ALEC Submission on Heat Stress Risk Assessment

Response to Issues Paper by the Technical Reference Panel

OCTOBER 2018

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1 About this Submission

1.1 Introduction

This submission by the Australian Livestock Exporters' Council (ALEC) is made in response to the *Heat Stress Risk Assessment Issues Paper* released by the Technical Reference Panel in September 2018 as part of the Review of the *Australian Standards for the Export of Livestock* (ASEL).

ALEC is a member-based, peak industry body representing Australia's livestock export sector. It sets industry policy, provides strategic direction to the industry and represents Australia's livestock export trade in Australia and internationally.

ALEC members account for more than 96 per cent of Australia's annual livestock exports, by volume and value. ALEC's membership also extends to supply chain participants including registered premise operators, ship owners, feed suppliers and other service providers to the trade.

ALEC welcomes the review of heat stress risk assessment procedures used in the export of Australian livestock. ALEC supports the application of science-based procedures to all areas of Australian live exports to underpin acceptable animal welfare outcomes, including heat risk assessment. As the Issues Paper recognises, over many years, but particularly since 2003, the Australian industry has invested heavily in scientifically based research to address heat stress risks. We submit that this research, taken as a whole, can be regarded as ground breaking – similar levels of endeavour are certainly not evident in the work of other live exporting countries and have rarely been, if ever, matched in other areas of livestock production.

Given the background to this Review pressure may be felt to immediately identify "solutions" to identified problems or shortcomings. The issue of heat risk assessment is highly technical requiring the joint expertise of statisticians, engineers, veterinarians and others involved with animal physiology. It is to be noted that a number of matters raised in the *Issues Paper* have been the subject of considerable levels of past research without a clear solution having been identified. Radical changes to heat risk assessment procedures should be rejected unless they carry a high level of scientific support and certainty.

1.2 Good Regulation Applied to Heat Risk Assessment

Because the recommendations of the Heat Assessment Technical Review are likely to result in new regulations it is important for the Panel to have an appreciation of the essential elements of good regulation.

A list of the basic characteristics of a good regulatory system should possess can be quite extensive; however, it is generally agreed that such a system should exhibit at least the following five characteristics[1]:

[1] See, for instance, Commonwealth of Australia, Department of the Prime Minister and Cabinet, 2014, The Australian Government Guide to Regulation, Canberra, March; Council of Australian Governments, 2007, Best Practice Regulation: A Guide for Ministerial Councils and National Standard Setting Bodies, Canberra, October; Victorian Commission for Better Regulation, 2016, Victorian Guide to Regulation: A Handbook for Policy-Makers in Victoria, State of Victoria, November; Agriculture Victoria, 2016, Key characteristics of good regulatory systems, http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/protecting-victoria-from-pest-animals-and-weeds/legislation-policy-and-permits/new-invasive-species-management-legislation/discussion-paper-invasive-species-management-bill/appendix-1-key-characteristics-of-good-regulatory-systems; Riviere, J.E. & Buckley, G.J., 2012, Ensuring Safe Foods and Medical Products Through Stronger Regulatory Systems Abroad, Th National Academies Press, Washington DC.

- Clear objectives: At the centrepiece of any regulation must be statements about the policy objectives that are trying to be achieved (the problem the regulation is trying to solve). Policy objectives and principles should be made explicit. Where trade-offs are involved, object clauses should make clear what balance is sought – for example, the need to pursue identified social objectives cost-effectively taking into account wider economic interests – and how such a balance is to be achieved.
- Effectiveness: Regulation must be focussed on the problem to be solved and achieve its intended policy objectives with minimal side-effects and cost. Regulatory measures should contain compliance strategies which ensure the greatest degree of compliance at the lowest cost to all parties. Measures to encourage compliance may include regulatory clarity, brevity, public education and consultation and the choice of alternative regulatory approaches with compliance in mind.
- Outcome focussed: To maximise effectiveness regulations need to focus on outcomes rather than inputs or details about how to achieve the outcomes. Outcome-oriented regulatory systems do not get in the way of innovation. Furthermore, in an outcome-oriented system, industry should have a clear avenue to petition the regulatory authority to use alternative processes, and this process should not be unduly onerous.
- Proportionality: Regulatory measures must be proportional to the problem that they seek to address. This principle is particularly applicable in terms of any compliance burden or penalty framework, which may apply. A proportional based system allocates controls based on risk of not meeting the most important objectives, while those with few or insignificant risks or objectives of lower importance receive less attention. Likewise, enforcement options under a proportionate system should differentiate between the good corporate citizen and the renegade, to ensure that 'last resort' penalties are used most effectively (rarely) but model behaviour is encouraged. Enforcement measures and the regulatory framework should not have the effect of encouraging otherwise good corporate citizens to subvert compliance measures.
- Consistency and predictability: Regulation should be consistent with other policies, laws and agreements affecting regulated parties. It should also be predictable, in order to create a stable regulatory environment and foster confidence. The regulatory approach should be applied consistently across regulated parties with like circumstances. Rules should be applied consistently and enforced fairly, with the decisions made by regulators being neither arbitrary nor capricious.

Characteristics of good regulation relating to proportionality, consistency and predictability are especially important with respect to heat stress risk assessment. The focus of heat risk assessment should be on the areas of highest risk. Moreover, when coupled with consequence, the risk settings applied should be broadly consistent with those used elsewhere across the livestock sector and society. Finally, for regulatory settings to be applied consistently across live exports, measurement error for variables related to heat stress risk assessment must be kept within a very narrow range.

1.3 Remainder of This Submission

In the remainder of this submission ALEC addresses many of the issues raised in the Heat Risk Assessment Issues Paper.

Research from the joint LiveCorp / Meat & Livestock Australia (MLA) Live Export Program (LEP) is heavily referenced in remaining chapters, as is other research where relevant. The recommendations made by ALEC have been based on research outcomes and are focussed on securing high standards of animal welfare.

The order of chapters in this submission does not follow that of the Issues Paper. In this submission ALEC provides a coherent, scientifically supported, total approach to setting stocking densities and undertaking a heat stress risk assessment. This is best done (perhaps, can only be done) by presenting material in a certain order.

Because of the above, throughout the major chapters of this submission, responses are not directly and explicitly provided to Issues Paper questions. All material presented, however, is highly relevant to matters under consideration by the Technical Reference Panel.

It is important that the submission be read in the order provided. However, for ease of reference of the Panel, the last chapter of this submission provides direct responses to questions raised in the Issues Paper. This is done mainly by referring to earlier sections of the submission, but some new material is also provided.

Some of the questions asked in the Heat Stress Risk Assessment Issues Paper are highly technical and may be best left to experts for responses.

Generally, Heat Stress Risk Assessment is an extremely complex area, best addressed using the combined expertise of animal behaviour and welfare experts, engineers, statisticians, regulators and practitioners. While respecting the academic qualifications of individual Panel members, ALEC is surprised that Panel is dominated by veterinarians, addressing just one of the skill sets required. In the view of ALEC, the composition of the Panel would have been improved through inclusion of statistical and engineering expertise. A further improvement may have been the inclusion of a member with practical experience in live export shipping.

2 THE DETERMINATION OF STOCKING DENSITIES USING HEAT RISK STRESS ASSESSMENT AND ALLOMETRY

2.1 INTRODUCTION

Chapter 4 of the Issues Paper authored by the Technical Reference Panel contains a discussion of methods to calculate stocking densities on live export voyages.

Two methods are proposed in this chapter to determine stocking densities. One method involves the use of an appropriately calibrated heat stress risk assessment model. The other method involves using the allometric equation with an appropriately set k-value. In Chapter 4 of the Issues Paper these methods are separately presented, with no information provided on how they should be ***jointly*** applied to determine stocking densities.

ALEC submits that these two methods of determining stocking densities are directed at meeting two quite distinct objectives:

- The heat risk assessment is aimed at setting stocking densities so that the risk of animals dying or unduly suffering from heat on a live export voyage is minimised.
- The allometric determination of stocking densities is to ensure that sufficient space is provided to meet the basic behavioural and physiological needs of animals whilst being transported.

The second objective applies to all voyages irrespective of whether there is a risk of heat stress. Because of this the allometric equation, with an appropriately set k-value, should be used to determine minimum space allocations - to meet the basic behavioural and physiological needs of animals. If heat stress is a proven risk for a particular voyage route, a heat stress risk assessment should be undertaken. The final determination of space allocations should be the ***maximum*** of the space allocations as calculated from the allometric equation and from the heat stress risk assessment.

Dealing with heat stress by setting a lower stocking density for all voyages and vessels at certain times of the year (say by using a higher k-value in the allometric equation) does not represent outcomes-based regulation and only penalises those with good vessel ventilation.

The remaining chapters of this submission address various aspects of the heat stress risk assessment. This chapter addresses issues raised by the Technical Reference Panel on use of the allometric equation.

2.2 USE OF THE ALLOMETRIC EQUATION TO DETERMINE STOCKING DENSITIES AND THE CHOICE OF K-VALUE

The use of allometric principles to the determination of stocking densities on-board vessels has been extensively covered by ALEC in its Stage 2 Submission to the ASEL Review. In summary these principles are:

- Allometric equations are an accepted means for determining stocking densities. The equation generally recommended for space allocation is: $A = k\ W^{0.66}$ where A is the area allocated per animal, W is the weight of the animal and k is a constant. In determining the amount of space allocated per animal the value assigned to k is critical.
- Broadly speaking the k-values used within these equations for static activities appear to be well accepted. For example: standing / sternal lying = 0.019 – 0.020; semi-recumbent lying = 0.025 – 0.027; and fully recumbent lying = 0.047.

- K-values for behavioural activities, particularly in group situations, are less accepted or validated. Very little is known about the ways in which livestock – particularly cattle and sheep – time-share space, perform behaviours in synchronicity, and the effects of spatial restrictions on behaviour and welfare – all of which affect how applicable and effective the use of allometrics and k-values is in group situations.
- For situations where confinement is of reasonably limited duration, k-values of 0.025-0.027 are generally accepted as appropriate (allowing animals to lie semi recumbent simultaneously). For long term confinement a k-value of 0.033 is accepted as appropriate (drawn from studies of long-term intensive housing situations).

Further information is now provided, on the last three of these summary points.

2.3 Space allocations for various lying positions adopted by livestock

The OIE provides the following recommendation for stocking densities during live export:

> *"The amount of space required, including headroom, depends on the species of animal and should allow the necessary thermoregulation. Each animal should be able to assume its natural position for transport (including during loading and unloading) without coming into contact with the roof or upper deck of the vessel. When animals lie down, there should be enough space for every animal to adopt a normal lying posture"*

In choosing a k-value that meets the OIE recommendation, the lying positions that livestock adopt is critically important. Three basic lying positions can be observed along with corresponding k-values:

- Lying on the sternum with all legs tucked beneath the animal (termed "sternum space") - the space occupied is not dissimilar to standing space (k-value=0.019-0.020)[2].
- Partial lying on the sternum with legs tucked against the animal's body (termed "semi-recumbent space") – minimum k-value=0.025[3].
- An animal lying laterally (on its side) with legs fully extended (termed "fully recumbent space") – this occupies the most space – k-value=0.047[4].

Importantly, Catherine Stockman for cattle on voyages to the Middle East[5] found that lateral recumbency was rarely observed and when it was observed cattle seldom held this position until the next sampling point (there was 10 minutes between sampling points). Cattle are unlikely to stay in a lateral recumbent position for a long period as it prevents eructation of gases from the rumen. Generally healthy ruminants do not lie flat out. Semi-recumbent lying is accepted as the normal lying behaviour, although sternal lying is also common.

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[2] Petherick, J.C., 1983, "A biological basis for the design of space in livestock housing" in *Farm Animal Housing and Welfare* (S.H. Baxter, M.R. Baxter, J.A.D. MacCormack, Eds.), Martinus Nijhoff, The Hague, pp. 103-120 and Petherick, J.C., Baxter, S.H., 1981, "Modelling the spatial requirements of livestock" in MacCormack, J.A.D. (Ed.), *Proceedings of the CIGR Section II Seminar on Modelling, Design and Evaluation of Agricultural Buildings*, Scottish Farm Buildings Investigation Unit, Aberdeen, pp. 75–82, cited in Petherick, J.C. and Phillips, C.J., 2009, "Space allowances for confined livestock and their determination from allometric principles", *Applied Animal Behaviour Science*, 117, pp1–12.

[3] Petherick, J.C., 2007, Spatial requirements of animals: allometry and beyond, Journal of Veterinary Behavior, Vol 2, pp 197- 204 and Petherick, J.C. and Phillips, C.J., 2009, p3.

[4] Petherick, J.C. and Phillips, C.J., 2009, p3.

[5] Catherine Stockman, 2009, Quantitative assessment of cattle behaviours on board livestock ships, Final Report Project W.LIV.0251, Meat & Livestock Australia, September, http://www.livecorp.com.au/LC/files/1c/1c35a31a-52e0-4359-9afc-6165b7bb551e.pdf.

2.4 THE CHOICE OF K-VALUE IN GROUP SITUATIONS

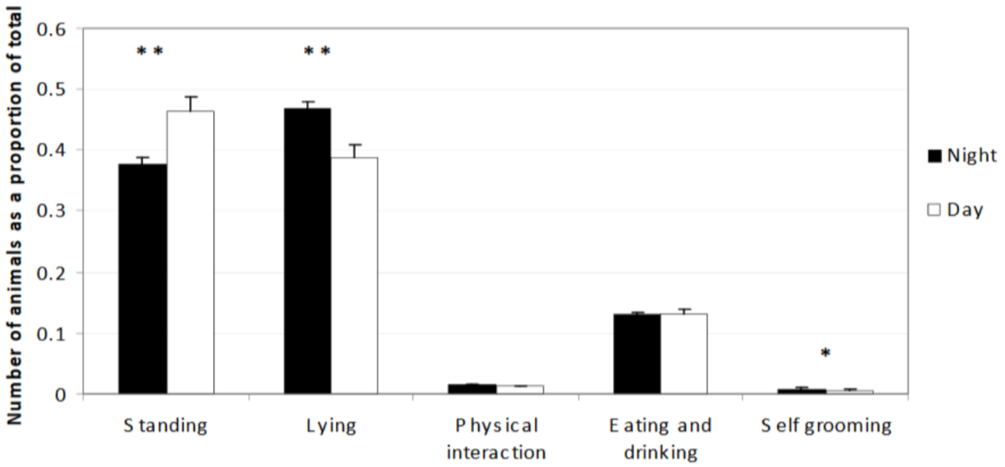
As has been noted, the most commonly accepted k-values are for individual animals performing static activities (standing, lying). However, the k-values for groups of animals, or for determining the space required to perform active / behavioural functions, is less clear / accepted and needs to be determined by research and evidence particular to the situation.

Critically, when allometry is applied to a group of animals in order to determine space allocations to meet animal welfare requirements, the k-value used needs to take into account interactions between livestock and their ability to time share space to perform activities. This requires practical evidence, rather than simply multiplying the space required for one animal by the number of animals. For instance, if space is allocated to an animal of 1.08 m^2, based on semi recumbency requirements[6], the animal when standing would have free space of 0.26 m^2 (i.e. 1.08 m^2 - 0.82 m^2, the latter using a k-value of 0.019). It can be envisaged that additional space of 0.26 m^2 may be insufficient to allow an individual to carry out necessary behaviours. However, if 50 animals were allocated to a pen, when all are standing, there would be free space of 13.9 m^2. A free space allocation of 13.9 m^2 may allow each individual animal in the pen to carry out necessary behaviours.

Cattle, in particular, demonstrate shared vigilance, with some members of a herd staying standing while others rest by lying down[7]. Petherick and Phillips in their literature review observed "*animals share space in time and all would not show lying down (or standing up) behaviours simultaneously*"[8].

Catherine Stockman et. al., 2009, for cattle on voyages to the Middle East found that during the night cattle stood for about 38% of the time, were lying for about 46% of the time and engaged in other activities for about 16% of the time. Respective figures during the day were standing 46%, lying 38%, other activities 16% (see Figure 2.1)[9].

Figure 2.1: Mean number of cattle as a proportion of total number of focal animals that were standing (not eating or drinking), lying (sternal and lateral recumbency), eating and drinking and self-grooming (licking and rubbing) at night (1800 to 600 hours) compared to during the day (0550 to 1750 hours)



[6] This space allocation would be that recommended by application of the allomwtric equation for a 300kg animal using a k-value of 0.025.

[7] Clive J. Phillips, 2002, *Cattle Behaviour and Welfare*. Blackwell's Scientific, Oxford, p. 264. It is not known if such sharing of vigilance is shown during transportation.

[8] J.C. Petherick and C.J. Phillips, 2009, p8.

[9] C. Stockman, A. Barnes and D. Beatty, 2009, What is the impact of sea transport on cattle behaviour?, Poster presented at the International Ethological Conference, 2009.

2.5 REAL WORLD STUDIES OF LIVESTOCK SPACE REQUIREMENTS

Theoretically calculating space requirements from allometric equations, and comparing space allocations in a range of very different situations, represents valuable research, but equally, if not more, valuable is actual observation of welfare outcomes in real livestock export voyage situations. This is particularly the case when group interactions are taken into account.

The CSIRO completed a stocking density project in 2013 that assessed 2 long haul sheep voyages to MENA in June and December 2010 and 1 short haul cattle voyage of 320 kg steers to Indonesia between 14 – 22 June 2012. This work was partly undertaken as a result of statements by Petherick and Phillips that there is little actual data supporting the selection of k-values. The CSIRO report considered the following stocking densities – ASEL, ASEL less 10 per cent, and ASEL plus 10 per cent or space allocated allometrically using a k-value of 0.027 (whichever was greater).

The key finding of the CSIRO report was that, based on the animal welfare indicators applied, the ASEL v2.3 stocking densities are appropriate, but a 10 per cent increase should be further investigated. These conclusions of the CSIRO, based on real world observations, that:

- ASEL v2.3 stocking densities are appropriate; and
- A 10% increase in space is worthy of further investigation

are at odds with suggestions that a k-value of 0.033 should be used. A k-value of 0.033 would involve a 39% increase in space for 50kg sheep shipped in November to April and a 28% increase in space for 300kg cattle (above the ASEL base table).

2.6 ALEC DISAGREES WITH STATEMENTS IN THE ISSUES PAPER ON K-VALUES

For live export voyages ALEC does not accept the statement that appears in the Heat Stress Risk Assessment Issues Paper that "*According to Petherick and Phillips (2009) a k-value of 0.033 appears to be the threshold below which there are adverse effects on welfare*". Apart from the fact that no account is taken of space sharing, which is critical, the recommendation of a k-value of 0.033 in the Petherick and Phillips review applied to situations of "*long-term confinement*". Petherick and Phillips state: *"For long-term confinement, a minimum allowance per head determined from the equation: area (m^2) = $0.033W^{0.66}$ appears to reduce risks to welfare and productivity"*[10]. Petherick and Phillips do not explicitly specify what is meant by "*long term confinement*", although the reference to productivity provides clues and the intensive housing studies Petherick and Phillips review to reach this conclusion involved confinement over a number of months.

2.7 INTERNATIONAL COMPARISONS

Tables 2.1 and 2.2 provide comparisons for cattle and sheep space allocations from the current ASEL provisions, determined allometrically using a k-value of 0.027, and space allocations that are regulated or provided as guidelines by other economically advanced countries.

[10] J.C. Petherick and C.J. Phillips, 2009, p10.

Table 2.1: International comparison of space allocation for cattle transported by sea

Weight (kg)	Minimum pen area space allocation (sq. metres per head)					
	ASEL Base Table[1]	k = 0.027[2]	Ireland	EU	NZ	US
200	0.770	0.891	0.810	0.810	0.900	0.770
300	1.110	1.165	1.058	1.058	1.180	1.110
400	1.450	1.408	1.305	1.305	1.450	1.450
500	1.725	1.795	1.553	1.553	1.790	1.790
600	2.000	2.025	1.800	1.800	2.000	2.130

[1] Short haul, not southern cattle

[2] Includes an additional 10% space allocation for cattle over 500kg - see ALEC Stage 2 ASEL Submission

Table 2.2: International comparison of space allocation for sheep transported by sea

Weight (kg)	Minimum pen area space allocation (sq. metres per head)			
	ASEL Nov to April	k = 0.027	EU	US
40	0.290	0.308	0.290	0.226
50	0.315	0.357	0.315	0.260
60	0.360	0.403	0.340	0.294

The international comparisons show that allometrically allocating space using a k-value of 0.027 (with an additional 10% allowance for cattle of 500kgs and over – see ALEC Stage 2 ASEL Submission) results in generous space provisions compared to those applied by other countries.

2.8 Conclusion

ALEC supports the application of allometry to guide the determination of “base” stocking densities for sheep (and other livestock) exported by sea from Australia.

A space allowance that allows all livestock in a pen to simultaneously lie down represents strong grounds for setting densities for live exports from Australia. The agreed allometric k-value that allows livestock to lie down simultaneously is 0.027. ALEC recommends that on-board stocking densities for all voyages be determined using this k-value.

ALEC recognises that space allocations greater than this may result from a consideration of heat stress risk (see other material contained in this submission), but space allocations due to heat stress need to be independent of space allocations from allometry (the two should not be confused). Additional space allocations to avoid heat stress should be separately determined via application of an appropriately calibrated heat stress risk assessment (HSRA) model.

3 Thermoregulation in Homeotherms

The remainder of this submission is devoted to a consideration of the heat stress risk assessment process, including issues associated with the process and advantages and disadvantages of possible changes under consideration. The ground work for this consideration is laid in this chapter which provides information on thermoregulatory processes in homeotherms.

Homeotherms are organisms that maintain body temperature at a constant level (within certain boundaries) even when environmental temperatures are very different. Humans, sheep and cattle are homeotherms.

Where there is a difference between environmental temperatures and normal body temperature homeotherms have available a variety of different mechanisms to cool or heat the body. Once these mechanisms have been exhausted the body temperature will either start to rise or fall. If the fall or rise is large enough death will occur.

Important points made in this chapter included the following:

- Both cold stress and heat stress, although at opposite ends of the spectrum, in terms of welfare and health, share significant attributes as they both challenge the ability of animals (and humans) to thermoregulate. Those concerned with one, in terms of welfare, must necessarily be concerned with the other.
- Measuring cold and heat stress in animals is best done by monitoring changes in core body temperature (e.g. through rectal temperature probes) – this provides a direct measure of the degree of cold or heat stress. In field situations or on live export ships, however, there are huge challenges in doing this. The practical challenges are obvious. But the practical challenges are compounded by the need to monitor the same *individual* animal over time to accurately measure cold or heat stress. This is because the base level temperatures of individual animals vary considerably. Furthermore, individual animals have varying abilities to cope with low or high environmental temperatures.
- Given the practical difficulties of measuring changes in body temperatures some veterinarians have suggested that heat stress can be measured through behavioural changes in the animal, especially the degree of panting. This presupposes a very high correlation between panting and changes in body temperature (since there is general agreement that changes in body temperature represent the best measure). To the knowledge of ALEC no large-scale studies have been conducted demonstrating the strength of this correlation – and large-scale studies would be needed to provide certainty. Very small experimental studies (involving, typically, about 20 sheep or cattle) have been conducted and these report the variables are "somewhat" correlated. There is also evidence from these experimental studies that there can be significant individual differences between when panting occurs and changes in body temperature. It should be noted that panting and sweating to a certain level represents the body taking precautionary/pre-emptive action against increasing heat exposure to prevent body temperatures rising too high. If a behavioural measure, such as panting, is to be used as a regulatory mechanism for heat stress, it is critical that a direct and extremely strong association exists between this variable and changes in body temperature.
- Dealt with later in this submission is the fact that ALEC is committed to collecting measures on animal welfare – a LiveCorp research project to do this is well underway. This will provide substantially more data as a basis for examining the issues raised above.

3.1 Stages of Thermoregulatory Stress

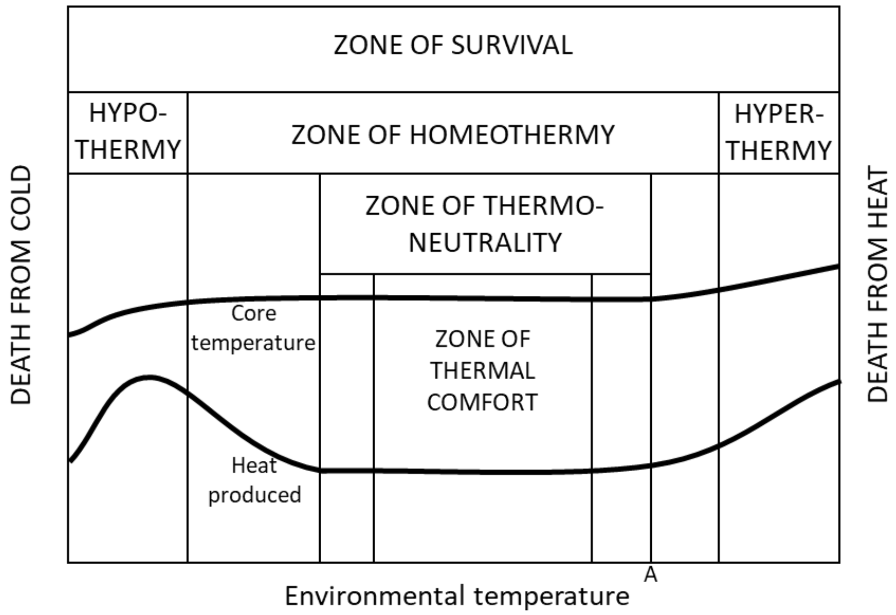
How homeotherms manage in changing ambient temperatures in depicted in Figure 3.1.

Within the thermoneutral zone animals can maintain a constant temperature by utilising processes that involve little physical effort. These processes include postural and behavioural changes as well as shifts in blood flow patterns[11]. The thermoneutral zone, may be defined as the range of ambient temperatures wherein no regulatory changes in metabolic heat production occur.

When environmental temperatures are outside the thermoneutral zone energy requirements increase in order to dissipate or maintain heat production. In extreme cold the metabolic rate is increased to generate heat to maintain body temperature. Conversely, as environmental heat increases, sweating and / or panting and a variety of other mechanisms are employed to dissipate heat. If body temperature continues to rise, the animal enters into an acute phase of heat stress that induces heavy panting and maximal sweating. Heat production will rise under this condition because of the acceleration in the biochemical processes (the van't Hoff effect) and because of the energetic cost of heavy panting[12].

If the mechanisms of the homeotherm fail to keep body temperature within a normal range, core body temperatures will either begin to fall or rise. A change in body temperature is not immediately lethal. For example, body temperature rises during exercise in humans and humans regularly place themselves into sauna baths where heat balance is not possible. While exposed to such conditions, body core temperature will increase at a rate that is proportional to the imbalance in heat gain and loss. While some change in core body temperature is not lethal, continual heat loss or heat gain is untenable, and if continued will eventually result in hypothermia or hyperthermia and then death.

Figure 3.1: How homeotherms manage in changing ambient temperatures.



[11] Stonewell, R.R. and Bickert, W.G., 1996, "Warm season heat transfer model for dairy cattle naturally ventilated facilities", *ASAE Annual International Meeting, Paper 96406*. St Joseph, MI.
[12] Hales, J.R.S., and Brown, G.D., 1974, "Net energetic and thermoregulatory efficiency during panting in sheep", *Comparative Biochemistry and Physiology*, Vol 49A, pp413-422.

A complication with the situation depicted in Figure 3.1, and in measuring heat stress and cold stress generally, is that normal body temperature varies significantly between individuals and even within the one individual at different times. In humans, for instance, the commonly accepted average core body temperature is 37.0°C, with a commonly used range of 36°C to 37°C. However, some studies have shown that the "normal" body temperature can have a wider range, from 36.1°C to 37.8°C[13]. Similarly, in sheep the mean daytime rectal temperature of sheep is approximately 39˚C, with a typically accepted range of 38.5°C to 39.5°C, but some studies have found a range of 37.5°C to 40.5°C[14]. Opinions vary both for sheep and cattle on what constitutes a normal temperature range.[15]

Variations in body temperature are dependent on a number of internal and external causes, many of which are unknown. For given thermoneutral environmental conditions, modulations of body temperature are directly and inherently subjected to circadian rhythms, sexual status and rhythms, especially estrus. Pregnancy, parturition, and lactation also influence body temperature.[16].

Hypothermia occurs when the body temperature drops well below normal. Hypothermia is defined:

- In humans as a body temperature 2°C less than normal,
- In lambs mild to moderate hypothermia is characterized by a body temperature between 37°C and 39°C; severe hypothermia occurs when the body temperature is below 37°C.

Hyperthermia and the upper critical temperature (defined as point A in Figure 3.1) is more complex.

In humans:

- The most commonly used definition of heat stroke worldwide is the Bouchama's definition[17]. Bouchama has defined heat stroke as a core body temperature that rises above 40°C, accompanied by hot dry skin and central nervous system abnormalities, such as delirium, convulsions, or coma.
- A human admitted to the emergency room with a body temperature lower than 42.5°C has better than 50% chance of survival[18]. If body temperature exceeds 42.5°C there is a less than 50% chance of survival.

In sheep it is not known what the maximum body temperature is that can be survived. As noted above the normal body temperature in humans is 36°C to 37°C, while in sheep it is 38.5°C to 39.5°C. Simply extrapolating the situation in humans would suggest that for sheep a body temperature of 42.5°C is survivable. Core body temperatures of 42.5°C have been recorded in free-living antelope

[13] See, for example, Simmers, L, 1998, *Diversified Health Occupations*, 2nd Ed, Canada, Delmar, pp150-151 and Shoemaker, A.L., 1996, "What's Normal? Temperature, Gender, and Heart Rate", *Journal of Statistics Education*, Vol. 4, No. 2.

[14] See Stockman, C.A., 2006, *The Physiological and Behavioural Responses of Sheep Exposed to Heat Load within Intensive Sheep Industries*, PhD Thesis, Murdoch University, p32.

[15] See Stockman, C.A., 2006, p32, for sheep. For cattle this conclusion has been drawn from an extensive review of the literature.

[16] Sellier, N., Guettier, E., Staub, C., 2014, "A review of methods to measure animal body temperature in precision farming", *American Journal of Agricultural Science and Technology*, Vol. 2, No. 2, pp.74-99.

[17] Bouchama, A.,and Knochel, J.P., 2002, "Heat stroke", *New England Journal of Medicine*, Vol. 346, pp.1978–88.

[18] Piantadosi, C.A., 2003, *The biology of human survival*, Oxford University Press, Oxford.

without apparent ill effects[19], and in sheep the combination of heat exposure and dehydration for 5-days resulted in an average core body temperature of 40.96°C without ill effect[20].

In experiments conducted at Murdoch University, sheep were exposed to high heat and humidity[21]. In one set of experiments, conducted in March on animals that were acclimatised to summer conditions in Perth, Merino wethers and Awassi rams were exposed for several days to a wet-bulb-temperature of up to 31°C, apparently without incident. The average core body temperature of the twelve Merinos was higher than 40.5°C during exposure to 31°C wet-bulb-temperature. All animals are reported to have recovered quickly and physiological parameters returned to normal.

In a second set of experiments[22], winter-acclimatised Merino wethers, rams, and ram lambs were exposed to similar conditions to those described above. As above, the temperature of each sheep was taken prior to increasing the environmental temperature and then several times each day as the experiment progressed. This allowed the various levels of heat stress to be precisely assessed. Results can be summarised as follows:

- When the wet-bulb-temperature reached 25°C the mean core body temperature for all of the classes of sheep increased above baseline.
- When the wet-bulb-temperature had further increased to 26-28°C mean core body temperature had risen by 0.5°C for all sheep.
- Finally, when wet-bulb-temperature was increased to 27°C for Merino lambs, 28°C for wethers, and 29°C for rams core body temperatures had risen by 1.0°C.

Sheep were removed from the heat exposure once core body temperatures had risen by 1.0°C. All animals survived. We can thus say that a core body temperature of 40.5°C is not lethal to a sheep.

It is also to be noted that, although body temperatures rose in all sheep, there were considerable differences between sheep on the timing of these increases.

More generally, many studies have used increased core temperature as the best indicator of the onset or degree of thermal stress in an animal[23]. For example, Stockman in her study used three heat stress thresholds (HST) defined as follows[24]:

- HST 1: The daily mean wet bulb temperature on the day that daily mean core body temperature first significantly increased above pre-heat values.
- HST 2: The daily mean wet bulb temperature on the day that daily mean core body temperature first significantly increased 0.5˚C above pre-heat values.

[19] Fuller, A., Mitchell, D., Maloney, S.K. & Hetem, R.S., 2016, "Towards a mechanistic understanding of the responses of large terrestrial mammals to heat and aridity associated with climate change", *Climate Change Responses*, Vol. 3, No. 10. (doi:10.1186/s40665-016-0024-1).
[20] Strauss, W.M., Hetem, R.S., Mitchell, D., Maloney, S.K., Meyer, L.C.R. & Fuller, A., 2015, "Selective brain cooling reduces water turnover in dehydrated sheep", *PLoS ONE,* Vol. 10.
[21] Stockman, C.A., 2006.
[22] See Stockman, C.A., 2006. Also, Barnes, A., Beatty, D., Stockman, C., Maloney, S. and Taplin, R., 2008, "Electrolyte supplementation of export cattle and further investigations into heat stress", *Final Report Project LIV.224*, Meat & Livestock Australia, Sydney, August.
[23] Monty, J.D.E., Kelley, L.M. and Rice, W.R., 1991, "Acclimatisation of St. Croix, Karakul and Rambouillet sheep to intense and dry summer heat", *Small Ruminant Research*, Vol. 4, pp.379-392 and Silanikove, N., 2000, "Effects of heat stress on the welfare of extensively managed domestic ruminants", *Livestock Production Science*, Vol. 67, pp.1-18.
[24] Stockman, C.A., 2006, p.95. No justification is provided for the cut-off values used to define the various heat stress thresholds, apart from the fact that some were based on the original Maunsell Australia work.

- HST 3: The daily mean wet bulb temperature on the day that daily mean core body temperature first significantly increased 1˚C above pre-heat values.

In everyday situations, however, measuring the core body temperatures of livestock is impractical. Due to this a number of livestock researchers suggest that behavioural measures, such as panting, but used to measure heat stress.[25].

Sheep, for instance, exhibit two types of panting, termed first and second phase panting. First phase panting involves rapid shallow breathing, whereas second phase panting is characterised by a slower deeper panting[26]. Both are initiated by thermoreceptors located in exposed areas of skin (e.g. scrotum, mammary skin, etc).

It is generally concluded that first stage panting in sheep is a good indicator of the onset of thermal stress, while second phase panting indicates severe heat load and risk of respiratory alkalosis, but uncertainty surrounds this conclusion.

Studies have certainly shown that an increase in both first and second phase panting is highly correlated with increasing ambient temperature and humidity[27]. However, the correlation between panting and changes in body temperature does not seem to have been extensively studied. Studies have found that first and second phase panting began even with rectal temperatures in the normal range[28]. Stockman notes that: *"Although the stimulus for panting is thought to be via peripheral thermoreceptors, the onset of first and second phase panting is* ***somewhat*** *correlated with core body temperature"* (our emphasis). Research discussed by Stockman[29] and Thompson[30] have found that the change from first to second stage panting does not depend on the attainment of a particular hypothalamic temperature.[31]

Anne Barnes and her co-researchers did not report a correlation between changes in core body temperature and panting, although they did report that all sheep in the climate rooms did progress to open-mouthed panting, some with the additional feature of having their tongues out (panting score 4)[32].

3.2 Measuring environmental temperature

Apart from challenges in measuring the degree of heat stress, there are also challenges in determining the best measure of environment temperature which gives rise to heat stress. There are many different ways of measuring temperature and many have been proposed in studies on heat stress in livestock.

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[25] Savage, D., Gaughan, J. Godwin, I. and Nolan, J., 2008, "Post Discharge Induction Procedures for Sheep in the Middle East", *Final Report Project B.LIV.0127*, Meat and Livestock Australia, October.
[26] Hales, J.R.S., and Webster. M.E.D., 1967, "Respiratory function during thermal tachypnoea in sheep", *Journal of Physiology*, Vol. 190, pp.241 – 260.
[27] Bligh J., 1959, "The receptors concerned in the thermal stimulus to panting in sheep", *Journal of Physiology*, Vol. 146, pp142–151; Ames D.R., Nellor J.E., Adams T., 1971, "Energy balance during heat stress in sheep", *Journal of Animal Science*, Vol. 32, pp.784–788., Nejad, J.G. and Sung, K., 2017, "Behavioral and physiological changes during heat stress in Corriedale ewes exposed to water deprivation", *Journal of Animal Science and Technology*, Vol 59.
[28] See Bligh, J., 1959; Hales, J.R.S., and Webster, 1967, and Stockman, C.A., 2006.
[29] Stockman, C.A., 2006, p.53.
[30] Thompson, G.E., 1985, "Respiratory systems" in *Stress Physiology in Livestock. Volume 1: Basic Principles*, Yousef, M.K. (ed), pp155-162, CRC Press, Florida.
[31] Some may still maintain that, with evidence of panting, an animal is under heat stress irrespective of body temperature. Claims that heat stress may exist, however, in the absence of pysiological correlates, are extremely problematic – especially once panting is at phase 2 while body temperature remains normal.
[32] Barnes, A., 2008, p.26.

The following represent an inexhaustive set of measures for environmental temperature:

- Dry bulb temperature.
- Wet bulb temperature.
- Black globe temperature.
- Temperature – humidity index (which takes into account dry bulb temperature and humidity, with some formulations taking into account dry and wet bulb temperatures).
- Temperature – humidity – hour index (which attempts to incorporate a measure of accumulated heat load).
- Heat load index (incorporating dry bulb temperature, humidity, solar radiation and wind-speed).
- Effective temperature index (a combination of dry bulb temperature and black globe temperature).
- Wet bulb globe index.
- Black globe humidity index.

Within each of these temperature indicators there are often further variations and measurement issues to face. For example, there are at least two ways of measuring wet bulb temperature and these lead to different values for wet bulb temperature – wind speed may explain some variability in the data[33]. Furthermore, wet bulb temperature can vary considerably between different locations within a relatively confined spatial area[34].

To a degree different measures have greater relevance in particular circumstances. For instance, for the conditions experienced on a live export voyage, wet bulb temperature measures are accepted as of greater relevance than dry bulb temperatures (as wet bulb temperature allows incorporation of high relative humidity and dry bulb temperature). In an experiment Hales and Webster exposed Merino sheep to temperatures of up to 60°C (dry bulb) and none are reported to have died, but the humidity was low in these experiments[35]. In contrast it is known that if a sheep, with a core body temperature of 39°C, is exposed to an environment where the wet-bulb-temperature is 39°C, no heat exchange by any route will be possible and all of the metabolic heat generated within the animal will be stored in the body, resulting in a rise in body temperature.

Despite different measures having greater relevance in certain circumstances, for any particular circumstance a range of measures may be of relevance. For instance, Phillips argues that there is *"an urgent need to develop both a THI [temperature – humidity index] and a panting scale for sheep that are properly validated with physiological measures"*[36].

3.3 SYSTEMATIC VARIATIONS IN BODY TEMPERATURES AND HEAT STRESS THRESHOLDS

Variations in body temperatures and heat stress thresholds have been found to be systematically associated with a number of factors related to the animal, including recent activity. A number of these factors are listed below.

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[33] Some measure wet bulb temperature with a sling psychrometer. This device includes two thermometers, one a dry bulb and the other a wet bulb, in such a way that they can be swung around. Others measure wet bulb temperature using a stationary thermometer with a wick.

[34] Caulfield, M.P., Cambridge, H., Foster, S.F. and McGreevy, P.D., 2014, "Heat stress: A major contributor to poor animal welfare associated with long-haul live export voyages", *The Veterinary Journal*, Vol. 199, pp.223-228.

[35] Hales, J.R.S. & Webster, M.E.D., 1967, "Respiratory function during thermal tachypnoea in sheep", *Journal of Physiology*, Vol. 190, pp.241-260.

[36] Phillip, C., 2016, The welfare risks and impacts of heat stress on sheep shipped from Australia to the Middle East, Accepted Manuscript, *The Veterinary Journal*.

3.3.1 Weight

A close relationship exists between the mass of an animal and amount of heat generated.

3.3.2 Breed

Breeds of ruminants indigenous to tropical and subtropical environments generally perform better than their counterparts from more temperate zones in terms of heat stress.

With sheep there is general agreement that Merino sheep are more heat tolerant than the European breeds[37]. There is also very strong evidence that fat tailed sheep are more heat tolerant than Merinos[38].

3.3.3 Age and sex

Studies have found that rams react more dramatically to hot conditions in terms of body temperature and respiratory rate than do ewes. The age of an animal also influences its level of heat tolerance.

3.3.4 Diurnal impacts

Generally body temperatures are higher in the afternoon than morning. Even in climate controlled rooms with the environmental temperature kept constant researchers at Murdoch University found that there were diurnal variations in body temperatures of about 1°C.[39]

3.3.5 Accumulated heat

There is strong evidence that accumulated heat is important, causing heightened physiological responses.

3.3.6 Recent activity

Heat is produced during the digestion of food. Muscular work is also a major source of heat production, with skeletal muscle accounting for as much as 80% of the total metabolic heat[40].

3.4 INDIVIDUAL VARIATIONS IN HEAT STRESS THRESHOLDS

In sheep the ability to cope with high temperatures can vary between individuals that are otherwise physiologically similar. In hot environments, some sheep are able to maintain relatively normal body temperatures, whereas others are not. This phenomenon is repeatable over consecutive days and over subsequent years. Adaptation to hot temperatures is likely to play an important role in individual differences, but there are also significant unexplained differences.

In Catherine Stockman's experiments, for instance, the days on which core temperature did increase above pre-heat generally was different for individual sheep. Sheep differed not only in which days

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[37] Statement made in Stockman, C.J., 2006, p.77 relying on Miller, J.C., and Monge, L., 1946, "Body temperature and respiration rate, and their relation to adaptability in sheep, *Journal of Animal Science*, Vol. 5; Johnson, K.G., 1971, "Body temperature lability in sheep and goats during short – term exposures to heat and cold", *Journal of Agricultural Science*, Vol. 77, pp267 – 272; Thwaites, C.J., 1985, "Physiological responses and productivity in sheep", in *Stress Physiology in Livestock Volume 1 Basic Principals*, Yousef, M.K. (ed), pp47–55, CRC Press: Florida.

[38] See Stockman, C.J., 2006; Eyal, E., 1963, "Shorn and Unshorn Awassi sheep. I. Body temperature", *Journal of Agriculture Science*, Vol. 60, pp.159-168; Macfarlane, W.V., 1968, "Adaptation of ruminants to tropics and deserts", in *Adaptation of Domestic animals*, Hafez, E.S.E. (ed), pp164 -182, Lea and Febiger, Philadelphia; Shafie, M.M. and Abdelghany, F. M., 1978, "Structure of the respiratory system of sheep as related to heat tolerance", *Acta Analytica*, Vol. 100, pp.441-460.

[39] Barnes, A., Beatty, D., Stockman, C., Maloney, S. and Taplin, R., 2008, "Electrolyte supplementation of export cattle and further investigations into heat stress", *Final Report Project LIV.224*, Meat & Livestock Australia, Sydney, August.

[40] Andersson, B.E., and Jonasson, H., 1993, "Temperature regulation and environmental physiology", in *Dukes Physiology of Domestic Animals,* 11th edition, Swenson, M.J. and Reece, W.O. (eds), pp.886-895, Cornell University Press, Ithaca.

their mean, minimum and maximum core temperature increased above that at pre-heat but also how many days core temperature was above pre–heat. In one experiment simulating voyage conditions to the Middle East one wether and one ram were particularly tolerant of the hot CCR conditions and took longer than other sheep in their class to reach each heat stress threshold 1 and 2 and did not reach heat stress threshold 3. These sheep also took longer to have a significantly increased panting score than other sheep in their class. Some sheep were much less heat tolerant, reaching each heat stress threshold earlier and progressing to open mouth panting earlier than other sheep in the same class. Stockman concludes that this "*between-animal variation highlights the need for judicious use of a group-determined heat stress threshold as a management tool*"[41].

3.5 Conclusion

From a review of the literature conducted by ALEC it is obvious that the issues of heat and cold stress are extremely difficult to research and knowledge remains very incomplete. This statement is applicable to research on humans; it is even more the case with research on animals.

The following uncertainties, in particular, are to be noted:

- Normal temperature ranges can vary considerably between individuals.
- Heat stress is best associated with changes in internal body temperature, but baseline temperatures vary (between individuals) as do temperatures by time of day (potentially inconsistently between days) and as a result of recent activity, amongst other things.
- Due to practical difficulties in measuring body temperatures (which ideally should be measured on the same animal on successive days) heat stress in animals is often associated with panting. However, there is not enough evidence on the correlation between panting and internal temperature to make this a reliable indicator of heat stress. Evidence is available that there can be significant individual differences between when panting occurs and changes in body temperature.
- Significant Individual differences exist in abilities to cope with heat stress, some of which are associated with known factors, others of which are unknown.

[41] Stockman, C.A, 2006, p.185.

4 Mortalities and health / welfare issues arising from heat and cold stress represent a general problem for society

The impact of heat stress in live exports has received significant public and regulatory attention. But the impact of heat stress and cold stress across society is substantially wider than just live exports. This brief chapter highlights the impact of heat and cold stress on the human population as well as in other areas of livestock production. Providing information on the impact of heat and cold stress on the human population and in other areas of livestock production is relevant to the possible risk settings for live exports.

4.1 Heat and cold stress in the human population

4.1.1 Human mortalities due to heat stress

Heat is known as the "silent killer". Major heat waves result in substantial human mortalities even in economically advanced countries:

- A high-profile heat wave in western Europe killed an estimated 52,000 people during the summer of 2003. This estimate has been produced by the Earth Policy Institute based on data published by national health authorities[42].
- It is estimated that between 2006 and 2010 heat stroke resulted in more than 600 deaths a year in the United States[43]. Rates have increased between 1995 and 2015[44].
- Heat waves in India in 2010 killed more than 1300 people in the city of Ahmedabad alone, prompting the start of efforts to develop coordinated Heat Action Plans[45]. In India, hundreds die every year from summer heat waves, including more than 2,500 in 2015.[46]. Research led by Mazdiyasni concluded that "*the relationship between income and human health is stronger than that between physical conditions and health, perhaps as the result of access to air conditioning or medical care*"[47]. In other research in India a heat wave in 2010 was associated with an estimated 43.1% increase in deaths when compared to the reference period[48].
- In Australia major heatwaves have caused more deaths since 1890 than bushfires, cyclones, earthquakes, floods and severe storms combined. Across southeast Australia, the 2009 heatwave resulted in a total of nearly 500 excess deaths[49]. In Adelaide there was a 14-fold

[42] Larsen, J, 2006, Setting the Record Straight: More than 52,000 Europeans Died from Heat in Summer 2003, Earth Policy Institute, Rutgers University, http://www.earth-policy.org/mobile/releases/update56.

[43] Berko, J, Ingram, D.D., Saha, S., and Parker, J.D., 2014, "Deaths Attributed to Heat, Cold, and Other Weather Events in the United States, 2006 – 2010", *National Health Statistics Report*, No. 76.

[44] Leon, L.R.; Bouchama, A., 2015, "Heat stroke", Comprehensive Physiology, Vol. 5, pp.611–47.

[45], O., AghaKouchak, A., Davis, S.J., Madadgar, S., Mehran, A., Ragno, E., Sadegh, M., Sengupta, A., Ghosh, S. Dhanya, C.T. and Niknejad, M, 2017, "Increasing probability of mortality during Indian heat waves", *Science Advances*, Vol. 3, No. 6, pp.1-5.

[46] The information comes from articles in Reuters, Bloomberg and Indiapend.

[47] Mazdiyasni, O., AghaKouchak, A., Davis, S.J., Madadgar, S., Mehran, A., Ragno, E., Sadegh, M., Sengupta, A., Ghosh, S., Dhanya, C.T., and Niknejad, M., 2017, "Increasing probability of mortality during Indian heat waves", Science Advances, Vol 3, http://advances.sciencemag.org/content/3/6/e1700066.

[48] Azhar, G.S., Mavalankar, D., Nori-Sarma, A., Rajiva, A., Dutta, P., Jaiswal, A., Sheffield, P., Knowlton, K., Hess, J.J., 2014, Heat-Related Mortality in India: Excess All-Cause Mortality Associated with the 2010 Ahmedabad Heat Wave, *PLoS ONE*, Vol. 9, No. 3.

[49] Nairn J. and Fawcett, R., 2013, "Defning heatwaves: heatwave defned as a heat-impact event servicing all communiy and business sectors in Australia", *CAWCR Technical Report*, No. 60.

increase in direct heat related hospital admissions during this heatwave[50] and Khalaj et al.[51] reported 590% increase in emergency hospital admissions due to heat-related injuries in five regions of New South Wales (including Sydney). In Queensland a number of occupational deaths and injuries have been associated with heat waves in 2000 and 2004[52]. More generally, ambulance call outs, hospitalisations and deaths spike during extreme heat events in Australia, but few are recorded as the direct result of heat illnesses; instead, most cases are recorded as heart attacks or renal failure.

Deaths and morbidity from heat stress can be avoided. For instance, Zhang et al. in the Adelaide research found that social isolation was a risk factor. Similarly, they found that "*that having an air-conditioner in bedrooms may reduce the risk of having direct heat-related morbidity by >80% during heatwaves in Adelaide*".

The fact that more deaths and morbidity from heat stress and cold stress (see next section) are not avoided (since avoidance measures for both heat stress and cold stress are known) reflects economic decisions that Governments are making on whether to intervene with support or not.

4.1.2 Human mortalities due to cold stress

A recent publication in The Lancet has thrown more light on the impact of temperature variations in human mortalities[53].

The research team analysed mortality data for 74 million deaths across 13 countries, in what they described as "*the largest dataset ever collected to assess temperature-health associations*".

The study concluded that temperature was responsible for "advancing" 7.7 per cent of all studied deaths. Most of these (6.7 per cent of all deaths) were not caused by heat stress, but by cold stress – and not by "extreme cold" but by "moderate cold".

In Australia, surprisingly cold temperatures were found to be responsible for 6.5 per cent of deaths, but only 3.7 per cent of deaths in Sweden (a much colder country). An estimated 5,338 Australians died each year between 2010/11 and 2014/15 from cold stress.

International comparisons have linked higher winter death rates in milder climates to poor building insulation. Studies in New Zealand and England have linked cold-related mortality with low incomes and hard-to-heat buildings[54]. The World Health Organisation has made a conservative estimate that

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[50] Zhang, Y., Nitschke, M., Krackowizer, A., Dear, K., Pisaniello, D., Weinstein, P., Tucker, G., Shakib, S., Bi, P., 2016, "Risk factors of direct heat-related hospital admissions during the 2009 heatwave in Adelaide, Australia: a matched case–control study", *BMJ Open*, Vol. 6.

[51] Khalaj, B., Lloyd, G., Sheppeard, V., and Dear, K., 2010, "The health impacts of heat waves in five regions of New South Wales, Australia: a case-only analysis", *International Archives of Occupational and Environmental Health,* Vol. 83, pp.833-842.

[52] Srinivasan, K. Maruthy, N., Venugopal, V., and Ramaswamy, P. 2016, "Research in occupational heat stress in India: Challenges and opportunities", *Indian Journal of Occupational and Environmental Medicine*, Vol. 20, No. 2 pp.73-78.

[53] Gasparrini, A., Guo, Y., Hashizume, M., Lavigne, E., Zanobetti, A., Schwartz, J., Tobias, A., Tong, S., Rocklöv, J., Forsberg, B., Leone, M., De Sario, M., Bell, M.L., Guo, Y.L. Wu, C., Kan, H., Yi, S., de Sousa Zanotti, M., Coelho, S., Saldiva, P.H.N., Honda, Y., Kim, H., Armstrong, B., 2015, "Mortality risk attributable to high and low ambient temperature", *Lancet*, Vol. 386, pp.369-375.

[54] Wilkinson, P., Landon, M., Armstrong, B., Stevenson, S., Pattenden, S., McKee M., and Fletcher, T., 2001, *Cold comfort: The social and environmental determinants of excess winter deaths in England, 1986-96*, Published for the Joseph Rowntree Foundation by The Policy Press, Bristol.

30 per cent of excess winter deaths in Europe are due to cold housing[55]. It is likely that similar links exist in Australia.

Why there has not been more research into factors contributing to cold stress in humans in Australia and greater Government regulation of these factors is unknown[56].

4.2 Heat and cold stress also a factor in general livestock production

Just as heat and cold stress affects humans, so also does it affect livestock in intensive and extensive production situations.

- In 2006 a major heat wave moving across the USA resulted in the death of 25,000 cattle and 700,000 poultry in California[57]. Other heat wave episodes in the USA have also resulted in major losses[58]. Unrecorded losses may also occur for less extreme weather events.
- In the UK about 15% of lambs born annually are lost – mostly due to exposure and starvation[59]. Cold stress is a particular threat for new born lambs.
- Similar figures to those in the UK are thought to apply to Australia[60].

4.3 Conclusion

Significant human and livestock deaths occur annually in Australia and the rest of the world due to heat stress and cold stress. ALEC understands these issues attract attention in live exports. More generally, however, the human cost of heat and cold stress, in particular, is enormous and would seem to warrant more attention.

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[55] Braubach, M., Jacobs, D.E., Ormandy, D., 2011, *Environmental Burden of Disease Associated with Inadequate Housing*, World Health Organisation, Regional Office for Europe, Denmark.

[56] A cynic might believe that inaction is for reasons contained in a statement made by Professor Alan Lopez, Director of the Global Burden of Disease Group, University of Melbourne, School of Population and Global Health, to the ABC: "Many of those deaths attributed to cold would have been old people who might have died soon in any case. So the fraction of potential years of life lost due to temperature might have been much less than 7 per cent". The underlying message in this statement would appear to be "don't worry, they're old, they are about to die anyway". ALEC hopes that this is not the reason for inaction – if it is there are potential implications for risk settings in the livestock sector.

[57] Nienaber, J.A., Hahn, G.L., 2007, "Livestock production system management responses to thermal challenges", *International Journal of Biometeorology*, Vol. 52, pp.149–157

[58] See, for example, Hahn, G.L, Mader, T.L, Gaughan, J.B., Hu, Q. and Nienaber, J.A., 1999, "Heat waves and their impacts on feedlot cattle", *Proceedings, 15th International Society Biometeorology Congress*, pp.353-357.

[59] *Department for Environment, Food and Rural Affairs, Improving Lamb Survival, http://adlib.everysite.co.uk/resources/000/107/984/lambsurvival.pdf;* ADAS Consulting Limited, 1999, "Effects of best management practices and supplementing ewes with Vitamin E on reducing lamb mortality", *Final Report Project LS1507*, Ministry of Agriculture, Fisheries and Food.

[60] Trompf, J, 2018, "The sheep supply chain balancing act", Presentation given at Lambex 2018, Perth.

5 THE HEAT STRESS RISK ASSESSMENT MODEL

One of the recommendations from the investigatory reports on the voyage of MV Becrux in 2002, where a high number of cattle deaths occurred due to heat stress, was that industry "*as a matter of urgency [develop] a computer-based system to assess and manage [heat stress] risks*"[61]. Some preparatory work on developing a *computer-based system to assess and manage [heat stress] risks* had already commenced prior to 2002.

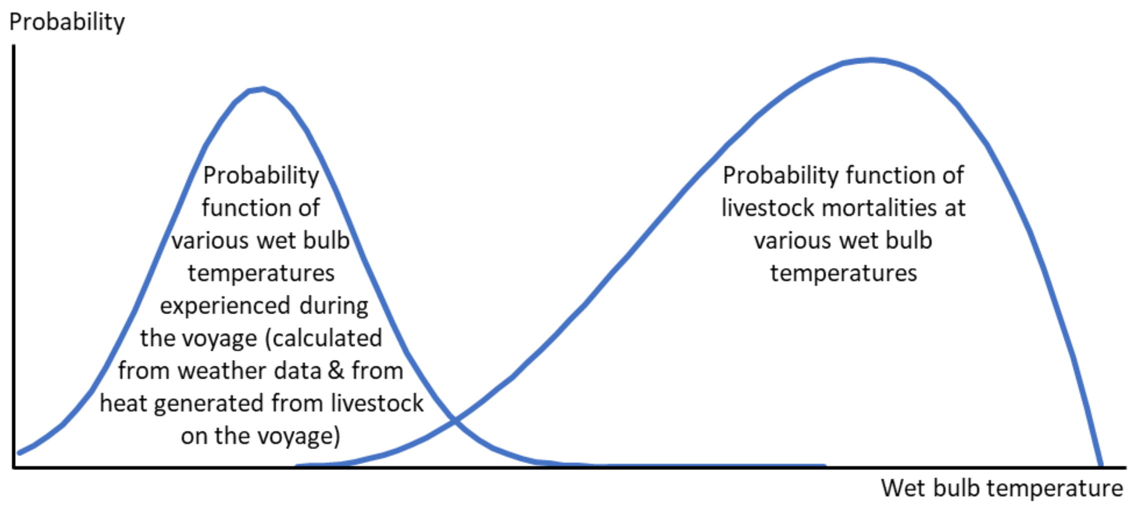
Industry acted rapidly on this recommendation and commissioned Maunsell Australia to develop a heat stress risk assessment model for voyages to the Middle East with the work completed in December 2003[62]. The model has been progressively updated over time as software enhancements were needed and new information came to light. The latest developed version is Version 5.

5.1 THE HSRA RISK SETTING AND PROBABILITY DISTRIBUTIONS

The risk setting of the HSRA model is a 2% probability of a 5% mortality event for each line of livestock loaded onto a vessel. This is the risk setting that is contained in the current version of ASEL.

The HSRA model uses two probability distributions to achieve the target risk setting (see Figure 5.1). One is a probability distribution of various wet bulb temperatures likely to be experienced during a voyage (taking into account weather and the heat generated by the livestock themselves). The other is a probability distribution of livestock mortalities at various environmental temperatures.

Figure 5.1: Probability distributions used in the HSRA model



5.1.1 Probability distribution of various wet bulb temperatures

The probability function for various wet bulb temperatures likely to be experienced during a voyage was parameterised by Maunsell Australia using weather data from two sources:

- Weather data for all ports in the Persian Gulf and Red Sea to which Australian livestock are shipped was sourced from official national meteorological organisations. Temperature and humidity data was obtained from observing stations closest to the port.

[61] More, S., 2002, op. cit.

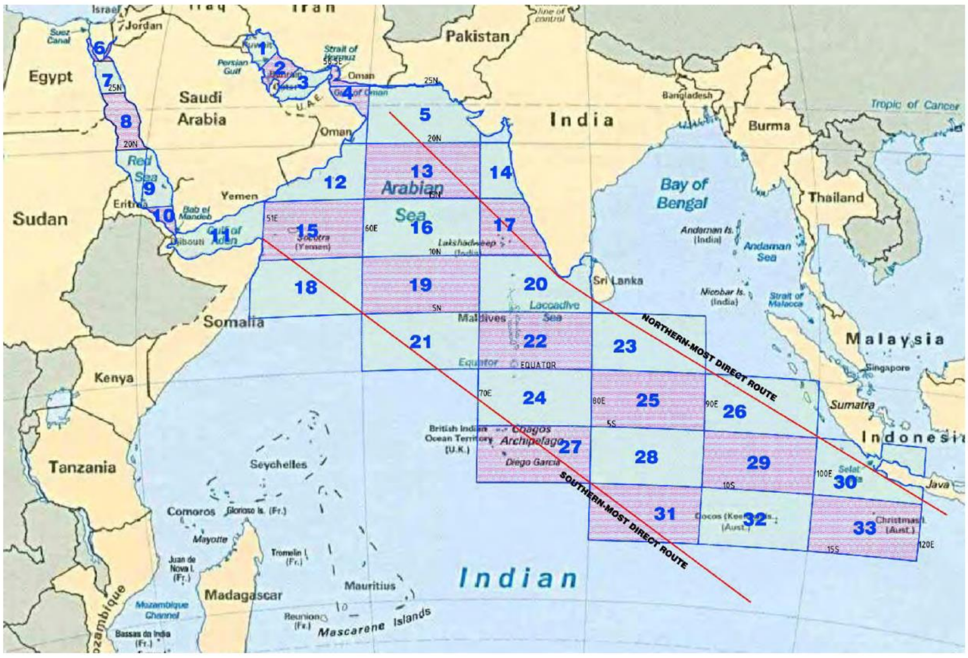
[62] Maunsell Australia Pty Ltd, 2003, Development of a heat stress risk management model, *Final Report for Project LIVE.116*, Meat & Livestock Australia, Sydney, December

- Weather data along sea routes taken by live export vessels to the Middle East was sourced from the voluntary observing ships program and from drifting and moored buoys.

In terms of the voyage, for ease of analysis, the oceanic regions studied by Maunsell Australia were subdivided into 33 separate zones (see Figure 5.2):

- The Persian Gulf was divided into 4 zones, representing the northern, central and southern regions of the Gulf plus the Gulf of Oman;
- The Red Sea was subdivided into four latitudinal zones, with an additional zone for the Gulf of Aden.
- The open oceanic zones were generally divided into boxes of five-degree latitude and ten-degree longitude, increasing to ten-degree square latitude / longitude boxes south of 10°S where the wet bulb regime was considered more benign.

Figure 5.2: Zones used by Maunsell Australia in studying wet bulb temperatures.



Each of the zones had sufficient data (>1000 points/month) to generate a realistic probability distribution of wet bulb temperature within the zone for each month. Means and standard deviations were calculated for each zone by month and a normal distribution assumed. Over ten years of weather data is now referenced by the HSRA model and the wet bulb temperature used in the model is the 98th percentile most extreme reading during that time (hence, the 2% probability).

To take into account heat generated by the livestock themselves, a thermal model was constructed by Maunsell Australia.

- Animals are constantly generating heat. For example, the metabolic heat production of a 50 kg wether is about 100 watts, or 100 joules per second.
- If all of that metabolic heat were stored in the body, core body temperature would increase at a rate of about 1°C every 30 minutes.
- When an animal is capable of thermoregulating, an increase in body temperature in response to continual metabolic heat production does not occur because the animal loses heat continually to the environment.

Due to the fact that sheep are continually producing metabolic heat, that is lost to the environment via conduction, convection, radiation, and evaporation, the air surrounding the animals will be warmer and more humid than the air outside the ship. The extent to which the deck is warmer and wetter than the outside conditions is known as the wet-bulb-rise, or the delta-T.

Because the heat and water that emanates from the sheep is carried away by the air that exits the deck, the extent to which the deck conditions are warmer and wetter than the outside air depends on the rate that air enters and leaves the deck, that is the ventilation of the deck. The HSRA model uses a value referred to as the Pen-Air-Turnover (PAT) that is a measure of the number of times per hour that the air above a deck is changed. That value is generally calculated from the performance characteristics given by the manufacturer of the fans that are installed on a ship as part of the ventilation system (and is currently being audited for vessels to the Middle East). ALEC recognises that ventilation is a complex subject and differences of opinion exist on what represents the best measure.

The wet-bulb-rise is calculated based on the heat that is generated on a deck and the rate that the generated heat is removed (the PAT). The former is calculated based on the average body mass and number of livestock on the deck and their condition. In general, the higher the PAT, the smaller the wet-bulb-rise.

Through these calculations the probability distribution of environmental temperatures obtained from weather data is shifted hotter by an amount corresponding to the heat output of the animals diluted by the fresh air flow rate (PAT value).

Through this process the left-hand probability distribution shown in Figure 5.1 is estimated. The remaining major task, therefore, is to estimate the right-hand side probability distribution of animal mortalities at various wet bulb temperatures.

5.1.2 Probability distribution of mortalities at various wet bulb temperatures

Given the material contained in Chapter 3 of this submission it is not surprising that Maunsell Australia experienced significant difficulty in parametrising the probability distribution for livestock mortalities due to heat stress. Maunsell Australia note that: *"Although the concepts of 'thermoneutral zone' and 'upper critical temperature' appear to be universally accepted, definition of these particular concepts remains somewhat problematic".* On ALEC's review of the literature, we concur.

Based on available data and justifiable assumptions Maunsell Australia used a skewed beta distribution for animal mortalities (such as shown in Figure 5.1). This distribution had the property that as wet bulb temperatures rise first a small number of animals die, but as temperatures further increase the number of mortalities rapidly rises (see Figure 5.1). As temperatures increase further still all animals die – none survive.

The lower limit of the beta distribution is 33.58°C for a standard adult Merino and 33.17°C for a standard Merino lamb. The upper limit is a theoretical number (being the wet-bulb-temperature at which 100% of animals would be expected to die) and was set at 36.52°C for an adult Merino and 36.29°C for lambs. The mortality limit for an adult Merino was established as 35.5°C and for lambs as 35.2°C. Corresponding values for cattle can be found in the original Maunsell Australia report.

For sheep, the distribution of livestock mortalities was made dependent on breed (Awassi and all other for sheep), age (adults, lambs), weight, condition, coat (shorn, hairy) and acclimatisation. Maunsell Australia note that for studies with populous data sets, a form of multi-variate regression would have normally been applied to estimate the impact of these factors. This, however, was not possible – due to the paucity of data. Instead the fitting of factors to raw data was done manually (scaling).

Despite being based on limited knowledge and a number of assumptions, perusal of mortality investigation reports indicates that the parameterisation of the mortalities probability distribution undertaken by Maunsell Australia has been reasonably accurate. For example, the lower limit of the beta distribution (where animals start dying due to heat stress) for *Bos taurus* beef cattle (standard animal) has been set at a wet bulb temperature of 30.3°C and the upper bound (where all animals have died due to heat stress) has been set at 34.7°C. Similarly, for merino sheep (standard animal) the lower limit of the distribution has been set at 33.6°C and the upper limit at 36.5°C. The mortality investigation reports seem to generally support the lower limits (i.e. where animals start dying due to heat stress) used in the HSRA model.

5.1.3 Solution to the HSRA model

For given weather data, livestock data and vessel data (PAT values) essentially the HSRA model works by adjusting stocking densities until the 98th percentile of the distribution representing wet bulb temperatures for the voyage is equivalent to a 5% probability for mortalities.

5.2 Duration of exposure to high environmental temperatures

A factor missing from the HSRA model is the length of exposure to high environmental temperatures and degree of relief that might stem from periodic exposure to lower temperatures. Most experimental studies show that heat stress builds up *over time* in response to high temperatures[63]. One advantage of land-based facilities, such as feedlots, is that often temperatures cool considerably overnight, thus providing respite.

This deficiency is well known, having been highlighted in the original Maunsell Australia report. Maunsell Australia also carefully explained why they had not taken into account duration of exposure. Including duration entails many complexities, not the least of which is demonstrated in Figure 5.3. If exposure to higher temperatures is long, livestock will die at lower temperatures – so the beta distribution will be flatter (as shown in red in Figure 5.3). For short duration exposures mortalities will occur at higher temperatures and the distribution will be more compressed (as shown by the black line in Figure 5.3). This means that, if duration is to be taken into account, for each wet bulb temperature there will be multiple probability distributions associated with different levels of duration.

Moreover, to take duration into account the probability distribution of possible temperatures for each day of the voyage would have to be calculated, including the diurnal variation in these temperatures. There will no doubt be an association between probability distributions for temperatures on successive days – the distributions will not be independent. These probability distributions would have to be multiplied together to derive information on the probable duration of various temperatures for the voyage as a whole.

Maunsell Australia noted that, possibly, Monte Carlo techniques could be used to derive solutions; but including duration is complex and computationally resource intensive.

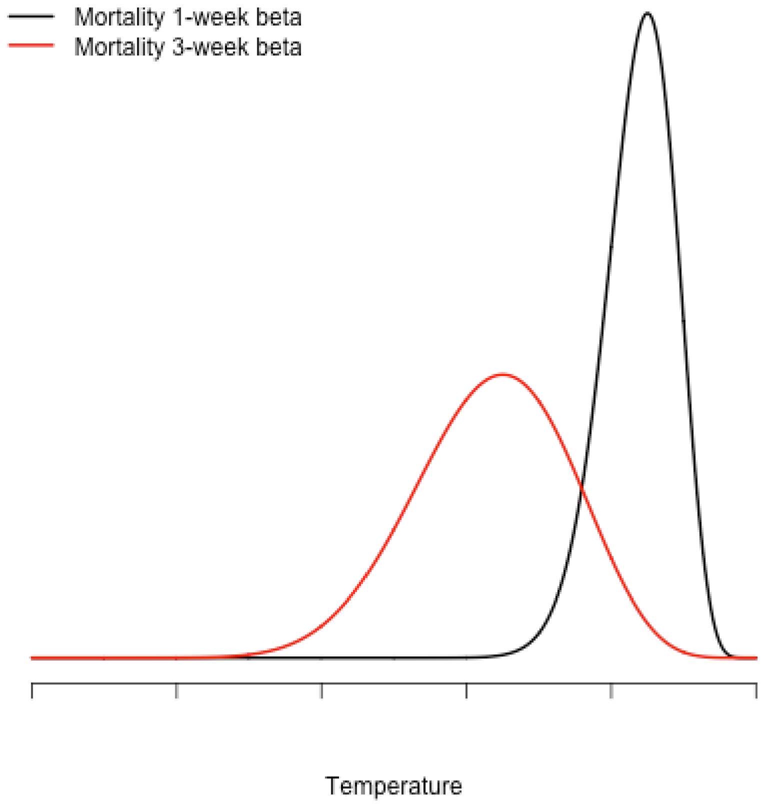
Since the original Maunsell Australia report many authors have criticised the HSRA model for not taking into account duration of exposure. Given this issue was extensively covered in the original

[63] See, for example, Stockman, C.A., 2006.

report, with a complete explanation of why duration was not included, it is surely incumbent on the critics to offer possible solutions as well as drawing attention to the problem.

With advancements in weather data and computer performance a greater possibility exists today of incorporating duration than in 2003. Certainly a greater possibility exists of incorporating duration into the model if mortalities are retained as the objective, rather than some other threshold. However, the challenge associated with this task should not be under-estimated.

Figure 5.3: Probability distribution of livestock mortalities for two different durations



5.3 Independent Review of the HSRA model

In 2008 LiveCorp commissioned an independent review of the HSRA model by the CSIRO and three other researchers.

The review panel concluded that whilst there are limitations in the data, the methodology and assumptions central to the model are sound, reasonable and supported by scientific literature. Several recommendations were made with the aim of either engendering greater confidence in the technical elements of the model or potentially improving the model's accuracy.

The following statements made by the Independent Review Panel are worth noting:

> *"There are obvious animal welfare risks associated with the export of livestock to Middle Eastern countries. Notably, the risk of heat stress on vessels is a major issue particularly during the northern hemisphere summer. The Australian livestock export industry has been proactive in its attempts to develop practical solutions to manage such risks. In 2003, the HotStuff model was introduced to enable livestock exporters to predict the risk of heat stress mortality occurring during a voyage and to identify strategies to minimise these risks. …*

The panel acknowledges that there are deficiencies in the available data used to develop HotStuff, particularly those from animal heat stress studies which explore interactions with factors known to influence the susceptibility of animal mortality due to heat stress. Nevertheless, the best available data have been utilised and the biological assumptions have been revised in light of new evidence. ….

Despite the THI [Temperature Humidity Index] being used more commonly, the developers' decision to use wet bulb temperature as the critical environmental measure for determining risk of heat mortality in livestock on board ships is sound. …

Examination of the total dataset used in LIVE.116 and the initial development of the HotStuff model indicates that while it is not extensive, it provides useful coverage of the key animal types and gives a good indication of the critical wet bulb temperature thresholds. …

Although the dataset of mortality and near-mortality events for livestock in conjunction with wet bulb temperature is useful, each set of data is for a particular class of livestock in terms of body weight, condition, coat or wool length and pre-heat challenge acclimatisation temperature. Accordingly the developers of the HotStuff model have undertaken a scaling procedure from each core dataset in order to estimate relevant ML for such animals at different condition scores, coat lengths and acclimatisation temperatures. For example, the estimated scaling factor for condition score ranges from 0.9 for condition score 1, to 1.2 for condition score 5 for both sheep and cattle. Although these scaling factors are based on estimates, they reasonably reflect existing knowledge that animals in fatter body condition are less heat tolerant. ..

The developers of HotStuff …. have used a skewed beta distribution, rather than a normal (or gaussian) distribution. ….. From a biological perspective, the type of non-symmetric distribution chosen by the developers, with its longer tail toward the lower end of the wet bulb temperature axis, is not unreasonable. This is because in any sample, there are likely to be weaker animals that succumb earlier to heat stress, but there are unlikely to be many animals that can survive beyond certain limits

The data and calculations used in the HotStuff model for identifying the critical values for heat induced mortality and the distribution of the accompanying incidence of mortality are supported by biological knowledge and reasonable assumptions derived from existing knowledge."

5.4 Mortalities have fallen since HSRA was introduced

Since the implementation of the HSRA model there has been a significant reduction in livestock mortality rates (see Figures 5.4 and 5.5). For sheep the rate of mortality during live-export has been decreasing, from around 2.5% in the mid 1990's to less than 1.0% in 2011[64]. The HSRA model has undoubtedly played a large part in this outcome, but it is recognised that there have also been other contributing factors such as the introduction of ASEL, changes to Marine Order 43, improvements in vessels, management practices and changes to the livestock types exported.

[64] Norris, R.T. & Norman, G.J., 2012, *National livestock export industry shipboard performance report 2011*, Meat & Livestock Australia, North Sydney.

Figure 5.4: Live sheep export mortality rates 1988-2017

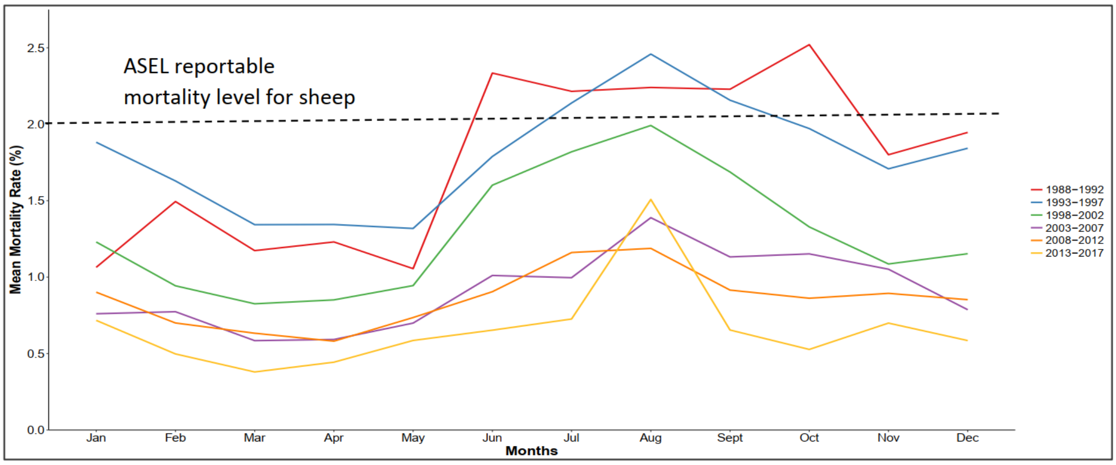
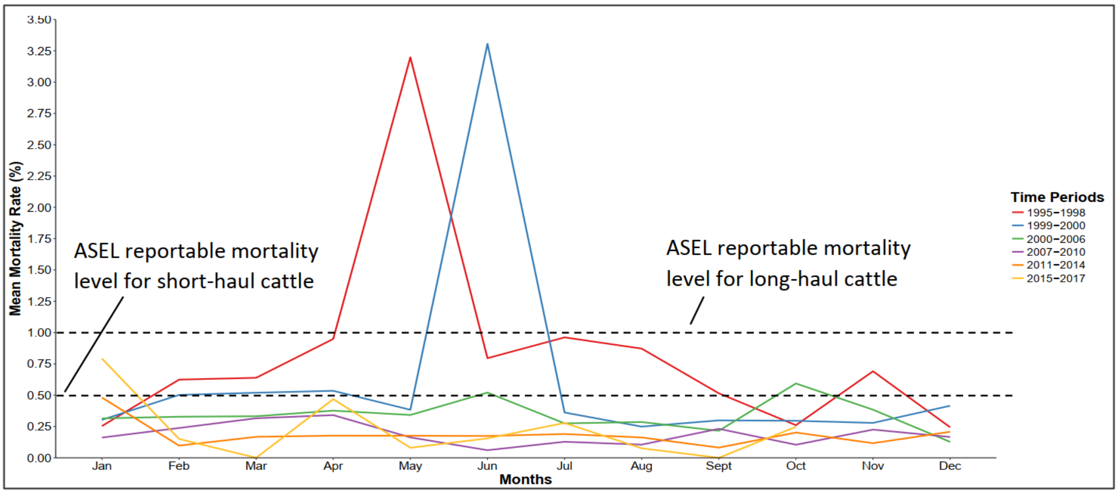


Figure 5.5: Live cattle export mortality rates 1995-2017



5.5 Conclusion

The HSRA model represents ground breaking research. When devised in 2003 it was the first attempt, and is still the only attempt, to place within a coherent risk framework most factors shown to have been relevant live export mortalities due to heat stress. To ALEC's knowledge, in terms of heat stress analysis, the degree of sophistication in the HSRA model has no equal.

The HSRA model has succeeded in its primary objective: to reduce live export mortalities due to heat. Mortalities due to heat stress have fallen for both cattle and sheep. For cattle to the Middle East heat stress no longer represents the most significant cause of mortalities – other factors now dominate[65].

Importantly, the HSRA model allows outcomes to be directly referenced by regulation (i.e. an outcome related to minimising mortalities on a live export voyage). As ALEC has pointed out in the Introduction to this submission, good regulations directly reference an outcome rather than inputs to achieve an outcome.

The whole area of thermoregulation in animals, however, is bedevilled by a lack of knowledge and even contradictory findings. As a result the HSRA model contains many assumptions. Because of

[65] Perkins, N, O'Hara, M., Creeper, J, Moore, J., Madin, B. and McCarthy, M., 2015, Identifying the causes of mortality in cattle exported to the Middle East, Final Report Project W.LIV.0252, Meat & Livestock Australia, Sydney, October.

this it is crucial that outcomes from the model are kept simple and transparent, are not subject to measurement error and that validation can readily occur, unencumbered by the need for interpretation.

6 CHANGING THE RISK OBJECTIVE OF THE HSRA MODEL

6.1 INTRODUCTION

Recommendation 3 of the McCarthy review is: "*Industry should move from a risk assessment based on mortality to a risk assessment based on animal welfare*."

Recommendation 8 from the McCarthy review is: "*A future version of the industry heat stress risk assessment model to be developed, adopted and used by industry during the northern hemisphere summer of 2019 should reassess:*

- *the 'heat tolerance' level*
- *the probability risk settings*."

The Issues Paper notes that: "*Moving to a HSRA based on excessive heat load represents a significant shift from the current arrangements and will have implications for stocking densities*".

According to the Issues Paper the department has established the Technical Reference Panel "*to advise on moving from HSRA based on mortality, to one based on the animal's physiological signs of excessive heat load*".

In this chapter ALEC argues that, until further knowledge is obtained, the HSRA model objective should remain focussed on mortalities. Mortalities provide an easily recognisable, permanent, census level measure of a consignment that captures a wide range of disease, health and welfare issues. Other welfare indicators, by comparison, are open to significantly greater measurement error, involve greater interpretation and often comprise a number of different elements, including qualitative components.

If mortalities are not to be the HSRA objective, any replacement HSRA objective must reference a new variable that can be easily and confidently measured *en masse*. If this is not done the model can never be validated and the accuracy of the model can never be determined, including identifying the circumstances in which the model may be performing well and areas of underperformance. ALEC is unsure what new objective can meet these criteria. Given the information presented in Chapter 3 the objective certainly cannot be rise in core body temperature. Michael McCarthy seems to advocate that the new variable should be "heat stress score"[66]. Heat stress score (HSS) is a multi-factorial welfare measure that includes amongst other things "demeanour". How this variable is correlated with changes in body temperature is entirely unknown. Certainly, as was highlighted in Chapter 3, the degree to which one component of this variable, panting score, is correlated with heat stress has not been satisfactorily verified. Moreover, as will demonstrated in this chapter, there are very significant challenges in measuring just one component of HSS, panting scores, and the potential for bias. Although measurement difficulties in this chapter are mostly demonstrated with respect to panting scores, given the current state of knowledge, measurement uncertainties are likely to exist with any animal welfare measure (other than mortalities).

Quite simply there is not enough knowledge and experience to immediately incorporate an animal welfare objective into the HSRA model. A model incorporating this objective may be very inaccurate; however, because of inherent difficulties in measuring animal welfare outcomes, the

[66] Confusingly heat stress score (HSS), as used by Michael McCarthy, is very different to heat stress threshold (HST) as used by Stockman and others. HSS is a multi-factorial welfare measure that includes amongst other things "demeanour". In contrast HST refers to changes in core body temperature – which has scientific validity, but measurement difficulties (see Chapter 3).

degree of inaccuracy may never be known - indeed, unlike mortalities, it is *impossible* to ever measure animal welfare outcomes with total accuracy.

While arguing that the HSRA model should remain focussed on mortalities, ALEC notes that the risks settings in the HSRA model could be adjusted. For instance, rather than a 2% probability of 5% mortalities, the percentage of mortalities could be adjusted downwards. ALEC also believes that collection of information on a range of animal welfare indicators should commence immediately. As knowledge is gained over time, potentially, information from these indicators could be incorporated into the HSRA model or used in other ways to monitor trade performance.

6.2 DIFFICULTIES IN MEASURING ANIMAL WELFARE

Mortalities are dichotomous (either an animal is dead or alive), objective, irrefutable and easy to measure. Moreover, because of individual animal differences, which are considerable (see Chapter 3), the fact that a small number of animals are dying is an indicator (in itself) that other animals are at various other stages of heat stress. In this sense mortalities represent a proxy for animal welfare conditions generally on the voyage. Through this proxy relationship the level set for animal welfare conditions generally on a voyage can be adjusted by changing the mortalities setting.

In contrast to mortalities, more general measures of animal welfare are continuous (or at the very least polychotomous), subjective (as recognised by Michael McCarthy), multifactorial (animal welfare, if measured properly, consists of many different components which, ideally, should be combined into a single index[67]) and, because of these reasons, inherently difficult to measure.

Michael McCarthy proposed a "heat stress score" as a measure of animal welfare due to heat stress and seemed to suggest that this could be used as the objective of the HSRA model. This score has the attributes shown in Table 6.1.

Table 6.1: Heat stress scores[68]

Heat Stress Score	Panting Score	Respiratory Rate	Respiratory Character	Appearance or demeanour
0: Normal	0: Normal	25-80	Normal	Normal
1: Elevated respiratory rate	1: Normal (elevated RR)	80-100	Increased RR	Normal
2: Heat affected	2: Mild panting	100-160	Rapid RR	Discomfort
3: Onset of heat stress	3: Open mouth panting	160-220	Laboured	Extreme discomfort
4: Severe heat stress	4: Open mouth panting with tongue out	Usually second stage	Extremely laboured	Distressed

The McCarthy HSS is multifactorial which raises the question of score assignment if attributes do not align at a particular level. For example, Stockman notes in some of her experiments that only adult rams had a higher panting score and adult weathers a higher respiratory rate[69]. To address this situation presumably some weightings should be adopted and applied against the individual components, but to the knowledge of ALEC no agreement exists, or research conducted, into these weightings. Furthermore, given the inclusion of "demeanour" as an attribute in the HSS, scoring is

[67] Many animal welfare experts argue that distilling welfare down to a simple index should not be done and represents a misuse of the science.

[68] McCarthy, M., 2018, *Independent Review of Conditions for the Export of Sheep to the Middle East during the Northern Hemisphere Summer*, Department of Agriculture and Water Resources, Canberra, p.19.

[69] Stockman, C.A., 2006, p.166.

likely to be highly subjective. Note from Table 6.1 “demeanour” is described using the following terms: whether appearance is “normal”, whether there are signs of “discomfort”, signs of “extreme discomfort” or signs of “distress”.

Even measuring just one of the components of the HSS, panting score, entails significant difficulties[70]. Panting score is itself multidimensional and embraces the following:

- respiratory rate,
- position of the mouth,
- position of the tongue, and, in the case of Stockman,
- drooling.

It will be demonstrated below that complications arise when considering how measurement of panting would occur in real world situations.

6.2.1 Practical measurement complexities

This multidimensional aspect of panting in itself creates measurement difficulties. The prime difficulty is that there are many things to observe (respiratory rate, position of the mouth, position of the tongue, drooling). Potentially, also, an animal could exhibit some characteristics of a particular panting score, but not others.

There is also a considerable challenge in physically counting the number of animals at various stages of panting. Again the process is complicated given the number of dimensions of panting to take into account, the number of panting scores and the number of animals to count.

- Presumably the process would be to count the number of animals in a pen exhibiting panting at a certain score, say 0, then score 1, score 2, score 3 and score 4. But animals may change their panting behaviour between counting scores.
- Or would the process be to just record an overall impression – it looks as though about 25% of animals in this pen are exhibiting panting score 3, 50% panting score 2, and 25% panting score 1 so, given say 120 sheep in a pen, the observer would record 30 animals for panting score 3, 60 for panting score 2 and 30 for panting score 1?

There is also the question to be confronted of whether all animals in a group should be measured roughly or a few measured precisely. If the former course of action is taken how can it be demonstrated that the measurements are accurate? If the latter course of action is adopted, how should the animals be chosen, how can it be demonstrated that animals are representative, how can abuse of the system (either way) be prevented and how should the findings be aggregated with associated statistical uncertainties. Because mortalities are a census measure, use of mortalities avoids these issues.

6.2.2 Potential bias in counting scores

The complexities of the counting process and the subjective nature of panting score measurement means that bias will almost certainly become a problem. The introduction of bias reduces regulatory certainty and equity. Added to this problem of bias is the fact that panting scores represent a

[70] We note that McCarthy uses a different panting score to Stockman. McCarthy uses the scores: 1=” Normal”, 2=”Normal (elevated repiratory rate)”, 3=”Open mouth panting”, 4=”Open mouth panting with tongue out”. Stockman’s descriptors are as follows: 0=”No panting”, 1=” Slight panting, mouth closed”, 2=” Fast panting, occasional open mouth”, 3=” Open mouth and some drooling”, 4=”Open mouth, tongue out and drooling”. These differences would seem to highlight the measurement problems.

measurement at a moment in time. Before or after measurement is undertaken panting scores may be different. Unlike mortalities panting scores cannot be verified after the fact.

The problem with bias in panting scores has been demonstrated in research experiments. A study by F.A.M. Tuyttens et al.[71], for instance, using veterinary students, showed how animal welfare measurement could be biased by expectations. The study involved several trials, all of which have relevancy to the issue of potential bias, but one trial is of particular relevance – the recording of panting scores.

The experiment involved first training the veterinary students to score the degree of panting in cattle. The students were then shown duplicated video recordings of the same animals: the original video and a slightly modified version (to prevent recognition at second viewing). For both videos the veterinary students (after training) were asked to record panting scores. When scoring the duplicated recordings students were told false information: that the ambient temperature was 5°C hotter than it was in reality. In other trials they were also told false information about the conditions in which the animals had been filmed.

In all trials undertaken by F.A.M. Tuyttens et al. there was evidence of expectation bias. For the panting trial recorded scores were higher when told the false information. The authors conclude: "*Observer expectations may invalidate subjective recordings of behaviour*".

The context in which panting scores are collected on a live sheep voyage and the potential for bias needs to be fully appreciated. The context includes the following:

- The politically charged atmosphere of live exports generally.
- Extreme pressure from animal activists.
- The expectation that an increase in panting scores would precede any reportable mortalities incident (now 1%).
- The inevitability of a published Government investigation if mortalities exceed the reportable threshold in which preceding panting scores would also be examined.

Within this context, in the view of ALEC, the potential for the introduction of upward bias in the scoring of panting is high.

6.2.3 Scoring to take into account duration?

Apart from practical measurement issues and the potential for bias there is yet another problem with animal welfare measures – to obtain an accurate picture duration needs to be taken into account.

Mortalities do not need to take into account duration as part of the metric – an animal is alive until it dies and once it dies it is in that state for ever.

However, an animal is only in a certain welfare state for a period of time. As a result, to accurately measure welfare for animals over a set period (e.g. the length of a voyage) the metric needs to take into account time spent in the various welfare states.

The time related index of welfare also requires weights to be applied to the various welfare states. For example, is it a worse outcome for an animal during a voyage:

[71] Tuyttens, F.A.M., de Graaf, S., Heerkens, J.L.T., Jacobs, L., Nalon, E., Ott, S., Stadig, L., van Laer, E., and Ampe, B, 2014, "Observer bias in animal behaviour research: can we believe what we score, if we score what we believe?", Animal Behaviour, Vol. 90, pp273-280.

- to be at panting score 1 for half the voyage and at panting score 2 for the other half, or
- to be at panting score 0 for 10% of the voyage, to be at panting score 1 for 60% and to be at panting score 2 for 30%?

Of course, it would be possible to disregard duration and to set a simple objective for animal welfare on a voyage, say, *"less than a 2% probability that 10% of animals have a panting score of greater than 2"* (this could be the objective used in the HSRA model). But this simple objective may give an entirely misrepresentative reading of welfare:

- It is surely important, in order to gain an accurate picture of overall welfare, to know the number of animals at panting scores 0, 1, and 2.
- Equally, in order to gain an accurate picture of overall welfare, it is surely important to know the number of animals at panting scores 3 and 4. If all 10% of animals were at panting score 4, this is surely a worse outcome than if they were at panting score 3.
- Finally, and also equally, for those animals above panting score 2, it is surely important to know how long they have been in that state. If different animals are at panting score 3 today than yesterday, surely that matters.

If the response to these issues is that a simple measure and target for panting scores is just a proxy for more complex underlying animal welfare measures and targets, then the same is true for mortalities.

6.2.4 Panting represents only a partial measure of animal welfare

Despite being multidimensional, how an animal is breathing represents only one measure of the welfare implications from heat stress. To accurately measure welfare would require collection of wide array of data. Just like mortalities, panting scores (and for that matter HSSs which also represent a partial measure of animal welfare) might be regarded as a proxy for general animal welfare issues arising from heat stress. Just like mortalities, panting scores (and HSSs) represent only a partial measure of animal welfare.

6.3 Substantial revision of the HSRA model needed to incorporate a welfare objective

Not surprisingly changing the objective of HSRA would mean a substantial overhaul of the model.

Michael McCarthy recommended that the objective of the model be changed from "*2% probability of 5% mortalities*" to "*2% probability of 5% of animals experiencing heat stress level 3*". However, there is no way of directly including this objective in the existing model. Therefore, Michael McCarthy recommended using 75% of the mortality limit instead. The objective of the HSRA model as recommended by Michael McCarthy, therefore, becomes a: "*2% probability of 5% of animals being 75% of the way towards the mortality limit".* Apart from numerous other deficiencies, this objective is unvalidatable.

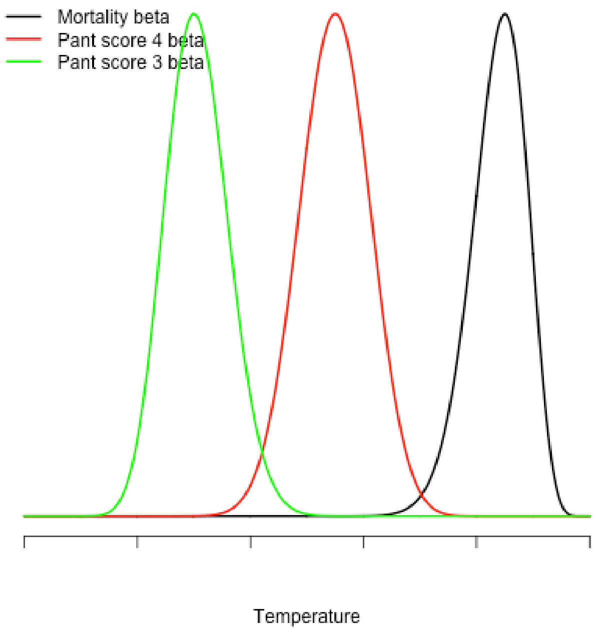
In providing this HSRA model objective recommendation, McCarthy recognises that "*there is no industry specific research that directly correlates this tolerance level [associated with heat stress level 3] to a percentage of the mortality limit*", nor is there shore based experimental work. McCarthy states that he has based the 75% of mortality threshold for the HSRA model "*on extrapolation*", but apart from this provides no explanation of the method used. In light of this, the recommendation of Michael McCarthy to change the HSRA objective to 75% of mortality threshold can be seen to be lacking scientific validation. The recommendation converts risk management to a less well defined, intangible system that is not founded in science.

ALEC rejects the McCarthy solution of simply setting the heat stress as "75% of mortality limit". Outcomes from such an objective would lack scientific rigour and may be quite erroneous – but because validation is impossible the degree of error will never be known. On these grounds ALEC opposes this objective being included in the HSRA model.

If a welfare objective is to be included in HSRA, the model should be substantially redesigned. Just as there is a probability distribution associated with mortalities for various environmental temperatures, so there will be different probability distributions (almost certainly of different shapes) for other animal welfare measures associated with heat stress.

For simplicity we demonstrate these concepts for panting scores (see Figure 6.1)[72]. Also, in the discussion that follows we assume that Michael McCarthy's recommendation on changing the objective of the HSRA model to refer to HSS really is a change to panting scores – since, given the included attributes, HSS is a totally subjective and intangible concept.

Figure 6.1: Probability distributions for different panting scores



There are several points to note from Figure 6.1.

- First, Figure 6.1 throws further light on the McCarthy recommendation to replace the current HSRA objective with a new objective: "*2% probability of 5% of animals being 75% of the way towards the mortality limit*". All this recommendation does is to shift (holus-bolus) the mortality distribution shown in black in Figure 6.1 to the left so that the new mortality limit of this function is 75% of its current value. This is an extremely simplistic approach to the issue. There is no guarantee that with such a shift the black curve will align with the green curve (the distribution for panting score 3). Any alignment is supposition only. Without alignment an arbitrary shifting of the mortalities distribution results in an intangible objective which has no meaning – it does not relate to mortalities or any heat stress level.
- In Figure 6.1, for simplicity, distributions for the two panting scores shown and for mortalities all have the same shape. But there is no reason to assume that the shape will be the same. To the

[72] This discussion could also be applied to body temperatures as an objective if a practical way of measuring this can ever be devised.

contrary, the expectation is that they will be different - mostly likely flatter and with less pronounced tails - making them harder to use in distributions with defined limits (of which the beta distribution is an example). Neither is there reason to believe that that scaling factors used by Maunsell Australia for factors such as breed and acclimatisation will be the same – all will have to be changed. This suggests that the research project to design the new model will be at least as large as the 2003 project – and probably larger (due to the increased complexity associated with animal welfare measures compared to mortalities).

- As previously noted, once different welfare states other than mortalities are used in the model, duration is important. We will not elucidate further on this issue – needless to say, it significantly increases complexity. The need to include duration adds another reason, to the very significant reasons already provided, on why the mortalities distribution cannot simply be shifted holus bolus to the left.

6.4 If the objective in the HSRA model is to change from mortalities to animal welfare should the other settings be changed as well?

In its current formulation the HSRA model is conservative. The settings for the objective (particularly the 2% probability) are conservative. Moreover, the model calculations made within these settings are conservative. In unpublished work the model architect notes the following:

> *"To our knowledge, when past voyages have been analysed in detail, the risk estimate produced by the method is seen to be slightly conservative. That is; the actual risk, when the method is fully complied with, is somewhat below a 2% chance of a 5% mortality".*

An issue to consider is that, if a move is to be made away from mortalities to animal welfare as the model objective, should other settings in the objective also be changed. For instance, is it acceptable for 5% of animals to be panting at some score, or should this be some higher or lower level? Similarly, should be the 2% probability remain or should this be adjusted downwards or upwards.

The point being made is that if a change is to be made to the objective, the totally new objective needs to be justified, not just one part of the objective (e.g. a shift from mortalities to panting or some heat stress threshold). A significant deficiency in the McCarthy Report is that no attempt was made to do this – the matter does not even seem to have been considered.

Ultimately it is ALEC's view that the objective in the HSRA model should be based on community attitudes using a well structured questionnaire and a demographically representative sample. This questionnaire should acknowledge that mortalities are inevitable when dealing with living entities and provide information on mortalities elsewhere in livestock production and in humans due to heat and cold stress as a backdrop to providing any responses on live export.

Gauging community views through the Issues Paper, on a matter that involves substantial individual value judgement, will almost certainly lead to unrepresentative outcomes. This is because passionate parties will be the only parties to respond to the Issues Paper.

6.5 Incorporating welfare through other mechanisms

Notwithstanding the recommended HSRA focus on mortalities, ALEC recognises that there is merit in assessing the animal welfare outcomes on voyages using a broader set of animal welfare indicators than mortalities – and outcomes from these indicators should be considered by the regulator (recognising that any indicators considered by the regulator must be objective and validatable). Our recommendation that HSRA continue to focus on mortalities does not suggest that welfare should not be assessed or is not important. HSRA needs to provide a clear baseline (mortalities), based on objective, irrefutable data. It, however, should be supplemented by a framework based on animal welfare indicators that provides an early warning and prompts continuous improvement. This highlights that HSRA should be regarded as one part of a broader approach to heat stress and welfare management. ALEC members are committed to collecting a range of animal welfare indicators on-board vessels and these being published.

The animal welfare indicators research being conducted by the LEP R&D program is a critical project for the livestock export industry. The project was previously commenced as part of an industry reform proposal initiated by ALEC to develop meaningful indicators of welfare along the supply chain that would move performance measurement away from a focus on mortality, support transparency and reporting to the community, and enable benchmarking of exporters and the industry.

This project is being undertaken by Murdoch University, and, after an initial literature review and survey to identify potential indicators, it is now in the pilot phase where a range of potential measures – including qualitative behavioural assessments – are being piloted and trialled. This project has a final reporting date in 2021. However, along that pathway there are a range of steps that will be rolled out. This includes the adoption by exporters of app-based data collection platforms.

Current regulations require the collection of data on a number of indicators of which mortalities is the only one widely reported. Recognising the importance of immediately expanding the performance measurement of shipments beyond mortality, ALEC has requested that LiveCorp work with the researchers to identify a limited number of indicators to report, focusing on key animal welfare issues, and using data already collected or data that would be immediately possible to collect. Selection of indicators is not an easy task. They need to underpin the collection of meaningful and comparable data - too many indicators will result in ambiguity and a lack of focus, while too few may not allow appropriate coverage of the range of animal welfare issues.

A list of animal welfare measures has been identified on which collection is intended to be tested and then commence with the re-start of shipments to the Middle East. These indicators represent un-validated, yet educated, selections that will be revised as the project gathers and assesses sufficient data to make scientifically valid conclusions. ALEC plans to use the collected information on animal welfare to publicly and transparently report on industry performance.

It is important not to underestimate the amount of work required in establishing animal welfare indicators and what we do not know. Whilst experience is being gained with the use of indicators they are best regarded as an early warning system, prompting continuous improvement, rather than acting as a sole referee. Things we don't know about animal welfare indicators on-board vessels include:

- What are the best welfare things to measure
- When does 'heat distress' begin
- What and when is 'distress' excessive (triggers)
- How easy and reliably can welfare be measured?
- How should combined data be analysed and interpreted?

Gaining knowledge on these aspects - and more - represents a very large research project.

Collection of such data is a prerequisite to any change in the HSRA model. Over time, as data on these indicators is collected, information might be used to improve the HSRA model. Even if this does not occur, collection of data on animal welfare indicators will allow the regulator to take a broader view of animal welfare than provided mortalities alone.

6.6 Conclusion

In the area of heat stress impacts on animals (and, to a lesser extent, on humans) there seem to be many more “known unknowns” and “unknown unknowns” than “known, knowns”. A reformulation of the HSRA model towards an animal welfare objective would firmly plunge model outcomes into the territory of “known unknowns” (since understanding of animal welfare is embryonic) and even “unknown unknowns (depending on the weight given to all the measurement difficulties listed in Section 6.1), creating uncertainty for the regulator and industry.

Commentary and science is required behind the desire to move away from a simple mortality threshold in the HSRA model towards an animal welfare threshold. If a welfare-based index is to be used, then an appropriate easy-to-understand threshold that also can be easily validated will be required. This needs to be carefully described and agreed. Any new measure must be simple to collect and explain, robust, reliable and repeatable. Use of mortalities conforms to all these criteria.

This consideration also needs to demonstrate clarity around the objective of a risk model versus the value of measuring and meeting animal welfare objectives generally.

The size of the research task in any reformulation of the HSRA model to an animal welfare objective is gargantuan. It is simply not scientifically acceptable to arbitrarily nudge a probability distribution holus-bolus this way or that way to obtain a different outcome. Rather, if a new objective is to be adopted, new probability distributions must be researched and defined. ALEC submits that the Technical Reference Panel would be best served by defining this research work rather then attempting to identify answers within an impossibly short time period.

ALEC recommends that no radical changes be implemented to the HSRA model until a new objective has been identified and tested that is simple to collect and explain, robust, reliable and repeatable. Until a new measure has been identified, scientifically validated and tested, the HSRA objective should remain focussed on mortalities. While maintaining this focus it would be possible to lower the current 5% mortality setting in the objective.

7 Economic Implications of Options Included in the Issues Paper

Use of a high k-value in the allometric equation or use of a heat stress risk assessment with inappropriately conservative settings will impact on stocking densities on live export voyages.

The impacts to the industry and to producers from any change to stocking densities are significant, as it is the primary determinant of productivity for transport purposes.

Table 7.1 provides information on changes in freight costs for a number of typical live export voyages from Australia using current ASEL stocking densities (for November to April) and those that would apply using the allometric equation with k-values of 0.027 and 0.033. Underlying Table 7.1 is extensive information on livestock weights on each of these voyages, current shipping costs, typical vessel sizes and a range of other data. The table does not consider the influence of the HSRA model on stocking densities and hence freight costs.

It can be observed from Table 7.1 that, even using a k-value of 0.027, freight costs significantly increase – particularly for sheep voyages and longer cattle voyages (compared to the current ASEL stocking densities). For these voyages freight cost increases of 10% or more are not uncommon.

Using a k-value of 0.033 causes freight costs to increase by a huge amount for all voyages included in the table – with costs increasing by up to 39%.

The cost information in Table 7.1 has been combined with average shipment volumes by market for the period 2014/15 to 2017/18 and other cost information (for voyages not considered in Table 7.1) to estimate the total cost increases from changes to stocking densities. The total cost estimates also take into account seasonal shipment patterns and different stocking densities currently applying under ASEL by season.

- Using a k-value of 0.027 the additional costs imposed on the industry would be $16.8 million per annum.
- Using a k-value of 0.033 the additional costs imposed on the industry would be $99.9 million per annum.

Particularly for a k-value of 0.033, in a number of markets the increase in the landed price of Australian livestock, resulting from reduced stocking densities, is likely to render the market uneconomic or result in reduced trade.

In this context it is to be noted that in Indonesia the trade in Australian live cattle is now under severe pressure from Indian buffalo meat. Elsewhere, in the Middle East, North Africa and Tukey, fierce competition exists from EU and South American cattle suppliers and European sheep suppliers - this competition has intensified over the last decade. Any significant new impost will affect Australia's competitive position in these markets. In general competitor countries provide space allowances less than those calculated allometrically with a k-value of 0.027 (see Tables 2.1 and 2.2) – with South American countries having no regulated allowances.

In considering these cost imposts it is important to appreciate that freight rates are currently at low levels historically. Two years ago freight rates were more than 50% higher than they are now – there is evidence that freight rates will increase again in the near future. If the freight rates of two years ago are used a k-value of 0.027 would increase costs by over $30 million and a k-value of 0.033 would increase costs by close to $200 million.

Table 7.1: Impact of changes in stocking densities on freight costs

Voyage / change in stocking densities	Freight cost increase Per head	
	$AUD	%
Indonesia cattle (Darwin to Jakarta)		
ASEL to allometric, k=0.027	$3.67	2.8%
ASEL to allometric, k=0.033	$33.99	25.6%
Vietnam - Cattle (Townsville to Hai Phong)		
ASEL to allometric, k=0.027	-$8.09	-2.9%
ASEL to allometric, k=0.033	$52.77	18.7%
China - Slaughter Cattle (Portland to Tianjing)		
ASEL to allometric, k=0.027	-$21.60	-4.3%
ASEL to allometric, k=0.033	$85.87	17.0%
China - Breeder cattle (Portland to Tianjing)		
ASEL to allometric, k=0.027	$7.79	1.9%
ASEL to allometric, k=0.033	$99.44	24.6%
Israel - Cattle (Fremantle to Eilat)		
ASEL to allometric, k=0.027	$20.19	4.9%
ASEL to allometric, k=0.033	$115.82	28.2%
Russia - Cattle (Portland to Novorosyk)		
ASEL to allometric, k=0.027	$12.38	2.8%
ASEL to allometric, k=0.033	$114.72	25.6%
Middle East - Sheep (Fremantle to Kuwait)		
ASEL to allometric, k=0.027	$7.00	13.3%
ASEL to allometric, k=0.033	$20.22	38.5%
Turkey feeder cattle (Fremantle to Mersin)		
ASEL to allometric, k=0.027	$22.17	5.6%
ASEL to allometric, k=0.033	$114.61	29.1%
Turkey Sheep Based on double tier decks combined with a cattle shipment (Fremantle to Mersin)		
ASEL to allometric, k=0.027	$8.46	13.3%
ASEL to allometric, k=0.033	$24.44	38.5%

It is impossible to come to a conclusion about the impacts flowing from a change to the HSRA model without definitive information about those changes, but the information already provided can be used as a guide.

Significant changes to stocking densities for Australian livestock exports will impact not only on live exporters but also producers. Work done for the Meat Industry Strategic Plan showed that closure of the live export trade would cost producers $8.0 billion in Net Present Value terms to 2030[73]. ALEC understands that a closure of the trade is not being contemplated, but substantial reductions in stocking densities would affect viability. Any cost impacts from a reduction in the viability of the trade would fall disproportionately on producers in north Australia and Western Australia.

Annually, the live sheep export trade comprises of around 30% of the Western Australia sheep and lamb turnoff. Some assert that these sheep currently being sold by producers to live exporters could

[73] Centre for International Economics, 2015, *Meat Industry Strategic Plan 2015-20: Quantifying the Payoffs from Collaborative Investments by the Red Meat Industry*, Report prepared for the Red Meat Industry Council, September.

instead be used for wool production and then processed in Australia. But analysis undertaken by Mercado[74] noted that "*suggestions that the additional 1.6 million head of sheep per annum currently heading offshore as live exports from WA could be kept until cast for age to be cut for wool is impractical*"[75]. Mercado concluded that cessation of the live sheep trade could see prices decline between 18-35%.

ALEC notes that the Western Australia live sheep trade has now been dormant for several months and during this time price spreads between western and eastern markets for lamb and sheep have turned unfavourable for Western Australia producers. In mid-August Mercado reported that saleyard price spreads had moved adversely for Western Australia producers by an average of over 200¢ from April to July – the period (at that stage) over which the live sheep export trade had ceased operating[76]. This demonstrates that the estimates produced in the Meat Industry Strategic Plan and by Mercado in April on impacts on producers are more than theoretical – they are real impacts.

[74] Mecardo, 2018, *Live Sheep Export – Brief Report*, Report prepared for Western Australia Farmers Federation with support of Sheep Producers Australia, April.
[75] Ibid, p5.
[76] Mecardo, 2018, "A reversal of fortune for WA producers", Mecardo Market Analysis, http://www.mecardo.com.au/commodities/sheep/analysis/a-reversal-of-fortune-for-wa-producers.aspx.

8 Answers to Questions Included in the Issues Paper

In previous chapters of this submission answers have been provided indirectly to many questions posed by the Technical Reference Panel in the Heat Stress Risk Assessment Issues Paper. In this chapter we attempt to provide direct answers to questions asked by the Panel – by referring to previously provided information or by supplying new information. A number if the questions posed by the Panel require a high degree of scientific expertise to appropriately answer. ALEC does not possess this expertise, but has approached experts well known to the Panel who do possess such expertise. A number of the answers below rely heavily on this outside expertise.

8.1 Questions asked in Chapter 3 of the Issues Paper

How should the effects of heat on animals be defined?

Core body temperature is an excellent physiological indicator for the onset or degree of thermal stress in animals, with increased core temperature indicating that heat gain is exceeding heat loss – see discussion in Chapter 3 of this submission. As highlighted throughout the submission, however, particularly Chapter 3 there are significant issues associated with measuring body temperature in operational environments – these issues being compounded by substantial variation between animals.

How would you detect heat load in the animal? (How is the animal acting?)

An expert consulted by ALEC provided the view that:

> *"'Heat load' is a nonsense term in the context of the thermal balance of an animal - it is variously trying to mean 'high core body temperature' or 'hot ambient conditions'. The flow of heat is not into the animal, so in that sense there is no heat 'load'. The flow of heat is out of the animal, and core temperature rises when the ambient conditions are such that the animal cannot reject its metabolic heat at the core temperature it prefers. As a term, 'heat load' is at best undefined, and at worst, misleading. It should not be used".*

To ALEC's knowledge no scientifically validated barometer exists that relates an animal's observed behaviour to the degree of heat stress. Panting is the measure most often cited but has problems (see discussion throughout this submission, but particularly Chapter 3 and Section 6.1). ALEC could find no study that correlated panting scores with changes in core body temperature. Stockman and Barnes et al. had this information available in small experimental studies, but did not report it. In any case these studies were conducted with a handful of animals - large scale studies would be needed in order to secure scientific validation.

The industry, through LiveCorp, has a number of projects underway to improve data collection on animal welfare indicators and on the environmental measures that may give rise to heat stress. Over time these projects should provide data in sufficient quantities to allow greater knowledge of animal welfare and heat stress issues.

What level of heat load is tolerable/acceptable? (Considerations might be: What can a sheep's body temperature be before the animal starts to suffer heat stress? / What are the signs the sheep is too hot?)

In ALEC's view it is clearly unacceptable for livestock:

- To die in significant numbers due to heat stress (or cold stress);
- To suffer permanent damage in significant numbers due to heat stress (or cold stress).

These measures have the advantage that major measurement problems are avoided (verification is possible after the event). These measures will also be correlated with underlying measures of welfare for all animals on a voyage (see Section 6.1).

Below these levels the answer to this question is totally dependent on individual value judgement.

Ultimately the community must determine what is tolerable / acceptable in terms of animal welfare standard (see Section 6.3 of this submission) – and very substantial variations will exist between individuals. In animal welfare science has a role to play, but value judgements are also important.

As Hugh Millar has noted[77]:

> *"… animal welfare is necessarily both science-based and values-based. In that sense animal welfare is like some other difficult public policy areas charged by often vocal individual and collective opinions – such as environmental sustainability – where the tools of science are used within a framework of values.*
>
> *In other words, animal welfare, though quite amenable to scientific study, is also founded in values based ideas about what people believe to be more or less desirable. There is no 'absolute truth'.*
>
> *….Indeed the frameworks can be seen as representing a spectrum, from a strongly science/evidence-based approach (biological functioning) to a currently more values-based approach (affective states), in which ethical judgements (moral values) will be increasingly brought into play."*

However, community input into setting standards for animal welfare needs to be carefully obtained. Seeking advice through the Issues Paper on a matter that involves substantial individual value judgement will lead to potentially unrepresentative outcomes. This is because passionate parties will be the only parties to respond to the Issues Paper.

As noted in Chapter 6, if community input is to be obtained this should be via a well structured questionnaire using a demographically representative sample. This questionnaire should provide information on mortalities elsewhere in livestock production and in humans due to heat and cold stress as a backdrop to providing any responses on live export.

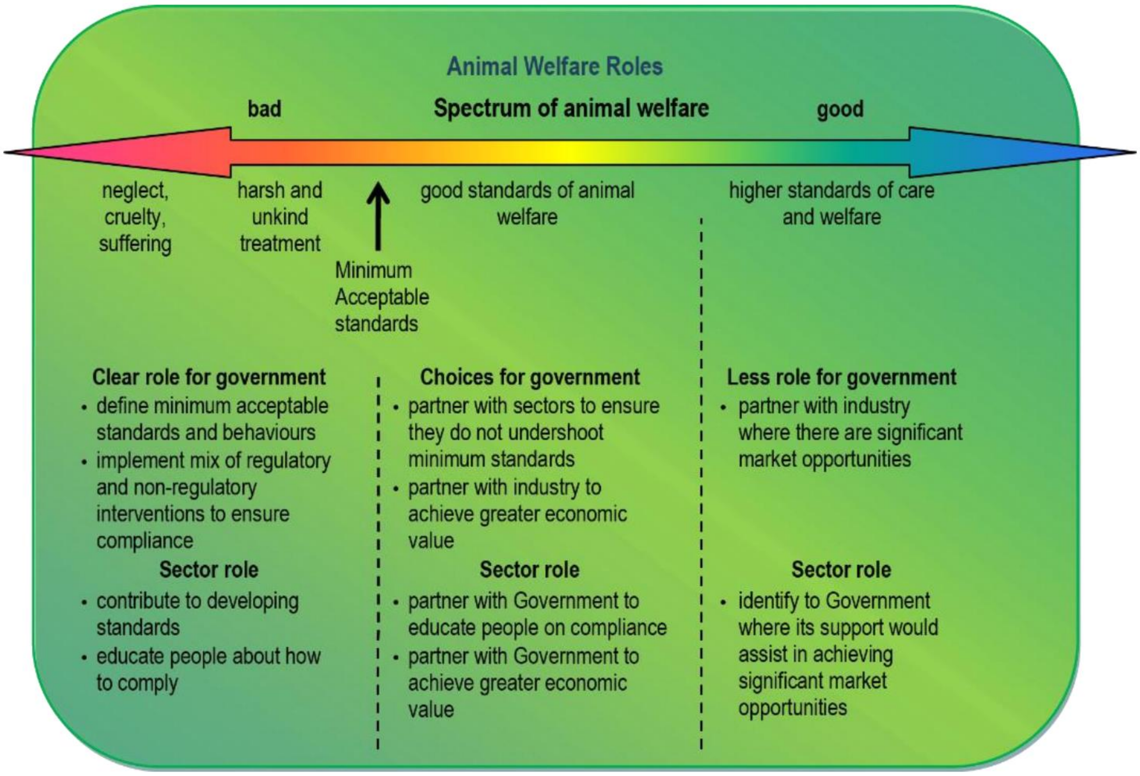
There must also be regulatory consistency around setting animal welfare standards and the degree of regulatory oversight (refer to the Introduction). In this regard the discussion in Chapter 3 provides guidance – by providing some insight into heat and cold stress issues in other areas of livestock production and for the human population.

Within a framework of consistency, boundaries for a regulatory role need to be carefully considered. The policy approach adopted by New Zealand, as espoused in its animal welfare strategy, is worthy of consideration (see Figure 8.1). This approach recognises that there is an animal welfare spectrum, with cruelty/ suffering/neglect and harsh treatment being at one end, and high standards of care and welfare at the other end of the spectrum. The greatest role for Government is in defining and regulating ***minimum acceptable standards*** of animal welfare. Higher standards of animal welfare, however, should be left to industry and commercial players. This framework suggests that the

[77] Millar, H, 2018, A Review of Animal Welfare Policy and Assessment Frameworks, *Final Report Project 1HS802*, Australian Eggs Limited, Sydney, July.

regulation of animal welfare due to heat stress should be confined to outcomes that are clearly unacceptable.

Figure 8.1: Animal Welfare Roles[78]



Are the model standard Merino estimates for heat stress threshold (30.6°C WBT) and mortality limit (35.5°C WBT) appropriate/accurate or are there other estimates, supported by the available science that should be considered?

In the view of ALEC heat stress must be measured through changes in core body temperature (refer to discussion in Chapter 3 of this submission). There is then a need in the HSRA model to relate this to WBT and define a mortality limit. It is clear from an examination of the material in LIV.212, but also from the work of Stockman, amongst others, that significant individual differences exist between livestock in the ability to thermoregulate (see discussion in Section 3.4) as WBTs increase.

At the time the HSRA model was constructed all available science was sourced, using international and Australian veterinary and animal science researchers to assist. From a review by ALEC of subsequent studies, no compelling reasons exist to change the heat stress threshold and mortality limit. As has been highlighted throughout this submission, proper data are surprisingly few and far between.

As has been described in Section 5.1.2 of this submission the "base" mortality limits and HSTs are parameters for the beta distribution. The upper and lower limits of the beta distribution are also described in this section. For the mortality limit of 35.5°C quoted above, the corresponding minimum and maximum are 33.58°C and 36.52°C. That is; in a sufficiently large sample, for a

[78] New Zealand Ministry for Primary Industries, 2013, *Animal Welfare Matters – New Zealand Animal Welfare Strategy*, http://www.mpi.govt.nz/news-resources/publications.aspx.

standard animal recording of some mortalities would commence at a wet bulb temperature of only 33.58°C. All animals would have died at a WBT of 36.52ºC.

As has been explained in Chapter 5 of this submission, the beta distribution for mortalities is scaled by many factors including acclimatisation, coat / wool length, weight, fat score breed and age, each of which can have a substantial impact on the mortality limit. The fact that the mortality limit for a standard merino is 35.5 does not mean that it is this for a specific sheep.

Are there other physiological indicators linked to the effects of excessive heat on sheep that could be measured and considered for inclusion in the HSRA model?

In the view of ALEC mortalities should remain as the objective of the HSRA model. Reasons for this conclusion have been explained extensively in Chapter 6. ALEC's recommendation that HSRA continues to focus on mortalities, however, does not suggest that welfare should not be assessed or is not important. HSRA needs to provide a clear baseline (mortalities), based on objective, irrefutable data. It, however, should be supplemented by a framework based on animal welfare indicators that provides an early warning and prompts continuous improvement. This highlights that the HSRA should be regarded as one part of a broader approach to heat stress and welfare management. ALEC members are committed to collecting a range of animal welfare indicators on-board vessels and these being published.

What animal welfare indicators could be considered in assessing the effects of heat on animals?

Murdoch University is involved in a current animal welfare project for LiveCorp that is exhaustively looking at possible animal welfare indicators generally, including those related to heat stress. In response to this question the Panel is referred to the work being undertaken with this Project (of which Associate Professor Ann Barnes is familiar).

8.2 Questions Asked in Chapter 4 of the Issues Paper

How should the probability settings used in the HSRA model be determined?

The probability settings should be based on three considerations:

- Regulatory consistency (refer to the Introduction in this submission and the material in Chapter 3).
- Community attitudes – perhaps elicited through a well-constructed questionnaire based on a representative demographic sample (see Section 6.3).
- Statistical certainty.

The probability settings also should not be determined independently of other settings – they all combine to achieve a certain outcome (see Section 6.3).

On the grounds of statistical certainty there is an argument that the probability setting should not be below 2%. Depending on the objective chosen for the model there may be grounds for increasing the probability setting.

How might the change from mortality to heat load be incorporated in the mathematical model?

ALEC has been informed by experts that this question is "misguided". As described in a previous answer, the expert consulted by ALEC is of the view that "heat load" is a "nonsense term" – it is a parameter that does not exist.

ALEC is firmly of the view that, if mortalities are to be rejected as the objective, any new HSRA model objective must reference another measure that allows the model to be validated. If this is not done the degree of error in the model will never be known.

It would be theoretically possible to change the model to reference a variation in body temperature. But, as noted in Chapter 3, the challenges of measuring body temperature in real world settings are substantial, particularly given high variability in base temperatures between individual animals.

Because of the practical difficulties of measuring core body temperature, a number of studies suggest use of panting scores (see Section 3.1). Again, however, there are very substantial problems with this measure which are covered in Sections 3.1, 3.4 and 6.2.

The size of the research task in embedding an entirely new objective in the HSRA model should not be under estimated – it is gargantuan. It is simply not scientifically acceptable to arbitrarily nudge a probability distribution for mortalities, holus-bolus, this way or that way to obtain a different outcome. Rather, if a new objective is to be adopted, new probability distributions must be researched and defined. ALEC submits that the Technical Reference Panel would be best served by defining this research work rather than attempting to identify answers within an impossibly short time period.

ALEC recommends that no radical changes be implemented to the HSRA model until any new objective has been identified and tested that is simple to collect and explain, robust, reliable and repeatable. Until a new measure has been identified, scientifically validated and tested, the HSRA objective should remain focussed on mortalities. While maintaining this focus it would be possible to lower the current 5% mortality setting in the objective.

What other probability settings might be considered for inclusion in the HSRA model and on what basis?

See above and discussion in Chapter 6.

How can allometric stocking densities most effectively be used?

Two methods have been identified in the Issues Paper and elsewhere for determining stocking densities:

- One method involves the use of an appropriately calibrated heat stress risk assessment model.
- The other method involves using the allometric equation with an appropriately set k-value. In

These two methods are directed at meeting two quite distinct objectives:

- The heat risk assessment is aimed at setting stocking densities so that the risk of animals dying or unduly suffering from heat on a live export voyage is minimised to a certain risk level.
- The allometric determination of stocking densities is to ensure that sufficient space is provided to meet the basic behavioural and physiological needs of animals whilst being transported.

The second objective applies to all voyages irrespective of whether there is a risk of heat stress. Because of this the allometric equation, with an appropriately set k-value, should be used to determine minimum space allocations - to meet the basic behavioural and physiological needs of animals. If heat stress is a proven risk for a particular voyage route, a heat stress risk assessment should be undertaken. The final determination of space allocations should be the ***maximum*** of the space allocations as calculated from the allometric equation and from the heat stress risk assessment.

What k-value (constant) should be used in the allometric equation, and what is the scientific basis for this choice?

ALEC recommends that on-board stocking densities for all voyages be determined using a k-value of 0.027. Extensive justification for this k-value is provided in Chapter 2.

ALEC recognises that space allocations greater than this may result from a consideration of heat stress risk (see other material contained in this submission), but space allocations due to heat stress need to be independent of space allocations from allometry (the two should not be confused). Additional space allocations to avoid heat stress should be separately determined via application of an appropriately calibrated heat stress risk assessment (HSRA) model.

How might potential duration and repeated exposure to high heat loads be incorporated into the HSRA model?

A discussion of this issue is contained in Section 5.2.

It is to be noted that the original Maunsell Australia report quite clearly stated that: "*An early ambition for the statistical assessment was to allow, in the estimation of risk, for duration of exposure*". It then went on to report why this "*early ambition*" was not realised.

As noted in this submission, many authors have criticised the HSRA model for not taken into account duration of exposure. Given this issue was extensively covered in the original Maunsell Australia report, with a complete explanation of why duration was not included, it is surely incumbent on the critics to offer possible solutions as well as drawing attention to the problem.

Reasons provided by Maunsell Australia for not proceeding with the incorporations of exposure duration in the model were:

- A far more sophisticated model of the weather involving comparison of weather time scales and ocean zone transition time scales would be required.
- The statistics then would most probably require a Monte-Carlo type simulation for each stocking entry as it was completed, requiring significant computing.

Furthermore, for voyages to the Middle East the benefits of including exposure duration may not be substantial because WBTs are relatively constant.

It is to be noted that the Independent Review of HSRA stated that:

> *Although the model does not take duration of heat exposure directly into account, this is a reasonable position given that the temperature and humidity conditions when at their worst are unlikely to fluctuate greatly over a short time, the relative conservatism of the model in seeking to safeguard animal welfare, and the possibility of introducing greater error by attempting to build in duration of stress.*

With advancements in weather observations and computer technology it may now be possible to include duration in the model – but the complexities (including conceptual complexities) remain significant.

If use of the HSRA model were ever to be extended beyond the Middle East, the importance of including duration would increase. The same applies if the objective of the model was ever to move from mortalities to some other measure of animal welfare.

How might minimum daily temperatures be factored into the HSRA model?

This issue is referenced in Section 5.2.

How might multiple discharge ports be taken into account when assessing heat stress risk?

The model currently assesses the voyage and port heat stress risks to the first port. This reflects the fact that once unloading has occurred the sheep are generally stocked at a rate lower than originally loaded. In light of this it would need to be demonstrated that multiple port discharges represented a significantly increased risk.

If multiple port discharges were demonstrated to represent significantly increased risk, a possible approach would be to undertake a second HSRA assessment to the second port, with the stock spread out as expected after the first port. This approach would not incorporate any benefit or after-effects of any potential exposure up until the first port, but would capture the port risk reasonably if that is the controlling risk for the second port. The same approach could be taken for subsequent ports.

Depending on the nature of the increased risk demonstrated it may also be possible to incorporate multiple port discharges more simply into the model.

What elements or factors contribute to good ventilation performance on a vessel?

Refer to reports LIVE.211, LIVE.116 and LIVE.212.

How might ventilation performance be incorporated into the HSRA model?

Ventilation performance *is* incorporated into the HSRA model (see Section 5.1.1). The incorporation of ventilation in the HSRA model, including possible improvements, is comprehensively covered in the original Maunsell Australia report and in preceding and subsequent reports. The Panel is particularly referred to LIVE.211, LIVE.116 and LIVE.212.

As noted in Chapter 5, ALEC recognises that ventilation is a complex subject and differences of opinion exist on what represents the best measure. However, the use of PATs was explained and justified by the architects of the HSRA model. ALEC is open to suggestions of scientifically valid improvements that could be made to ventilation measures – some members have commented on the complexity of the PATs and lack of general understanding. Any changes, however, would require changes to the model itself (since the model is currently calibrated around PATs).

PAT is the ratio of the ventilation flow (typically in m^3 /hour or m^3 /second) to the pen area in the ventilated section (in m^2). PAT has the dimensions of a velocity and can be most conveniently written in metres per hour (m/hr). The PAT value can be related to the dimensions of the livestock housing as follows: if the fresh air could be introduced evenly through the floor of each pen and be extracted evenly through the ceiling above each pen, then the vertical air velocity through the floor and ceiling would be the PAT.

Because of the relationship between animal weight and stocking density and between liveweight and the production of heat and CO^2, PAT is a direct measure of the average effectiveness in controlling heat and pollutant build-up. On vessels monitored for the 2001 ventilation study report, PAT fell in the range of 100 to 300m/hr. The traditional measure ‘air changes per hour’ relates flow to deck volume. With the same stocking density and heat load, a space with twice the deck height requires twice the flow to have the same ‘air changes’. This treatment of deck height is the principal reason why ‘air changes per hour’ is not as relevant as PAT.

It has been a recommendation for some time that independent PAT audits be conducted and following the Awassi Express incident, ALEC, McCarthy and the Department all agreed to implement this as a requirement for ships using the HSRA for sheep exports.

How might we ensure ventilation design delivers efficiency/performance/output requirements?

See references above.

How should open decks be treated for the purposes of assessment in the model?

Recent changes implemented by the Australian Maritime Safety Authority (AMSA) will require open decks to be ventilated as per closed decks from 1 January 2020. LiveCorp / MLA intend to change the model to remove the current open deck cross-wind ventilation calculations and use the closed deck calculations for open decks concurrent to the AMSA Marine Order changes.