Heat Stress Risk Assessment

Draft Report by the Independent Heat Stress Risk Assessment Technical Reference Panel

December 2018

Thank you for your interest in the Heat Stress Risk Assessment (HSRA) review.

This draft report outlines a number of recommendations for moving from HSRA based on mortality to one focused on animal welfare. As required by this panel's terms of reference, the recommendations are focused on recommendations 3–5, 7 and 8 of the review into the export of live sheep to the Middle East during the northern hemisphere summer (McCarthy review).

In forming recommendations, we have:

– considered submissions provided during a previous HSRA issues paper consultation process

– undertaken consultations with industry groups

– drawn on available research.

We are now keen to share these draft recommendations with stakeholders, and are particularly interested in receiving any new information relevant to the key issues underpinning these recommendations.

We look forward to hearing from you.

Technical Reference Panel
Heat Stress Risk Assessment Review
December 2018

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1 Executive summary

Under the Australian Standards for the Export of Livestock (ASEL) the regulator requires a heat stress risk assessment (HSRA) to be completed for any livestock export shipment to and through the Middle East. The model alters stocking densities based on the time of year and other factors in order to allow sufficient space for airflow and heat removal from livestock vessels.
The current estimated risk for a voyage must be below a 2 per cent chance of a 5 per cent mortality event.

The technical reference panel was established to provide advice to the Department of Agriculture and Water Resources (the department) on the assessment of heat stress risk in the live sheep export trade from Australia to the Middle East during the northern hemisphere summer. The panel undertook consultation and testing of analysis of the HSRA-related recommendations arising from the independent review on the conditions of sheep being exported to the Middle East (McCarthy review)

In developing advice for the department, the panel circulated an issues paper containing questions about heat stress risk assessment in the live sheep export trade. The panel considered public submissions and responses to the issues paper. We also reviewed available research and information on the HSRA model, livestock heat stress physiology and animal welfare, ship board ventilation and other relevant material including a literature review on the topic.

The HSRA model incorporates weather data, livestock data (species, breed, age, weight, body condition, coat length, month and district of origin) and vessel data (ventilation values) in determining the risk of mortality for export voyages to the Middle East and estimating any required increase in space allowance. The probability of animal mortality is described statistically as a function of wet bulb temperature (WBT) by a distribution which is a function of the animal's characteristics.

On board a livestock vessel, the conditions on decks are typically hotter than the weather outside, due to the release of animal body heat. Once a loaded ship is enroute and meets conditions where the ambient WBT exceeds the threshold at which mortality increases, apart from changing route to seek cooler conditions, there is relatively little that can be done to alleviate heat stress to the sheep on board.

The WBT has been used as a measure combining dry bulb temperature and relative humidity to indicate the capacity of livestock to lose heat. The WBT has been shown to be the most useful combination measure related to heat loss/stress in a shipboard environment. If there is effective ventilation, the hot and saturated air is blown away from the animals, this provides capacity for both convective and evaporative cooling.

The panel recommends the incorporation of a WBT-related animal welfare limit into the model, in accordance with the McCarthy report. The proposed welfare limit takes account of animal characteristics such as sheep class, weight, acclimatisation, body condition and fibre length. This

WBT is selected to minimise the risks to the welfare of the sheep, recognising that a sheep's welfare is adversely affected well before mortality occurs.

The WBT welfare limit is recommended to be 28°C for a standardised Merino wether sheep of 56 kg adult, body condition score 3, zone 3, winter acclimatised, and recently shorn. It is recommended to be used prospectively in planning voyages as a limit, whereby there would be a 98 per cent probability that the deck temperatures the sheep would be exposed to during a planned voyage would remain at or below the WBT welfare limit.

This limit conforms closely with the heat stress threshold derived, but not currently utilised, in the industry heat stress risk assessment model. This provides a straightforward means of implementation, including calculated adjustments within the model for different classes of sheep based on breed, bodyweight, body condition, wool length and acclimatisation.

2 Recommendations

1. That in moving from a heat stress risk assessment (HSRA) framework focused on mortality to one focused on animal welfare, we recommend wet bulb temperature (WBT) should be used as the criterion to ensure exported sheep do not suffer poor welfare outcomes due to excessive heat load. This is the best criterion because WBT most closely influences the physiological impacts of heat load on the animal, and because there is more data available documenting animal responses to varying WBTs than for other criteria.

2. The recommended WBT limit for a standardised shipper sheep (56 kg adult Merino wether, body condition score 3, zone 3, winter acclimatised, recently shorn) is 28^{o}C. This threshold is based on the data evaluated by the panel that consistently indicates an unrelenting challenge to homeostasis once sheep are exposed to WBTs above this value. This limit conforms closely with the heat stress threshold derived, but not currently utilised, in the industry heat stress risk assessment model. This provides a straightforward means of implementation, including calculated adjustments within the model for different classes of sheep based on breed, bodyweight, body condition, wool length and acclimatisation.

3. In incorporating Recommendation 2 into the HSRA model, it is recommended that the 28^{o}C WBT welfare limit (once adjusted for sheep class, weight, acclimatisation, body condition, fibre length) be applied as a vertical line to intersect with the 98 per cent point on the distribution of deck WBT probabilities throughout the voyage.

4. The base stocking density to be used for each class of sheep, that is then subject to adjustments through application of the HSRA model, should be the stocking density determined by the ASEL.

5. That future refinements of the HSRA model examine diurnal and day-to-day variations in deck WBT data. This may help inform further refinements of the HSRA model and the welfare WBT threshold, based on the likelihood of respite from high WBT that sheep may experience for a planned voyage.

6. Care for sheep welfare should extend beyond the voyage period. Therefore it is recommended that the environmental conditions that sheep may be exposed to at their destinations in the Middle East be considered in the risk assessment process.

7. These recommended refinements to the HSRA model to shift to an animal welfare basis are accompanied by a parallel and ongoing need to measure and record environmental conditions accurately, as well as the monitoring of sheep responses to heat accumulation during the voyage. These data should be used in a feedback loop for future use in the heat stress risk assessment model, and to enable effective, objective, defensible and transparent monitoring and protection of animal welfare of transported sheep. This suggests a need to deploy well maintained monitoring equipment (such as to monitor WBT) at a sufficient number of relevant locations on the livestock decks of ships transporting sheep.

8. We recognise there are other factors on-board ships that may influence sheep response to environmental heat and therefore recommend that consideration is made to record other factors such as CO_2 and ammonia.

3 Background and previous reviews

The McCarthy review provided recommendations on conditions and actions required to assure health and welfare outcomes for sheep being transported to the Middle East during the northern hemisphere summer. Given the short time available to Dr McCarthy to conduct his review and the far-reaching impact of some of his recommendations, the department committed to conduct consultations and test key factors impacting the live sheep export trade. In particular, the development of a welfare-based approach to HSRA in response to recommendations 3–5, 7 and 8 of the McCarthy review.

3.1 Review of the Australian Standards for the Export of Livestock

A comprehensive review of the Australian Standards for the Export of Livestock (ASEL) is underway and due to be completed in 2018. The standards ensure livestock are fit for export and help manage the risks to health and welfare during the voyage. The review is being undertaken by a technical advisory committee, made up of independent Chair, Mr Steve McCutcheon, and experts in animal health and welfare, regulatory design and the livestock industry. The committee is engaging with a reference group of representative industry bodies with direct interests in the livestock export industry. The reference group's role is to provide the committee with a resource to discuss technical and practical aspects of the review using their experience with export conditions relevant to Australian livestock species and export processes.

The review builds on the previous ASEL review that started in 2012, and is in line with recommendations from the Farmer Review (2011).

It is expected the review will be completed by the end of 2018, following public consultation processes. Submissions received and further information is available on the Department of Agriculture and Water Resources' website at agriculture.gov.au/animal/welfare/export-trade/review-asel.

3.2 McCarthy review

In April 2018, footage was released showing live sheep in severe heat stress while being transported to the Middle East. The footage was taken over 5 voyages between May and October 2017, and the video shown on *60 Minutes* was mostly from a voyage in August 2017. The McCarthy review was announced by the Minister for Agriculture and Water Resources on 10 April 2018 as part of the Government's response to the incident. The McCarthy review was published on 17 May 2018.

The McCarthy review identified stocking density, ventilation and thermoregulation in the sheep as the central issues relevant to sheep health and welfare during shipping to the Middle East from May to October and made recommendations related to these factors.

The McCarthy review recommended moving from a risk assessment based on mortality to one based on animal welfare, with an interim measure risk threshold of less than a 2 per cent probability that 5 per cent of sheep on a voyage experience heat stress. Moving to HSRA based on excessive heat load represents a significant shift from the current arrangements and will have implications for stocking densities. The review and the Department of Agriculture and Water Resources' response can be found at agriculture.gov.au/export/controlled-goods/live-animals/livestock/history/review-northern-summer.

The department supported the recommendations, while noting consultation and testing of analysis of the HSRA-related recommendations was not achievable in the short time allowed for the review. As a result, the department undertook to do further consultation and testing of the findings relating to HSRA (recommendations 3–5, 7 and 8 of the McCarthy review).

3.3 Regulatory framework

The ASEL is given effect under the *Australian Meat and Live-stock Industry (*Standards*) Order 2005* and is referenced in instruments including the *Export Control (Animals) Order 2004.* Exporters must comply with the ASEL to be permitted to export livestock by the department.

The *Australian Meat and Live-stock Industry (Standards) Order 2005* requires livestock export licence holders to comply with the ASEL (Version 2.3, which is incorporated by reference) when exporting livestock. Compliance with ASEL is, by virtue of the *Australian Meat and Live-stock Industry (Standards) Order 2005* and subsection 17(5) of the *Australian Meat and Live-stock Industry Act 1997*, a condition of a livestock export licence.

Non-compliance with the ASEL by a licence holder may attract a range of compliance measures and sanctions, including offences and penalties under the *Australian Meat and* Live-*stock Industry Act 1997* and *Export Control Act 1982* frameworks, as well as various administrative sanctions relating to the refusal to grant certain approvals under the *Export Control (Animals) Order 2004*.

Livestock sourced for export must also meet all requirements under relevant state and territory legislation, including animal welfare Acts. State and territory governments are responsible for ensuring that these requirements are met. Areas of state and territory responsibilities include animal health and welfare, vehicle registration and operation, licensing and operation of facilities and equipment where appropriate, occupation health and safety, and environmental protection and operation of companies.

3.4 Literature Review

The department commissioned Murdoch University to conduct a literature review of scientific animal health and welfare literature relevant to heat load in livestock species during the export process. The literature review was a resource for the technical reference panel and supported the panel's work in determining appropriate setting for HSRA.

The authors systematically reviewed research into heat load and livestock in Australian live export. They found similar numbers of peer-reviewed articles and industry reports, along with several theses and conference proceedings relating to this topic. The authors synthesised this information to provide a summary of contemporary scientific knowledge of this issue.

4 The review process

4.1 Independent panel

The department established a 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. They provided expertise in animal welfare, heat stress and animal science, with the panel comprising Professor Andrew Fisher (University of Melbourne), Professor Clive Phillips (University of Queensland) and Associate Professor Anne Barnes (Murdoch University). David Anderson from the Australian Maritime Safety Authority (AMSA) provided input on ship ventilation. Further details on the panel members can be found in Appendix 8.2.

4.2 Meetings and consultation and next steps

The panel met on a number of occasions via teleconference and face to face between 8 August 2018 and 27 November 2018 to discuss issues, consider information and form a position on issues in order to deliver on the terms of reference.

During the process, the panel consulted with the ASEL review technical advisory committee as well industry bodies, producers, non-government organisations, exporters, ship owners and other stakeholders and researchers involved in development of the HSRA model (HotStuff).

During the public consultation process submissions were received from (not exhaustive):

- Australian Livestock Export Corporation Limited (LiveCorp)
- Australian Livestock Exporters' Council
- Australian Veterinary Association Ltd
- Vets Against Live Export
- RSPCA
- Animals Australia
- Cattle Council of Australia
- Sheep Producers Australia
- Department of Primary Industries and Regional Development WA
- various Australian Government Accredited Veterinarians, exporters and others.

Copies of relevant submissions will be made available on the department's website agriculture.gov.au. The panel has also taken into account submissions lodged for the ASEL review. Those submissions can be viewed on the department's website.

Following submission of this report to the department, the panel's draft recommendations will be tested with stakeholders via a second public consultation process. The panel welcomes submissions from stakeholders at that time.

The panel will consider submissions when finalising its report, which is due to be provided to the department in early 2019.

5 Evaluation of key issues

In September 2018 the panel released an issues paper on HSRA for public consultation. The issues paper posed particular questions to encourage feedback on key issues that inform the panel's recommendations to the department on how a future HSRA model might look. The panel's responses to those questions are provided in this report.

5.1 Heat Stress Risk Assessment

5.1.1 Why does the heat stress risk assessment need to change?

Currently, the HSRA model is used to determine space allocation for the intended voyage, in order to reduce mortality risks. The McCarthy review noted it is time for the industry to place the focus on animal welfare and move away from measures that use mortality as a benchmark. Reportable levels, voyage success and risk parameters have all been based around mortality. It was envisaged by the McCarthy review that a new operating model will replace mortality with a raft of welfare measures and involve a quantum shift in attitude and behaviour (McCarthy, 2018).

It is apparent that, taken in isolation, mortality is an insufficient indicator of animal health and welfare, given that animals may suffer and have reduced welfare without actually dying, and that mortality levels may represent the 'tip of the iceberg' in terms of impacts on animal welfare. A change is needed in the approach to HSRA to predict the risk of the animal experiencing reduced welfare due to excessive heat load, rather than the likelihood of mortalities during the proposed voyage.

5.1.2 Panel Responses to the issues paper questions

How should the effects of heat on animals be defined?

Animals—in this case sheep—can tolerate a wide range of environmental conditions, evidenced by their survival and continued production and reproduction in many different regions and environments. The effects of hot environments on the animals will depend on a range of biological factors, such as the animal species, breed, sex, age, body condition, hair/wool covering, nutrition, prior exposure to hot conditions, and physiological state (for example hydration status, reproductive status). All these factors need to be considered in any model predicting an animal's response to heat, noting that within all those variables, there still exists the potential for further individual variation. Physiological responses to increased environmental heat include cutaneous blood flow, evaporative heat loss, and behavioural thermoregulation.

Cutaneous blood flow increases in response to detection of heat (by peripheral or central thermoreceptors), which enables increased heat loss at the surface of the animal. This can potentially be detected by infrared thermography. Cardiovascular responses to changes in blood flow include increased heart rate, and this can be measured directly. Evaporative heat loss responses include sweating, respiratory heat loss (panting) and in some animals saliva is used to wet the skin to increase evaporation.

Thus we can use measurement of standard physiological responses to determine how the animals are being affected by the heat. Invasive measurements such as taking blood and other samples for measurement of hormones can themselves change the physiological responses, as can handling the animals for less invasive measurements of heart rate and core temperature. Assessment of the animals' respiratory rate and character are very useful for those animals which use respiratory means to lose heat, while it can be useful to observe and measure sweating in those animals which use visible sweating (noting for instance that sheep do sweat, but that it is difficult to observe).

A further consideration of the effects of heat on animals should also include their affective state. The relevant question here is: "How do animals 'feel' when it is hot?" Their behavioural responses may give some indication—what they are doing, and how they are doing it, and other responses may be observed, such as facial expressions. However, for practical situations, animal affective state is not commonly assessed and recorded because there is relatively little research-based validation in these contexts.

In the live export and animal production settings, excessive handling and invasive monitoring of animals is neither practical nor useful, because it subjects the animals to physiological and psychological distress and can change their responses. Therefore under these situations, methods that observe non-invasively are more useful. It is important to consider whether it is an individual animal or a group which is being assessed and recorded, given the range of responses possible in a group. Some studies have highlighted the difference between individual and group responses; for instance Stockman (2006) showed a range of responses to high environmental heat and humidity, even in a small group of animals. The panel is not aware of any other literature which adequately describes the range of responses for any group of animals; therefore, we assume it is a standard distribution but cannot verify this, and in any shipment of animals there will be a range, given their variable origins and other factors.

Despite individual difference, we do expect there to be some standard, average response, and the current values of thermal zones are based on that. The consideration of thermal zones starts with the thermoneutral zone (TNZ)—which is defined as the range of environmental temperatures at which metabolic rate is basal, with no requirement to either increase heat production or use additional processes to lose heat (refer Figure 1). While exposure to cold is an important issue, it will not be further considered here. In the TNZ, and with basal metabolism, an animal loses heat from the skin, through radiation, conduction and convection. If this is insufficient to lose enough heat compared to how much is made through regular metabolism and the heat of the environment, further methods of heat loss are used, which engage evaporative heat loss.

Evaporation is an effective method of heat loss; when the environment is as hot as the body, water can be turned to vapour and lost, energy/heat will be removed from the body. In some animal species, sweating is useful to increase heat loss from moistened skin, and increased sweating rate can be observed in increasingly hot conditions. In other species, evaporation of water from the respiratory tract removes heat, and to increase the heat loss from the respiratory system the animals increase first the rate of their respiration (so that more air is moved over moist upper respiratory tract tissues) and then the depth of respiration (which can as a side effect then result in greater gas exchange in the lungs and lead to perturbations of acid-base balance).

In humid conditions, the effectiveness of evaporative heat loss is reduced or lost. Thus it is very humid conditions that pose the greatest challenges for heat loss. If there is insufficient heat loss, the body temperature will rise, stimulating escalated physiological responses.

Describing the effects of heat

Firstly, heat should be described in terms of the animals' responses given that animals themselves provide an integrated response to their thermal environment (LeRoy Hahn et al, 2009). Normal physiological responses may escalate if they are not effective at maintaining the heat balance in the animal. The input temperature, that is, the environmental conditions at which that occurs will differ slightly for each individual. How an animal 'feels' about what is going on remains to be determined; behavioural responses may be useful in gauging affective state.

From the animals' responses, some threshold values for the environment can be measured or calculated. Researchers use a variety of indices to evaluate the environment, and have described thresholds for these indices which correspond to heat stress (e.g. for summary see LeRoy Hahn et al, 2009). The THI (temperature humidity index) has been used for assessing environmental conditions for cattle, and there are also tables to indicate the effect of prolonged exposure to high environmental heat. There have been further refinements of thermal indices and their use for feedlot cattle, with the development of a heat load index (HLI) and the consideration of accumulated heat load (AHL). The THI threshold values for sheep are not as well described, and the AHL has not been applied to sheep.

The live export shipping process currently uses WBT as the most useful combination measure related to heat loss/stress in that environment. Under shipboard conditions, WBT has been used as a convenient measure combining dry bulb temperature and relative humidity, to indicate the capacity of livestock to lose heat. When the dry bulb temperature is at or above body temperature, the only method for heat loss will be via evaporation, and if the air already contains much moisture, further saturation of the air will be limited, meaning heat loss is diminished. If there is good ventilation, the hot and saturated air is blown away from the animals, and therefore there is capacity for both convective and further evaporative cooling. Thus, even if the air is as hot as or hotter than the animal, if the humidity is low, evaporative cooling can still occur.

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

This is best determined from the effects of heat load in the animal in terms of their behavioural and physiological responses. The most widely accepted method is the measure of core body temperature, but this is obviously impractical for shipped animals. In the absence of this information, panting score is probably the best of the current measures.

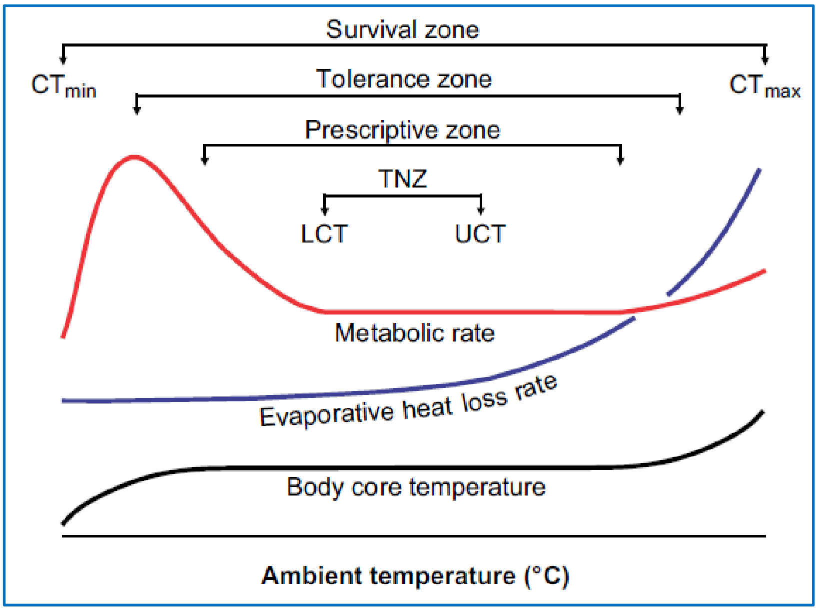
There is a reasonably linear increase in the responses within the prescriptive zone of temperatures (refer to Figure 1—Mitchell et al, 2018). Further escalation of responses (when the animal is subjected to environments which are outside that zone but within the tolerance zone) result in physiological malfunction, which can be detected as abnormal physiology such as:

- changed cardiovascular parameters (increased heart rate, altered peripheral perfusion, dehydration)
- altered respiratory function (changed rate and/or character)
- altered behaviours (for example posture, stance, stepping and pawing, eating and drinking)
- altered mental state (for example increased activity/frenzy, or lethargy, depression, coma)
- altered cell and tissue biochemistry (for example blood cortisol responses)
- other changes.

If temperatures increase further into the survival zone, individual lives are at risk, from drastically altered physiology, which can lead to death.

Figure 1 below demonstrates the relationship between the ambient temperature and the body core temperature, evaporative heat loss rate, and metabolic rate of mammals. The TNZ is shown, as well as three zones of thermal safety. In the prescriptive zone, mammals are homeothermic and fully functional, with sustainable increased metabolic rate and evaporative heat loss (water loss) outside the TNZ. LCT is lower critical temperature, UCT is upper critical temperature, CT_{min} is critical thermal minimum, and CT_{max} is critical thermal maximum.

Figure 1: The relationship between the ambient temperature and the body core temperature, evaporative heat loss rate, and metabolic rate of mammals



Source: Adapted from Figure 5 from Mitchell et al (2018) cited in Collins et al (2018)

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?)

The level of heat load that can be tolerated depends on the extent of other stressors that increase susceptibility to heat stress. There is evidence of the synergistic action of stressors to sheep in simulated ship conditions. The other important factor is the conditions that sheep have experienced on land; if they are adapted to heat, they are less likely to be affected by heat stress during hot conditions in the Gulf region.

Measurement of physiological responses is reasonably straightforward, even if invasive in some cases. Therefore it can appear simple to decide on a level of a physiological response that can be used as a 'cut-off'. For instance, a specific body temperature, or specific rise in body temperature, could be chosen. However, choosing that temperature is not as straightforward as it would appear, or as some submissions indicated. Animals appear to have a different tolerance for increased body temperature at different times of year, with different prior experiences in different temperatures (for example through acclimatisation), and under different physiological conditions (for example pregnancy or pyrexia).

In choosing a threshold cut-off temperature, a key consideration is whether this should be a maximum, mean, or minimum body temperature. An animal may 'allow' its body temperature to increase more (for example under hot conditions), if acclimatised to heat, if well hydrated, than at colder times of the year or if they have had different prior heat experience. Therefore the maximum body temperature may not be the most useful temperature, and will also mathematically influence the mean temperature. The daily minimum body temperature may provide better information about the animal's thermoregulatory balance, because it indicates whether the animal has the capacity to 'dump' heat during the normal circadian fluctuation of body temperature. This remains to be validated by research.

Other physiological responses can be used to measure heat stress. McCarthy and now others have indicated several versions of panting and heat stress scores, which primarily use respiratory responses for sheep, based on those described by Gaughan et al (2008) for cattle. These revolve around defined respiratory rates and character, as non-invasive, non-intrusive indications of whether the animal is using sensible means to lose heat, or has needed to escalate their physiological responses to include increasing evaporative heat loss. The principle seems sound, because it allows for the variation in body temperature and other aspects of individual variation, while recognising the escalation of physiological heat loss mechanisms. The choice of table of panting scores and respiratory rates will be a continued matter of debate. The panel believes rather than adding more detail and description, a useful panting score that could be used by all parties throughout the live export chain would be less detailed. Once there is agreement about the scores, a series of videos/photos could be developed to ensure everyone is using the same system.

Table 1: Panting Score and Character

Panting score	**Description**	**Respiratory Rate (breaths per minute)**
0	Normal resting respiratory / active	40–60
1	Increased respiratory rate	61–80
2	Further increased respiratory rate accompanied by increased breathing effort, the whole animal works harder to breathe and body movements are obvious	81–120
3	Mouth open panting	121–192
4	Mouth open and tongue protruding as they pant	>192

Accordingly, the respiration rate can be used for assessing the level of heat stress based on the scale proposed by Silanikove (2000) and McManus et al. (2015) as follows:

- fewer than 40 breaths per minute indicates absence of stress
- 40–60 breaths per minute indicates low stress
- 61–80 breaths per minute indicates medium to high stress
- 81–120 breaths per minute indicates high stress
- 121–192 breaths per minute indicates very high stress
- more than 192 breaths per minute indicates severe stress, and this can serve as a non-invasive method as it does not involve sophisticated tools (Wojtas et al. 2014).

Rectal temperature may also serve as an indicator of heat stress in sheep (Sejian et al. 2017). The increased body temperature due to exposure to high temperatures will be reflected in an increased rectal temperature, and it has been established that the rectal temperature can serve as a representative of body temperature in several livestock species. Hence, the increased rectal temperature can reflect the stress level in sheep (Indu et al. 2015).

There are several blood parameters which may reflect the stress level in sheep. These variables are hemoglobin (Hb), packed cell volume (PCV), cortisol, thyroxin, and triiodothyronine (Sejian et al. 2013a, b). The Hb and PCV have been established to have a strong positive correlation for heat tolerance in Brazilian sheep (McManus et al. 2009). During severe dehydration, both Hb and PCV increased in heat-stressed sheep. The increased cortisol level was correlated with the stress level in domestic ruminants, including sheep. Further, environmental temperature was established as one of the major regulators of thyroid gland activity (Rasooli et al. 2004; Sejian et al. 2010b). Heat stress suppresses the thyroid gland activity, resulting in lowering of thyroid hormone levels (Rasooli et al. 2004; Saber et al. 2009; Sejian et al. 2014).

The general consensus appears to be that when a sheep is panting with its mouth open—score 3—it has moved away from the TNZ and is having to work much harder to try and lose heat from the body, and this is considered to be beyond what is acceptable. How the animal ‘feels’ about being in this state is unknown.

There is literature that correlates these respiratory characteristics and panting scores in sheep with internal body temperature (e.g. Stockman, 2006), and there is evidence that open mouth panting does correspond to elevated body temperatures.

Sheep within their prescriptive zone (as described above) may pant during the hotter parts of the day, but with some diurnal respite they may de-escalate their responses, dropping back on the panting score during the night. In hot weather on land, it is not unusual to observe sheep at panting score 1 (or even 0) in the early morning, increasing to 2 later in the day with occasional open mouth panting (3) in the hot afternoon and evening, before dropping back to score 1 at night. These animals have only minor changes in blood variables. Thus, the opportunity for thermal respite seems very important. Ship environments, especially travelling around the equatorial regions, provide little diurnal respite and therefore are more challenging. How cool it must get, and for how long, to enable sheep to 'dump' heat, is unknown.

Stockman (2006) tested Poll Dorset x Merino weaners in climate controlled rooms over summer, and subjected them to increasing daytime temperatures. When the rooms were at 28°C wet bulb, the weaner wethers had statistically increased maximum and mean core body temperatures, but minima remained similar to pre-heat values. When the rooms were kept hot during the night as well as the day, minimum core body temperatures also increased.

How do you know the sheep is too hot?

A simple indicator of moderate heat stress in sheep is the onset of first phase panting, and for severe heat stress is the onset of second phase (open mouth) panting. The measurement of respiratory frequency as a simple index of heat stress may not be appropriate unless the differences in first and second phase panting are taken into account.

A sheep is too hot when it is panting score 3 (mouth open panting), without a reduction in the panting score through the day and night.

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?

Maunsell Australia (2003) cited the TNZ for livestock shipping as the range of environmental temperatures at which the deep body temperature should remain constant. Within that zone, body temperature can be kept in the normal range by constant heat loss through usual sensible and insensible mechanisms. The upper limit of this zone is the upper critical temperature, and when the animal is exposed to environmental conditions above that limit, body temperature rises (Collins et al 2018).

Stockman (2006) described the responses of sheep exposed to increasing WBTs and reported that the core temperature of 56 kg, recently shorn, four-year old merino wethers from zone 3 (reference to numbered zones relates to geographical regions—refer to Appendix 8.3), in winter experiments, rose significantly above pre-heat values when the animals were exposed to a stepwise increase in WBT in climate-controlled rooms, and was significantly elevated 0.5°C above pre-heat values when the rooms were at 28°C WBT.

The data from Stockman's thesis, along with real case data on board ships was used in the HSRA model development, leading to the current heat stress threshold for the 'base' animal in the model, that is, 30.6°C for a 40 kg, summer-adapted (15°C), recently shorn Merino wether of body condition score 3. Further investigation of shipboard incidents and recent monitoring on ship corroborates the use of 28°C WBT as the heat stress threshold for most shipped wethers travelling from the southern Australian winter (i.e. 56 kg Merino adult, zone 3, recently shorn). Beyond that environmental WBT there is an increase in body temperature indicating the animals are no longer maintaining homeostasis. It is important to consider the site of the environmental readings relative to the sheep, to ensure appropriate correlation with the actual conditions experienced by the sheep. Zhang et al (2017) determined that, although 6–8 measurements per deck would accurately estimate dry bulb temperature, in excess of 20 measurements are required to obtain an accurate measure of the humidity.

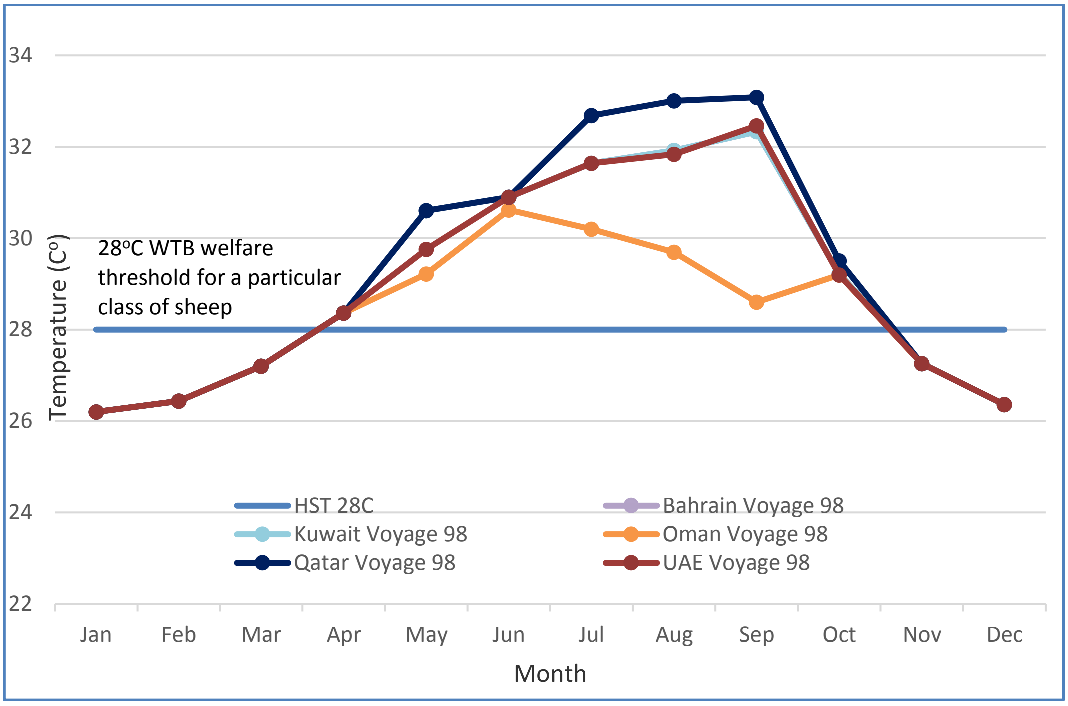
An assessment of available data shows that it is at the industry defined heat stress threshold that animals are experiencing a challenge to their homeostasis, which will result in poor welfare. Using values higher than these thresholds means that sheep will be subjected to conditions that can compromise their welfare, even though they may not die of heat related pathology.

McCarthy's suggestion that the mortality limit be lowered appears a relatively straightforward method by which the HSRA could be adapted to predict whether animals will be exposed to environmental heat conditions which compromise their welfare. However, there is currently no objective method to determine the percentage of the mortality limit that is appropriate to use, based on the welfare responses of the sheep. Using the heat stress threshold (as currently defined and extrapolated for different classes of animals) as the absolute cut off/limit is more defensible than McCarthy's recommended extrapolations and this threshold will further limit risk to animal welfare from heat effects.

Using the heat stress threshold as the cut off WBT may alleviate concerns about duration of exposure, because it appears that the animals are able to make physiological adjustment over time because they are within their 'prescriptive zone' as defined above.

Figure 2 below illustrates 98th percentile WBTs that may be experienced on voyages to the Middle East from southern Australia and demonstrates the peaks in WBTs during the northern hemisphere summer, based on historical weather data. Figure 2 was derived from data sourced from Stacey 2017b.

Figure 2: Southern Australia to Middle East voyages 98th percentile temperatures



Source: Based on data from Stacey (2017b) W.LIV.0277

Are there other physiological indicators linked to the effects of excessive heat on sheep?

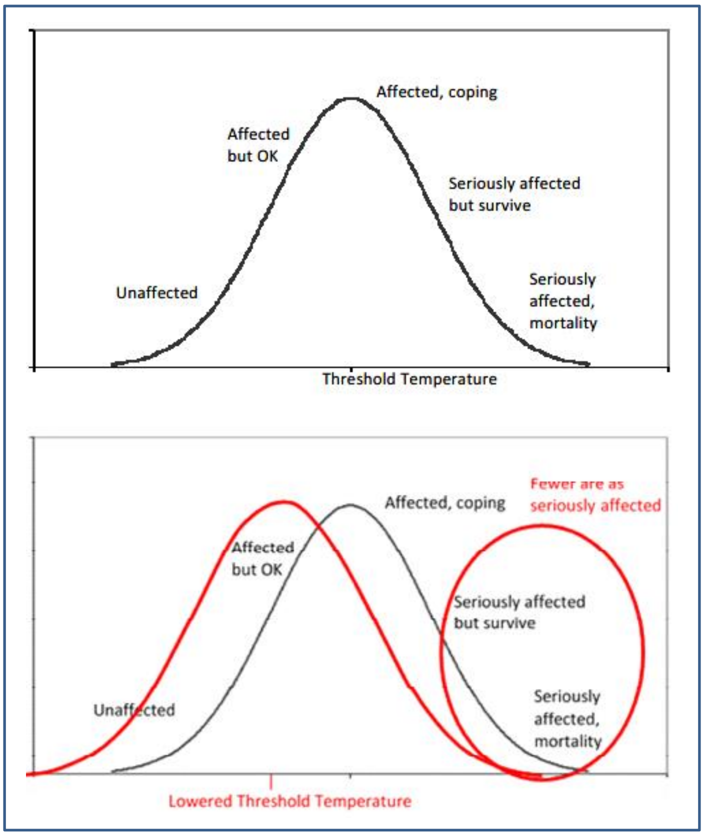
While core body temperature is the most definitive indicator of thermal homeostasis, it is not easily measured in a practical situation. Rectal temperature taken with a hand held thermometer is not always accurate, and requires catching and handling the sheep which may further elevate the temperature and distress of the sheep disturbed while being caught. Infra-red thermography or other remote sensing of specific body parts such as eye or tail base may be useful but not yet validated as to the relationship with core temperature in hot environments, and may not be straightforward in a practical setting.

Panting score, as described in Table 1 above, appears a useful measure to indicate the effects of environmental heat on sheep. It is not clear how panting scores could be easily and objectively taken to be included in the current HSRA model. The industry HST is aligned with a panting score of around 3 as there is a reasonably close association between animals panting at score 3 and their body temperature rising 0.5–1 degree above normal.

The further development of risk assessment and environmental management for sheep would benefit from continued collection of data on animal responses to the environment, to link these responses to an index or measure of the environment (perhaps WBT, or other indices which also capture details for example on duration of heat event and respite from the heat). In the absence of further detailed observations of sheep responses to thermal environment, it appears panting score is the most useful biological response we have.

If the HSRA model is then used to predict the likelihood (2 per cent of a 5 per cent) of adverse animal physiology/panting score 3 instead of mortality, then there is a very large shift 'to the left' (in red in Figure 3 below). If we assume there is a standard distribution of response to the heat, there will be groups of animals affected by heat exposure as shown below (in black). If we lower the threshold temperature, fewer animals will be exposed to the extreme and therefore overall there will be fewer affected animals.

Figure 3: Fewer animals affected as a result of lowering the threshold temperature



How can allometric stocking densities most effectively be used?

Baseline space allowances are determined through the ASEL minimum pen area per head tables. The HSRA will provide additional adjustments to space allowances based on expected environmental conditions.

Space allowances under ASEL are described in two dimensions (e.g. m^2) and is linked to an animal's weight, which exists in three dimensions. Therefore it is reasonable to relate space requirements not to weight per se, but weight to the power 0.66, which is referred to as an allometric equation. The *k*-value used in the allometric space allocation equation below can be used to compare space allocation for different postures and is not dependent on body weight.

The panel notes the draft ASEL review report recommends an allometric approach be adopted for calculating on-board space allowances for sheep, with a *k*-value of 0.030 to be applied to voyages during November to April, and a *k*-value of 0.033 for voyages during May to October.

The ASEL review committee's position is that the 0.033 *k*-value should remain in place for the May to October period and be reviewed in the light of voyage reports and industry performance after several northern hemisphere summer periods. To this effect, the panel notes that the current ASEL review process is examining stocking densities and that it is appropriate that base stocking density to be used for each class of sheep, that is then subject to adjustments through application of the HSRA model, should be the stocking density determined by the current ASEL review process.

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

As the current HSRA model is designed to identify risks of actual mortality rather than the risk of heat stress, the data to identify critical WBTs needed to have been collected in events or studies in which sheep either actually died, or came so close to death that the WBT at which they would have died can be estimated with reasonable confidence. As described earlier in this report, there is a set of both shipboard and experimental data describing the heat stress responses of sheep at given WBTs, although rather less data for a wide range of heat challenge durations or various intermittent patterns. Nonetheless, the available research on heat stress thresholds is probably as (or more) robust than that used to define or infer mortality thresholds.

The probability setting that needs to be determined is that of the WBT exceeding a defined threshold—that is, the heat stress threshold of the animals. Currently this is set at 98 per cent—that is a 2 per cent chance during a voyage that the WBT will exceed the selected value. An absolute value such as zero is not easily applicable because of the asymptotic nature of probability distributions.

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

A 2008 review of the HSRA model included the following recommendation (Ferguson et al. 2008):

'Mortality is clearly the ultimate measure of an animal's welfare (or lack thereof). However, it is recognised that it is not the only measure of welfare in response to heat challenge and that some consideration should be given to protecting animals that might otherwise suffer severe heat stress but not actually die. Some consideration of this issue is built into the selected threshold of a 2% chance of a 5% mortality event (i.e. these low values should provide some protection against undue stress in the animals). Consideration should also be given to utilising the HST values that have been developed, but not actually applied in the output and use of the HotStuff model.'

The validity of input values, including pen air turnover (PAT) and animal-based parameters that are entered into a HSRA calculation in order to solve the mortality or heat stress risk probability equation needs to be considered. This is largely beyond the scope of this section of the report, other than to note the McCarthy (2018) recommendation for independent audit of vessel PAT values, and that the nature of models such as the HSRA means that useful outputs that can provide protection for animal welfare are dependent on humans accurately entering animal characteristics such as weight and wool length.

When sheep are present on the deck of a ship, their own metabolic heat production will modify the conditions on the deck compared to the outside ambient conditions. Because sheep are continually producing metabolic heat, which is lost to the environment, 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.

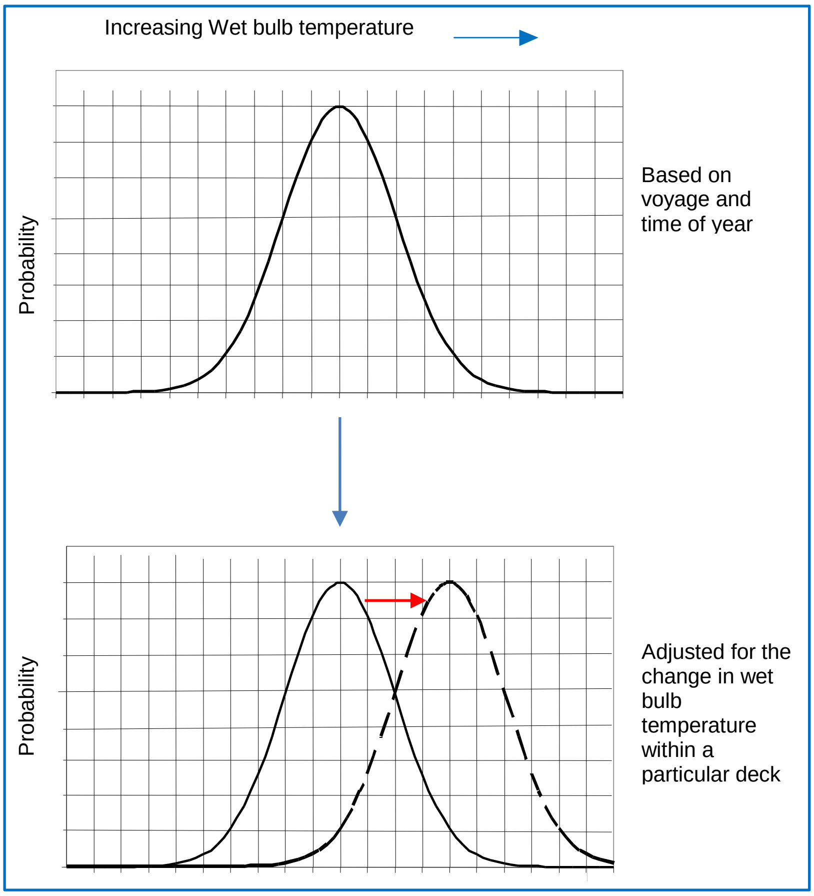
The wet bulb rise is calculated based on the heat that is generated on a deck and the rate that the generated heat is removed through ventilation. The heat generated on a deck is calculated based on the average body mass and number of sheep on the deck and their condition. In general, the higher the PAT, the smaller the wet bulb rise.

The model adds the wet bulb rise to the expected ambient conditions to arrive at a probability distribution of the expected deck wet bulb temperature for a given voyage (refer to Figure 4 below).

The mathematical model of the HSRA is based on calculating the increase in deck WBT, in this case on a ‘closed’ deck (see Stacey (2017) for a more detailed explanation). According to Ferguson et al (2008) the form of the equation that calculates the wet bulb rise aligns to a conservation of energy calculation, which holds as one of the primary tenets in fluidynamic and thermodynamic modelling. As such, it forms a strong basis on which to make the calculation (Ferguson et al, 2008).

The wet bulb rise for a particular deck and line of sheep is used to adjust the probability distribution for the ambient WBT, which is based on a database of ship observations over a number of years, based on location and time of year, to obtain the WBT which sheep are expected to be exposed to.

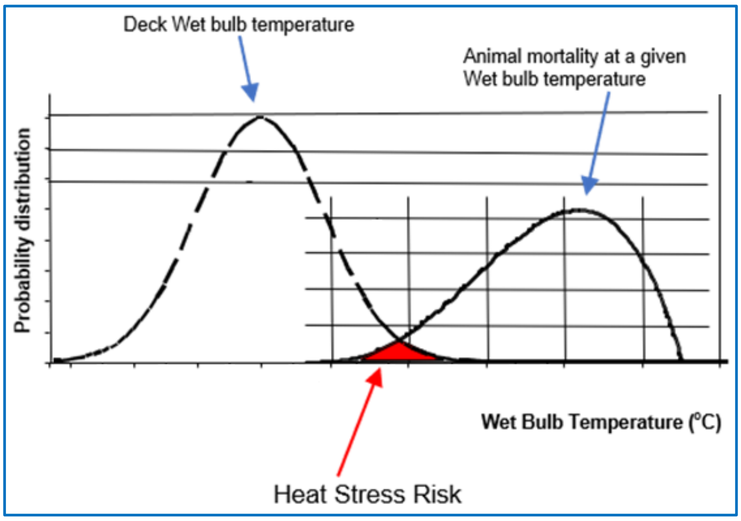
Figure 4: Adjustment of the wet bulb probability distribution for a particular deck, based on voyage route and time of year (Stacey 2017)



This part of the model does not need to be changed *per se* in order to move from a mortality based risk assessment to one based on heat load. However, under our proposal the mortality limit WBT for sheep will be replaced by a suitable heat stress threshold WBT (see previous section).

In the current HSRA model, the mortality limit (WBT) for a particular class of sheep is also subjected to a probability distribution, based on the aim of modelling no more than a 2 per cent chance of a 5 per cent mortality among a line of sheep on a particular deck (Figure 5) . If this is unable to be achieved, then the equation for calculating wet bulb rise is reversed to solve for a stocking density based on the required maximum WBT, which provides the stocking density adjustment.

Figure 5: HSRA current model: Intersection of the lower end of animal heat mortality probability distribution with the upper end of the probability distribution for deck WBT (Stacey 2017)



In moving to a model based on avoiding heat stress, the key question that arises is whether the relevant heat stress threshold WBT for a given sheep class should itself be subject to a probability distribution, or whether simply testing this value against the 98th (or similar) probability distribution for WBT is sufficient.

Although there is likely to be a distribution of individual sheep susceptibility to adverse welfare due to excessive heat load, it is our assessment that selecting a reasonably conservative WBT welfare threshold is simpler and more effective than assuming a particular susceptibility distribution, for which there would be limited data.

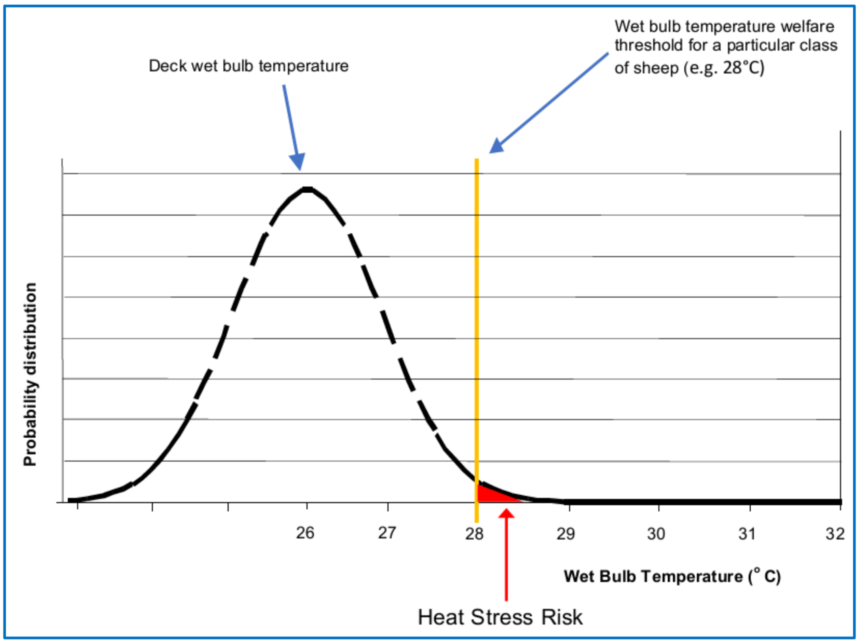
What other probability settings might be considered for inclusion in the HSRA model and on what basis?

The current HSRA does not directly take into account the duration of high WBTs. Rather it calculates the 98th percentile probability of the highest WBT along the route, using an approximate 12-hour sailing window. As noted by in the report by Ferguson et al. (2008), this approach has an indirect duration component, because the 98th percentile yielding a high WBT at one point is likely to be surrounded by similarly high values. However, as described in the previous section, the effective HST is lower for sheep that have not had respite from the preceding day's high WBT.

Accordingly, instead of trying to model probability distributions from datasets based on whether 'voluntary observing ship' data showed sustained high WBT or significant intermittent respite (which would be exceedingly complex), a simpler alternative would be to select a HST that is known to be relevant for sheep that are exposed to elevated WBTs (for example, 28°C WBT for the 'standardised' shipper sheep referred to in section 5.1.2).

Figure 6 below shows a WBT welfare threshold intersecting with the upper end of the probability distribution for deck WBT to provide an estimate of heat stress risk. The graph shows that there is a low probability of either a very high or low WBT for a particular voyage route and time of year, as modified by factors such as vessel PAT. The welfare threshold WBT for a particular class of sheep (in this case 28°C for a 56 kg adult Merino wether, body condition score 3, zone 3, winter-acclimatised) is applied to intersect with the 98th percentile upper part of the deck WBT probability distribution. This would mean that there would be a 2 per cent probability for a particular voyage that some sheep would undergo a welfare challenge due to heat load.

Figure 6: Intersection of the WBT welfare threshold with the upper end of the probability distribution for deck WBT



5.2 Vessel configuration

5.2.1 Open decks

There is provision in the model for assessment of open decks, with a crosswind assumption and reliance on the captain not berthing if still air is expected. Due to the lack of mechanical ventilation of some open decks, risk assessment is not covered as rigorously as it is for closed decks.

When there is a good crosswind, the effective PAT on open decks is very high. When there is no or little crosswind, the lack of any clearing air movement towards the centre or leeward side of the vessel can mean the conditions rely solely on the provided mechanical ventilation. Marine Order 43 (MO43) has been changed so ships with open decks will not be allowed to have reduced or no ventilation after 1 January 2020.

McCarthy (2018) stated there have been reports of high mortality heat stress events on Middle East voyages, particularly in the early open deck vessels. Future modification of the HSRA model may be required to incorporate the way open decks are managed.

5.2.2 Panel Responses to relevant issues paper questions

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

Open decks should be treated the same as closed decks. Testing should be carried out with the effects of weather/wind excluded during testing. This already occurs on the vast majority of the vessels in the trade since they were built/converted on or after 27 May 2004. From 1 January 2020 it will be 100 per cent of vessels with open decks that hold an Australian Certificate for the Carriage of Livestock.

What other things need to be considered in assessing heat stress risk on open decks?

The issue of lack of shading for animals at the perimeters could be examined. If there is sufficient (additional) space to assist circulation in those outside pens, that could mitigate the risk. After 1 January 2020 adding physical shading to the outer perimeter will make no difference to compliance with MO43—doing that currently on an older ship with reduced ventilation (as the deck is not enclosed/open) would mean the deck would be enclosed and ventilation requirements for enclosed decks would apply now.

5.3 Ventilation and air quality

5.3.1 Panel Responses to relevant issues paper questions

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

Mechanical/powered ventilation is the only type consistent enough to provide a reliable measure of ventilation performance and is comparable against minimum requirements. Natural ventilation may add to the mechanical ventilation but it should not be relied upon. The factors that affect the ‘freshness’ of the air in the whole of the livestock space are also important. Whether one refers to air changes per unit of time, or PAT, the major factors are fresh air being delivered at a rate and in all areas where it can displace and expel air that is not fresh. Therefore, in addition to the quantity of fresh air being provided, it is important to ensure effective distribution at sheep level, efficient exhaust and minimal (or no) ingestion of exhaust with fresh inlet air. The MO43 effectively legislates against the re-ingestion of air and provides a basic minimal level of effective distribution of the air with no livestock in the pens.

How might ventilation performance be incorporated into the HSRA model?

The current use of PAT is acceptable providing it is clear the ventilation parameters used in the model are at least equivalent to those required of the ships in federal legislation.

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

This can be achieved by ensuring the regulated requirements are measurable and provide a fit-for-purpose minimum. The performance must be measured at agreed points in time. Measuring environmental conditions on livestock decks during a voyage is an easy and low impact way to track ventilation performance. Measuring locations (and what must be measured and how) need to be considered to ensure all areas are monitored effectively. Measurements of the actual ventilation during a voyage to characterise ship performance is problematic since animals will always block flow. Similarly it is problematic and impractical to set measurable criteria for air quantity delivered/exhausted and effective distribution with animals in the pens.

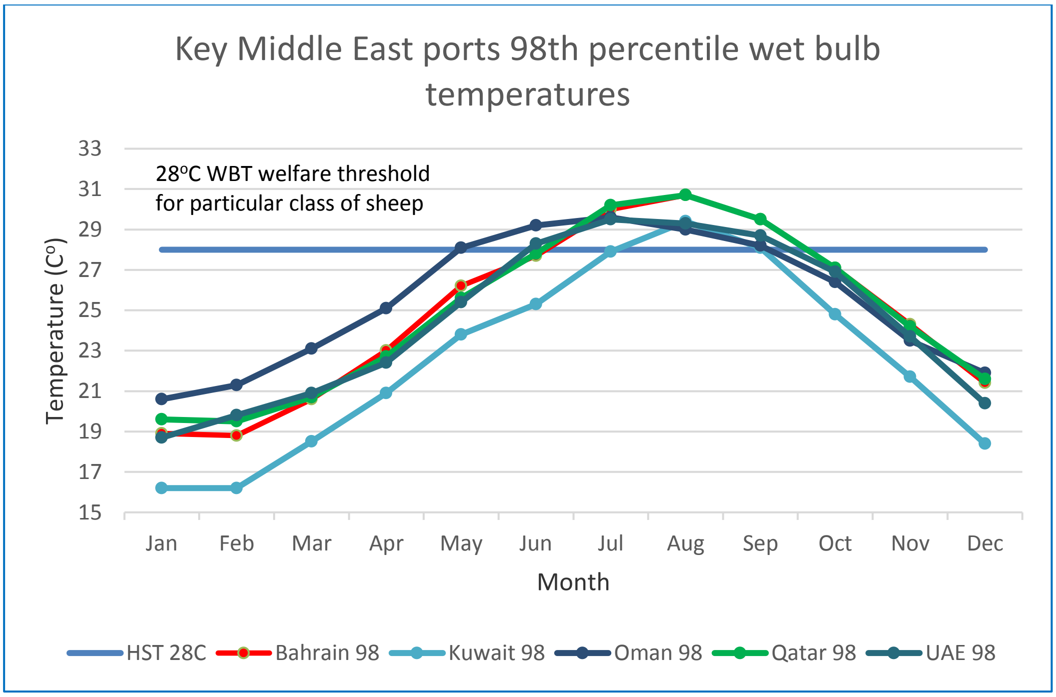
5.4 Destination ports

According to Maunsell (2003) the heat and humidity levels increase rapidly across all Middle East ports during the period from May through to June. First affected are the southern-most ports of Muscat and Fujairah where heat and humidity climb quickly during May. The heat and humidity extend northwards with central Gulf ports from Dubai to Doha, Bahrain and Dhahran becoming consistently hot and humid from June onwards (Maunsell 2003). Further summary voyage and discharge port weather data can be in Stacey (2017b).

The peak of heat and humidity sets in for the northern most ports of Kuwait in the Gulf and Aqaba in the Red Sea (Gulf of Aqaba) towards the end of June into early July. The high heat and humidity levels continue through until the end of September, except for the southern Persian Gulf ports where the high humidity levels linger into October (Maunsell 2003).

Some ports in the Persian Gulf have more than a 2 per cent chance of WBTs exceeding 30^{o}C between July and September, peaking in August (refer Figure 7 below). WBTs in Muscat peak earlier than in any ports in the northern Gulf, with the 98th percentile reaching a maximum of 29.5^{o}C in July.

Figure 7: Annual port-specific WBT distributions in the Persian Gulf region



Source: Stacey (2017) W.LIV.0277

5.4.1 Panel responses to relevant issues paper questions

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

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

As described earlier in this report, duration of effect is an important aspect in considering the effects of high heat loads. While the current model incorporates some aspects of duration in the threshold temperatures used, it is not apparent that it sufficiently includes the true impact of duration of exposure to high environmental heat and humidity without respite. Extended duration of repeated exposure to high heat loads will lower the mortality threshold, in that animals cannot lose heat overnight in their usual manner. If an animal has a high daily minimum body temperature, that effectively means they have less buffer for accepting increased heat retention during the hotter parts of the day. It appears from monitoring sheep in experimental research and on ships that exposure to hot environmental conditions above the heat stress threshold, without respite, leads to a significant increase in body temperatures. While data is available to model the risk of accumulated heat load in cattle[1]; it is not known for sheep what environmental cooling is required, nor for how long, to effect useful respite. However, sustained exposure to conditions above the heat stress threshold will lead to pathology, and poor welfare. Therefore the impacts of extended duration without respite need to be factored into the predictions and risk settings of the model, given

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[1] https://chlt.katestone.com.au/

that it can be expected that on ship there is little diurnal variation especially across the equator.

Repeated exposure to heat—if there is an opportunity for the animal to cool before the next exposure, this may actually result in some acclimatisation. How long that takes is not known, but two to three weeks of heat exposure is considered to cause some acclimatisation in other species, for example athletic horses competing in hot, humid conditions. Therefore, travelling from Australia to the Middle East during the northern hemisphere summer, which takes around two to three weeks, may provide some opportunity for animals to develop a greater tolerance to the heat.

Acclimatisation results in changes in blood and tissue physiology, so that there is lowered overall metabolism and therefore reduced metabolic heat production, increased body water, for example more extracellular fluid which presumably allows more capacity for evaporative cooling. To make these physiological changes effectively, the animal needs to have access to appropriate and sufficient food and water. For instance, there is a lot of literature regarding the provision of electrolytes to cattle to assist in their maintenance of acid-base balance under conditions of repeated exposure to heat; Stockman (2006) found little alteration in blood gas values when the sheep in her experiments were exposed to a second heat insult, but in neither period of heat exposure in that work were the animals heated for as long or as hot as can happen during the live export process.

Provision of ad libitum clean water is essential, noting that animals appear to prefer warm not cold or hot water; feedlot literature exists on optimum water temperature. McKinley et al (2009) reported on the effects of dehydration and rehydration of sheep on panting, noting that 'it is likely that thermoregulatory panting is suppressed in dehydrated sheep' and 'the rapid onset of a panting response following rehydration suggests that dehydration-induced suppression of panting is extinguished by the drinking of fluid'. The temperature of the fluid consumed does influence both core temperature and panting, such that in their experiment, drinking water at 20^{o}C transiently inhibited thermal panting.

Therefore we conclude that the incorporation of variables around repeated exposure to heat needs to include consideration of respite, and provision of suitable management and resources that allow the animals to make the physiological changes as they acclimatise.

The incorporation of daily minimum temperatures into the model is most desirable in considering whether there is respite. Rather than working from a position that lower minima would enable the animals to cope with exposure to hotter maxima than currently as per model thresholds, it must be considered that if there is little or no night-time cooling, animals should not be subjected to such hot day time temperatures, thus meaning lower maximum thresholds.

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

It cannot be assumed that exported sheep will be subject to respite from high heat when unloaded at their destinations, and as such, the issue of heat load at destination ports must be considered in this process. There is no point in managing animals adequately on a ship to then unload and leave them in an environment which imposes greater heat challenges. Weather data for Middle Eastern destination markets shows that the hot and humid regions, particularly during their summer, will have some periods when the environment is extreme, and above the heat stress threshold for prolonged periods. Therefore, there are some regions to which sheep should not be sent unless it can be proven that the holding facilities are capable of providing adequately cool conditions.

It is also recognised that docking in some ports subjects the animals to extreme conditions, both on the ship and during unloading and transport to the destination feedlots. Sufficient weather data exists to factor in the conditions in each location to model the environment to which the animals will be exposed at each site, and also while the ship transits the region.

The model currently uses historical VOS data in considering the future weather risk. A better indicator of future risk may be to include weather forecasts or a combination of historic records and current forecasts in the model. This could allow future assessments to become more dynamic and responsive to predicted conditions for the voyage.

Single destination shipments, which do not dock at the high risk ports and therefore can move through the hottest regions quickly, may be able to travel if the conditions on board do not exceed the heat stress threshold, and if the end destination can be shown to provide suitable facilities for the animals' good health and welfare.

6 Acronyms

AHL	Accumulated heat load
AMSA	Australian Maritime Safety Authority
ASEL	Australian Standards for the Export of Livestock
HLI	Heat load index
HSRA	Heat stress risk assessment
HST	Heat stress threshold
LCT	Lower critical temperature
MO43	Marine Order 43
PAT	Pen air turnover (measure of ventilation rate; the ventilation flow rate divided by the pen area)
THI	Temperature humidity index
TNZ	Thermoneutral zone (the range of environmental temperatures at which metabolic rate is basal, with no requirement to either increase heat production or use additional processes to lose heat)
UCT	Upper critical temperature
WBT	Wet bulb temperature (the temperature read by a thermometer with the bulb covered by a water-soaked cloth over which air is passed)

7 Glossary

Allometric	The relationship of body size to shape, anatomy, physiology and behaviour
Heat load	Exposure of livestock to hot environmental conditions likely to require physiological changes to allow them to maintain homeostatic body temperature
Heat stress	Excessive heat load
Homeostasis	The state of steady internal conditions maintained by living things
HotStuff	Software program for the assessment of heat stress risk for live export voyages
K-value	*K*-values are used in allometric principles as a determinant of the threshold for all sheep to be able to either stand, sit or lie down at the same time
McCarthy review	Independent review into conditions for sheep being transported to the Middle East during the northern hemisphere summer published May 2018
Mortality limit	The wet bulb temperature at which the animal will die
Northern hemisphere summer	Refers to the months of May to October
Panting score	Characterises the panting of livestock; considers more than respiratory rate (e.g. open mouth, protruding tongue)
Standardised shipper sheep	For the purposes of this review, 56 kg adult Merino wether, body condition score 3, zone 3, winter acclimatised, recently shorn
Stocking density	Number of stock per unit area in a high-density housing situation
Summer months	Referring to northern hemisphere: May to October
The department	Department of Agriculture and Water Resources
The model	Heat stress risk assessment model (HotStuff)
The panel	Heat stress risk assessment review technical reference panel
Thermoregulation	Process that allows the body to maintain its core internal temperature within a normal range
Winter months	Referring to northern hemisphere: November to April

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9 Appendices

9.1 Terms of reference

Heat Stress Risk Assessment—Technical Reference Panel

A recent review into the export of live sheep to the Middle East during the northern hemisphere summer by Dr Michael McCarthy made 23 recommendations on conditions and actions required to assure health and welfare outcomes for sheep being transported by sea.

The Australian Government Department of Agriculture and Water Resources (the department) has undertaken to test and consult on the development of a welfare-based approach to HSRA arising from Dr McCarthy's recommendations 3–5, 7 and 8 of the review.

The department has established a Technical Reference Panel to guide consultation with stakeholders and provide expert advice. The department will conduct a public submission processes to ensure all interested stakeholders are given the opportunity to participate in the review process.

The panel will:

- advise on animal welfare, heat stress, ship ventilation and animal science generally
- review relevant research and literature on the development and operation of the HSRA model, livestock heat stress physiology and animal welfare
- examine on-board vessel data from livestock export voyages through Independent Observers and Australian Government Accredited Veterinarian (AAV) reports and other relevant data
- undertake consultations
- draft a findings document based on research, consultation and submissions.

The panel will then provide a consultation report to the department for consideration, outlining the relevant issues raised by stakeholders (and the panel itself) in reaching final recommendations.

Objectives

The panel will:

- review and edit the issues paper prior to its release for public consultation
- provide the department with a findings and proposals document on the heat stress risk assessment (HSRA) model.

To achieve these objectives, the panel will:

- draw on available research and information on the HSRA model, livestock heat stress physiology and animal welfare, ship board ventilation and other relevant material
- consider public submissions to the issues paper

- consult with (not exhaustive) Dr Michael McCarthy, the ASEL Review technical advisory committee and reference group, producer groups, livestock export industry organisations, animal welfare non-government organisations, ship owners, researchers and academics, and other interested organisations.

Out of scope

The panel will not:

- assess other livestock export licencing and regulatory arrangements such as ASEL, approved arrangements and the Exporter Supply Chain Assurance System (ESCAS)
- examine legislation enabling livestock exports with the view to amending it
- comment on the suitability of domestic animal welfare standards for livestock
- seek endorsement of recommendations after providing them to the department, nor draft final orders.

Should other live animal export policy issues arise in the course of the review, it is open to the panel to refer these issues to the Live Animal Export Program within the department, via the secretariat. Issues raised in the process that are relevant to the ASEL review will be collated by the panel secretariat and provided to the ASEL review secretariat.

Guiding principles of the panel

The panel will:

- operate in a transparent, timely and accountable manner at all times
- communicate clearly and regularly with stakeholders and the department as appropriate
- endeavour to reach consensus within the panel, taking into account the views of all members.

The panel's recommendations must:

- not be inconsistent with World Organisation for Animal Health (OIE) standards
- be based on the best available scientific information, evidence based policy and encourage best practice in animal welfare
- be cognisant of the government's policy that supports a sustainable livestock export trade while expecting exporters to meet their animal welfare responsibilities
- be clear, logical and verifiable
- demonstrate that the views of affected stakeholder groups have been considered.

Membership

The panel consists of:

- three animal health and welfare specialists
- one shipping industry specialist.

Other external experts and participants may be invited by the secretariat to discuss particular agenda items.

Secretariat support is provided by the Department of Agriculture and Water Resources.

Meeting arrangements

Members will meet via teleconference fortnightly or as agreed by all parties. An agenda for each meeting will be prepared by the secretariat, which will be circulated to all members prior to meetings.

The secretariat will prepare a summary record of each meeting, including action items.

Two face-to-face meetings (venues to be advised) may be required and in that event, travel and accommodation will be covered by the Department of Agriculture and Water Resources.

Eligibility requirements and declarations of personal interests (conflicts of interest)

Each panel member made a declaration confirming they met the eligibility requirements upon their appointment to the panel. As part of each contract, members must continue to comply with the eligibility requirements.

During the operation of the panel, members are to declare to the secretariat all known actual or potential conflicts of interest as soon as they become aware of the conflict. The initial declaration of eligibility made to the department will be deemed to be a 'standing statement' for all meetings of the panel.

At each meeting, members are to advise of any new actual or potential conflicts of interest arising in respect of issues on the meeting agenda. These should be recorded in the minutes of the meeting, along with the course of action taken in relation to managing the conflict of interest.

Where a conflict of interest is declared by a member on a particular agenda item, the chair and remaining panel members are to consider the nature and extent of the conflict and adopt one of the following courses of action:

- allow the member to participate in discussion and in decision-making on the matter
- allow the member to be involved in discussions on the matter but not be involved in making a decision in relation to the matter
- exclude the member from participation in any discussion or decision-making on the matter
- direct the member to leave the meeting during deliberation on the matter.

The use of external experts is also subject to conflict of interest considerations. Each potential external expert must declare any potential conflict of interest or any possible perception of bias that could prevent him or her from participating in the review of a particular issue/standard. If this declaration raises concerns about whether the external expert should participate in the review, the chair may nominate an alternative expert.

Sunset clause

The panel is initially appointed for three months and will provide a final report by the end of September 2018, or at the earliest possible date thereafter.

9.2 Technical Reference Panel

9.2.1 Associate Professor Anne Barnes

College of Veterinary Medicine, Murdoch University

Anne Barnes is an Associate Professor in Theriogenology at the College of Veterinary Medicine, Murdoch University. Coming from rural Queensland, she graduated as a veterinarian from the University of Queensland, and has a long history of veterinary clinical and research work with large animals, with a particular focus on production animal industry-relevant research related to health, welfare and behaviour. Anne completed a production animal internship, research Honours, and PhD at Murdoch University, worked at CSIRO with the group investigating a vaccine against methanogens, and returned to an academic positon in 2000. She has been heavily involved in LiveCorp-funded research on thermal physiology relevant to the live export industry, as Chief Investigator and principal supervisor for projects on the effects of heat on cattle and sheep, leading the climate controlled room experiments which resulted in data for HotStuff modelling. More recently, Anne has led projects and conducted experiments on animal and environmental monitoring regarding sheep being shipped and in destination markets, with particular emphasis on the effects of high environmental heat load. Anne is Chief Investigator on projects investigating inanition of sheep pre-embarkation, and a co-investigator on the work developing Qualitative Behavioural Assessment of livestock, and on the Welfare Indicators project. Anne is thus well positioned to integrate research on animal physiology, health, behaviour and welfare—particularly as related to the live export industry.

9.2.2 Professor Clive Phillips

Clive Phillips studied agriculture at the University of Reading, UK. He then obtained a PhD in dairy cow nutrition and behaviour from the University of Glasgow. He lectured in and researched livestock production and welfare at the Universities of Cambridge and Wales. In 2003 he joined the University of Queensland as the inaugural Chair in Animal Welfare, where he established the Centre for Animal Welfare and Ethics. Since that time he has been largely involved in animal welfare and ethics research, policy development in animal welfare and teaching students in a number of disciplines about animal welfare. He edits a journal in the field, Animals, and a series of books on animal welfare for Springer. He has published widely on animal welfare in the livestock industries, including animal transport. Recent books include The Animal Trade, published by CABI in 2015, and Principles of Cattle Production, 2nd edition, published by CABI in 2010. He chairs the Queensland Government's Animal Welfare Advisory Board.

9.2.3 Professor Andrew Fisher

Director, Animal Welfare Science Centre, University of Melbourne

Professor Andrew Fisher joined the Faculty of Veterinary Science at the University of Melbourne in 2009 and holds the position of Chair of Cattle and Sheep Production Medicine. Andrew has significant experience in the area of animal welfare, with a particular focus on production animal management and transport. His career spans 25 years in farm animal welfare and veterinary science. Andrew was on the World Organisation for Animal Health (OIE) writing group for the development of international beef cattle standards, including chairing its final meeting. He was also on the writing group for the development of the Australian Animal Welfare Standards and Guidelines for the Land Transport of Livestock, and the Australian Animal Welfare Standards and Guidelines for Sheep. He was on the reference group for the development of the Australian Animal Welfare Standards and Guidelines for Cattle. Formerly head of CSIRO's livestock welfare research group, he was part of a team of scientists and engineers reviewing the live export 'HotStuff' model in 2008. Professor Fisher has published over 80 papers in peer-reviewed journals, 10 book chapters and one book.

9.2.4 AMSA (represented by Mr David Anderson)

AMSA is a statutory authority established under the *Australian Maritime Safety Authority Act 1990 (AMSA Act).* It is the national regulatory body promoting the safety and protection of Australia's marine environment and combating ship-sourced pollution. It provides the infrastructure for safety of navigation in Australian waters, and maintains a national search and rescue service for the maritime and aviation sectors.

David Anderson began his career in the British Merchant navy as an Engineer Cadet in 1981. By 1995, Dave was Chief Engineer with Acromarit (UK) in Glasgow and moved into the office there as Superintendent Engineer. Dave moved to Graig Ship Management in Cardiff, also as Superintendent Engineer, before immigrating to Australia in January 2006. After a short few months as Senior Surveyor with Det Norske Veritas in Sydney, Dave joined AMSA in August 2006 as Senior Surveyor in Canberra responsible for cargoes and port State Control—policy and operation oversight, progressing to Principal Surveyor in 2008. In 2011 Dave was appointed the role of head of Section, Cargoes and Technical in Operations. In 2018 the Cargoes and Technical team moved to Vessel Standards, focusing on cargo standards and legislative policy.

9.3 Australia's climate zones