those cattle falling in the holding pens when being drafted for restraint in the

			absence of a race.
		Hitting cows	Subjective categorical observation of the group rather than the individual cow: 1) no hitting; 2) occasional hitting (≤10% of cows); 3) frequent hitting (>10% of cows) into the forcing pen and race. Included proportion of cattle hit in pens when being drafted for restraining in the absence of a race.
		Use of electrical prodders	Estimate the proportion of cows that were prodded with an electrical goad on any part of the body while drafted or standing in the race, pens or yards on a 3-point level: 1) no prodding, 2) few/ occasional prod (≤ 1% cows) and 3) many/frequent prod (>1% cows prodded).
		Tail twisting	Estimate the proportion of cows with tail twisted while drafted or standing in the race or pens on a 3-point level: 1) no twisting, 2) occasional/few twist (≤ 10% of cows) and 3) frequent twist (>10% of cows).
		Mis-catching	Estimate of the proportion of cows that were mis-caught on any part of the body while gates were closed into or within the race. If no race, available mis-catch was recorded if more than one attempt was made to capture/restrain an individual animal with ropes or if a cow did not stand still when a rope was secured around the legs.
		Noise of Handlers Noise of Equipment/ machinery	Subjective categorical assessment of handlers' noise (e.g. shouting) and equipment noise (e.g. race or chute gate) and machinery (e.g. generators etc.): 1) no noise, 2) minor less frequent audible noise or 3) repeated, unpleasantly noisy.
		Dogs noise around the yard	Categorical subjective assessment: 1) no dogs; 2) quiet dogs; 3) Noisy or repeatedly audible dogs.
		Health checks	Record frequency of health checks on cows during winter/pregnancy: 1) daily, 2) once-twice/week and 3) more than weekly.
		Yarding frequency	Record frequency (number of times) of yardings per year. Emphasised cattle yardings that only involve restraining (e.g. vaccinations and tagging); 1) >4 times, 2) 3-4 times and 3) 0-2 times.
		Yard design flow	In the absence of a race, assessment included farmers' cattle handling skills and movement: 1) effective handling (manual restraint of cows was easily achieved), 2) minor issues with flow and/or restraint/ of cattle, 3) major issues with flow and/or restraint (e.g. lengthy periods of running behind cows while trying to capture and restrain them).

454 **Appendix B.** Questionnaire-Guided Interview Questions Used for Welfare Assessment at beef herds in the
455 production systems in Namibia

Farm……..Owner:…… ……..Date:……

Questionnaire guided interview questions (based on UC Davis cow and calf animal welfare assessment protocol, 2016) will address the following welfare management related questions on each farm.

a. Please state your cattle herd number ( ), number of breeding females ( ) and number of males/bulls ( )
b. Which type and numbers of other animals you have on the farm (breed, class)?

General Herd Management

1. How are your cattle identified (ear tag, ear notch, branded, other marking)? At what age?
2. Do you do dehorn or disbudding operations on your cattle? At what age? Which method?
3. Do you castrate your cattle? At what age? Which method?
4. At what age are your calves weaned? How?
5. What is the source of water for cattle on the farm? How far do cattle walk to water source?
6. Do you monitor the grazing of your cattle? How often? How far do cattle walk to grazing?
7. What is the condition of grazing (quantity and quality)? Stocking density rate/carrying capacity?
8. What are the main supplementary feeds for cattle used? Any other wintering practices that you do regarding feeding of animals? What is the general body condition of cattle now?
9. Do you get veterinarian or veterinary services visits? How often? What purpose?
10. What training do you have relating to animal health and husbandry? How do you keep abreast?

Stockpersonship

11. How many handlers per stock do you have on the farm (ratio of staff per stock unit)?
12. How frequently do you yard cattle for handling/restraining? For what purpose?
13. Do you use any other handling devices (sticks, ropes, plastics) to handle the cattle?
14. Do you use horses to handle the cattle on the farm? Do you use dogs in the cattle yards?

Health

15. Do you do health checks on your cattle (especially pregnant cows)? How often or when?
16. In the last year, how many cattle did you cull for any health-related issues?
17. How many died from diseases/disorders/ deficiency? What were the main causes of sickness and deaths of cattle on the farm? (Respiratory, diarrhoea, bloat, pink eyes, lameness, lumpy skin disease, botulism? udder problems etc.)
18. What were the main clinical signs of unknown causes of cattle sickness and deaths on the farm? Any other disease or health abnormalities in the herd?
19. What treatments are you likely to perform on your cattle? How many cattle recovered from treatment?
20. Do you vaccinate your cattle? For which diseases? When or how often?
21. Do you control internal and external parasite on your cattle? How/With what products? When or how often?
22. Do you get animals injured in the yard, chute/race or paddocks? How many? From what exactly?
23. Have you lost animals from hazards (falling in dams/ creeks, hills etc., wire sticking etc.)? How many and from what exactly?
24. Do you get cattle injured in the yard (kraal), paddocks (camps) or chute (manga? How many?
25. Do you lose animals from poisonous plant/ other poisoning? Which type? How many cattle died?
26. Do you have predation problems? What predators? How many cattle succumbed to the specific predators?
27. Any cattle bitten by snake? What was the outcome?

Reproduction

28. Did you experience any reproductive conditions in cattle in the last year? Which one? (Retained placenta, prolapse vagina/uterus, abortion, dystocia). How many cases of each? What was the outcome (assisted/culled/died, etc?

Appendix C. Table of mean ranks of commercial, semi-commercial and communal beef cattle production systems in Namibia

Mean Ranks	Commercial (n=17)	Semi-commercial (n=20)	Communal (n=18)	Mean rank p- value
Thin cows	13.9	69.4	69.9	<0.001
Emaciated cows	11.5	25.4	46.5	<0.001
Poor rumen fill	9.6	29.7	43.5	<0.001
Dirtiness	28.2	23.5	32.8	0.021
Swelling	25.9	30.3	27.5	0.470
Hair loss	17.0	30.2	35.9	0.002
Abrasion	16.3	25.8	41.4	<0.001
Extraneous brands/cuts	20.6	29.9	32.9	0.007
Broken tails	-	-	-	-
Long horns	10.1	32.3	40.2	<0.001
Blindness	30.9	26.0	27.5	0.113
Ocular discharge	28.6	27.0	28.5	0.552
Nasal discharge	28.6	27.0	28.5	0.552
Diarrhoea	31.5	17.5	36.4	<0.001
Lameness	24.2	21.4	39.0	0.001
Dystocia	26.8	26.5	30.9	0.637
Tick burden	18.5	31.0	33.6	0.002
Fly burden	21.1	31.1	31.1	0.073
Deaths from disease	30.0	24.8	29.7	0.546
Accidental deaths	28.8	25.2	30.4	0.197
Culling for health	30.3	25.5	28.7	0.363
Predation/snake	24.4	17.4	43.1	<0.001
[a]Nutritional deficiency deaths	17.5	38.3	26.4	0.002
Poisoning deaths	26.5	29.3	28.0	0.410
[b]Reproduction deaths	30.4	23.6	30.6	0.018
Annual mortality rate	13.3	34.0	35.2	<0.001
Fearful/Agitate	25.3	28.3	30.3	0.693
Fall/lie	31.0	25.3	28.2	0.347
Stumble	32.4	27.6	24.3	0.147
Run exit	34.8	24.2	25.9	0.197

[a] Nutritional deaths included weight loss and mineral deficiency (e.g. phosphate) deaths. [b]Reproduction related deaths included dystocia, retained placenta and vaginal prolapse complications

463 **Appendix D.** Frequency (%) of categorical measures in the 3 welfare scores at the cow-calf production systems
464 herds in Namibia (CF- Commercial (N=17), SCV-Semi-commercial (N=20), CV- Communal (n=18)

	Production systems	**Good welfare**	**Marginal welfare**	**Poor welfare**
Water distance	CF	94	6	0
	SCV	0	5	95
	CV	0	0	**100**
Grazing distance	CF	6	77	18
	SCV	0	5	95
	CV	0	0	**100**
Hazards	CF	0	88	12
	SCV	0	65	**35**
	CV	0	67	33
Dehorning	CF	47	53	0
	SCV	20	5	**75**
	CV	33	0	67
Castration	CF	47	18	35
	SCV	15	0	**85**
	CV	33	0	67
Ear tagging	CF	0	100	0
	SCV	0	5	95
	CV	0	0	**100**
Hot-iron branding	CF	0	82	18
	SCV	0	5	**95**
	CV	0	83	17
Mis-catch	CF	71	24	6
	SCV	95	5	0
	CV	100	0	0
Electrical prodders	CF	71	0	29
	SCV	100	0	0
	CV	100	0	0
Hitting	CF	35	35	29
	SCV	35	30	35
	CV	22	39	**39**
Tail twisting	CF	0	88	12
	SCV	15	65	20
	CV	28	39	33
Handlers noise	CF	12	82	6
	SCV	30	45	25
	CV	0	50	**50**
Equipment noise	CF	53	35	**12**
	SCV	85	10	5
	CV	83	17	0

Dogs noise	CF	71	24	**6**
	SCV	90	10	0
	CV	100	0	0
Health checks	CF	94	6	0
	SCV	100	0	0
	CV	100	0	0
Yarding/handling frequency	CF	24	71	6
	SCV	20	55	25
	CV	0	11	89
Yard flow/ handling	CF	53	41	6
	SCV	5	25	70
	CV	0	50	50

465 * **Highest frequency for each poor welfare category is in red/bold**

466

Appendix E. Pictures of various identification markings at the beef cattle herds in Namibia. Top pictures show the skin-flap cuttings and bottom right cow has a sign for easy identification and bottom left shows a cow with multiple brands for traditional treatment

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STATEMENT OF CONTRIBUTION
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Candidate's Signature:	
Date:	**10 May 2021**
Primary Supervisor's Signature:	
Date:	**10 December 2020**

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4.3 Assessing Extensive Semi-Arid Rangeland Beef Cow-Calf Welfare in Namibia. Part 2: Categorisation and scoring of welfare assessment measures

This paper is presented in the journal format and style, and was under journal review by thesis submission, but was since published in January 2021 (see Additional thesis appendices: Appendix 4 for the published version). This is the third chapter in the series of developing an animal welfare assessment protocol for extensive beef systems in Namibia. This chapter shows the practical derivation and application of welfare standards that can be validated by data sets from three farm or enterprise types. This is an important first step in monitoring and bench-marking cattle welfare in extensive systems. Two sets of thresholds setting were discussed; imposed (derived from those described in NZ farms and authors' opinion) and those derived from collected data.

animals

MDPI

1 *Article*

2 Assessing Extensive Semi-Arid Rangeland Beef 3 Cow-Calf Welfare in Namibia. Part 2: Categorisation 4 and scoring of welfare assessment measures

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12 **Simple Summary:** Basing welfare assessment standards on protocols developed for industrialised
13 beef exporting countries could enhance the beef production and export standards in Namibia. The
14 current paper compared imposed thresholds of welfare measures of categorisation and derived
15 thresholds to see which was the most appropriate to the range of observations and welfare
16 implication in three cow-calf production systems in Namibia. Using the same thresholds based on a
17 New Zealand protocol regardless of the farm system, commercial herds achieved most welfare
18 measures thresholds, but semi-commercial and communal herds attained acceptable welfare
19 thresholds only in a few measures. For measures with significant welfare implications, the stricter
20 threshold was retained, while derived thresholds appeared more appropriate for commonly
21 occurring traits but of less welfare importance, and some measures threshold were temporarily
22 adjusted to reflect drought conditions. The welfare assessment identified the strengths and
23 weaknesses in thresholds in measures across the farm types, which is envisioned to draw attention
24 for remedial intervention to improve welfare standards of the beef industry.

25 **Abstract:** The study aimed to develop standards for a welfare assessment protocol, by validating
26 potential categorisation thresholds for assessment of beef farms in various beef cow-calf
27 production systems in Namibia. Forty measures combined from a New Zealand-based protocol
28 plus Namibia-specific measures, were applied on 55 beef farms (17 commercial farms, 20
29 semi-commercial and 18 communal village farms) during pregnancy testing, and a questionnaire
30 guided interview. The categorised measures on a 3-point welfare score of 0: good 1: marginal and 2:
31 poor/unacceptable welfare were subsequently compared with derivation of thresholds based upon
32 the poorest 15% and best 50% of herds for each measure. Overall combined thresholds of
33 continuous measures across the 3 farm types, showed 10/22 measures that posed welfare
34 compromise across Namibia, where commercial farms had 4/22 measures and semi-commercial
35 and communal village farms had 12/22 and 11/22 respectively with high thresholds. Most
36 measures-imposed thresholds were retained because of significant importance to welfare of
37 animals and preventiveness of the traits, while leniency was given to adjust good feeding and
38 mortality measures to signify periods of drought. Handling measures (fearful, falling/lying) and
39 abrasions thresholds were adjusted to reflect the temporary stress caused by infrequent cattle
40 handling, and faulty yard designs/design and possible cattle breed influence on handling. Hence,
41 the country needs prioritised investigation of underlying contributing factors and remediation to
42 reduce the high thresholds.

43 **Keywords:** animal welfare assessment; categorisation; beef cow systems; semi-arid rangelands;
44 Namibia

1. Introduction

Animal welfare in Namibia has been increasingly acknowledged as important in the production and trade of farm animals and their products. International trading partners for Namibia's beef are seeking assurances that acceptable animal welfare standards are maintained. This requires concrete animal welfare legislation including a standardised validated protocol for assessment of beef cattle welfare. Currently, the Farm Assured Namibian Meat (FAN Meat) scheme provides assurance that Namibian beef is produced under a natural, safe environment and is traceable and of good quality, but the scheme is not comprehensive as a welfare assessment protocol [1]. For example, key aspects of the FAN Meat animal welfare standards pertain to livestock keeping and transportation and state that animal handling facilities must be adequate to ensure ease of handling and to prevent injuries to animals but does not provide specific recommendations or determine thresholds. The significant thresholds relevant to animal welfare covered under the FAN Meat scheme are those related to dehorning and castration which require that these procedures are undertaken in animals younger than 2 months of age.

Currently, welfare standards in Namibian cattle are only routinely assessed at export abattoirs [2] with no standardised on-farm assessment. A validated, comprehensive, farm-based animal welfare assessment protocol with thresholds comparable to those used in other beef exporting countries would thus be useful for Namibia.

On-farm welfare data from both categorical measures (i.e. recorded at the individual farm level as good, marginal and poor welfare) and continuous measures (recorded as the percentage of cattle affected on each farm) need meaningful interpretation to reflect the welfare status of farms [3]. The results of categorical measures provide clear indications for farmers and their advisors regarding future actions: good welfare – continue current practices; poor welfare – remedial action is needed; marginal welfare – assess current practice and aim for improvement [4]. The raw results for continuous measures do not provide such clear indications; they may be useful for benchmarking but unless thresholds are identified at which action should be taken [5], farmers and their advisors may simply focus on prevalence as a means for determining actions rather than whether the prevalence is acceptable or not. Putting achievable thresholds across the prevailing beef production systems is critical for the country to benchmark and apply adequate remedial strategies for identified welfare compromise [6, 7].

The aim of this study was to replicate, using Namibian data, the process used by us, as part of the development of an animal welfare assessment protocol for extensive beef systems in New Zealand [4], to develop thresholds which could be used to categorise continuous animal welfare measures into acceptable, marginal and non-acceptable welfare. The aim was achieved through the setting and comparing of imposed categorisation thresholds with derived thresholds to see, across the farm systems in Namibia, which were the most appropriate thresholds to use to identify poor welfare and to stimulate improvement.

2. Materials and Methods

2.1 Description of the study areas

The study areas were representative of their farm types within Namibia as described by Kaurivi (Part 1). In summary, **commercial farms** (n =17 farms/herds) (Gobabis area, Omaheke region, eastern Namibia) were large privately-owned farms (range 3000-10000ha) that were individually fenced off in several grazing paddocks. **Semi-commercial village farms** (n =20 herds) in Okakarara area (Otjozondjupa region) were government-owned settlement villages predominantly inhabited by farmers who were dependent on livestock production for their livelihood. Multiple families' (~10-30 families) cattle grazed and shared water on the same permanent communal land with limited or no internal and external border fencing. These farms were eligible to produce beef for export markets. **Communal village farms** (n =18 herds) in Opuwo/Kaokoland area, (Kunene region, north-western

Namibia) were exclusive government-owned communal settlements with inhabitants farming with small multipurpose (i.e. milk, meat, dung for building) cattle holdings mainly for subsistence. As on semi-commercial village farms, multiple families' (~10-30 families) cattle grazed and shared water on the same permanent communal land with limited or no internal and external border fencing. These farms were not eligible to produce beef for overseas export markets.

2.2. Welfare assessments

The protocol used is described in full in Kaurivi [8]. The welfare assessment took place in March/April 2019 (autumn) on 55 farms during yarding of 2529 cows for pregnancy testing. In the yards, observations were made in the race (or pens) of body condition, rumen-fill, physical health, presence of long/sharp horns and behaviour. Stockpersonship was evaluated as cows entered, were handled and exited the race (or, if no race, when cows were restrained for pregnancy testing in pens). The yard design and handling facilities were also evaluated for ease of handling of cows. A farm resource evaluation and a questionnaire guided assessment of health and management of the herd in the preceding 12 months was undertaken; i.e. castration, dehorning, cattle identification practices, vaccinations, cattle deaths and disease incidences.

2.3. Data analysis

All data were analysed using SPSS version 24 (IBM). Descriptive statistics for continuous measures were used to capture central tendency (median), and range (minimum and maximum). Qualitative methods were used to analyse the frequency of ordinal measures. The Shapiro-Wilk test was used to test for normality, and log10(n+1) was used to transform those variables that were not normally distributed.

2.4. Categorisation and refinement of measures

Categorisation of measures was principally based on the New Zealand protocol on a 3-point welfare score of 0: good welfare (no intervention necessary, but monitoring) 1: marginal welfare (plan for intervention, increase monitoring), and 2: poor/unacceptable welfare (immediate intervention required) [4]. The initial categorisation of welfare thresholds in the New Zealand protocol was based upon the authors' perception of acceptable welfare standards and the consensus of the literature, with subsequent derived thresholds being based on values associated with best 50% (arbitrary) and poorest 15%. The 15% was chosen to fit with the '15% rule' where animals (in this case herds) below this point are considered as worse-off in terms of animal welfare compromise [9, 10]. The New Zealand thresholds were compared with the pre-determined thresholds of each continuous measure in the current data from the three farming systems in Namibia. For example, for good health measures (i.e. blindness, mortality), painful conditions (e.g. dystocia) and absence of injuries or physical impairment the welfare thresholds were kept the same at 2%. For the additional Namibia-specific measures, the thresholds for extraneous (multiple) brands/cuts (5%), long/sharp horns (10%) and external parasites (10%) were based on authors' opinion of good welfare. The threshold (10%) for tail twisting was aligned with that of hitting of cows. The distance to water and grazing categorisation was based on Holechek [11] and the use of electrical prodders (<1%) on Grandin [12]. The imposed thresholds were applicable for all farm types; there was no division between village farms or from commercial farms. Farms/herds were not given an 'overall' welfare score [13] because each of the measures were considered important, and an overall acceptable score may mask unacceptable welfare in some measures [5]. Categorisation thresholds and details of how each measure in the Namibia protocol was assessed are presented in Table 1-3.

Table 1. Categorical ranking of good feeding and appropriate environment measures in the proposed Namibia extensive beef cow-calf systems protocol

Welfare Criteria	Animal welfare measure/indicator	Scoring description	Categorical ranking
Absence of hunger	Body condition score (thin cows)	% thin/emaciated cows in herd of score (score 1-2 .5) on 1-5 scale; [14].	0: 0-5.0%, 1: 5.1-10%, 2: >10%
	Rumen fill score (poor rumen fill)	% of animals with hollow/ empty rumen observed in the race [15].	0: 0-20.0%, 1: 20.1-50%, 2: >50%
	Distance to grazing	The questionnaire asked how far cattle had to walk to access grazing. (This included the distance to grazing for cattle that daily come to drink after grazing at water points that are provided close to yards).	0: 0- 1.60km 1: 1.61km-3.2km 2: > 3.2km
Absence of thirst	Distance and availability of water	Average distance to access water. (Distance to water was estimated as the distance to grazing as water points are close to yards and cattle come to drink after grazing in some herds).	0: 0- 1.6.0km 1: 1.61km-3.2km 2: > 3.2km
Comfort around resting	Dirty body	Total number of animals assessed as having dirty tail, hind and flank (>25% of combined areas covered with dirt or manure).	0: 0- 10.0%, 1: 10.0-20%, 2: >20%
Ease of movement	Absence of hazardous objects/environment	Hazardous objects observed in the yard and paddocks (i.e. sharp objects lying around, steep hills).	0: no hazards 1: 1or 2 hazards 2: 3 or more hazards or cattle had to fall in any hazard

156 **Table 2.** Categorical ranking of good health measures in the proposed Namibia extensive beef cow-calf systems protocol

Welfare Criteria	Animal welfare measure/indicator	Scoring description	Categorical ranking
Absence of injuries/physical impairment	Abrasions, Swelling Hair loss/hairless	% of observed cows with abrasions/fresh scratches, swelling or hairless patches (>1 cm).	0: 0.0%, 1: 0.1-2%, 2: >2%
	Extraneous cattle markings/ branding wounds (e.g., multiple brands, dew lap cutting)	% of observed cows with brand mark wounds (>2cm) or more than one extraneous brand mark (i.e. stock brand, initials or name of a farmer branded).	0: 0.0%, 1: 0.1-5%, 2: > 5%
	Size and shape of horns	Number of observed cows with sharp/long horns (> 5cm in length, sharp and forward facing to pose a risk of injuring others).	0: 0-5.0%, 1: 5.1-10%, 2: >10%
Absence of disease	Blindness, Ocular and Nasal discharges	% of observed cows with blindness in one or both eyes. % of observed cows with ocular and nasal discharges extending 2cm.	0: 0.0%, 1: 0.1-2%, 2: >2%
	Lameness	% of observed cows with gait abnormality.	0: 0.0%, 1: 0.1-2%, 2: >2%
	Diarrhoea	% of observed cows with evidence of diarrhoea (more than a hand wide on both sides from base of tail).	0: 0-10%, 1: >10-20%, 2: >20%
	Dystocia	% of cows recorded with difficult births.	0: 0.0%, 1: 0.1-2%, 2: >2%
	Mortality rate	Sum of accidental deaths, deaths due to disease, or culling because of disease/accidents the last 12 months.	0: 0.0%, 1: 0.1-2%, 2: >2%
	Fly burden Tick burden (External parasite burden)	Proportion of observed cows with more than an estimated 20 flies (i.e. horse flies). Proportion of observed cows with more than an estimated 20 ticks on any part of the body of a cow.	0: 0-5.0%, 1: 5.1-10%, 2: >10%

Painful procedures	Disbudding Castration	Specify age at disbudding and use of anaesthetics. Specify age at castration and use of anaesthetics.	0: No disbud/castration 1: ≤2 months 2: >2 months 0: No disbud/castration 1: use of anaesthetics 2: no anaesthetics
	Ear tagging/notching	Specify age at ear tagging and ear notching and with/without use of anaesthetic.	0: no tag or use anaesthetics 1: tag with no anaesthetics 2: notching/cutting with no anaesthetics
	Hot-iron branding	Record branding events and use of local anaesthetic (from questionnaire).	0: no branding or use anaesthetics 1: one brand (compulsory) 2: more than 1 brand
	Use of electrical prodders	Estimated proportion of cows prodded with an electrical goad while drafted or standing in the race, pens or yards.	0: no prodding 1: few/ occasional prod (≤ 1% cows) 2: many/frequent prod (>1% cows prodded)

157 **Table 3.** Categorical ranking of appropriate stockpersonship measures in the proposed Namibia extensive beef cow-calf systems protocol

Welfare Criteria	**Animal welfare measure/indicator**	**Scoring description**	**Categorical ranking**
Stockpersonship animal-based measures in and out of race	Fearful/agitated	% cows showing fearful/agitated behaviour (climbing on others or attempting to escape).	0: 0.0%, 1: 0.1-5%, 2: > 5%
	Falling	% cows lying in or falling in race/forcing pen or on exiting.	0: 0.0%, 1: 0.1-2%, 2: >2%
	Stumbling	% cows stumbling while exiting to paddocks.	0: 0.0%, 1: 0.1-5%, 2: > 5%

	Running	% cows running out of the race/holding pens into paddocks.	0: 0-5.0%, 1: 5.1-10%, 2: >10%
Animal handling stockpersonship and resource-based measures	Mis-catching (in chute/race)	# of cows mis-catch with gates on any part of the body either in the race or chute head bale. If no race, available mis-catch was recorded if more than one attempt was made to capture/restrain an individual animal with ropes or if a cow did not stand still when a rope was secured around the legs.	0: no mis-catch, 1: mis-catch ≤1%, 2: mis-catch >1%
	Hitting	% of cows hit or poked with moving aids.	0: no hitting 1: occasional/few hit 2: frequent hit/poke (>10% cows)
	Tail twisting	Estimate the proportion of cows with tail twisted while drafted or standing in the race or pens.	0: no twisting 1: occasional/few twist (≤ 10% of cows) 2: frequent twist (>10% of cows)
	Noise of handlers Noise of equipment/machinery Dogs noise around the yard	Evaluate noise of handlers, noise of equipment (race or chute gate) and machinery (generators etc.) and observe the presence and noise frequency of dogs around the yard.	0: no noise/dogs 1: minor audible/occasional noise 2: unpleasantly/ persistent noisy handlers/equip/dogs
	Health checks	Frequency of health checks on cows during pregnancy.	0: daily 1: once-twice/week 2: more than weekly
	Yarding frequency	Frequency of yarding of cows per year for handling or restraining.	0: >4 times, 1: 3-4 times 2: 0-2 times
	Yard flow/handling of cattle	Yard flow of cattle influenced by handling facilities design/quality.	0: very effective cattle flow 1: effective but with flaws 2: difficult flow

3. Results

3.1. Categorisation results

Categorised observational data are illustrated in Figure 1 (measures of feeding, and environmental factors), Figure 2 (health indicators), Figure 3 (frequencies of painful procedures), Figure 4 (animal-based stockpersonship scores) and Figure 5 (resource and management-based stockpersonship scores).

Feeding measures: Cattle on commercial farms did not walk long distances to grazing and water (<1.6 km - 3.2 km), and there were no emaciated cows observed, and 76% herds were in good body condition and 88% of cows had good rumen fill. Semi-commercial and communal herds obtained a good welfare score for BCS only in 40% and 17% of herds, respectively, of which most cattle herds in communal villages were classified as more emaciated (<2/5 scale) than just thin. Cattle walked long distances to water and grazing (>3.2 km) and all village farm herds scored poorly in this. Hazards were mostly marginal across the farm types, with semi-commercial and communal showing 35% and 33% of herds with poor welfare score.

Health observations: The worst scores were observed for abrasions and mortality at all farm types. Only 35% of commercial and 25% of semi-commercial herds had a good score for abrasions and none of the communal herds had a good score for abrasions. Mortality rate was categorically poor in 65%, 95% and 100% of commercial, semi-commercial and communal herds, respectively. Fifty percent of semi-commercial herds had a good score for dystocia, while only 24% and 33% of commercial and communal herds did, respectively. Lameness and extraneous brands/cuts were worst in communal followed by semi-commercial herds. The tick and fly burden were worse in semi-commercial with 20% and 40% herds with poor score, and 17% and 11% of communal herds had poor welfare for ticks and flies respectively, while the majority of commercial herds had a good score for both ectoparasites types.

Painful management measures: Procedures were performed without the use of anaesthesia or analgesics. All farm types identified cattle with ear tags (marginal welfare), while most herds at the village herds had poor scores for ear notching (with knives) and extraneous branding/cuttings. In relation to disbudding, those commercial herds who disbud, the mode for age was 2 months, while it was 6 months at the village herds. Only 29% of herds had cows with long/sharp horns in commercial compared to 95% and 100% for semi-commercial and communal herds respectively. Communal village farms had the most herds with poor scores for dehorning, castration, and ear tagging/notching.

Animal-based stockpersonship measures: Scores were similar across the farm types, except for electrical prodders that was only used at 5/17 commercial herds, obtaining a poor score at those herds (>1% cows prodded). Commercial farms had the least herds with poor welfare for fearful/agitated, hitting and tail twisting. All the farm types scored poorly (>2% threshold) for falling/lying.

Resource- and management-based stockpersonship measures: Good welfare score was showed for equipment noise and dog noise and health checks, at most herds across the farm types. Commercial farms had less noisy handlers and more herds with > 4 times yarding frequency per year (good welfare), and effective yard handling/flow. The communal (95% of herds) cattle yarding frequency/year (2 or less times) was the poorest than the other farm types.

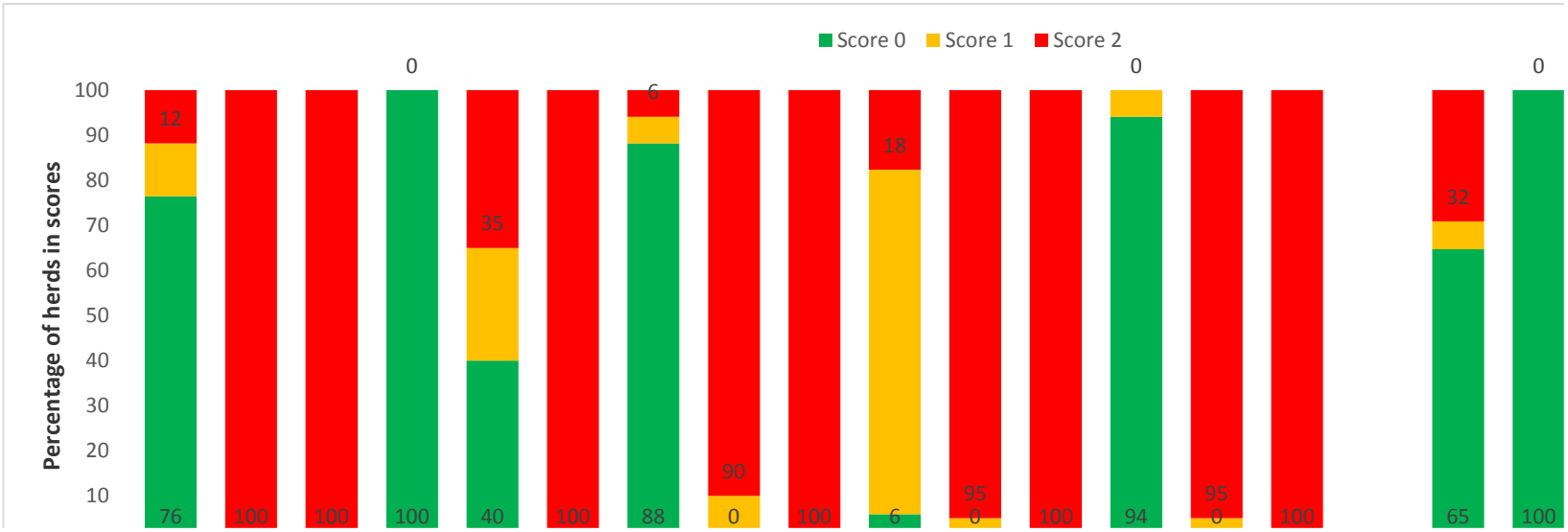

Figure 1. Good feeding and environment measures (separated by a gab before dirtiness) at the commercial (CF), semi-commercial (SCV), and communal (CV) beef cow herds in Namibia showing percentage of herds per welfare scores. * Thin included all thin cows ≤ 2.5/5 scale and emaciated was only cows with BCS 1-2/5 scale. See Table 1 for measures scoring descriptions and categorical ranking.

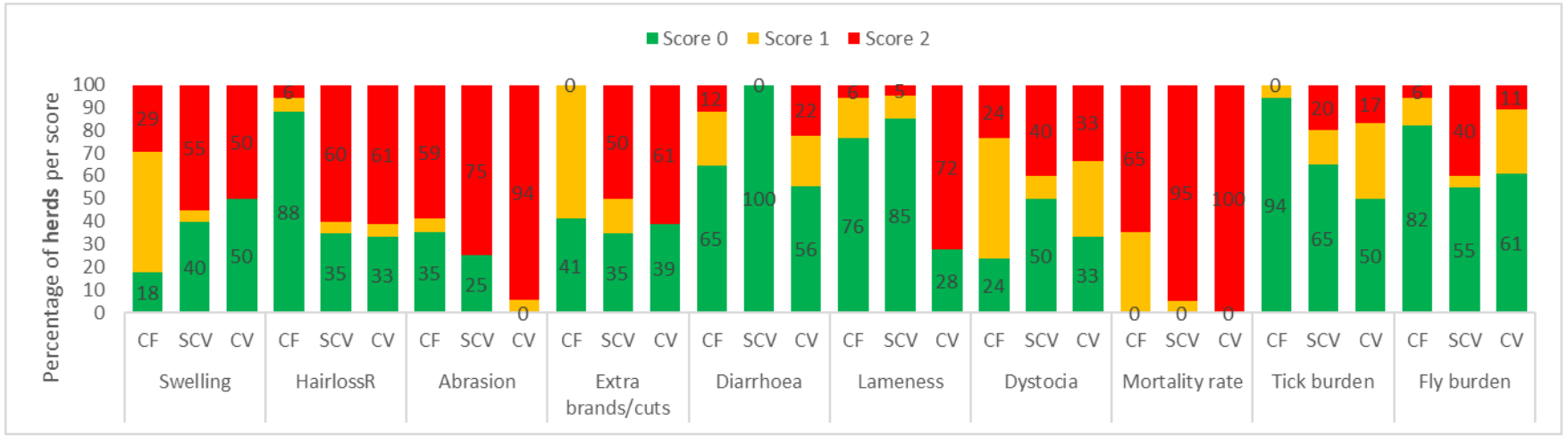

Figure 2. Categorised health measures at the commercial (CF), semi-commercial (SCV), and communal (CV) beef cow herds in Namibia showing percentage of herds per welfare scores. See Table 2 for measures scoring descriptions and categorical ranking.

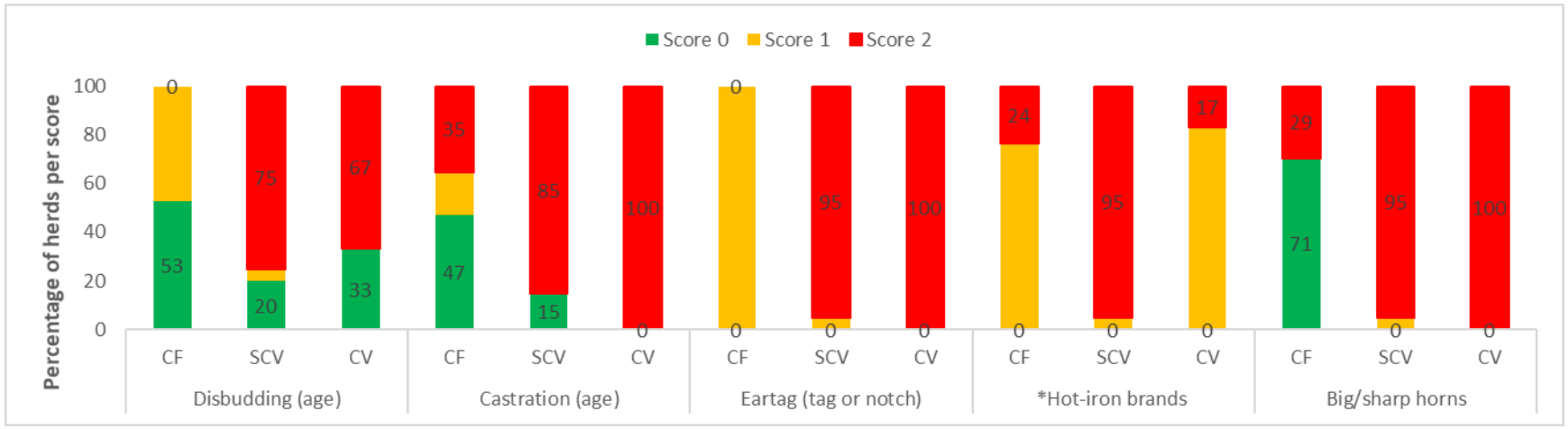

Figure 3. Painful management procedures at the commercial (CF), semi-commercial (SCV), and communal (CV) beef cow herds in Namibia showing percentage of herds per welfare scores. * Hot-iron branding described one compulsory brand (score 1) or more than the one brand (score 2). See Table 2 for measures scoring descriptions and categorical ranking.

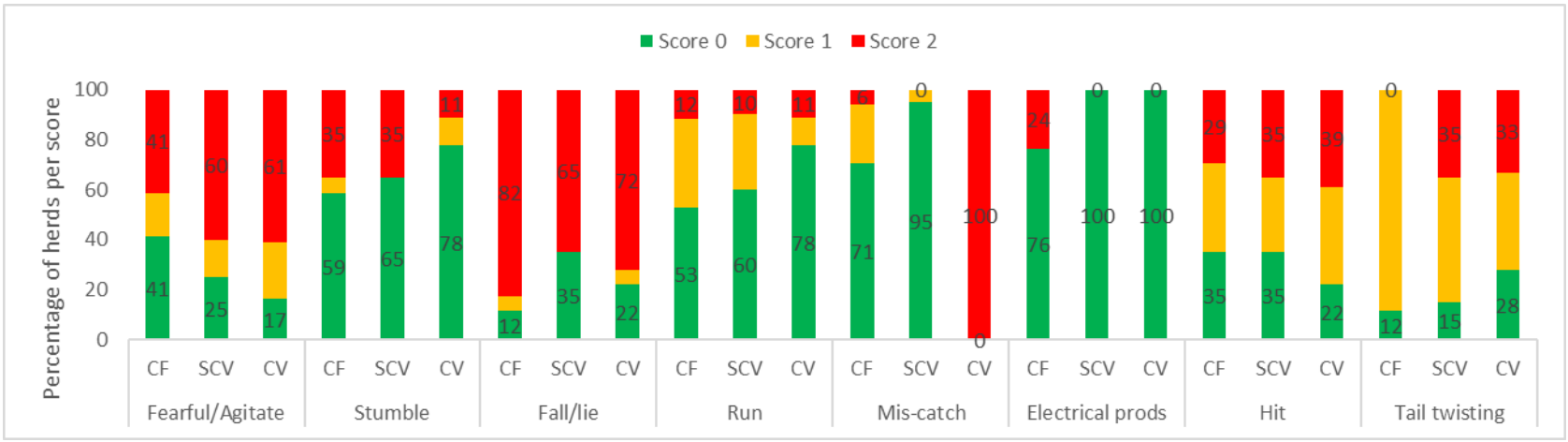

Figure 4 Animal based stockpersonship measures at the commercial (CF), semi-commercial (SCV), and communal (CV) beef cow herds in Namibia showing percentage of herds per welfare scores.

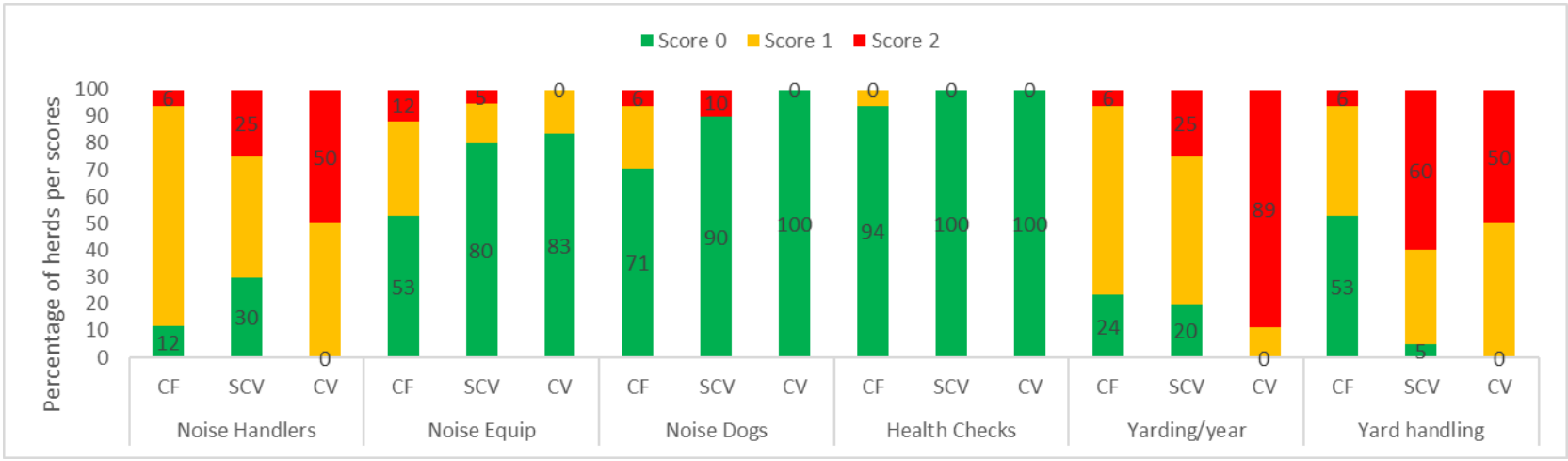

Figure 5. Resource- and management based stockpersonship measures at the commercial (CF), semi-commercial (SCV), and communal (CV) beef cow herds in Namibia showing percentage of herds per welfare scores.

3.2. Refined thresholds

Derived threshold values for the three farm types are shown in Table 5. For commercial, of the 22 measures, only falling/lying was normally distributed. The measures that were normally distributed for semi-commercial herds were thin and poor rumen fill cows, long/sharp horns, and mortality rate. In addition to these latter measures, abrasions, falling/lying and fearful/ agitated cows measures were also normally distributed for communal herds. Commercial herds had 4/22 measures (abrasion, mortality, fearful and falling/lying) with a derived red threshold that were >2 times the imposed threshold, with ratios ranging from 2.5 (fearful/agitated) to 6.9 (falling/lying). Including these measures, both semi-commercial and communal herds had similar total of 12/22 and 11/22 measures respectively with a derived red threshold that was >2 times the threshold imposed by categorisation. The measures were related to good feeding (thin, emaciated and poor rumen fill cows), extraneous brands/cuts, long/sharp horns, swelling and hair loss, and as well as dystocia at semi-commercial herds and lameness at communal herds. All three farm types had similar red thresholds (~12%) for cows falling/lying during handling. The highest red threshold was thin cows for communal (97.7%), whilst the proportion of emaciated cows was 82.9% for communal herds.

All combined derived thresholds for the 55 beef cow herds are showed in Table 6. In this regard, 10/ 22 measures had derived red threshold that were >2 times the imposed threshold with ratios ranging from 2.4-16.6%. These included all the four measures where commercial herds failed (abrasion, mortality, fearful and falling/lying) and in addition, three measures related to good feeding (thin, emaciated, poor rumen fill) and swelling, hair loss and long/sharp horns.

238 **Table 4.** Ratio of red thresholds over the imposed categorisation value of the 3-beef cow-calf farming systems in Namibia.

Measures	Imposed categorisation threshold (%)	Commercial (CF; n =17)				Semi-commercial (SCV; n =20)				Communal (CV; n=18)			
		Mean (%)	Orange threshold	Red threshold	Ratio of threshold	Mean (%)	Orange threshold	Red threshold	Ratio of thresholds	Mean (%)	Orange threshold	Red threshold	Ratio of thresholds
#Thin cows	10	7.2	2.5	11.6	1.2	70.7[n]	65.6	102.6	**10.3***	97.7 [n]	97.6	102.7	**10.3***
#Emaciated cows	10	0.0	0.0	0.0	0.0	11.1 [n]	5.4	23.8	**2.4***	82.9 [n]	81.8	98.0	**9.8***
Poor rumen fill	50	4.4	1.2	6.3	0.1	49.1 [n]	44.7	72.9	1.5	76.2 [n]	74.3	95.7	1.9
Dirtiness	20	0.7	0.3	1.5	0.7	0.0	0.0	0.0	0.0	2.0	0.8	3.6	0.2
Swelling	2	2.1	1.6	3.8	1.9	4.9	2.2	9.1	**4.6***	3.3	1.7	6.7	**3.3***
Hair loss	2	0.3	0.1	0.7	0.3	3.6	1.9	7.2	**3.6***	6.8	3.5	14.9	**7.5***
Abrasion	2	3.2	1.9	6.6	**3.3***	8.7	4.8	18.9	**9.5***	20.4 [n]	16.9	35.7	**17.8***
Extraneous brands/ cuts	5	1.0	0.8	2.1	0.4	8.1	3.0	15.1	**3.0***	10.7	4.0	19.1	**3.8***
Long/sharp horns	10	7.2	3.1	13.6	1.4	45.5 [n]	40.1	70.6	**7.1***	59.3 [n]	54.9	88.3	**8.8***
Blindness	2	0.3	0.2	0.8	0.4	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.1
Ocular discharge	2	0.1	0.1	0.3	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.1
Nasal discharge	2	0.1	0.1	0.3	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.1
Diarrhoea	10	3.4	1.7	6.9	0.7	0.1	0.1	0.3	0.0	7.1	3.5	14.9	1.5
Lameness	2	0.5	0.3	1.1	0.6	0.3	0.1	0.7	0.4	5.1	2.8	10.5	**5.3***
Dystocia	2	0.9	0.7	1.7	0.8	2.2	1.2	4.5	**2.3***	1.9	1.3	3.8	1.9
Tick burden	10	0.4	0.1	0.9	0.1	11.8	2.6	17.3	1.7	6.0	2.8	12.2	1.2
Fly burden	10	1.8	0.6	3.2	0.3	14.1	3.5	25.2	**2.5***	9.5	3.3	17.2	1.7
Mortality rate	2	3.4	2.8	5.4	**2.7***	12.3 [n]	9.5	23.9	**11.9***	13.2 [n]	10.7	22.7	**11.4***
Fearful/Agitate	5	6.2	3.4	12.7	**2.5***	7.1	4.5	14.8	**3.0***	7.4 [n]	5.2	15.6	**3.1***
Fall/lie	2	6.5 [n]	4.8	12.9	**6.4***	6.4	2.7	12.7	**6.4***	5.7 [n]	3.8	12.0	**6.0***
Stumble	5	3.8	1.8	7.5	1.5	3.9	1.2	6.2	1.2	1.8	0.6	3.2	0.6

Run exit	10	5.6	3.5	11.2	1.1	3.3	1.2	6.2	0.6	3.1	1.4	6.0	0.6

[n] **Measures were normally distributed.**

*** Measures had the ratio of derived red threshold: imposed threshold that was >2 times.**

#Thin cows included all cows with BCS ≤ 2.5/5 scale and emaciated was only the proportion of thin cows with severity of BCS 1-2/5 scale.

242 **Table 5.** Combined ratio of red thresholds over the imposed categorisation value of the 3-beef
243 cow-calf farming systems in Namibia (n =55).

Measures	Imposed categorisation threshold (%)	Mean (%)	Orange threshold (%)	Red threshold (%)	Ratio of red thresholds/ Imposed
#Thin cows	10	59.9	29.4	166	**16.6***
#Emaciated cows	10	31.2	0.9	62.4	**6.2***
Poor rumen fill	50	44.2	20	121.8	**2.4***
Dirtiness	20	0.9	0.3	1.6	0.9
Swelling	2	3.5	1.7	5.2	**2.6***
Hair loss	2	3.6	1.3	6.6	**3.3***
Abrasion	2	10.6	6.5	25.2	**12.6***
Extraneous brands/ cuts	5	6.8	2	8.9	1.8
Long/sharp horns	10	38.2	14.7	82	**8.2***
Blindness	2	0.1	0.1	0.4	0.2
Ocular discharge	2	0	0	0.2	0.1
Nasal discharge	2	0	0	0.2	0.1
Diarrhoea	10	3.4	1.3	6	0.6
Lameness	2	1.9	0.7	3.4	1.7
Dystocia	2	1.7	0.7	3.3	1.7
Tick burden	10	6.4	1.6	8.9	0.9
Fly burden	10	8.8	2.2	13.5	1.4
Mortality rate	2	9.8	6.9	18.1	**9.1***
Fearful/Agitate	5	6.9	4.3	14.2	**2.8***
Fall/lie	2	6.2	3.6	12.7	**6.4***
Stumble	5	3.2	1.2	5.4	1.1
Run exit	10	3.9	1.8	7.7	0.8

244 *** Measures had the ratio of derived red threshold: imposed threshold that was >2**
245 **#Thin cows included all cows with BCS ≤ 2.5/5 scale and emaciated was only the proportion of thin cows**
246 **with severity of BCS 1-2/5 scale.**

247 **4. Discussion**

248 Kaurivi (Part 1) compared the effects of farm production systems on the welfare of beef cows
249 with results showing better welfare on commercial, followed by semi-commercial, and the
250 communal herds in the least. The current paper used that data to develop standards for a welfare
251 assessment protocol, by validating potential thresholds which could be used to categorise
252 continuous animal welfare measures into acceptable, marginal and unacceptable welfare for
253 assessment of beef farms in various cow-calf production systems in Namibia. The categorised
254 measures scores showed a marked separation of commercial farms from semi-commercial and
255 communal village farms, but no separation between the village farm types. The same thresholds
256 were used for all farm systems, regardless of the village herds not achieving imposed thresholds that
257 are achievable at commercial herds, because the impact of a situation or condition on the welfare of

the cow is not mediated by the type of farm she lives on. Setting of thresholds should reflect standards of "what should be and not what is", and common findings that are compromising the welfare of animals should not be accepted as acceptable standards [16].

The findings indicate that to improve most of the compromised traits, development of interventions should be geared towards what works in village farm herds. Whereas for some other traits, there are herds exceeding the threshold in all herd types, and solutions must be developed for all herd type. Although the long term target is to have improved derived threshold in all measures at all the farms (a target of at least 50% of the herds in good welfare), an initial target to improve the worst 15% of herds might be the logical first step, and then revise the red thresholds, to gradually to pull the recovering herds to better. It is risky to set a target that 90% of the herds currently fail; this may deter farmers from making improvements and instead dismiss the target as unrealistic.

With regards to *good feeding*, with below-average rainfall (since 2013) across Namibia, the 2019 drought (the driest year in 90 years) was treated as a state of emergency by the government by the middle of that year [17]. The impact of drought had more dire consequences on the village farm types (i.e. high thin and poor rumen thresholds and long distance walking to grazing) than for commercial farms, because of the challenges of communal grazing land without proper demarcation that doesn't allow sustainable rangeland management [18, 19]. In terms of identifying the need for nutritional intervention, stringent thresholds for low BCS (between 5-15%) was supported [20, 21]. This should even be truer for emaciated cows (BCS <2/5 scale) that indicate a greater unacceptable compromise of cattle welfare [14]. In New Zealand, recommendations are that cows' body condition not to be below 4/10 scale [22] and under Australian legislation, it is not acceptable for producers to allow animals to die because of starvation and thirst [23]. For Namibia, an adjustable lenient threshold setting could be climate-responsive, i.e. in a drought, cows are going to get thinner than a normal year, and a farmer who has thin cows in a good year is a worse farmer than a farmer who has the same prevalence of thin cows in a drought, but the level of emaciation in cattle is unacceptable regardless. Taken together, an adjusted threshold to reflect drought conditions could be 30% (orange thresholds 29.4%), while retaining the imposed threshold of 10% during sufficient rainfall periods. Nonetheless, drought in Namibia is predicted be more frequent than before, due to the impact of climate change [19]. Hence, there is a need to put mitigating strategies in place (i.e. supplementary feeding, targeted livestock grazing, and timely adjustments to animal numbers; [24, 25], especially in the village farms. Similar adjustments could also apply to poor rumen fill (RFS). However, the low imposed threshold of 50% is appropriate for the detection of poor nutrition of extensively reared cows that are likely to be drafted a day before an assessment.

Regarding *appropriate environmental issues*, dirtiness and diarrhoea were the only measures where the thresholds (both thresholds were 20%) fit for Namibia were reduced. In New Zealand, diarrhoea was faecal soiling due to the high-water content in the pasture. Thus, a 5% threshold (between 3% and 6% orange and red threshold respectively) fit for Namibia where grass grows seasonally and between years, and where diarrhoea cases may also be of pathological nature (i.e. infectious causes, internal parasites, and plant toxicity) was essential. Similarly, a 5% threshold was more fitting for dirtiness where cattle on drier pasture are less dirty; red thresholds were only up to 3.6% in this study (Table 4). Moreover, stringent thresholds might also not be relevant for dirtiness, a welfare measure that is questionable for the assessment of cattle in an extensive system [4, 26], unless cattle were destined for slaughter [12].

For most *health-related measures*, the imposed thresholds were retained despite the high occurrence of traits, considering the welfare implications to animals, possible preventative and mitigating strategies available. For painful conditions like lameness and dystocia, a 2% threshold was retained and is attainable on Namibia beef herds (mean 1.9 and 1.7% respectively). For measures related to skin alterations (swelling, hair loss and abrasion) the derived thresholds were more than twice the imposed threshold for the combined herds, indicating high prevalence. The prevalence of swelling was attributed to faulty injections, thus, there is room for improving the skills of injections across all farm types, through awareness and training. Similarly, the high derived thresholds of hair loss at the village herds could have been prevented with preventative vaccination

of the endemic lumpy skin disease in the country. Hence, an imposed threshold of 2% was also retained as fitting for these conditions. On the other hand, the much higher prevalence of abrasions on cattle across all the beef farm types is indicative of a welfare concern in the country, so an initial target of 2% would likely be unrealistic. However, abrasions are painful and cause suffering for the animal. Efforts should be directed toward identifying the causes of the abrasions and attempting to remove relevant hazards from the environment such as faulty yard designs and yard structural materials [26]. Given 59-96% of herds in the different herd types exceed the imposed threshold, a higher threshold (e.g. 7%; orange threshold) could be applied initially to allow improvements to be made in the worst affected herds first.

Setting welfare thresholds for any measures should reflect the significance of that trait to the welfare of animals and not necessarily according to the status quo. A good example was the mortality rate that varies in extensive beef systems with the type of production system, the location, and herd management [27, 28]. In this study, cattle losses indicated a worrisome occurrence in all farm types (derived thresholds >9 times the imposed thresholds). Mortality rate on commercial herds at an average of 3.4% (range 0-11.5%) was consistent with an average of 3.5% cattle losses in another commercial herd in Namibia over a 13 year period [28]. These figures are similar to cattle losses (average 3.9%) at 25 beef farms in New Zealand, where the feasibility of categorisation thresholds used in this study was verified [29]. However, an imposed threshold of 2% was retained in that protocol in view of the significance of the measure to the welfare of cattle [4], and the same threshold was thus taken for Namibia. Judging from the mortality rate median of 2.4% at commercial herds, there is potential for attaining the imposed thresholds. However, like for feeding measures, an adjusted lenient threshold to reflect drought condition (i.e. increased predation, poor nutrition effects), that contributed to cattle losses could be 7% (orange thresholds of combined herds). It will be interesting and useful to validate mortality threshold at farms during years of an average rainfall. Setting mortality threshold for Namibia beef production systems is an important step towards creating awareness of the risks of cattle losses on the farm towards, strategising remedial actions, and thus, a stringent threshold is worth keeping.

Ectoparasites have a significant impact on the welfare of animals (i.e. transmit diseases, biting stress, skin injuries, and irritation) and a high incidence can markedly impair farm productivity [30, 31]. However, the impact of different parasites on animals is different, i.e. cattle with high-level tick burden are more likely to be welfare compromised than those with fly burden. Thus, the category imposed as an acceptable or nonacceptable compromise might have to vary depending on the welfare impact of each parasite type. In the present study, the number of ticks or flies on any animal to be regarded as a burden was the same at 20, and the threshold for unacceptable welfare was the same at 10%. The presence and thresholds setting of ectoparasites on extensive cattle hasn't been validated in animal welfare assessment protocols, and it is worthwhile validating our findings elsewhere in similar production systems to determine acceptable thresholds. For example, in northern Australia, treatment is only recommended for individual beef cattle infested with more than 200 buffalo flies [32]. Most of the predominant cattle breeds in Namibia are also tick tolerant [33] and ectoparasites burden is significantly influenced by seasonality and environmental factors [34]. Thus, thresholds might differ in countries, production systems and seasons. Nonetheless, a threshold of 10% (for both flies and ticks) is attainable across beef production systems with preventative herd health management. This was evident in the low mean incidence of both ticks and flies at commercial farms where ectoparasites treatment is commonly done.

With regards to *painful management procedures*, unlike castration and disbudding that can be performed at an early age (<2months) and with anaesthesia to mitigate pain [35], the downside of branding early is that the brand becomes unreadable with time in adult cattle. Rebranding is a permissible requirement for cattle trading in Namibia [36] but the practice of multiple brands requires longer restraining of animals and causes more wounds on any part of the animals' body [37]. Farms with only the initial brand were given a marginal score of welfare, while the extraneous brands/cuts (to mitigate the risk of stock theft) were regarded more extreme and indicated a poor welfare score. The village farms had derived red thresholds that were ≥ 3 times higher than their

imposed thresholds for extraneous brands/cuts, indicating a trait with a high occurrence at these farm types. However, the imposed threshold of > 5% of cattle in a herd with this trait (also close to the orange threshold of 3% and 4% at the villages) was retained as reasonable to bring awareness to these painful practices. Hence, the mounting scientific evidence that relates hot-iron branding to the welfare compromise of cattle [38-40] could guide Namibia to abolish hot-iron branding and join many countries that are increasingly prohibiting this practice [37]. To this end, mitigating strategies for stock theft along with awareness of compromising welfare practices (e.g. dewlap cuts, ear cuts) are immediate remedial actions to be taken to improve cattle welfare at most herds in the village farms.

The threshold (10%) considered as unacceptable welfare for herds with long/sharp horns was motivated by difficulty in handling, injuries, bruises, and condemnation at slaughter [41] that are associated with horned cattle. In this study, herds with long/sharp horns had a combined derived red threshold that were more than > 8 times higher than their imposed thresholds. Arguments are many for keeping of horned cattle; for example, traditional customs and sacredness at some households [8], natural tools against predation [41, 42] and for behavioural and physiological functions of cattle [41]. Thus, keeping a proportion of cows with horns e.g. 40% (close to 38% orange threshold; Table 5) might be more appropriate as a compromise. Also, the downside of keeping the imposed 10% threshold than an adjusted 40% will be the caveats of increased disbudding of calves. Breeding for a polled state might solve the surrounding debate of keeping horned cows [43, 44]. Indeed, Broom, [45] advocated for holistic critical scrutiny of issues conflicting with animal welfare standards (i.e. horned cattle), and what is accepted as normal by the farmers is not necessarily acceptable for the welfare of animals [16]. Further investigation on the impact of keeping of horned cattle against predation mitigating advantage is, thus, worth an undertaking and thresholds might be adjusted accordingly.

For *stockpersonship and handling measures*, it appears that three main issues, namely 1) yarding frequency, 2) breed variations and 3) yard design/quality contributed to the high derived thresholds of fearful and falling/lying across the farm types. Fearfulness in cattle was associated with adverse handling [46, 47] and sub-optimal production and reproductive performance ([48, 49] . Thus, critical analysis and understanding of the causes of high incidences of fearful cattle in the country are important. In New Zealand, infrequent yarding of beef cattle was thought accountable for the adjustment of the original imposed 2% to 5%, a more appropriate derived red threshold. This adjusted threshold was used for Namibia, but all farm types still obtained high derived red thresholds. This may indicate a need for adjustment of the imposed threshold, for example to 7% (orange threshold). It is likely that the commonness of fearful/agitated behaviour may have been a temporary response to the infrequent handling and stressful environment caused by the yard's designs and/or construction quality (see Appendix A). The predominant Brahman cattle were also noted to exhibit flight behaviours (as was noted by Cooke [50]), which could explain the comparable fearfulness incidences at semi-commercial and communal herds, although communal herds with more tamer crossbreds and Sanga breeds were less restrained. Brahman cattle were also noted to lie in the race more than other breeds (mostly for no apparent reason), contributing to the high derived thresholds (ratio of 6 times) of falling/lying cows across all the farm types. Like fearfulness, an adjustment in the threshold from an imposed 2% to 7% (close to 6.2% orange threshold) might be suitable as the temporary stress of handling could have likely caused cattle to lie in the yards. However, the observation of breed influence on cattle behaviour and welfare compromise demands further investigation, for possible mitigation. Cattle lying in the race contributed to others falling on top of them, which led to compromised cattle flow and more use of electrical prodders, hitting and noisy handlers.

It was important for animal-based and stockpersonship assessments to be made while cattle were handled for purposes other than the assessment itself. Thus, it might be worth describing and validating yard construction and design quality in a welfare assessment, such as to define what entails a yard, differentiate those with enough holding pens, the race and chute as well as materials used e.g. metal, wooden poles, tree poles and thorny bushes (see Appendix A) for the different yard

designs and quality found at the farms). The definition of the yard quality and designs could bring awareness to the welfare compromise caused by poor yards [12, 26] and in return encourage channeling of resources, skills and knowledge for the construction and maintenance of better standards facilities.

Finally, the study was undertaken at only 55 herds, but all herds represented the prevailing production system in the three regions. The welfare thresholds need to be validated across multiple beef herds across the country with more assessors and consideration of the prevailing environmental conditions (e.g. seasonality and dry periods.) It is hoped that this categorisation will also be validated by expert opinions to apply the correct decisions when an assessment is made such as for on-farm benchmarking and certification of cattle or beef from such establishments. The current assessment results and thresholds could also be used as a basis for the welfare status of Namibia farms, such that, especially the village farms prioritise intervention areas of welfare compromise to either attain or maintain beef markets.

5. Conclusions

The study provided thresholds which could be used to categorise continuous animal welfare measures into acceptable, marginal and non-acceptable welfare, hence, providing guidance for when intervention was needed on Namibian beef farms. Commercial farms attained welfare measures thresholds based on a New Zealand protocol, which suggest opportunities to create a system and a suitable environment that promote animal welfare in Namibia. However, the same thresholds regardless of the system was set for the country's beef herds, and semi-commercial and communal herds showed less acceptable welfare of beef cows. The long-term target is to have improved derived threshold in all measures at all herds, but an initial target could be geared towards improving the worst 15% of herds. Adjusted lenient thresholds to reflect drought condition were suggested for measures related to good feeding and mortality, whilst the original imposed thresholds were still retained under "normal conditions". This was a good example of setting welfare threshold for "what should be and not what is". Nevertheless, it may be an advantage that the current thresholds were validated in the possible worst-case scenario that can hit the beef industry in Namibia. Some of the imposed thresholds (i.e. swelling, hair loss, dystocia, lameness) were retained because of the significant importance to welfare of animals and preventiveness of the traits. Handling measures (fearful, falling/lying) and abrasions thresholds were adjusted to reflect the temporary stress caused by infrequent cattle handling, and faulty yard designs and or constructions and possible influence of Bahaman cattle behaviour during handling. There is a need to validate this categorisation and scoring of measures on multiple farms, and with more experts in order to classify Namibian beef farms status correctly. It is to the advantage of Namibia to have a validated, comparable animal welfare assessment protocol based on other beef exporting countries to strive for maintaining good welfare standards across the beef production chains.

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Appendix A Various cattle handling facilities of different designs and made of different construction materials found at the beef cattle herds in Namibia

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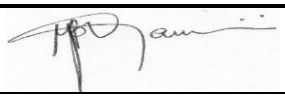
Candidate's Signature:	
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Chapter 5 GENERAL DISCUSSION

The overarching aim of the study was to develop an effective protocol for the assessment of welfare in pasture-based beef cattle in New Zealand, which with a few modifications would also be suitable for use on semi-arid rangeland farms in Namibia. To further test the applicability of the developed animal welfare assessment protocol, the study embarked on assessing an association between welfare assessments outcome and reproductive performance of beef cows on the extensive cow-calf system in New Zealand. The status of animal welfare relating production outcome (i.e. reproductive performance) is one way that may encourage farmers to adopt better cattle management practices.

5.1 Developing a welfare assessment protocol for extensive beef farms

The focus was to create a protocol where most animal-based measures are observed in cattle yarded for other operations than the welfare assessment itself, and which reflects common accurate handling practices of the actual situation. The focus was also on creating an "ideal" animal welfare protocol by generating measures that are likely to be repeatable and comparable if assessed by different observers on the same farm under the same management situation (Kirchner et al., 2014; Knierim & Winckler, 2009). It was important to choose measures that were feasible to be measured in the shortest possible time across operations. The current protocol timing was influenced by the progress of pregnancy testing of cows (i.e. depending on handling facilities such as absence of a race) and took on average 2.5 hours for a 100-cow herd in New Zealand and Namibia commercial farms, and it took longer at the village farms, with 2.5 hours needed for 50 cows. Nevertheless, this was an improvement to the Welfare Quality protocol for example that was criticised as too time consuming (Andreasen et al., 2014; Heath et al., 2014).

5.1.1 Identification and selection of welfare assessment measures

Animal welfare assessment protocols need to reflect the system they are being used in. During the protocol development process, it was evident that protocols developed for intensive systems (i.e. the Welfare Quality protocol), would need more modification when used in an

extensive system than protocols developed for extensive systems (even for very different extensive systems – i.e. the UC Davis protocol). On piloting the protocol, all measures (except bloat) that were in the UC Davis rangeland-based protocol were relevant to both New Zealand and Namibian production systems. On the other hand, nine out of 11 measures (e.g. access to pasture, space and cleanliness of water troughs, hock lesions, idling behaviour) that were irrelevant for extensive systems were from the intensive-based Welfare Quality protocol. The UC Davis protocol is focused on handling, and has no resource-based measures; so, it is less likely to exclude more measures. However, our conclusion is supported by only one loss (short tails) from New Zealand protocol and nine additions (e.g. distance to grazing, tick burden, hot-iron branding) for the Namibia-specific measures.

The additions of welfare measures were mainly influenced by the environmental conditions of the systems (Hernandez et al., 2017b). In New Zealand, environmental welfare threats were mostly related to environmental hazards, whereas predation, inadequate water and grazing, toxic plants, a harsh topography, and environmental challenges were present on Namibian beef farms. An obvious difference between New Zealand and Namibia farm systems was feeding. Provision of grazing and access to water on semi- arid rangeland where nutritional quality of the fodder is rain fed and heavily depended on the seasons is different from a pasture-based system where reasonable grass growth occurs throughout the year. Thus, an additional measure of distance to grazing and a category of very thin (emaciated) animals had to be included to reflect the greater compromise associated with recurring drought conditions in Namibia. In New Zealand, sloughed-off tails from fecoliths was viewed as a welfare indicator, whereas cattle in semi-arid rangelands are not prone to watery faeces.

Other factors that influenced the addition of measures to the protocol was the herd management and cultural aspects, which contribute to the prevalence of some traits. In New Zealand, cattle are herded with dogs; and dogs (e.g. presence at yarding) can affect animal behaviour (Petherick et al., 2009; Phillips, 1993). Cattle farming on Namibian village farms is also for traditional reasons, which influence cattle management; i.e. keeping of horned cattle ("the bigger the horns, the more aesthetic"; communal farmer), that may compromise the

welfare of animals (Knierim et al., 2015). Regardless of the production system, there is a need to scrutinise welfare compromising issues that became a norm and "de-normalise" them through science-based evidence (Broom, 2019; Mee, 2020). To break through such compromising practices (e.g. hitting cattle with sticks and whips) may require gradual awareness of alternative practices that ensure practicable management and still maintain good welfare (Mee, 2020).

Regarding the exclusion of measures, if taking an observation was non-feasible at most farms, the measure was removed. Measures were regarded as not feasible if they could not be easily or conveniently assessed during yarding (i.e. a pregnancy diagnosis visit), or measures required a specific separate examination. However, such measures were only removed after attempts to keep them in an adjusted form were not feasible. For example, difficulties in observing udder dirtiness and hoof conditions from an elevated platform in New Zealand resulted in the removal of these measures. In Namibia, where observation was on flat ground next to the race, it was still difficult to observe these traits in cattle in tight single files. Nonetheless, udder dirtiness which is related to mastitis (Martelli et al., 2010) was not common in these extensive systems and thus could be excluded from the protocol. It was also difficult to see poor hoof conditions from the available vantage points. An assessment of lameness was included in our protocol; feet structural problems were associated with lameness incidences in dairy cattle (Olechnowicz et al., 2010; Ring et al., 2018) and sheep (Kaler et al., 2010). However, if an animal welfare assessment allows a lengthy evaluation of individual cows such as during a hoof structural trait scoring for breeding, assessment of hoof problems could be retained.

The absence of certain measures also influenced their removal from the protocol. However, measures should not be removed only on condition of no observation as it only shows an absence of a welfare concern in that system. For example, it appeared that broken tails were not a welfare concern in extensive beef systems. In New Zealand, farmers were not observed tail twisting and tail docking is prohibited; thus, the measure was not specifically counted but

should be recorded if observed. In Namibia, the measure was retained as tail twisting was common, and there is a possibility of breaking tails when twisting (Laven & Jermy, 2020).

The challenges of assessing negative behavioural observations across all the beef farms led to the exclusion of these measures from a welfare assessment protocol for extensive cow-calf systems. We were trying to observe what was covered in the protocol; negative behaviours such as agonistic behaviours (head butt, displacement, chasing and fighting) and other restless behaviours (e.g. shifting legs up and down) but this was not feasible across all farms. Similarly, observations of positive emotional behaviours (affective state of enhancement of animal welfare; Mellor (2017) that were claimed to be practicable to form an appropriate base for an animal welfare assessment (Mattiello et al., 2019; Mellor & Beausoleil, 2015) may be impracticable on extensive systems. It was difficult to quantify and assess subjective states of 'calm/content', 'friendly' or 'happy', measures. Other positive emotional indicators such as ruminating, standing still, lying down, social licking and 'playful', were not feasible in crowded pens, and cattle on pasture are likely to spend time grazing than engaging in other behaviours. Similar challenges in behavioural assessments of cattle in extensive systems were also noted elsewhere as subjective and difficult to quantify (Hernandez et al., 2017b; Simon et al., 2016b). Conversely, reliable behavioural assessment is regarded as time consuming and is often not included in protocols (Winckler, 2018). As a result, the fearful/agitated behaviour (e.g. jumping fences, pushing others attempting to escape) was the most practicable measure depicting the negative "mental state" of cattle, within the constraint of testing our protocol at pregnancy testing. Again, if an animal welfare assessment allows a lengthy evaluation of individual or a group of animals, assessment of affective state could be retained, especially when the aim is to enhance welfare rather than just avoiding negative welfare impacts.

Some measures needed modification rather than removal, when applying between systems. For example, animal handling and stockpersonship measures in the UC Davis protocol were designed to be captured in the chute, but most farms in New Zealand and Namibia rarely use a chute for routine operations (e.g. pregnancy testing). Thus, modification had to include observation in the race, and in an absence of a race, observation was done in holding pens.

Similarly, some measures (i.e. hitting, tail twisting) were also observed in the forcing pen where it was as common as in the race.

5.1.2 Categorisation and thresholds refinement

As much as possible, assessment thresholds should be consistent across systems and countries, with similar targets for similar conditions. For a cow, the welfare impact of dystocia does not vary across systems, so why should the target vary between systems? However, it could be argued that the impact of welfare in individual animals in different production system vary; e.g., a lame cow in New Zealand can sit in a paddock with long grass and be well fed without having to move much, whereas a lame cow at communal grazing in Namibia where there isn't a paddock of lush grass will starve if she can't walk far. Thus, if systems are extremely different then targets may have to be modified. This was particularly apparent when comparing body condition (as an indicator of nutrition) between New Zealand and Namibian beef cattle. Drought conditions caused more than 80% of cows on communal village farms and 35% in semi-commercial village farms to be classified as emaciated; levels which would result in prosecution on New Zealand farms. Setting body condition score targets for Namibian farms based on New Zealand targets may not be entirely appropriate. Hence, thresholds for feeding measures and mortality were adjusted to reflect leniency under drought conditions, while original imposed thresholds could be retained in "normal years". Nevertheless, consideration should be taken that if the targets are made too easy, then they are no longer useful to meet the welfare of animals and demands of overseas consumers.

The difference in the production systems also caused diarrhoea and dirtiness to be the only measures where the thresholds for Namibia were reduced from the New Zealand protocol. In Namibia, where grass grows seasonally and between years, diarrhoea cases may be of pathological nature (i.e. infectious causes, internal parasites, and plant toxicity) whilst in New Zealand faecal soiling is commonly a physiological response of cows reared on grass pasture (Gibbs, 2012).

It was necessary to set thresholds for all measures that reflect their significance to the welfare of animals rather than their derived status. A good example was the mortality rate in extensive beef systems that varies with the type of production system, the location, and herd management (Kandiwa et al., 2017; Mõtus et al., 2017). Economically, mortality represents the total loss of the cow, and has the potential to reflect the overall performance of beef farms. Moreover, mortality rate indirectly reflects other hidden health related aspects such as herd health management (i.e. vaccination, deworming) that are not covered under welfare assessments. Hence, stringent categorisation threshold appears to be rational to trigger investigation of underlying contributing factors to reduce mortality rate.

Similarly, welfare thresholds also have significance for animals' level of pain. Hence, the decision was to keep high thresholds for painful conditions (i.e. lameness and dystocia). This was a good example of setting welfare threshold for "what should be and not what is". It is important for farmers to strive for best possible welfare outcomes, instead of being complacent because of lower thresholds.

Legislation changes both the welfare impact (e.g. curbing animal welfare-compromising practices) and what happens in the country (Mellor & Bayvel, 2008). In New Zealand, the impact of laws, regulations and codes for animal welfare for cattle, for example, is evident in the restricted use of electrical prodders and the compulsory use of anaesthesia for disbudding (MPI, 2019). However, previous studies questioned the practicality, cost and time involved in using pain relief for painful management procedures (Tucker et al., 2014b). These drugs are also under veterinary care and is not practical with limited access to veterinary services (for instance in developing countries like Namibia). Alternatives such as the use of the caustic paste for disbudding that is gaining popularity in Namibia should be validated as the use of it (even with pain relief) is questioned elsewhere (Stilwell, 2009; Reedman et al., 2020). Regardless, consideration should be to the welfare of animals and the common practice of performing painful procedures without the use of analgesics need considerate reflection in legislations. Thus, similar categorisation scores were kept for Namibia systems, despite poor welfare scores of painful procedures such as disbudding and castration in most herds.

Legislation also influenced the threshold setting for hot iron-branding in the Namibian protocol. The presence of one compulsory brand (requirement for cattle identification) on an animal was considered a marginal score, whilst extraneous branding is a worse welfare compromise. To abolish the practice of hot- iron branding might be a solution, but farmers' compliance will be questionable; the practise of multiple branding and marking is thought best to mitigate stock theft at the village farms. Alternatives like freeze branding is frown upon elsewhere (Schwartzkopf-Genswein et al., 1997; Tucker et al., 2014a; Tucker et al., 2014b) and thus might not be an amicable solution. Compliance is a crucial part of setting welfare assessment standards or regulations (Colditz et al., 2014) and stricter regulations for hot-iron branding may not ensure a legislative environment that is conducive for compliance and enforcement.

A restraint to the categorisation and scoring approach was the variations in herd sizes at the beef farms. For example, it doesn't take many cows to hit a threshold of 2%; if a herd has 80 cows, a single lame cow will get the farm an orange grade/ marginal welfare score. Nevertheless, for the protocols developed in this study, each score of animal welfare compromise (marginal or poor score) for any measure could designate that interference is required.

5.1.3 Overall judgement of welfare scores

An important aspect in developing an animal welfare assessment protocol that may cause controversy is the provision of an overall judgement from the collected data. The consensus that aggregation of welfare assessments may hugely impact on animal welfare when schemes are applied on-farm (Botreau et al., 2007b) made it challenging for us to come to one aggregation system that is easy to compute, transparent and is yet practicable (Sandøe et al., 2019). Current studies questioned the provision of an overall judgement of animal welfare on a farm where different welfare measures are aggregated and weighted (Mellor, 2017; Sandøe et al., 2019). Critically, averaging two moderate or marginal welfare scores will not necessarily equal one severe welfare compromise score, the same way that a good score in one criterion cannot compensate for deprivation in another? Thus, we took the approach of basing the

thresholds that have been imposed or derived in this study on individual measures, rather than an aggregated 'score' for each farm. Consideration was given to categorise measures into a 3-tier to reflect levels of severity (Cook, 2018; Kubasiewicz et al., 2020). Farms were not categorised as having bad welfare, but weight was given to each specific measure that had a 1 and 2 score, indicating marginal welfare that needs monitoring, or unacceptable poor welfare standard that needs immediate intervention.

5.1.4 Outcomes from testing the protocols at extensive beef farms

It was evident that human-animal relationship is an important component of animals' welfare on beef farms, and the assessment of good stockpersonship is challenging in extensive systems (Simon et al., 2016). Thus, stockpersonship assessment should take precedence in a welfare protocol for extensive beef operations as a stand-alone principle and not be "hidden" as criteria under animals' "appropriate behaviour" principle. The focus on stockpersonship would reinforce the importance of positive human-animal relationship and why animal handling and restraint techniques and facilities impact on the welfare of cattle (Fraser, 2008a; Hemsworth, 2003; Simon et al., 2016a).

The study revealed differences in yard constructions and designs effects on the welfare of cattle. It wasn't only the quality of the yards (e.g. construction materials- steel bars, tree poles or thorn bushes) that affects stockpersonship and the welfare of animals, but also the type of designs. For instance, oversized holding pens, sharp corners and poor accessibility of the forcing pen resulted in lengthy handling, adverse stockpersonship and risk of injuries. The yard functionality is a very important aspect of cattle handling which affects the welfare of animals (Coleman & Hemsworth, 2014) and our recommendation to define what constitute a good yard for inclusion in welfare protocols thus warranted further consideration.

The current findings coincide with others that cattle that are yarded/handled frequently allows better stockpersonship and less fearfulness (Francisco et al., 2012; Hemsworth, 2003). In fact, yarding > 4 times a year showed better results of handling. Although it might be argued that frequent yarding contradicts with the concept that extensiveness is associated

with naturalness, having few restraining events are not helping the welfare of animals. Thus, it is worth investigating how many times handling/restraining of extensively reared cattle begins to show negative response in cattle. Concurrently, there is a need for expert opinion to validate the inclusion of 'yarding frequency' as a measure of animal welfare for extensive beef systems. Contrary studies did not show a negative effect of extensiveness on the handling (i.e. fearfulness) of dairy cows in the tropics (e.g., Hernández et al. (2017a). It could be linked to the difference in the management systems between dairy and beef cattle rather than extensiveness of the systems. The weaning practice of some farmers in New Zealand was designed to limit the effect of extensiveness on the behaviour of cattle by confining calves in the cattle yards for a week or two and letting them become accustomed to people to tame them. So, cattle then don't need to be yarded more than necessary thereafter, but they are not stressed by it when they do (Ramsay et al., 2017).

Threats to the welfare of cattle were exacerbated by the prevailing drought conditions, so that thresholds were less achievable especially for semi-commercial and communal village farms that showed less acceptable welfare standards. As drought conditions worsened, the welfare of animals also deteriorated. The impact of drought is what influenced most welfare standards and reproduction performance (Kaurivi unpublished observation). In future studies, it is recommended that multiple observers can be used to score welfare assessments and inter-observer variation in different seasons can be calculated to further reduce environmental bias. Drought also caused the limited availability of cattle to be assessed; e.g. a herd of 300 cows could only avail 30 cows for observation as cattle were moved or dispersed in search of better grazing in the village farms. Comparing different production systems using the same assessment indicators and methods may have favoured one system over another. In "normal" rainy years, the expectation is to find abundant forage, cattle walking short distances to grazing and cattle in good body condition in Namibia during the time of assessment (March-April). However, drought conditions were already underway, making the situation more of an "effect of drought on cattle welfare", rather than an assessment of welfare standards.

The economic status of the farmers and availability of resources also influenced animal welfare standards. In Namibia, it was no surprise that cattle in communal government-owned land with inadequate grazing were in suboptimal body conditions, during a drought period. The provision of better opportunities and access to resources, training and education of farmers could aid in the improvement of animal welfare standards. Although advocacy of animal welfare is claimed to be present throughout the livestock value chain in Namibia (DVS, 2016), some of these solutions/strategies (i.e. land allocation to the village farmers) are not necessarily practical in a country with limited grazing areas. The concept of animal welfare is relatively new to most developing countries like Namibia, where a stronghold in African cultural preference still exists. Hence, discussions on animal welfare tend to receive apprehension because the question of human welfare remains a concern and a priority for these nations. A counter argument might also be that caring for animals is likely to result in enhanced welfare standards and hence improved production; thus, efforts should be geared towards improving the welfare of animals. These efforts are spearheaded by regional organisations including the African Union (AU) that recently put in place an animal welfare strategy for Africa in order to lead animal welfare issues across the continent (Molomo & Mumba, 2014).

5.2 Limitations

5.2.1 Sample size

The main limitation was in the small sample size of herds in each production system in both countries. A sample size of 25 farms in New Zealand and the 55 farms (subdivided in different farming systems) for Namibia, may have made it harder to make a conclusive decision on findings. For example, 3/18 heifers with dystocia on New Zealand farms added to 17% incidences, and 3/4 pregnant cows on one communal herd in Namibia contributed to a 75% pregnancy rate, influencing the averages of measures in the herds. Comparing and interpretation of data (presented as a percentage) from smaller herds with bigger herds and with the industry standards thus, should be done with caution. Nonetheless, the findings

indicated trends that can be validated in bigger sample sizes. A greater sample size would also improve the confidence of findings and analysis and thus the validity of the results.

5.2.2 Inter observer reliability and repeatability of assessments

Inter observer reliability of assessing animal welfare standards was not assured. Conversely, given that all the welfare assessment scores were done by the same person in both New Zealand and Namibia, reliability of the assessment for the protocol development in terms of repeatability was defined. However, reliability is attained through getting comparable scores from different observers on the same farm under the same management situation (Blokhuis et al., 2013; Kirchner et al., 2014). The validity of the application of a single animal welfare assessment tool for certification without repeating is sure to find significant variation in the welfare criterion and measures after re-testing months later (Kirchner et al., 2014). A good example was the known difference in the effect of drought on the cattle in Namibia which justifies repeating similar studies in different seasons.

5.2.3 Time limitation

The focus was creating a protocol where animal-based measures were assessed during yarding of cows other than for the assessment itself, and within the shortest time possible. Thus, measures that required a specific separate examination that was separate from observations during pregnancy testing were not included in the protocol, which may have excluded important welfare indicators. For example, the assessment of fearful behaviour (e.g. jumping fences, pushing others attempting to escape) was subjective without backing it up with any physiological measurements (i.e. heart rate/cortisol; (Barrell, 2019).

Chapter 6 FUTURE RESEARCH AND CONCLUSIONS

6.1 Future research

i. Validate our evidence of using measures from an animal welfare assessment protocol and associated welfare outcomes with reproductive KPI in extensive beef cow-calf operations on multiple beef farms in New Zealand, considering confounding factors for reproductive performance.

ii. Assess any association between selected welfare measures and the reproductive performance on Namibia cow-calf production systems. It will be interesting to investigate whether the obvious separation of commercial herds from the village farms in terms of welfare outcomes will also reflect similarly in the reproductive performance.

iii. The finalisation process of the thresholds and categories started in this study should involve stakeholders' opinions (i.e. beef farmers, beef exporters, animal welfare experts, veterinarians, consumers, and ideally, animal welfare advocacy groups). Both the public and producing farmers' views and opinions tend to differ, with the farmers perspective gearing towards the health and physiological wellbeing of the cattle, whilst the public concern also include the mental wellbeing of cattle (Mellor & Webster, 2014). The latter perceptions tend to be bordering on emotions, without considering the challenges involved in husbandry practices of raising food producing cattle (Kirchner et al., 2014b).

iv. Describe and validate yard construction and design quality in a welfare assessment. This could define what a yard entails, differentiate those with enough holding pens, the race and chute as well as materials used (e.g. metal, wooden poles, tree poles and thorny bushes). The facility design and handling infrastructure measure of assessing effective movement of cattle in the yards has been described (Simon et al., 2016a) and recommendations of yard designs was widely documented (Grandin, 2014b; Smeaton, 2007; Stafford, 1997) but thresholds are not clear for welfare assessments.

v. Validate the role cattle play in keeping on-farm animal welfare standards. In New

Zealand, short tails were only noted in Angus cattle. In addition, research could classify tail dag or dirty tail scoring on a 3-point scale: 0: no evidence of faecal soiling (clean and dry) to dry with slight faecal soiling, 1: wet with hardening faecal soiling, 2: harden faecal ball formed around tail or short tail. A similar dag score was described by Munoz et al. (2018) to assess extensively managed sheep on a 6-point scale. In pigs, tail injury scoring was also described to detect tail biting and damage (D'Eath et al., 2018; Honeck et al., 2019). The envisioned scale could be used as a tool to caution farmers about the state of tail faecal soiling, so that remedial actions can be taken to prevent sloughed-off tails from fecoliths.

vi. In Namibia, Brahman cattle showed more fearful behaviours and lying while being handled. The suitability of breeds to production systems in terms of animal welfare could assist farmers to find strategies to alleviate adverse animal welfare.

vii. Develop a plausible way that may solve the controversy of "overall score" and lengthy assessments.

viii. For example, select "core" measures to highlight all important issues of animal welfare for that specific system before those indicative of marginal compromise.

ix. Validate the presence and thresholds setting of ticks and fly burdens on extensive cattle in animal welfare assessment protocols to determine acceptable thresholds.

x. Validate and categorise the type of moving aids used during yarding in a cattle welfare assessment, for example on a 3-point score; 0: no moving aids or a flag on a paddle stick, 1: pipes, 2: whips or sticks.

xi. Investigate the impact of predation on the welfare and cattle production in Namibia.

xii. Investigate the impact of drought on the welfare and reproductive performance of beef cattle in Namibia.

xiii. Further research on the impact of identification practices on the welfare of cattle in Namibia.

xiv. Investigate the effects of overcrowding on the behaviour of cows (i.e. shovelling, lifting of heads, and climbing on others) in the yard. Extensive cattle accustomed to free spaces climbing on each other in the pens or race were not necessarily on heat but

could indicate restlessness in overcrowded pens or in confined spaces of the race. Overcrowding was reported to affect behaviour and productivity in dairy cows (Templeton et al., 2014; Winckler et al., 2015) and beef cattle (Grandin, 2015). Future assessments could define overcrowding of cattle in pens as a welfare measure of stockpersonship such that to allow 1.5 square meters per adult cow (Stafford, 1997).

6.2 Main conclusions

An amalgamation of the Welfare Quality and UC Davis protocols facilitated the development of fitting and practical animal welfare assessment protocols for extensively reared beef cattle in New Zealand (32 measures) and Namibia (40 measures). During the protocol development, it was clear that the assessment of animal welfare is dependent on the type and purpose of the assessment and the prevailing system, time limitation, and is influenced by environmental conditions and cattle management. Hence, the removal of unsuitable measures, modification of some and addition of system-specific measures (including new measures that were not validated in welfare assessments before) were necessary to perfect a protocol fit for each system.

The study demonstrated variable animal welfare standards under extensive systems. However, the animal welfare status of beef cows on Namibia commercial farms under semi-arid rangeland systems were comparable with those on pasture in New Zealand. This indicates that commercial farming of exporting beef countries can be at par despite the vast differences in the cattle management, topography and climate. This allows existing opportunities to create a system and a suitable environment that promote animal welfare in Namibia, even on semi-commercial and communal herds with less acceptable welfare scores. Both village farms systems are faced with similar welfare challenges, despite semi-commercial village farms having an advantage of access to commercial markets. In all attempt to impose sustainable animal welfare standards, farmers need to benchmark good welfare standards and examine and prioritise intervention of current practices that are compromising the welfare of animals.

It was important to set thresholds of measures according to the welfare to animals and not always according to the status quo. What is acceptable by farmers is not necessarily acceptable to the welfare of the animals. Hence, attempts were made to set the same thresholds regardless of the system. However, setting thresholds should also be flexible to allow adjustments of

thresholds that reflect prevailing differences of systems. These thresholds provide indicators to farmers and farm advisors regarding the levels at which intervention and remediation is required.

The focus of the research was not just to assess animal welfare at beef operations and give a score, but to give feedback for recommendation of practical steps for possible monitoring and intervention for the improvement of animal welfare standards. The research findings provided baseline data with which veterinarians and farmers can compare their results to identify significant patterns of welfare concern on specific farm types, and thus better guide prevention programmes, especially in the Namibian village farms to either attain or maintain beef markets. Given the development in the field of animal welfare, that have occurred in the developed countries like New Zealand, developing nations like Namibia could learn and adapt some applications that are utilised in these countries. Changing perceptions and behaviour in cattle management will be more attainable if farmers benchmark and realise the benefits of good welfare standards, such as in relation to improved productivity or reproductive performance.

Further testing of this protocol on more farms by more assessors will pave the way to the improvement and standardisation of animal welfare assurance protocol in New Zealand and Namibian extensive beef production systems. Further analysis of the categorisation and refining of thresholds process started in this study across the two countries and production systems is hoped to be completed by evaluating stakeholders opinions on aggregation of selected welfare measures so that their views are represented when formalising decisions of the assessment protocol.

ADDITIONAL THESIS APPENDICES

Appendix 1. A standardised data collection form for a welfare visit on New Zealand beef farm

Scoring Sheet for an Animal Welfare Assessment Protocol for Pasture-based Beef Cattle (New Zealand)											
ANIMAL & MANAGEMENT BASED MEASURES AT RACE			**Procedure**			**Date**		**Farm**			
Cow Nr/ID	Scoring*										
Physical condition of cattle											
Blind eye	√ /x										
Ocular discharge	√ /x										
Nasal discharge	√ /x										
Rumen fill score	0,1,2										
BCS	0,1,2										
Short (fecoliths) tail	0,1,2										
Dirtiness	√ /x										
Diarrhoea	√ /x										
Swelling	√ /x										
Hair loss (bare/bald skin patches)	√ /x										
Skin abrasions (scratches/wounds)	√ /x										
Cow behaviour in & out of race											
Fearful/agitated behaviour	√ /x										
Fall/lie in chute	√ /x										
Stumble- exit chute	√ /x										
Run- exit chute	√ /x										
Lameness exiting chute	√ /x										
Stockpersonship of cattle in yard											
mis-catch	0,1,2										
hitting (moving aid use)	0,1,2										

noise of handlers	0,1,2											
noise of equipment/machinery	0,1,2											
noise of dogs	0,1,2											
yard design flow	0,1,2											
NOTES: Mention if observed; presence of external parasites, broken tail, hooves deformities, tail twisting, use of electrical prodders, etc.												
Draft the design of yard, race and chute and holding pens. Note if it allows easy flow and handling of cattle												
*Use accompanying Table for descriptions of scoring measures												

ANIMAL & MANAGEMENT BASED MEASURES IN QUESTIONNAIRE					
	Descriptions		Scoring		
Health measures (last 12 months)					
Dystocia %	Dystocia cows (nr)	Pregnant cows in herd	%		
Mortality rate	Number of deaths	Cattle herd	%		
- accidental deaths					
-deaths from disease					
-culling for disease					
Management/ Resource measures					
Ear tagging	Specify tag/ notching & use of anaesthetics		0: no tag or use anaesthetics	1: tag with no anaesthetics	2: notching/cutting with no anaesthetics
Castration	Specify age at castration & use of anaesthetics		0: No castration	1: ≤2 months, no anaesthetics	2: >2 months, no anaesthetics
Disbudding	Specify age at disbudding & use of anaesthetics		0: No disbudding	1: ≤2 months, no anaesthetics	2: >2 months, no anaesthetics

Health checks frequency	Frequency of inspection of pregnant cows/season	0: daily	1: once-twice/week	2: less than weekly
Yarding frequency	Frequency of yarding cows/year	0: >4 times	1: 3–4 times	2: 0–2 times
Distance/availability of water	Average distance to access water	0: 0–250.0 m	1: 250.1 ≤500 m	2: >500 m.
Shade	Subjective assessment of shade in the paddocks	0: sufficient		2: insufficient
Hazards	Hazardous objects observed in the yard and paddocks (i.e., tomos, steep hills, sharp objects)	0: no hazards	1: 1–2 hazards	2: 3 or more hazards or animals dying in any hazard)
NOTES:				

Appendix 2. A standardised data collection form for a welfare visit on Namibian beef farm

Proposed Animal Welfare Assessment Protocol for Semi-arid Rangeland-based Beef Cattle (Namibia)										
ANIMAL & MANAGEMENT MEASURES IN RACE/PENS			**Handling Procedure**			**Date**			**Farm**		
Cow Nr/ID	**Scoring***									
Physical condition of cattle										
Blind eye	√ /x									
Ocular discharge	√ /x									
Nasal discharge	√ /x									
Rumen fill score	0,1,2									
BCS	0,1,2									
Dirtiness	√ /x									
Diarrhoea	√ /x									
Fly burden	√ /x									
Tick burden	√ /x									
Swelling	√ /x									
Hair loss (bare/bald skin patches)	√ /x									
Skin abrasions (scratches/wounds)	√ /x									
Extraneous markings/brands	0,1,2									
Horns length/shape	0,1,2									
Cow behaviour in & out of race										
Fearful/agitated in race/pens	√ /x									
Falling/lie in race	√ /x									
Stumbling on exit	√ /x									
Running on exit	√ /x									
Lameness on exit	√ /x									
Stockpersonship of cattle in yard										
Mis-catching	0,1,2									

Hitting (moving aid use)	0,1,2										
Use of electrical prodders	0,1,3										
Tail twisting	0,1,2										
Noise of handlers	0,1,2										
Noise of equipment/machinery	0,1,2										
Noise of dogs	0,1,2										
Yard/handling flow	0,1,2										

NOTES: Mention if observed, presence of broken tail, hooves deformities etc,

Draft the design of yard, race and chute and holding pens. Note if it allows easy flow and handling of cattle

*****Use accompanying Table for descriptions of scoring measures

ANIMAL & MANAGEMENT BASED MEASURES IN QUESTIONNAIRE

Measures	**Descriptions**		**Scoring**		
Health measures (last 12 months)					
Dystocia	Dystocia cows (nr)	Pregnant cows in herd	%		
Mortality rate	Number of deaths	Cattle herd	%		
accidental deaths					
deaths from disease					
culling for disease					
Management/ Resource measures					
Ear tagging/notching	Specify tag/ notching & use of anaesthetics		0: no tag or use anaesthetics	1: tag with no anaesthetics	2: notching/cutting with no anaesthetics
Castration	Specify age at castration & use of anaesthetics		0: No castration	1: ≤2 months, no anaesthetics	2: >2 months, no anaesthetics
Disbudding	Specify age at disbudding & use of anaesthetics		0: No disbud	1: ≤2 months, no anaesthetics	2: >2 months, no anaesthetics
Hot iron branding	Branding events and the use of anaesthetic		0: no branding or use anaesthetics	1: one brand (compulsory)	2: more than 1 brand

Health checks frequency	Frequency of inspection of pregnant cows/season	0: daily	1: once-twice/week	2: less than weekly
Yarding frequency	Frequency of yarding cows/year	0: >4 times	1: 3–4 times	2: 0–2 times
Distance to water	Average distance to access water	0: 0–1.60 km	1: 1.61 km–3.2 km	2: >3.2 km
Distance to grazing	How far cattle had to walk to access grazing	0: 0–1.60 km	1: 1.61 km–3.2 km	2: >3.2 km
Shade	Subjective assessment of shade in the paddocks	0: sufficient		2: insufficient
Hazards	Hazardous objects observed in the yard and paddocks (i.e., steep hills, sharp objects)	0: no hazards	1: 1–2 hazards	2: 3 or more hazards or animals dying in any hazard)
NOTES:				

Adapting a beef cow welfare assessment protocol from New Zealand for use in assessing Extensive Cow-Calf Welfare in Namibia

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Adapting A Beef Cow Welfare Assessment Protocol from New Zealand for Use in Assessing Extensive Cow-Calf Welfare in Namibia

Abstract

Namibia needs a robust welfare assessment protocol for beef cattle for purposes of benchmarking and trade. As there is presently no such protocol, one was developed for Namibian conditions based on one designed for extensive beef cattle in New Zealand. The original protocol had been derived from the Welfare Quality and the UC Davis Cow-Calf protocols, with additional criteria relevant to extensively managed beef cattle. The modified protocol was evaluated in a semi-commercial farming village in Namibia during the pregnancy testing of 141 cows from 5 herds of different households. Animal- and stockperson-based measures were assessed directly, cows were observed at grazing, and a questionnaire-guided interview was conducted. The protocol provided a good basis for welfare assessment, but additional measures and modifications were needed to reflect specific challenges of the Namibian system. Specifically, these were the effects of recurrent drought, predation, plant poisoning, external parasites, walking long distances to water and grazing, compulsory hot-iron branding, extraneous cattle marking, and variable standards of handling facilities. The protocol was modified to incorporate these changes, resulting in a total of 40 measures. It now needs full validation through widespread testing across the range of beef production systems used in Namibia.

Keywords: welfare assessment, extensive beef cows, Namibia, New Zealand

Introduction

The Namibian economy is heavily dependent on the agriculture sector which contributes around 7.1% of the GDP, of which 70% represents the output of the livestock sector. The beef industry is

important not only in terms of GDP (1-2%) but also in terms of employment (~6% of total employment) (Olbrich et al., 2016). Much of the value of beef to the Namibian economy is derived from ensuring that beef production is of a sufficiently high standard to be exported to high value markets such as Europe and North America (MAWF, 2017; Meat Board, 2019). The development of the Farm Assured Namibian (FAN) Meat scheme has provided assurance to consumers that Namibian meat for export is healthy, safe, of good quality, and traceable according to standards laid down by its trading partners (FAN Meat, 2019). Key aspects of the FAN Meat cattle welfare standards pertain to husbandry and transportation, animal handling facilities, and management procedures. However, providing assurance for animal welfare remains a challenge, as the FAN Meat scheme has few animal-based welfare thresholds and is used on a voluntary basis. The country is in the process of updating animal welfare legislation (last updated in 1971), and there is no routine assessment of on-farm beef cattle welfare (Meat Board, 2019).

Namibia could adapt welfare protocols created for beef systems in developed countries. But animal welfare assessment protocols are systems-based (Mellor & Webster, 2014; Winckler, 2018) and it is impractical to simply impose a protocol developed for one system on another (Hernández et al., 2017a; Laven & Fabian, 2016). Moreover, most of the existing welfare assessment protocols are focused on intensive, rather than extensive beef production systems. Because of the unique beef production systems in Namibia, with its preponderance of semi-commercial and communal village farms in semi-arid rangeland systems, a specific assessment protocol is needed for the country. For example, in these production systems, multiple families use the same permanent government-owned communal land for grazing and water and with limited or no internal and external border fencing and animals roam freely. Cattle herds are mostly multi-purpose, mainly kept for beef trading and for subsistence purposes (i.e., meat, milk, customary

functions). Commercial farms on the other hand are privately owned farms, have livestock grazing behind fences, and where the focus of beef farming is principally commercial.

A welfare assessment protocol for extensive pasture-based beef cows in New Zealand, which used measures from Welfare Quality (Welfare Quality, 2009) and the University of California (UC Davis) Cow-Calf protocol (UC Davis, 2017), with additional measures specific to New Zealand was recently created (Kaurivi et al., 2020b; Kaurivi et al., 2020a; Kaurivi et al., 2019). The aim of the current study was to adapt this New Zealand protocol as the basis for identifying suitable welfare measures for a protocol applicable for use in extensively semi-arid rangeland-based beef cow systems in Namibia. The intention of the study was to critically evaluate the New Zealand protocol in order to understand its suitability for use on Namibian cattle farms, that would pave the way to a practicable and credible animal welfare assessment protocol for beef cow-calf systems in Namibia. This aim was achieved through the application of measures on 5 herds in one semi-commercial village farm and making judgements as to whether the measures the New Zealand protocol were suitable for inclusion, suitable after modification or not suitable for inclusion, and by identifying additional measures that were not included in the New Zealand protocol, but which were required on Namibian beef farms.

Material and Methods

Location

The protocol developed by (Kaurivi et al., 2020b) for use in beef herds in New Zealand was tested in a semi-commercial farming village in Namibia. Semi-commercial villages are communal livestock farming setups (herein referred to as village farms), in which multiple families own livestock but use the same communal land, with common grazing and water supply points

(Mendelsohn, 2008). Thus, unlike a typical commercial farm with one herd, each village farm has several herds that are under partially common management, but with differences in herd health management (e.g. vaccination, treatments, disbudding), supplementary feeding, stockpersonship and handling facilities quality. The village chosen for the present study, Welgeluk, in the Otjombinde constituency, Omaheke region, eastern Namibia (~21.8 S latitude, 20.65 longitude), was situated in the foot and mouth disease (FMD) free zone of Namibia and therefore had access to high-value beef export markets. Welgeluk has ~6000 hectares of flat, sandy land with open savanna-type vegetation predominating. Annual rainfall in the area is between 100 and 300 mm (~2/3 in January-March) and temperatures range from <0°C in winter to 35°C in summer (Climate-data, 2020). At the time of the protocol testing (summer, February 2019) there had been no significant rainfall since March 2018 and the region was under threat of drought. Farming of sheep, goats and cattle is the predominant economic activity in the village. The principal beef breed was Brahman, and their crosses with Simmental, Bonsmara, Nguni and Sanga.

Welfare assessment

The welfare assessment was undertaken by the same assessor who performed the assessments on New Zealand beef farms during the development of the protocol. Welfare observations were made on all available cows during manual pregnancy testing of herds from five different households. These herds varied in size from 50 to 200 cows (see Table 1). The number of cows that were pregnancy tested per herd ranged from 17 to 50 (a total of 141 cows across all five herds). For each herd, the assessor took a general view of the cows in holding pens before visual observations of body condition, rumen fill, physical health and cattle behaviour were made in a single-file race during pregnancy testing, except for the one herd which did not have a race. On that herd, cows were captured with ropes (as if for milking), and pregnancy tested and assessed whilst standing in

a holding pen. All animal based physical measures were assessed on one side of the cow. Stockpersonship (i.e. hitting cows, tail twisting, noise) was evaluated as cows entered, were handled, and exited the race or the pens. Information was collected on yard design and accessibility (i.e., shape and size of forcing pens, race structure as well as cow flow and effective handling from pens to race). On exiting the race or holding pen to the paddocks, assessments of lameness, running or walking and stumbling were performed. A questionnaire-guided interview and farm resource visit captured health and management of cattle over the previous 12 months. The measures and methods of assessment are shown in Table 2. The assessments at the five herds were done over 3 days with visits typically lasting 2 hours per 20 cows in the herd.

Table 1 Beef cattle herds assessed at one semi-commercial village farm Welgeluk showing number of cows assessed in five herds

Beef herds	Cow/ heifers herd size	No of cows/ heifers available at assessment
Herd 1	120	26
Herd 2	50	17
Herd 3	87	20
Herd 4	80	50
Herd 5	200	28
Sum	537	141
Average	107.4	28.2
Min	50	17
Max	200	50

Additional measures were identified and assessed for use in Namibia based on two criteria: i) welfare issues identified at the time of assessment that were not covered by the New Zealand protocol, that ii) were feasible to assess either during pregnancy testing or from farmer's recollection. Data on these measures were gathered to guide their future incorporation into the protocol. Following the herd visits, the measures tested during the herd assessments were divided into (i) measures that were not relevant for the Namibia systems and which were excluded; (ii) measures that were feasible and were retained unchanged in final protocol; (iii) measures that were

kept in an adjusted form in the final protocol; and (iv) additional measures that were deemed necessary for welfare assessment of Namibia beef cattle on semi-arid rangeland.

Results

Most of the measures that had previously been identified for the assessment of beef cow welfare by (Kaurivi et al., 2020a) were retained in the modified protocol after it was evaluated under Namibian conditions. Measures that were retained unchanged or which had relatively minor modifications are shown in Table 2.

Short tails, which are sloughed tails resulting from constriction of blood supply to the tails by hardened faecal rings (faecoliths), were excluded from the final protocol. This abnormality was noted in pasture-based Angus cows in New Zealand but was not present in semi-arid rangeland-based cattle of Namibia, so the measure was excluded. Other types of damage to the tail, such as stumpy or broken tails, were incorporated into the protocol as 'injury' (Table 3).

An additional nine measures were incorporated into the final protocol, as shown in Table 3. These largely expanded the existing measures to address potential welfare compromises that occurred during observations. Thus, the principle of 'good feeding' was modified to include the proportion of emaciated animals and had the additional criterion of 'distance to grazing' added. Additional measures related to the presence of long horns (which are almost entirely absent in New Zealand beef cattle), the presence of branding marks and wounds, and the use of hot-iron branding, tail twisting and electrical goads (prodders).

Table 2: Measures assessed and retained as feasible for inclusion in a welfare protocol without change and those modified to suit Namibia conditions

Welfare Principle	**Welfare criteria**	**Welfare measures**	**New Zealand assessment method** Observations made in the race. D: direct observation, Q: questionnaire interview	**Adjustments to suit Namibia assessment** Observation in the race or in holding pens if no race
Good Feeding	Absence of hunger	Body condition score (BCS)	D: % thin cows in the herd, based on visual score ≤4/10 on 1-10 scale (Hickson et al., 2017).	% thin cows in the herd based on score 1-2.5 on the 5-point BCS scale (Hulsen, 2005; Roche et al., 2004) that is commonly used in Namibia. Due to the drought conditions, another score of severity was added to differentiate between thin (>2-2.5 scale) and very thin/emaciated (1-2 scale) cows.
		Rumen fill score	D: % of cows with hollow/empty rumen (Hulsen, 2005).	Retained
	Absence of thirst	Distance to water	Average distance to water source as a categorical measure based on average distance to water source (<250; 250–500 m and >500 m).	Distance to water was estimated as the distance to grazing (km) as water points are close to yards and cattle come to drink after grazing.
Appropriate Environment	Comfort around environment	Dirtiness	D: "Dirtiness" recorded by averaging the three measures of dirty tails, dirty hind quarters and dirty flanks	Retained
	Ease of movement	Hazards	D and Q: Identify pasture hazards (e.g. steep hills, cliffs, gullies, and sinkholes), and presence of dangerous objects/garbage, and loss of animals to such hazards on a 3-point scale: 1; No hazards, 2; ≤two hazards; 3; >2 hazards or animals dying in any hazard.	Retained to capture prevailing hazards.
	Thermal comfort	Shade	D: Subjective assessment of shade in the paddocks (presence of trees, shrubs, galleys, man-made canopies) as enough or insufficient.	Retained
Good Health	Absence of injuries/ physical impairment	Abrasions, Swelling and Hair loss	D: % of cows with abrasions/fresh scratches or cuts, swellings and hairless patches extending >1 cm.	Retained
		Blindness	D: % of cows with affected eye(s) by visual assessment and/or testing with hand.	Retained
	Absence of disease and pain	Ocular discharges	D: % of cows with ocular discharges extending 2 cm.	Retained
		Nasal discharges	D: % of cows with nasal discharges extending 2 cm.	Retained
		Lameness	D: % of cows with unsteady gait exiting the race to paddocks or from the holding pen to the paddocks	Retained
		Diarrhoea	D: % of cows with diarrhoea. Watery faeces are	Watery faeces are not common in Namibia (especially during the dry

			extremely common in grass-fed in New Zealand cattle because of the high-water content of pasture, so could not be differentiated from a pathological condition and was assessed with environmental measures.	season) and diarrhoea was retained as a health measure.
		Dystocia	Q: % reported by famers during questionnaire guided interview.	Retained
		Mortality	Q: % of cattle which had accidental deaths and deaths/slaughter on-farm due to disease were combined.	It was emphasised that mortality rate included deaths due to predators, toxic plants and snake bites.
	Painful management procedures	Castration, Disbudding, Ear tagging/notch	Q: Record age and use of local anaesthetic.	Retained
Stockpersonship	Expression of negative behaviour and animal handling stock-personship and resource-based measures	Fearful/agitated	D: % cows showing fearful/agitated behaviour in the race/forcing pen (climbing on others, persistent pushing, or trying to escape or climb over the fence/rails).	Retained and adjusted to also include those cattle showing fearful/agitated behaviour in the holding pens when being drafted for restraint in the absence of a race.
		Running	D: % of cows running (taking ≥2 strides at a gait faster than a trot) when cows exit from the race or holding pen to the paddocks.	Retained
		Stumbling	D: % of cows stumbling was defined as cows with their knees/hocks contacted the ground, on exiting the race or if moving into a group of cows include assessment from holding pen to the paddocks.	Adjusted to also include those cattle stumbling in the holding pens when being drafted for restraint in the absence of a race.
		Falling	D: % of cows falling (torso contacted the ground) or lying down while in the race and forcing pen were recorded.	Adjusted to also include those cattle falling in the holding pens when being drafted for restraint in the absence of a race.
		Hitting cows	D: Estimated proportion of cows in a group hit with moving aids throughout the duration of the assessment rather than the individual cow on a categorical basis: no hitting; occasional hitting (≤10% of cows); frequent hitting (>10% of cows) into the forcing pen and race.	Included proportion of cattle hit in pens when being drafted for restraining in the absence of a race.
		Mis-catching	D: Estimate of the proportion of cows that were mis-caught on any part of the body while gates were closed into or within the race (<1% versus ≥1% mis-caught).	If no race, available mis-catch was recorded if more than one attempt was made to capture/restrain an individual animal with ropes or if a cow did not stand still when a rope was secured around the legs.
		Noise of Handlers Noise of Equipment/ machinery	D: Subjective categorical assessment to estimate handlers' noise (e.g. shouting) and equipment noise (e.g. race or chute gate) and machinery (e.g. generators etc.) throughout the duration of the assessment: 1) no noise, 2) some noise but less frequent or 3) loud and repeated noise.	Retained
		Dogs noise around the yard	D: Categorical assessment: 1) no dogs; 2) quiet dogs; 3) Noisy or repeatedly audible dogs.	Retained
		Health checks	Q: Record frequency of health checks on cows during winter/pregnancy.	Retained

		Yarding frequency	Q: Record frequency (number of times) of yardings per year.	Retained and emphasised cattle yardings that only involve restraining (e.g. vaccinations and tagging) as at most herds cattle are frequently yarded in pens but with no restraint.
		Yard design flow	D: Subjective categorical assessment: 1) easy movement and flow; 2) effective movement with minor problems (e.g. more gates needed) and 3) poor flow and difficult handling (e.g. forcing pen with too many corners or gate too big).	In the absence of a race, assessment included farmers' cattle handling skills and movement: 1) effective handling (manual restraint of cows was easily achieved), 2) minor issues with flow and/or restraint/ of cattle, 3) major issues with flow and/or restraint (e.g. lengthy periods of running behind cows while trying to capture and restrain them).

%- percentage

Table 3: Additional measures fit for a Namibia animal welfare assessment protocol and assessment methods

Welfare principles	Welfare criteria	Welfare measures	Assessment method (in race unless otherwise stated)
Good feeding	Absence of hunger	Distance to grazing	The questionnaire asked how far cattle had to walk to access grazing.
Good Health	Absence of injuries	Extraneous brands/wounds/cuts	Direct observation of brand mark wounds (>2cm) or more than once branded/marked (i.e. stock brand, initials or name of a farmer branded) and extraneous cuts (i.e. dew-lap skin cuts)
		Long horns	Number of observed cows with long horns (> 5cm in length and forward facing to pose a risk of injuring others).
		Broken tails	Observations of abnormal tails (misaligned or broken at the tail head).
	External parasites burden	Fly burden Tick burden	Separate impression of more than 20 number of flies (i.e. horse flies) and ticks on any part of the body of a cow.
	Absence of pain (from management procedures)	Hot-iron branding	Record age of branding and use of local anaesthetic (in questionnaire).
Stockmanship	Animal handling stockpersonship	Use of electrical prodders	Estimate the proportion of cows that were prodded with an electrical goad on any part of the body while drafted or standing in the race, pens or yards.
		Tail twisting	Estimate the proportion of cows with tail twisted while drafted or standing in the race or pens.

The final protocol, after modification, included 40 measures (Appendix A). Four measures were related to good feeding, three to appropriate environment, 18 to health measures and 15 to stockpersonship. The main welfare measures observed with considerable variations across the herds or with high occurrence were poor body condition (range 0- 29%; BCS 1-2.5/5 scale) and poor rumen fill (range 0-15%; hollow rumen/'hungry cows'). Dirtiness was only seen in one herd and then only in 3.8% of cows. The prevalence for all health measures that had been included in the New Zealand protocol was <8%, on all herds except for nasal discharge which was 18% in one herd. Results for the four health measures which were added to the protocol are shown for each of the five herds in Figure 1. The main issue in all herds was the presence of long horns (prevalence range: 18 to 62%) (Figure 2a). Extraneous brand marks, although less common (prevalence range 0 to12%), represented a significant welfare concern (Figure 2b). The poorest performance for stockpersonship (Table 4) was in the proportion of cows hit, with hitting of >10% of cows occurring in 3/5 herds. No hitting of cows was observed on the one herd without a race. See appendix B for additional results of welfare measures observed in cows in the 5 herds, showing feeding and environment measures (Figure A), animal-based health measures (Figure B) and behavioural measures (Figure C).

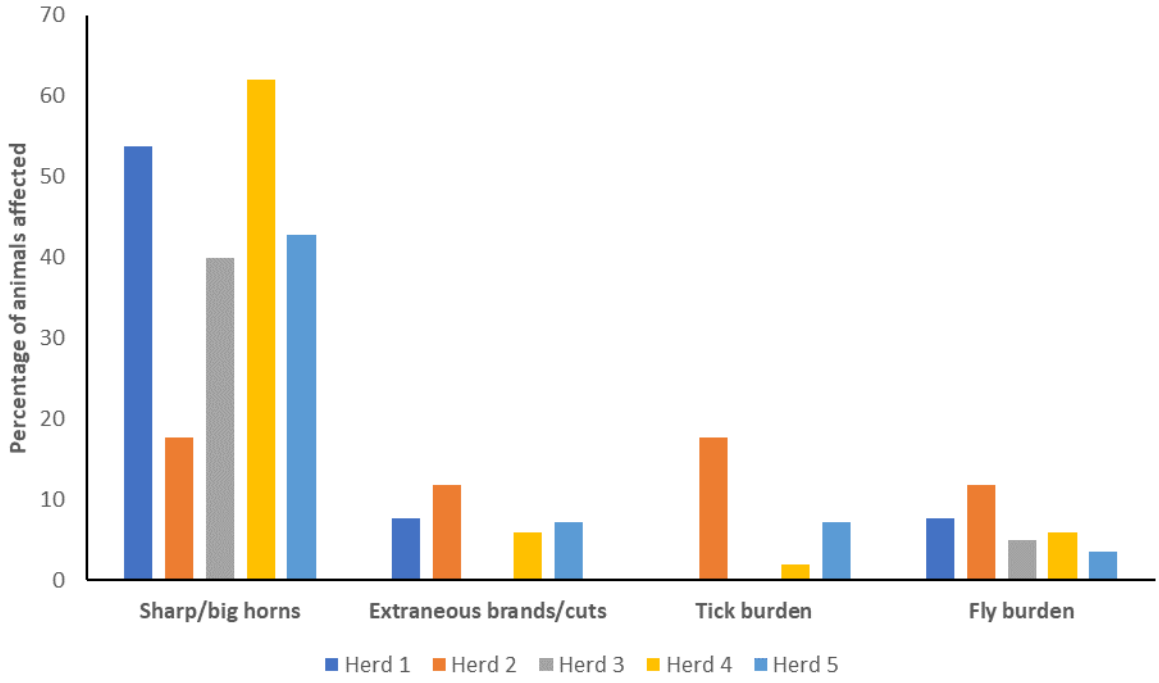

Figure 1: The four additional health related welfare measures incorporated into the New Zealand protocol (Kaurivi et al., 2020b) to make it fit for use in semi-commercial Namibian beef herds, based upon observations of 5 herds in a semi-commercial farming village.

Table 4 Categorical stockpersonship measures observed on 5 cow herds in Welgeluk at yarding for pregnancy diagnosis according to welfare scores (0- good welfare, 1- sufficient welfare and 2- poor welfare)

Herds	Hitting	Noise of handlers	Handling effectiveness
	0- no hitting 1- hit ≤ 10% 2-hit/poke ≥10%	0- No noise 1- Minor noise 2-Noisy handlers	0- Easy handling 1- Average handling 2-Difficult handling
Herd 1	2	2	2
Herd 2	2	1	2
Herd 3	0	1	1
Herd 4	2	2	1
Herd 5	1	1	1

(a) (b)

Figure 1: Additional measures fit for Namibia included: (a) long horns and (b) extraneous hot-iron brands/wounds

Discussion

The original protocol used in this study was designed for beef cows in New Zealand where reasonable grass growth occurs throughout the year. It formed a good basis for cattle welfare assessments in Namibian system where grass growth is much more variable throughout the year and between years. Only one measure (short tails due to fecoliths) from the original protocol was deleted from this study. This measure was specifically identified as being required for New Zealand conditions (Kaurivi et al., 2019) as beef cattle there have a high rate of fecoliths because they produce watery faeces because of the high-water content of pasture (Gibbs, 2012) which can accumulate and then dry on the tail. As the diet of Namibian beef cattle does not result in watery faeces it was unsurprising that this New Zealand-specific measure was not required in Namibia.

When developing the New Zealand protocol used in this study, 12/50 welfare assessment measures, identified from amalgamating the Welfare Quality and the UC Davis Cow-Calf protocols, were identified as not relevant for pasture-based beef cattle (Kaurivi et al., 2019). These results suggest that although welfare assessment protocols need to reflect the system they are being used in (Hernandez et al., 2017b; Hernández et al., 2017a; Laven & Fabian, 2016) the changes required when moving from assessing welfare in a confined (housed or feedlot) system to assessing it in an extensive system are likely to be greater than the changes required when moving from one extensive system to another.

Cattle managed in extensive systems are often assumed to have good welfare because of naturalness (Fraser, 2008b). The counter argument is that these production systems are faced with threats to their welfare, including predation, inadequate water and grazing, toxic plants, a harsh topography and environmental challenges (Barrell, 2019; Petherick, 2005). Under New Zealand conditions, these welfare threats were almost

entirely limited to environmental hazards. But these threats are all present on Namibian beef farms. For example, predators (mostly cheetahs, leopards, hyenas and lions), snake bites and poisonous plants can all cause losses of livestock in Namibia (MAWF, 2017). Provision of grazing and access to water is significantly affected by environmental conditions, especially drought (Rothauge et al., 2007). These threats affected the protocol principally through modifications of assessments rather than their removal. For example, in New Zealand, recording of herd mortality focused on deaths due to disease and accident, while in Namibia it had to be specified that it included deaths due to predators, snake bite and toxic plants. Similarly, the measurement of BCS remained a key part of the assessment, but whereas in New Zealand, the focus was on moderately compromised animals (≤4 on 1-10 BCS scale; (Hickson et al., 2017), in Namibia an additional category of very thin (emaciated) animals; 1 to 2 on 1-5 scale (Hulsen, 2005; Roche et al., 2004) had to be included to reflect the greater compromise associated with drought conditions. Additionally, the semi-arid environment of Namibia is commonly associated with ectoparasite infestations. These parasites are of negligible welfare significance on most New Zealand beef farms (Heath, 1994); however, on Namibian beef farms they can be a major irritant (Davis et al., 2014) and transmit significant disease e.g. lumpy skin disease, theileriosis, babesiosis, anaplasmosis and sweating sickness (Mashebe et al., 2014; Pascucci et al., 2017), so it was considered important that tick and fly burdens should be reflected in the welfare protocol. It was impractical to count ticks and flies on individual animals, thus an impression of more than a count of 20 flies or ticks on any part of the body of a cow was regarded as abundance to signify a burden.

Another area which required modifications to the protocol was stockpersonship. In the New Zealand protocol, many of the measures were related to handling and behaviour of cows in a race and/or chute. Many farms in the semi-commercial and

communal areas of Namibia do not have these facilities. This meant that measures such as stumbling, falling, fearful/agitated behaviours and hitting of cows all had to be modified to account for this (see Table 2 for how these measures were adjusted). Interestingly, in creating the New Zealand protocol, similar modifications had to be made to account for cows being handled as a group in the race, as the UC Davis protocol focused on cows being restrained in a head bail (which rarely happened during pregnancy diagnosis on New Zealand beef farms) (Kaurivi et al., 2019).

Development of a protocol for use in Namibia required the addition of nine measures that were specific to the country. The first of these, which was related to feeding, was distance to grazing. This measure was excluded from the New Zealand protocol because cows remain at grazing except for handling. In contrast, Namibian cattle on most farms in semi-commercial and communal villages are grazed separately from their calves during the day and at night but return in the morning to drinking points close to the yards. Suckling cows then meet with their calves for suckling in the yards (without restraint) or for milking (with restraint). This practice ensures the return of cows for daily monitoring. In the dry season, especially, this can mean that cattle must walk long distances to access feed, resulting in longer distance walking to and returning from grazing, which can affect their BCS and production (Jung et al., 2002). An earlier research reference was for rangeland cattle in rough country not to walk more than 1.6km to water, and on flat topography a 3.2km distance was specified to attain more value for grazing (Hart et al., 1993; Heady, 2019; Holechek et al., 1999).

Two handling assessments were added to the protocol: tail twisting and use of electrical prodders (goads). Both are rarely used on New Zealand beef farms (Kaurivi et al., 2020a), in contrast to Namibia where tail twisting was observed in the current study. The use of electrical prodders was not noted on the five herds but should be validated on

multiple farms. The use of the electric prodder highlights the differences between New Zealand and Namibia in animal welfare legislation. In New Zealand, the use of the electric prodder is constrained by legislation (New Zealand Dairy Cattle Code of Welfare; (MPI, 2019). In contrast, in Namibia there are no such regulations, although the FAN Meat scheme advises on the avoidance of the use of electric prodders on livestock (FAN Meat, 2019). This painful practice is associated with undesirable cattle behaviours (i.e., vocalisation and fearfulness), and subsequent handling ease (Pajor et al., 2000; Simon et al., 2016b) and reduced meat quality when used at pre-slaughter (Grandin, 2020; Warner et al., 2007).

Another aspect of animal welfare concern of cattle in Namibia arises from legislation. This is the compulsory requirement for hot-iron branding. Under the Stock Brand Act (1995), all cattle must be branded clearly with a hot-iron by 6 months of age and all cattle taken to auction or slaughter should be clearly branded with the brand mark of their current owner; thus, rebranding when animals change owner is also a legal requirement (FAN Meat, 2019). In addition, farmers in communal and semi-commercial areas opt for multiple hot-iron brands (i.e. letters, names, certain signs) in an attempt to reduce stock theft. Hot-iron branding causes considerable, long-lasting pain (Schwartzkopf-Genswein et al., 1997; Tucker et al., 2014b), so needs to be included as a management procedure which causes pain. However, in addition to simply recording whether branding is undertaken, the number of brands per cow and the presence of extraneous wounds associated with hot-iron brands need to be included. There is also an issue with other painful identification measures used on communal and semi-commercial farms especially ear marking and cutting, as well as cutting of the dewlap-flap skin. The presence/absence of these were therefore recorded in addition to hot-iron branding.

The final additional measure was the size and shape of horns. In New Zealand, almost all commercial beef cattle are either genetically polled or disbudded soon after birth. The social difference between the two countries could be reflected in the addition of this measure. In most African countries, including Namibia, there are strong cultural preferences towards keeping cattle with long horns. For example, some customs (e.g. of OvaHerero people) in Namibia require cattle used for paying a bride price (lobola) and for slaughter at weddings and funerals to be horned. This has meant that breeding polled cattle is not common and that until recently calves in many herds were not disbudded or dehorned. Dehorning is a painful procedure but disbudding cattle improves human safety and improves cattle welfare as cattle cause fewer injuries to other cattle, and other animals (Stafford & Mellor, 2005b). Thus, the size, length and shape of horns was added to the welfare assessment, so that this welfare risk could be identified. The concept of animal welfare is relatively new to most developing countries like Namibia, where a stronghold in African cultural preference still exists. Hence, deliberations on animal welfare tend to receive apprehension because the question of human welfare remains a concern and a priority for these nations, which may influence assessment of welfare parameters.

Conclusion

The animal welfare assessment protocol developed for pasture-based beef cattle in New Zealand provided a good foundation for a protocol to assess welfare in rangeland beef cattle in Namibia, with only one measure being excluded, the New Zealand-specific measure of short tails due to fecoliths. However, several measures needed minor modification to reflect differences between the New Zealand and Namibian environment, e.g. the inclusion of predators and toxic plants as causes of mortality in addition to accident and disease and identifying handling issues on farms where a race is not available. There was also a need for additional measures, because of differences between

the Namibian and the New Zealand systems in feeding practice (distance to grazing), cattle identification (use of hot-iron branding), and horn management and relative importance of ectoparasites. The adoption of welfare protocols such as this based on industrialised countries will be to the advantage of Namibia and other developing countries to provide benchmarking and transparency. However, before it is finalised and used more widely it needs to be tested across multiple commercial, semi-commercial and communal beef farms by multiple assessors with the aim of paving the way to a validated animal welfare assessment protocol for extensive beef farming enterprises such as those in Namibia (see Kaurivi et al. (2021b); Kaurivi et al. (2021a) for further testing of the protocol).

Authors Contributions

Author Contributions: Y.B.K.—main researcher who did the project proposal and data collection, analysis and main write up. R.L.—main supervisor who did conceptualisation, methodology, funding acquisition, review and editing. R.H.— editing and validation. K.S.—conceptualization, methodology and editing. T.P.—review and editing. All authors have read and agreed to the published version of the manuscript.

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Appendices

Appendix A. A summary of all 40 potential measures identified as suitable (selected measures amalgamated from Welfare Quality & UC Davis assessment protocols and additional measures fit for New Zealand extensive pasture-based beef cattle farms plus additional measures fit for Namibia)

Welfare Principles	Welfare Criteria		New Zealand Assessment Protocols suitable measures for Namibia	Additional Measures Fit for Namibia Beef Farms
Good feeding	1	Absence of prolonged hunger	body condition score, rumen fill score	distance to grazing points
	2	Absence of prolonged thirst	distance to water points	
Appropriate environment	3	Comfort around environment	dirtiness (flank, hind, tail)	
	4	Thermal comfort	availability of shade in paddocks	
	5	Ease of movement	absence of hazardous objects/terrain	
Good health	6	Absence of injuries	swelling, hair loss, abrasions	broken tail, size and shape of horns, extraneous brands/wounds/ cuts (e.g., 2 or more brands, dew-lap cuts)
	7	Absence of disease	blindness, ocular discharge, nasal discharge, diarrhoea, lameness, dystocia, mortality (deaths, accidents and culling for health), disease history*	ticks burden, flies burden, mortality to include predators, poisoning plants and snake bite, deaths,
	8	Absence of pain induced by management procedures	disbudding/dehorning, castration, ear-tagging/notching	hot-iron branding
Appropriate Stockpersonship	9	Negative emotional state	fearful/agitated behaviour	
	10	Animal handling stockpersonship	stumbling, falling or running exiting, mis-catching, hitting cattle	use of electrical prodders, tail twisting
	11	Management-based stockpersonship	noise of handlers, noise of equipment /machinery, presence/noise of dogs at yards, frequency of yarding cows/year animal, health checks frequency	
	12	Resource-based stockpersonship	flow of handling affected by facility design/quality	

*Disease history data collection was kept in the protocol but not used as part of an individual farm's assessment

Appendix B. Additional results of welfare measures observed in cows at one semi-commercial village Welgeluk in 5 different beef farming herds showing feeding and environment measures (Figure A), animal-based health measures (Figure B) and behavioural measures (Figure C).

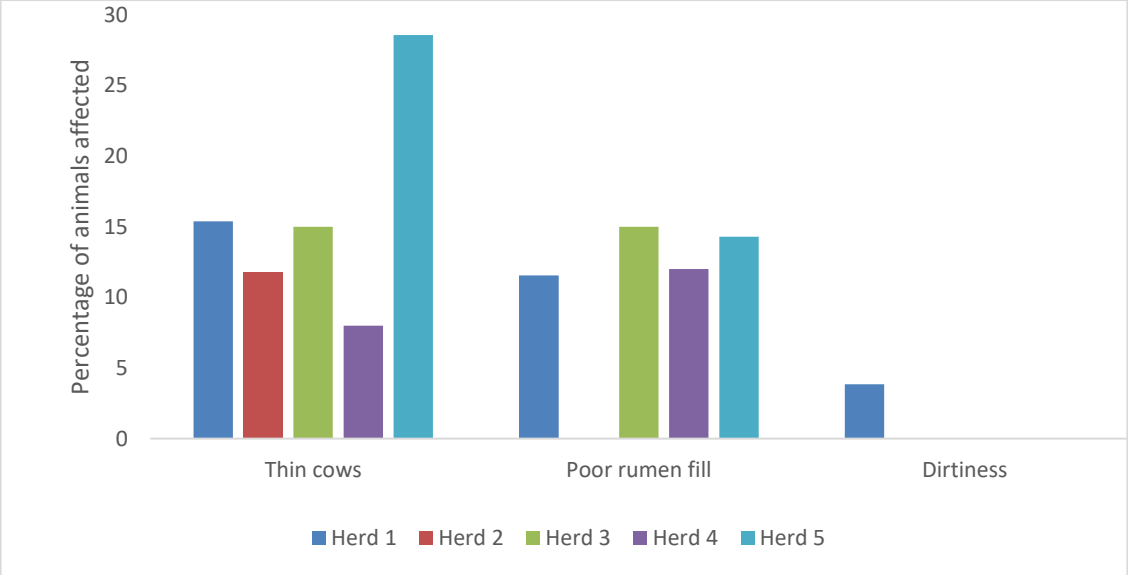

Figure A: The good feeding (thin cows - ≤2.5 /5 scale, and hollow rumen fill) and environment animal-based welfare measures (dirtiness) observed in cows at one semi-commercial village Welgeluk in 5 different beef farming herds.

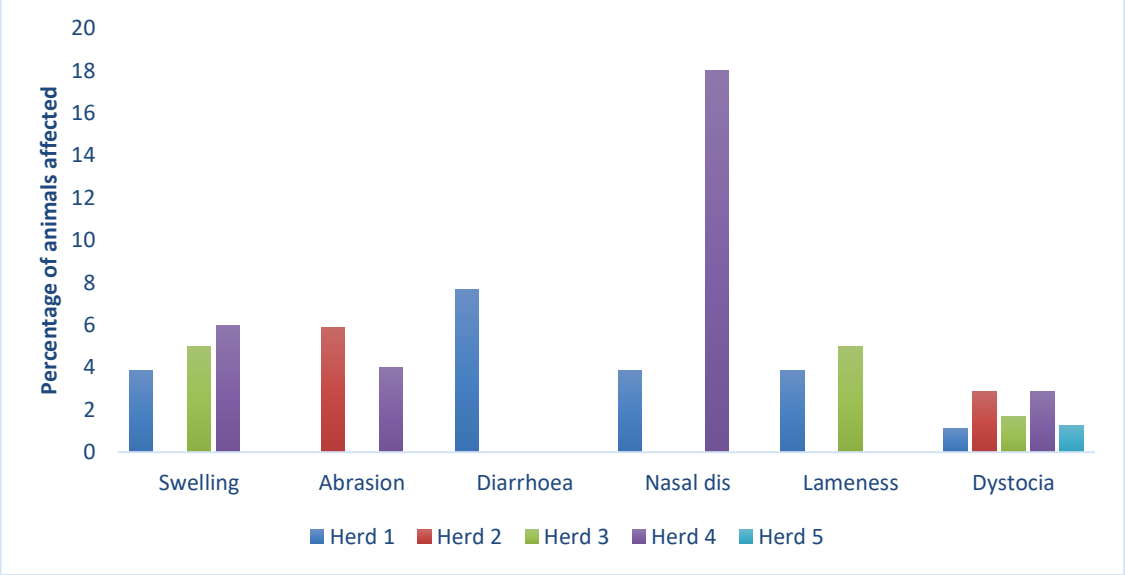

Figure B: The health-related animal-based welfare measures observed in cows at one semi-commercial village Welgeluk in 5 different beef farming herds.

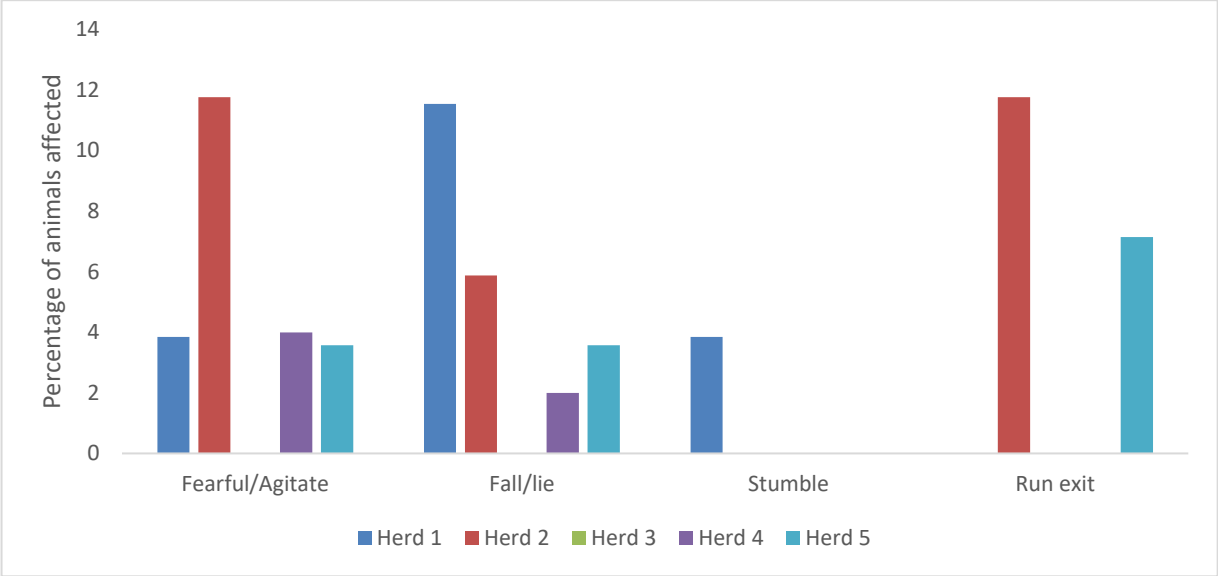

Figure C: The behavioural animal-based welfare measures observed in cows at one semi-commercial village Welgeluk in 5 different beef farming herds (Herd 3 did not have a race)

animals

MDPI

Article

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

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Simple Summary: Namibia is in the process of updating animal welfare legislation. This needs to include an assessment protocol for beef cattle production systems that is sufficiently rigorous for the country to gain and maintain access to high-value beef export markets. Beef is produced in commercial and semi-commercial systems and in communal village farms. Privately owned commercial farms allow maximum herd and rangeland management to ensure optimum productivity and profitability. Village farms (semi-commercial and communal) have limited grazing land, with consequent challenges of grazing and water management, as well as traditional customs of cattle management. A protocol was developed to assess the welfare of beef cattle in the context of these production systems. The application of the welfare assessment protocol indicated that the standards of welfare differed across production systems, with commercial farms achieving the best standard of welfare, followed by semi-commercial, then communal village farms. The greatest opportunity for change exists within the semi-commercial village farms, which need to attain to the requirements imposed by international markets to maximize their returns; hence herd management and welfare status is better than in the purely communal farms. This suggests that commercialization of communal farming may have benefits for animal welfare.

Abstract: A proposed animal welfare assessment protocol for semi-arid rangeland-based cow–calf systems in Namibia combined 40 measures from a protocol developed for beef cattle in New Zealand with additional Namibia-specific measures. Preliminary validation of the protocol had been undertaken with five herds in one semi-commercial village. The aim of the current study was to apply this protocol and compare animal welfare across three cow–calf production systems in Namibia. A total of 2529 beef cows were evaluated during pregnancy testing in the yards of 17 commercial, 20 semi-commercial, and 18 communal (total: 55) herds followed by an assessment of farm resources and a questionnaire-guided interview. Non-parametric tests were used to evaluate the difference in the welfare scores between the production systems. The results indicated a discrepancy of animal welfare between the three farm types, with a marked separation of commercial farms from semi-commercial, and communal village farms in the least. The differences in these production systems were mainly driven by economic gains through access to better beef export market for commercial farms and semi-commercial villages, as well as by the differences in the available grazing land, facility designs/quality, and traditional customs in the village systems. The results indicate an advantage of commercialization over communalization.

Keywords: animal welfare assessment; beef cow systems; semi-arid rangelands; Namibia

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1. Introduction

Namibian beef farming is dependent on extensive grazing under semi-arid, rain-fed conditions [1,2]. The beef cattle industry is predominantly driven by the demarcation of Namibia into two parts (northern and southern) by the veterinary cordon fence (VCF; see Figure 1). The VCF is an important biosecurity measure for animal disease control, particularly for contagious bovine pleuropneumonia and foot and mouth disease (FMD). North of the VCF, livestock and livestock products are not eligible for overseas export because of the risk of FMD which is endemic in north-east Namibia [3,4]. All farming rangeland north of the VCF is allocated to communal farmers with customary tenure [5,6]. Most households in these areas are subsistence-based and labor intensive, with inadequate access to technology [6].

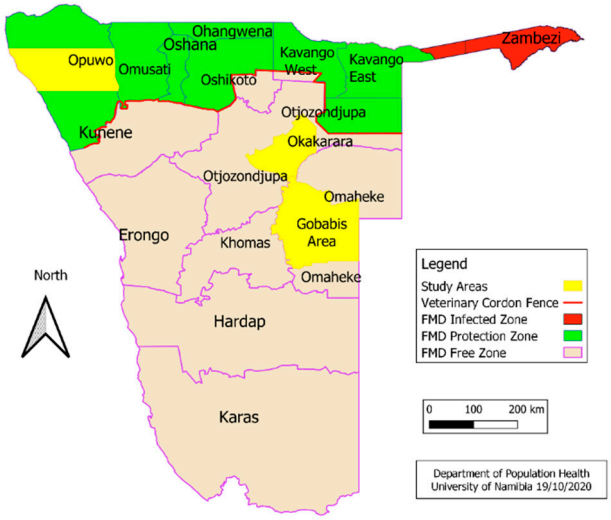

Figure 1. Namibia regional map showing the foot and mouth disease (FMD) zones and fences and study areas for commercial (Gobabis area), semi-commercial (Okakarara area) and communal farming (Opuwo area) [4], (source Dr Alec Bishi).

The southern part of Namibia (below the VCF) was declared FMD free by the World Organisation for Animal Health (OIE) and can export beef to overseas markets [4]. In this zone there are two types of farms; privately owned commercial farms [2] and communally owned village farms with customary tenure. The latter "semi-commercial" village farms are set-up in the same way as communal village farms north of the VCF but have access to high-value commercial and overseas markets [6,7]. The line of these two systems is also blurred by the resettlement freehold farms where the Namibian government buys farms from commercial farmers and resettle people mostly from communal areas.

These three different beef farming systems, commercial, semi-commercial and communal, have different management styles, income streams, and levels of productivity. Commercial farms are farms that are not communally owned, have livestock grazing behind fences, and where the focus of beef farming is principally commercial rather than being a traditional tribal practice. In contrast, both semi-commercial and communal villagers farm in communal areas. The main difference between the two is that semi-commercial farms have access to commercial markets and thus have different cattle marketing and management strategies, but in both systems, traditional tribal practices in relation to cattle farming are important. In this paper we use the term village farms as an inclusive term for both semi-commercial and communal farms, as a way of contrasting these communal farms to commercial beef farms.

These differences are likely to have a significant effect on cattle welfare, although there are no data on beef cattle welfare on Namibian beef farms. In part, this dearth of information is because there is no standardized system of independent assessment of

animal welfare under Namibian production systems. However, welfare assessment is commonly demanded by the type of markets to which Namibian farm animal products are exported. Importing countries commonly have welfare assessments that are applied to their domestic beef production, but such assessments are focused upon the species and production systems that pertain in those countries [8–10], and do not take into consideration the conditions that pertain in (for example) the semi-arid conditions of countries such as Namibia. Thus, as different systems need different welfare assessment protocols [11,12], the value of developing a system of welfare assessment that was relevant to Namibian conditions became evident.

As part of a project to create welfare assessment protocols for extensively reared beef cattle in the semi-arid conditions of Namibia, Kaurivi [13] assessed the use of a protocol that was originally developed for New Zealand semi-intensive temperate pastoral beef production systems (based on the Welfare Quality protocol [14] and University of California Davis protocol [15]). The protocol was validated on five herds in one semi-commercial village in Namibia. That preliminary study identified nine further Namibian-specific measures that could be incorporated into the protocol to make it suitable for use on Namibian beef farms. By using the protocol on commercial, semi-commercial, and communal beef farms in Namibia, the aim of this study, was to confirm that conclusion and to determine the impact of farm system on the welfare of Namibian beef cows.

2. Materials and Methods

Three areas were selected for inclusion in the study based on being representative of their farm type within Namibia. The herds included in the study were a convenience selection based on the willingness of the farmers to be involved. A total of 55 herds were enrolled, 17 commercial herds (from 17 separate farms), 20 semi-commercial herds (from 8 villages) and 18 communal herds (from 8 villages). Thus, both semi-commercial and communal farms were village-based, with multiple herds examined per village. Details of these herds are given in Table 1.

Table 1. Study areas for commercial, semi-commercial, and communal farming areas showing number of herds, farms/villages and number of cows assessed.

Beef Cattle System	Area	No. of Herds Assessed	No. of Farms/Villages	Total Cattle	Average Cattle/Herd	Total Cow/Heifers	No of Cows/Heifers Assessed			
							Average	Min	Max	Total
Commercial	Gobabis	17	17	5887	346	3923	76.7	34	141	1305
Semi-commercial	Okakarara	20	8	2196	110	1590	29.7	11	55	593
Communal	Opuwo	18	8	4563	254	2485	35.1	8	78	631

Both semi-commercial and communal villagers farm in communal areas (village farms). The main difference between the two is that semi-commercial farms have access to commercial markets and thus have different cattle marketing and management strategies. In this paper, we use the term "village farms" as an inclusive term to include both semi-commercial and communal farms, to contrast them with commercial farms which are not communally owned, which have livestock grazing behind fences, and where the focus of beef farming is principally commercial rather than being a traditional tribal practice.

2.1. Description of the Study Areas

Commercial farming system: (Gobabis area, Omaheke region, eastern Namibia, lat 22°26′ S, long 18°58′ E). Commercial farms are large farms (range 3000–10,000 ha) that have a boundary fence and fenced grazing paddocks [16]. On most farms (every farm represents one herd), the owners are full-time farmers or employ managers [2]. On the study farms, beef cattle farming was the predominant economic activity of interest, through auctioning or direct abattoir marketing of cattle. Cattle farming was supplemented by small stock (sheep and goats) farming and wildlife ranching. Horses were commonly used for cattle mustering on most farms. The principal beef breed was Brahman, alongside pure breeds or crosses of Simmental, Charolaise, Bonsmara, Afrikaner, and Nguni. The area is a flat sandy thorn-bush highland with predominant open acacia savannah-type vegetation [17]. Annual rainfall in the area ranged between 200–400 mm (~2/3 in January–March) and average annual temperature is 19.3 °C; ranging from 0 °C in winter to 33 °C in summer [18].

Semi-commercial farming system: (Okakarara area, Otjozondjupa region, central Namibia, lat 20°35′ S, long 17°27′ E). In a semi-commercial village farm, multiple families use the same permanent communal land for grazing and water. The land is government-owned with limited or no internal and external border fencing and animals roam freely [5,19]. Semi-commercial village farmers in Okakarara are mainly dependent on livestock production (multi-purpose cattle, sheep and goats) for their livelihood. Weaner calf trading at auctions was the main marketing activity. In the study area, the grazing area associated with an individual village ranged from ~3000 to 6000 ha, with ~10–30 families/households per village. Herds were selected for inclusion on a convenience basis with 1–5 herds selected from each of eight separate villages (total n = 20 herds; Table 1). In one of the eight study villages, government-built, village-maintained, common cattle handling facilities (yard with a race) were available; in the other villages, farmers were responsible for erecting their own facilities. Some households, without adequate handling facilities, took their cattle to yards with better facilities on days of mass handling. The principal beef breed was Brahman, alongside crosses with Simmental, Hereford, Nguni, and Sanga. The area is a sandy thorn-bush highland acacia savannah [7]. Annual rainfall in the area ranged between 100–430 mm (~2/3 in January–March) and average annual temperature was 19.6 °C; ranging from 0 °C in winter to 32 °C in summer [18].

Communal farming system: (Opuwo/Kaokoland area, Kunene region, north-western Namibia, lat 18°3′ S, long 13°51′ E). As in semi-commercial villages, in communal villages, animals of different households graze together on the same government-owned communal land with limited or no internal and external border fencing. The small cattle herds were mainly kept for subsistence purposes and were mostly multi-purpose; i.e., milk and meat as well as manure for fire and building houses. Cattle farming was supplemented by herds of goats and some sheep. In the study area, farmers tend to be semi-nomadic with livestock being moved from permanent structures (yards and water troughs) to temporary ones in seasons of limited grazing (e.g., winter or drought). Cattle marketing was mainly for oxen (more than 2 years old bullocks) and cattle must go through a quarantining system, before slaughter at an approved abattoir a long distance away. In this area, the government had constructed community crush pens (forcing pen and race only) within ~3 km of each village. These were completed and maintained by the villagers. The main breed in the area was indigenous Sanga cattle alongside Nguni and Brahman crosses. Average cattle herd size was ~ 254 cattle, ranging from 30–548 cattle (one herd with 1900 cattle was owned by multiple members of the same family but managed as one group). From the selected eight villages, a selection of 2–5 herds per village farm was included in the study (total n = 18 herds; Table 1). The area vegetation is classified as mopane savannah with shrubland-woodland mosaic vegetation partly with rocky and bare mountains [20]. Annual rainfall in the area ranged between 50–320 mm (~2/3 in January–March) and average annual temperature was 21.6 °C; ranging from 10 °C in winter to 30 °C in summer [18].

2.2. Welfare Assessment and Data Collection

The welfare assessments took place in March/April 2019 (autumn). The protocol was used on 55 herds with animal-based measures being assessed on 2529 cows (Table 1). (See Appendix A for protocol and description of measures). All animal-based and handling assessments were made during pregnancy testing, with all cows presented for pregnancy testing being assessed on each herd. On farms where a race was present, pregnancy testing was undertaken in the race. In the absence of a race, cows were captured with ropes (as if for milking) and pregnancy tested while standing (or lying) in a holding pen.

All observations were made by the same observer (first author). For each herd, the observer took a general overview of the cows in holding pens, before observations of body condition, rumen fill, behavior, and physical health were made in single-file races (or in pens where there were no races). Stockpersonship was evaluated as cows entered, were handled and exited the race or the pens. Information was collected on yard design and accessibility (i.e., shape and size of forcing pens, race structure as well as cow flow

and effective handling from pens to race). As animals exited the race (or pens), their exit speed (running or walking), whether they fell or stumbled, and lameness signs were all recorded. Depending on accessibility and race design, the position of the assessor varied from standing on the side of the race or in pens as cattle moved around. For observation of cows exiting the race/pens the observer stood as close to the exit as possible without interfering with cow flow.

A farm resource visit and a questionnaire-guided interview were conducted to assess health and management of each herd over the last 12 months. These included records of dehorning/disbudding, castration, vaccination, diseases, or disease symptoms seen in cattle, cattle deaths, access to water and grazing and wintering practices. (See Appendix B for questionnaire).

2.3. Data Analysis

All data were analyzed using IBM SPSS Statistics for Windows Version 24 (IBM Corp. Released 2016. Armonk, New York, USA). Descriptive statistics for continuous measures were used to capture central tendency (median), and range (minimum and maximum). The effect of farm type on continuous measures of welfare was analyzed by using the Kruskal-Wallis test, and on categorical measures using the Fisher's exact test. Where the p-value was <0.2 for either test, post-hoc testing was used for pairwise comparisons (Dunn test for continuous measures, and Fisher's exact for categorical). Holm-Bonferroni correction was used to account for multiple comparisons. For this analysis α was set at 0.05.

3. Results

The proposed protocol took on average 2.5 h for a 100-cow herd at commercial farms (yard assessment-1 hour and questionnaire and farm resource visit-1.5 h) and 2.5 h for a 50-cow herd at the village farms (semi-commercial + communal).

3.1. Continuous Measures

The median and range for the 30 continuous indicators included in the assessment are shown in Table 2 (mean ranks for these measures are shown in Appendix C). Of those measures, only one, broken tails, had no recording on any farm of any type. Five measures (dirtiness, blindness, ocular and nasal discharge and poisoning deaths) had medians of 0 on all three farm types. Of the other 24 measures, commercial herds had the lowest median for 15 (including one tie) and the highest median for seven (including one tie). Semi-commercial herds had the lowest median for 9 (including three ties) and highest median for two. In contrast communal herds had the lowest median for three measures (including two ties) and highest median for 16 measures (including one tie).

No effect of farm type was identified on the numbers of cattle affected with 14/24 measures (swelling, blindness, ocular and nasal discharges, dystocia, fly burden, deaths from disease, accident, culling or poisoning, fearful behavior, falling/lying, stumbling or running ($p \geq 0.35$)). Of the measures where the Kruskal-Wallis test returned a p-value of 0.05 to 0.2 (i.e., blindness, fly burden, run and excess branding/wounds), none could be separated by farm category using the Dunn test. As such, the lowest adjusted p-value for a pairwise comparison was >0.0167 in all cases, as there were 3 pairwise comparisons (commercial vs. semi-commercial and communal and semi-commercial vs. communal), and using the Holm-Bonferroni correction all pairwise comparisons are statistically non-significant if the lowest p-value is > 0.05/3.

For the remaining measures, grouping by farm category using the Dunn test is shown in Table 3. The analysis separated the three farm types for proportion of emaciated cows and proportion of cows with poor rumen fill. In both cases, the median was lowest on commercial herds (0%) and highest in communal herds (83.9% and 78.9%), with semi-commercial herds (13% and 48.1%) in between the two. For long/sharp horns, hair loss, tick burden and mortality, commercial herds were separated by the analysis from semi-

commercial and communal herds, but the analysis did not separate the village farms. In all cases, the median was lowest on commercial herds (see Table 2).

Table 2. Descriptive analysis (median and range in percentage) of continuous welfare indicators in three Namibian beef production systems.

Measure	Commercial (*n* = 17)	Semi-Commercial (*n* = 20)	Communal (*n* = 18)
Thin cows	2.5 (0–46.9)	78.3 (25–100)	**100** (83.3–100)
Emaciated cows	0	7.3 (0–40)	**83.9** (52.5–100)
Poor rumen fill	0 (0–45.2)	48.1 (14.3–100)	**78.9** (39.3–100)
Dirtiness	0 (0–8.8)	0	0 (0–16.7)
Swelling	1.7 (0–8.2)	**3.7** (0–37.1)	2.3 (0–13.3)
Hair loss	0 (0–2.8)	2.8 (0–16.7)	**5.3** (0–20)
Abrasion	2.8 (0–12.5)	5.6 (0–27.3)	**19** (1.8–40)
Multiple brands/wounds/cuts	0.8 (0–3.6)	2.8 (0–44.4)	**5.3** (0–87.5)
Broken tail	0	0	0
Long/sharp horns	2.5 (0–37)	40.5 (10–96.6)	**61.8** (13.1–85)
Blindness	0 (0–2.5)	0	0 (0–1.3)
Ocular discharge	0 (0–1.4)	0	0 (0–1.3)
Nasal discharge	0 (0–1.4)	0	0 (0–1.3)
Diarrhea	0.9 (0–12.9)	0 (0–1.8)	**4.3** (0–25)
Lameness	0 (0–3.9)	0 (0–3.3)	**3.4** (0–16.7)
Dystocia	0.8 (0–3.3)	1 (0–10.0)	**1.4** (0–6.7)
Tick burden	0 (0–6.8)	1.4 (0–81.3)	**4.4** (0–35)
Fly burden	0 (0–12.3)	1.4 (0–61.5)	**4.5** (0–55)
Deaths from diseases	**0.7** (0–4.1)	0 (0–2)	0.4 (0–7.9)
Accidental deaths	**0.2** (0–1.6)	0 (0–3)	0.1 (0–16)
Culling for health	**0.2** (0–2.3)	0 (0–3.1)	0 (0–3.3)
Predation/snake bite deaths	0.4 (0–9)	0 (0–4.1)	**4** (0–20)
*Nutritional deaths	0 (0–3.2)	**6.6** (0–50)	1.1 (0–10)
*Poisoning deaths	0	0 (0–2.4)	0 (0–0.3)
*Reproduction deaths	**0.2** (0–0.8)	0 (0–4)	**0.2** (0–2.6)
Annual mortality rate	2.4 (0–15.5)	11.3 (0–26.9)	**11.7** (2.2–26)
Fearful/Agitate	3 (0–25)	6.2 (0–19.4)	**7.7** (0–17.5)
Fall/lie	**5.8** (0–17.7)	3.4 (0–26.7)	5 (0–17.5)
Stumble	**1.4** (0–4.9)	0 (0–40)	0 (0–14.3)
Run exit	**3.8** (0–16.9)	1 (0–20)	0.8 (0–15)

Highest median(s) for each category is in bold (if >0). See Appendix A for description of how each measure was assessed. *Nutritional deaths included weight loss and mineral deficiency (e.g., phosphate) deaths. *Poisoning deaths were plant poisonings and other poisonings (e.g., urea). *Reproduction related deaths included dystocia, retained placenta, and vaginal prolapse complications.

Table 3. Groupings by farm category (1: Commercial (*n* = 17), 2: Semi-commercial (*n* = 20), 3: Communal (*n* = 18)), using the Dunn test (with Holm-Bonferroni correction for multiple comparisons)).

Farm Grouping	Measures
1 < 2 < 3	Emaciated, poor rumen fill
1 < 2, 1 < 3, 2 = 3	Thin, horns, hair loss, ticks, mortality rate
2 < 3, 1 = 2, 1 = 3	Dirtiness
1 < 3, 2 < 3, 1 = 2	Abrasion, lameness, predator deaths
2 < 3, 2 < 1, 1 = 3	Diarrhea, reproduction deaths
1 < 2, 3 < 2, 1 = 3	Deficiency (nutritional) deaths

The analysis for dirtiness showed no separation between commercial and semi-commercial herds or between commercial and communal herds but separated semi-commercial from communal herds. Although in all farm types, the median was 0, semi-commercial herds had a lower mean rank than communal herds. The comparison of farm effects for diarrhea and reproduction deaths separated semi-commercial from commercial

and communal herds but did not separate commercial from communal herds. In both cases, semi-commercial had the lowest median value and communal had the highest (Table 2).

There was an effect of farm type on the proportion of cows with skin abrasion and lameness, and the number of reported predator deaths. The analysis separated commercial and semi-commercial herds from communal herds, but not commercial from semi-commercial herds. In both these cases the median was highest in communal herds (Table 2). For deaths associated with nutritional deficiency, the analysis separated semi-commercial herds (which had the highest median) from commercial and communal herds but did not separate communal and commercial herds.

3.2. Categorical Measures

Shade (natural savannah-type rangeland trees) was sufficient on all the farm types. The remaining frequencies of ordinal measures by farm type in each welfare category are shown in Appendix D. Commercial herds had the highest frequency of farms in the poor welfare category for 4/17 measures (dog noise, equipment noise, mis-catch, and use of electric prodders). Semi-commercial village herds had the highest frequency of farms in the poor welfare category for 4/17 measures (late castration and dehorning, hazards, and poor flow of cattle during handling). Communal herds had the highest frequency of farms in the poor welfare category for 8/17 measures (distance to water/grazing, ear tagging, hitting and tail twisting in the yards, handler noise, and yarding frequency).

Of the categorical measures, no effect of farm type was found on 4/17 measures (hazards, hitting, equipment noise, and health checks; $p > 0.2$ in the initial analysis). The p-values for the multiple comparisons and direction of the difference for the remaining measures are shown in Table 4. Although the overall p-value was <0.2 for mis-catch and dog noise, the analysis did not separate these measures by farm (lowest adjusted p-value >0.0167).

Table 4. Pairwise comparisons for the Fishers exact test for the frequency of categorical measures at the cow–calf production systems herds in Namibia (1—Commercial (n = 17), 2—Semi-commercial (n = 20), 3—Communal (n = 18)).

Ordinal Measures	Fishers Exact p-Value			Pairwise Outcomes
	1 vs. 2	1 vs. 3	2 vs. 3	
Water distance	<0.001	<0.001	1	1 < 2, 1 < 3, 2 = 3
Grazing distance	<0.001	<0.001	1	1 < 2, 1 < 3, 2 = 3
Dehorning	0.001	<0.001	0.468	1 < 2, 1 < 3, 2 = 3
Castration	0.005	<0.001	0.135	1 < 2, 1 < 3, 2 = 3
Ear tagging	<0.001	<0.001	0.526	1 < 2, 1 < 3, 2 = 3
Hot-iron branding	<0.001	0.466	<0.001	1 < 2, 1 = 3, 3 < 2
Mis-catch	0.094	0.019	0.526	1 = 2 = 3
Electrical prodders	0.019	0.015	1	2 < 1, 3 < 1, 2 = 3
Tail twisting	0.013	0.005	0.639	1 < 2, 1 < 3, 2 = 3
Handlers noise	0.068	0.005	0.028	1 = 2, 1 < 3, 2 = 3
Dog noise	0.270	0.019	0.027	1 = 2 = 3
Yarding/handling freq.	0.363	<0.001	<0.001	1 = 2, 1 < 3, 2 < 3
Yard/handling flow	<0.001	<0.001	0.512	1 < 2, 1 < 3, 2 = 3

Electrical prodders were only used on commercial farms, so the analysis separated commercial herds from communal and semi-commercial herds, but not communal from semi-commercial. For distance to water/grazing, dehorning, castration, ear tagging, tail twisting and yard/handling flow, the analysis separated commercial from semi-commercial

and communal herds, but not semi-commercial from communal herds. For all these measures, commercial herds had the lowest frequency of herds with poor welfare and communal the highest frequency.

For hot-iron branding, semi-commercial herds had the highest frequency of poor welfare. The analysis separated them from commercial and communal herds but did not separate communal from commercial herds. For noise of handlers, the analysis separated commercial and communal herds (with the latter having a higher proportion of farms with poor welfare than the former) but did not separate semi-commercial herds from communal or commercial herds. For yarding/handling frequency the analysis separated communal from commercial and semi-commercial herds, but not commercial from semi-commercial herds. For this measure communal herds had the highest of herds with poor welfare

Painful management procedures: Castration was performed on 9/17 commercial herds (mode and median 2 months of age; range 1 week to 8 months), 8/20 semi-commercial herds (mode and mean 6 months) and on all 18 communal herds (all after 6 months). Disbudding was performed at all commercial herds (mode 2 months; 1 week to 8 months), 17/20 semi-commercial and 12/18 communal herds (mode 6 months at the villages; range 4 months to 12 months). Ear tagging was performed on all herds with median and mode of 2 months at the commercial herds and mode and median of 6 months in both types of village herds. Ear notching (cutting with a knife) was routinely performed on all village herds as a form of identification but not on the commercial herds. Skin cutting (dew-lap cuts) was performed on 7/20 and 4/18 herds in the semi-commercial and communal herds, respectively. Cattle branding with hot iron was used on all herds; secondary branding (i.e., letters, marks) was routinely performed on commercial stud farms (5/17 commercial farms) and on all the village herds. No anesthesia was used for any procedure.

4. Discussion

The current study confirmed the findings of Kaurivi [13] that a 40 measure protocol developed for use on extensive cow–calf farms in New Zealand was, with the addition of nine Namibian-specific measures, feasible for use during yarding on all classes of Namibian beef farms. The use of this protocol has identified marked differences between production systems in animal welfare. For 25 of the total 47 indicators (30 continuous + 17 categorical) included in the protocol, the analysis separated welfare outcome by system. For 16/25 measures, the welfare outcome was better on commercial herds than semi-commercial herds, and for 19/25 it was better on commercial herds than communal herds (Tables 3 and 4). For 9/25 measures, semi-commercial herds had a better welfare outcome than communal herds, while communal herds had better outcomes overall than semi-commercial herds for only two measures.

The most obvious difference between farm systems was related to feeding. For proportion of emaciated cattle and proportion with poor rumen fill, commercial farms performed better than the village farms, and semi-commercial farms performed better than communal farms. This is likely to be because commercial farms have more control over cattle feed supply than village farms. Village systems also have limited fencing, which limits the ability of farmers to manage grazing [1,19,21]. Moreover, social obligations and customary factors contribute to a widespread failure of village farmers to undertake timely reductions of stock numbers, even when feed is scarce [7]. Nevertheless, despite these challenges, semi-commercial farmers were able to maintain cattle in better body condition score (BCS) than their communal counterparts. This may be due to the better feeding, herd management, and genetics associated with the cash income from beef sales. On the other hand, it may reflect differences between the selected regions rather than farm system. Siegmund-Schultze [7] reported that the average BCS was higher on communal than semi-commercial village farms (3.0 vs. 2.5 respectively; 1–5 scale), concluding that this was related to feed supply, as the communal farms in northeast Namibia had significantly more rainfall than the semi-commercial farms in central Namibia (550 vs. 350 mm/year, respectively). Similar considerations may pertain to the present study, the communal farms

were in northwest Namibia (Opuwo area), which has a much drier environment than the region (Kavango West) studied by Siegmund-Schultze [7]. Indeed, in the rainy season prior to the start of the study (i.e., September 2018–March 2019), Okakarara semi-commercial area had >140 mm more rain than Opuwo (457 vs. 314 mm, respectively). Thus, the differences of BCS in the present study may, at least partly, reflect the effect of rainfall on feed availability rather than system differences.

The distances that animals had to walk to grazing may also have exacerbated pressures upon BCS [22]. Distances are characteristically shorter on commercial farms (2–4 km) than on semi-commercial (3–6 km) or communal farms (4–8 km). The distance to grazing also had an impact on distance to water. In village farms, water is provided in or around the yards, so distance to water is strongly related to distance to grazing, whereas in commercial farms, water troughs are in the grazing paddocks. The relationship between BCS and lameness may therefore be of interest, since lameness was rare on commercial and semi-commercial herds (median 0% on both max. 3.9% and 3.3%, respectively), but more common on communal herds (median 3.3, max 17%). The association between the prevalence of lameness and distance walked is well recognized [23,24] and cattle on communal village farms walked the longest distances. Lameness rates could be also related to handling facilities, which could cause injury and acute lameness. However, there was no difference between semi-commercial and communal herds in yard handling/flow (Table 4), despite a difference in the prevalence of lameness prevalence. The older age of cattle at communal farms could also have contributed to lameness. Finally, BCS itself can affect the risk of lameness, as poorer BCS has been associated with increased risk of lameness [25], hence, the increased lameness in communal herds could have been related to underfeeding. There is clearly a need for further research to unravel these relationships.

Differences between systems were also noted in relation to animal health. Skin abrasions/injuries were more common in communal than semi-commercial and commercial herds, probably because the quality of handling facilities on communal farms were poorer (i.e., greater use of thorny bushes and tree poles tight with wires), and thus the risk of accidental injury higher. Hairless patches were less common in commercial than semi-commercial/communal farms, although this may reflect the prevalence of lumpy skin disease than of welfare *per se.* Relatively few animals were assessed as having diarrhea, although the prevalence was highest in communal than other herds (4.3% vs. 0% and 0.9% at semi-commercial and commercial respectively).

There was a large difference between the median of mortality rates on commercial (2.4%) versus semi-commercial (11.3%) and communal (11.7%) herds. It was likely that underlying differences between systems were exacerbated by the impact of the prevailing drought. Deaths due to predation, dystocia (reproduction) and nutrition varied between farm systems. Interestingly, death due to predation was higher in communal herds but there was no difference between commercial and semi-commercial herds. This may reflect the value of internal fencing and the ability of commercial farmers to control where cattle go (such as calving in calving camps in areas not frequented by cheetahs; [26]). Risk of death due to predation may also reflect changes in the population of wild prey associated with drought conditions [27,28]. Opuwo communal area borders the Etosha National Park where livestock are at a risk from predators. Deaths due to dystocia (reproduction deaths) were lowest in semi-commercial herds, but there was no difference between commercial and communal herds. However, the risk of deaths due to dystocia was not significantly related to the reported incidence of dystocia per se. There is no clear explanation for this, except to note that the rate of dystocia and reproduction deaths in communal herds was probably related to the lower plane of BCS [29]. It is likely that the higher rate of reproduction deaths on commercial farms was due to better recording of the cause of death as on commercial farms pregnant cows were kept in paddocks close to the main yards to allow for close monitoring and assistance in case of cows with difficult births.

Deaths reported as nutritional were far higher in semi-commercial than communal or commercial herds. Again, the reasons for this pattern are not clear, although the lower

prevalence in commercial herds is consistent with better body condition and the use of supplementary feeding. Conversely, the lower prevalence on communal herds is not consistent with the higher proportion of emaciated cattle in those herds. It may be that the discrepancy lies in the effects of phosphate deficiency [30], which is widespread, but whose distribution and severity varies between the different areas included in the present study. For example, sandy soil around Okakarara areas has significantly lower phosphate than that at the harder and drier sand around Opuwo area (3.35 mg P/kg; [17], vs. 12.4 ± 1.7 mg P/kg; [20]), while the available soil phosphorus threshold is intermediate (≤10 mg kg -1 DM; [30]). A comprehensive investigation in the suspected phosphate deficiency related deaths of cattle is warranted and would help to unravel this question.

No effect of farm system on fly burden was found, but tick burdens were lowest on commercial farms. It is likely that this reflects parasite management with commercial farms using external parasite control as a key part of herd health management, whereas semi-commercial farmers treat cattle for ticks when necessary to do so (i.e., when preparing them for sale, when there are high tick burdens or in response to tick-borne diseases). No difference was found between semi-commercial and communal herds in tick burden, despite communal farmers rarely, if ever, using tick control. These data suggest that the limited use of tick control in semi-commercial herds is not having any impact on ticks.

There are issues with painful management procedures on all farm types. No anesthesia was used for any procedure on any farm. On commercial farms, dehorning/castration is generally performed when calves are younger than on village farm types (mode 2 vs. 6 months respectively). The FAN (Farm Assured Namibian) Meat scheme [31] requires that these operations are performed on calves younger than 2 months of age to ensure reduced pain and faster healing [32]. However, the FAN Meat is a voluntary scheme, and farmers in the villages have a traditional but erroneous conviction that late castration allows faster growth and muscle gain [33].

Keeping of horned cattle is traditional in the villages, but there is clear evidence of long horns injuring other animals and hampering handling flow in the race. There is increasingly strong advocacy for keeping polled cattle (which would also eliminate the need for dehorning: [34]). However, horns are natural defense tools against predators' attacks [35] and imposing such restrictions in areas that lose livestock to predators may hinder the sustainability of farming.

Hot-iron branding and ear tagging are compulsory for cattle identification and traceability in Namibia. Analgesia was not provided on any farm for cattle during or after hot-iron branding, so hot iron branding was a significant welfare concern on all farms. However, on many farms additional painful methods were used to permanently identify cattle in addition to the statutory brand. On commercial farms, stud breeders (5/17) used an extra brand on stud cattle, while on village farms additional brands (e.g., letters, names, certain signs) as well as markings (e.g., dew-lap skin-flap cutting; see Appendix E) were used for security and easy identification. Rebranding of cattle that change ownership was also common. Branding was also used on village farms for treatment of musculoskeletal problems (e.g., hip tendon slipping), with cattle being branded over the affected site. Branding for security reasons was most common in semi-commercial areas, due to the high levels of stock theft in such areas. Furthermore, on village farms, ear notching (with knives), was used in addition to compulsory ear tagging because of the perception that ear tags were easily lost or dislodged. Thus, cattle identification, for whatever reason, was a welfare issue on all farms, especially village farms. On the other hand, the national traceability system (NamLITS) benefits cattle movement control [36], which is itself a critical underpinning of the Namibian beef industry. There would be great value in reducing the need to use painful methods for such identification.

There were differences between systems in measures related to stock handling. Only 6% of commercial herds had poor cattle flow/handling, compared to 50% and 70% in communal and semi-commercial herds, respectively. The effects of farm type on cattle handling were determined by differences in yard design and quality. For commercial

farms with marginal flow, the main issues were related to yard design (e.g., oversized holding pens, sharp corners, and poor accessibility of the forcing pen). The problems on village farms were more fundamental, notably lack of gates, races, and forcing pens. In semi-commercial village farms yards were well constructed (usually) with wooden poles, whereas some communal villages yards were partially, or fully, constructed using thorny bushes. Thus, on village farms, poor construction and poor design of yards resulted in poor cow flow and subsequently increased handling times, frequency of hitting and tail twisting, and noise of handlers.

Despite differences across farm types in facilities and stock handling behavior, there was no farm type effect on behavior related to handling (fearful/agitated, fall/lie, stumble and run). This may be related to the "flighty" temperament of the Brahman breed which was predominant across all farm types [37]. For example, Brahman cattle and their crosses lay down in the race more commonly than other breeds, contributing to the high proportion of fall/lie cows in this study across all farm types.

Importantly, however, not all issues related to cow handling were worse on village farms. Electric prodders were only present on commercial farms (5/17); and all these farmers were using prodders on more than the 1% recommended by Grandin [38]. The use of prodders was related to cow flow in the yards with marginal designs and cattle lying in the race. The data from this study on stock handling suggest that improvements are needed across all farm types. In particular, training on alternatives to sticks, whips, pipes, and prods, such as flags on sticks [39,40] is needed. It also reinforced the value of a race in reducing stress during handling [41,42], especially for extensively reared cattle that are not frequently restrained [43].

5. Conclusions

The study evaluated the welfare of beef cattle in the various extensive beef production systems of Namibia. It showed that the welfare of cows varied between farm types: 25 of the 44 criteria in the present study varied across systems. Of those 25 measures, the welfare outcome was better on commercial herds than semi-commercial herds in 16 and better than communal in 19. The main reason for the better performance of commercial herds were better nutrition and management of grazing land, better cattle handling infrastructure, and preventative disease control. Despite the similar animal welfare challenges facing semi-commercial and their communal counterparts, of the 25 measures found to be affected by farm type, 9 were better on semi-commercial herds than communal herds and only 2 were better on communal than semi-commercial herds. This suggests that even limited commercialization of communal farming may have benefits for animal welfare. However, this conclusion needs testing on more farms in more areas of Namibia. There is an immediate need however, to categorize measures across the farm production systems to indicate thresholds of acceptable and unacceptable welfare, to give guidance regarding the levels at which intervention and remediation is required. This will be addressed in a companion Part 2 paper of the current study.

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Appendix A. Table of Description of Welfare Measures Included in the Assessment Protocol for Cow–Calf Welfare in Namibia (Kaurivi et al., 2020c)

Welfare Principle	Welfare Criteria	Welfare Measures	Assessment Method Observations Made In The Race Or In Holding Pens If No Race
Good Feeding	Absence of hunger	Body condition score (BCS)	% thin cows in the herd based on score 1–2.5 on the 5-point BCS scale that is commonly used in Namibia. Due to the drought conditions, another score of severity was added to differentiate between thin (>2–2.5 scale) and very thin/emaciated (1–2 scale) cows.
		Rumen fill score (RFS)	% of cows with hollow/empty rumen.
		Distance to grazing	The questionnaire asked how far cattle had to walk to access grazing (≤1.6 mm, 1: 1.6 km–3.2 km and >3.2 km).
	Absence of thirst	Distance to water	Average distance to water source. Distance to water in semi-commercial and communal villages was estimated as the distance to grazing as water points are close to yards and cattle come to drink after grazing (≤1.6 mm, 1: 1.6 km–3.2 km and >3.2 km).
Appropriate Environment	Comfort around environment	Dirtiness	"Dirtiness" recorded by averaging the three measures of dirty tails, dirty hind quarters, and dirty flanks.
	Ease of movement	Hazards	Identify pasture hazards (e.g., steep hills) and presence of dangerous objects/garbage, and loss of animals to such hazards: (1) no hazards, (2) 1 or 2 hazards and (3) 3 or more hazards or animals dying in any hazard.
	Thermal comfort	Shade	Subjective assessment of shade in the paddocks (presence of trees, shrubs, galleys, synthetic canopies) as enough or insufficient.
Good Health	Absence of injuries/physical impairment	Abrasions, Swelling, and Hair loss	% of cows with abrasions/fresh scratches or cuts, swellings and hairless patches extending >1 cm.
		Extraneous (multiple) brands/wounds/cuts	Observation of brand mark wounds (>2 cm) or more than once branded/marked (i.e., stock brand, initials or name of a farmer branded) and extraneous cuts (i.e., dew-lap skin cuts).
		Long/sharp horns	Number of observed cows with sharp/long horns (>5 cm in length, sharp and forward facing to pose a risk of injuring others).
		Broken tails	Observations of abnormal tails (misaligned or broken at the tail head).

Welfare Principle	Welfare Criteria	Welfare Measures	Assessment Method Observations Made In The Race Or In Holding Pens If No Race
	Absence of disease and pain	Blindness	% of cows with affected eye(s) by visual assessment and/or testing with hand.
		Ocular discharges	% of cows with ocular discharges extending 2 cm.
		Nasal discharges	% of cows with nasal discharges extending 2 cm.
		Lameness	% of cows with unsteady gait exciting the race to paddocks or from the holding pen to the paddocks.
		Diarrhea	% of cows with diarrhea.
		Dystocia	% reported by famers during questionnaire-guided interview.
		Mortality	% of cattle which had accidental deaths and deaths/slaughter on-farm due to disease were combined. It was emphasized that mortality rate included deaths due to predators, toxic plants, and snake bites.
	External parasites	Fly burden Tick burden	Separate impression of more than 20 number of flies (i.e., horse flies) and ticks on any part of the body of a cow.
	Painful management procedures	Castration, Disbudding, Ear tagging/notch	Record age and use of local anesthetic on a 3-point level: (1) No disbud/castration, (2) $\leq$2 months and (3) >2 months. For ear tagging/notching the scoring was: no tag or use anesthetics; tag with no anesthetics and notching/cutting with no anesthetics.
		Hot-iron branding	Record age of branding and use of local anesthetic (in questionnaire) on a 3-point score: (1) no branding or use anesthetics, (2) one brand (compulsory) and (3) more than 1 brand.
Stockpersonship	Animal handling stock-personship and resource-based measures	Fearful/agitated	% cows fearful/agitated in the race/forcing pen (climbing on others).
		Running	% of cows running (taking $\geq$2 strides at a gait faster than a trot) when cows exit from the race or holding pen to the paddocks.
		Stumbling	% of cows stumbling were cows with their knees/hocks contacted the ground, on exiting the race or if moving into a group of cows include assessment from holding pen to the paddocks. Also included those cattle stumbling in the holding pens when being drafted for restraint in the absence of a race.
		Falling	% of cows falling (torso contacted the ground) or lying down while in the race and forcing pen were recorded. Also include those cattle falling in the holding pens when being drafted for restraint in the absence of a race.

Welfare Principle	Welfare Criteria	Welfare Measures	Assessment Method Observations Made In The Race Or In Holding Pens If No Race
		Hitting cows	Subjective categorical observation of the group rather than the individual cow: (1) no hitting; (2) occasional hitting (≤10% of cows); (3) frequent hitting (>10% of cows) into the forcing pen and race. Included proportion of cattle hit in pens when being drafted for restraining in the absence of a race.
		Use of electrical prodders	Estimate the proportion of cows that were prodded with an electrical goad on any part of the body while drafted or standing in the race, pens or yards on a 3-point level: (1) no prodding, (2) few/occasional prod (≤1% cows) and (3) many/frequent prod (>1% cows prodded).
		Tail twisting	Estimate the proportion of cows with tail twisted while drafted or standing in the race or pens on a 3-point level: (1) no twisting, (2) occasional/few twist (≤10% of cows) and (3) frequent twist (>10% of cows).
		Mis-catching	Estimate of the proportion of cows that were mis-caught on any part of the body while gates were closed into or within the race. If no race, available mis-catch was recorded if more than one attempt was made to capture/restrain an individual animal with ropes or if a cow did not stand still when a rope was secured around the legs.
		Noise of Handlers Noise of Equipment/ machinery	Subjective categorical assessment of handlers' noise (e.g., shouting) and equipment noise (e.g., race or chute gate) and machinery (e.g., generators etc.): (1) no noise, (2) minor less frequent audible noise or (3) repeated, unpleasantly noisy.
		Dogs noise around the yard	Categorical subjective assessment: (1) no dogs; (2) quiet dogs; (3) Noisy or repeatedly audible dogs.
		Health checks	Record frequency of health checks on cows during winter/pregnancy: (1) daily, (2) once-twice/week and (3) more than weekly.
		Yarding frequency	Record frequency (number of times) of yardings per year. Emphasized cattle yardings that only involve restraining (e.g., vaccinations and tagging); (1) >4 times, (2) 3–4 times and (3) 0–2 times.
		Yard design flow	In the absence of a race, assessment included farmers' cattle handling skills and movement: (1) effective handling (manual restraint of cows was easily achieved), (2) minor issues with flow and/or restraint/of cattle, (3) major issues with flow and/or restraint (e.g., lengthy periods of running behind cows while trying to capture and restrain them).

Appendix B. Questionnaire-Guided Interview Questions Used for Welfare Assessment at Beef Herds in the Production Systems in Namibia

Farm . . . .Owner: . . . . . Date: . . . . . .

Questionnaire-guided interview questions (based on UC Davis cow and calf animal welfare assessment protocol, 2016) will address the following welfare management related questions on each farm.

a. Please state your cattle herd number ( ), number of breeding females ( ) and number of males/bulls ( )
b. Which type and numbers of other animals you have on the farm (breed, class)?

General Herd Management

1. How are your cattle identified (ear tag, ear notch, branded, other marking)? At what age?
2. Do you do dehorn or disbudding operations on your cattle? At what age? Which method?
3. Do you castrate your cattle? At what age? Which method?
4. At what age are your calves weaned? How?
5. What is the source of water for cattle on the farm? How far do cattle walk to water source?
6. Do you monitor the grazing of your cattle? How often? How far do cattle walk to grazing?
7. What is the condition of grazing (quantity and quality)? Stocking density rate/carrying capacity?
8. What are the main supplementary feeds for cattle used? Any other wintering practices that you do regarding feeding of animals? What is the general body condition of cattle now?
9. Do you get veterinarian or veterinary services visits? How often? What purpose?
10. What training do you have relating to animal health and husbandry? How do you keep abreast?

Stockpersonship

11. How many handlers per stock do you have on the farm (ratio of staff per stock unit)?
12. How frequently do you yard cattle for handling/restraining? For what purpose?
13. Do you use any other handling devices (sticks, ropes, plastics) to handle the cattle?
14. Do you use horses to handle the cattle on the farm? Do you use dogs in the cattle yards?

Health

15. Do you do health checks on your cattle (especially pregnant cows)? How often or when?
16. In the last year, how many cattle did you cull for any health-related issues?
17. How many died from diseases/disorders/deficiency? What were the main causes of sickness and deaths of cattle on the farm? (Respiratory, diarrhea, bloat, pink eyes, lameness, lumpy skin disease, botulism? udder problems etc.)
18. What were the main clinical signs of unknown causes of cattle sickness and deaths on the farm? Any other disease or health abnormalities in the herd?
19. What treatments are you likely to perform on your cattle? How many cattle recovered from treatment?
20. Do you vaccinate your cattle? For which diseases? When or how often?
21. Do you control internal and external parasite on your cattle? How/With what products? When or how often?
22. Do you get animals injured in the yard, chute/race or paddocks? How many? From what exactly?
23. Have you lost animals from hazards (falling in dams/creeks, hills etc., wire sticking etc.)? How many and from what exactly?
24. Do you get cattle injured in the yard (kraal), paddocks (camps) or chute (manga? How many?
25. Do you lose animals from poisonous plant/other poisoning? Which type? How many cattle died?
26. Do you have predation problems? What predators? How many cattle succumbed to the specific predators?
27. Any cattle bitten by snake? What was the outcome?

Reproduction

28. Did you experience any reproductive conditions in cattle in the last year? Which one? (Retained placenta, prolapse vagina/uterus, abortion, dystocia). How many cases of each? What was the outcome (assisted/culled/died, etc.?)

Appendix C. Table of Mean Ranks of Commercial, Semi-Commercial, and Communal Beef Cattle Production Systems in Namibia

Mean Ranks	Commercial (n = 17)	Semi-commercial (n = 20)	Communal (n = 18)	Mean Rank p-Value
Thin cows	13.9	69.4	69.9	<0.001
Emaciated cows	11.5	25.4	46.5	<0.001
Poor rumen fill	9.6	29.7	43.5	<0.001

Mean Ranks	Commercial (n = 17)	Semi-commercial (n = 20)	Communal (n = 18)	Mean Rank p-Value
Dirtiness	28.2	23.5	32.8	0.021
Swelling	25.9	30.3	27.5	0.470
Hair loss	17.0	30.2	35.9	0.002
Abrasion	16.3	25.8	41.4	<0.001
Extraneous brands/cuts	20.6	29.9	32.9	0.007
Broken tails	-	-	-	-
Long horns	10.1	32.3	40.2	<0.001
Blindness	30.9	26.0	27.5	0.113
Ocular discharge	28.6	27.0	28.5	0.552
Nasal discharge	28.6	27.0	28.5	0.552
Diarrhea	31.5	17.5	36.4	<0.001
Lameness	24.2	21.4	39.0	0.001
Dystocia	26.8	26.5	30.9	0.637
Tick burden	18.5	31.0	33.6	0.002
Fly burden	21.1	31.1	31.1	0.073
Deaths from disease	30.0	24.8	29.7	0.546
Accidental deaths	28.8	25.2	30.4	0.197
Culling for health	30.3	25.5	28.7	0.363
Predation/snake	24.4	17.4	43.1	<0.001
[a] Nutritional deficiency deaths	17.5	38.3	26.4	0.002
Poisoning deaths	26.5	29.3	28.0	0.410
[b] Reproduction deaths	30.4	23.6	30.6	0.018
Annual mortality rate	13.3	34.0	35.2	<0.001
Fearful/Agitate	25.3	28.3	30.3	0.693
Fall/lie	31.0	25.3	28.2	0.347
Stumble	32.4	27.6	24.3	0.147
Run exit	34.8	24.2	25.9	0.197

[a] Nutritional deaths included weight loss and mineral deficiency (e.g., phosphate) deaths. [b] Reproduction related deaths included dystocia, retained placenta, and vaginal prolapse complications.

Appendix D. Table of Frequency (%) of Categorical Measures in the 3 Welfare Scores at the Cow–Calf Production Systems Herds in Namibia (CF—Commercial (n = 17), SCV—Semi-Commercial (n = 20), CV—Communal (n = 18)

	Production Systems	Good Welfare	Marginal Welfare	Poor Welfare
Water distance	CF	94	6	0
	SCV	0	5	95
	CV	0	0	**100**
Grazing distance	CF	6	77	18
	SCV	0	5	95
	CV	0	0	**100**
Hazards	CF	0	88	12
	SCV	0	65	**35**
	CV	0	67	33
Dehorning	CF	47	53	0
	SCV	20	5	**75**
	CV	33	0	67
Castration	CF	47	18	35
	SCV	15	0	**85**
	CV	33	0	67

	Production Systems	Good Welfare	Marginal Welfare	Poor Welfare
Ear tagging	CF	0	100	0
	SCV	0	5	95
	CV	0	0	**100**
Hot-iron branding	CF	0	82	18
	SCV	0	5	**95**
	CV	0	83	17
Mis-catch	CF	71	24	**6**
	SCV	95	5	0
	CV	100	0	0
Electrical prodders	CF	71	0	**29**
	SCV	100	0	0
	CV	100	0	0
Hitting	CF	35	35	29
	SCV	35	30	35
	CV	22	39	**39**
Tail twisting	CF	0	88	12
	SCV	15	65	20
	CV	28	39	**33**
Handlers noise	CF	12	82	6
	SCV	30	45	25
	CV	0	50	**50**
Equipment noise	CF	53	35	**12**
	SCV	85	10	5
	CV	83	17	0
Dogs noise	CF	71	24	**6**
	SCV	90	10	0
	CV	100	0	0
Health checks	CF	94	6	0
	SCV	100	0	0
	CV	100	0	0
Yarding/handling frequency	CF	24	71	6
	SCV	20	55	25
	CV	0	11	**89**
Yard flow/handling	CF	53	41	6
	SCV	5	25	**70**
	CV	0	50	50

Highest frequency for each poor welfare category is in bold.

Appendix E. Pictures of Various Identification Markings at the Beef Cattle Herds in Namibia. Top Pictures Show the Skin-Flap Cuttings and Bottom Right Cow Has a Sign for Easy Identification and Bottom Left Shows a Cow with Multiple Brands for Traditional Treatment

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Assessing Extensive Semi-Arid Rangeland Beef Cow-Calf Welfare in Namibia. Part 2: Categorisation and Scoring of Welfare Assessment Measures

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Simple Summary: Basing welfare assessment standards on protocols developed for industrialised beef exporting countries could enhance the beef production and export standards in Namibia. This paper compares imposed thresholds of welfare measures of categorisation and derived thresholds to see—which was the most appropriate to the range of observations and welfare implication in three cow-calf production systems in Namibia. Using the same thresholds as the New Zealand protocol, regardless of the farm system, commercial herds achieved most welfare measures thresholds, but semi-commercial and communal herds attained acceptable welfare thresholds only in a few measures. For measures with significant welfare implications, the stricter threshold was retained, while derived thresholds appeared more appropriate for commonly occurring traits (but of less welfare importance), and some measures threshold were temporarily adjusted to reflect drought conditions. The welfare assessment identified the strengths and weaknesses in thresholds in measures across the farm types, which is envisioned to draw attention for remedial intervention to improve welfare standards of the beef industry.

Abstract: This paper aims to develop standards for a welfare assessment protocol by validating potential categorisation thresholds for assessing beef farms in various beef cow-calf production systems in Namibia. Forty measures, combined from a New Zealand-based protocol plus Namibia-specific measures, are applied to 55 beef farms (17 commercial farms, 20 semi-commercial and 18 communal village farms) during pregnancy testing, and a questionnaire guided interview. The categorised measures on a 3-point welfare score (0: good, 1: marginal, and 2: poor/unacceptable welfare) are subsequently compared with the derivation of thresholds based upon the poorest 15% and best 50% of herds for each measure. The overall combined thresholds of continuous measures across the three farm types show 10/22 measures that posed welfare compromise across Namibia, whereas commercial farms have 4/22 measures, and semi-commercial and communal village farms have 12/22 and 11/22, respectively, with high thresholds. Most measures-imposed thresholds are retained because of significant importance to the welfare of animals and preventiveness of the traits, while leniency was given to adjust good feeding and mortality measures to signify periods of drought. Handling measures (fearful, falling/lying) and abrasions thresholds are adjusted to reflect the temporary stress caused by infrequent cattle handling, and faulty yard designs/design and possible cattle breed influence on handling. Hence, Namibia needs prioritised investigation of underlying contributing factors and remediation to reduce the high thresholds.

Keywords: animal welfare assessment; categorisation; beef cow systems; semi-arid rangelands; Namibia

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1. Introduction

Animal welfare in Namibia has been increasingly acknowledged as important in the production and trade of farm animals and their products. International trading partners for Namibia's beef are seeking assurances that acceptable animal welfare standards are maintained. This requires concrete animal welfare legislation, including a standardised, validated protocol for assessing beef cattle welfare. Currently, the Farm Assured Namibian Meat (FAN Meat) scheme provides assurance that Namibian beef is produced under a natural, safe environment and is traceable and of good quality, but the scheme is not comprehensive as a welfare assessment protocol [1]. For example, key aspects of the FAN Meat animal welfare standards pertain to livestock keeping and transportation, and state that animal handling facilities must be adequate to ensure ease of handling and to prevent injuries to animals but does not provide specific recommendations or determine thresholds. The significant thresholds relevant to animal welfare covered under the FAN Meat scheme are those related to dehorning and castration, which require that these procedures are undertaken in animals younger than two months of age.

Currently, welfare standards in Namibian cattle are only routinely assessed at export abattoirs [2] with no standardised on-farm assessment. A validated, comprehensive, farm-based animal welfare assessment protocol with thresholds comparable to those used in other beef exporting countries would, thus, be useful for Namibia.

On-farm welfare data from both categorical measures (i.e., recorded at the individual farm level as good, marginal and poor welfare) and continuous measures (recorded as the percentage of cattle affected on each farm) need meaningful interpretation to reflect the welfare status of farms [3]. The results of categorical measures provide clear indications for farmers and their advisors regarding future actions: Good welfare—continue current practices; poor welfare—remedial action is needed; marginal welfare—assess current practice and aim for improvement [4]. The raw results for continuous measures do not provide such clear indications; they may be useful for benchmarking, but unless thresholds are identified at which action should be taken [5], farmers and their advisors may simply focus on prevalence as a means for determining actions rather than whether the prevalence is acceptable or not. Putting achievable thresholds across the prevailing beef production systems is critical for the country to benchmark and apply adequate remedial strategies for identified welfare compromise [6,7].

Using Namibian data we collected in Part 1 of the study [8], the present paper aimed to replicate the process used by us as part of the development of an animal welfare assessment protocol for extensive beef systems in New Zealand [4]. This is done to develop thresholds which could be used to categorise continuous animal welfare measures into acceptable, marginal and non-acceptable welfare. This aim was achieved through the setting and comparing of imposed categorisation thresholds with derived thresholds to see, across the farm systems in Namibia, which were the most appropriate thresholds to use to identify poor welfare and to stimulate improvement.

2. Materials and Methods

2.1. Description of the Study Areas

The study areas represent their farm types within Namibia, as described by Kaurivi [8]. In summary, commercial farms (n = 17 farms/herds) (Gobabis area, Omaheke region, eastern Namibia) were large privately-owned farms (range 3000–10,000 ha) that were individually fenced off in several grazing paddocks. Semi-commercial village farms (n = 20 herds) in Okakarara area (Otjozondjupa region) were government-owned settlement villages predominantly inhabited by farmers who were dependent on livestock production for their livelihood. Multiple families' (~10–30 families) cattle grazed and shared water on the same permanent communal land with limited or no internal and external border fencing. These farms were eligible to produce beef for export markets. Communal village farms (n = 18 herds) in Opuwo/Kaokoland area, (Kunene region, north-western Namibia) were exclusive government-owned communal settlements with inhabitants farming with small

multipurpose (i.e., milk, meat, dung for building) cattle holdings mainly for subsistence. As on semi-commercial village farms, multiple families' (~10–30 families) cattle grazed and shared water on the same permanent communal land with limited or no internal and external border fencing. Communal village farms were in an area restricted for animal disease control to produce beef for overseas export markets.

2.2. Welfare Assessments

The protocol used is described in full in Kaurivi [9]. The welfare assessment took place in March/April 2019 (autumn) on 55 farms during yarding of 2529 cows for pregnancy testing. In the yards, observations were made in the race (or pens) of body condition, rumen-fill, physical health, presence of long/sharp horns and behaviour. Stockpersonship was evaluated as cows entered, were handled and exited the race (or, if no race, when cows were restrained for pregnancy testing in pens). The yard design and handling facilities were also evaluated for ease of handling of cows. A farm resource evaluation and a questionnaire guided assessment of health and management of the herd in the preceding 12 months was undertaken, i.e., castration, dehorning, cattle identification practices, vaccinations, cattle deaths and disease incidences.

2.3. Data Analysis

All data were analysed using IBM SPSS Statistics for Windows Version 24 (IBM Corp. Released 2016. Armonk, New York, USA). Descriptive statistics for continuous measures were used to capture central tendency (median), and range (minimum and maximum). Qualitative methods were used to analyse the frequency of ordinal measures. The Shapiro-Wilk test was used to test for normality (significance level $p \leq 0.05$), and $\log10^{(n+1)}$ was used to transform those variables that were not normally distributed.

2.4. Categorisation and Refinement of Measures

The categorisation of measures was principally based on the New Zealand protocol on a 3-point welfare score of 0: Good welfare (no intervention necessary, but monitoring); 1: Marginal welfare (plan for intervention, increase monitoring); and 2: Poor/unacceptable welfare (immediate intervention required) [4]. The initial categorisation of welfare thresholds in the New Zealand protocol was based upon the authors' perception of acceptable welfare standards and the consensus of the literature. Subsequently, an alternative approach to applying pre-determined value judgements was to determine the threshold from the data, so that an arbitrary 15% of herds were considered poor and 50% good. Derived thresholds were determined based on z scores to result in approximately 50% of herds falling into an acceptable welfare band ('green') and 15% of herds into a poor welfare band ('red'). Herds not in the green or red band were classified as orange. The 15% was chosen to fit with the '15% rule' where animals (in this case, herds) below this point are considered as worse-off in terms of animal welfare compromise [10,11]. For each non-categorical measure, the derived red threshold and the imposed score 2 threshold were then compared by dividing the derived threshold by the imposed threshold.

The New Zealand thresholds were compared with the pre-determined thresholds of each continuous measure in the current data from the three farming systems in Namibia. For example, for good health measures (i.e., blindness, mortality), painful conditions (e.g., dystocia) and absence of injuries or physical impairment the welfare thresholds were kept the same at 2%. For the additional Namibia-specific measures, the thresholds for extraneous (multiple) brands/cuts (5%), long/sharp horns (10%) and external parasites (10%) were based on authors' opinion of acceptable welfare standards (no concrete thresholds could be found in literature). The threshold (10%) for tail twisting was aligned with that of hitting of cows. The distance to water and grazing categorisation was based on Holechek [12] and the use of electrical prodders (<1%) on Grandin [13]. The imposed thresholds were applicable for all farm types; there was no division between village farms or from commercial farms. Farms/herds were not given an 'overall' welfare score [14] because all of the measures were

considered important, and an overall acceptable score may mask unacceptable welfare in some measures [5]. Categorisation thresholds and details of how each measure in the Namibia protocol was assessed are presented in Tables 1–3.

Table 1. Categorical ranking of good feeding and appropriate environment measures in the proposed Namibia extensive beef cow-calf systems protocol.

Welfare Criteria	Animal Welfare Measure/Indicator	Scoring Description	Categorical Ranking
Absence of hunger	Body condition score (thin cows)	% thin/emaciated cows in herd of score (score 1–2.5) on 1–5 scale [15].	0: 0–5.0% 1: 5.1–10% 2: >10%
	Rumen fill score (poor rumen fill)	% of animals with hollow/empty rumen observed in the race [16].	0: 0–20.0% 1: 20.1–50% 2: >50%
	Distance to grazing	The questionnaire asked how far cattle had to walk to access grazing. (This included the distance to grazing for cattle that daily come to drink after grazing at water points that are provided close to yards).	0: 0–1.60 km 1: 1.61 km–3.2 km 2: >3.2 km
Absence of thirst	Distance and availability of water	Average distance to access water. (Distance to water was estimated as the distance to grazing as water points are close to yards and cattle come to drink after grazing in some herds).	0: 0–1.6.0 km 1: 1.61 km–3.2 km 2: >3.2 km
Comfort around resting	Dirty body	Total number of animals assessed as having a dirty tail, hind and flank (>25% of combined areas covered with dirt or manure).	0: 0–10.0% 1: 10.0–20% 2: >20%
Ease of movement	Absence of hazardous objects/environment	Hazardous objects observed in the yard and paddocks (i.e., sharp objects lying around, steep hills).	0: no hazards 1: 1 or 2 hazards 2: 3 or more hazards or cattle had died in any hazard

%: percentage.

Table 2. Categorical ranking of good health measures in the proposed Namibia extensive beef cow-calf systems protocol.

Welfare Criteria	Animal Welfare Measure/Indicator	Scoring Description	Categorical Ranking
Absence of injuries/physical impairment	Abrasions, Swelling Hair loss/hairless	% of observed cows with abrasions/fresh scratches, swelling or hairless patches (>1 cm).	0: 0.0% 1: 0.1–2% 2: >2%
	Extraneous cattle markings/ branding wounds (e.g., multiple brands, dew lap cutting)	% of observed cows with brand mark wounds (>2 cm) or more than one extraneous brand mark (i.e., stock brand, initials or name of a farmer branded).	0: 0.0% 1: 0.1–5% 2: >5%
	Size and shape of horns	Number of observed cows with sharp/long horns (>5 cm in length, sharp and forward facing to pose a risk of injuring others).	0: 0–5.0% 1: 5.1–10% 2: >10%
Absence of disease	Blindness, Ocular and Nasal discharges	% of observed cows with blindness in one or both eyes. % of observed cows with ocular and nasal discharges extending 2 cm.	0: 0.0% 1: 0.1–2% 2: >2%
	Lameness	% of observed cows with gait abnormality.	0: 0.0% 1: 0.1–2% 2: >2%

Table 2. *Cont.*

Welfare Criteria	Animal Welfare Measure/Indicator	Scoring Description	Categorical Ranking
	Diarrhoea	% of observed cows with evidence of diarrhoea (more than a hand wide on both sides from the base of tail).	0: 0–10% 1: >10–20% 2: >20%
	Dystocia	% of cows recorded with difficult births.	0: 0.0% 1: 0.1–2% 2: >2%
	Mortality rate	Sum of accidental deaths, deaths, due to disease, or culling because of disease/accidents in the last 12 months.	0: 0.0% 1: 0.1–2% 2: >2%
	Fly burden Tick burden	Proportion of observed cows with more than an estimated 20 flies (i.e., horse flies). Proportion of observed cows with more than an estimated 20 ticks on any part of the body of a cow.	0: 0–5.0% 1: 5.1–10% 2: >10%
Painful procedures	Disbudding Castration	Specify age at disbudding and use of anaesthetics. Specify age at castration and use of anaesthetics.	0: No disbud/castration 1: ≤2 months 2: >2 months 0: No disbud/castration 1: use of anaesthetics 2: no anaesthetics
	Ear tagging/ notching	Specify age at ear tagging and ear notching and with/without the use of anaesthetic.	0: no tag or use anaesthetics 1: tag with no anaesthetics 2: notching/cutting with no anaesthetics
	Hot-iron branding	Record branding events and the use of local anaesthetic (from the questionnaire).	0: no branding or use anaesthetics 1: one brand (compulsory) 2: more than 1 brand
	Use of electrical prodders	Estimated proportion of cows prodded with an electrical goad while drafted or standing in the race, pens or yards.	0: no prodding 1: few/occasional prod (≤1% cows) 2: many/frequent prod (>1% cows prodded)

%: percentage.

Table 3. Categorical ranking of appropriate stockpersonship measures in the proposed Namibia extensive beef cow-calf systems protocol.

Welfare Criteria	Animal Welfare Measure/Indicator	Scoring Description	Categorical Ranking
Stockpersonship animal-based measures in and out of race	Fearful/agitated	% cows showing fearful/agitated behaviour (climbing on others or attempting to escape).	0: 0.0% 1: 0.1–5% 2: >5%
	Falling	% cows lying in or falling in race/forcing pen or on exiting.	0: 0.0% 1: 0.1–2% 2: >2%
	Stumbling	% cows stumbling while exiting to paddocks.	0: 0.0% 1: 0.1–5% 2: >5%
	Running	% cows running out of the race/holding pens into paddocks.	0: 0–5.0% 1: 5.1–10% 2: >10%

Table 3. *Cont.*

Welfare Criteria	Animal Welfare Measure/Indicator	Scoring Description	Categorical Ranking
Animal handling stockpersonship and resource-based measures	Mis-catching (in chute/race)	# of cows mis-catch with gates on any part of the body either in the race or chute head bale. If no race, available mis-catch was recorded if more than one attempt was made to capture/restrain an individual animal with ropes or if a cow did not stand still when a rope was secured around the legs.	0: no mis-catch 1: mis-catch ≤1% 2: mis-catch >1%
	Hitting	% of cows hit or poked with moving aids.	0: no hitting 1: occasional/few hit 2: frequent hit/poke (>10% cows)
	Tail twisting	Estimate the proportion of cows with tail twisted while drafted or standing in the race or pens.	0: no twisting 1: occasional/few twist (≤10% of cows) 2: frequent twist (>10% of cows)
	Noise of handlers Noise of equipment/ machinery Dogs noise around the yard	Evaluate noise of handlers, noise of equipment (race or chute gate) and machinery (generators etc.) and observe the presence and noise frequency of dogs around the yard.	0: no noise/dogs 1: minor audible/occasional noise 2: unpleas-antly/persistent noisy handlers/equip/dogs
	Health checks	Frequency of health checks on cows during pregnancy.	0: daily 1: once-twice/week 2: more than weekly
	Yarding frequency	Frequency of yarding of cows per year for handling or restraining.	0: >4 times 1: 3–4 times 2: 0–2 times
	Yard flow/handling of cattle	Yard flow of cattle influenced by handling facilities design/quality.	0: very effective cattle flow 1: effective but with flaws 2: difficult flow

%: percentage. #: proportion.

3. Results

3.1. Categorisation Results

Categorised observational data are illustrated in Figure 1 (measures of feeding, and environmental factors), Figure 2 (health indicators), Figure 3 (frequencies of painful procedures), Figure 4 (animal-based stockpersonship scores) and Figure 5 (resource and management-based stockpersonship scores).

Feeding measures: Cattle on commercial farms did not walk long distances to grazing and water (<1.6 km–3.2 km), and there were no emaciated cows observed, and 76% herds were in good body condition, and 88% of cows had good rumen fill. Semi-commercial and communal herds obtained a good welfare score for BCS only in 40% and 17% of herds, respectively, of which most cattle herds in communal villages were classified as more emaciated (<2/5 scale) than just thin. Cattle walked long distances to water and grazing (>3.2 km), and all village farm herds scored poorly in this. Hazards were mostly marginal across the farm types, with semi-commercial and communal showing 35% and 33% of herds with poor welfare score.

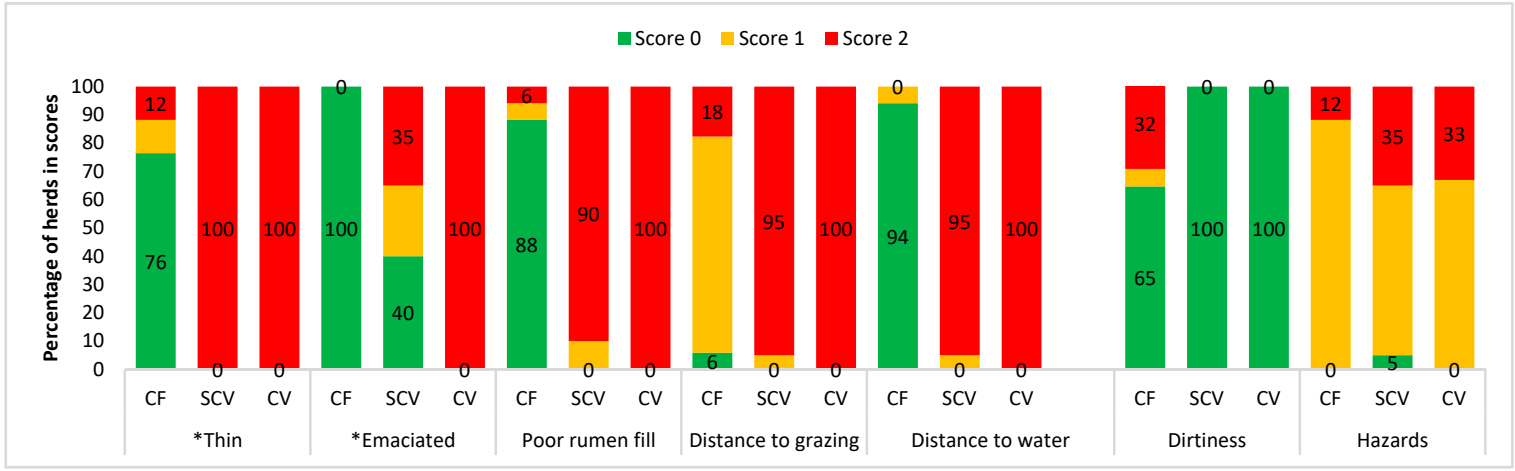

Figure 1. Good feeding and environment measures (separated by a gab before dirtiness) at the commercial (CF), semi-commercial (SCV), and communal (CV) beef cow herds in Namibia showing the percentage of herds per welfare scores. * Thin included all thin cows ≤2.5/5 scale, and emaciated was only cows with BCS 1–2/5 scale. See Table 1 for measures scoring descriptions and categorical ranking.

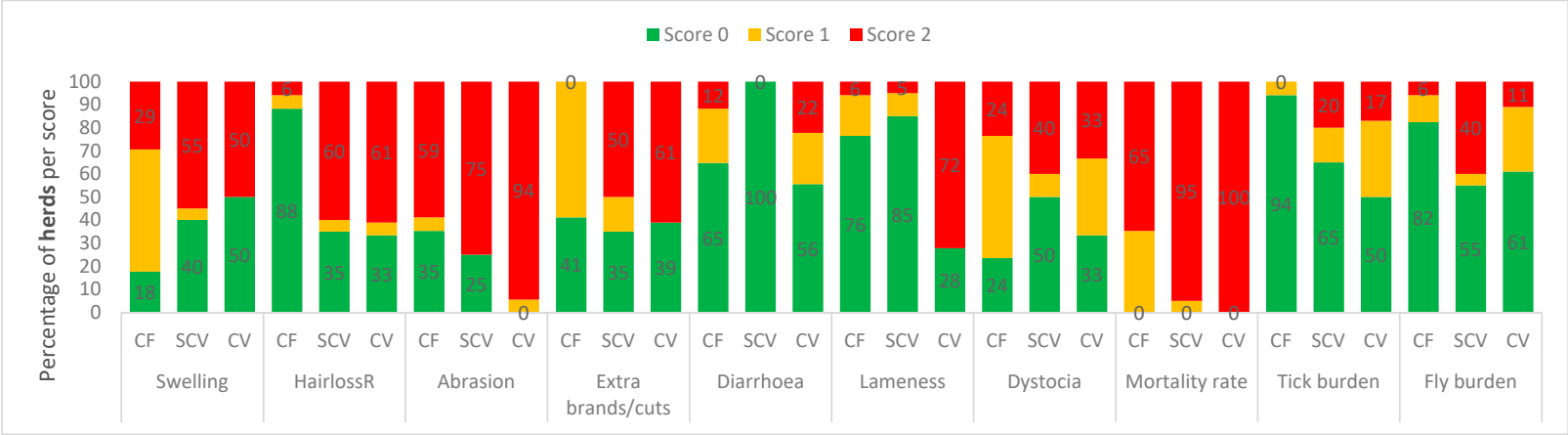

Figure 2. Categorised health measures at the commercial (CF), semi-commercial (SCV), and communal (CV) beef cow herds in Namibia showing the percentage of herds per welfare scores. See Table 2 for measures scoring descriptions and categorical ranking.

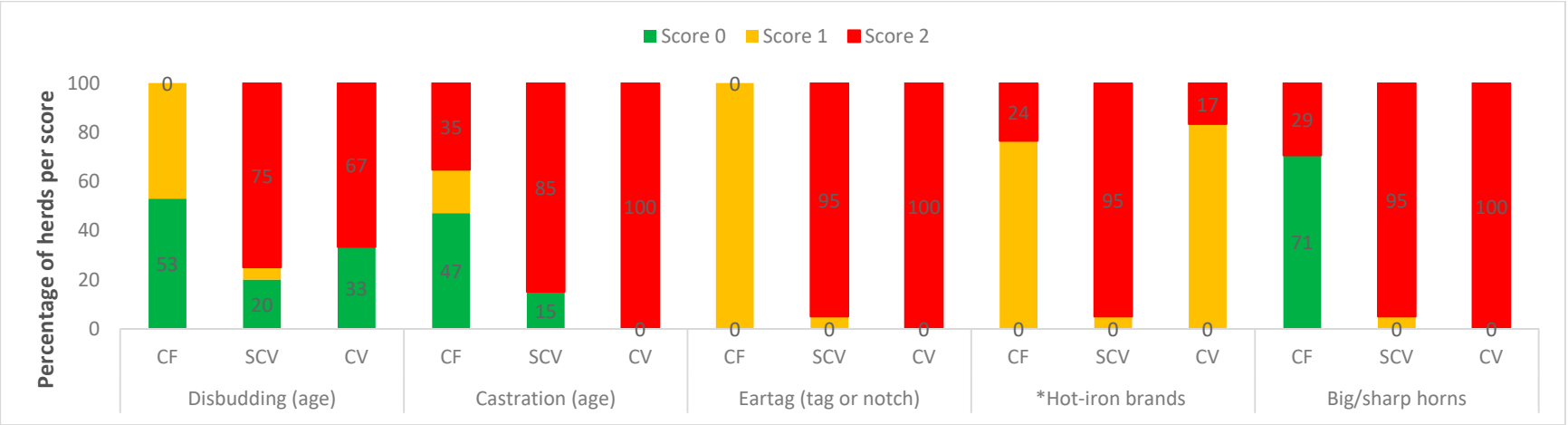

Figure 3. Painful management procedures at the commercial (CF), semi-commercial (SCV), and communal (CV) beef cow herds in Namibia showing the percentage of herds per welfare scores. * Hot-iron branding described one compulsory brand (score 1) or more than the one brand (score 2). See Table 2 for measures scoring descriptions and categorical ranking.

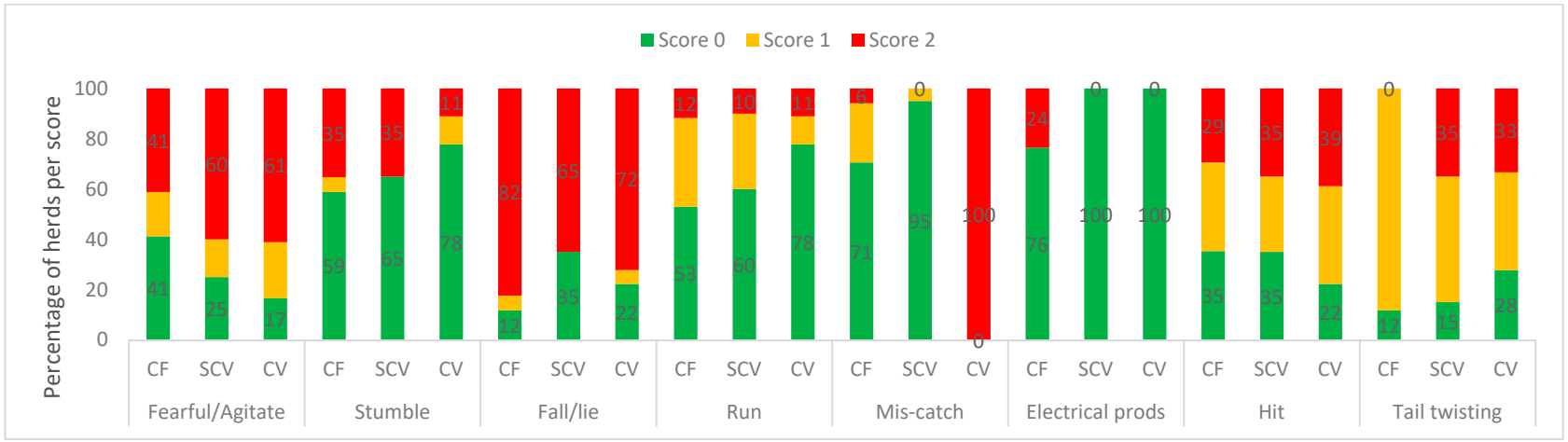

Figure 4. Animal based stockpersonship measures at the commercial (CF), semi-commercial (SCV), and communal (CV) beef cow herds in Namibia showing the percentage of herds per welfare scores.

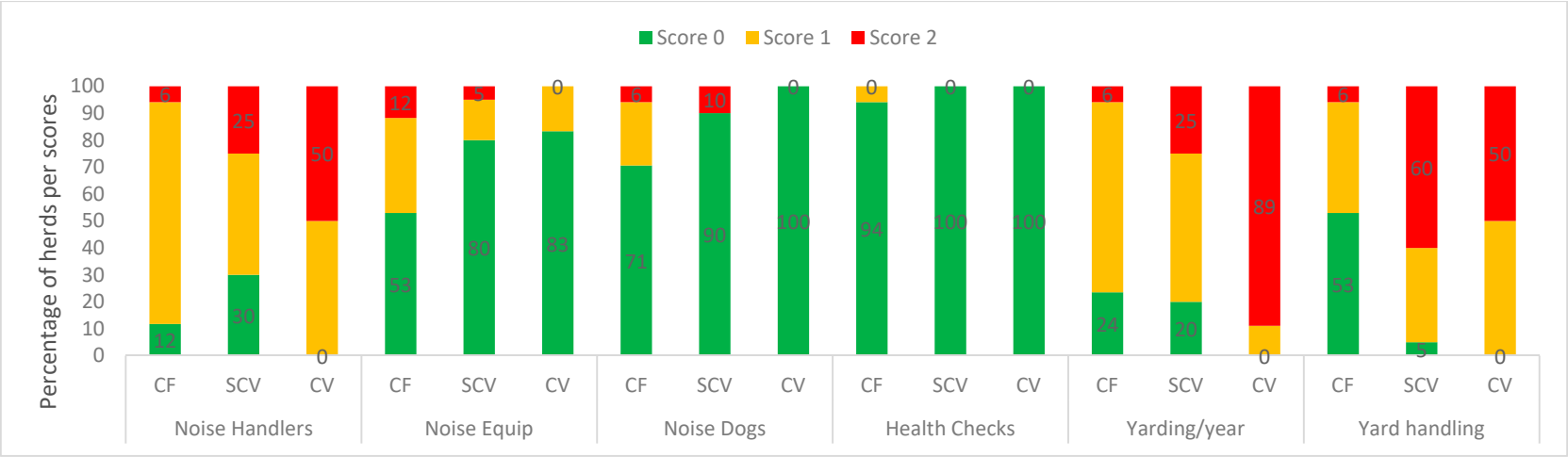

Figure 5. Resource-and management based stockpersonship measures at the commercial (CF), semi-commercial (SCV), and communal (CV) beef cow herds in Namibia showing the percentage of herds per welfare scores.

Health observations: The worst scores were observed for abrasions and mortality at all farm types. Only 35% of commercial and 25% of semi-commercial herds had a good score for abrasions, and none of the communal herds had a good score for abrasions. The mortality rate was categorically poor in 65%, 95% and 100% of commercial, semi-commercial and communal herds, respectively. Fifty percent of semi-commercial herds had a good score for dystocia, while only 24% and 33% of commercial and communal herds did, respectively. Lameness and extraneous brands/cuts were worst in communal followed by semi-commercial herds. The tick and fly burden were worse in semi-commercial with 20% and 40% herds with a poor score, and 17% and 11% of communal herds had poor welfare for ticks and flies, respectively, while the majority of commercial herds had a good score for both ectoparasites types.

Painful management measures: Procedures were performed without the use of anaesthesia or analgesics. All farm types identified cattle with ear tags (marginal welfare), while most herds at the village herds had poor scores for ear notching (with knives) and extraneous branding/cuttings. In relation to disbudding, those commercial herds who disbud, the mode for age was 2 months, while it was 6 months at the village herds. Only 29% of herds had cows with long/sharp horns in commercial compared to 95% and 100% for semi-commercial and communal herds, respectively. Communal village farms had the most herds with poor scores for dehorning, castration, and ear tagging/notching.

Animal-based stockpersonship measures: Scores were similar across the farm types, except for electrical prodders, which were only used at 5/17 commercial herds, producing a poor score at those herds (>1% cows prodded). Commercial farms had the least herds with poor welfare for fearful/agitated, hitting and tail twisting. All the farm types scored poorly (>2% threshold) for falling/lying.

Resource-and management-based stockpersonship measures: Good welfare score was showed for equipment noise and dog noise and health checks, at most herds across the farm types. Commercial farms had less noisy handlers and more herds with >4 times yarding frequency per year (good welfare), and effective yard handling/flow. The communal (95% of herds) cattle yarding frequency/year (2 or fewer times) was the poorest than the other farm types.

3.2. Refined Thresholds

Derived threshold values for the three farm types are shown in Table 4 For commercial, of the 22 measures, only falling/lying was normally distributed. The measures that were normally distributed for semi-commercial herds were thin and poor rumen fill cows, long/sharp horns, and mortality rate. In addition to these latter measures, abrasions, falling/lying and fearful/ agitated cows' measures were also normally distributed for communal herds. Commercial herds had 4/22 measures (abrasion, mortality, fearful and falling/lying) with a derived red threshold that were >2 times the imposed threshold, with ratios ranging from 2.5 (fearful/agitated) to 6.9 (falling/lying). Including these measures, both semi-commercial and communal herds had a similar total of 12/22 and 11/22 measures, respectively, with a derived red threshold that was >2 times the threshold imposed by categorisation. The measures were related to good feeding (thin, emaciated and poor rumen fill cows), extraneous brands/cuts, long/sharp horns, swelling and hair loss, and as well as dystocia at semi-commercial herds and lameness at communal herds. All three farm types had similar red thresholds (~12%) for cows falling/lying during handling. The highest red threshold was thin cows for communal (97.7%), whilst the proportion of emaciated cows was 82.9% for communal herds.

All combined derived thresholds for the 55 beef cow herds are shown in Table 5. In this regard, 10/22 measures had derived red threshold that were >2 times the imposed threshold with ratios ranging from 2.4–16.6%. These included all the four measures where commercial herds failed (abrasion, mortality, fearful and falling/lying) and in addition, three measures related to good feeding (thin, emaciated, poor rumen fill) and swelling, hair loss and long/sharp horns.

Table 4. The ratio of red thresholds (derived from data) over the imposed categorisation thresholds of the individual 3-beef cow-calf farming systems in Namibia. Derived thresholds were determined based on z scores to result in approximately 50% of herds falling into an acceptable welfare band ('green') and 15% of herds into a poor welfare band ('red'). Herds not in the green or red band were classified as orange".

Measures	Imposed Categorisation Thresholds (%)	Commercial (*n* = 17)				Semi-Commercial (*n* = 20)				Communal (*n* = 18)			
		Mean(%)	Orange Threshold	Red Threshold	Ratio of Threshold	Mean (%)	Orange Threshold	Red Threshold	Ratio of Threshold	Mean (%)	Orange Threshold	Red Threshold	Ratio of Threshold
# Thin cows	10	7.2	2.5	11.6	1.2	70.7 [n]	65.6	102.6	10.3 *	97.7 [n]	97.6	102.7	10.3 *
# Emaciated cows	10	0.0	0.0	0.0	0.0	11.1 [n]	5.4	23.8	2.4 *	82.9 [n]	81.8	98.0	9.8 *
Poor rumen fill	50	4.4	1.2	6.3	0.1	49.1 [n]	44.7	72.9	1.5	76.2 [n]	74.3	95.7	1.9
Dirtiness	20	0.7	0.3	1.5	0.7	0.0	0.0	0.0	0.0	2.0	0.8	3.6	0.2
Swelling	2	2.1	1.6	3.8	1.9	4.9	2.2	9.1	4.6 *	3.3	1.7	6.7	3.3 *
Hair loss	2	0.3	0.1	0.7	0.3	3.6	1.9	7.2	3.6 *	6.8	3.5	14.9	7.5 *
Abrasion	2	3.2	1.9	6.6	3.3 *	8.7	4.8	18.9	9.5 *	20.4 [n]	16.9	35.7	17.8 *
Extraneous brands/cuts	5	1.0	0.8	2.1	0.4	8.1	3.0	15.1	3.0 *	10.7	4.0	19.1	3.8 *
Long/sharp horns	10	7.2	3.1	13.6	1.4	45.5 [n]	40.1	70.6	7.1 *	59.3 [n]	54.9	88.3	8.8 *
Blindness	2	0.3	0.2	0.8	0.4	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.1
Ocular discharge	2	0.1	0.1	0.3	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.1
Nasal discharge	2	0.1	0.1	0.3	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.1
Diarrhoea	10	3.4	1.7	6.9	0.7	0.1	0.1	0.3	0.0	7.1	3.5	14.9	1.5
Lameness	2	0.5	0.3	1.1	0.6	0.3	0.1	0.7	0.4	5.1	2.8	10.5	5.3 *
Dystocia	2	0.9	0.7	1.7	0.8	2.2	1.2	4.5	2.3 *	1.9	1.3	3.8	1.9
Tick burden	10	0.4	0.1	0.9	0.1	11.8	2.6	17.3	1.7	6.0	2.8	12.2	1.2
Fly burden	10	1.8	0.6	3.2	0.3	14.1	3.5	25.2	2.5 *	9.5	3.3	17.2	1.7
Mortality rate	2	3.4	2.8	5.4	2.7 *	12.3 [n]	9.5	23.9	11.9 *	13.2 [n]	10.7	22.7	11.4 *
Fearful/Agitate	5	6.2	3.4	12.7	2.5 *	7.1	4.5	14.8	3.0 *	7.4 [n]	5.2	15.6	3.1 *
Fall/lie	2	6.5 [n]	4.8	12.9	6.4 *	6.4	2.7	12.7	6.4 *	5.7 [n]	3.8	12.0	6.0 *
Stumble	5	3.8	1.8	7.5	1.5	3.9	1.2	6.2	1.2	1.8	0.6	3.2	0.6
Run exit	10	5.6	3.5	11.2	1.1	3.3	1.2	6.2	0.6	3.1	1.4	6.0	0.6

[n] Measures were normally distributed. * Measures had the ratio of derived red threshold: Imposed threshold that was >2 times. # Thin cows included all cows with BCS $\leq$ 2.5/5 scale, and emaciated was only the proportion of thin cows with the severity of BCS 1–2/5 scale.

Table 5. Combined ratio of red thresholds (derived from data) over the imposed categorisation value of the 3-beef cow-calf farming systems in Namibia (n = 55). Derived thresholds were determined based on z scores to result in approximately 50% of herds falling into an acceptable welfare band ('green') and 15% of herds into a poor welfare band ('red'). Herds not in the green or red band were classified as orange".

Measures	Imposed Categorisation Threshold (%)	Mean (%)	Orange Threshold (%)	Red Threshold (%)	Ratio of Red Thresholds/Imposed
# Thin cows	10	59.9	29.4	166	16.6 *
# Emaciated cows	10	31.2	0.9	62.4	6.2 *
Poor rumen fill	50	44.2	20	121.8	2.4 *
Dirtiness	20	0.9	0.3	1.6	0.9
Swelling	2	3.5	1.7	5.2	2.6 *
Hair loss	2	3.6	1.3	6.6	3.3 *
Abrasion	2	10.6	6.5	25.2	12.6 *
Extraneous brands/cuts	5	6.8	2	8.9	1.8
Long/sharp horns	10	38.2	14.7	82	8.2 *
Blindness	2	0.1	0.1	0.4	0.2
Ocular discharge	2	0	0	0.2	0.1
Nasal discharge	2	0	0	0.2	0.1
Diarrhoea	10	3.4	1.3	6	0.6
Lameness	2	1.9	0.7	3.4	1.7
Dystocia	2	1.7	0.7	3.3	1.7
Tick burden	10	6.4	1.6	8.9	0.9
Fly burden	10	8.8	2.2	13.5	1.4
Mortality rate	2	9.8	6.9	18.1	9.1 *
Fearful/Agitate	5	6.9	4.3	14.2	2.8 *
Fall/lie	2	6.2	3.6	12.7	6.4 *
Stumble	5	3.2	1.2	5.4	1.1
Run exit	10	3.9	1.8	7.7	0.8

* Measures had the ratio of derived red threshold: Imposed threshold that was >2, # Thin cows included all cows with BCS $\leq$ 2.5/5 scale, and emaciated was only the proportion of thin cows with the severity of BCS 1–2/5 scale.

4. Discussion

Kaurivi [8] compared the effects of farm production systems on the welfare of beef cows with results showing better welfare on commercial, followed by semi-commercial, and the communal herds in the least. The current paper used that data to develop standards for a welfare assessment protocol, by validating potential thresholds which could be used to categorise continuous animal welfare measures into acceptable, marginal and unacceptable welfare for assessing beef farms in various cow-calf production systems in Namibia. The categorised measures scores showed a marked separation of commercial farms from semi-commercial and communal village farms, but no separation between the village farm types. The same thresholds were used for all farm systems, regardless of the village herds not achieving imposed thresholds that are achievable at commercial herds, because the impact of a situation or condition on the welfare of the cow is not mediated by the type of farm she lives on. The setting of thresholds should reflect standards of "what should be and not what is", and common findings that are compromising the welfare of animals should not be accepted as acceptable standards [17]. Critically, multiple observers would ensure better reliability of scoring of the measures, and hence, confidence in the validity of the results, than the imminent subjectivity that may be caused by one person.

The findings indicate that to improve most of the compromised traits, development of interventions should be geared towards what works in village farm herds. Whereas for some other traits, there are herds exceeding the threshold in all herd types, and solutions must be developed for all herd type. Although the long term target is to have improved derived threshold in all measures at all the farms (a target of at least 50% of the herds in good welfare), an initial target to improve the worst 15% of herds might be the logical first step, and then revise the red thresholds, to gradually to pull the recovering herds to better. It is

risky to set a target that 90% of the herds currently fail; this may deter farmers from making improvements and instead dismiss the target as unrealistic. See Appendix A (Table A1) for the summary of continuous welfare measures scoring threshold for Namibia beef cattle systems compared to New Zealand thresholds.

With regards to *good feeding*, with below-average rainfall (since 2013) across Namibia, the 2019 drought (the driest year in 90 years) was treated as a state of emergency by the government [18]. The impact of drought had more dire consequences on the village farm types (i.e., high thin and poor rumen thresholds and long-distance walking to grazing) than for commercial farms, because of the challenges of communal grazing land without proper demarcation that does not allow sustainable rangeland management [19,20]. In terms of identifying the need for nutritional intervention, stringent thresholds for low BCS (between 5–15%) was supported [21,22]. This should even be truer for emaciated cows (BCS < 2/5 scale) that indicate a greater unacceptable compromise of cattle welfare [15]. In New Zealand, recommendations are that cows' body condition not to be below 4/10 scale [23] and under Australian legislation, it is not acceptable for producers to allow animals to die because of starvation and thirst [24]. For Namibia, an adjustable lenient threshold setting could be climate-responsive, i.e., in a drought, cows are going to get thinner than a normal year, and a farmer who has thin cows in a good year is a worse farmer than a farmer who has the same prevalence of thin cows in a drought, but the level of emaciation in cattle is unacceptable regardless. Taken together, an adjusted threshold to reflect drought conditions could be 30% (orange thresholds 29.4%), while retaining the imposed threshold of 10% during sufficient rainfall periods. Nonetheless, drought in Namibia is predicted to be more frequent than before, due to the impact of climate change [20]. Hence, there is a need to put mitigating strategies in place (i.e., supplementary feeding, targeted livestock grazing, and timely adjustments to animal numbers; [25,26], especially in the village farms. Similar adjustments could also apply to poor rumen fill (RFS). However, although RFS is a good indicator of nutritional status of cows, it reflects animals recent feed intake, thus, the low imposed threshold of 50% is appropriate for the detection of poor nutrition of extensively reared cows that are likely to be drafted a day before an assessment. This short-term deprivation of feed might be true during normal rainy seasons across Namibia beef farms, but it reflected a long-term underfeeding, due to the forage shortage at the village farms. Distinguishing between short and long-term poor RFS was impractical, hence, the imposed threshold was retained. Over a long period of time, poor RFS could bring awareness and correction of compromising feed deprivation or other underlying problems.

Regarding *appropriate environmental issues*, dirtiness and diarrhoea were the only measures where the thresholds (both thresholds were 20%) fit for Namibia were reduced. In New Zealand, diarrhoea was faecal soiling, due to the high-water content in the pasture. Thus, a 5% threshold (between 3% and 6% orange and red threshold, respectively) fit for Namibia where grass grows seasonally and between years, and where diarrhoea cases may also be of pathological nature (i.e., infectious causes, internal parasites, and plant toxicity) was essential. Similarly, a 5% threshold was more fitting for dirtiness, where cattle on drier pasture are less dirty; red thresholds were only up to 3.6% in this study (Table 4). Moreover, stringent thresholds might also not be relevant for dirtiness, a welfare measure that is questionable for assessing cattle in an extensive system [4,27], unless cattle were destined for slaughter [13].

For most *health-related measures*, the imposed thresholds were retained despite the high occurrence of traits, considering the welfare implications to animals, possible preventative and mitigating strategies available. For painful conditions like lameness and dystocia, a 2% threshold was retained and is attainable on Namibia beef herds (mean 1.9% and 1.7%, respectively). For measures related to skin alterations (swelling, hair loss and abrasion) the derived thresholds were more than twice the imposed threshold for the combined herds, indicating high prevalence. The prevalence of swelling was attributed to faulty injections; thus, there is room for improving the skills of injections across all farm types, through

awareness and training. Similarly, the high derived thresholds of hair loss at the village herds could have been prevented with preventative vaccination of the endemic lumpy skin disease in the country. Hence, an imposed threshold of 2% was also retained as fitting for these conditions. On the other hand, the much higher prevalence of abrasions on cattle across all the beef farm types is indicative of a welfare concern in the country, so an initial target of 2% would likely be unrealistic. However, abrasions are painful and cause suffering for the animal. Efforts should be directed toward identifying the causes of the abrasions and attempting to remove relevant hazards from the environment, such as faulty yard designs and yard structural materials [27]. Given 59–96% of herds in the different herd types exceed the imposed threshold, a higher threshold (e.g., 7%; orange threshold) could be applied initially to allow improvements to be made in the worst affected herds first.

Setting welfare thresholds for any measures should reflect the significance of that trait to the welfare of animals and not necessarily according to the status quo. A good example was the mortality rate that varies in extensive beef systems with the type of production system, the location, and herd management [28,29]. In this study, cattle losses indicated a worrisome occurrence in all farm types (derived thresholds >9 times the imposed thresholds). The mortality rate on commercial herds at an average of 3.4% (range 0–11.5%) was consistent with an average of 3.5% cattle losses in another commercial herd in Namibia over a 13 year period [29]. These figures are similar to cattle losses (average 3.9%) at 25 beef farms in New Zealand, where the feasibility of categorisation thresholds used in this study was verified [30]. However, an imposed threshold of 2% was retained in that protocol, given the significance of the measure to the welfare of cattle [4], and the same threshold was, thus, taken for Namibia. Judging from the mortality rate median of 2.4% at commercial herds, there is potential for attaining the imposed thresholds. However, like for feeding measures, an adjusted lenient threshold to reflect drought condition (i.e., increased predation, poor nutrition effects), that contributed to cattle losses could be 7% (orange thresholds of combined herds). It will be interesting and useful to validate the mortality threshold at farms during years of average rainfall. Setting mortality threshold for Namibia beef production systems is an important step towards creating awareness of the risks of cattle losses on the farm towards, strategising remedial actions, and thus, a stringent threshold is worth keeping.

Ectoparasites have a significant impact on the welfare of animals (i.e., transmit diseases, biting stress, skin injuries, and irritation) and a high incidence can markedly impair farm productivity [31,32]. However, the impact of different parasites on animals is different, i.e., cattle with high-level tick burden are more likely to be welfare compromised than those with fly burden. For example, ticks in Namibia transmit significant cattle disease, e.g., babesiosis, anaplasmosis, sweating sickness, and including lumpy skin disease, while flies are of a lesser impact [32,33]. Thus, the category imposed as an acceptable or nonacceptable compromise might have to vary depending on the welfare impact of each parasite type. In the present study, the number of ticks or flies on any animal to be regarded as a burden was the same at 20, and the threshold for unacceptable welfare was the same at 10%. The presence and thresholds setting of ectoparasites on extensive cattle has not been validated in animal welfare assessment protocols, and it is worthwhile validating our findings elsewhere in similar production systems to determine acceptable thresholds. For example, in northern Australia, treatment is only recommended for individual beef cattle infested with more than 200 buffalo flies [34]. Most of the predominant cattle breeds in Namibia are also tick tolerant [35], and ectoparasites burden is significantly influenced by seasonality and environmental factors [36]. Thus, thresholds might differ in countries, production systems and seasons. Nonetheless, a threshold of 10% (for both flies and ticks) is attainable across beef production systems with preventative herd health management. This was evident in the low mean incidence of both ticks and flies at commercial farms where ectoparasites treatment is commonly done.

With regards to *painful management procedures*, unlike castration and disbudding that can be performed at an early age (<2 months) and with anaesthesia to mitigate pain [37],

the downside of branding early is that the brand becomes unreadable with time in adult cattle. Rebranding is a permissible requirement for cattle trading in Namibia [38], but the practice of multiple brands requires longer restraining of animals and causes more wounds on any part of the animals' body [39]. Farms with only the initial brand were given a marginal score of welfare, while the extraneous brands/cuts (to mitigate the risk of stock theft) were regarded more extreme and indicated a poor welfare score. The village farms had derived red thresholds that were ≥3 times higher than their imposed thresholds for extraneous brands/cuts, indicating a trait with a high occurrence at these farm types. However, the imposed threshold of >5% of cattle in a herd with this trait (also close to the orange threshold of 3% and 4% at the villages) was retained as reasonable to bring awareness to these painful practices. Hence, the mounting scientific evidence that relates hot-iron branding to the welfare compromise of cattle [40–42] could guide Namibia to abolish hot-iron branding and join many countries that are increasingly prohibiting this practice [39]. Alternatively, the country could opt for microchipping for identification, or freeze branding or the use of cooling gel to reduce pain sensitivity and aid in faster brand wound healing [40–42]. However, the practicalities and resource availability of such alternatives may hinder their applicability. To this end, mitigating strategies for stock theft along with awareness of compromising welfare practices (e.g., dewlap cuts, ear cuts) are immediate remedial actions to be taken to improve cattle welfare at most herds in the village farms.

The threshold (10%) considered as unacceptable welfare for herds with long/sharp horns was motivated by difficulty in handling, injuries, bruises, and condemnation at slaughter [43] that are associated with horned cattle. In this study, herds with long/sharp horns had a combined derived red threshold that were more than >8 times higher than their imposed thresholds. Arguments are many for the keeping of horned cattle; for example, traditional customs and sacredness at some households [9], natural tools against predation [43,44] and for behavioural and physiological functions of cattle [43]. Thus, keeping a proportion of cows with horns, e.g., 40% (close to 38% orange threshold; Table 5) might be more appropriate as a compromise. Also, the downside of keeping the imposed 10% threshold than an adjusted 40% will be the caveats of increased disbudding of calves. Breeding for a polled state might solve the surrounding debate of keeping horned cows [45,46]. Indeed, Broom, [47] advocated for holistic critical scrutiny of issues conflicting with animal welfare standards (i.e., horned cattle), and what is accepted as normal by the farmers is not necessarily acceptable for the welfare of animals [17]. Further investigation on the impact of keeping of horned cattle against mitigating predation advantage is, thus, worth an undertaking and thresholds might be adjusted accordingly.

For *stockpersonship and handling measures*, it appears that three main issues, namely, (1) yarding frequency, (2) breed variations and (3) yard design/quality contributed to the high derived thresholds of fearful and falling/lying across the farm types. Fearfulness in cattle was associated with adverse handling [48,49] and sub-optimal production and reproductive performance [50,51]. Thus, critical analysis and understanding of the causes of high incidences of fearful cattle in the country are important. In New Zealand, infrequent yarding of beef cattle was thought accountable for the adjustment of the original imposed 2% to 5%, a more appropriate derived red threshold. This adjusted threshold was used for Namibia, but all farm types still obtained high derived red thresholds. This may indicate a need to adjust the imposed threshold, for example, to 7% (orange threshold). It is likely that the commonness of fearful/agitated behaviour may have been a temporary response to the infrequent handling and stressful environment caused by the yard's designs and/or construction quality (see Appendix B; Figure A1). The predominant Brahman cattle were also noted to exhibit flight behaviours (as was noted by Cooke [52]), which could explain the comparable fearfulness incidences at semi-commercial and communal herds, although communal herds with more tamer crossbreds and Sanga breeds were less restrained. Brahman cattle were also noted to lie in the race more than other breeds (mostly for no apparent reason), contributing to the high derived thresholds (ratio of 6 times)

of falling/lying cows across all the farm types. Like fearfulness, an adjustment in the threshold from an imposed 2% to 7% (close to 6.2% orange threshold) might be suitable as the temporary stress of handling could have likely caused cattle to lie in the yards. However, the observation of breed influence on cattle behaviour and welfare compromise demands further investigation, for possible mitigation. Cattle lying in the race contributed to others falling on top of them, which led to compromised cattle flow and more use of electrical prodders, hitting and noisy handlers.

It was important for animal-based and stockpersonship assessments to be made while cattle were handled for purposes other than the assessment itself. Thus, it might be worth describing and validating yard construction and design quality in a welfare assessment, such as to define what entails a yard, differentiate those with enough holding pens, the race and chute, as well as materials used, e.g., metal, wooden poles, tree poles and thorny bushes (see Appendix A) for the different yard designs and quality found at the farms). The definition of the yard quality and designs could bring awareness to the welfare compromise caused by poor yards [13,27] and in return encourage channelling of resources, skills and knowledge for the construction and maintenance of better standards facilities.

Finally, the study was undertaken at only 55 herds, but all herds represented the prevailing production system in the three regions. The welfare thresholds need to be validated across multiple beef herds in the country, with more assessors and consideration of the prevailing environmental conditions (e.g., seasonality and dry periods). It is hoped that this categorisation will also be validated by expert opinions to apply the correct decisions when an assessment is made, such as for on-farm benchmarking and certification of cattle or beef from such establishments. The current assessment results and thresholds could also be used as a basis for the welfare status of Namibia farms, such that, especially the village farms prioritise intervention areas of welfare compromise to either attain or maintain beef markets. This study can help to improve animal welfare in other countries with different status of animal welfare with individual thresholds of measures.

5. Conclusions

The study provided thresholds which could be used to categorise continuous animal welfare measures into acceptable, marginal and non-acceptable welfare, hence, providing guidance for when the intervention was needed on Namibian beef farms. Commercial farms attained welfare measures thresholds based on a New Zealand protocol—which suggest opportunities to create a system and a suitable environment that promote animal welfare in Namibia. However, the same thresholds, regardless of the system, were set for the country's beef herds, and semi-commercial and communal herds showed less acceptable welfare of beef cows. The long-term target is to have improved derived threshold in all measures at all herds, but an initial target could be geared towards improving the worst 15% of herds. Adjusted lenient thresholds to reflect drought condition were suggested for measures related to good feeding and mortality, whilst the originally imposed thresholds were still retained under "normal conditions". This was a good example of setting the welfare threshold for "what should be and not what is". Nevertheless, it may be an advantage that the current thresholds were validated in the possible worst-case scenario that can hit the beef industry in Namibia. Some of the imposed thresholds (i.e., swelling, hair loss, dystocia, lameness) were retained because of the significant importance to the welfare of animals and preventiveness of the traits. Handling measures (fearful, falling/lying) and abrasions thresholds were adjusted to reflect the temporary stress caused by infrequent cattle handling, and faulty yard designs and or constructions and the possible influence of Bahaman cattle behaviour during handling. There is a need to validate this categorisation and scoring of measures on multiple farms, and with more experts to classify Namibian beef farms status correctly. It is to the advantage of Namibia to have a validated, comparable animal welfare assessment protocol based on other beef exporting countries to strive for maintaining good welfare standards across the beef production chains.

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Data Availability Statement: All relevant data were analysed and reported in Part 1 (https://pubmed.ncbi.nlm.nih.gov/33445688/) or the current Part 2 of the study.

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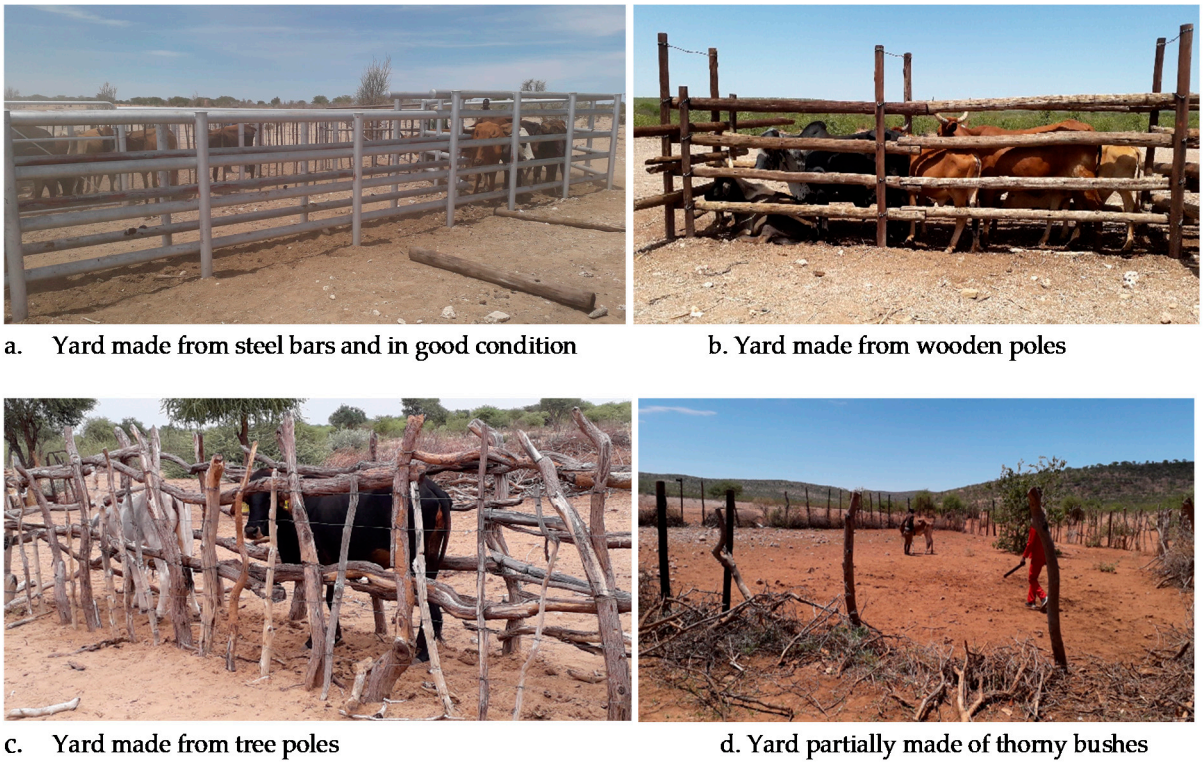
Appendix A

Table A1. Summary of continuous welfare measures scoring threshold for Namibia beef cattle systems compared to New Zealand thresholds.

Measures	Imposed Categorisation Thresholds (%) (Based on New Zealand Protocol)	Namibia Scoring Thresholds (%)	Namibia Scoring Thresholds Adjustment
# Thin cows	10	10	30% in drought
# Emaciated cows	-	10	
Poor rumen fill	50	50	
Dirtiness	20	5	reduced
Swelling	2	2	
Hair loss	2	2	
Abrasion	2	2	7% initial threshold to allow improvements
Extraneous brands/cuts	-	5	
Long/sharp horns	-	10	40% initial threshold to allow improvements
Blindness	2	2	
Ocular discharge	2	2	
Nasal discharge	2	2	
Diarrhoea	10	5	reduced
Lameness	2	2	
Dystocia	2	2	
Tick burden	-	10	
Fly burden	-	10	
Mortality rate	2	2	7% in drought
Fearful/Agitate	5	5	7% initial threshold to allow improvements
Fall/lie	2	5	7% initial threshold to allow improvements
Stumble	5	5	
Run exit	10	10	

Thin cows included all cows with BCS $\leq$ 2.5/5 scale, and emaciated was only the proportion of thin cows with the severity of BCS 1–2/5 scale.

Appendix B



a. Yard made from steel bars and in good condition

b. Yard made from wooden poles

c. Yard made from tree poles

d. Yard partially made of thorny bushes

Figure A1. Various cattle handling facilities of different designs and made of different construction materials found at the beef cattle herds in Namibia.

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