Manaaki Whenua
Landcare Research

Assessing animal welfare in New Zealand pastoral farms

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‘Think piece’ on Regenerative Agriculture in Aotearoa New Zealand: project overview and statement of purpose

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Find the full project overview, white paper and topic reports at ourlandandwater.nz/regenag and www.landcareresearch.co.nz/publications/regenag

This report is one of a series of topic reports written as part of a ‘think piece’ project on Regenerative Agriculture (RA) in Aotearoa New Zealand (NZ). This think piece aims to provide a framework that can be used to develop a scientific evidence base and research questions specific to RA. It is the result of a large collaborative effort across the New Zealand agri-food system over the course of 6 months in 2020 that included representatives of the research community, farming industry bodies, farmers and RA practitioners, consultants, governmental organisations, and the social/environmental entrepreneurial sector.

The think piece outputs included this series of topic reports and a white paper providing a high-level summary of the context and main outcomes from each topic report. All topic reports have been peer-reviewed by at least one named topic expert and the relevant research portfolio leader within MWLR.

Foreword from the project leads

Regenerative Agriculture (RA) is emerging as a grassroot-led movement that extends far beyond the farmgate. Underpinning the movement is a vision of agriculture that regenerates the natural world while producing ‘nutrient-dense’ food and providing farmers with good livelihoods. There are a growing number of farmers, NGOs, governmental institutions, and big corporations backing RA as a solution to many of the systemic challenges faced by humanity, including climate change, food system disfunction, biodiversity loss and human health (to name a few). It has now become a movement. Momentum is building at all levels of the food supply and value chain. Now is an exciting time for scientists and practitioners to work together towards a better understanding of RA, and what benefits may or not arise from the adoption of RA in NZ.

RA’s definitions are fluid and numerous – and vary depending on places and cultures. The lack of a crystal-clear definition makes it a challenging study subject. RA is not a ‘thing’ that can be put in a clearly defined experimental box nor be dissected methodically. In a way, RA calls for a more prominent acknowledgement of the diversity and creativity that is characteristic of farming – a call for reclaiming farming not only as a skilled profession but also as an art, constantly evolving and adapting, based on a multitude of theoretical and practical expertise.

RA research can similarly enact itself as a braided river of interlinked disciplines and knowledge types, spanning all aspects of health (planet, people, and economy) – where curiosity and open-mindedness prevail. The intent for this think piece was to explore and demonstrate what this braided river could look like in the context of a short-term (6 month) research project. It is with this intent that Sam Lang and Gwen Grelet have initially approached the many collaborators that contributed to this series of topic reports – for all bring their unique knowledge, expertise, values and worldviews or perspectives on the topic of RA.

How was the work stream of this think piece organised?

The project's structure was jointly designed by a project steering committee comprised of the two project leads (Dr Gwen Grelet[1] and Sam Lang[2]); a representative of the New Zealand Ministry for Primary Industries (Sustainable Food and Fibre Futures lead Jeremy Pos); OLW's Director (Dr Ken Taylor and then Dr Jenny Webster-Brown), chief scientist (Professor Rich McDowell), and Kaihāpai Māori (Naomi Aporo); NEXT's environmental director (Jan Hania); and MWLR's General Manager Science and knowledge translation (Graham Sevicke-Jones). OLW's science theme leader for the programme 'Incentives for change' (Dr Bill Kaye-Blake) oversaw the project from start to completion.

The work stream was modular and essentially inspired by theories underpinning agent-based modelling (Gilbert 2008) that have been developed to study coupled human and nature systems, by which the actions and interactions of multiple actors within a complex system are implicitly recognised as being autonomous, and characterised by unique traits (e.g. methodological approaches, world views, values, goals, etc.) while interacting with each other through prescribed rules (An 2012).

Multiple working groups were formed, each deliberately including a single type of actor (e.g. researchers and technical experts only or regenerative practitioners only) or as wide a variety of actors as possible (e.g. representatives of multiple professions within an agricultural sector). The groups were tasked with making specific contributions to the think piece. While the tasks performed by each group were prescribed by the project lead researchers, each group had a high level of autonomy in the manner it chose to assemble, operate, and deliver its contribution to the think piece. Typically, the groups deployed methods such as literature and website reviews, online focus groups, online workshops, thematic analyses, and iterative feedback between groups as time permitted (given the short duration of the project).

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[1] Senior scientist at MWLR, with a background in soil ecology and plant ecophysiology - appointed as an un-paid member of Quorum Sense board of governors and part-time seconded to Toha Foundry while the think piece was being completed

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Assessing animal welfare in New Zealand pastoral farms

Contract Report: LC3954-11

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Contents

1 Introduction

Whether we know it or not, we all value animal welfare. What animals experience, how they perform and whether they are being treated with respect are important both to 'them' and to us.

Animal welfare is, however, a complicated and emotive subject. We benefit from the compromises we make to the animal's natural 'needs and wants', and as a society we have different expectations borne of our own individual preferences and prejudices (Fisher 2019). As Mark Fisher states, based on Herzog's observation: "Some we love, some we hate, some we eat" (Herzog 2010). Also heavily contested is what we think and understand is important to animals and whether the way we farm them adequately emulates their underlying nature or 'telos'.

The general concept of animal welfare embraces a 'continuum–cluster' between negative and positive experiences that ultimately builds towards animal emotions (Beck & Gregorini 2020). Early approaches to conceptualising animal welfare were based on the exclusion of negative emotions/states, most famously captured in the 'Five Freedoms', but this neglects the fact that during evolution, animals optimise their ability to interact with and adapt to their environment(s) in pursuit of comfort or positive experiences (Gregorini et al. 2017). An animal's welfare status might therefore be represented better by the degree of their adaptation within a given setting (Ohl & van der Staay 2012).

Animal welfare cannot be evaluated solely by means of subjective biological measurements of an animal's emotional response within a certain context. In practice, interpretation of welfare (either positive or negative) and its translation into treatment/management options are both strongly influenced by external factors, most notably by societal values (Ohl & van der Staay 2012).

At its most fundamental level, animal welfare is about the individual, and how he or she responds to the various challenges in its environment (both social and physical). Individuals differ in their ability to cope with challenge, due to their specific physiological make-ups and the effects of past experience, i.e. learned responses. This can make it difficult to determine the degree or scale of welfare compromise, especially when dealing with ruminants, which tend to be herd animals. Thus, assessing the welfare of an individual animal if removed from its herd structure is challenging.

In addition, human perceptions of relative well-being and levels of stress, may differ entirely from what is actually being experienced by the animal, particularly when dealing with sentient, domesticated species, such as farmed animals.

As an example, during extreme and frequent mustering, animals may demonstrate an aggressive 'fight/flight' response or a completely passive and outwardly calm 'learned helplessness' response. When observing these behaviours, humans normally associate fight/flight responses with acute stress, whereas they are, in fact, natural coping strategies. In contrast, animals expressing learned helplessness responses experience all of the negative biological responses associated with 'unavoidable' stress and have poorer welfare as a result (Griffin 1989). At the other extreme, two animals might have identical endocrine profiles in response to a stressor, yet vastly different subjective experiences. This is why it is so important to use a suite of complimentary measures, both physiological and behavioural, when assessing animal welfare, in order to build up the most complete picture possible.

2 Overarching approach – the Five Domains

Regenerative agriculture represents a holistic approach to farming which encompasses animal welfare as a core pillar. As a result, it is appropriate to set aside the 'Five Freedoms' model and embrace the more modern and widely accepted 'Five Domains' model for considering animal welfare (Mellor 2011, 2016; Villalba & Manteca 2019). The Five Domains are:

- good nutrition
- good environment
- good health
- appropriate behaviour
- all of which, contribute to the provision of the fifth domain: opportunities for positive mental experiences, i.e. promoting 'healthy' emotional states.

<table>
<tr><th colspan="8">Physical/Functional Domains</th></tr>
<tr><th colspan="6">Survival-Related Factors</th><th colspan="2">Situation-Related Factors</th></tr>
<tr><th colspan="2">1: Nutrition</th><th colspan="2">2: Environment</th><th colspan="2">3: Health</th><th colspan="2">4: Behaviour</th></tr>
<tr><td>Negative
Restricted water & food; poor food quality</td><td>Positive
Enough water & food; balanced and varied diet</td><td>Negative
Uncomfortable or unpleasant physical features of environment</td><td>Positive
Physical environment comfortable or pleasant</td><td>Negative
Disease, injury and/or functional impairment</td><td>Positive
Healthy, fit and/or uninjured</td><td>Negative
Behavioural expression restricted</td><td>Positive
Able to express rewarding behaviours</td></tr>
<tr><th colspan="8">Affective Experience Domains</th></tr>
<tr><th colspan="8">5: Mental State</th></tr>
<tr><th colspan="3">Negative Experiences</th><th colspan="3">Positive Experiences</th></tr>
<tr><td>Thirst
Hunger
Malnutrition malaise
Chilling/overheating
Hearing discomfort</td><td>Breathlessness
Pain
Debility, weakness
Nausea, sickness
Dizziness</td><td>Anger, frustration
Boredom, helplessness
Loneliness, depression
Anxiety, fearfulness
Panic, exhaustion</td><td>Drinking pleasures
Taste pleasures
Chewing pleasures
Satiety
Physical comforts</td><td>Vigour of good health & fitness
Reward
Goal-directed engagement</td><td>Calmness, in control
Affectionate sociability
Maternally rewarded
Excited playfulness
Sexually gratified</td></tr>
<tr><th colspan="8">Welfare Status</th></tr>
</table>

Figure 1. An abbreviated version of the Five Domains Model. It summarises survival-related and situation-related factors and their associated physical/functional domains, and provides examples of negative or positive affects assigned to the mental domain. The overall affective experience in the mental domain equates to the welfare status of the animals. (Mellor 2016).

Adopting the Five Domains not only recognises that animals should have positive experiences, as well as avoiding negative states, but also aligns strongly with the amended Animal Welfare Act 1999, which acknowledges the status of animals as sentient beings.

In the following sections, we consider each of the domains in turn and present examples of potential indicators and broad methodologies that could be used in a regenerative agriculture setting to measure welfare outcomes. We also summarise these by research type, where appropriate.

Finally, we present key issues and knowledge gaps that need to be addressed through further research/evaluation, where these are evident.

NB. The fifth domain, 'Positive Mental Experiences' is by its nature, subsumed within the other four domains, so is not considered as a standalone section in this document.

2.1 Note on Methodologies to Monitor Animal Welfare within the Five Domains

Because we do not share a common language with animals, it is necessary to identify surrogate markers or behaviours that can be linked accurately with their welfare state. In the vast majority of cases, environmental stimuli, both positive and negative, are responsible for provoking a corresponding positive or negative response in the host. Environmental signals received in the brain stimulate neuropeptide secretions that impact on downstream endocrine glands (thyroid/adrenal/ovarian/lymphatic) and influence a wide range of physiological functions, in addition to modifying future responses through learning. Markers of welfare (and/or stress) include a range of hormones and regulatory molecules that directly affect metabolic, reproductive, and immunological responses in the affected host. By targeting reproductive, immunological or behavioural responses that are uniquely affected by neuroendocrine activators, it is possible to measure the degree and direction (positive/negative) of these responses and relate them to well-being. In general, negative stimuli tend to suppress reproductive or immunological functions, while positive stimuli tend to optimise reproductive or immunological functions.

3 Good nutrition

The importance of good nutrition in any farming system cannot be understated and is a key component of good animal welfare. Animals that are not adequately fed face challenges in all aspects of life, including increased risk of disease and reproductive challenges/failure (Beck & Gregorini 2020). It is here, where the accurate definition, understanding, and practice of allocating feed with a good feeding value in the appropriate temporal and spatial scale is paramount. Gregorini (2007) redefines the feeding value of grazed herbage as a cluster of three main components (herbage chemical composition; nutrient requirements of the animal; and the availability and accessibility of particular morphological or biochemical components of the sward plants to the 'desires/needs of the grazer'). This redefinition can help us evaluate not only the productivity of alternative swards and grazing methods better than traditional assessments of pasture quality, but also how dietary diversity enhances functionality of herbage and it impact on hedonic and eudaemonic well-being in grazing ruminant.

The following are indicators of animal welfare that can be used in various research settings.

3.1 Academic-driven research

Academic-driven research requires specialised expertise, equipment, and/or experimental designs that are not generally available to lay persons, including farmers.

Indicator	*Methodology (where appropriate)*
Grazing and rumination patterns	Assessment of consumption and rumination patterns.
Green infrastructure	Comparison of different spatial arrangements and different degrees of diverse herbage species, to identify animal preferences/create effective functional swards.
Macro/Micronutrient balance	Analysis of soil/plant chemistry (incl. 2° compounds) in relation to an animal's biological status, using blood samples, ELISA, etc.
Swards diversity & composition	Comparison of diverse swards vs monocultures in relation to animal performance, growth rate, and health status.
Rumen dynamics/fill/function	Comparison of rumen function across animals fed different types of swards.
Rumen microbiome composition	Characterisation of gut flora species and abundance in the rumens of animals fed different types of swards.
Satiation dynamics	Time to satiation, number of feeding bouts per unit of time. Linked to grazing patterns above.
Utilisation/perception of foodscapes	Choice tests and temporal/spatial allocation of animals when presented with diverse swards vs. monocultures.

3.2 Research by proxy/collaboration

Research by proxy/collaboration is work that can be developed by academics or diverse stakeholder groups, with one group collecting the data and another group conducting the analysis, either in conjunction with other stakeholders or retrospectively.

Indicator	*Methodology (where appropriate)*
Faecal egg count (FEC)	3rd party analysis of dung samples collected by farmers, to assess parasite loads in the pasture and downstream animal health issues. Parasite loads can be determined using molecular PCR, with multiple probes targeting different parasitic groups.
Forage feeding value	3rd party analysis of swards samples, to provide insight into nutritional content of the herbage.
Nutrient density	Targeted assessment of primary and secondary plant compounds, in herbage samples collected by farmers.
Blood testing	Blood/liver samples collected by veterinarians and analysed by researchers/3rd parties, to establish trace element deficiencies and appropriate remedies. NB. Selenium deficiency in NZ soils is an important co-factor in inflammatory and immune responses. Also, inflammatory markers, indicators of immunometabolic state.

3.3 Farm-led/community research

Farm-led/community research is work that is primarily designed, conducted, and analysed on-farm, in order to identify/address specific management concerns or local-scale issues.

Indicator	*Methodology (where appropriate)*
Animal weight	Weigh individual animals and compare to industry guidelines or breed specific targets, to identify underweight/poorly performing animals.
Body Condition Score (BCS)	Assess whole herd or a percentage of the herd/flock at key times during the year, according to industry guidelines, to identify poorly performing animals.
Drop off in milk yield	In dairy cows, a sudden reduction in milk yield may be indicative of underlying conditions that compromise animal welfare.
Dung scoring	Assess the consistency of dung as an indicator of intestinal infection and nutritional state, as well as coat condition.
Feed consumption	Measure residuals following grazing, at the herd level, to estimate total amount of feed consumed and selectivity. Divide by the number of animals to get an average intake.

4 Good environment

The environment in which an animal is kept can have a huge effect on its well-being. Commonly, sward management receives much focus; however, considering the 'environment' also includes aspects such as elevation, topography, shade/shelter provision, and overall complexity, not to mention the social environment (see Appropriate Behaviour section for details).

Increasing the amount and complexity of 'green infrastructure', including the use of agroforestry, can provide environmental enrichment and help maximise the diversity of the flora and fauna (including local wildlife).

4.1 Parameters that ensure Good Environmental Management

1 Adequate shelter and shade.

2 Permanent soil cover and prevention of excessive mud.

3 Supplementation of herbage –if required- to support animal health and boost immune systems.

4 Monitor salivary cortisol levels (a stress hormone), to minimise concurrent or multiple stressors.

4.2 Academic driven research

Indicator	*Methodology (where appropriate)*
Environmental enrichment provision	Comparison of different environmental features, using choice tests, to identify those of greatest utility to animals.
Shade/shelterbelt optimisation	Comparison of different shade/shelterbelt configurations, to identify those best suited to protecting animals from extreme weather.

4.3 Research by proxy/collaboration

Indicator	*Methodology (where appropriate)*
Utilisation of paddocks by animals	Scan/focal sampling of animals at different times of day/season, to identify which aspects of the environment they are using and if problems are evident, e.g. huddling during cold weather or clustering around trees in shade-sparse areas during hot weather.

4.4 Farm-led/community research

Indicator	*Methodology (where appropriate)*
Complexity assessment	Aerial photograph/Google Maps image used to visually assess the topography of paddocks/pasture and the elements contained within it, e.g. waterways, trees, gullies, etc.
Green infrastructure assessment	Visual assessment of the number and location of beneficial plant species in the paddock, including trees, hedges, and shrubs, as an estimate of environmental enrichment.

5 Good health (including reproduction)

Animal health is a highly complex, multi-faceted aspect of animal welfare, which, like feed, permeates all aspects of the animal's existence. Anecdotal evidence suggests regenerative principles can positively affect disease prevalence and reduce the need for unnecessary spending on animal health products.

Spending on animal health can be broken into prophylactic (preventative) and therapeutic categories and compared, in order to determine the prophylactic to therapeutic ratio. This information is readily available to farmers through their animal health providers and can provide useful insights into the welfare status of individuals and herds/flocks. In addition, disease prevalence measurements and ongoing surveillance are also necessary for the prevention of and protection from, diseases that have the potential to impact on animal health and welfare at all levels from local to national.

Another readily available on-farm indicator of animal welfare is mortality rate. This can provide a rough indication of animal health and welfare, as non-thriving animals are more likely to succumb to environmental pressures and disease.

Immunity, resistance, and resilience to disease are another important aspect of good health. The adaptive immune response to infection is the most versatile and powerful physiological response known in mammals. The immune system is also superbly sensitive to extrinsic behavioural and endocrine signals, so it is an ideal target to monitor the positive and negative impacts of stimuli that are linked to stress or welfare. Immune markers that can be monitored include specific antibody or cellular adaptive markers, e.g. antibodies/T cell cytokines and non-specific inflammatory monocyte markers, e.g. Monokines.

Current methodological platforms for monitoring immunology in ruminants include:

- Antibody based ELISA testing
- Cytokine based Molecular assays (PCR)
- Diagnosis of infectious pathogens (PCR).

All have proven useful for measuring non-specific/innate (Monocytic Inflammation), specific (Antibody) and Cell Mediated Immune (CMI) responses to infection. In addition, molecular platforms to diagnose *multiple* infectious diseases using Polymerase Chain Reaction (PCR) methods are also available.

With regard to reproduction, the transition from pregnancy to parturition (birth) and subsequent lactation imposes huge metabolic demands on lactating females and demands a precipitous transition to a high metabolic state. This evokes the production of a series of exudative enzymes and hormones, which can lead to a pathological response known as 'Oxidative Stress'. Measuring molecules associated with Oxidative Stress in the weeks following parturition can provide evidence of welfare compromise that may be linked with recovery from, or exacerbation of, the Oxidative Stress response.

Molecules that can be monitored (Bernabucci et al. 2005) include:

- NEFA: Non-esterified fatty acids
- GSH-x; Glutathione peroxidase
- BHB; β–Hydroxybutyrate
- α–T; α–Tocopherol
- ROS; Reactive oxygen substance/species
- SAC; Serum Antioxidant Capacity
- SOD; Superoxide Dismutase
- Haptoglobin

In addition, a number of observational parameters are linked to clinical conditions to an uncontrolled oxidative stress response, including:

- Anoestrus interval from parturition to oestrus
- Retained foetal membranes
- Pyometritus or Endometritis
- Proportion of non-pregnant animal
- Calf to calf interval
- Clinical and subclinical ketosis

These conditions can be diagnosed through accurately recording animal symptoms in the weeks following parturition.

As far as lactational stress (Bernabucci et al. 2005) is concerned, indicators include:

- Elevated levels of the oxidative stress molecules listed above
- Onset of clinical parasitism in the 1st postpartum period
- Postpartum emergence of chronic clinical diseases, such as Johne's Disease
- Onset of acute infections, such as mastitis, detected during routine milk sampling
- Onset of laminitis or foot rot

Finally, the development of new technologies, including rumination collars, pedometers, thermal imaging cameras, and pH and temperature boluses, may provide information that allows better health and earlier intervention.

5.1 Academic driven research

Indicator	*Methodology (where appropriate)*
Cytokines	Blood sampling. Cytokines (adaptive biomarkers) can indicate disease/immunity status.
Incidence/degree of ketosis	Blood sampling and measurement of Beta-hydroxybutyrate (BHOB) around mating or calving time.
Inflammatory markers	Interleukins: IL-2 & IL-6, measured by PCR tests are classical markers of inflammation.
Oxidative stress	Lactation stress produces changes in the levels of non-esterified fatty acids (NEFA) that can be measured by biochemical assays (Adewuyi et al. 2005).
Pathogen challenge	Measure colostral (Quigley et al. 2012) and serum antibody titres (ELISA), following infection or vaccination. This monitors immunocompetence and can identify compromised animals or those showing elevated levels of immunity.
pH and body temperature	Monitor remotely using bolus administration.

5.2 Research by proxy/collaboration

Indicator	*Methodology (where appropriate)*
Animal health spend	Farm records/veterinary input. Break down into prophylactic and therapeutic spend to give an indication of proactive vs. reactive treatment.
Antimicrobial use (AMU)	Farm records/veterinary input. Calculated as mg of active ingredient/population corrected unit (PCU). Linked to animal health spend and an indication of overall herd health.
Blood Urea Nitrogen (BUN)	BUN is measured in biochemical assays and can identify animals that have inadequate or excessive levels of protein in their diet. (Stoop et al. 2007).
Endometritis	Assessed during uterine scanning, 14 days post-calving.
Incidence of disease	Faecal or blood, and/or milk sampling conducted by a veterinarian. A presumptive diagnosis would likely implicate one of the following pathogens or disease complexes: • Barber's Pole • Bovine Viral Diarrhoea (BVD) • Campylobacter • Clinical parasitism • Coronavirus • Facial Eczema • Foot rot • Infectious Bovine Rhinotrachetitis (IBR) • Johne's disease • Leptospirosis • Liver Fluke • Milk Fever • Neospora • Pneumonia • Rotavirus • Salmonella • Theileria • Toxoplasma • Tuberculosis and mycoplasma bovis, Yersiniosis
Non-Esterified Fatty Acid (NEFA)	Measured using biochemical tests (Adewuyi et al. 2005).
Reactive Oxygen Substance (ROS)	A measure of inflammation produced by neutrophils or monocytes, following infection or tissue damage.
Retained foetal membranes	Farm records. Potential indicator of low selenium, frequently resulting in endometritis often as a result of ketosis /Subclinical ketosis.
Somatic Cell Counts (SCC)	Tanker dockets/processor records. Indicator of mastitis (infection/inflammation of mammary tissues) and is common in animals exposed to stress, inadequate nutrition or poor environmental conditions. Tests may be conducted on the individual level or on bulk milk.
Tail scoring	Conducted by a trained professional. Is an indicator of poor stock handling on farm and a diagnostic method for scouring associated with acute or chronic intestinal infection

NB. With regard to the incidence of disease, a great deal could be put down to high stress or incomplete diets, e.g. low Selenium/Vitamin E, so better nutrition may result in lower rates. Also, some diseases are only found in certain areas of the country, so are harder to compare between farms.

5.3 Farm-led/community research

Indicator	*Methodology (where appropriate)*
3-week submission rate (90%)	Number of cows submitted for mating in the first three weeks after the planned start of mating, as a proportion of cows present at that time. Gives a good indication of oestrus activity.
6-week in-calf rate (78%)	Measured by pregnancy testing the whole herd and confirming conception within 6 weeks of mating, by crow-rump measurements of the foetus, to determine its age precisely.
Animal health spend	Farm and veterinary records. Break down into prophylactic and therapeutic spend to give an indication of proactive vs reactive treatment. Include all vaccinations, mineral supplementation, anthelmintic and drench use, reproductive interventions, anti-inflammatories, pain relief and prescription medicines.
Body Condition Score (BCS)	Assess a percentage of the herd/flock in four seasons throughout the year, according to industry guidelines, to identify poorly performing animals. BCS results should also be confirmed by an accredited personnel (e.g. veterinarian).
Calf-to-calf interval	Number of days between birth of successive offspring (it is normally within one calendar year).
Coat condition, lethargy, depressed appearance	A gross indicator of potential infection/disease. Need to be aware of the difference between summer/winter coats.
Foot rot (sheep)	Farm records. An indicator of bacterial infection of the hoof.
Frequency of return to oestrus (non-return rate)	Indicator of good conception/reproductive health. Measured as % of inseminations where cows did not return to heat, over total inseminations conducted. NB. Each infertile cycle adds 21 days to the calf-to-calf interval.
Interval to first oestrus postpartum	Influenced by the Dominant Follicle that normally ovulates 15–25 days post parturition (Roche et al. 1992). NB. May not be routinely measured on NZ farms.
Lameness	Farm records and/or 3rd party assessment. An indicator of foot condition and potential disease.
Mortality/euthanasia rate	Farm records. Provides a gross indicator of animal health and allows the identification of problematic trends.
Not-in-calf rate	Number of cows not in calf as a proportion of those given the opportunity to get in calf. Provides an indicator of overall health and nutritional status, as well as indicating potential reproductive problems.
Rapid Mastitis Test (RMT)	Indicator of presence/absence of mastitis. Not a substitute for diagnosing mastitis through elevated Somatic Cell Counts.
Red/sunken/discharging eyes	A gross indicator of potential infection/disease.
Scanning rate (sheep)	Pregnancy rate based on scanning for twins and triplets.
Scouring (diarrhoea)	An indicator of dietary problems or exposure to intestinal pathogens.

6 Appropriate behaviour

Animal behaviour is one of the easiest indicators of animal welfare to measure, yet one of the hardest to interpret accurately. Nonetheless, how an animal behaves in any given situation can provide a valuable insight into its subjective experience and resultant welfare state.

Comparing behaviour against a known and standardised repertoire can be a useful method of detecting abnormalities related to problems with the physical or social environments. Such abnormalities do not have to be as extreme as stereotypic behaviour to be a source of concern, as disruptions in the ability to completely execute a specific behaviour, as well as temporal/spatial displacement or the so-called 'rebound' effect – where an animal performs an exaggerated amount of a behaviour, after being deprived of the ability to perform it – all indicate that something is wrong.

Another useful method to assess well-being is to give the animal a choice between different variables. So called 'preference testing' can reveal what an animal does and does not want with regard to its environment. This is especially powerful, when a cost or trade-off is applied to the resources in question and has been used extensively in a research setting to help inform environmental design and determine animal needs.

Behavioural assessment is a particularly useful tool for on-farm use because it is non-invasive and requires no special skills other than an understanding of the standardised behavioural repertoire of the species in question. In addition, farmers and stock-people spend a much time observing their animals as part of their day-to-day activities, so are well placed to spot problems early on.

Finally, in general terms, appropriate behaviour can be thought of in terms of animals doing the right things at the right time and in the right proportions, in an environment (both social and physical) that allows them to achieve this without unnecessary restriction.

6.1 Academic driven research

Indicator	*Methodology (where appropriate)*
Abnormal behaviour	Comparison of affected animals with 'normal' animals. Abnormal behaviours may take on a variety of forms, including temporal or spatial displacement (doing things in the wrong place at the wrong time), degree of intensity (over/under activity) and inappropriateness to the situation (overt aggression, fence pacing). An indicator or environmental or social problems.
Activity levels	Linked to lying time. Pedometers/collars can be used to remotely collect data on animal movement, rumination, and health status.
Choice/preference tests (Y-maze etc.)	Give the animal a choice between two or more variables. Provides an indication of resource preference. This can be combined with paying a 'price', to establish the relative importance of a preference or willingness to make a trade-off.
Individual variation analysis	Emerging area, relating individual differences in behaviour to welfare status/preference. Especially useful in to designing appropriate environments for animals.
Infra-red thermography (IRT)	Remote sensing method, used to measure body temperature. Can indicate heat/cold stress, as well as potential ill-health.
Lying time (duration and bout length)	Choice test or depravation situation used to measure an animal's desire to lie down and/or ruminate. Useful for assessing the suitability of pastures during adverse weather conditions or during confinement/housing.
Minimum Alveolar Concentration (MAC)	Research method using Electro-encephalographs (EEG) and light anaesthesia, to measure the response to painful stimuli, e.g. castration, without conscious awareness of pain occurring.
Stereotypic behaviour	Repetitive, unvarying behaviour, with no obvious biological function, performed because of chronic stress, usually in response to being prevented from achieving an important, desired behaviour. An indicator of severe behavioural/environmental compromise often associated with irreversible changes in the animal's underlying physiology, e.g. brain damage. Assessed by depravation experiments and field observations.

6.2 Farm-led/community research

Indicator	*Methodology (where appropriate)*
Flight distance	An indicator of fearfulness. The closest distance that an animal or group of animals will approach a novel object/person. Extensively farmed animals generally have longer flight distances than intensively farmed animals, so results need to be interpreted with caution.
Herd level assessment	Scan sampling of the group at set times of the day. Can indicate whether behaviour patterns are normal or disrupted, indicating a potential problem.
Human-animal interaction	Observation of animal's responses to the presence of familiar/unfamiliar people/situations. An indicator of fearfulness. Exposure to positive interactions can help build more resilient and less fearful animals.
Play behaviour	Observation of animals, especially young ones, when introduced to novel situations/paddocks. An indicator of positive welfare.

7 Issues and knowledge gaps

7.1 Wintering livestock

This is the most compelling challenge in NZ pastoral farming today, which impacts differentially on every farm in the country. We need to develop composite solutions, rather than quick-fix options and work out how each region in NZ will take ownership of and resolve their unique animal welfare challenges.

7.2 Cleanliness of freshwater

Adapting farming infrastructure to maintain wetlands, riparian strips and soil porosity, so as to prevent nutrient leaching or topsoil erosion affecting water quality.

7.3 National disease surveillance

In addition to current programmes, all farms in NZ should have comprehensive surveillance and treatment programmes in place for the control of infection caused by specific pathogenic bacteria, viruses, and parasites (see Good Health section for a list of diseases). Establishing herd/flock freedom from these diseases should be a national priority and core part of any 'healthy animal' accreditation programme

7.4 Monitoring post-calving/lambing health markers

These represent the most sensitive biomarkers of stress and wellbeing in mothering livestock. Demonstrable disease resilience and the absence of oxidative stress or clinical symptoms in the month following parturition can provide valuable evidence of a return to physiological homeostasis.

7.5 Comparative assessment of disease incidence

Recording and comparing disease rates between conventional and regenerative farms would be of key interest to veterinarians, animal health professionals, and the wider industry. In the context of breeding females, parturition and peak milk production are two critical stress periods when cows and ewes are more susceptible to inter-current infections and reduced welfare. Assessment of disease incidence between different farm types during these periods could provide useful information on potential management/intervention strategies. However, infrastructure to be able to compare these systems fairly has been a challenge on some-farm trials. Additional infrastructure is needed to keep systems separate, including colostrum storage, calf rearing facilities, managing many more mobs than normal.

7.6 Diverse and functional swards on the context of feeding value

Gregorini (2007) redefine feeding value of grazed herbage as a cluster of three main components (herbage chemical composition; nutrient requirements of the animal, and the availability and accessibility of particular morphological or biochemical components of the sward plants to the 'desires/needs of the grazer' in terms on nutrients, medicines, and prophylactics. This redefinition can help us evaluate not only productivity of alternative swards and grazing methods better than traditional assessments of pasture quality, but also how dietary diversity enhances functionality of herbage and it impact on hedonic and eudaemonic well-being in grazing ruminant (Beck & Gregorini 2020). Preliminary results on Lincoln University Pastoral Livestock Production Lab indicate that grazing phytochemically diverse swards improve animal welfare and environmental health (Beck & Gregorini 2020, 2021; Garret et al. 2021; Marshall et al. 2021); however, their ecological implications have not been fully evaluated. Also, this Lab has reported preliminary data indicating that diverse swards containing plants with metabolites/secondary chemical compounds – terpenoids, phenols, carotenoids, and anti-oxidants, as well as other bioactive compounds reduce oxidative and physiological stress in grazing ruminants (van Vliet et al. 2020; Beck & Gregorini 2020; Garret et al. In press). This result, however, needs more investigation in terms of plant secondary compounds ingestion levels and the fine line of nutrient, medicine, and toxin.

7.7 High stoking density and 'Mob grazing'

Many scientific studies indicate that high stoking density induces animal stress, but these studies are mostly focussed on grazing management where animals are moved less frequently than occurs in regeneratively managed farming systems. Information is still lacking about the combined effect of high stoking density, high frequency of animal movement, and high frequency of defoliation, especially when offering swards at high herbage mass (i.e. adaptive multi-paddock grazing, or mob grazing).

7.8 Technology and measurement devises

The increasing call for farm management practices that enhance animal welfare has led to the development of technologies focused on the continuous collection - at high frequency- of dynamic animal data linked to wellbeing and health, such as body temperature, movement or facial expressions. Those are then modelled and algorithms developed to translate these data into wellbeing metrics or develop predictive tools for wellbeing. The ultimate goal of these new technologies is the optimisation of animal management decisions for better animal welfare. Examples of such technologies include Halter, a NZ made technology, Allflex tags, as well as facial expression evaluations and thermography. Many of these technologies are still in development and will need further evaluation. However, their potential for animal welfare monitoring and research is huge.

Table 1. Indicators and methods used to assess animal welfare states, within the Five Domains framework

Outcome / indicator	*Priority*				*Indicators*				*Method*	*Benchmark Exists*
	Dairy	*Drystock*	*Arable*	*Viticulture*	*Cheap & scalable*	*Accurate*	*Observational*	*R&D needed*		
					GOOD NUTRITION					
Grazing patterns	1	1	2	3	Y		Y	Y	Assessment of consumption patterns per unit of time.	
Green infrastructure	1	1	2	3	Y		Y	Y	Comparison of different spatial arrangements and different degrees of diverse pasture species to identify animal preferences / create effective functional pastures.	
Macro / micronutrient balance	1	1	1	3		Y		Y	Analysis of soil/plant chemistry (incl. 2° compounds) in relation to an animal's biological status, using blood samples, ELISA, etc.	
Pasture diversity & composition	1	1	2	3		Y		Y	Comparison of diverse pastures vs. monocultures in relation to animal performance, growth rate and health status.	
Rumen dynamics / fill / function	1	1	2	3		Y		Y	Comparison of rumen function across animals fed different types of pasture.	
Rumen microbiome composition	1	1	2	3		Y		Y	Characterisation of gut flora species and abundance in the rumens of animals fed different types of pasture.	
Satiation dynamics	1	1	2	3		Y	Y	Y	Time to satiation, number of feeding bouts per unit of time – linked to grazing patterns above.	
Utilisation / perception of foodscapes	1	1	2	3		Y	Y	Y	Choice tests and temporal/spatial allocation of animals when presented with diverse pastures vs monocultures.	
Faecal egg count (FEC)	1	1	2	3	Y	Y			Third-party analysis of dung samples collected by farmers, to assess parasite loads in the pasture and downstream animal health issues. Parasite loads can be determined using molecular PCR, with multiple probes targeting different parasitic groups.	

Outcome / indicator	*Priority*				*Indicators*				*Method*	*Benchmark Exists*
	Dairy	*Drystock*	*Arable*	*Viticulture*	*Cheap & scalable*	*Accurate*	*Observational*	*R&D needed*		
Forage feed value (dry matter or DM)	1	1	1	3		Y			Third-party analysis of pasture samples to provide insight into the nutritional content of the grass.	Y
Nutrient density	1	1	1	3		Y			Targeted assessment of sugars, starches, protein and 2° compounds in pasture samples collected by farmers.	Y
Trace element testing	1	1	1	3		Y			Blood/liver samples collected by veterinarians and analysed by researchers/third parties to establish trace element deficiencies and appropriate remedies.	Y
Animal weight	1	1	2	3	Y	Y	Y		Weigh individual animals and compare to industry guidelines to identify underweight/poorly performing animals.	Y
Body condition score (BCS)	1	1	2	3	Y		Y		Assess a percentage of the herd/flock at key times during the year, according to industry guidelines, to identify poorly performing animals.	Y
Drop-off in milk yield	1	3	3	3	Y		Y		In dairy cows, a sudden reduction in milk yield may be indicative of underlying conditions that compromise animal welfare.	
Dung scoring	1	1	2	3	Y				Assess the consistency of dung as an indicator of intestinal infection and to determine nutritional state.	
Feed consumption	1	1	2	3	Y				Measure residuals following grazing, at the herd level, to estimate total amount of feed consumed. Divide by the number of animals to get an average intake.	Y
GOOD ENVIRONMENT										
Environmental enrichment provision	1	1	2	3		Y	Y	Y	Comparison of different environmental features, using choice tests, to identify those of greatest utility to animals.	
Shade / shelterbelt optimisation	1	1	3	3	Y		Y	Y	Comparison of different shade/shelterbelt configurations to identify those best suited to protecting animals from extreme weather.	

Outcome / indicator	*Priority*				*Indicators*				*Method*	*Benchmark Exists*
	Dairy	*Drystock*	*Arable*	*Viticulture*	*Cheap & scalable*	*Accurate*	*Observational*	*R&D needed*		
Soil organic carbon (SOC)	1	1	1	1		Y		Y	Measure at 0–30 cm (topsoil), which contains labile carbon, and at 30−100 cm (deep soil), which contains stable stored SOC.	
Utilisation of paddocks by animals	1	1	2	3	Y		Y	Y	Scan/focal sampling of animals at different times of day/season to identify which aspects of the environment they are using and if problems are evident (e.g. huddling during cold weather or clustering around trees in shade-sparse areas during hot weather).	
Complexity assessment	1	1	3	3	Y		Y		Aerial photographs/Google Maps images used to visually assess the topography of paddocks/pasture and the elements contained within them (e.g. waterways, trees, gullies).	
Green infrastructure assessment	1	1	2	2	Y		Y		Visual assessment of the number and location of beneficial plant species in the paddock, including trees, hedges, and shrubs, as an estimate of environmental enrichment.	
					GOOD HEALTH					
Cytokines	1	1	3	3		Y			Blood sampling – cytokines (adaptive biomarkers) can indicate disease/immunity status.	
Incidence / degree of ketosis	1	1	3	3		Y			Blood sampling and measurement of beta-hydroxybutyrate (BHOB) around mating or calving time.	
Inflammatory markers	1	1	3	3		Y		Y	Interleukins, IL-2 & IL-6, measured by PCR tests are classical markers of inflammation.	
Oxidative stress	1	1	3	3		Y			Lactation stress produces changes in the levels of non-esterified fatty acids (NEFA), which can be measured by biochemical assays.	

Outcome / indicator	*Priority*				*Indicators*				*Method*	*Benchmark Exists*
	Dairy	*Drystock*	*Arable*	*Viticulture*	*Cheap & scalable*	*Accurate*	*Observational*	*R&D needed*		
Pathogen challenge	1	1	3	3		Y		Y	Measure colostral and serum antibody titres following infection or vaccination. This monitors immunocompetence and can identify compromised animals or those showing elevated levels of immunity.	
pH and body temperature	2	2	3	3		Y		Y	Monitor remotely using bolus administration.	
Animal health spend	1	1	3	3	Y				Farm records/veterinary input – break down into prophylactic and therapeutic spending to give an indication of proactive vs reactive treatment.	
Antimicrobial use (AMU)	1	1	3	3	Y				Farm records/veterinary input – calculated as mg of active ingredient/population corrected unit (PCU). Linked to animal health spending and an indication of overall herd health.	
Blood urea nitrogen (BUN)	1	1	3	3		Y			BUN is measured in biochemical assays and can identify animals that have inadequate or excessive levels of protein in their diet.	
Endometritis	2	2	3	3		Y			Assessed during metrichecking, 14 days post-calving.	
Incidence of disease	1	1	3	3		Y			Blood and/or milk sampling conducted by a veterinarian.	
Non-esterified fatty acid (NEFA)	1	1	3	3		Y			Measured using biochemical tests.	
Reactive oxygen substance (ROS)	1	1	3	3		Y			A measure of inflammation produced by neutrophils or monocytes, following infection or tissue damage.	
Retained foetal membranes	2	2	3	3	Y	Y			Farm records – a potential indicator of low selenium, frequently resulting in endometritis.	
Somatic cell counts (SCC)	1	1	3	3	Y	Y			Tanker dockets/processor records – an indicator of mastitis.	Y

Outcome / indicator	*Priority*				*Indicators*				*Method*	*Benchmark Exists*
	Dairy	*Drystock*	*Arable*	*Viticulture*	*Cheap & scalable*	*Accurate*	*Observational*	*R&D needed*		
Tail scoring	2	2	3	3	Y		Y		Conducted by a trained professional – an indicator of poor stock handling on the farm and a diagnostic method for scouring associated with acute or chronic intestinal infection	
3-week submission rate (90%)	1	1	3	3	Y	Y	Y		Number of cows submitted for mating in the first 3 weeks after the planned start of mating, as a proportion of cows present at that time – gives a good indication of oestrus activity. Measured by pregnancy testing the whole herd and confirming conception within 6 weeks of mating, by crow–rump measurements of the foetus, to precisely determine its age.	Y
6-week in-calf rate (78%)	1	1	3	3	Y	Y	Y		Measured by pregnancy testing the whole herd and confirming conception within 6 weeks of mating, by crow–rump measurements of the foetus, to precisely determine its age.	Y
Animal health spending	1	1	3	3	Y				Farm records – break down into prophylactic and therapeutic spending to give an indication of proactive vs reactive treatment. Include all vaccinations, mineral supplementation, anthelmintic and drench use, reproductive interventions, anti-inflammatories, pain relief and prescription medicines.	
Body condition score (BCS)	1	1	3	3	Y		Y		Assess a percentage of the herd/flock at key times during the year, according to industry guidelines, to identify poorly performing animals.	Y
Calf-to-calf interval	2	2	3	3	Y	Y	Y		Number of days between birth of successive offspring (it is normally within one calendar year).	
Coat condition / lethargy / depressed appearance	3	3	3	3	Y		Y		A gross indicator of potential infection/disease. Need to be aware of the difference between summer/winter coats.	

Outcome / indicator	*Priority*				*Indicators*				*Method*	*Benchmark Exists*
	Dairy	*Drystock*	*Arable*	*Viticulture*	*Cheap & scalable*	*Accurate*	*Observational*	*R&D needed*		
Foot rot (sheep)	2	2	3	3	Y		Y		Farm records – an indicator of bacterial infection of the hoof.	
Frequency of return to oestrus	2	2	3	3	Y	Y	Y		An indicator of good conception/reproductive health. Measured as % of inseminations where cows did not return to heat, over total inseminations conducted. Note: each infertile cycle adds 21 days to the calf-to-calf interval.	Y
Interval to first oestrus postpartum	2	2	3	3	Y	Y	Y		Influenced by the dominant follicle, which normally ovulates 15–25 days' post parturition. Note: may not be routinely measured on NZ farms.	
Lameness	1	1	3	3	Y		Y		Farm records and/or third-party assessment – an indicator of foot condition and potential disease.	
Mortality / euthanasia rate	2	2	3	3	Y		Y		Farm records – provides a gross indicator of animal health and allows the identification of problematic trends.	
Not-in-calf rate	2	2	3	3	Y	Y	Y		Number of cows not in calf as a proportion of those given the opportunity to get in calf – provides an indicator of overall health and nutritional status, as well as indicating potential reproductive problems.	Y
Rapid mastitis test (RMT)	3	3	3	3	Y		Y		Indicator of presence/absence of mastitis. Not a substitute for SCC.	
Red / sunken / discharging eyes	3	3	3	3	Y		Y		A gross indicator of potential infection/disease.	
Scanning rate (sheep)	2	2	3	3	Y	Y	Y		Pregnancy rate based on scanning for twins and triplets.	Y
Scouring (diarrhoea)	1	1	3	3	Y		Y		An indicator of dietary problems or exposure to intestinal pathogens.	

Outcome / indicator	Priority				Indicators				Method	Benchmark Exists
	Dairy	Drystock	Arable	Viticulture	Cheap & scalable	Accurate	Observational	R&D needed		
							APPRORIATE BEHAVIOUR			
Abnormal behaviour	1	1	2	3	Y	Y	Y	Y	Comparison of affected animals with 'normal' animals. Abnormal behaviours may take on a variety of forms, including temporal or spatial displacement (doing things in the wrong place at the wrong time), degree of intensity (over/under activity) and inappropriateness to the situation (overt aggression, fence pacing). An indicator of environmental or social problems.	
Activity levels	1	2	3	3		Y	Y	Y	Linked to lying time. Pedometers/collars can be used to remotely collect data on animal movement, rumination, and health status.	
Choice / preference tests (Y-maze etc.)	1	1	2	3		Y	Y	Y	Give the animal a choice between two or more variables – provides an indication of resource preference. Can be combined with paying a 'price', to establish the relative importance of a preference or willingness to make a trade-off.	
Individual variation analysis	2	2	3	3			Y	Y	An emerging area, relating individual differences in behaviour to welfare status/preference. Especially useful in regard to designing appropriate environments for animals.	
Infra-red thermography (IRT)	2	2	3	3		Y	Y	Y	A remote-sensing method, used to measure body temperature – can indicate heat/cold stress, as well as potential ill-health.	
Lying time (duration and bout length)	1	1	2	3	Y		Y	Y	Choice test or deprivation situation used to measure an animal's desire to lie down and/or ruminate. Useful for assessing the suitability of pastures during adverse weather conditions or during confinement/housing.	

Outcome / indicator	*Priority*				*Indicators*				*Method*	*Benchmark Exists*
	Dairy	*Drystock*	*Arable*	*Viticulture*	*Cheap & scalable*	*Accurate*	*Observational*	*R&D needed*		
Minimum alveolar concentration (MAC)	3	3	3	3		Y		Y	A research method using electro-encephalographs (EEGs) and light anaesthesia to measure the response to painful stimuli (e.g. castration) without conscious awareness of pain occurring.	N/A
Stereotypic behaviour	1	1	3	3	Y	Y	Y	Y	Repetitive, unvarying behaviour, with no obvious biological function, performed as a result of chronic stress, usually in response to being prevented from achieving an important or desired behaviour. An indicator of severe behavioural/environmental compromise, often associated with irreversible changes in the animal's underlying physiology (e.g. brain damage). Assessed by deprivation experiments and field observations.	
Flight distance	1	1	3	3	Y		Y		An indicator of fearfulness – the closest distance that an animal or group of animals will approach a novel object/person. Extensively farmed animals generally have longer flight distances than intensively farmed animals, so results need to be interpreted with caution.	
Herd level assessment	1	1	2	3	Y		Y		Scan sampling of the group at set times of the day – can indicate whether behaviour patterns are normal or disrupted, indicating a potential problem.	
Human–animal interaction	2	2	3	3	Y		Y		Observation of an animal's responses to the presence of familiar/unfamiliar people/situations. An indicator of fearfulness. Exposure to positive interactions can help build more resilient and less fearful animals.	
Play behaviour	2	2	3	3	Y		Y		Observation of animals, especially young ones, when introduced to novel situations/paddocks – an indicator of positive welfare.	

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