Ministry for Primary Industries
Manatū Ahu Matua

Thermal Stress

Thermal stress summary for dairy cattle, beef cattle, sheep and deer in Aotearoa New Zealand

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1.1 Introduction

Pastoral farming in New Zealand is almost exclusively reliant on keeping animals outdoors all year round, with animal management, such as calving and lambing timed to coincide with seasonal patterns of grass growth. This allows for lower cost, efficient farming systems compared to farming systems in many overseas countries. Pastoral farming also means animals are able to display a greater range of behaviours and often have more choice within their environment compared to animals kept in housing systems. These factors are known to contribute to better animal welfare. However, being outdoors exposes animals to weather conditions such as intense sunlight, heat and humidity, or wet, cold and windy conditions. Weather conditions vary on a daily and seasonal basis and include extreme weather events. Such conditions can be outside the thermal comfort zone for animals and potentially lead to heat or cold stress, collectively termed thermal stress.

There are a number of mitigation measures that farmers can take to reduce the impact of thermal stress, and in particular the provision of shade from sun and shelter from wind and rain. The provision of adequate shade and shelter on New Zealand farms has been a concern for many years and is regularly the underlying cause for complaints to MPI about animal welfare. Communication to farmers about the importance of managing thermal stress, and in particular providing adequate shade and shelter for their animals has occurred over many years. A report produced for MPI in 2019[1] looked at the expectations for animal shelter among farmers, stakeholders and the general public and concluded that while the provision of shelter is part of good farming, there are different understandings of what is good, and different barriers or constraints, including finances, time and resources. There also appear to be different understandings of what level of shelter is required, for example, that required for animal comfort, productivity or survival[2].

The Animal Welfare Act 1999, and the various codes of welfare that relate to the pastoral species all have requirements and minimum standards for the provision of shade and shelter. It is clear that a number of farmers are not meeting their obligations for the provision of shade and shelter for their livestock. As a result, the Sector Liaison Team within the Animal Welfare team at MPI have initiated a project with the ultimate goal of improving shade and shelter for animals on New Zealand farms.

This paper has been prepared to summarise current knowledge of both heat and cold stress on production animal species in New Zealand, that is for dairy and beef cattle, sheep and deer. It is clear that thermal stress impacts both the welfare and productivity of animals. Minimising thermal stress has flow on effects for farm sustainability and should be factored into all farm management considerations.

This work is important as climate change has already, and will continue to bring, higher summer temperatures for longer periods to more parts of New Zealand, affect winter weather with more storms bringing heavy rain, and strong wind to all parts of the country, and snow to the South Island, and make adverse weather events more frequent and severe.

1.2 What is thermal stress?

Cattle, sheep and deer are homeothermic animals which means that they maintain a relatively constant body temperature despite wide fluctuations in environmental temperature. A constant body temperature is required to support the physiological processes and biochemical reactions for normal metabolism to occur, and therefore enable activity, growth and reproduction, and to maintain wellbeing and reduce discomfort.

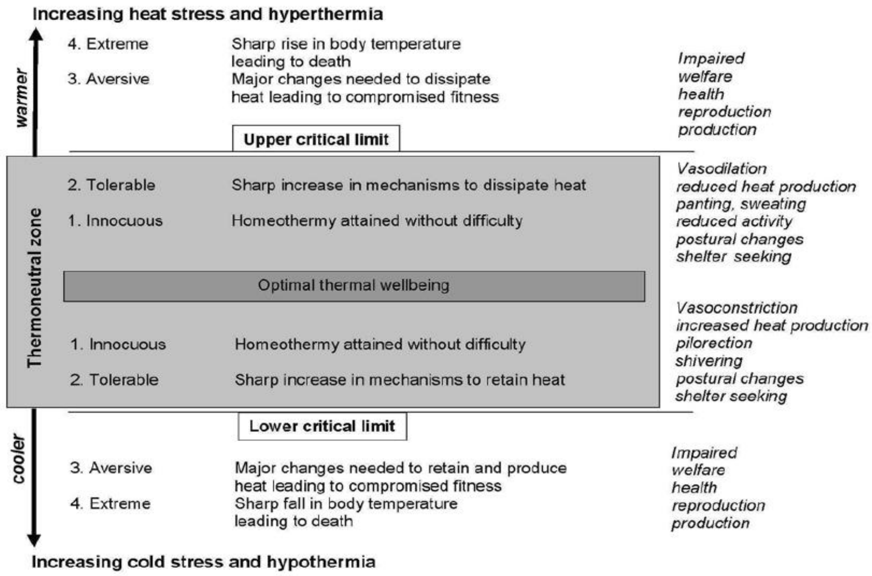
Homeothermic animals have an environmental temperature range within which normal metabolic processes occur and the animals are comfortable, and this is known as the thermoneutral zone. The range of temperatures individual animals can tolerate varies depending on factors such as species, breed, sex, age, body condition, physiological state (e.g., pregnant, lactating), coat or fleece length and

[1] MPI Technical Paper No:2019/08. July 2019. Expectations of Pastoral Animal Shelter among farmers, Stakeholders and the general public.

[2] Fisher MW, Stockwell W, Hastings A, Brannigan JIE, Lyons CE and Timmer-Arends P. 2019. Barriers to the adoption of animal welfare standards: shelter on pastoral farms. *New Zealand Journal of Animal Science and Production* **79**: 37-42.

colour, nutrition and hydration, health status and level of acclimatisation, as well as environmental conditions such as humidity, wind speed, rain/snow, solar radiation, and food and water availability.

Once environmental temperatures move outside the thermoneutral zone for an animal, thermoregulatory processes are initiated in an attempt to stabilise body temperature. As temperatures fall below the lower limit of the thermoneutral zone animals will increase their metabolic rate to produce more heat and maintain body temperature. Food intake will increase, and animals also seek shelter, may display shivering, huddle together and change their posture. As temperatures rise above the upper limit of the thermoneutral zone food intake is usually reduced along with activity, animals will seek shade, water and areas with more wind flow, peripheral blood flow and respiration rate will increase, and panting and sweating will occur – all aimed at reducing body temperature. An animal's capacity to accommodate environmental temperature rises or falls is limited, and thermal stress will result when mechanisms to control body temperature are inadequate. Continued failure to control body temperature will lead to hypothermia or hyperthermia. Both conditions adversely affect animal welfare and lead to death if not resolved. The diagram below summarises the thermal stages affecting livestock behaviour, physiology and survival[3].



1.3 What we know about thermal stress

1.3.1 Heat stress

Within the New Zealand climatic range, cattle, sheep, and deer are in general more likely to be affected by heat stress than cold stress, and the incidence of heat stress is likely to increase as climate change occurs.

During thermoneutral conditions cattle core body temperatures range from 38.0-39.3°C (Idris et al., 2021[4]) and sheep core body temperatures range from 38.3-39.9°C [5]. Conditions that cause heat stress operate by increasing core body temperature towards the Upper Critical Limit (UCL) (about 40.5°C), at which point major changes are needed to dissipate heat. If these do not occur body temperature will continue to rise resulting in hyperthermia and death. Livestock rely to a large extent on evaporation from the lungs and to a lesser extent from the skin to lose excess heat, so increased respiratory rate is evidence that core body temperatures are under threat of heat loading.

[3] Fisher MW. 2007. Shelter and welfare of pastoral animals in New Zealand, New Zealand Journal of Agricultural Research **50**:3, 347-359, DOI: 10.1080/00288230709510303

[4] Idris M, Uddin J, Sullivan M, McNeill DM and Phillips CJC. 2021. Non-invasive physiological indicators of heat stress in cattle. *Animals* **11**: 71.

[5] Schutz KE. 2022. Effects of heat stress on the health, production and welfare of sheep managed on pasture. Report for the Ministry for Primary Industries.

The susceptibility of animals to heat stress depends on a number of intrinsic factors such as species, breed, age, genotype, coat colour, coat type, sex, body condition, total mass, surface area to mass ratio, health, physiology, and metabolic heat production, and a number of extrinsic factors such as ambient temperature, humidity, solar radiation, wind speed, cloud cover, rainfall, and management practices (Gaughan et al., 2002[6]). The point at which heat stress occurs depends on the internal heat load of the animal (e.g., digestion of feed, milk production) and on the factors that govern heat exchange (ability to lose heat). Heat loss occurs via conduction, convection, radiation, evaporation of water and through expired air (Silanikove, 2000[7]; Kadzere et al., 2002[8]).

Heat stress can dramatically alter animal productivity, physiology and behaviour (West, 2003[9]; Schütz et al., 2010[10]; Tao et al., 2018[11]; Al-Dawood, 2017[12)] leading to increased body temperature and respiration rate, and decreased feed intake, rumination, milk production, time spent lying and poorer fertility and immune function, and in severe instances can result in mortalities (Brown-Brandl *et al*., 2005[13]; Mader *et al*., 2006[14]; Cook *et al*., 2007[15]; Abeni and Galli, 2017[16], Al-Dawood, 2017[12]).

Much of the research into heat stress in New Zealand livestock has been carried out with dairy cows and can be used as a basis for assessing and managing heat stress in beef cattle. Research is underway to better understand heat stress in sheep in New Zealand and includes evaluation of breed and regional differences. Overseas research on heat stress in beef cattle and sheep has been carried out in farming systems that are not always applicable to New Zealand such as feedlot cattle in Australia and USA, and for very extensively grazed sheep in tropical climates. However, it is clear that sheep and beef cattle do adjust their behaviour in response to heat stress, with shade seeking, altered grazing patterns and reduced lying times apparent.

Studies have observed deer physiological and behavioural changes in response to warm ambient conditions (daily maximum temperatures of up to 41.0°C). These include increased thermoregulatory behaviour involving placing forelegs in water troughs, wallowing, water and shade seeking, as well as lower weaning weights and reduced activity (Alvarez Ramírez *et al*., 2021[17]; Perez-Barberia *et al*., 2020[18]).

Shade appears to be a resource which is highly valued by livestock as a strategy for mitigating heat stress and they will seek and use shade during the heat of the day (Silanikove, 2000[7]). The provision of shade has been shown to reduce the radiant heat load of an animal by 30% and reduce black globe temperature by approximately 8°C (Bond *et al*., 1967[19]; Roman-Ponce *et al*., 1977[20]).

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[6] Gaughan JB, Mader TL, Holt SM, Hahn GLD and Young BA. 2002. Review of current assessment of cattle and microclimate during periods of high heat load. *Australian Journal of Animal Production* **24**: 77-80.

[7] Silanikove N. 2000. Effects of heat stress on the welfare of extensively managed domestic ruminants. *Livestock Production Science* **67**: 1-18.

[8] Kadzere CT, Murphy MR, Silanikove N and Maltz E. 2002. Heat stress in lactating dairy cows: a review. *Livestock Production Science* **77**: 59-91.

[9] West JW. 2003. Effects of heat-stress on production in dairy cattle. *Journal of Dairy Science* **86**: 2131-2144.

[10] Schütz KE, Rogers AR, Poulouin YA, Cox NR and Tucker CB. 2010. The amount of shade influences the behavior and physiology of dairy cattle. *Journal of Dairy Science* **93**: 125-133.

[11] Tao S, Orellana R, Weng X, Marins T, Dahl G and Bernard J. 2018. Symposium review: The influences of heat stress on bovine mammary gland function. *Journal of Dairy Science* **101**: 5642-5654.

[12] Al-Dawood A. 2017. Towards heat stress management in small ruminants – a review. *Annals of Animal Science* **17(1)**: 59–88.

[13] Brown-Brandl TM, Eigenberg RE, Nienaber JA and Hahn GL. 2005. Dynamic response indicators of heat stress in shaded and non-shaded feedlot cattle: Part 1. Analyses of indicators. *Biosystems Engineering* **90**: 451-462

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[15] Cook NB, Mentink RL, Bennett TB and Burgi K. 2007. The effect of heat stress and lameness on time budgets of lactating dairy cows. *Journal of Dairy Science* **90**: 1674-1682.

[16] Abeni F and Galli A. 2017. Monitoring cow activity and rumination time for an early detection of heat stress in dairy cow. *International Journal of Biometeorology* **61**: 417-425.

[17] Alvarez Ramírez L, Mejia NG, Alejandra A, Cercantes S. 2021. Artificial shade effects on behavior and body weight of pregnant grazing red deer (Cervus elaphus). *Journal of Veterinary Behavior* **44**: 32-39.

[18] Pérez-Barbería FJ, García AJ, Cappelli J, Landete-Castillejos T, Serrano MP, Gallego L. 2020. Heat stress reduces growth rate of red deer calf: Climate warming implications. *PLoS ONE* **15(6)**: e0233809. https://doi.org/10.1371/journal. pone.0233809

[19] Bond TE, Kelly CF, Morrison SR and Periera N. 1967. Solar, atmospheric, and terrestrial radiation received by shaded and unshaded animals. *Transactions of the American Society of Agricultural Engineers* **10**: 622–627.

[20] Roman-Ponce H, Thatcher WW, Buffington DE, Wilcox CJ and Van Horn HH. 1977. Physiological and production responses of dairy cattle to a shade structure in a subtropical environment. *Journal of Dairy Science* **60**: 424-430.

Work in New Zealand with dairy cows confirms high levels of motivation to use shade during hot weather. Cows will often increase the amount of time spent in shaded areas as ambient temperatures and levels of solar radiation increase and adjust their grazing patterns to eat more at night (Kendall *et al*., 2006[21]; Tucker *et al*., 2008[22]; Schütz *et al*., 2008[23]). Compared to cows without access to shade, the provision of shade has been shown to be beneficial for dairy cattle in terms of reducing body temperature even in temperate climates (Fisher *et al.*, 2008[24]). In a New Zealand study with relatively mild summer conditions, a mean maximum temperature of 25.2°C, Kendall *et al*. 2006[25] reported that dairy cows provided with access to shade produced 3% more milk than cows without access to shade, and Becker *et al.* 2020[26] reported that cows without access to shade reduced the time spent grazing in order to seek relief from the heat. Cattle without access to shade may also compensate for the increased heat load by increasing the amount of time they spend standing and increasing the amount of time they spend around the water trough (Widowski, 2001[27]; Schütz *et al*., 2010[10]). Palacio *et al*. (2015)[28] reported that cows with access to shade were observed at the water trough on average 34.2% less than cows with no access to shade. The reason for cattle increasing the time spent around the water trough in hot conditions, apart from drinking, is considered to relate to evaporation from the trough creating a microclimate which helps the cows reduce the level of heat stress they are experiencing (Palacio *et al*., 2015[28]).

It is important to note that the use of shade as a heat mitigation strategy is only fully effective if enough shade is provided. The amount of shade provided is important in ensuring not only that animals are able to cool down efficiently but also that they can do so without the negative effects of aggression. Schütz *et al*. (2010)[10] demonstrated that dairy cows that had access to nearly 9.6m^2 of shade per cow spent more than twice as much time in the shade compared to cows that had access to 2.4m^2 per cow and there were fewer aggressive interactions in the larger shade area.

The type of shade, and in particular the level of solar radiation blockage, also influences how effective it is as a strategy for preventing discomfort and thermal stress due to the microclimate created under the shadow cast by the shade structure (Tucker *et al*., 2008[22]). The amount of shade and the level of protection from solar radiation that trees can provide throughout the day will depend on how they are orientated relative to the sun (Becker and Stone, 2020[26]), and is contingent on tree height, spacing and the density of the various species (Hawke and Wedderburn, 1994[29]). Shade structures are effective at providing protection against solar radiation, however, if air movement under the structure is limited or does not occur it may not improve the air temperature or humidity around the animals, which may inhibit

[21] Kendall PE, Nielsen PP, Webster JR, Verkerk GA, Littlejohn RP and Matthews LR. 2006. The effects of providing shade to lactating dairy cows in a temperate climate. *Livestock Science* **103**: 148-57.

[22] Tucker CB, Rogers AR and Schütz KE. 2008. Effect of solar radiation on dairy cattle behaviour, use of shade and body temperature in a pasture-based system. *Applied Animal Behaviour Science* **109**: 141-154.

[23] Schütz KE, Cox NR and Matthews LR. 2008. How important is shade to dairy cattle? Choice between shade or lying following different levels of lying deprivation. *Applied Animal Behaviour Science* **114**: 307-318.

[24] Fisher AD, Roberts N, Bluett SJ, Verkerk GA and Matthews LR. 2008. Effects of shade provision on the behaviour, body temperature and milk production of grazing dairy cows during a New Zealand summer. *New Zealand Journal of Agricultural Research* **51(2)**: 99-105. DOI: 10.1080/00288230809510439

[25] Kendall PE, Nielsen PP, Webster JR, Verkerk GA, Littlejohn RP and Matthews LR. 2006. The effects of providing shade to lactating dairy cows in a temperate climate. *Livestock Science* **103**: 148-57.

[26] Becker CA and Stone AE. 2020. Graduate student literature review: Heat abatement strategies used to reduce negative effects of heat stress in dairy cows. *Journal of Dairy Science* **103:** 9667-9675.

[27] Widowski TM. 2001. Shade-seeking behavior of rotationally-grazed cows and calves in a moderate climate. In *Livestock Environment IV: Proceedings of the 6th International Symposium*, pp 632-639, Louisville, KY.

[28] Palacio S, Bergeron R, Lachance S and Vasseur E. 2015. The effects of providing portable shade at pasture on dairy cow behavior and physiology. *Journal of Dairy Science* **98**: 6085-93.

[29] Hawke MF and Wedderburn ME. 1994. Microclimate changes under Pinus Radiata agroforestry regimes in New Zealand. *Agricultural Forest Meteorology* **71**: 133–145.

their natural ability to dissipate heat (Flamenbaum *et al*., 1986[30]; Gaughan *et al*., 2004[31]; Renaudeau *et al*., 2012[32]).

Work with dairy cows has shown that evaporative cooling methods (reviewed by Becker and Stone, 2020[26]) such as the use of sprinklers or misters can be an effective method to reduce heat load and enable cows to dissipate heat (Schütz *et al.,* 2011[33]). Compared to providing shade, fans or sprinklers alone, a combination of fans and sprinklers were found to be more effective at reducing body temperatures and respiration rate by enhancing the ability for cows to dissipate heat (Kendall *et al*, 2007[34]). Schütz *et al*. (2011)[33] reported that in a controlled trial, when given a choice, 62% of dairy cows chose shade over the use of sprinklers and that 65% also chose shade over no form of heat mitigation. However, whilst shade was the preferred option over sprinklers or no heat abatement, sprinklers were found to better reduce respiration rates and decrease both skin and core body temperatures (Schütz *et al*., 2011[33]).

Heat stress may be managed in a number of ways other than by the provision of shade or evaporative cooling and ensuring a plentiful water supply. For reasons that are not fully understood, animals may not always choose shade, even on hot days. For pastoral sheep and beef cattle farmers there is limited scope to use evaporative cooling to manage heat stress in their livestock, however these systems are implementable in off-pasture situations, and in particular, for feedlots.

Heat stress may occur in dairy yards, after the herd has walked to the farm dairy on hot summer afternoons (Kendall *et al*, 2008[35]). Altering milking times to cooler parts of the day, milking once a day, and reducing walking distances on hot afternoons by selecting paddocks close to the dairy for daytime grazing may assist in reducing the risk of heat stress.

Other longer term potential heat mitigation strategies, aside from farm infrastructure developments such as planting trees and building shade structures, include nutritional management to reduce internal heat load and genetic selection. Nutritional strategies such as the use of a high energy diet which balances decreased feed intake and increased energy requirements for thermoregulation have been investigated (Das *et al*., 2016[36]). Other nutritional strategies have focused on feed additives, managing the proportion of roughage, and altering feeding time to reduce metabolic heat loads during the hottest periods of the day (Dunshea *et al*., 2019[37]; Moallem *et al*., 2009[38]; Calamari *et al*., 2011[39]; Mader *et al*., 1999[40]; Brosh *et al*., 1998[41]).

An animal's genotype has a major influence on its tolerance to heat load. Genetic selection of heat tolerant breeds has progressed with varying levels of success (Roland *et al*., 2016[42]; Lees *et al*., 2019[43]).

[30] Flamenbaum I, Wolfenson D, Mamen M and Berman A. 1986. Cooling dairy cattle by a combination of sprinkling and forced ventilation and its implementation in the shelter system. *Journal of Dairy Science* **69**: 3140-3147.

[31] Gaughan JB, Tait LA, Eigenberg R and Bryden WL. 2004. Effect of shade on respiration rate and rectal temperature of Angus heifers. *Animal Production Science* **25**: 69-72.

[32] Renaudeau D, Collin A, Yahav S, de Basilio V, Gourdine JL and Collier RJ. 2012. Adaptation to hot climate strategies to alleviate heat stress in livestock production. *Animal* **6**: 707-728.

[33] Schütz KE, Rogers AR, Cox NR, Webster JR and Tucker CB. 2011. Dairy cattle prefer shade over sprinklers: Effects on behavior and physiology. *Journal of Dairy Science* **94**: 273-283.

[34] Kendall PE, Verkerk GA, Webster JR, and Tucker CB. 2007. Sprinklers and Shade Cool Cows and Reduce Insect-Avoidance Behaviour in Pasture-Based Dairy Systems. Journal Dairy Science **90**: 3671-3680.

[35] Kendall PE, Tucker CB, Dalley DE, Clark DA and Webster JR. 2008. Milking frequency affects the circadian body temperature rhythm in dairy cows. *Livestock Science* **117**: 130-138.

[36] Das R, Sailo L, Verma N, Bharti P and Saikia J. 2016. Impact of heat stress on health and performance of dairy animals: A review. *Veterinary World* **9:** 260.

[37] Dunshea FR, Oluboyede K, DiGiacomo K, Leury BJ and Cottrell JJ. 2019. Betaine Improves Milk Yield in Grazing Dairy Cows Supplemented with Concentrates at High Temperatures. *Animals* **9:** 57.

[38] Moallem U, Lehrer H, Livshitz L, Zachut M and Yakoby S. 2009. The effects of live yeast supplementation to dairy cows during the hot season on production, feed efficiency, and digestibility. *Journal of Dairy Science* **92**: 343-351.

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[40] Mader TL, Gaughan JB and Young BA. 1999. Feedlot diet roughage level for Hereford cattle exposed to excessive heat load. *Professional Animal Scientist* **15:** 53-62.

[41] Brosh A, Aharoni Y, Degen AA, Wright D and Young BA. 1998. Effects of solar radiation, dietary energy, and time of feeding on thermoregulatory responses and energy balance in cattle in a hot environment. *Journal of Animal Science* **76**: 2671-2677.

[42] Roland L, Drillich M, Klein-Jobstl D and Iwersen M. 2016. Invited review: Influence of climatic conditions on the development, performance, and health of calves. *Journal of Dairy Science* **99**: 2438-2452.

[43] Lees AM, Sejian V, Wallage AL, Steel CC, Mader TL, Lees JC and Gaughan JB. 2019. The impact of heat load on cattle. *Animals* **9**: 322.

Australian feedlot beef cattle research demonstrated that increasing *Bos indicus* (Brahman) content in the genotype decreased the probability of panting scores (a measure of respiration rate) exceeding thresholds in hot conditions (Gaughan *et al*., 2019[44]). A study in Brazil (McManus *et al*., 2016[45]) compared eye temperature and respiration rate in 11 sheep breeds to assess tolerance to heat load. In general sheep breeds with a hairy coat were more tolerant of heat than sheep with wool. Of breeds common in New Zealand, Dorpers (hair breed) were most tolerant, then Merinos, Corriedales, Texel, Hampshire, Romney and Suffolk sheep, in order of decreasing heat load tolerance.

Compared to New Zealand Jersey cattle, New Zealand Holstein Friesian cattle are more sensitive to impacts of heat or cold (Bryant et al., 2007[46]) and this has relevance when crossbred cattle are present on beef farms. A specific mutation that increases the ability of cattle to regulate body temperature has been identified, which is known as the slick gene, due to animals having a short, sleek hair coat (Hansen, 2020[47]). This provides opportunities to reduce the impacts of heat stress by transferring specific genetic alleles that confer thermotolerance to breeds which are not adapted to hot climates. The slick gene mutation identified in Senepol cattle has been introgressed in dairy cattle in Puerto Rico, Florida and New Zealand (Hansen, 2020[47]). The motivation to select for heat tolerant cows may continue in response to the increasing impacts of climate change (Hoffman, 2010[48]).

There has been some suggestion that selection for heat tolerance may impact negatively on production (Rhoads *et al*., 2013[49]) especially in breeds that are highly selected for factors such as milk yield, growth or carcass quality. However, as proposed by Hansen (2020)[47], the impacts of heat stress on cattle production can be reduced by genetic strategies which may be advantageous over crossbreeding to avoid production losses. In New Zealand work is underway to incorporate heat tolerant genetics into the dairy cattle population without negatively impacting production (Personal communication).

1.3.2 Cold stress

Healthy well-conditioned adult livestock are relatively robust in their ability to tolerate adverse cold conditions encountered in a New Zealand winter including its wet and changeable nature.

Cattle, sheep and deer will seek shelter or microclimates that reduce their exposure to cold, wet or windy conditions. When cold is also accompanied by wind and /or rain heat loss to the surrounding environment increases and this includes to the ground when lying surfaces are wet (Webster *et al*., 2008[50]).

Some animals are more susceptible to cold stress due to higher rates of heat loss and/or their inability to maintain heat production. These include thinner animals, those that are sick as well as newborn and young animals. Newborn and young animals are subjected to high rates of heat loss due to their high surface to body weight ratio (Randall, 1978[51]) and this is exacerbated by a number of factors including wind, moisture, breed, coat and available shelter. Newborn animals are particularly at risk if the dam does not lick her newborn dry soon after birth as remaining wet from amniotic fluid increases heat loss via evaporation. Cold, wet conditions have also been reported to prolong the time taken to stand after birth which may delay colostrum intake and thus further reduce the animal’s ability to maintain adequate

[44] Gaughan J, Perkins N and Woldeyohannes S. 2019. Evaluation of a heat load model for feedlot cattle. Meat and Livestock Australia Limited.

[45] McManus C, Dallago BSL, Lehugeur C, Ribeiro LA, Hermuche P, Guimarães RF, de Carvalho Júnior OA and Paiva SA. 2016. Patterns of heat tolerance in different sheep breeds in Brazil. *Small Ruminant Research* **144**: 290-299.

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[47] Hansen PJ. 2020. Prospects for gene introgression or gene editing as a strategy for reduction of the impact of heat stress on production and reproduction in cattle. *Theriogenology* **154**: 190-202.

[48] Hoffmann I. 2010. Climate change and the characterization, breeding and conservation of animal genetic resources. *Animal Genetics* **41**: 32-46.

[49] Rhoads RP, Baumgard LH and Suagee JK. 2013. 2011 and 2012 Early Careers Achievement Awards: Metabolic priorities during heat stress with an emphasis on skeletal muscle. *Journal of Animal Science* **91**: 2492–2503.

[50] Webster JR, Stewart M, Rogers AR and Verkerk GA. 2008. Assessment of welfare from physiological and behavioural responses of New Zealand dairy cows exposed to cold and wet conditions. *Animal Welfare* **17**: 19-26

[51] Randall BCB. 1978. Perinatal mortality: Some problems of adaptation at birth. *Advances in Veterinary Science and Comparative Medicine* **22**: 53-81.

heat production in addition to increasing the risk of failure of passive transfer of immunity thus increasing disease susceptibility and mortality rates (Diesch *et al.,* 2004[52]).

There has been extensive research on dairy cattle regarding behavioural responses to cold and wet conditions and these include seeking shelter or microclimates to mitigate the impact of weather, standing with lowered heads, reducing food intake and time spent lying, and adopting postures that reduce heat loss (Schutz et al., 2010[53]; Tucker *et al.,* 2008[22]; Webster *et al*., 2008[50]). Reduced lying times are likely associated with the reluctance of dairy cattle to lie on wet or muddy surfaces (Fisher *et al*., 2003[54]; Fregonesi *et al*., 2007[55]; Tucker *et al*., 2008[22]; Reich *et al.,* 2010[56]; Chen *et al.,* 2017[57]). Cattle have a strong motivation to lie and will choose to reduce feeding time rather than lying time if faced with a trade-off (Munksgaard *et al*., 2005[58]). While dairy cattle have been reported to lie down on wet surfaces eventually, lying postures that reduce the area exposed to surroundings, and hence reduce heat loss, are common, for example lying with front legs in a tucked position (Tucker *et al*., 2008[22]). The quality of lying when on wet or muddy surfaces is also likely affected with less time being spent in postures that have been associated with sleep (Schütz *et al*., 2019[59]). The provision of dry, insulated bedding helps to reduce the impact of cold conditions by providing a layer of insulation between the animal and the ground (Girma and Gebremariam, 2019[60]; Dewell *et al.,* 2021[61]). Without adequate bedding, the amount of heat loss cattle experience will be greater.

The provision of shelter, or suitable cold mitigation strategies including provision of additional feed and water to maintain heat production and access to suitable well-drained lying surfaces to reduce heat loss, are important to ensure animals do not experience adverse welfare impacts as a result of cold stress. Animals should be able to access effective shelter freely when they choose to do so, recognising that individual animals may have different preferences for shelter and not all animals may use the shelter provided.

1.4 Transport and thermal stress

Transport exposes animals to environmental conditions such as high ambient temperatures and humidity, or rain and wind chill that they are unable to avoid. When conditions are such that heat or cold stress could occur this adds to the welfare impacts of transport which can be stressful for all classes of stock (Fisher *et al.,* 2009[62]).

Internationally, heat and cold stress during transport have been well documented. Advice for farmers and transporters on choosing the right animals for transport, preparing them adequately and transporting them in a way that reduces the risk of thermal stress is available[63].

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[52] Diesch TJ, Mellor DJ, Stafford KJ and Ward RN. 2004. The physiological and physical status of single calves at birth in a dairy herd in New Zealand. *New Zealand Veterinary Journal* **52**: 250-5.

[53] Schütz KE, Clark KV, Cox NR, Matthews LR and Tucker CB. 2010. Responses to short-term exposure to simulated rain and wind by dairy cattle: time budgets, shelter use, body temperature and feed intake. *Animal Welfare* **19**: 375-383.

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[55] Fregonesi JA, Tucker CB and Weary DM. 2007. Overstocking reduces lying time in dairy cows. *Journal of Dairy Science* **90**: 3349-3354.

[56] Reich LJ, Weary DM, Veira DM and von Keyserlingk MA. 2010. Effects of sawdust bedding dry matter on lying behavior of dairy cows: A dose-dependent response. *Journal of Dairy Science* **93**: 1561-1565.

[57] Chen JM, Stull CL, Ledgerwood DN and Tucker CB. 2017. Muddy conditions reduce hygiene and lying time in dairy cattle and increase time spent on concrete. *Journal of Dairy Science* **100**: 2090-103.

[58] Munksgaard L, Jensen MB, Pedersen LJ, Hansen SW and Matthews L. 2005. Quantifying behavioural priorities – effect of time constraints on behaviour of dairy cows, *Bos Taurus*. *Applied Animal Behaviour Science* **92**: 3-14.

[59] Schütz KE, Cave VM, Cox NR, Huddart FJ and Tucker CB. 2019. Effects of 3 surface types on dairy cattle behavior, preference, and hygiene. *Journal of Dairy Science* **102**: 1530-1541.

[60] Girma F and Gebremariam B. 2019. Review on effect of stress on production and reproduction of dairy cattle. *Journal of Scientific and Innovative Research* **8**: 29-32.

[61] Dewell GA, Lundy EL and Schwab DL. 2021. Caring for cow herds during cold weather. *Iowa State University Extension Outreach,* IBC143.

[62] Fisher AD, Colditz IG, Lee C and Ferguson DM. 2009. The influence of land transport on animal welfare in extensive farming systems. *Journal of Veterinary Behavior* **4**: 157-162

[63] http://omafra.gov.on.ca/english/livestock/sheep/facts/02-013.htm

Some work has been carried out in New Zealand to assess the risk of heat stress for sheep, especially lambs during transport. Ventilation on New Zealand transport vehicles is passive, that is dependent on airflow generated by the movement of the vehicle. Of particular concern are periods of time when transport vehicles are stationary such as during driver rest periods, when trucks and trailers are loaded separately, or while vehicles are on interisland ferries. Airflow for the animals is limited at these times and temperature and humidity increase, especially for animals in interior pens, in proportion to the duration of the stationary period. This work concluded that increases in temperature and humidity on stationary transport vehicles could be detrimental to sheep welfare at most daytime ambient temperatures during summer in New Zealand[64].

Other factors that can contribute to the build-up of heat in livestock vehicles include the design of the vehicle including crate design, the stocking density and the type of animals.

Anecdotally, animals suffering from thermal stress, particularly heat stress, are seen often. Data from MPI Compliance indicates that complaints about thermal stress during transport are limited to those concerning heat stress and animals in trucks or trailers parked on the side of the road. Most of these complaints are unable to be substantiated as the truck has moved on by the time an animal welfare inspector is able to get to the site or are the result of things beyond the control of the truck driver, such as a break-down.

MPI Verification Services provided information about cases of thermal stress in 2021 and 2022 in animals arriving at slaughter premises. The assessment of thermal stress is made by Verification Services veterinarians at the time the animals are unloaded. During this time nine cases of heat stress were recorded. There was one case of heat stress in pigs involving four deaths during transport and further deaths in the yards. There was also one case involving a cattle beast where weather conditions may have contributed to heat stress. The remaining seven cases were sheep, involving 388 animals of which 9 died, and of these cases three were for animals that had crossed the Cook Strait. In two of these cases the report noted that the daytime temperatures were high, and no water was available for the animals.

Measuring the welfare impact of heat stress during transport by the number of animals that die does not take into account the impact of heat stress on the animals that are affected but do not die. Therefore, the incidence of heat stress during transport in summer, especially for sheep, is likely to be a lot higher than that recorded by Verification Services since 2021.

Cases of cold stress in 2021 and 2022 are confined to bobby calves, with eleven cases recorded in this time. Almost all of these note very wet and sometimes windy conditions on the day of transport. Trucks carrying bobby calves are required to have covers, but these are not always waterproof, and some drivers claim that water coming through ventilation vents will make calves wet when the weather is poor. The total number of animals involved was 341, however this is a mix of animals that died (5) and those that arrived wet and cold but survived.

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[64] AD Fisher, M Stewart, DM Duganzich, J Tacon and LR Matthews. 2005. The effects of stationary periods and external temperature and humidity on thermal stress conditions within sheep transport vehicles. *New Zealand Veterinary Journal* **53(1)**: 6-9. DOI: 10.1080/00480169.2005.36461

1.5 Saleyards, slaughter plant lairage and other facilities where animals are penned

1.5.1 Saleyards

There are a large number of saleyards in New Zealand, and these vary greatly in their facilities and state of repair. Common concerns include lack of cover or rooves for animals, and not all pens having water available. This means animals are unable to seek shelter from both hot and cold conditions or drink to help mitigate the impacts of hot conditions. MPI Compliance reported 11 animal welfare responses relating to saleyards and two proactive visits from 2017 to 2021. Four of these were in relation to shade and shelter, six were for lack of water for animals, and three for inadequate facilities. In one case, an offence was detected. A common finding for these responses was although minimum standards are being met, more could be done to improve conditions for the animals, and advice and/or education were given.

1.5.2 Slaughter plants

Licensed meat processing premises are built and operated under the requirements of the Code of Welfare for Slaughter, including Minimum Standard 3c which states the lairage must provide adequate shelter from adverse weather conditions and ventilation to protect the welfare of the animals being held for slaughter, and pertinent meat processing regulations. This should mean the risk of heat or cold stress is minimised once animals are unloaded, however some of these requirements are vague and could lead to a risk of thermal stress for some animals. All sheep and bobby calf pens are covered, however at some premises not all pens for adult cattle are covered.

Anecdotally, the biggest risk, especially for heat stress, is when trucks have to wait to unload stock and are stationary, often with no shade to park under. This risk can be minimised if truck arrival is properly scheduled to ensure animals can be unloaded on arrival, or trucks keep moving until they are able to unload.

1.5.3 Other animal holding facilities

There are a number of other situations where animals may be penned for various periods of time such as at exhibitions or events. Uncovered outdoor pens may mean animals do not have access to shelter from adverse weather, including hot sun, and therefore could lead to thermal stress. Indoor or covered pens should have sufficient air flow, especially on hot days to prevent temperatures getting too high for the animals.

1.6 Signs of thermal stress

1.6.1 Heat stress

Signs of heat stress relate to actions the animal takes to reduce its core body temperature by removing heat, and also to prevent further heat build-up from both internal and external heat sources.

Heat loss occurs via conduction, convection, radiation, evaporation of water and through expired air (Silanikove, 2000[7]; Kadzere *et al*., 2002[8]). Cattle, sheep and deer rely to a large extent on evaporation from the lungs, and to a lesser extent from the skin to lose excess heat. The first sign that core body temperatures are under threat of heat loading is an increased respiratory rate usually with the mouth closed. This will progress to panting and open mouth breathing. Drooling may occur, especially in cattle. As the degree of heat stress increases the rate of panting will increase, the neck will be lowered and extended with the head tilted upwards, and the tongue will protrude from the mouth. In extreme cases of heat stress, the tongue will be fully extended, and the head is often lowered. At this point the respiration rate may include short periods of deeper breathing (see Appendix 2).

The amount of heat the animal generates is related to its metabolic rate, and those animals with a high metabolic rate, for example pregnant or lactating females will generate more internal heat and be more susceptible to heat stress. Higher producing animals are more susceptible to heat stress for this reason. In ruminants, digestion processes also generate heat, with the amount of heat generated dependent on both the volume and type of feed. High energy diets enable the animal's nutritional needs to be met with a lower volume of food and can form part of a strategy to increase animal resilience to heat stress.

Behaviours seen when heat loading increases include seeking shade, increased water intake, reduced feed intake, less lying, animals bunching together in an attempt to find shade from each other, and in severe cases immobility or staggering. Animals may also congregate around water troughs as it is thought the microclimate associated with water troughs may mean the air is somewhat cooler. In deer, wallowing has been observed in response to conditions likely to lead to heat stress, however there are also other likely motivations for wallowing in deer.

The point at which behaviours indicative of heat stress occur varies with species, breed, sex, age, body condition, physiological state (e.g. pregnant, lactating), coat or fleece length and colour, nutrition and hydration, health status and level of acclimatisation, as well as environmental conditions such as temperature, humidity, wind speed, rain, solar radiation, and shade and water availability. Animals will lose heat gained during the day if overnight temperatures are cooler, however when night-time temperatures and humidity levels remain high heat loss is limited and the risk of heat stress occurring increases. In general, the higher the humidity the lower the ambient temperature at which heat stress signs occur, and for grazing animals the level of solar radiation and lack of air movement will also contribute to heat stress.

1.6.2 Cold stress

Signs of cold stress relate to actions the animal takes to reduce heat loss to the surrounding environment, and to increase internal heat generation.

Heat loss occurs via conduction, convection, radiation, evaporation of water and through expired air (Silanikove, 2000[7]; Kadzere *et al*., 2002[8]). Heat loss increases as the environmental temperature drops and is exacerbated if animals are wet and/or exposed to wind which increases the chill factor. Being wet not only increases the rate of heat loss via evaporation but also reduces the insulating properties of fleece or hair cover by reducing the amount of air trapped in the coat.

Signs of cold stress include seeking shelter, shivering, adopting a hunched body posture, animals huddling together and orienting themselves with their hindquarters facing the incoming weather, all aimed at reducing the amount of heat loss. Breathing may become shallow to reduce respiration rate and heat loss. Shelter includes trees, shelter belts and other vegetation (even clumps of tussocks in high country), naturally sheltered areas of the landscape such as hollows and the lee side of hills, and artificial shelters such as buildings and constructed wind breaks. Individual animal covers will reduce heat loss and provide protection from rain.

In cold stress situations animals will also attempt to increase their metabolic rate to increase internal heat production. To do this, feed intake will increase (if available), and as water is required for digestion of feed, water intake will also increase. Animals that are not provided with sufficient feed will mobilise body reserves to increase heat production and this will ultimately lead to weight loss, or poorer production such as reduced growth rates. Animals that are well conditioned prior to periods of cold weather will be able to mobilise body reserves for longer before weight loss becomes a welfare issue.

The point at which behaviours indicative of cold stress occur varies with species, breed, sex, age, body condition, physiological state (e.g. pregnant, lactating), coat or fleece length and colour, nutrition and hydration, health status and level of acclimatisation, as well as environmental conditions such as temperature, wind speed, rain/snow, and shelter, feed and water availability. In general, healthy, well-conditioned, well fed adult animals will cope reasonably well with winter conditions in New Zealand provided they have some shelter and suitable surfaces for lying.

1.7 Production impacts of thermal stress

1.7.1 Heat stress

The production impacts of heat stress have been more widely studied than those for cold stress, particularly in dairy cattle.

In their review of the physiological and behavioural effects of heat stress in dairy cows Becker *et al.* (2019)[65] describe impacts on reproduction, nutrition, milk production, milk components, health, and behaviour. Al-Dawood, (2017)[66] describes similar effects in sheep and goats.

Heat stress may alter duration of oestrus, and uterine function, and high temperatures can affect male fertility. Extended periods of heat stress can also affect early embryonic development and survival, and foetal growth. These effects have also been reported in beef cattle and sheep[66].

Heat stress conditions cause a loss of appetite, and when energy availability is reduced due to decreased intake, coupled with increased maintenance requirements, heat stressed cows can go into a state of negative energy balance where energy intake does not meet the animal's needs. This can lead to an increase in metabolic disorders and health issues, as well meaning less energy is available for milk production. Water is also an important nutrient for health and performance of animals especially during conditions that are likely to cause heat stress. Dairy cattle, beef cattle and sheep will all increase their water intake during hot conditions.
Estimates from the Waikato region indicate that the impact of heat stress on milk production is a reduction of 6kg of milksolids (MS)[67] produced per cow over summer, or for a 300-cow herd a loss of over $15,000 at $8.50/kg MS.

As well as impacting milk production, heat stress has been shown to reduce total protein and total fat yield in milk. The results of studies are variable, and as milk composition is influenced by a range of factors, further research is needed to fully understand the impact of heat stress on milk composition.

Heat stress can lead to suppression of the immune system in both cattle and sheep. This can lead to an increase in the occurrence of disease, and an increased risk of mastitis in dairy cows has been associated with periods of hot weather. The incidence of lameness in dairy cows has been shown to increase with a rise in ambient temperatures and this could be due to increased standing times and reduced lying times as cows attempt to dissipate heat. An increase in the incidence of metritis due to heat stress has also been recorded, this probably occurring because heat stress reduces the uterine defence mechanisms, and high temperatures and humidity increase the pathogen loading in the environment. Increasing the amount of high energy feed during a time when cows will reduce their overall dry matter intake can also predispose animals to ruminal acidosis.

Physiological changes and changes in animal behaviour in response to heat stress are linked. As the heat load increases, animals will change their behaviour to a greater extent and therefore exacerbate the flow on physiological effects. For example, increasingly reducing food intake will lead to a greater negative energy balance, increasing the incidence of metabolic disease which in itself will further reduce food intake. Longer term reductions in food intake can also affect growth rates. In a study in environments which provided Red Deer with opportunities to abate heat, the weaning weight for calves (both male and female) increased by up to 5kg in weight for those calves who had access to sprinklers compared to calves with no access to sprinklers. In this study the mean maximum daily temperature was 30.1˚C. Several behavioural changes were observed in animals offered cooling opportunities; spending less time in shaded areas, less frequent need to drink and increased movement overall (Pérez-Barbería et al., 2021[68]).

For those animals destined for slaughter, high environmental temperatures, exercise and dehydration can affect meat quality, carcase characteristics and organoleptic qualities of the meat and result in dark cutting or dry-firm dry, high pH, low glycogen meat (Al-Dawood, 2017[69]). Increased adrenaline as a response to heat stress, dehydration, and anaerobic metabolism prior to slaughter from hyperthermia and exercise all contribute to dark cutting meat.

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[65] Becker CA, Collier RJ and Stone AE. 2019. Invited review: Physiological and behavioral effects of heat stress in dairy cows. *Journal of Dairy Science* **103**: 6751-6770. https://doi.org/10.3168/jds.2019-17929

[66] Al-Dawood A. 2017. Towards heat stress management in small ruminants – a review. *Annals of Animal Science* **17(1)**: 59-88. DOI: 10.1515/aoas-2016-0068

[67] https://www.dairynz.co.nz/animal/cow-health/heat-stress/

[68] Pérez-Barbería FJ, Arroyo-González I, García AJ, Serrano MP, Gallego L and Landete-Castillejos T. 2021. Water sprinkling as a tool for heat abatement in farmed Iberian red deer: Effects on calf growth and behaviour. *PLoS ONE* **16(4)**: e0249540. https://doi.org/10.1371/journal.pone.0249540

[69] Al-Dawood A. 2017. Towards heat stress management in small ruminants - a review. *Annals of Animal Science* **17**: 59-88.

1.7.2 Cold stress

The normal physiological response of animals to cold stress is to increase metabolic rate to maintain body temperature. This requires energy, and if this energy is not provided by feed then body stores will be used. If body stores are not available, such as in animals in poor condition, or the animal is suffering from some condition that reduces its feed intake (e.g. ketosis), then a condition known as starvation-exposure syndrome may occur and this can be fatal.

Using body stores will result in weight loss, and for growing animals, a reduction in growth rates. This has been shown to occur in dairy heifers, lambs[70] and deer[71]. In adult animals, losses of production efficiency have been linked to cold stress, with impacts on beef cattle, milk production in dairy cows, and wool growth in some breeds of sheep. When deer are exposed to temperatures below their lower critical limit, physiological and behavioural responses occur to generate and conserve heat. Such conditions can lower growth rate, reduce food conversion efficiency and contribute to increased disease susceptibility as well as reduce calf survival rates (Pollard *et al*., 2003[71]; Semiadi *et al.,* 1996[72]).

If animals are unable to maintain body temperature, then hypothermia will result and unless resolved will cause death. Newborn animals are particularly vulnerable as their high surface area to body weight ratio, wet condition from amniotic fluid or rain and lack of energy if they have not suckled, means their susceptibility to cold stress is higher than for older animals. Studies have demonstrated increased lamb survival when ewes are provided with shelter during wet and windy conditions over the lambing period (Gregory, 1995[70]). Cuttance *et al.* (2017)[73] reported an increased death rate for newborn dairy calves born on days with increased rainfall on New Zealand dairy farms with the odds of death increasing by 8% for every 10mm of extra rainfall on the day of birth.

1.8 Welfare impacts of thermal stress

The effects of thermal stress on animals can be assessed using the three constructs for animal welfare considerations; namely biological functioning and health of the animal, the affective state the animal is experiencing, and the naturalness of its life under the conditions it is currently experiencing[74].

Biological functioning and health of the animal is an assessment of the animal's physiological functioning, that is its state of health and productivity. Good health is important for good welfare as this reduces the impact of disease and injury, and usually has a flow-on effect of better productivity such as higher milk production, better growth rates and improved reproductive performance.

The affective state of the animal is an assessment of how the animal feels as it perceives and experiences its environment. These are both immediate perceptions such as feeling hot or cold and longer lasting mood states (such as anxiety or depression) which are usually the result of an accumulation of experiences rather than being caused by a single stimulus. Affective states can be either positive (e.g., enjoyment of play) or negative (e.g., fear from poor handling).

Naturalness is an assessment of the opportunities the animal has to behave in a way that is natural for them, for example the strong herding instinct of cattle, sheep and deer suggests that membership of a social group fulfils an important 'natural' need. For good welfare it is important that animals have some control over their environment, such as being able to access shade in hot weather if they choose to do so.

The three constructs overlap, that is welfare is not just health and production, but also what an animal experiences and feels, and the ability for the animal to behave in a natural way. In an ideal world all three would be fully provided for, but in reality, trade-offs often occur. For example, breeding higher

[70] Gregory NG. 1995. The role of shelterbelts in protecting livestock: A review. *New Zealand Journal of Agricultural Research* **38(4)**: 423-450. DOI: 10.1080/00288233.1995.9513146

[71] Pollard JC, Littlejohn RP and Pearse AJT. 2003. Shade and shelter for farmed deer in New Zealand: Results from a survey of farmers. New Zealand Journal of Agricultural Research **46(4)**: 287-294. DOI: 10.1080/00288233.2003.9513556

[72] Semiada G, Holmes CW, Barry TN and Muir PD. 1996. Effects of cold conditions on heat production by young sambar (Cervus unicolor) and red deer (Cervus elaphus). *Journal of Agricultural Science* **126**: 221-226.

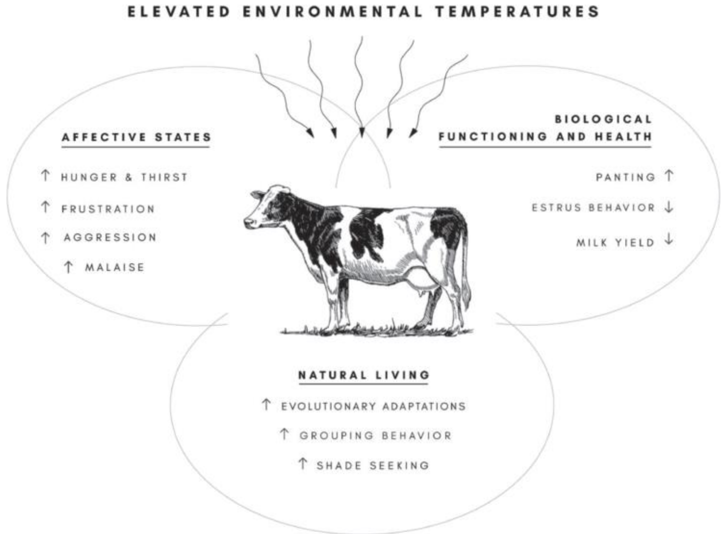
[73] Cuttance EL, Mason WA, McDermott J, Laven RA, McDougall S, and Phyn CVC. 2017. Calf and replacement heifer mortality from birth until weaning in pasture-based dairy herds in New Zealand. *Journal of Dairy Science* **100**: 8347-8357. https://doi.org/10.3168/jds.2017-12793

[74] Fraser D, Weary DM, Pajor EA and Milligan BN. 1997. A scientific conception of animal welfare that reflects ethical concerns. *Animal welfare* **6**: 187-205.

producing animals may mean increased susceptibility to heat stress compared to lower producing animals under the same care in the same environment.

Animal welfare is negatively impacted when animals experience thermal stress. Polsky and von Keyserlingk, (2017)[75] suggest that during heat stress the affective state of an animal can be compromised by feelings of hunger due to reduced food intake, thirst if sufficient water is not supplied or accessible, frustration when attempts to alleviate the stressful situation are hampered, aggression when there is competition for resources such as shade or water, and an overall feeling of malaise. Heat stress also increases the incidence of some diseases, such as mastitis, lameness and metritis in dairy cows therefore affecting the biological functioning and health of the cow. The welfare impacts of disease include pain, discomfort and malaise, and are often accompanied by a loss of appetite. Disease effects may also impact on the ability of the animal to carry out normal behaviours (naturalness) such as eating and walking.

The diagram below is an illustration of the interplay between animal welfare considerations for dairy cows under environmental conditions that may cause heat stress and will be similar for beef cattle, sheep and deer.



The relationship between the immediate effects of environmental heat stress and the 3 key constructs of animal welfare: (1) the biological functioning (and health) of the animal, (2) the affective states the animal is experiencing, and (3) the naturalness of its life under current heat management strategies. (From Polsky and von Keyerlingk, 2017)

The welfare impacts of cold stress are similar to those of heat stress. Animals will attempt to increase their metabolic rate to generate more heat and alter their behaviour to reduce heat loss. The main way to increase metabolic rate is to increase food intake and if this is not provided then animals will feel hungry impacting their affective state. Other impacts on affective state can include frustration when animals seek shelter and if this is not available, or if it is only available in a limited way, and aggression when resources such as food, water and shelter are limited and there is competition for these resources. More dominant animals, who are usually larger, will have better access to resources. Less dominant animals, who due to smaller size, age or reduced fitness are more susceptible to cold stress will have fewer resources exacerbating the welfare impact of cold stress for these individuals. Inability to access resources such as shelter also means animals do not have the opportunity to carry out behaviours that are important to them (naturalness) and allow some control over their environment. Longer term effects of cold stress include biological functioning and health impacts such as weight loss making animals even more susceptible to cold stress, and an increased incidence of conditions such as ketosis, which then adds the welfare impacts of disease to those of cold stress for the animals concerned.

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[75] Polsky L and von Keyserlingk MAG. 2017. Invited review: Effects of heat stress on dairy cattle welfare. *Journal of Dairy Science **100***: 8645-8657. https://doi.org/10.3168/jds.2017-12651

1.9 Relevance to New Zealand

New Zealand has a largely temperate climate, however being narrow islands stretching from sub-tropical in the northern part of the North island, to areas in the South Island that can experience continental-like winter conditions, weather extremes do occur. Weather conditions can also change very rapidly, and in a matter of hours move from settled to a tropical cyclone or a freezing winter storm. Winters over most of the country are generally regarded as moderate, however winter storms, especially in the South Island can bring snow and freezing conditions. Extended periods of rain are common in all parts of the country during winter and can lead to water-logged paddocks and grazing areas. Summer temperatures are generally also moderate however, periods of higher temperatures and increased humidity do occur, and these may last for weeks on end. Such summer conditions appear to be becoming more common and the frequency of such conditions is expected to increase with climate change.

1.9.1 On farm

Livestock production systems in New Zealand are largely pasture based and this means animals are outside all year round and exposed to prevailing weather conditions. Many animals will be exposed to conditions that could lead to heat or cold stress at some point during the year. The risk is greater for animals that are less able to cope with such conditions such as newborn and young animals, high producing dairy cows, animals in either very poor or very high body condition and those suffering from disease or injury. Various on-farm mitigation measures are possible (for example provision of shade and shelter, an adequate supply of water), however whether these are available and used on any farm is largely managed by the owner or person in charge of the animals.

1.9.2 Transport

Though it is clear that conditions that can lead to thermal stress, particularly heat stress, occur frequently in New Zealand, there are few substantiated cases of thermal stress during transport, especially considering the number of livestock journeys undertaken each year.

Minimum Standard 9 (monitoring animals) in the Code of Welfare: Transport within New Zealand requires that animals must be inspected for injury or signs of pain or distress at regular intervals during the journey, including at rest breaks taken by the driver and at refuelling stops. Animals found to have fallen down, to be injured, distressed or with a limb protruding from the container or conveyance must be assisted, treated or euthanised as soon as practicable. Therefore, drivers should be monitoring animals for heat and cold stress, however it is often difficult to view animals onboard at stops, especially those in inside pens, and options for managing thermal stress may be limited.

Thermal stress as a result of transport can really only be properly assessed once the animals arrive at their destination and are unloaded unless there is onboard monitoring on vehicles such as cameras or thermometers which are not currently used in New Zealand. It may be possible to get an indication of the state of animals onboard during a period when the vehicle is stationary, and it is possible to view some of the animals. It is extremely difficult to assess any aspect of animal welfare by observing a livestock vehicle while it is moving. Hence reports of thermal stress in transported animals usually only come when unloading is supervised, such as animals arriving at a slaughter premises.

1.9.3 Saleyards / Slaughter plant lairage

When animals are confined in pens their welfare is very dependent on the physical environment and the care provided by those looking after the animals. There are a number of situations where animals may be held in pens, sometimes for extended periods of time. Examples include saleyards, slaughter plant lairage, at events and during shows.

There is no code of welfare specifically for animals in saleyards, requirements for managing animals at these facilities are covered by the relevant species codes, and to a certain extent, by requirements in the Code of Welfare for Transport. There is no formal oversight of saleyards by MPI. The Compliance Team do some visits to saleyards and information gathered indicates that though these facilities mostly meet minimum standards, there is scope for improvement in both the physical facilities and in the way animals are managed to reduce the risk to animal welfare in general, and thermal stress in particular.

All slaughter plant lairages are required to meet the criteria set out in Minimum Standard 3 of the Code of Welfare for Commercial Slaughter which are:

- The design and construction of slaughter premises must be suitable for the species passing through the premise, and facilities must be maintained in such a condition as to minimise the likelihood of distress or injury.
- The lairage must provide adequate shelter from adverse weather conditions and ventilation to protect the animals being held for slaughter.
- All animals must have access to water that is palatable and not harmful to health in a quantity sufficient to satisfy their thirst.

As noted earlier these standards are vague and may not always be sufficient to protect all animals from heat stress.

The code of welfare requirements are audited by MPI Verification Services staff stationed at slaughter premises as part of their duties under Animal Products Act Risk Management Programme requirements, and corrective actions will be required if animals are suffering from either heat or cold stress.

1.10 Technologies to assist with thermal stress management

Thermal indices have been developed to model the association of thermal parameters (e.g., temperature, humidity, wind speed, and solar radiation) with animal responses to assess the impact of heat stress on animals (Ji *et al*., 2020[76]). The likelihood that heat stress may occur can be estimated by considering a calculated temperature-humidity index (THI) that may also incorporate black globe temperature as an estimate of radiant heat input. Whilst earlier research has suggested an upper threshold THI value of 72 (ambient temperature of 25°C and relative humidity above 50%) for cattle thermal comfort (Bohmanova *et al*., 2007[77]), recent research has suggested a lower value of 60-68 as the upper threshold THI value for high-producing cattle (Carabaño *et al*., 2016[78]). This study evaluated milk production and weather conditions in Holstein cows in four European locations with a mean daily production of between 24.5 and 31.5kg milk. However, THI may not be accurate enough to estimate heat load in grazing animals as it does not take into account solar radiation and wind speed.

A Grazing Heat Load Index (HLI) specific for dairy cows grazing in the Waikato region has recently been developed (Bryant *et al*., 2022[79]). Further work will validate this in other regions of New Zealand. In this work a welfare stressor potentially occurs above a Grazing HLI of 70 which is equivalent to a maximum ambient temperature of 24.4°C with average wind speeds of 7.05m/s and average solar radiation at 2.41 MJ/m^2.

Heat stress can also be indicated by measuring surface and core body temperatures, although surface temperature may not provide a true representation of core body temperature (Islam *et al*., 2021[80]). Rectal temperature is considered a robust indicator of core body temperature and taking an animal's temperature by using a thermometer placed in the rectum is an easy procedure that can be carried out by non-veterinarians, noting that this does require restraint that can be stressful. However, this is only of practical use to assess the core body temperature of individual animals at the time the temperature is taken as issues associated with defaecation mean monitoring sensors do not stay in place (Lea *et al*., 2008[81]). Vaginal temperature is highly associated with rectal temperature, and sensors can be attached to CIDR devices to monitor core body temperature in female cattle (Lees *et al*., 2018[82]). Another method

[76] Ji B, Banhazi T, Perano K, Ghahramani A, Bowtell L, Wang C and Li B. 2020. A review of measuring, assessing and mitigating heat stress in dairy cattle. *Biosystems Engineering* **199**: 4-26.

[77] Bohmanova J, Misztal I and Cole JB. 2007. Temperature-humidity indices as indicators of milk production losses due to heat stress. *Journal of Dairy Science* **90**: 1947-1956.

[78] Carabaño MJ, Logar B, Bormann J, Minet J, Vanrobays ML, Díaz C, Tychon B, Gengler N and Hammami H. 2016. Modelling heat stress under different environmental conditions. *Journal of Dairy Science* **99**: 3798-3814.

[79] Bryant JR, Huddart FJ and Schütz KE. 2022. Development of a heat load index for grazing dairy cattle. *New Zealand Journal of Agricultural Research*. DOI: 10.1080/00288233.2022.2114504

[80] Islam MA, Lomax S, Doughty A, Islam MR, Jay O, Thomson P, and Clark C. 2021. Automated monitoring of cattle heat stress and its mitigation. *Frontiers of Animal Science* **2:** 737213.

[81] Lea JM, Niemeyer DDO, Reed MT, Fisher AD and Ferguson DM. 2008. Development and validation of a simple technique for logging body temperature in free-ranging cattle. *Australian Journal of Experimental Agriculture* **48**: 741-745.

[82] Lees AM, Lea JM, Salvin HE, Cafe LM, Colditz IG and Lee C. 2018. Relationship between rectal temperature and vaginal temperature in grazing Bos taurus heifers. *Animals* **8**: 156.

of measuring body temperature is through the use of rumen boluses (Koltes *et al.,* 2018[83]). Whilst measuring rectal or vaginal temperatures is a more suitable measure for research purposes, rumen boluses are a technology which is more suitable for use on-farm. Rumen boluses provide a method of measuring rumen (or reticulum) temperature, but recordings can be influenced by fluid intake or by the bolus shifting from the reticulum to the rumen (Davison *et al*., 2020[84]). However, rumen or reticular temperature has been correlated with rectal temperature and respiration rate in beef cattle and has been assessed as an indicator of heat stress in dairy cattle (Boehmer *et al.,* 2015[85]; Ammer *et al.,* 2016[86]).

A further example of current technology which is being investigated in terms of its suitability for identifying heat stress are accelerometer-based neck-mounted collars. Davison *et al*. (2020)[84] reported that during periods of high ambient temperatures accelerometer-based neck-mounted collars were able to identify cattle exhibiting signs of heat stress through the detection of periods of high respiration rates but noted further studies would be needed to determine the accelerometers precision for detecting heat stress. Ear temperature monitoring systems have been developed for use in cattle (e.g., Cow Manager BV, Gerverscop, NL; DoggTag, Herddogg systems, Longmont, CO; Fever Tags, Amarillo, TX; SenseTag, Quantified Ag, Lincoln, NE; TekVet Health Monitoring System, East Palmetto, FL). These devices are mounted on the ear and have a temperature sensor that is placed within the ear canal to measure body temperature and whilst they are primarily used for monitoring illness, they can also be applied for monitor heat stress (Koltes *et al.,* 2018[83]). All such technologies need to be properly validated under New Zealand conditions, which do vary by region, before being used to identify and manage heat stress.

As technology continues to advance, future monitoring and mitigation of heat stress will be based on minimally invasive smart technologies which can be used either singularly or as part of a larger integrated system. Continued technological developments will enable real-time solutions to monitor animal responses across a range of production systems and environmental conditions (Islam *et al*., 2021[80]). The uptake of monitoring technologies capable of providing weather alerts to enable early intervention and prevent heat stress will also be important.

1.11 Conclusions

New Zealand's advantages as an agriculture-based economy are based on a climate and topography that allows almost all year-round grass growth. This means livestock can be kept outdoors on pasture and this has welfare advantages in allowing animals to display a greater range of behaviours and have more choices than for animals that are housed, as is common in other countries. However, being outdoors means animals are exposed to conditions such as hot summer, and wet and cold winter weather, that could lead to thermal stress. Public perception and market access expectations are that farmers manage their farms so that their animals do not suffer from thermal stress.

A report produced for MPI in 2019[87] looked at the expectations for animal shelter among farmers, stakeholders and the general public and concluded that while the provision of shelter is part of good farming, there are different understandings of what is good, and different barriers or constraints, including finances, time and resources. There also appear to be different understandings of what level of shelter is required, for example, that required for animal comfort, productivity or survival. It should be noted that there are number of farmers who do have management strategies to reduce the risk of thermal stress for their animals, and many farmers who carry out some thermal stress mitigations such as changing milking times during hot weather.

The issue of animal shelter is a complex one and this needs to be acknowledged when communicating with farmers and other stakeholders. However, given the increased risk of thermal stress in livestock with climate change, it is even more important now than it has been for farmers to review their shelter

[83] Koltes JE, Koltes DA, Mote BE, Tucker J and Hubbell DS. 2018. Automated collection of heat stress data in livestock: New technologies and opportunities. *Translational Animal Science* **2**: 319-323.

[84] Davison C, Michie C, Hamilton A, Tachatzis C, Andonovic I and Gilroy M. 2020. Detecting heat stress in dairy cattle using neck-mounted activity collars. *Agriculture* **10**: 210.

[85] Boehmer BH, Pye TA and Wettemann RP. 2015. Ruminal temperature as a measure of body temperature of beef cows and relationship with ambient temperature. *The Professional Animal Scientist* **31**: 387-393.

[86] Ammer S, Lambertz C and Gauly M. 2016. Is reticular temperature a useful indicator of heat stress in dairy cattle? *Journal of Dairy Science* **99**: 10067-10076.

[87] MPI Technical Paper No:2019/08. July 2019. Expectations of Pastoral Animal Shelter among farmers, Stakeholders and the general public.

provisions and be planning ahead to reduce this risk. To achieve this change managing thermal stress has to become a higher priority for farmers noting that managing the risk of thermal stress does not sit in isolation from managing other aspects of the farm system, such as environmental management, and should be integrated into these programmes. Doing so would make achieving change easier for farmers and potentially speed up this change.

Appendix 1- Thermal stress mitigation measures

On-farm

These are general mitigation measures that have been sourced from the literature and anecdotal experience. More research into both heat and cold stress may result in additional mitigation measures being identified. At an individual farm level, these will need to be considered based on many factors including the species of animal, the type of stock on farm, the layout and topography of the farm, existing resources, farmer and farm staff capability, the time of year and weather patterns.

Managing heat stress

Mitigation	Description	Comments
Shade – natural	Trees, shelter belts, vegetation such as flax, rushes Land contours	Animals have a strong drive to seek shade to mitigate heat stress. Existing trees and shelter belts provide readily available shade however, the amount of shade will depend on the number and density of the trees and how they are oriented for the movement of the sun during the day. Trees in the middle of paddocks may provide shade that animals can use for most of the day. Trees and shelter belts along the edges of paddocks may only provide useable shade for part of the day. The amount of shade available needs to be considered taking into account the number of animals that may want to seek shade, and if shade is limited then only some animals will be able use the shade at any one time. Lower growing vegetation such as flax, rushes, toi toi and tussocks, especially where these are used along fence lines, can provide some shade for use by smaller animals such as sheep, or individual larger animals. Sloping land contour may also provide shade at certain times of the day depending on its orientation and degree of slope, for example south and east facing slopes may be shaded in afternoons. New plantings will provide very limited shade initially, however farmers should be encouraged to consider planting trees as a strategy to assist with heat stress mitigation in the future. *Trees on a farm need to be managed and may impact on other aspects of farm management such as using paddocks to grow crops. Advice needs to be prepared to assist farmers to successfully incorporate trees for shade into the farm system.*
Shade - artificial	Buildings Covered stand-off pads and yards	Animals have a strong drive to seek shade to mitigate heat stress. Buildings provide shade for animals that are inside the building and may also provide shade from the shadow of the building itself, which will vary during the day. Covered yards and stand-off pads usually have no sides, other than fences to contain the animals. Buildings and covered areas provide a roof that gives protection from the sun. A key consideration for using these structures is the air flow through the shaded area as air

		movement is necessary to prevent the build-up of humid hot air and noxious gases such as ammonia. Without sufficient air flow conditions may be hotter and more humid under cover than outside. A secondary consideration is the flooring or ground cover. This needs to be comfortable so animals will lie down, especially if they are confined to the building or yards for extended periods of time. In hot conditions a surface such as wood chips that has urine or faecal material embedded in it may start to compost and this will produce heat which will add to the heat load of the animals. *Construction of buildings or covered yards and stand-off pads to house animals is a significant investment. Farmers should seek advice on the design and siting of such structures before construction.*
Water	Access Supply Quality	All species and classes of stock increase their intake of water as environmental conditions become warmer. To ensure all animals can access sufficient water as environmental conditions become warmer there need to be enough water troughs, or other drinking sources (e.g. nipples), to allow ready access for all animals in the mob or flock. If this is not the case, there will be competition for access to water and smaller or less dominant animals may not be able to get sufficient water for their needs. All water sources, including water troughs, should be placed where they don't impede animal flow or create corners where animals can become trapped. Water troughs etc must be suitable for the species and size of animal, for example small animals must be able to reach the water to drink. The quantity and quality of water is important. The flow of water to the access point must be sufficient to keep up with demand from the animals at all times. For example, if a trough does not refill fast enough then some animals may miss out on a drink. Water should be clean as animals prefer to drink clean water and dirty water may mean animals limit the amount they drink. This also applies if treatments such as zinc have been added to the water supply as these may alter the taste of the water. Note that in hot conditions animals may congregate around water troughs as it appears that the microenvironment around the trough may provide some relief from heat stress.
Feed	Energy density Timing of feeding	In ruminants, digestion of feed creates a large amount of internal heat for the animal. As conditions get warmer it is more difficult for animals to dissipate internal heat. The temperature difference between the animal's core body temperature and the external environment is less and this makes heat loss via conduction, convection and radiation less effective. The heat created by digestion can be reduced by giving animals smaller volumes of feed that is higher in energy therefore still providing animals with their nutritional needs while reducing internal heat generation. Providing animals with the majority of their daily feed intake in cooler parts of the day means that it is easier for them to dissipate the heat generated from digestion. Pasture grazed animals will alter their grazing

		patterns and increase feed intake during cooler parts of the day during hot conditions. This should be taken into consideration when paddocks are being allocated. *Advice from a ruminant nutritionist should be sought prior to making any significant changes to feeding regimes for dairy cattle, beef cattle and sheep.*
Animal management	Milking time Paddock selection Animal handling Shearing New introductions	Animal management practices on a farm can influence the risk of heat stress and may be able to be adjusted to reduce this risk. Walking animals to a farm dairy increases activity levels and increases internal heat load. When this is done during a hot part of the day, in particular in the afternoon, animals may have difficulty in dissipating this increased heat load. Adjusting milking times to cooler parts of the day, for example from afternoon to evening, or adjusting milking regimes from twice a day to 3 milkings in 2 days, or once a day milking, may enable milking routines to be maintained while reducing the risk of heat stress for the animals. On every farm there will be paddocks with more shade than others, and on farms with dairy cows or dairy sheep some paddocks that are closer to the farm dairy than others. The risk of heat stress can be reduced by allocating paddocks with more shade for daytime grazing and those with less shade for night-time grazing. Using paddocks closer to the farm dairy during the day will mean a shorter walking distance for milking during the hotter part of the day, therefore reducing the heat load, with paddocks further away allocated for night-time grazing. Minimise handling and disturbance of animals especially during the hotter parts of the day. Moving and restraining animals for procedures such as carrying out vaccination programmes and drenching, dealing with health issues, for example lameness treatments, and sorting out groups of animals involve increased activity and a degree of stress. These increase the internal heat load of the animals and should be carried out in cooler parts of the day or completed before the hottest part of the year. Wool is an insulator for sheep which can provide some protection from heat stress, however long fleeces limit heat loss via evaporation. Having a fleece length of 30-40mm is considered optimal for providing protection from solar radiation while still enabling evaporative cooling. Shearing should be timed so that sheep are not newly shorn or carrying heavy fleeces during the hottest months of the year. To a certain extent, animals will adapt to local environmental conditions. Animals that are kept in a region where summer conditions mean heat stress needs to be managed are likely to be somewhat more tolerant of hotter conditions than an equivalent animal kept in a cooler climate. If animals are being moved from a region with less risk of heat stress occurring to one of higher risk, then this should be done during the cooler months of the year, so animals have time to adapt to increasingly warmer temperatures during summer.

Genetics	Selection of breeds Use of heat tolerant genetics	There is variation in heat tolerance amongst breeds of both cattle and sheep, and specific genetics have been identified that result in more heat tolerant animals. Changing the genetic makeup of a herd or flock is usually a long-term strategic change for a farm, and at least initially, is likely to come with a reduction in productivity until heat tolerant genetics are included in the genetic makeup of higher producing animals. For sheep, the hairy breeds of sheep are generally more heat tolerant than the woolly breeds. In the NZ context Dorpers, Merinos and Corriedales are more heat tolerant than Romneys or Suffolks with Texels in between. *Bos indicus* (Brahman) cattle are slower to show signs of heat stress than *Bos taurus* cattle. Within the dairy breeds, Jersey cattle are more heat tolerant than Holstein Friesian cattle. Slick cattle have a gene derived from a mutation in Senepol cattle that increases the ability of the animal to control body temperature. Cattle with the Slick gene are not widely available in NZ currently.
Cooling systems	Fans Sprinklers	Mechanical means of managing environmental temperatures may be applicable in some situations, however, usually require animals to be gathered together in some sort of constructed area such as yards. This precludes use for animals that are grazed outdoors and not regularly yarded. Fans can be installed in farm dairies or animal housing and will move air around and over the animals. This can increase the ability of the animals to lose heat via evaporation, conduction and convection. Sprinklers that provide a water spray over cows waiting in yards prior to milking are effective in reducing respiration rates, and skin and core body temperatures. Water droplets must be big enough to thoroughly wet the cows. A fine spray will raise humidity and not necessarily wet the cows well enough to provide a cooling effect. When combined with a fan the cooling effect is better than providing shade. Water can also be used to cool concrete surfaces reducing the foot discomfort for animals and the amount of reflected heat.

Managing cold stress

Mitigation	**Description**	**Comments**
Shelter- natural	Shelter belts, trees, forested areas and other vegetation Paddock contour and orientation	Animals will seek shelter when they experience conditions that they find cold, wet and/or windy. The risk of cold stress is higher when cold conditions are accompanied by wind and if animals are wet from rain or snow. Depending on orientation, density and height, vegetation, including trees can provide shelter for animals. For protection from wind animals will seek the lee side of vegetation. The amount of shelter available will depend on how much wind mitigation the shelter provides. For shelter belts this depends on the height and density of the shelter belt vegetation and how it is oriented to the direction of the wind. Tall-growing open plantings will reduce wind speeds downwind for distances of 25 to 30 times the height of the barrier. Individual trees in paddocks will also provide some wind mitigation, and even smaller growing vegetation such as clumps of tussock or flax can provide small areas of protection able to be used by individual animals or small numbers

		of smaller animals such as sheep. Forested areas can act as a shelter belt if animals have access to the lee side of the area and can provide significant shelter from both wind and wet conditions if animals are able to enter the area. The orientation and contour of paddocks may provide some natural shelter for animals, for example a paddock on the north facing aspect of a hill may be more sheltered when winds come from the southerly direction. Gullies, hollows and outcrops in paddocks can also provide localised areas that are more sheltered for animals to use. Rain and snow are often accompanied by wind, and shelter that provides wind protection may also provide some protection from wet conditions. Shelter that provides cover such as under trees will be more effective at reducing how wet animals get. New plantings will provide very limited shelter initially, however farmers should be encouraged to consider planting trees as a strategy to assist with cold stress mitigation in the future. *Trees on a farm need to be managed and may impact on other aspects of farm management such as using paddocks to grow crops. Advice needs to be prepared to assist farmers to successfully incorporate trees for shelter into the farm system.*
Shelter - artificial	Buildings Covered stand-off pads and yards Animal covers	Animals will seek shelter when they experience conditions that they find cold, wet and/or windy. The risk of cold stress is higher when cold conditions are accompanied by wind and if animals are wet from rain or snow. Buildings provide shelter for animals that are inside the building and may also provide shelter from wind on the lee side of the building. Covered yards and stand-off pads usually have no sides, other than fences to contain the animals therefore animals may still be exposed to windy or draughty conditions depending on where these facilities are sited and the orientation to prevailing weather conditions. Providing wind protection along one side of the facility may reduce wind flow through the facility. Buildings and covered areas provide a roof that gives protection from rain and snow. The flooring or groundcover needs to be comfortable so animals will lie down, especially if they are confined to the building or yards for extended periods of time. Individual covers for animals can be useful for providing vulnerable animals some protection from cold stress by keeping them drier and warmer. However, these need to be well fitted and animals regularly checked to ensure the covers are still correctly fitted and not causing any distress. *Construction of buildings or covered yards and stand-off pads to house animals is a significant investment. Farmers should seek advice on the design and siting of such structures before construction.*

Feed and water	Amount and type of food Water	The normal physiological response of animals to cold stress is to increase metabolic rate to maintain body temperature and to do this by eating more. In cold conditions animals need more feed to maintain body condition, or to be sufficiently well conditioned prior to cold weather that the loss of some condition does not lead to health and welfare issues, though taking this approach is likely to lead to prolonged feelings of hunger. Digestion of feed produces internal heat, especially for ruminants, therefore larger volumes of higher fibre feed are preferable providing these still provide the nutrients required by the class of stock. Feed needs to be provided in such a way that all animals can access sufficient feed without undue competition. Allowance needs to be made for wastage, for example if feed is provided on the ground there will be some wastage from trampling. If supplementary feed is provided, either as brought in feed (e.g. hay) or from crops, this needs to be done in an area where animals can still access shelter and suitable places for resting. Note that immediately after shearing sheep need be fed around 40% above maintenance level to cope with cold stress and this needs to continue for at least a week after any weather event that may cause cold stress. Ruminants require water to digest feed and still need water even in cold conditions. Sufficient quantities of clean, palatable drinking water that is accessible by all animals should be available at all times. *Advice from a ruminant nutritionist should be sought prior to making any significant changes to feeding regimes for dairy cattle, beef cattle and sheep.*
Animal management	Paddock selection Shearing New introductions	Animal management practices on a farm can influence the risk of cold stress and may be able to be adjusted to reduce this risk. On every farm there will be paddocks with more shelter than others. The risk of cold stress can be reduced by allocating paddocks with more shelter for grazing during the time of year when there is the highest risk of cold stress, and for animals that may be more at risk of cold stress, for example lambing ewes and calving cows. This will require planning ahead of time and should be done in the autumn when winter grazing regimes are confirmed. If the winter grazing regime includes supplementary feed, either in the form of feed brought to the animals such as hay, or feed the animals graze such as crops, then planning considerations should consider which paddocks will be used to ensure the animals will have access to shelter as well as feed. Newly shorn sheep are prone to hypothermia. The shorter the period after shearing in which the cold weather occurs, the greater the risk of death from hypothermia. Recently shorn sheep may only have about three millimetres of insulating wool remaining, which can cause up to a three-fold increase in heat loss. Although a

		couple of weeks of wool growth does offer some protection, high mortalities have occurred in mobs up to four weeks after shearing. If bad weather is forecast shearing should be delayed. The timing of shearing is important. Sheep shorn in late winter or spring have been exposed to cold weather prior to shearing and are acclimatised. This acclimatisation takes about two weeks to develop and lasts about two months. Once acclimatised, sheep are less likely to die from hypothermia, even if a cold spell occurs immediately after shearing. Sheep that have been shorn in summer are conditioned to hot weather, and if cold weather occurs shortly after shearing, they are at greater risk of dying from hypothermia. Note that immediately after shearing sheep need be fed around 40% above maintenance level to cope with cold stress and this needs to continue for at least a week after any weather event that may cause cold stress. To a certain extent, animals will adapt to local environmental conditions. Animals that are kept in a region where winter conditions mean cold stress needs to be managed are likely to be somewhat more tolerant of colder conditions than an equivalent animal kept in a warmer climate. If animals are being moved from a region with less risk of cold stress occurring to one with a greater risk, this should be done prior to the onset of winter, so animals have time to adapt.

During transport

Managing heat stress

Mitigation	Description	Comments
Journey planning	Distance/length of journey Route Timing Rest stops	Transport is stressful for animals. Careful planning prior to transport can reduce stress for the animals involved. All transport has a degree of stress, and this stress is usually cumulative based on the length of the journey. Longer journeys are usually ones that cover a greater distance. Where possible animals should be transported over the shortest distance, for example to the closest slaughter premises or local grazing rather than grazing in another region. Where circumstances mean animals must be transported longer distances, for example if being moved to another region due to drought, journey planning is very important to reduce the welfare impact on the animals. Where there is a choice, the route selected should allow for the most comfortable ride for the animals. Winding roads mean slower truck speeds which limits ventilation in trucks and causes more movement for the animals meaning a greater chance of animals losing their footing and going down. Routes where traffic congestion is likely should be avoided as this will also slow trucks. Transport during warmer times of the year, and during the hottest part of the day should be avoided as this increases the risk of heat stress. Schedule transport for overnight or early mornings. Keeping temperatures to an acceptable level for the animals on a truck relies on the ambient air temperature being cooler than that within the truck and this may not be the case during summer or on a hot day at any time of the year. Ensuring effective ventilation in trucks is particularly important for reducing the heat stress during transport. Trucks are passively ventilated which means air movement over the animals is dependent on the air flow generated by the movement of the truck. Whenever a truck is stationary ventilation for the animals is very limited especially for those in internal pens. Journeys should be planned to limit the number of stops, keep the length of the stop to a minimum and to ensure trucks can be parked in the shade during stops. This is particularly relevant for journeys that involve crossing the Cook Strait.
Animals	Selection Preparation	The Code of Welfare: Transport within New Zealand, Minimum Standard 6 (c) states that animals must not be transported unless they are fit enough to withstand the entire journey without suffering unreasonable or unnecessary pain or distress. Animals must be selected for the journey based not only on the length of the journey, but also any expected stressors during the journey. This includes a consideration of heat stress when journeys are undertaken during summer months.

		Specific considerations in relation to heat stress include general health and fitness of the animals, and for sheep, fleece length. Optimal fleece length for sheep for minimising heat stress is 30-40mm. This provides some insulation against additional heat, allows for evaporation for cooling, and is long enough to prevent sunburn which is a consideration for sheep transported on the top deck of a truck. Sheep with long fleeces need more space as it is more difficult for them to dissipate heat if they are tightly packed in pens. General advice for preparing animals for transport is hold them off pasture for a minimum of 4 hours and no more than 12 hours prior to transport. It is important that animals have access to water at all times, and they should be fed an alternative feed source such as hay. The holding area should provide enough shade for all the animals. In warm conditions shade and water are essential to prevent the animals developing heat stress prior to transport.
Truck selection	Capacity Deck heights	During warm weather overcrowding on trucks can cause a severe heat build-up and increase the risk of heat stress. When conditions are warm and humid trucks should be loaded to 85% of maximum capacity only. Farmers and animal owners need to take this into account when trucks are booked for transporting stock. Adequate head room for the animals within the truck is important for air flow and heat stress mitigation. Farmers and animal owners need to aware of the height of their animals so that trucks can be ordered with enough height between decks to comfortably accommodate the animals.
Loading/unloading		Loading and unloading are the most stressful aspects of transport for animals. During hot and humid conditions handle animals carefully to prevent extra exertion as this can predispose animals to heat stress. Allow time after mustering for animals to rest, drink and cool down prior to loading. If possible, load animals at cooler times of the day, and ensure the truck starts moving as soon as possible after the animals are loaded so there is adequate ventilation. Once trucks reach their destination they should be unloaded as soon as possible. If trucks have to wait to unload, they should be parked in the shade. Note that air temperatures in shade on hot days can still be high enough for animals to suffer from heat stress while onboard a truck. Handle animals carefully at unloading to prevent extra exertion, provide them with water and shade, and an opportunity to rest once they are unloaded. Do not over-crowd pens.

Managing cold stress

Mitigation	Description	Comments
Journey planning	Distance/length of journey Route Timing Rest stops	Transport is stressful for animals. Careful planning prior to transport can reduce stress for the animals involved. All transport has a degree of stress, and this stress is usually cumulative based on the length of the journey. Longer journeys are usually ones that cover a greater distance. Where possible animals should be transported over the shortest distance, for example to the closest slaughter premises or local grazing rather than grazing in another region. Where there is a choice, the route selected should allow for the most comfortable ride for the animals. Winding roads mean slower truck speeds which limits ventilation in trucks and causes more movement for the animals meaning a greater chance of animals losing their footing and going down. Routes where traffic congestion is likely should be avoided as this will also slow trucks. Cold and wet weather conditions during the journey will predispose animals to cold stress. Even if conditions are not windy, the movement of the truck will generate wind chill meaning the animals will be exposed to lower temperatures, especially those in outside or top deck pens. If this is accompanied by rain, and animals are wet, the risk of cold stress increases. When the weather forecast predicts severe winter conditions transport should be delayed. Effective ventilation for animals in trucks is important even in cold weather. Trucks are passively ventilated which means air movement over the animals is dependent on the air flow generated by the movement of the truck. Whenever a truck is stationary ventilation for the animals is very limited especially for those in internal pens. Journeys should be planned to limit the number of stops, keep the length of the stop to a minimum and to ensure trucks can be parked in a sheltered position during stops. This is particularly relevant for journeys that involve crossing the Cook Strait.
Animals	Selection Preparation	The Code of Welfare: Transport within New Zealand, Minimum Standard 6 (c) states that animals must not be transported unless they are fit enough to withstand the entire journey without suffering unreasonable or unnecessary pain or distress. Animals must be selected for the journey based not only on the length of the journey, but also any expected stressors during the journey. This includes a consideration of cold stress when journeys are undertaken during winter months. If possible, animals that are particularly susceptible to cold stress should not be transported in cold wet conditions. This includes very young animals such as calves and lambs, freshly shorn sheep, and animals that are older, thinner or suffering from conditions that compromise their overall health and fitness.

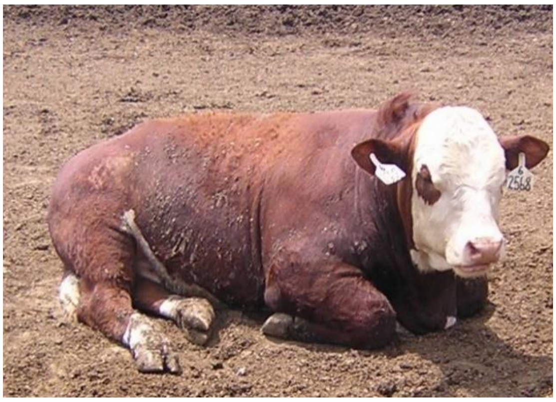
		General advice for preparing animals for transport is to hold them off pasture for a minimum of 4 hours and no more than 12 hours prior to transport. It is important that animals have access to water at all times, and they should be fed an alternative feed source such as hay. Some classes of stock such as cull cows may need mineral supplementation to reduce the possibility of developing metabolic diseases. If possible, the animals should be kept dry as this will reduce the effect of wind chill once they are loaded onto the truck.
Truck selection	Capacity Deck heights Covers	Trucks should not be overloaded in cold weather in the belief that keeping the animals tightly packed will reduce the risk of cold stress. Animals on the outside of the outer pens need to be able to reposition themselves to move away from cold winds and rain and are unable to do this if the pen has too many animals in it. Adequate head room for the animals within the truck is important for air flow even in cold conditions. Farmers and animal owners need to be aware of the height of their animals so that trucks can be ordered with enough height between decks to comfortably accommodate the animals. Covers for trucks may be considered when such use will protect animals from wet conditions and wind chill provided adequate ventilation can be maintained. It is a requirement that trucks carrying bobby calves have a cover, however these are not always waterproof. Even with a cover, depending on the weather conditions, animals may still get wet from rain and wind blowing into the sides of the truck.
Loading/ unloading		Loading and unloading are the most stressful aspects of transport for animals. When the weather is cold and wet keep animals in a sheltered area until the time of loading. If possible, under cover to prevent them getting wet, and this applies particularly to young animals who are at higher risk of cold stress. Once loaded ensure the truck starts moving as soon as possible so there is adequate ventilation. Once trucks reach their destination they should be unloaded as soon as possible. If trucks have to wait to unload, they should be parked in a sheltered area to minimise wind and rain exposure. Handle animals carefully at unloading to prevent extra exertion, provide them with water and shelter, and an opportunity to rest once they are unloaded. Do not over-crowd pens.

Appendix 2- Signs of heat stress

Recognising heat stress in cattle

From: Recognizing Heat Stress : USDA ARS

Pictured below are cattle displaying increasing levels of heat stress. A description of typical behaviours is associated with each level. Vulnerable animals will show stress symptoms early. Varying stages of stress will be evident throughout the herd as environmental conditions become more intense. As more animals display signs of increasing heat stress, action should be taken.

	Normal • no signs of heat stress
	Stage 1 • elevated breathing rate • restless • spend increased time standing

<table>
<tr>
<td></td>
<td>Stage 2
elevated breathing rate
slight drooling
most animals standing in pen and restless
animals may group together</td>
</tr>
<tr>
<td>
</td>
<td>Stage 3
elevated breathing rate
excessive drooling or foaming
most animals standing in pen and restless
animals may group together</td>
</tr>
</table>

	Stage 4 • elevated breathing rate • open mouth breathing • possible drooling • most animals standing in pen and restless • animals may group together
	Stage 5 • elevated breathing rate with pushing from flanks • open mouth breathing with tongue protruding • possible drooling • most animals standing in pen and restless
	Stage 6

	• open mouth breathing with tongue protruding • breathing is labored, and respiration rate may decrease • cattle push from flanks while breathing • head down • not necessarily drooling • individual animals may be isolated from herd

Gaughan, J. B., Holt, S. M., Hahn, G. L., Mader, T. L., and Eigenberg, R. A. 2000. Respiration Rate - Is it a good measure of heat stress in cattle? J. Anim. Sci. 13: 329-332.

Mader, T. L., Davis, M. S., and Brown-Brandl, T. M. 2006. Environmental factors influencing heat stress in feedlot cattle. J. Anim. Sci. 84: 712-719.

Silanikove, N. 2000. Effects of heat stress on the welfare of extensively managed domestic ruminants. Livestock Production Science 67: 1-18.

Recognising heat stress in sheep

From: [Signs and management of heat stress in sheep | Autumn 2020 | Sheep Notes newsletter | Newsletters | Support and resources | Agriculture Victoria]

Panting assessment

An easy-to-use visual sign that sheep are becoming heat stressed is a change in the way they are breathing. This is because 65% of the heat loss in sheep occurs by panting.

The degree to which sheep are panting is an important indicator of the extent to which they are suffering from heat stress:

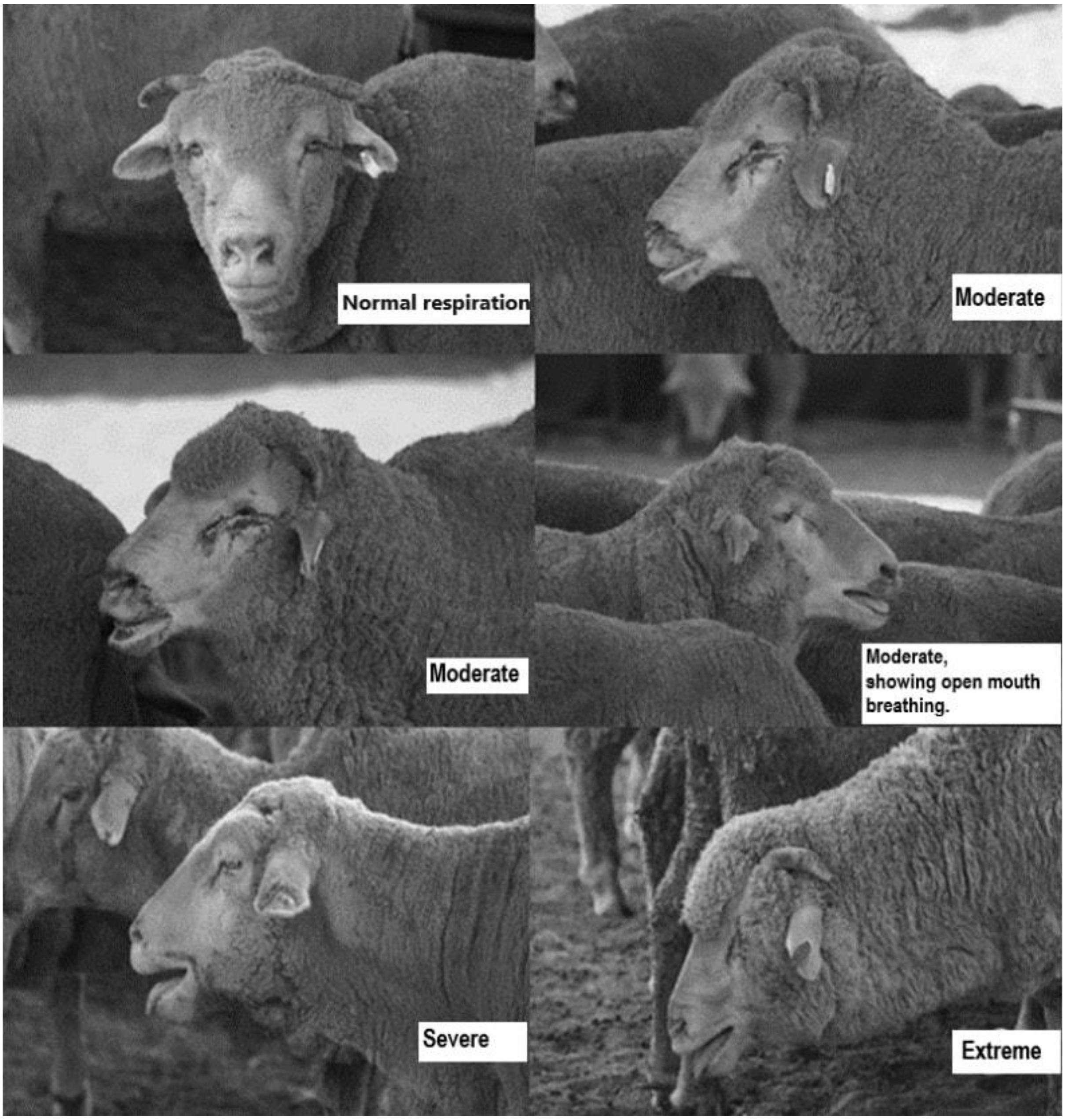
- **Mild heat stress** – sheep may show mild to fast panting, but with a closed mouth. Rapid chest movements will be easily observable.
- **Moderate heat stress** – sheep show fast panting, progressing to mouth slightly open, but the tongue is not extended beyond the lips. Rapid chest movements will be easily observable.
- **Severe heat stress** – rapid, open-mouth panting will be seen, with the neck extended, head held up and tongue extended.
- **Extreme heat stress** – open-mouth panting will be seen, with the tongue fully extended and the head often lowered. Deeper breathing will occur, with a reduction in the panting rate for short periods.

Sheep behaviour

The second assessment method is observing changes in sheep behaviour. Sheep will change or adapt their behaviour to maximise heat loss. These changes can be used together with panting assessment to assess the impact of heat on the animals.

Signs that may be seen in sheep as they are progressively exposed to heat conditions include:

1. shade seeking
2. increased standing
3. decreased dry matter intake
4. crowding of water troughs
5. increased water intake
6. bunching to seek shade from other sheep
7. changes to, or increased, respiratory rate
8. immobility or staggering.



Panting scores to gauge heat stress.

Appendix 3- Heat stress risk

These tables show the average risk and impact of heat for December, January, and February, between 2017 to 2020. Estimates are for Friesian and crossbreed herds, which start to reduce production when temperature is greater than about 21°C. Jerseys are more tolerant of heat, with production losses insignificant until 25°C.

	Average hours per day too warm for comfort	Average hours per day warm enough to reduce milk production	Days warm enough to reduce milk production	Estimated milksolids impact per cow each summer
Whangarei	16	11	83	6.9
Kerikeri	16	10	86	6.5
Dargaville	15	8	68	4.9
Hamilton	14	8	77	6.8
Karapiro	15	8	77	6.0
Matamata	14	8	79	6.8
Te Puke	15	8	77	6.2
Whakatane	16	9	82	5.5
Rotorua	12	6	65	4.6
Stratford	9	4	46	3.0
Waipawa	11	7	66	6.2
Palmerston North	12	5	58	4.1

Dannevirke	10	5	53	3.6
Richmond	14	7	63	4.0
Reefton	9	5	56	4.5
Arapito	10	4	49	2.8
Balmoral East	9	5	48	3.5
West Eyreton	7	3	39	2.5
Lincoln	8	4	43	3.1
Winchmore	7	3	44	3.4
Orari	7	3	42	2.6
Timaru	5	2	25	1.2
Waimate	5	2	29	1.6
Middlemarch	7	3	45	4.0
Gore	5	2	33	1.9
Invercargill	4	1	21	1.1

https://www.dairynz.co.nz/animal/cow-health/heat-stress/