LiveCorp Submission

March 2019

Heat Stress Risk Assessment for the Export of Sheep to the Middle East

Response to the draft HSRA Report and recommendations by the Independent Heat Stress Risk Assessment Technical Reference Panel

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THE AUSTRALIAN LIVESTOCK EXPORT CORPORATION

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Summary

This submission by LiveCorp, based on existing research findings and new analysis conducted during the last two months, raises questions concerning major findings contained in the "*Draft Report by the Independent Heat Stress Risk Assessment Technical Reference Panel*".

The aim of the work undertaken by the Technical Reference Panel (TRP) was to develop a "welfare-based approach to HSRA in response to recommendations 3–5, 7 and 8 of the McCarthy review" (p8).

The major recommendation of the Draft Report is that voyages involving standard sheep (56kg sheep, body condition score 3, recently shorn, winter acclimatised) should not be permitted if there is more than a 2% chance of deck wet bulb temperatures (a measure of environmental conditions) during the voyage exceeding 28°C.

The TRP's standard sheep is not representative of the current trade. About one-third of current shipments are lambs, with the remaining sheep commonly being considerably less than 56kgs. Recognising this, the TRP recommended adjusting the heat stress ('welfare') threshold wet bulb temperature for the standard sheep using the factors within the HSRA model for adjusting the mortality threshold. These HSRA mortality threshold adjustment factors and their underlying assumptions, when applied to the impact of environmental heat on animal welfare, have never been tested – since they were never used in this context or developed for such a purpose. Neither were they tested by the TRP before they were recommended.

With an allowance for heat generated by the animals themselves it is virtually impossible to meet the WBT thresholds set by the TRP. At the equator wet bulb temperatures are often around 28°C, even without adding an allowance for heat generated by the animals themselves. With the current state of technology, the conditions set by the TRP represent an insurmountable barrier to trade.

The WBT threshold recommendations made by the TRP were arrived at through a number of sequential steps, set out below. It will be shown in this submission that the steps used by the TRP are questioned by some of Australia's foremost scientific authorities in this area, are not supported by evidence gathered on board vessels and rely heavily on experiments involving a very few animals which did not precisely replicate on-board vessel conditions.

The first step used by the TRP was to define unacceptable welfare outcomes from environmental heat. The TRP defined two such outcomes:

- when core body temperature rises more than 0.5°C; and
- when sheep pant with an open mouth without a reduction in panting through the day and night.

Problems exist with both these definitions.

In a practical sense, while on board a live export vessel, rises in core body temperature for individual sheep cannot be observed.

Even if it could be observed, core body temperatures for individual sheep (as for humans) can vary considerably, depending on when measurement occurs, and the activities immediately preceding measurement. To give a human example, for a journalist in Darwin recently, a diurnal variation in body temperature of 2.1°C was observed. Similarly, across individual sheep, variations in body temperature of 38.1°C to 40.0°C are not uncommon.

The ***natural variations*** in core body temperatures ***are large compared to the minimal 0.5℃ rise defined by the Panel*** as comprising unacceptable animal welfare.

One of Australia's foremost, undisputed experts in this field, and author of a paper quoted extensively in the TRP's draft report, Professor Shane Maloney, has provided the view that a 1.0°C rise in body temperature should be used – double the TRP's recommended rise. A paper by Professor Maloney forms an appendix to this submission.

There are also problems with panting.

This includes problems with panting measurement, as evidenced by the plethora of different views on metrics for panting scores. The Panel has provided yet another set of panting score measures which are different from those provided by Dr McCarthy in a Government report not six months earlier (and placed into regulation on 21 September 2018). Dr McCarthy's scores themselves are different again from those in ASEL.

But measurement is not the only problem with the use of a threshold or outcome based on *open mouth panting without a reduction in panting through the day and night*. Sheep pant like people sweat. It need not signify welfare is compromised. The authority on sheep panting, Bob Hales, stated that sheep can open mouth pant when body temperatures are normal – that is, when there is no welfare issue. Additionally, Professor Maloney has noted that open mouth panting does not immediately nor necessarily equate to any physiological harm.

As the Panel recognises, it is not uncommon for sheep to open mouth pant on a hot afternoon in Australia.

Perhaps because of this recognition, the Panel specified that open mouth panting represented an unacceptable welfare outcome if it occurred "through the day and night". The rationale used by the Panel in setting this cut-off is, however, not clear. Why, for instance, is panting through the day and night unacceptable while panting through the day is acceptable? For how long does panting have to continue for it to be regarded as unacceptable and what is the evidence behind any cut-off used?

Professor Maloney states that *"Panting has gained the reputation of being unsustainable because it is energy demanding, …. but except perhaps in extremis, that is generally not the case. Because the muscular activity of panting is so economical and because its low energy requirements are offset by energy savings in other muscles, panting in sheep and oxen is achieved with little or no detectable increase in whole-body metabolic rate".* In other words, Professor Maloney does not regard panting as an issue except, <u>perhaps</u>, *in extremis.* What qualifies as *in extremis* is open to consideration, but it has been suggested should involve more than 48 hours of open mouth panting.

The Panel then went on to link a 0.5°C rise in body temperature / open mouth panting with a wet bulb temperature of more than 28°C (for a standard sheep).

- This link was largely based on small experimental studies involving less than 20 sheep.
- Conditions in the artificial experiments were different to those found in current live export voyages including in the following four important areas:
    - Differences in the type of animal included in the experiment and those currently exported.
    - Differences in environmental conditions – a dry bulb temperature of 40°C was used in one of the experiments and 37°C was used in another. These ambient temperatures may represent conditions encountered in the northern summer, but not over all of the year.
    - Ventilation (air turnover) – which was considerably less than in current vessels.

- Possibly most importantly, diurnal fluctuations in temperatures – temperatures in the experiment were increased and then held constant at high levels while diurnal temperature variations exist on live export voyages, even at the equator.

Professor Maloney believes that these differences between the experimental conditions and those encountered on-board real world vessels may be crucial.

Obviously, because of the potential – or often likelihood – that there will be differences between experimental studies (particularly within a laboratory) and the real world, it is important to verify any results using practical, real-world observations. This is part of normal scientific practice. It is especially important to complete this task when results from the experiment are to be applied in a context where impacts from such application are likely to be substantial. In the case of applying the findings from the experimental study used by the Panel, this would extend to correlations between wet bulb temperature, core body temperatures and panting. We note that it was in the TRP's Terms of Reference identified to "*examine on-board vessel data from livestock export voyages through Independent Observers and Australian Government Accredited Veterinarian (AAV) reports and other relevant data*". However, within the TRP report, there is little indication that such analysis has occurred in a systematic or rigorous way or what the outcomes were.

From the TRPs' analysis and experiments relied upon, for a group of standard sheep, open mouth panting day and night should commence at about a WBT of 28°C. For other sheep it should commence at an appropriately adjusted WBT using the procedures for adjustment outlined in the TRP's Draft Report. For a winter acclimatised standard lamb (40kg, body condition 3, recently shorn – i.e. with a coat of under 10mm) the adjusted WBT temperature is 24.4°C.

This fundamental prediction from the TRP's analysis is testable using real world voyage data.

LiveCorp has used a range of data sets involving live export voyages to and through the Middle East to test the validity of the TRP's analysis by placing actual measurement of WBTs and panting scores against the predictions of the TRP. Three data sets were used by LiveCorp:

- Detailed data on panting scores and WBTs independently collected at the time of the development of the HSRA model. This involved data on 7 voyages, 14 decks and 42 locations with WBT information collected every two hours and panting scores twice per day using a 5 point scale.
- AAV data on 13 voyages in 2017 and early 2018 – this included AAV recordings of WBTs (taken once per day) and panting scores (using a 3 point scale).
- More detailed data than above for 14 voyages in 2018 and early 2019. This dataset includes the AAV observations, but also more detailed data on livestock carried by deck.

The analysis of this real world data is contained in Chapter 4 of this submission. In summary, the data analysed does not support the conclusions of the TRP that at a WBT temperature of 28°C, for standard sheep, there is an *unrelenting challenge to homeostasis* as evidence by open mouth panting *day and night*.

A range of concepts are presented in this submission for regulation of welfare outcomes on voyages to and through the Middle East, different to current regulations. One possibility is to regulate welfare outcomes directly – e.g. by specifying that open mouth panting can only occur for a certain duration and to require an exporter to demonstrate due diligence in meeting this requirement before a voyage commences. This would represent a modern approach to regulation as it is *outcomes based*.

Concepts are also presented for modifying the HSRA model by introducing probabilities for duration and respite from hot environmental conditions. For instance, calculations are presented on the probability by month for encountering two hot days in a row where minimum deck WBTs remain above 30°C (i.e. no respite occurs over 48 hours). These calculations show that the probability of this occurring is only more than 5% for June, July and August – in other months there is a very high probability of respite from high temperatures.

When looking at regulatory solutions, however, the overriding message from research presented in this submission is to proceed with caution. The effect of environmental heat on animal welfare is a complex, uncertain area, unsuited to simple regulatory responses. To regulate an industry out of existence on the basis of ground breaking regulation, based on scant knowledge or overly simple solutions, would penalise the Australian economy, particularly rural Australia, and live exporters for an uncertain outcome.

A number of recent changes have been made to regulations including a reduction of at least 17.5 per cent in the base-line stocking density for sheep shipments, the placement of Independent Observers on all vessels, the halving of the notifiable mortality rate to one per cent and changes to AMSA regulations and the conduct of ventilation audits. Additionally, industry has implemented a moratorium on shipments to the Middle East for the northern summer months. The efficacy of these changes needs to be assessed to determine whether further changes are required. Only once this task has been completed should further regulatory change, that may impact substantially and detrimentally on producers and live exporters alike, be considered.

1 Introduction

The Australian Livestock Export Corporation Limited (LiveCorp) welcomes the opportunity to comment on the Technical Reference Panel's (TRP's) draft recommendations on changes to the heat stress risk assessment (HSRA) framework to be applied to sheep voyages to and through the Middle East during the northern hemisphere summer.

LiveCorp is a not-for-profit industry body funded through statutory levies collected on the live export of sheep, goats, and beef cattle, and a voluntary levy collected on live dairy cattle exports. LiveCorp is one of the 15 Australian rural Research and Development Corporations (RDCs), being the only RDC focused solely on the livestock export industry. In partnership with Meat & Livestock Australia, LiveCorp owns the HSRA model. As a result, LiveCorp is directly affected by the TRP's draft recommendations. LiveCorp is also indirectly affected by the TRP's recommendations through their potential impact on the trade in live sheep between Australia and the Middle East.

The key recommendation in the TRP's draft report is that the:

> *"WBT* [wet bulb temperature] *limit for a standardised shipper sheep (56 kg adult Merino wether, body condition score 3, zone 3, winter acclimatised, recently shorn) is 28℃".*

It is this recommendation to which most of this submission is devoted.

The basis for this recommendation is a conclusion reached by the TRP that sheep "*exposed to WBTs above this value*" are faced with "*an unrelenting challenge to homeostasis*". LiveCorp will provide evidence in this submission that:

- The data examined by the TRP are extremely limited, involving very small numbers of sheep.
- The experiments from which these data were obtained, in important areas, do not mirror conditions on live export vessels.
- Observations of welfare outcomes from actual live sheep export voyages encountering WBT in excess of 28°C provide no indication of "*an unrelenting challenge to homeostasis*".
- The TRP has applied extreme and compounding conservatism in a number of areas that may explain some of the differences between observations from actual live sheep shipments and the TRPs predictions – in the view of LiveCorp the application of such conservatism may be inappropriate in the context of Australia's live sheep trade to the Middle East.

Before examining these points in more detail, however, the next chapter of this submission presents analysis concluding that the TRP's draft recommendations will result in a cessation of the sheep trade from Australia to the Middle East.

2 Impact of the draft recommendations on the trade

Summary

- The TRP's recommendations will result in a cessation in the trade in live sheep to and through the Middle East.

2.1 Introduction

A requirement on the TRP is that in making recommendations it must "*be cognisant of the government's policy that supports a sustainable livestock export trade while expecting exporters to meet their animal welfare responsibilities*". The requirements for the ASEL Review (of which the HSRA Review is just one part) are even greater. A Guiding Principle of the ASEL Technical Advisory Committee is that the Committee must "*balance the implications for animal welfare with the practicalities of livestock management, compliance costs and industry sustainability*".

In light of the Government's interest in ensuring the sustainability of the trade it is important to analyse the impact of the TRP's draft recommendations on the ability of the trade to continue operating.

2.2 DAWR's assessment of the impact of the TRP's draft recommendations

Following the release of the TRP's draft recommendations the Department of Agriculture and Water Resources (the department) released a short paper entitled "What do the Heat Stress Risk Assessment Review Recommendations Mean?" which contained advice to stakeholders on the likely implications of the TRP's recommendations.

In this paper, the department advised that:

> " …. *live Merino sheep exports from Australia during … May to October .. may not meet the WBT animal welfare criterion* [i.e. may not meet Recommendation 2 in the TRP's Draft Report]. *It is also likely that decks on ships will carry reduced numbers of sheep during other months of the year, depending on the effectiveness of shipboard ventilation and the class of sheep to be exported.*
>
> *It may not be economic to export sheep to the Middle East during the northern summer, leading to a cessation of trade during this period. ….*
>
> *The impact on the broader industry over the course of a year remains to be determined. The impact will be dependent on the class of sheep available for export and the effectiveness of shipboard ventilation, including pen air turnover rates.*
>
> *It is likely that the numbers of sheep exported will decline and the trade will become more seasonal than it has been in the past. The bulk of sheep exports to the Middle East may take place between November and April".*

On the basis of the department's analysis quoted above, the impact of the TRP's draft recommendations on the trade may be described as catastrophic. The department's analysis suggests:

- Cessation of the trade for six months of the year (May to October); and
- Likely flow on effects, of an indeterminant level, to the other six months of the year (November to April).

LiveCorp, however, believes that the department's assessment of impact is significantly understated. In the following section information is presented to suggest that the TRP's draft recommendations will prohibit trade for almost all months of the year.

2.3 LiveCorp assessment of the impact of the TRP's draft recommendations

As pointed out in Chapter 1, the key TRP recommendation is that a:

> *"28 ℃ 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*".

With this draft recommendation live export voyages will not be permitted if, for a standard sheep shipment, there is more than a 2% probability that WBTs on board the vessel will be greater than 28°C. Given this recommendation, the task of determining which voyages will be permitted is then reduced to determining when there is less than a 2% chance that wet bulb temperatures on-board the vessel will exceed 28°C[1].

Wet bulb temperatures on board a vessel reflect a combination of the wet bulb temperature in the general environment and the heat generated by the animals themselves - or:

$W_v = W_e + \Delta W_a$

Where W_v is the wet bulb temperature on board a vessel deck, W_e is the environmental wet bulb temperature and ΔW_a is the wet bulb temperature increase arising from the heat generated by the sheep themselves (referred to as delta T in the HSRA reports). The TRP's draft recommendations involve calculating W_e at the 98th percentile level (so that there is less than a 2% chance of the selected level being exceeded).

In analysing the impact of the TRP's recommendations we first present information on wet bulb temperatures calculated at the 98th percentile level (i.e. W_e is calculated for the 98th percentile) and then separate calculations are undertaken for the wet bulb temperature rise due to the heat generated by the animals themselves (i.e. ΔW_a is calculated).

For voyages to various ports in the Middle East information on the 98th percentile WBTs by month is presented Table 2.1.

It can be seen, from Table 2.1 that 98th percentile environmental temperatures for voyages to the Middle East exceed 28°C for many months of the year. Just taking into account environmental temperatures (i.e. ignoring for the moment ΔW_a), under the TRP's 28°C recommendation, voyages involving standard animals to Aqaba (Jordan), Jeddah (Saudi Arabia), Mersin (Turkey) and Tekirdag (Turkey) would only be permitted for one month of the year. Similarly, taking into account only environmental temperatures, under the TRP's recommendation, voyages to Doha, Dubai (both in the UAE), Kuwait and Muscat would only be permitted for five months of the year.

[1] The analysis presented throughout this submission has a focus on the standard animail is all based on a standard animal. Given that the TRP decided to present information on the basis of a standard animal, this submission follows the same practice. Where important, however, information is presented on other (non "standard") animals which are more typical of the current trade. This is the case, for instance, in Table 2.2.

Table 2.1: Environmental Wet Bulb Temperatures at 98 Percentile for Voyages to Middle East/Turkey

Voyages to ports	Month of year (cells shaded in red are where the 28° threshold is exceeded)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Aqaba	28.2	29.1	28.6	28.6	30.2	30.8	30.7	32.0	30.8	29.8	29.4	27.2
Doha	26.2	26.4	27.2	28.3	30.6	32.6	32.4	33.0	33.1	29.5	27.6	26.3
Dubai	26.2	26.4	27.2	28.3	29.7	32.6	31.2	31.8	32.4	29.2	27.6	26.3
Jeddah	28.2	29.1	28.6	28.6	30.2	30.8	30.7	32.0	30.8	29.8	29.4	27.2
Kuwait	26.2	26.4	27.2	28.3	30.6	32.6	32.5	33.1	33.2	30.2	27.6	26.3
Mersin	28.2	29.1	28.6	28.6	30.2	30.8	30.7	32.0	30.8	29.8	29.4	27.2
Muscat	26.2	26.4	27.2	28.3	29.2	31.5	30.0	29.6	28.6	29.2	27.6	26.3
Tekirdag	28.2	29.1	28.6	28.6	30.2	30.8	30.7	32.0	30.8	29.8	29.4	27.2

Source: Hotstuff Version 5. LiveCorp calculations.

But Table 2.1 does not include the full implications of the TRP's recommendations since it ignores ΔW_a.

To conduct a more complete investigation of the impact of TRP's draft recommendations on the trade, LiveCorp has defined three categories of animals:

- The TRP's standard animal – a 56kg, body condition score 3, recently shorn Merino wether, sourced from zone 3. Instead of this illustrative wether being winter acclimatised (as in the TRP's report) we have designated acclimatisation to the month in which shipment occurs. Acclimatisation to the month of shipment means that the threshold wet bulb temperature is above 28°C for the Australian summer months.
- What is termed here a Merino shipper – a 45kg, body condition score 3, recently shorn (i.e. with a coat of under 10mm) wether, sourced from zone 3, acclimatise to the month in which shipment occurs.
- A Standard Merino lamb – specified here with a weight of 40kg, body condition score of 3, recently shorn (i.e. with a coat of under 10mm), sourced from zone 3 and acclimatised as above.

Analysis has been conducted using the three animal types specified above. The analysis involved:

- Calculating threshold wet bulb temperatures for each animal type using the recommendations contained in the TRP's draft report[2]. These threshold temperatures as well as being variant across animal types are also different across months of the year due to different acclimatisation.
- Calculating the 98th percentile highest environmental wet bulb temperatures for voyages to Aqaba and Kuwait using information from the HSRA reports.
- Calculating heat generated by the animals themselves based on ASEL loading densities plus 17.5%. This was done across a range of Pen Air Turnover (PAT) values – from a PAT of 125 to a PAT of 200. Equations from the HSRA model (and available in the HSRA reports) were used in these calculations.
- Adding the heat generated by the animals themselves to the environmental temperatures to derive the 98th percentile deck temperatures (this represents the temperatures that would exist on the deck of a livestock carrying vessel at the 98th percentile level). The heat generated by the animals themselves was small relative to the level of environmental heat – resulting in a rise of about 1.3°C to 2.5°C, depending on the animal type and PAT value.

[2] For non-standard animals this involved using the HST thresholds contained in the HSRA reports and then proportionately adjusting these downwards by 28 divided by the HSRA HST wet bulb temperature for the standard animal.

- Comparing the threshold wet bulb temperature with the deck wet bulb temperature. If the deck temperature exceeds the threshold temperature, the voyage would not be permitted.

Results from the process outlined above, as applied to voyage to Aqaba, is shown in Table 2.2. The colour coding in this table is as follows:

- Red = Threshold temperature exceeded for all PAT values examined.
- Amber = Threshold temperature exceeded for some PAT values examined.
- Green = Threshold value not exceeded for any PAT value examined.

Table 2.2: Trade impact of application of TRP's recommendations across animal types for voyages to Aqaba.

Animal Type	Month of shipment											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
TRP standard animal												
Merino shipper												
Merino lamb												

It can be seen from Table 2.2 that under the TRP's recommendations, involving a 28°C threshold for a standard animal with commensurate adjustments across other animal types:

- Lambs cannot be traded at the assumed stocking level and with PATs of 200 m/h or lower, during any month of the year; and
- Trading in the Merino shipper at the assumed stocking level and with PATs of 200 m/h or lower, would be prohibited during ten months of the year, but would be permitted in December and January; and
- Trading in the TRP's standard animal at the assumed stocking level and with PATs of 200 m/h or lower, would be prohibited during 10 months of the year, but would be allowed in December and January (the later for some PAT values only).

The impact of the TRP's recommendations on sheep classified as lambs are particularly significant. Table 2.3 shows that lambs comprised one-third of all sheep shipments in 2017. Lambs or young sheep make up the vast majority of shipments to some destinations due to customer demand).

Table 2.3: Shipments of adult sheep, hoggets and lambs to all destinations in 2017.

Animal Type	Number shipped	Percentage
Adult sheep	944,602	57%
Hoggets	166,542	10%
Lambs	535,821	33%
Totals	1,646,965	100%

2.4 Conclusion

It has been demonstrated in this chapter that the TRP's draft recommendations will result in a closure of the trade for all, or almost all, months of the year. Given the size of capital and logistic investment needed for any trade to occur, the fact that the draft recommendations allow trade for a few months of the year only, to a limited number of ports and for limited categories of livestock, will result in a complete cessation of the trade.

Such impacts will clearly have very significant real-world implications for the lives and wellbeing of producers, communities, businesses, Australian trading partners and more. It is critical, therefore, that any recommendations or regulatory decisions are strongly evidenced and do not apply unjustified conservatism, assumptions or generalisations beyond that which is necessary – as it is the aforementioned parties that will feel ultimately feel the impact of such an approach.

3 Thresholds used by the TRP based on judgement and uncertain evidence

3.1 Introduction

In the previous chapter it has been demonstrated that the TRP's draft recommendations, if implemented, will result in a cessation of the trade in live sheep from Australia to the Middle East, a trade that has been operating for more than half a century. In this chapter it is shown that the TRP's recommendations are underpinned by uncertain and limited knowledge and its analysis of the welfare impacts of environmental heat on sheep is demonstrably excessively conservative and reliant on scant, uncertain evidence on key issues.

LiveCorp fully appreciates the difficulty of the task assigned to the TRP of shifting risk assessment for live export voyages from mortalities to a welfare basis. This chapter will explore some of these difficulties which include limited available research, the application of value judgements, the prevalence of individual differences between sheep experiencing environmental heat and apparent inconsistencies between different research results.

3.2 Setting an appropriate heat stress welfare threshold

In considering the task of shifting risk assessment for live export voyages from mortalities to a welfare basis, the first decision to be made is the welfare setting to be used.

Clear examples exist of where welfare is compromised by heat – for example:

- if heat is the primary or significant cause of death in sheep carried on live export voyages; or
- if heat is a primary or significant cause of permanent impairment in sheep carried on live export voyages.

Outside these clear areas, however, value judgements are involved. What level of discomfort is appropriate for an animal to sustain as a result of heat? The issue is further complicated by the fact that we do not know the level of discomfort an animal is experiencing and how an animal may feel about it.

The Panel has tried to address this issue by using a framework devised by Mitchell et al. 2018.

3.2.1 Framework for considering the impact of environmental temperature on heat stress

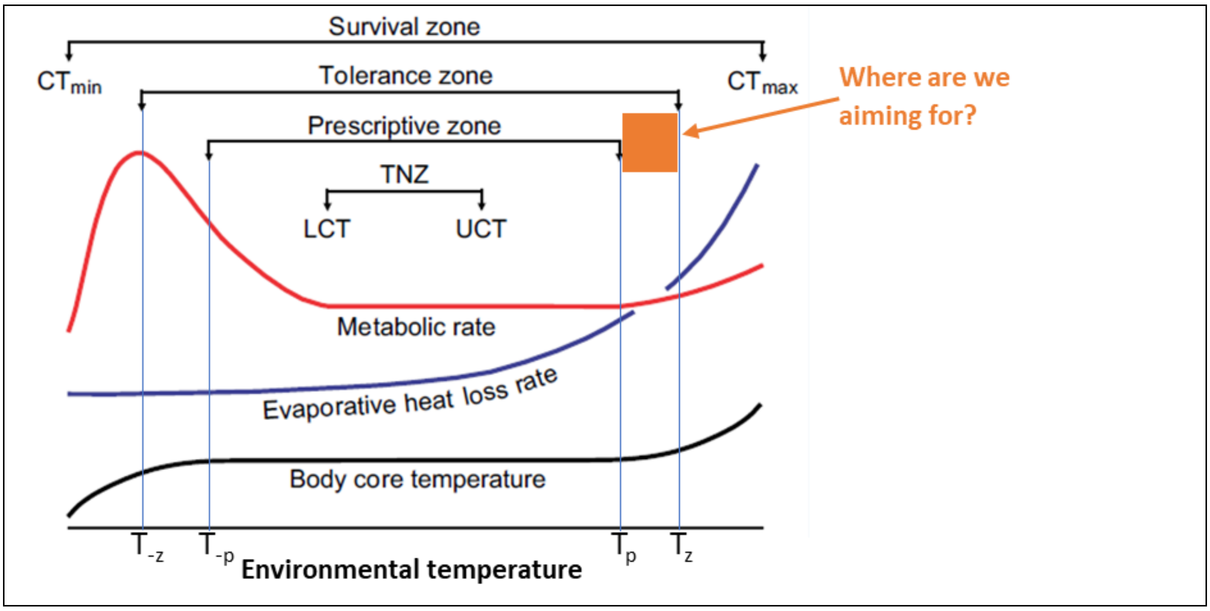
The framework used by the TRP to conclude that exposing standard sheep to environments with WBTs greater than 28°C represents unacceptable animal welfare is shown in Figure 3.1 (which closely mirrors Figure 1 in the draft report). LiveCorp believes that Figure 3.1 represents a useful framework to consider heat stress issues on sheep exported live.

As explained in the TRP's draft report, Figure 3.1 depicts the relationship between environmental temperature, core body temperature, evaporative heat loss rate, and metabolic rate of mammals. In the case of live exports, the relevant environmental temperature is taken to be represented by wet bulb temperature.

Shown in Figure 3.1 are four zones of thermal safety:

- The Thermoneutral Zone (TNZ) is the range of environmental temperatures which are perfect for the animal in terms of maintaining core body temperature, so the animal does not have to use energy to either increase or decrease body temperature. As Mitchell et al. point out, free-living mammals spend very little of their lives within the TNZ.

Figure 3.1: The relationship between the environmental temperature and the core body temperature, evaporative heat loss rate, and metabolic rate of mammals.



- In the prescriptive zone, outside the TNZ, stable body temperatures are maintained by increasing metabolic rate and evaporative heat loss (water loss). Animals can live within the prescriptive zone over the long term.
- In the tolerance zone, outside the prescriptive zone, core body temperatures rise, but the animal employs mechanisms to stabilize core body temperatures – survival of individuals is not threatened.
- In the survival zone, outside the tolerance zone, individual lives are at risk (e.g. from heatstroke or cold injury).

3.2.2 The prevalence of individual differences and the application of conservatism

A problem with applying Figure 3.1 in setting temperature thresholds is that there are differences in core body temperatures between sheep and, as is the case with humans, significant variations exist in the reaction of individual animals to heat. This means that the environmental temperature where an animal crosses the boundary from one zone to another (e.g. from the prescriptive zone to the tolerance zone) will differ between animals. The Panel recognises this, noting:

> *"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."*

The Panel's response to these individual differences is to be conservative. The Panel states:

> *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.*

Adopting conservative positions may have merit when there is no significant consequence from doing so or for relatively simple or well understood situations where the impact of being conservative on one aspect has predictable consequences. When the sustainability / future of an industry, and the communities that it supports, is riding on the answer, conservatism should be eliminated and the best science applied without modification – as opposed to using the best science to arrive at conclusions on heat stress parameters, but then adjusting these further downwards. . Where multiple issues arise within a complex situation that are addressed by adopting a conservative approach, it is even more critical to apply best science and guard against a multiplicative effect, whereby overall conservatism unintentionally compounds to create an unrealistic and unnecessary outcome.

Two engineering examples provide some illumination of where conservatism may and may not have merit.

- Red-tongue particle board flooring is 22 mm thick compared to 19 mm for the more common yellow-tongue. The extra thickness gives it 1.5 times the stiffness for the same span. That degree of conservatism is appealing when the additional cost is only $3.52/m2 plus extra lifting for the builders.
- High voltage transmission towers are a trussed assembly which is repeated many times and must sometimes be erected in inaccessible sites. The mass of steel is very important, not only for erection difficulty but also for direct cost. As a consequence, the design is finely honed with no conservatism left. While it has been known for towers to fail in extreme winds, making sure they never failed would incur very large costs.

Another example is regulation of vehicular speeds.

- A riskless (very conservative) approach to motor accidents would be to ban cars and trucks entirely, but society chooses not to do this in recognition that the consequences of this degree of conservatism would be too great.
- A less conservative approach would be to stipulate maximum speed of 40 km/hour on all roads. Again, society chooses not to do this in recognition that the consequences would be too great. Rather speeds are regulated on the basis of degree of risk involved – with very low speeds in school zones and relatively high speeds on divided rural expressways.

In terms of the Panel's report, every additional element of conservatism introduced further restricts the carriage of livestock and increases the impact on the trade and the people involved in it. As has been demonstrated in Chapter 2, the conservative recommendations of the Panel would result in a cessation of the trade. In this context, where there is a downside to the conservatism, it is not appropriate to arbitrarily add conservatism.

3.2.3 Defining the temperature threshold beyond which unacceptable welfare occurs

A second issue with Figure 3.1 is the placement of a temperature threshold. If a temperature threshold is to be defined, beyond which welfare outcomes are regarded as unacceptable, the question is: at what point along the environmental temperature axis in Figure 3.1 should this threshold be placed?

In determining this point the TRP place significant reliance on a statement by Duncan Mitchell and his co-authors that once an animal moves outside the prescriptive zone into the tolerance zone "physiological malfunction" will occur. The TRP implicitly conclude, therefore, that the threshold environmental temperature should be set at above, but close to, T_p – at about the point where "physiological malfunction" will occur.

“Physiological malfunction” is a powerful term and, on face value, would seem to imply unacceptable welfare consequences. However, a reading of the Mitchell et al 2018 paper leads to a different conclusion.

The use made of the term “physiological malfunction” by the TRP is very different to that by Mitchell and his co-authors. Michell et al. use “physiological malfunction” to refer to the deterioration in reproductive performance arising from ***long term*** climate change (over many weeks and months, but more generally over a lifetime). The TRP, however, attempt to apply this term to a live export voyage that occurs over a number of days, not weeks and months, and certainly not over a lifetime. This clearly represents significant and unnecessary conservatism by the TRP, if not an apparent misunderstanding of the nature of relevant physiological impacts within this zone.

It is evident from a close reading of the Mitchell et al. paper that some of the characteristics of “physiological malfunction” as defined by the Committee, such as:

- Altered respiratory function (changed rate and / or character)
- Altered behaviours (for example, posture, stance, stepping and pawing, eating and drinking)

would not be regarded by Mitchell et al. as “physiological malfunction” but normal physiological responses to climatic changes. On panting the authors note the following:

> *“Panting has gained the reputation of being unsustainable because it is energy demanding, …. but except perhaps in extremis, that is generally not the case. Because the muscular activity of panting is so economical and because its low energy requirements are offset by energy savings in other muscles, panting in sheep and oxen is achieved with little or no detectable increase in whole-body metabolic rate”.*

Within the ecological focus of their research, Mitchell et al. are quite clear that when the welfare focus is on individual animals the upper environmental temperature threshold should be placed at T_z:

> *“If it is the welfare of individual animals that are of concern, then it [the safe thermal limits} should be the lower and upper ends of the tolerance zone”.*

This placement by Mitchell et al. of the upper environmental temperature threshold at T_z is based on the following observations:

- Survival of individuals is not threatened at temperatures up to T_z.
- Large mammals, such as sheep and cattle, spend a significant amount of time in a state of heterothermy – that is, between ambient temperatures of T_{-z} to T_{-p} and T_p to T_z.
- Animals (including humans) will only maintain homeothermy if the following conditions are met: they are healthy, at rest, well-resourced and not facing demands from competing homeostatic mechanisms.
- If these conditions are not met, animals will be in the tolerance zone <u>and this will often be the case</u>.

The merits of a placement of the upper ambient temperature threshold at T_z are even stronger when the environmental temperature is only within the tolerance zone for a relatively short amount of time, as outlined below.

3.2.4 The problem of limited research

A third problem with using the concepts depicted in Figure 3.1 is that the amount of research conducted into the relationships shown is extremely limited. As a result, conclusions reached by the TRP are based on just a couple of studies – in fact, the conclusions appear heavily reliant on one particular study involving just eight sheep.

The following statements, drawn from a 2018 paper by Teresa Collins et al.[3] clearly point to this lack of research:

> *"We identified a lack of scientific literature relating to heat load in animals transported by sea and considerable potential for bias in the literature that was found".*
>
> *"The environmental WBT at which body temperature rises has been the subject of observational studies, experimental research and much debate. The data sets for establishing these WBT thresholds are somewhat limited .....*"

3.3 How did the TRP recommend a threshold temperature of 28˚C?

It is unclear precisely where the 28°C threshold, as recommended by the TRP, lies on the environmental temperature axis of Figure 3.1, other than it is between T_p and T_z, and highly likely to be close to T_p. The TRP, however, seemed to rely on two pieces of information in arriving at the 28°C threshold recommendation.

3.3.1 Determination of threshold environmental temperature through rise in core body temperature

The first piece of information was a result from the Stockman PhD thesis that at 28°C WBT for eight winter acclimatised sheep core body temperature rose by 0.5°C.

Several comments can be made on the use of a 0.5°C rise in body temperature to define the threshold environmental temperature.

1. First, the subject of body temperature is extremely complex - Lees et al. even assert "*providing a precise definition of core body temperature is difficult, as **a consistent definition is not available***"[4] [our emphasis].
2. Second, variations in body temperature are dependent on several internal and external causes:
   - For given thermoneutral environmental conditions, modulations of body temperature are directly and inherently subjected to circadian rhythms and sexual status and rhythms.
   - The most important biological functions have major effects on temperature, such as alimentation and digestion or any kind of muscular activity – for example, Smaill and Barrell found that the rumen temperature (one way that body temperature is approximated) in one sheep fell from 40.1°C to 38.2°C shortly after drinking water[5].
   - Body temperature is also modified when animals are placed in situations of stress or pain.
   - All the mechanisms involved in the fight against external pathogens, during an infection, or even locally when there is a tissue inflammation, will lead to hyperthermia.

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[3] Collins, T., Hampton, J.O. and Barnes, A.L., 2018, "A Systematic Review of Heat Load in Australian Livestock Transported by Sea", Animals, Vol. 8, https://www.mdpi.com/2076-2615/8/10/164.
[4] Lees, A.M., Lea, J.M., Salvin, H.E., Cafe, L.M., Colditz, I.G., Lee, C., 2018, "Relationship between Rectal Temperature and Vaginal Temperature in Grazing Bos taurus Heifers", Animals, Vol. 8, https://www.mdpi.com/2076-2615/8/9/156/htm.
[5] Smaill, A.L., and Barrell, G.K., 2006, "A comparison of sites for monitoring body temperature of cattle and sheep", *Proceedings of the New Zealand Society of Animal Production*, Vol. 66.

- Environmental conditions such as ambient temperature, humidity, wind, sun, shade, and air movements have an impact on body temperature.

3. Third, the 0.5°C rise in core body temperature is extremely small relative to variations in body temperatures between individuals and even the same individual at different times of the day:

   - In terms of differences between individual sheep, in an experiment by Smaill and Barrell[6] the range in rectal temperatures was 38.1°C to 40.0°C.
   - In terms of daily range, the Stockman wethers in Experiment A had a daily body temperature range of 0.8°C before entering the climate controlled rooms and a daily range of 1.1°C after exiting the rooms.

   Body temperature measurements can also vary considerably when taken at different sites. For instance, Goodwin[7] found that for sheep:

   - tympanic temperature was significantly higher than subcutaneous temperature,
   - rectal temperature was significantly higher than tympanic temperature,
   - rectal temperature was significantly higher than subcutaneous temperature.

   Correlations between temperatures obtained by the 3 methods were described by Goodwin as only "moderate".

   These variations also exist in humans:

   - Although 37°C is considered "normal" temperature, body temperature varies throughout the day. It is lowest in the early morning and highest in the late afternoon.
   - Variations in body temperature of about 0.5°C can occur through physical activity. In the "Australian Open" tennis tournament, until this year, matches would only be suspended if the wet bulb temperature reached 32°C. It is highly likely that during a tennis match, involving intense physical and metabolic activity, at this temperature the core body temperatures of the players would have risen well above 0.5°C and most likely above 1.0°C for most of the full period of the match. For instance, Hornery et al., 2007, found that in conditions milder than typically experienced during the Australian Open players reached a core body temperature almost 2°C higher than "normal"[8].
   - Temporary elevations in body temperatures of 1°C-3°C, caused by short-lived (acute) illnesses, are well-tolerated by healthy adults. A solid body of medical advice exists it is often better to leave short term fevers untreated[9].

4. Fourth, not surprisingly given the complexity of the subject and the prevalence of individual differences, different studies yield different results.

Given the complexity of the subject, the variation that exist in body temperatures (both in different animals and the same animal at different times), and the ability of animals and humans to tolerate body temperature fluctuations (both up and down), a rise in body temperature of 0.5°C is far too narrow a basis on which to base an environmental temperature threshold.

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[6] Ibid, p.291.

[7] Goodwin, S., 1998, "Comparison of body temperatures of goats, horses, and sheep measured with a tympanic infrared thermometer, an implantable microchip transponder, and a rectal thermometer", *Contemporary Topics in Laboratory Animal Science*, Vol. 37, pp.51-55.

[8] Hornery, D.J., Farrow, D., Mujika, I., Young, W., 2007, "An integrated physiological and performance profile of professional tennis", *British Journal of Sports Medicine*, Vol. 41, No.8, pp.531-6.

[9] For example, see advice from the Mayo clinic.

3.3.2 Determination of threshold environmental temperature through panting

In order to draw a welfare implication from a 0.5°C rise in body temperature, the TRP has linked this rise to panting scores.

Like core body temperature, the issue of panting scores is complex, as evidenced by the fact that three different scales for panting scales have been used by, or recommended to, the live export industry just over the last 18 months. These three panting scales are shown in Tables 4.1 – 4.3.

- Table 3.1 shows the simple ordinal 3 level scale that is used under ASEL V2.3.
- Table 3.2 shows that ordinal 5 level scale recommended in the McCarthy Report.
- Table 3.3 shows the ordinal 5 level scale now recommended by the TRP.

Table 3.1: ASEL panting scores to describe "respiratory character"

Score	Description
1	Normal
2	Panting
3	Gasping

Table 3.2: McCarthy report panting scores

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

Table 3.3: Panting scores as recommended by the TRP

Score	Description	Respiratory Rate (RR)
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

Although the general concept of sheep panting is simple, there is little agreement on where to place cut-off points to move from one point in the scale to another. It can be seen that there are important differences between panting scores recommended by the TRP and those recommended in a report commissioned by Government just a few months ago. There are some obvious question marks over the TRP's panting score recommendations – e.g. if the respiratory rate is 110, but the mouth is open does that get assigned to score 2 or score 3? The TRP notes that "*The choice of table of panting scores and respiratory rates will be a continued matter of debate*".

With limited justification provided in the draft report, the TRP concluded that panting above score 3, after some reference to duration, represents unacceptable animal welfare:

> *"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" (p18).*

An issue with the statement above is that it seems to imply that any move to PS3 represents unacceptable welfare, no matter how limited the duration. The TRP recognise, however, that it is not uncommon to witness sheep panting at score 3 on hot days, including in Australia:

> *"…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" (p18).*

As a result, the initial statement made by the TRP (as quoted above), implying that any move to PS3 represents unacceptable welfare, is also modified by reference to a duration:

> *"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" (p19).*

Duration is a critical area in terms of heat stress, but a topic that receives relatively little attention in the report (particularly with regard to those recommendations in the report that have direct regulatory impact) – and this is true for the consideration of panting. The TRP's statement on p19 would seem to imply that 24 hours of continuous panting at score 3 represents unacceptable welfare, but no justification is provided for selection of this time period. Why 24 hours of panting is considered unacceptable, rather than 48 hours, 72 hours, or 12 hours is not explained (or for that matter panting at score 2 for 144 hours versus panting at score 3 for 24 hours).

The scientific basis for the TRP's chosen welfare / duration threshold (pant score 3, day and night) and claimed consensus is unclear and appears divorced from known physiological impacts.

With the selection of PS3 as representing unacceptable animal welfare, the logic used by the TRP to determine that environmental conditions involving a WBT of more than 28°C can be succinctly expressed as follows:

- Continuously panting at score 3 for more than a period defined (without any stated justification) as "*through the day and night*" represents unacceptable animal welfare. The TRP state that there is "general consensus" that panting at score 3 is "beyond what is acceptable", but we are unsure of the process used to measure "consensus". As pointed out in our original submission, if "consensus" was measured through responses to the heat stress inquiry the results will almost certainly be biased.
- The TRP then notes that: "*there is a **reasonably close** association between animals panting at score 3 and their body temperature rising 0.5–1 degree above normal*" [our emphasis].
- The TRP then take into account ***only*** the extreme lower end of the body temperature range – that is, rather than using the upper end of the body temperature range (1.0°C), only the lower end of the range is used (0.5°C). This is, presumably, simply reflects the further compounding application of conservatism.

- The 0.5°C rise in body temperature is then linked to a WBT of 28°C using the 8 wethers involved in Stockman's experiment. The TRP note that for the 8 wethers in this experiment body temperatures rose by 0.5°C at a WBT of 28°C – therefore 28°C represents the recommended cut off point for regulating the live trade regarding heat stress.

Expressed in this light, it is apparent that the conclusions of the TRP are heavily dependent on individual judgement and just a few data points.

The transition from Phase I to Phase II panting (which is equivalent to the transition from PS 2 to PS3), is generally recognised to occur close to a heat stress threshold (HST) score of 3 (when body temperature rises 1°C). Yet the TRP have used HST2 (involving a 0.5°C rise in body temperature). It seems overly restrictive to consider that the PS3 threshold occurs between 0.5 and 1.0°C above normal, but to then use the lower end of that distribution.

3.4 Conclusion

The TRP's recommendation of a 28°C WBT threshold is the end result of a series of steps followed by the TRP. These steps are based on very limited knowledge, rely to an extent on the value judgements of the Panel and involve the application of conservatism at each stage (so that conservatism compounds). The 28°C WBT threshold recommendation depends crucially on a small, experimental study that imposed artificial conditions on sheep not matching those on live export voyages. As a result of all these factors the 28°C threshold recommendation is not solidly founded within science.

Basing recommendations on a weak repository of knowledge, including on an experimental study the results from which have not been verified against actual voyage data, would be problematic in any circumstance, but this is particularly the case where:

- individual differences abound (e.g. the differences in core body temperatures between individual sheep – and even in the same sheep at different times of day); and
- conditions in the study did not match those where the regulation is to be applied.

In order to recommend regulatory action that will cause cessation of a long-standing trade (and have clear and substantial flow-on implications for large parts of the red meat industry and associated businesses) it is reasonable to require a robust, reliable, certain scientific base on which to underpin the recommendations. Given the implications of the TRP's draft report, this robust, reliable, certain scientific base should not only relate to recommendations on threshold levels for a standard animal, but also to adjustments for different animal characteristics. There is no evidence in the TRP's draft report that a sufficient level of scientific robustness, reliability and certainly surrounds the TRP's 28°C threshold recommendation and adjusted threshold levels.

In the next chapter, we present data obtained from real live export voyages (rather than from experimental climate-controlled rooms which do not exactly replicate voyage conditions) which call into question the TRP's 28°C threshold recommendation.

4 Evidence that a 28˚C wet bulb temperature does not represent an "unrelenting challenge to homeostasis"

Part of the logic used by the Panel to recommend a threshold of 28°C was: "*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*" (p7). In this chapter evidence is presented, from live export voyages, that a wet-bulb temperature of 28°C does not present an "unrelenting challenge to homeostasis". Evidence is also presented that at wet bulb temperatures greater than 28°C for the standard animal panting is at less than PS3.

The first set of evidence uses analyses undertaken by Professor Shane Maloney, one of Australia's foremost, undisputed experts in thermal regulation in humans and animals. The second set of evidence uses data collected by Australian Accredited Veterinarians (AAVs) on individual recent voyages to the Middle East and reports of Independent Observers.

4.1 Work undertaken by Professor Maloney

Professor Maloney monitored the rumen temperature of cohorts of sheep on several voyages from Fremantle to the Persian Gulf during the southern hemisphere winter / northern hemisphere summer over 2016 to 2017.

A report by Professor Maloney is included as Appendix A to this submission. This report contains:

- a comprehensive analysis of the published scientific literature on physiological impacts and basis for heat stress; and
- analysis of the data referred to above.

Professor Maloney in his report draws the following conclusions:

- At a wet bulb temperature of 28°C or even higher, there was "*no evidence that the sheep were not able to maintain homeostasis*" (i.e. there was no evidence that sheep had moved from the tolerance zone into the survival zone). The rumen temperature of the sheep "*remained stable when the deck wet bulb temperature was stable*".
- *If "thermal homeostasis, had been challenged,* [as the TRP believes it should be at a WBT of 28°C] *then the sheep would have entered uncontrolled hyperthermia with an uncontrolled increase in core body temperature. There is no evidence that that was the case."*
- Rather than the fixed 28°C WBT threshold, it is the observation of Professor Maloney that animal welfare is not compromised unless the wet bulb temperature is in excess of 33°C for 12 hours, 32°C for 24 hours, or 30°C for 48 hours. Professor Maloney, however, openly concedes that these values are based on thin evidence.

4.2 Data collected from individual voyages and AAV reports

LiveCorp has also compiled data from a number of individual voyages carrying sheep to the Middle East to examine the impact of WBTs on animals.

A number of tranches of data have been collected and analysed:

- Detailed data which was collected as the HSRA model was being developed.
- Data that has been provided by exporters for a sample of voyages over the last 18 months.
- More detailed data provided by exporters for recent voyages, including on some voyages in which there are also reports from Independent Observers.

4.2.1 Data collected as the HSRA model was being developed

Very detailed data on wet bulb temperatures and panting scores were independently collected around the time the HSRA model was developed.

Wet bulb temperature data was collected every two hours.

Pant score data were collected twice a day using the scale shown in Table 4.1. We note, in passing, that this scale is yet again different to the panting scales shown in Tables 3.1 – 3.3, demonstrating once more the difficulty of achieving agreement in this area.

Table 4.1: Pant scoring system used at the time of the HSRA model development

Score	Description
1	Normal; up to 120 breaths per minute
2	Panting; mouth closed; 120-180 breaths per minute
3	Fast panting; greater than 180 breaths per minute with occasional open mouth panting
4	Open mouth panting; more than 180 breaths per minute
5	Second stage panting with drool

In all, data was collected on 7 voyages, 14 decks, and in 42 locations. Temperature loggers were placed in / directly adjacent to pens and the livestock in those pens were recorded. Data collected are displayed in Table 4.2. Table 4.2 contains a summary of all the data available to LiveCorp from this research.

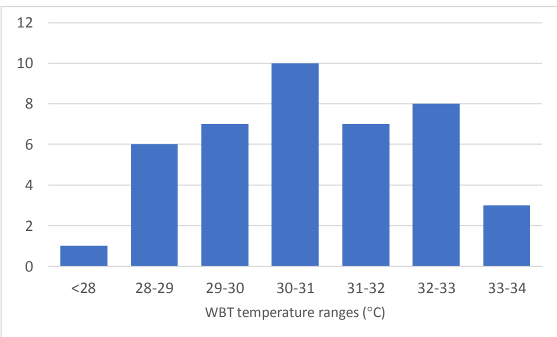
In Table 4.2 at each location where temperature was recorded:

- The maximum WBT is shown that occurred at any time during the voyage at that location.
- The pant score is shown for that location recorded closest to the time of recording of the maximum WBT[10].

  A number of points are worth highlighting from Table 4.2.

- First, there are numerous occasions in Table 4.2 where wet bulb temperatures exceeded 30°C. The highest wet bulb temperature recorded was 33.8°C. The distribution of maximum wet bulb temperatures encountered on each deck during the voyages, as presented in Table 4.2, is shown in Figure 4.1.

Figure 4.1: Distribution of temperatures displayed in Table 4.2



[10] Note that for a limited number of voyages the highest pant score recorded was different to that shown in Table 4.2. This higher pant score is not shown as it was temporally separated from the highest WBT recording.

Table 4.2: Summary of data collected at the time of the HSRA model development

Voyage	Deck	Logger	Month	Livestock carried	Highest WBT	Pant score recorded closest to WBT	Comments
2	7	9	June	C merino wethers	30.9°C	2	
4	6	15	July	Heavy merino wethers	32.9°C	4	Panting measurements were taken every 12 hours. Panting at score 4 was only recorded for one measurement
4	6	17	July	Young wethers	33.7°C	4	Panting measurements were taken every 12 hours. Panting at score 4 was only recorded for one measurement.
4	7	9	July	Heavy merino wethers	32.3°C	4	Panting measurements were taken every 12 hours. Panting at score 4 was only recorded for one measurement
4	7	16	July	Heavy merino wethers	32.5°C	4	Panting measurements were taken every 12 hours. Panting at score 4 was only recorded for one measurement.
4	8	13	July	Merino lambs	33.1°C	4	Panting measurements were taken every 12 hours. Panting at score 4 was only recorded for one measurement
4	8	14	July	Merino lambs	33.8°C	4	Panting measurements were taken every 12 hours. Panting at score 4 was only recorded for two measurements which were separated by a full day (when lower panting scores were recorded). Using the TRP's methodology lambs have a significantly lower heat WBT threshold than wethers.
5	7	3 (lower)	August	C wethers	30.6°C	2	
5	7	4 (lower)	August	C wethers	32.7°C	2	
5	7	4 (upper)	August	B wethers	32.7°C	3	
5	7	5 (lower)	August	C wethers	32.4°C	3	
5	7	5 (upper)	August	Merino lambs	32.4°C	3	
5	7	6 (lower)	August	C wethers	31.9°C	2	
5	7	6 (upper)	August	Merino lambs	31.9°C	3	

Table 4.2 (cont): Summary of data collected at the time of the HSRA model development

Voyage	Deck	Logger	Month	Livestock carried	Highest WBT	Pant score recorded closest to WBT	Comments
6	7	7	August	Damarrra ram lambs	29.6°C	1	
6	7	8	August	Heavy merino wethers	29.7°C	1	
6	7	10	August	Young merino wethers	28.7°C	1	
6	7	11	August	Young merino wethers	30.0°C	1	
6	7	12	August	Young merino wethers	29.7°C	1	
6	7	18	August	Heavy merino wethers	29.9°C	1	
7	2	14	September	Damarra ram lambs	31.4°C	2	
7	4	15	September	C wethers	32.1°C	2	
7	8	13	September	B wethers	29.6°C	1	
7	Open deck	17	September	B wethers	29.2°C	2	
8	4	10a	October	Young merino wethers	31.2°C	1	
8	4	10b	October	Young merino wethers	31.1°C	1	
8	4	11a	October	Merino wethers	31.2°C	1	
8	4	11b	October	Merino wethers	31.2°C	1	
8	4	12a	October	Merino wethers	30.6°C	1	
8	4	12b	October	Merino wethers	30.6°C	1	
8	4	7a	October	Merino wethers	30.1°C	1	

Table 4.2 (cont): Summary of data collected at the time of the HSRA model development

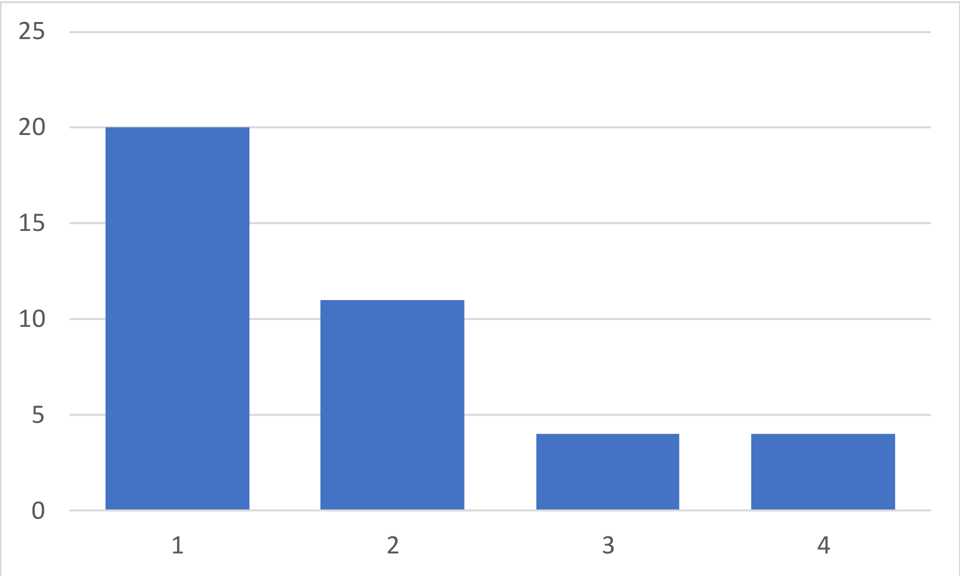
Voyage	Deck	Logger	Month	Livestock carried	Highest WBT	Pant score recorded closest to WBT	Comments
8	4	7b	October	Merino wethers	30.1°C	1	
8	4	8a	October	Young merino wethers	30.7°C	1	
8	4	8b	October	Young merino wethers	30.7°C	1	
8	4	9a	October	Merino wethers	30.4°C	2	
8	4	9b	October	Merino wethers	30.4°C	1	
9	1	13	November	Awassi lambs	28.4°C	2	
9	1	14	November	Awassi lambs	28.3°C	2	
9	4	15	November	Awassi lambs	28.6°C	2	
9	4	16	November	Awassi lambs	27.7°C	1	
9	5	17	November	Awassi lambs	28.6°C	2	
9	5	18	November	Awassi lambs	28.5°C	1	

- Second, the highest wet bulb temperatures for a given pant score were:
  - Pant score 1 - 31.2°C for young merino wethers
  - Pant score 2 - 32.7°C for merino wethers
  - Pant score 3 - 32.7°C for merino wethers
  - Pant score 4 - 33.8°C for young merino wethers

  To elaborate with an example for pant score 2, there were occasions when the WBT was as high as 32.7°C, but animals were still only panting at score 2.

- Third, in over 1200 recordings of panting scores, on only 7 occasions were panting scores of 4 recorded. In none of these cases did panting scores of 4 occur over two 12 hour measurement periods – that is sheep were not panting at score 4 "day and night" (to use the terminology of the TRP). The distribution of panting scores included in Table 4.2 is shown in Figure 4.2

Figure 4.2: Distribution of panting scores displayed in Table 4.2



To summarise, the detailed data collected on WBTs and panting scores at the time of development of the HSRA model does not support a conclusion that at a wet bulb temperature of 28°C there is an "*unrelenting challenge to homeostasis*" as evidenced by open mouth panting "*day and night*".

4.2.2 Data from voyages in 2017 and early 2018

Limited data, using AAV reports, were received from major exporters for 15 voyages that occurred from April 2017 to February 2018 involving sheep shipments from Australia to and through the Middle East. All voyages received by LiveCorp for this period are summarised in Table 4.3 (i.e. LiveCorp is not presenting selected data). Some of the separate "voyages" reported on in Table 4.3 involve the same vessel, but different exporters and different livestock. For these reasons they are presented as separated voyages in Table 4.3

The data compiled by LiveCorp on these voyages included WBTs, panting scores, and information on a limited number of characteristics for animals shipped:

- WBTs are collected manually by the AAVs, once per day – normally when temperatures are about their highest.
- Daily data were also compiled from AAV recordings of "respiratory character" / panting scores as per ASEL requirements. As pointed out in the previous chapter, ASEL uses a three part ordinal scale to measure panting: normal, panting, gasping.
- Some limited voyage data were collected e.g. when the shipment occurred.

- Finally, data were compiled from AAV reports on animals carried on the voyages. These data are limited (e.g. they do not include weight information or body condition scores), but normally do include major animal identifying characteristics (e.g. whether a lamb or adult, breed, etc).

Table 4.3 summarises data for each of the 15 voyages analysed by listing:

- the departure month of the voyage,
- types of livestock mostly carried on the voyage,
- the maximum WBT recorded on any day and any deck during the voyage,
- the maximum panting score recorded on any deck on any day of the voyage – this maximum panting score might have only occurred for a short period amongst limited numbers of sheep, but it represents the maximum pant score recording by the AAV.

Table 4.3: Heat stress data gathered on actual voyages to the Middle East during 2017 and early 2018

Voyage/ Exporter*	Departure month	Major types of livestock carried	Actual maximum WBT during the voyage	Maximum recorded panting score
1	February	Merino wethers, Merino lambs	30	2
2	February	Awassi lambs	29	2
3	April	Merino wethers, Merino lambs	31	2
4	April	Merino wethers, Merino lambs	31	2
5	May	Merino wethers, Merino lambs	33	2
6	August	Merino wethers, Merino lambs	34	2
7	September	Merino wethers, Merino lambs	33	2
8	September	Awassi lambs	32	2
9	November	Merino wethers, Merino lambs	30	2
10	November	Awassi lambs	29	2
11	May	Merino wethers, Merino lambs	32	2
12	May	Merino wethers, Merino lambs	32	3
13	November	Unspecified sheep / lambs	26	1
14	January	Unspecified sheep / lambs	27	1
15	January	Unspecified sheep / lambs	27	1

Based on the logic provided in the TRP's draft report panting should have been recorded by the AAVs at score 3 for voyages 1-12 but panting at score 3 only occurred during Voyage 12 (and then only for a relatively short time).

It is to be noted that all voyages carried some lambs. Using the methodology of the TRP the WBT threshold for a standard Merino lamb (the definition of which is contained in Chapter 2) winter acclimatised is just over 24°C. Several voyages included in Table 4.3 encountered WBTs 7°C - 9°C higher than this level yet, apart from Voyage 12, all voyages recorded a maximum panting score of 2.

Of course, it may be that ASEL PS 3 does not align exactly with the TRP PS 3 (as we have assumed). However, in a number of cases in Table 4.3, the actual WBTs experienced on the voyage are *well* in excess of the WBT HST thresholds calculated using the methodology of the TRP (this is the case particularly for Voyage 3, Voyages 5-8 and Voyages 11 and 12, all of which have maximum WBTs ranging from 31°C to 34°C and all of which involve the carriage of lambs – lambs, using the TRP's methodology, have a lower WBT threshold than the 28°C threshold for the standard animal). In these cases we would expect, if the TRP's analysis was correct, for a 3 to be definitely recorded on the ASEL scale. This is not the case, except, for Voyage 12.

The apparent inconsistency between the results presented in Table 4.3 and the recommendations of the TRP suggest one or more of three possible conclusions:

- Either the recommendation of the TRP of a 28C WBT threshold for a standard sheep is wrong, being significantly too low; and / or
- The HST adjustments for different animal classes that are included as part of the HSRA model are incorrect; and / or
- There are significant measurement errors in data collected by the AAVs and / or the ASEL panting scale is uncorrelated with the TRP panting scale.

Coupled with the very carefully collected data presented in Section 4.2.1 we believe that the first two dot points above provide the most likely explanations.

Again, the data provided in Table 4.3 does not support a conclusion that, at a WBT of 28°C for a standard animal (appropriately adjusted for other animal characteristics), there is an "*unrelenting challenge to homeostasis*" as evidenced by open mouth panting "*day and night*".

4.2.3 Recent data from voyages in 2018 and early 2019

Detailed data, including AAV reports, load plans and HSRA documents, were gathered from major exporters for 13 voyages that occurred from April 2018 to January 2019 involving sheep shipments from Australia to and through the Middle East. All voyages received by LiveCorp for this period are summarised in Table 4.4 (i.e. LiveCorp is not presenting selected data).

Detailed information was available from each deck, but in Table 4.4 the information shown relates to the deck that experienced the highest WBT during the voyage. If more than one deck had equal high WBTs which was sometimes the case) the deck was chosen containing livestock with the lower TRP calculated WBT threshold. The "voyages" shown in Table 4.4 may include information related to the same vessel, but different decks on that vessel that accommodated substantially different livestock (adult sheep, lambs) and contained different environmental measurements. Since precise details are known of the livestock on each deck, the TRP's threshold WBTs can be calculated with accuracy.

WBT information, panting scores and voyage data are as presented in Section 4.2.2, except that for 2 of the 13 voyages the McCarthy panting scores have been used.

Table 4.4: Data gathered on actual voyages to the Middle East during 2018 and early 2019

Voyage	TRP calculated threshold WBT	Actual maximum WBT during the voyage	Pant scores used	Maximum recorded panting score
1	29.7°C	31°C	ASEL	2
2	26.4°C	32°C	ASEL	1
3	29.6°C	30°C	ASEL	1
4	25.4°C	29°C	ASEL	1
5	26.7°C	29°C	McCarthy	1
6	28.0°C	29°C	ASEL	1
7	28.7°C	29.5°C	ASEL	1
8	24.8°C	31°C	ASEL	2
9	24.8°C	31°C	ASEL	2
10	24.5°C	32°C	ASEL	2-3
11	27.1°C	32°C	McCarthy	1
12	26.5°C	32°C	ASEL	1
13	26.0°C	31°C	ASEL	1
14	26.7°C	31°C	ASEL	1

It will be obvious to the astute observer that lambs are included in many of the voyages/decks contained in the above table. The calculated TRP threshold WBTs for lambs in Table 4.4 are as low as 24.8°C (for winter acclimatised lambs of certain weights and body condition scores).

As can be seen in Table 4.4, significant differences exist between wet bulb temperatures actually reported on voyages and the threshold WBTs set by the TRP's draft recommendations. In a number of voyages, with actual temperatures above the TRP calculated threshold temperatures by between 4°C and 5.5°C, panting at score 1 was recorded, calling into question the TRP's analysis. In other voyages panting at score 2 was recorded. Only on one voyage, where the difference between the actual and threshold WBT was 7.5°C, did panting at score 3 occur.

No evidence exists in the data reported in Table 4.4 to support the TRP's conclusion that at a wet bulb temperature of 28°C for a standard sheep (adjusted using TRP recommendations for other sheep and lambs) there is an "*unrelenting challenge to homeostasis*" as evidenced by open mouth panting "*day and night"*.

4.3 Reports from Independent Observers

Seven reports have been published from Independent Observers that relate to sheep voyages to and through the Middle East. None of these reports involved observations of open mouth panting for extended periods of time ("day and night"). Quotes from all relevant reports available at the time of writing are included below – additional information from AAV reports is also included.

4.3.1 Report 1: Maysora, Sheep and cattle to Turkey, April 2018.

The voyage of the Maysora involved sheep and cattle to Turkey. The report notes the following:

> *"Between Day 9 and Day 20, conditions were harsher as the vessel moved toward the Equator (Day 13) and to the Gulf of Aden (Day 15). The sea temperatures reached 30 degrees Celsius on Day 12, and the Bridge temperature went from 30 degrees Celsius to 33 degrees Celsius between Day 12 to Day 19. Sheep water consumption increased from 3.0 to 3.5 litres/head/day between Day 9 and Day 20 of the voyage. During this stage more than* ***90 per cent of sheep were observed to be slightly panting (closed mouth), and around 5 to 7 per cent were observed to be panting more rapidly with occasional mouth opening*** [our emphasis]*. Only one per cent exhibited sustained open mouth panting ….*
>
> *From Day 21, sheep respiration returned to a normal resting pattern with no panting observed".*

4.3.2 Report 2: Al Messilah, Sheep and cattle exported to Kuwait, Qatar, Oman and United Arab Emirates, May 2018.

Deck wet bulb temperatures on this voyage rose to 33°C and the voyage included a mix of wethers and lambs as well as a few rams and ewes.

The Independent Observer report indicates no issues with panting:

> *"The ventilation system provided a downward directed air flow directly into the pens. Although there was an increase in respiration rates when travelling north of the equator,* ***no animal was observed panting or demonstrating any signs of respiratory distress****"* [our emphasis]*.*

4.3.3 Report 3: Bader III, Sheep and cattle to Israel and Jordan, May 2018.

> *"Crew and animals encountered elevated temperatures and high humidity from the third day of the voyage out of Fremantle. There were no issues with the ventilation during the voyage. There was a specific equatorial plan for high temperature periods involving zig-zagging the vessel to increase air flow through the decks, the installation of fans for some pens and a program of washing down cattle and pens. Deck washing (cattle only) procedures were satisfactory, and*

sheep pads were observed to be in good condition due to regular maintenance and clearing of manure in corridors".

"The vessel's crew, AAV and Stock people managed the health and welfare of animals well. The voyage had low mortality rates for both sheep and cattle".

"The Bader III had its pens set up so the stock had room to move between 2-3 pens and there were two feed bins and two watering troughs per pen. The stocking density of the vessel allowed each animal 17.5 per cent more space than required by the ASEL. This allowed the stock sufficient room to always access food and water, to lay down when required and to have sufficient spacing even when the very hot days of ***34 degrees Celsius Wet Bulb Temperature (WBT)*** *were encountered"* [our emphasis].

The Independent Observer noted no issues with panting and none were noted by the AAV – panting scores remained within normal range.

4.3.4 Report 4: Yangtze Fortune, Sheep to Oman, May.

"Temperatures and humidity increased daily once the vessel left Fremantle. Temperatures on decks ranged from 21 to 34 degrees, with an average temperature of 31 degrees Celsius; and humidity between 74 and 80 per cent, with an average of 78 per cent.

Temperatures were taken once a day just before the 10.00 am daily meeting. The IO requested the CO take some afternoon temperatures for comparison, which were provided and remained fairly consistent. The AAV and IO both took readings with hand held temperature devices in the pens. Most of the time, pen temperatures were about one degree less than the walk ways (where ship thermometers are placed) as ventilation is directed into the pens.

On day five, pant scores began changing and were observed to fluctuate depending on the time of day. The sheep which had a bit more wool were most likely to demonstrate this behaviour. Most sheep in the morning were fast panting with mouths closed, however in the afternoon one to two in every other pen were observed open mouth panting with elevated heads. The IO noted that as humidity increased the sheep became more affected by the heat".

Again, despite high temperatures being encountered on this voyage, there is no evidence from either the Independent Observer report or from the AAV report that open mouth panting was occurring "day and night" – it was occasionally occurring as it does on a hot day in Australia.

4.3.5 Report 8: Maysora, Sheep and cattle to Turkey, May.

"Patented and Australian Maritime Safety Authority (AMSA) approved ventilation system used. Extra fans were placed at all pens located within identified 'hot spots' of the ship carrying livestock. Observations were made of crew members walking into pens to ensure that air from the fans was being directed at the animals to maintain comfort.

The IO noted that only a certain percentage of sheep will be demonstrating certain panting scores within a pen at any given time".

"The IO did not note any health and welfare issues. The crew performed their duties to a high standard ensuring health and welfare of all livestock was maintained throughout the voyage".

No issues are noted by the Independent Observer regarding panting or heat stress. Occasionally animals were panting – as they do in Australia. Deck wet bulb temperatures of up to 29.5°C were recorded by the AAV. The shipment included a large number of lambs, yet panting at score 1 only was recorded.

4.3.6 Report 9: Al Messilah, Sheep and cattle exported to Kuwait, Qatar and United Arab Emirates in June 2018.

The Independent Observer made a number of comments on the vessel's ventilation.

> *"Ventilation is supplied through a grid pattern of alternating vertical supply and exhaust shafts throughout the Al Messilah. The position of the ventilation shafts appears evenly distributed across the pen area with no apparent correlation to pen layout.*
>
> *In addition to the integrated ventilation system there are fans installed overhead of sheep pens to further circulate air. Smaller fans are sited against walls, corners and headspace of the larger decks to redirect and enhance airflow. Six of these large fans were obtained following the previous voyage and were installed during this voyage.*
>
> *Each of the decks has just one thermometer. These are located in a position that is generally central and handy to access for reading, but are unlikely to be representative of the worst environmental conditions on the particular deck".*

Notwithstanding the fact that the positioning of the thermometers might not record the most extreme temperatures, maximum WBTs of 30°C were recorded during the voyage.

The Independent Observer makes no comment regarding excessive panting or heat stress during the voyage and neither does the AAV. Recorded panting scores were mostly PS1 with the occasional PS2.

The report from the Independent Observer concludes:

> *"The IO found that from the commencement of loading to discharge, the processes, procedures and attention to the maintenance of pens and facilities was good. The Master, all the vessel's officers and crew were dedicated and diligent in performing their duties to ensure the wellbeing of the animals. The experienced AAV and stockperson collaborated with the vessel officers' well to maintain the health and welfare of the livestock in line with ASEL requirements".*

4.3.7 Report No 10, Bahijah, Sheep and cattle to Israel, June.

One period of open mouth panting did occur on this shipment, but only for an afternoon – the TRP state, correctly, that it is not uncommon for sheep to open mouth pant in Australia on a hot afternoon. The Independent Observer noted the following in the official report:

> *A degree of heat stress existed for the sheep on board the vessel from the equator until passage of the Suez Canal. There was a low level of discomfort and elevated respiratory rate of almost all sheep during this time. There was only one afternoon where this was observed to progress to open mouth panting and higher levels of heat stress existed across the ship.*

4.4 Conclusion

In this chapter real world data have been presented that calls into question the conclusions of the TRP.

The data presented in Tables 4.2 - 4.4 we believe, both individually and in combination, provide compelling reasons to question the draft report's conclusions.

No claims are made that the real world data presented in Tables 4.2 and 4.4 is a representative sample – but all data obtained by LiveCorp has been presented (there has been no selective presentation of data) – and the data in Tables 4.3 and 4.4 represents a reasonable proportion of total shipments for these periods.

What we do know is that the data used by the TRP to reach its conclusions is not a representative sample from actual livestock export voyages. Rather the TRP data are from artificial experiments that do not replicate precisely voyage conditions and involve extremely small numbers of animals.

In the next chapter one possible reason is presented on why the real world data may not match that from climate-control room experiments.

5 Duration of exposure an important, but missing, factor in the TRP's analysis

The TRP recognised the importance of duration of exposure and diurnal relief from heat in how an animal is affected. For example, the TRP state:

> *"…. duration of effect is an important aspect in considering the effects of high heat loads".*

> *"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"* [our emphasis].

> *"… if there is an opportunity for the animal to cool before the next exposure, this may actually result in some acclimatisation".*

The TRP also concede that:

> *"How cool it must get, and for how long, to enable sheep to 'dump' heat, is unknown".*

Despite recognition by the TRP of the importance of heat duration and diurnal relief, other than stating that research work should be conducted in this area, major TRP recommendations fail to explicitly incorporate these factors.

This apparently reflects a belief that there is no or limited diurnal temperature variation in live export voyages. This apparent lack of relief from high wet bulb temperatures on live export voyages is referred to on several occasions in the draft report.

In this chapter it is shown that, even at the equator, there exists diurnal variation in WBTs. Clearly, temperature variations at the equator are far less than in subtropical zones, but, as referenced above, the TRP, in terms of diurnal variations, states: *"how cool it must get, and for how long, to enable sheep to 'dump' heat, **is unknown**"* [our emphasis].

5.1 Experiments which the TRP relied upon for its recommendations did not include any diurnal temperature variation

As has been noted previously in this submission, the TRP, in arriving at its most important recommendations, have relied heavily on experiments conducted by Catherine Stockman in her PhD thesis. These experiments did not include any systematic diurnal variation in temperatures and, as a result, do not replicate conditions on a live export voyage.

Stockman's controlled climate room (CCR) experiments involved applying constant heat and humidity across the day and night to sheep in the treatment group, increasing this over time. In justifying this experimental design, the author states:

> *"One factor that separates conditions during live shipment from conditions in a feedlot or grazing system is the lack of diurnal fluctuations in environmental temperature (Bailey and Fortune 1992; MLA 2000a, b in Beatty et al. 2006)".*[11]

And,

> *"Wet bulb temperature on board the ships commonly reaches 30°C with little diurnal relief from these high temperatures at night (Norris and Richards 1989)".*[12]

---

[11] Stockman, C. A. 2006. 'The physiological and behavioural responses of sheep exposed to heat load within intensive sheep industries', PhD thesis. Murdoch University, p30.
[12] Ibid p98.

This resulted in the general aim and design for Experiment 1:

> *"Dry bulb temperature and moisture content of the air in Rooms 1 and 2 were changed over a period of 14 days to mimic a typical long haul ship voyage from Western Australia to the Middle-East, as described in voyage reports (MAMIC 2000a; b).* ***The wet bulb temperature was held relatively constant over the 24 hour period, to mimic the lack of diurnal variation in environmental temperatures experienced by animals transported in equatorial regions****. The aim was to gradually increase room temperatures and hold the sheep at a maximum of 30 to 32˚C wet bulb for 5 days"* [our emphasis][13].

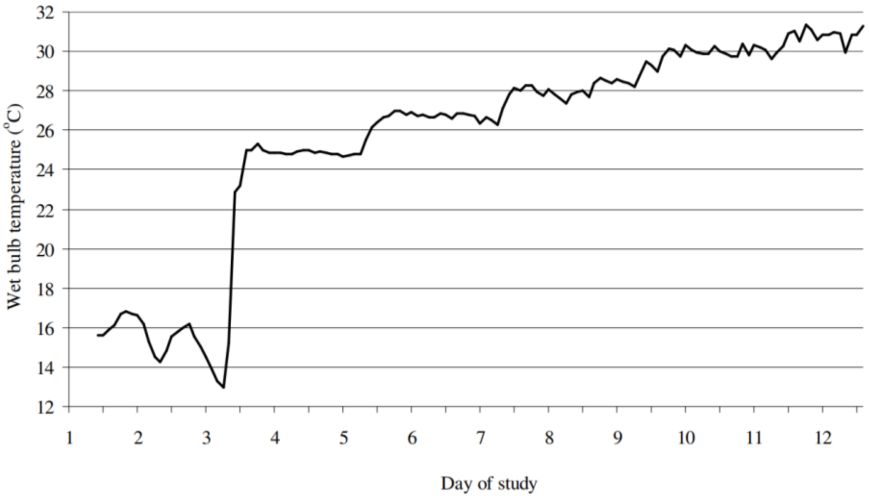
Similarly, for Experiment 2:

> *"Sheep spent the initial 4 days in the CCR at prevailing environmental conditions, to allow adjustment to the surroundings and determination of physiological measurements at these pre - heat conditions. Heat and humidity were then increased at 0800 hours to 26˚C wet bulb and 30˚C dry bub and the rooms held at that temperature for a period of 48 hours. After this, the conditions were changed so there was a 2˚C wet and dry bulb temperature increase every 48 hours until the rooms reached 32˚C wet bulb and 40˚C dry bulb. Room temperature was changed at 0800 hours on each of these particular days. Sheep spent a maximum of 12 days in the rooms with rooms being turned off at 1800 hours on day 12. The increase in ambient temperature was aimed to cause increased core temperature of the sheep without causing death".*[14]

In summary, the experimental conditions used by Stockman were simply to increase temperatures to a high level and then hold temperatures constant at this level irrespective of the time, day and night.

Figure 5.1 shows the WBT over the 12 days of Stockman's experiment 2. It can be seen that no significant drops in temperature occur, only increases[15].

Figure 5.1: WBT measurements from Experiment 2 in Stockman's PhD thesis



Stockman went onto conclude the following after completing experiment 1:

[13] Ibid p102.
[14] Ibid p152.
[15] The marginal fluctuations in temperatures in Figure 5.1 can apparently be attributed to researchers entering and exiting the CCRs to undertake measurements and maintenance – the very slight drop in temperature lasted on average for 14 minutes.

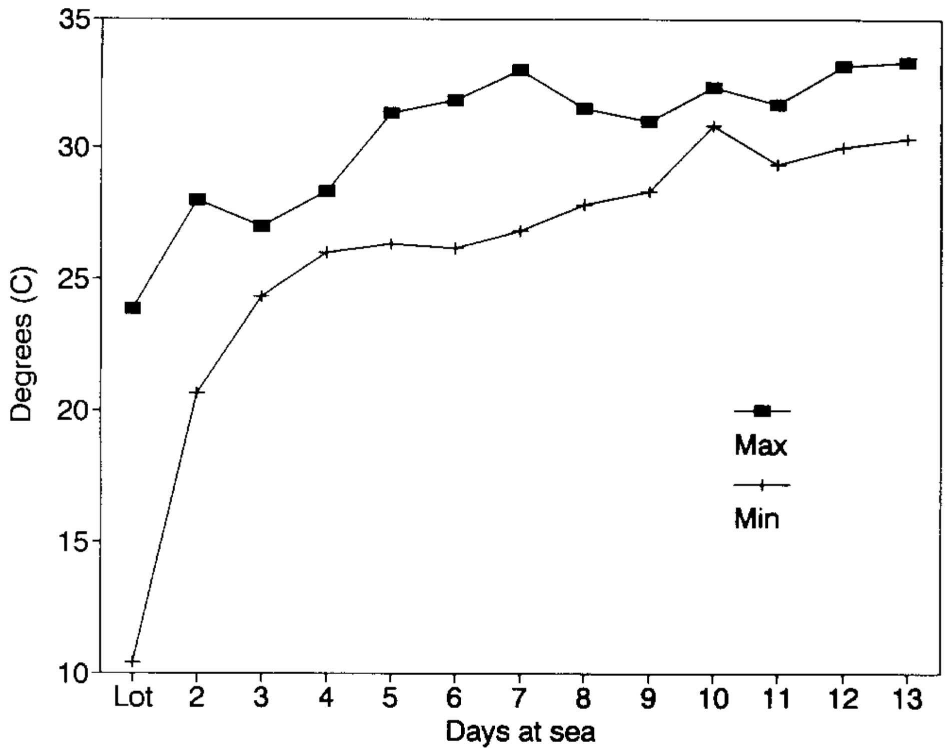
*"No other study has assessed the responses of sheep to prolonged high heat and humidity **without relief** for several days. Previous studies in climate rooms have focused on effects of high heat and/or humidity over several hours ……… In most of these studies, sheep had respite from these high temperatures for a number of days before the next heat period took place. In field studies there is diurnal fluctuation in environmental temperature, allowing sheep to lose heat gained from the previous day when the ambient temperature drops at night …. However, during live export and in the present study, there is little diurnal fluctuation in environmental temperature. The effect of this would be an accumulation of heat over several days with less opportunity for sheep to lose heat at night.*[16]

5.2 It was incorrect to believe there was no diurnal variation in live export voyages, as recognised even in studies quoted in Stockman's work

A review of even the source documents quoted by Stockman (namely, Bailey and Fortune, 1992,[17] and Norris and Richards, 1989[18] and the MLA documents) does not support the assumption that there is no diurnal relief on live export voyages.

Bailey and Fortune (1992) provide a chart in their paper, presented below, which shows daily maximum and minimum temperatures. The authors do not state explicitly whether the plot shows the dry-bulb temperature or the WBT, but they do state that the RH was relatively constant at around 85%. Therefore, the difference between the maximum and the minimum is indicative of both.

Figure 5.2: Recordings of maximum and minimum temperatures by Bailey and Fortune, 1992.



[16] Ibid, p136.
[17] Bailey, A.N. and Fortune, J.A., 1992, "The response of Merino wethers to feedlotting and subsequent sea transport", *Applied Animal Behaviour Science*, Vol. 35, pp167–180.
[18] Norris, R.T. and Richards, R.B., 1989, "Deaths in sheep exported by sea from Western Australia - analysis of ship Master's reports", *Australian Veterinary Journal*, Vol. 66, No. 4, pp97–102.

Figure 5.2 shows a diurnal variation in temperatures ranging between 2–8 degrees during the course of the voyage. Professor Maloney has used pixel counting technology to precisely measure the distance between the two lines in Figure 5.2. From this technique Professor Maloney has found that the difference between maximum and minimum WBTs for days 7 to 13 was 3.4°C.

Stockman was, therefore, incorrect in quoting Bailey and Fortune to support her statement that there was a "*lack of diurnal fluctuations in environmental temperature"* on board live export vessels.

Stockman's interpretation of temperature conditions recorded by Norris and Richards is similarly mistaken. Norris and Richards (1989) worked from the daily Master's report for the vessel and this included a ***single*** daily measurement for temperature and humidity taken on the ship's bridge at noon each day. Because of the ***single*** point of measurement, it is ***impossible to draw any inferences about diurnal variation*** from Norris and Richards - but this is what occurred in the Stockman work. Richard and Norris did note that "*temperature and humidity were relatively constant",* but this was apparently a conclusion drawn from a comparison of noon time temperatures.

Interestingly, Norris and Richards went on to state:

> *"Temperature and relative humidity measured on the ship's bridge were not closely related to daily death rate".*

Recent analysis undertaken by an AAV, that has been cited by LiveCorp, supports this finding – the R^2 of a regression of mortality rate against WBT using data from several recent voyages was only 0.1, with a much stronger correlation found with day of the voyage.

In concluding that there was no respite, Stockman also referred to two reports published by MLA authored by Maunsell Australia[19]. These reports involve the analysis of wet bulb temperature data collected using loggers and hand held devices on two voyages between Fremantle and the Middle East in June / July and September 2002. Professor Maloney has again used pixel counting technology on charts to be found in these reports. From this technique he has concluded that for days 11 to 20 of voyage 1 (when environmental conditions were hotter) the average daily range of WBT was 2.4°C with similar analysis on voyage 2 showing an average daily range of 1.8°C.

5.3 VOS data shows daily variation even at the equator

Even at the equator there is a diurnal variation in wet bulb temperatures. Charts contained in Appendix B to this submission show, for each month of the year, the daily variations in environmental wet bulb temperatures for latitudes 0 - 5° north on routes sailed by live export vessels. The data in these figures are from the Voluntary Observing Ships (VOS) program. VOS data are collected at regular times a few times each day (not, for instance, every hour), so the data shown in Figures in Appendix B ***understate*** the diurnal variation.

If there was no diurnal variation, all observations in the charts in Appendix B would lie on the dashed diagonal line. In fact, observations lie below this line, showing that minimum temperatures are different from maximum temperatures.

[19] Maunsell Australia Pty Ltd, 2002, Investigation of Ventilation Efficacy on Live Sheep Vessels, Voyage 1 Report Project LIVE.212, Meat & Livestock Australia, North Sydney and Maunsell Australia Pty Ltd, 2003, Investigation of Ventilation Efficacy on Live Sheep Vessels, Voyage 2 Report Project LIVE.212, Meat & Livestock Australia, North Sydney

5.4 VOS data and data from island weather stations show that even on the equator there is diurnal WBT variation.

Variations in temperatures are also evident from equatorial island weather stations.

Very detailed wet bulb temperature data are available from Singapore – with these data being recorded on an hourly basis since 1982. Meteorologist, Dr Bruce Buckley, has provided the view that variations in WBTs in Singapore would be slightly less than those experienced on voyages to and through the Middle East.

Table 5.1 shows the average difference between maximum and minimum WBTs recorded in Singapore across all days for which information is available.

Table 5.1: Differences between maximum and minimum temperatures in Singapore over 1 day, 2 successive days and three successive days.

Period of time	Difference between maximum and minimum WBTs
1 day	2.4°C
2 successive days	2.7°C
3 successive days	2.9°C

Table 5.2 is similar to Table 5.1 but shows the difference between maximum and minimum WBTs when the maximum temperature is at or above the 98th percentile level. From comparing Tables 5.2 and 5.1 it can be seen that temperatures drop comparatively more when extreme temperatures are encountered.

Table 5.2: Differences between maximum and minimum temperatures in Singapore for various periods of time after a maximum temperature at or above the 98th percentile level has occurred.

Period of time	Difference between 98th percentile maximum WBTs and minimum WBTs
24 hours	2.9°C
48 hours	3.3°C
72 hours	3.6°C

Dr Buckley has also examined data from the equatorial island weather stations of Diego Garcia (British Indian Ocean Territory) and Male (Maldives). Dr Buckley concluded from an examination of these data that daily wet bulb temperature variations of 1-4°C occur. Among Dr Buckley's selected sample, which included the months of January, April, July and October, the average variation in temperature was 2.8°C for Diego Garcia and 1.8°C for Male. Dr Buckley indicated that the data examined would indicate "*there are periods of respite even on days in equatorial Indian Ocean waters when there are relatively high wet bulb temperatures*".

5.5 Data from voyages with temperature loggers

Professor Shane Maloney has analysed wet bulb temperature data obtained from loggers placed on 36 voyages from Fremantle to the Gulf region. From this analysis Professor Maloney concluded that:

- The wet bulb temperature range across a day varied from 0.7 to 9.0°C, with a mean of 2.9±1.6°C. The most common range of variation was between 2.0 to 2.49°C.
- On average, sheep on board livestock export vessels near the equator receive 2.0 to 3.0°C WBT of respite in an average 24-h day.
- The temperature ranges found across the 36 voyages were consistent with findings from previous MLA publications which involved the use of temperature loggers and those from Bailey and Fortune, 1992.

The findings of Professor Maloney are also replicated in data taken from temperature loggers used on a voyage to the Middle East late in 2018. Across this entire voyage the average daily difference between maximum and minimum wet bulb temperatures was 3.8°C. For days in which the maximum environmental wet bulb temperature was greater than 28°C the average daily variation was 2.7°C.

5.6 Conclusion

Two strong conclusions emerge from this chapter which has examined variations in temperatures across periods of time.

First, there are diurnal variations in temperatures even as voyages cross the equator. Typically, these variations lie between 2°C to 3°C. These variations are small relative to variations in temperatures that occur in subtropical zones and on land. However, as the Panel has noted: "*How cool it must get, and for how long, to enable sheep to 'dump' heat, is unknown".* Professor Maloney is of the view that such temperature variations may be vitally important as they can cause temperatures to dip to levels where respite may occur.

Second, the work of Stockman cannot be relied upon to set threshold temperatures for live export voyages. Stockman's experiments were conducted with a constant WBT and, therefore, no respite, but the evidence suggests that during actual voyages 2 to 3°C WBT of respite is the norm.

Perhaps it is because of undue reliance on the work of Stockman (which does not match voyage conditions) and the lack of consideration of temperature variations and respite, that the Panel's analysis is not supported by real world data.

It will be shown in Chapter 7 that referencing minimum temperatures, as these are the temperature that result in relief, rather than referencing maximum temperatures, has a significant impact on the probability of heat stress arising on a voyage.

6 Consideration of risk

The HSRA model has been designed to address certain ***risks*** associated with transporting sheep to the Middle East. Due to the model purpose, any review of HSRA necessarily involves consideration of how risk should be assessed and acceptable levels of risk.

The notion that there is some level of risk that everyone will find acceptable is a difficult idea to reconcile, yet ***no*** human progress would have been made without risks being taken – from gathering food in the early evolution of human existence, to exploration of the planet and universe, to any advancement in science or even just travelling in a car or a plane. A goal of zero risk is neither attainable, ***nor is it desirable***.

In guiding many regulatory decisions, including those in setting standards, it is critical that a systematic approach be applied, both to assessing and managing risk. It is also important that the approach be transparent and consistent across relevant policy areas. We see insufficient evidence of a systematic, transparent, consistent approach to risk being applied in the HSRA Draft Report – yet it needs to be a focal point of the Review.

6.1 Systematically approaching risk identification / assessment

Food safety is just one area of public policy where assessment of risk is vital. Even in this area (which may involve human deaths) zero risk is neither attainable nor desirable. Food Standards Australia and New Zealand (FSANZ) has identified the following steps for identifying and assessing risks[20]:

- hazard identification – identifying the hazard and its potential adverse effects;
- hazard characterisation;
- exposure assessment; and
- risk characterisation.

6.1.1 Hazard identification – identifying the hazard and its potential adverse effects.

FSANZ states that "hazard identification" involves *clearly* describing the hazard and identifying the adverse consequences which flow from it.

In clearly defining the hazard, involved with the impact of environmental heat on animal welfare during live sheep voyages to and through the Middle East, we would have anticipated a detailed investigation into which environmental temperature should be used. This is particularly true given that one of Panel members had been critical of the industry for unquestionably using wet bulb temperature and has advocated the exploration of other measures (such as the Temperature Humidity Index – THI). Instead the Panel simply note:

> *"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 and presentation*

[20] http://www.foodstandards.gov.au/publications/riskanalysisfoodregulation/pages/default.aspx

of solid evidence of the welfare impacts of these temperatures …. " (p14).

6.1.2 Hazard characterisation

FSANZ states that "hazard characterisation" involves an assessment of the nature and severity of adverse health effects and determining whether those effects differ at different dose levels (e.g. levels of exposure).

To the degree that hazard characterisation occurs in the draft report, LiveCorp has identified in this submission a number of areas where we believe the evidence – both in terms of practical data and expert advice – questions the way that the TRP has characterised the nature and severity of adverse impacts caused by heat stress.

Some of these issues go to the science used to characterise it, set out in chapter 4, and others go to the judgments exercised by the TRP in attempting to define 'acceptable or tolerable risk', as set out in chapter 3 and further detailed later in this chapter.

Beyond these issues of dispute, however, under "hazard characterisation" we would have expected quantification of the welfare impacts of different wet bulb temperatures - for instance, within the general welfare framework used by the TRP (taken from Mitchell et al., 2018, and shown in Figure 1 of the Draft Report) wet bulb temperature cut offs between the prescriptive zone, the tolerance zone and the survival zone. Instead, it is impossible to precisely describe where the 28°C criteria suggested lies within the framework used by the TRP (except that, in the Panel's view, it is somewhere in the "prescriptive zone").

Furthermore, although "dose" (the length of exposure to higher wet bulb temperatures) is recognised as important by the Panel (and even more so in the source documents on which the Panel relies), the "hazard" is never fully characterised in these terms. On p30, for instance, the Panel notes that "*As described earlier in this report, <u>duration of effect</u> is an important aspect in considering the effects of high heat loads*"; however, no quantification is attempted. It seems that the Panel has attempted to avoid the problem of duration by deliberately setting a conservative wet bulb temperature (see p20, second last paragraph). If the allowable wet bulb temperature is set low enough, duration becomes irrelevant since any length of exposure will have no impact on welfare (but this results in greatest impact on the people and businesses involved in the trade and supply chains).

While the factors such as dose / level and exposure / duration complicate the risk assessment, they are incredibly pertinent and any hazard characterisation that does not consider the differences of these factors in the nature and severity of the impact cannot be taken as a legitimate representation of the real-world.

Ignoring duration or placing the threshold below the point where duration is relevant essentially mandates a regulatory objective that is divorced from the likelihood of physiological harm and is (at worst) based on an extremely low level adverse impact – well below where the actual 'acceptable or tolerable risk' level exists.

While this approach may be convenient in avoiding the complexities that necessarily result from shifting from a dichotomous, objective (mortality) basis to a subjective, multi-faceted basis (which we warned about in our first submission) it applies a conservatism and simplification that directly applies a very significant impact on the industry and the farmers, businesses, and families that rely on it.

Regulation can and should embrace the complexity necessary to represent the real-world and achieve the best solution as a whole, and from a risk perspective this may necessarily require a more complex approach or the running of multiple assessments.

It is also important to highlight that the above will be a core part in terms of the setting of 'acceptable or tolerable risk.'

In other areas where heat stress potentially may occur, sophisticated approaches to duration have been used. For instance, in mining, standards have been set in some countries for acclimatized miners to work with pick and shovel and digging (heavy work) for 25% of a shift at WBTs of up to 30°C, but for activities involving less exertion (e.g. hand or arm work, such as using a table saw) they can work 100% of a shift at WBTs of up to 31°C.

6.1.3 Exposure assessment

FSANZ states that "hazard characterisation" involves determining the level of exposure / intake" (in the case of FSANZ, this is from diet and other sources).

In the case of sheep this would involve conducting a thorough analysis of weather conditions applying to voyages to the Middle East to assess the frequency, magnitude and duration of exposure.

The Panel has relied on the existing HSRA data to assess the frequency and magnitude of exposure. The existing HSRA data analysis, however, was predicated on mortalities being the objective. With the change in the HSRA model objective, as recommended by the Committee, it is not sufficient to rely upon analysis of an outdated objective. Rather, the weather data should have been re-examined in light of the new objective and additional elements, such as duration, considered.

6.1.4 Risk characterisation

This involves integration of information from the hazard and exposure assessments (as outlined above) to determine the likelihood and severity of an adverse effect occurring in a given population.

6.2 Systematically approaching risk management and the task of defining acceptable risk

Beyond the four steps outlined above for risk ***assessment***, FSANZ notes that additional factors need to be considered in terms of risk ***management***. Two key steps involved in risk management are:

- the determination of what represents an 'acceptable or tolerable risk', and
- the application of risk management approaches to reduce the risk to the acceptable or tolerable level.

6.2.1 Acceptable risk – approach, processes and mechanisms

Acceptable risk refers to the level of loss that can be tolerated by an individual, household, group, organisation, community, region, state, or nation.

Defining an acceptable risk in a given situation is necessarily a complex matter, particularly for issues that have a national or wide-reaching and diverse sets of impacts or where values play a significant role.

A range of different standpoints or approaches can be adopted to define acceptable risk. For example, a World Health Organisation paper on water quality[21] identified that a risk may be determined as acceptable, when:

- It falls below an arbitrary defined probability.
- It falls below some level that is already tolerated.
- It falls below an arbitrarily defined attributable fraction of total disease burden on the community.
- The cost of reducing the risk would exceed the costs saved.
- The cost of reducing the risk would exceed the costs saved when the 'costs of suffering' are also factored in.
- The opportunity costs would be better spent on other, more pressing public health problems.
- Public health professionals (experts) say it is acceptable.
- The general public say it is acceptable (or more likely, do not say it is not).
- Politicians say it is acceptable.

Increasingly dot points 4 and 5 above are receiving emphasis under the concept of reducing risk so far as is reasonably practicable (SFAIRP). The SFAIRP approach is increasingly mandated legally, including being written into the Rail Safety National Law.

Importantly, each and every approach it identifies – and presumably others it has not included – have limitations – and this is recognised.

On the use of experts to define acceptable risk, the WHO states the approach is often limited by uncertainty in the available science, and the fact that professionals are, of course, individuals who will necessarily possess their own value systems. Accordingly, the WHO paper states: "*Consequently, we have to accept that experts form just one of several different stakeholder groups that does not necessarily have higher status over other stakeholders.*"

In practice, areas such as animal welfare are heavily subjective and emotive and present challenges for how government can reasonably establish acceptable risk levels. Animal welfare draws in both community perceptions heavily influenced by values and subjectivity, with the need for objectivity and science to provide a platform for business to operate profitably and deliver benefits to society.

As Dr Hugh Millar has noted[22]:

> *"… 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*

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[21] https://www.who.int/water_sanitation_health/dwq/iwachap10.pdf.

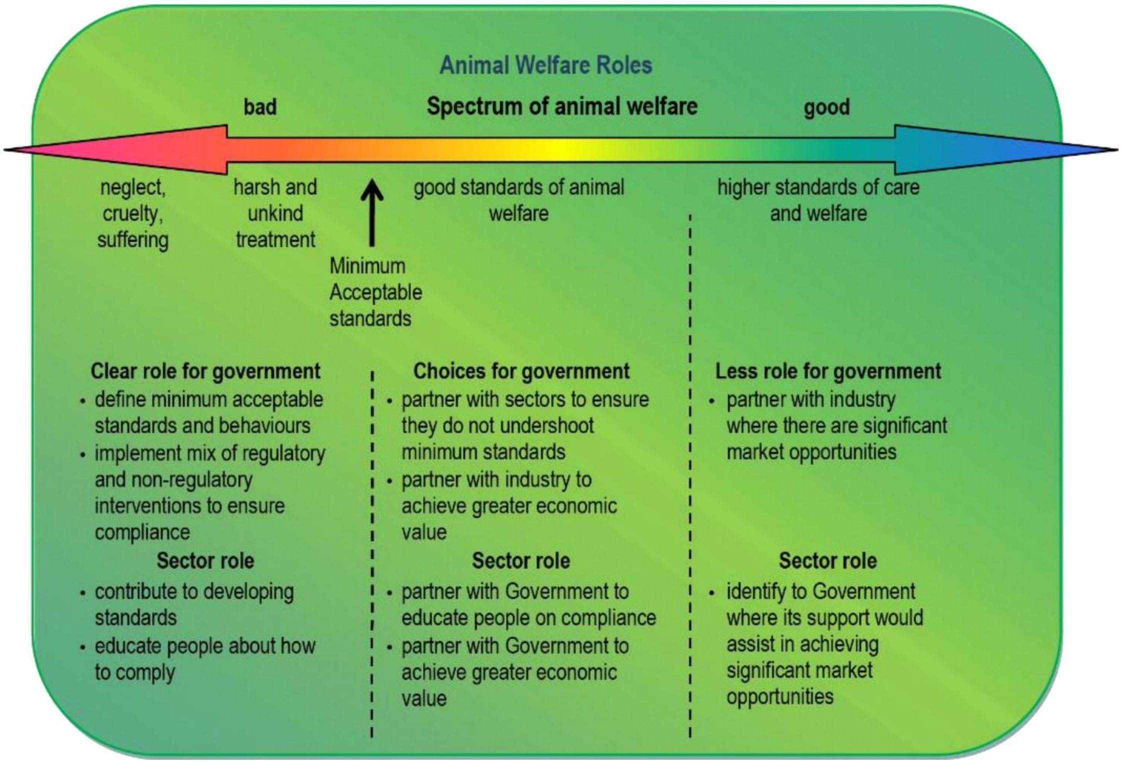
[22] Millar, H, 2018, A Review of Animal Welfare Policy and Assessment Frameworks, *Final Report Project 1HS802*, Australian Eggs Limited, Sydney, July.

approach (affective states), in which ethical judgements (moral values) will be increasingly brought into play."

Within the values-based sphere that is animal welfare, boundaries on the role adopted by regulation needs to be carefully considered. Dr Hugh Millar has drawn attention to the policy approach adopted by New Zealand, as espoused in its animal welfare strategy (see Figure 6.1). 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. This framework suggests that the regulation of animal welfare due to heat stress should be confined to outcomes that are clearly unacceptable.

By applying an extremely conservative approach to heat stress, it is LiveCorp's view that the TRP has moved away from the role that should be properly adopted by regulation. That is, the Panel has recommended imposing standards that go well beyond welfare outcomes that are **clearly** unacceptable. That the Panel has gone beyond regulating outcomes that are clearly unacceptable is self evidently the case, since many within the scientific community (perhaps even a majority) would dispute the heat stress parameters used in the report.

Figure 6.1: Animal Welfare Roles[23]

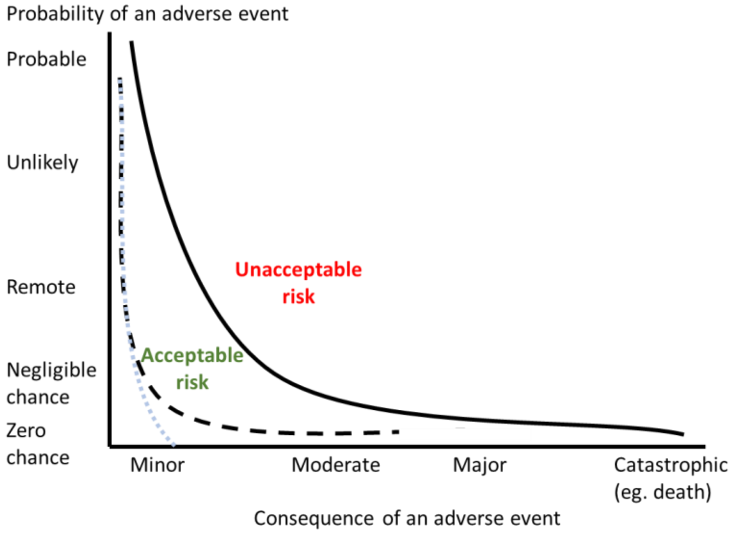


In terms of acceptable risk for live export voyages the Panel could have drawn parallels from domestic situations – in particular welfare outcomes flowing from extreme environmental situations in Australia that are either implicitly or explicitly accepted.

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

It is also important to recognise that "acceptable risk" is defined by a combination of two factors: the likelihood of an adverse event occurring and the consequence of that event if it did occur – see Figure 6.2.

Figure 6.2: Acceptable risk is defined both by likelihood and consequence



If the consequence is major or catastrophic (e.g. mortalities) the probability of occurrence must be very low for the risk to be acceptable. On the other hand, if the consequence is moderate or minor the likelihood of the event can be significantly greater and the risk still regarded as acceptable (see the division between acceptable and unacceptable risk as defined by the solid black line in Figure 6.2).

The trade-off between likelihood and consequence applied by society can be seen in numerous situations. The consequence of a car colliding with a school child (or, for that matter, pedestrians generally) is obviously greater than the consequence from a collision involving two vehicles (that might only involve property damage). It is for this reason that speed limits have been lowered in school zones (thus lowering the likelihood of collisions involving a school child – and in shared car / pedestrian zones generally) versus the open road. Lowering of speed limits lowers the probability of a collision occurring.

Under the TRP's recommendations the consequence has been very substantially adjusted from mortalities (major) to panting (minor to moderate, depending on duration). There has, however, been no commensurate adjustment in the probability of an adverse weather event arising – it remains at 2%. The impact of redefining the consequence, without also redefining the likelihood, is tantamount to imposing a quantum shift to the left in the curve separating acceptable and unacceptable risk (see dashed line in Figure 6.2).

It is the size of the shift of the acceptable risk curve to the left that has rendered the trade unviable under the Panel's recommendations. The likelihood of an event of low to moderate consequence has been set at an impossibly low level.

The fundamental point made in this section is the need to be explicit on how and who is defining acceptable risk, so that it can transparently recognise the limitations and adjust the processes and evidential needs accordingly.

6.2.2 Management of heat stress risk

The task of the Panel is to review the HSRA model. But to appropriately consider possible new risk settings for this model, it is important that the Panel consider HSRA within a wider context. HSRA should not be regarded as the ***only*** tool to address risk from heat, but ***a*** tool.

Other important risk management measures will include:

- Careful selection of animals –sourcing animals from properties where past records show they have performed well, particularly during the "shoulder periods", noting that natural tolerance and individual acclimation are important factors.
- Animal preparation
- Feeding regimes both in RPs and on-board, identifying, where possible, shy feeders.
- Cleanliness on board vessels, addressing such issues as possible ammonia build up.
- Sailing approach – such as zig-zagging the ship to maximise cross-wind and air flow into ventilation
- Moving individual animals that are identified as more intolerant of heat to different areas (or cool pens) of the ship

In analyses conducted by AAVs, using mortalities as an indicator, welfare seems to be much more influenced by factors other than WBT. The Panel may care to conduct its own investigations of these issues, for unless the role of the HSRA model is placed in context, it will be impossible for the Panel to appropriately complete its task of providing new risk settings for HSRA which address animal welfare. To view the HSRA model in isolation would be like describing a dining table from only examining one leg of that table. No knowledge is gained of the adequacy of that leg and the stability of the table (the risk of the table falling) without, at least, examining the other legs and the table as a whole.

In this regard, there has been a significant number of recent changes made by the Minister for Agriculture and Water Resources, the Department of Agriculture and Water Resources, and the livestock export industry that reduce heat stress risk separate to the HSRA assessment.

These particularly include the following:

- A reduction of at least 17.5 per cent in the base-line stocking density for sheep shipments. This change decreases the base level heat generation from animals on a vessel, affecting the risk balance.
- The placement of independent observers on all vessels. This is a very strong accountability and transparency measure. There can be no doubt that the placement of government personnel on vessels will provide – a) better information and evidence on which to base policy decisions and regulatory compliance action; and b) provide a strong, direct incentive to maximise both regulatory performance (i.e. against ASEL) as well as community consistent outcomes.
- The halving of the notifiable mortality rate to one per cent. Again, this is a strong incentive. While on average the mortality rates have been under this level for quite some time, individual shipments not-infrequently have exceeded this each year. This change, as for the observers, will again influence behaviours and internal industry risk tolerance.
- AMSA changes removing double tier sheep vessels from service and requiring ventilation consistency. These changes which will come into effect on 1 January 2020 will remove several vessels from service, essentially providing a generational shift in the composition of the sheep fleet.

- ALEC moratorium on exports during June, July and August. The moratorium, as for the stocking density reduction, reduces the baseline risk – significantly given these months reflect the highest risk periods for shipping to the Middle East.

These are important changes because:

- all regulatory options for the issue under consideration (heat stress) must be analysed as a whole to achieve balance; and
- any one of these items could change the subjective / values based views of members of the community or government about the 'tolerability' of the risk.

Noting all of the above, there is a clear challenge for the TRP in how it navigates and fits into this broader purpose. To engage in trying to be definitive on subjective, values based thresholds – trying to reflect public acceptance without the evidence to substantiate it – would undermine the strength of the science. Rather, we think the process would be improved if the TRP were to prepare a range of options reflecting different risk profiles and identify key principles which policy makers can then consider and comfortably fit into the RIS process, where broader consideration can be undertaken.

6.3 Conclusion

At the heart of any review of HSRA is the task of determining how risk should be assessed and acceptable levels of risk. A thorough, complete review would have systematically addressed the risk assessment and management steps outlined in the chapter, steps that are used in other important areas of public policy. It is LiveCorp's observation that in the Draft Report risk assessment and management steps have been completed with various levels of carefulness and exactitude, but as a whole a systematic approach has not been precisely followed.

Amongst other things a systematic approach would have involved:

- Careful consideration and justification of which environmental temperature should be used (wet bulb or some other measure).
- Quantification of the impacts on welfare of different environmental conditions - for instance, wet bulb temperature cut offs between the prescriptive zone, the tolerance zone and the survival zone.
- Quantitatively taking into account "dose" – that is, duration of exposure.
- Reassessing weather data on the basis of the new risk objective.
- Being open and transparent about the population impact.
- Justifying why the risk likelihood setting should remain at previous levels while the risk consequence setting has been very substantially altered – this justification needs to rely on more than the value-judgments of Panel members or their perceptions or assumptions of community sentiments.
- Justifying the risk settings used within the wider context of management of heat stress risks, including very significant recent changes to these management conditions.

7 Options to address risk of heat stress

Preceding chapters of this submission have highlighted the following factors relevant to the welfare risk of heat stress in live sheep shipments to the Middle East.

- The ***complexity*** of assessing the welfare impacts on sheep of exposure to environmental heat. Amongst other things this complexity is brought about by:
  - Significant individual variability in how sheep react to environmental heat.
  - An inability to measure, across the population of sheep on board a vessel, factors potentially relevant to an assessment of welfare such as rise in individual core body temperatures.
  - The difficulty / impossibility in measuring changes in behaviour and how a sheep feels (which are inherent elements in any assessment of welfare).
- A ***lack of knowledge*** of the factors influencing the welfare impacts of heat stress. Current knowledge on heat stress in sheep on voyages to the Middle East can be described as extremely inadequate, particularly, as there are limited data linking heat related behavioural (observations) and physiological responses. The following statements, drawn from a paper specially commissioned for the HSRA Review, clearly point to this lack of knowledge:

  "We identified a lack of scientific literature relating to heat load in animals transported by sea …".

  "The environmental WBT [wet bulb temperatures] at which body temperature rises has been the subject of observational studies, experimental research and much debate. The data sets for establishing these WBT thresholds are somewhat limited".

  In terms of lack of knowledge, the Panel notes that:
  - Only one small study exists which describes the range of responses for any group of sheep to high environmental heat and humidity (p13).
  - In practical situations there has been little assessment of an animal's affective state and relatively little research-based validation exists in these contexts (p13).
  - For respite, the extent of environmental cooling required and for how long is not known (p30).
  - That it is not known how long acclimatisation takes (p31).
- The critical need to incorporate ***duration*** of exposure when assessing the welfare impacts on sheep of environmental heat and the role of respite.
  - The Panel itself acknowledge the critical role of duration and respite stating:

    "the opportunity for thermal respite seems very important" (p18).

    "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)" (p21).

"if there is an opportunity for the animal to cool before the next exposure, this may actually result in some acclimatisation" (p31) – i.e. the impact of exposure with respite may actually be positive for welfare in allowing the animal to acclimatise.

- Notwithstanding that such acknowledgements are important, the TRP chose to ignore duration on the basis that:

  "it can be expected that on ship there is little diurnal variation especially across the equator" (p31).

  This conclusion by the TRP has been challenged in this submission and advice from Professor Maloney and meteorologist Dr Bruce Buckley. In particular, evidence has been presented in Chapter 5 that there are diurnal variations in WBTs on live export voyages to the Middle East of 2-3°C and Professor Maloney believes that these may be important.

- That the ***Stockman experiments should not be relied upon*** for conclusions regarding the impact of environmental heat on sheep welfare, without recognising the limitations of the study. This is not only because a very small number of sheep were included in these experiments, but also because no respite was built into the experiments – on real world voyages there is substantial evidence that potentially important variations in temperature do occur of both a diurnal and longer term nature.

- The need to systematically and explicitly approach the task of determining "***acceptable risk***" through examining the two settings that define risk: the probability of an adverse event occurring and the consequence of the event. With the move to a welfare basis for heat stress assessment, several strong reasons exist to adjust significantly upwards the probability adjudicated to be acceptable:

  - The heat stress threshold has been very substantially lowered from animals dying to animals panting or experiencing a rise in body temperature, both common events. A substantially lower consequence is involved with an animal panting or experiencing a rise in body temperature, compared to an animal dying.

  - Individual variability will be greater with an animal welfare objective versus a mortality objective. It is well known that some sheep pant when no rise, or only a small rise, has occurred with body temperature – that is, panting can occur when there is no welfare issue in terms of significantly elevated body temperatures or physiological outcomes.

  - Measurement error will be greater with an animal welfare objective versus a mortality objective.

    - Experts consulted by LiveCorp noted there is significant scope for differing interpretations of panting score (which may have significant implications if there is more than one veterinarian involved in collecting data). In this context we note the varying and often strong views on what reflects an appropriate scoring system.

    - There is also difficulty in assessing a mob, as opposed to an individual, and further difficulties in assessing sheep that will move from open mouth panting back to elevated respiratory rate whilst being assessed or shortly thereafter.

- ***Incompatibility of results*** from experimental research involving very small numbers of sheep in climate-controlled rooms with observations on board vessels that involve substantially larger sample sizes and sets of data. Data brought together and analysed by LiveCorp in the short time available and set out in this submission clearly presents evidence of an unexplained mismatch between laboratory results, the TRP's conclusions and the real-world experience – particularly as they relate to non-mortality based responses to environmental heat.

In light of the above, in this chapter options are presented in how to address the welfare risks of heat stress in sheep shipped to the Middle East.

7.1 In determining risk settings there is a need to consider the proportion of the population that will be impacted

In the interests of transparency and thoroughness, in defining levels of "acceptable risk", as Figure 6.2 implies, it is important to describe the likelihood of an adverse event arising (the y-axis in Figure 6.2) and the consequence if an adverse event did arise (the x-axis in Figure 6.2). In turn, when dealing with heterogeneous populations, "consequence" is determined by the proportion of the population that will be affected by the adverse event and the impact on affected members – both should be described. That the Panel chose not to do this, in our view, reveals a failure to be fully transparent[24]. As discussed in Chapter 3, there are very significant variations in the reaction of animals when faced with heat. If the Panel chose the 28°C WBT threshold on the basis of zero chance of ***any*** animal being affected, then this should be explicitly stated (in which case "acceptable risk" might take the form of the dotted blue line in Figure 6.2 which touches the x-axis at the minor or moderate point on the x-axis, depending on duration of the panting). If the Panel chose the 28°C WBT threshold on the basis of 5% of animals being affected then this should be explicitly stated – ***and justified***. Not to explicitly describe the proportion of the population affected by a heat event is to avoid responsibility and has the appearance of deliberately engaging in obscurity and ambiguity.

If the duration of panting is reasonably short (say less than 48 hours), the consequence on affected animals might be regarded as minor. In this case If the consequence on affected animals is minor, a large proportion of the population (50th percentile level) could be affected with the risk considered as acceptable. Even though panting for 48 hours is considered a minor consequence, a 50% threshold has been selected, as opposed to a larger percentage, to reduce the likelihood of a minority of animals entering the survival zone (again recognising the heterogeneity of sheep in their reaction to heat).

[24] The Panel noted that:

> *"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" (p28).*

Two points emerge from the statements above:

- The Panel recognises that "*there is likely to be a distribution of individual sheep susceptibility*" to heat, but Panel has not quantified this, so is unaware of the level of importance that it may assume (the use of the term "likely" in itself involves obscuration as there will ***certainly*** be a distribution of individual sheep susceptibility" to heat).
- Even when selecting "*a reasonably conservative WBT welfare threshold*", contingent on the quantification described above, a proportion of the population will be affected, which perhaps will be zero. To be transparent the proportion needs to be explicitly calculated and stated.

For panting durations of greater than 48 hours the consequence for affected animals may be regarded as moderate or major. In this case defining acceptable risk would involve a significantly lower proportion of the population being affected than that determined by the 50th percentile.

The important point being made is that to be transparent and open the Panel needs to explicitly define acceptable risk by selecting values for each of the following:

- The probability of an adverse (heat) event arising.
- The impact on welfare for affected animals (e.g. panting for a certain duration or durations)
- The proportion of the population so affected.

7.2 A measured, staged regulatory response is required

The almost total vacuum of precise knowledge on the relationship between animal welfare and environmental measures, the complexity of the subject matter under consideration, and the potential for severe impacts on regional communities and the economy, indicates that a cautious regulatory response is required.

A considered, responsible regulatory approach would be to set initial boundary conditions for export when heat stress is a potential issue, monitoring the impact of those considerations and progressively tightening them if required.

With such an approach, the best and most knowledge will be gained by setting the initial boundary conditions relatively widely and progressively narrowing the boundaries if results prove unsatisfactory. Unnecessary and unjustified commercial and trading disruptions and impacts on regional communities will also be minimised from this course of action.

Newly introduced arrangements by the Government, including the appointment of Independent Observers and an expanded collection of welfare information on panting, provide an excellent platform to monitor the effect of regulations and make quick adjustments if required. Proceeding in this manner would allow a rapid acquisition of knowledge under real voyage situations, validated by independent government employees (the observers) and allow fine tuning of regulations.

Given current significant knowledge gaps, progressively tightening regulations as / if evidence is gathered of unsatisfactory welfare outcomes is a principled regulatory approach to addressing the issue of the impact of environmental heat on animal welfare in sheep shipments to and through the Middle East. Conversely, given current knowledge gaps, introducing excessive regulation, based on a very limited number of academic studies that are imperfectly aligned with real world voyages and with minimal relevant validation, would penalise producers, regional communities, the Australian economy, trading partners and live exporters for an uncertain outcome. Taking such an approach when a regulated structure exists – through the independent observers – to rapidly gather the validation data necessary to provide the evidence and confidence to make what is a significant regulatory decision would seem unnecessarily impactful.

7.3 Welfare outcomes from heat stress events are dependent on many factors, not just HSRA

A second observation to be made is that numerous factors contribute to welfare outcomes on board a vessel, including those that may arise when hot weather conditions are encountered. The success of the HSRA model in reducing mortalities from heat stress has resulted in far too much attention being focussed on this single input rather than looking holistically at the range of pertinent factors that can influence outcomes. Prescriptive, input based regulations, in which use of the HSRA model has been mandated to prevent high mortality events, have contributed to this narrow perspective.

The current approach to regulating for heat stress, involving prescribed use of the HSRA model, should not be assumed to be the best way to regulate an altered regulatory objective focused on welfare.

Other factors that are relevant to addressing welfare outcomes when hot climatic conditions may be encountered include:

- Careful selection of livestock. Although HSRA includes some selection criteria, there are many other livestock factors that can influence results. The time spent in registered premises, preparing livestock for the journey, is also vitally important.
- Using the first few days of a voyage to prepare for the prospect of hotter weather - it is better to make preparations before it gets hot rather than when it is already hot.
- Evening out stocking densities and opening up pen areas so that the stock have good access to watering points and ventilation outlets (areas around exhaust fans will be hotter and more humid than areas around supply fans).
- Making sure water troughs are well maintained, preventing any leaks that will increase humidity and affect the manure pad. Making sure that the troughs are filling to an appropriate level: not too high, or the troughs will spill with sea swell, and not too low that stock cannot get a good drink.
- Maximising ventilation and airflow wherever possible, opening those hatches or doors that will improve airflow. If any black spots are identified making use of auxiliary fans, if possible. On ships with open decks, move and stack all the loading infrastructure or any solid panels so air flow is unobstructed. Also proceeding in a zig-zag fashion to take advantage of cross winds.
- Progressively obtaining weather forecasts for upcoming days and if hot weather is forecast put in place mitigations steps such as:
  - Possibly adjusting feeding, reducing the pellet component and increasing chaff – as pellets give off more heat when fermenting in the rumen than chaff.
  - Minimising the disturbance of the livestock when the temperatures peak, minimising stock movements and activities on decks.
  - Making sure there is access to clean fresh water for all sheep.

7.4 The panel's work should be allowed to continue until recommendations made can be scientifically supported

A number of steps have been used by the Panel in arriving at its recommendation that live sheep voyages to the Middle East should be prohibited if there is more than a 2% probability that wet bulb temperatures of greater than 28°C will be encountered – and each of these steps may be questioned. These steps include:

- Assuming, incorrectly in our view and in the view of respected experts, that there will be an immediate or significant welfare impact (an unrelenting challenge to homeostasis) to animals once they enter the tolerance zone. As pointed out in Chapter 3, and observed by Mitchell et al, animals in natural conditions are not infrequently in the tolerance zone.
- Determining that panting represents an unacceptable welfare outcome if it is longer than "day and night" without the provision of supporting evidence.

- Ignoring the impact of respite by assuming that there is little diurnal variation especially across the equator, without (apparently) examining the extent of any diurnal variation or presenting evidence that the identified diurnal range is unimportant.
- Linking open mouth panting for a standard sheep with a WBT of 28°C based on one or two experimental studies involving extremely small numbers of animals housed in climate-controlled rooms. Conditions in the climate-controlled rooms, in potentially important aspects, did not replicate those on board vessels.
- Proposing that factors used in the HSRA model to adjust mortality limits across animal characteristics could also be used to adjust heat stress limits. This is despite the fact that the HST distributions in the HSRA model have never been validated, nor have the adjustment factors when used in this context. Put plainly, we believe that these adjustment factors, when applied to the HST distribution, are incorrect, probably substantially so – this is also the view of experts we have consulted. If the Panel believes they are, in fact, correct, it is incumbent on the Panel to provide strong supporting evidence (on exact magnitudes).

The most critical of these logical leaps are the last three – but all reveal significant gaps in knowledge and inadequate further research and investigation. This further research and investigation, amongst other things, should have involved a close examination of data on actual voyages.

Under regulation a range of data are collected on every live export voyage departing Australia - these data presumably are stored at the Department of Agriculture and Water Resources. Data items collected under regulation include panting scores (although, as noted in Chapters 3 and 4, these keep on changing) and wet bulb temperatures per deck. The department also has information on exact characteristics of livestock loaded on each deck, so appropriate investigation may have shed light on HST sheep adjustment factors to be used and helped to assess / validate the applicability of those applied in the HSRA for mortality estimates.

The TRP were specifically directed to "*examine on-board vessel data from livestock export voyages through Independent Observers and Australian Government Accredited Veterinarian (AAV) reports and other relevant data*". There is insufficient evidence in the draft report to suggest that this specific task assigned to the Panel has been systematically undertaken.

The fact that regulation is being contemplated when this work has not been completed, or if it has been completed when it has not been transparently set out as part of the consultation, points to major shortcomings in process. Regulating an industry out of existence, as the analysis in Chapter 2 shows the panel's recommendations will do, is a step that should not be taken lightly, but only after the most exhaustive, exacting examination and research. The work of the Panel, possibly under expanded membership, should be allowed to continue until this work has been completed and there is greater certainty around the influence of environmental heat on animal welfare. The provision of greater certainty should include validation, in real world situations, of results obtained from small experiments.

7.5 Advantage in specifying required welfare outcomes directly in regulation

If the Panel's work is not allowed to continue, rather than to apply a threshold WBT of 28°C based on inadequate research and an extremely poor knowledge base, one option would be to regulate directly to the welfare outcome required – i.e. sheep are not allowed to open mouth pant for more than a certain duration.

The Australian Productivity Commission recommends that, where possible, outcomes based conditions should be the default approach to regulation. Outcomes based regulation also represents the approach that the Government and department said it would adopt in the current ASEL Review (of which the HSRA Review is a part).

Benefits from specifying required outcomes in regulations, rather than required inputs or processes (as is the case with prescriptive regulation), include the following:

- It allows individual operators to meet the regulation in different ways using methods tailored to particular circumstances. In contrast specifying inputs and processes in regulation implies a 'one size fits all' approach.
- It encourages innovation. Often superior outcomes are achieved more effectively when they are specified directly in regulation.
- It encourages management to continually monitor the required outcome and adopt flexible, adaptive approaches to ensure it is being met. This contrasts with management merely being concerned that they have met regulatory requirements in terms of inputs and processes.
- It may improve community understanding of the regulatory objectives, by clearly linking regulation to the desired outcome (in this case, the desired animal welfare outcome).
- It assists in clearly setting out the expectations between the regulator and regulated of what satisfactory / unsatisfactory performance looks like, in turn allowing compliance to be easily monitored and evidenced to underpin regulatory responses.

Specifying the required outcome directly in regulation is particularly pertinent to a consideration of heat stress. The myriad of factors that potentially lead to welfare outcomes on a voyage when hot climatic conditions are encountered were covered in Section 7.2. It would be impossible to include all these factors in regulation – a simpler, more productive approach is to regulate to the outcome.

Specifying the outcome in regulation also avoids the problem of an undue focus on the HSRA model. It is certainly highly unusual to mandate in regulation use of an industry proprietary model – but this is the current approach with heat stress. Rather than specifying use of an industry proprietary model, under an alternative approach, prior to a voyage, exporters would be expected to demonstrate that they have exercised due diligence in avoiding open mouth panting. Under guidance from the regulator, several paths could be identified by which an exporter could demonstrate he/she has exercised due diligence. These could include use of a re-designed HSRA model (but use of this model would no longer be mandated in regulation) or simpler schemes such as use of threshold temperatures and various durations based on expert advice.

Regulating directly on open mouth panting builds on measures already implemented by the Government. A key plank in regulating panting scores directly would be the role of Independent Observers. The newly created Animal Welfare section in the department may also have a role.

Over time direct regulation of welfare outcomes could be expanded to embrace items like identification of those not feeding or drinking, health issues, etc.

Regulating directly to open mouth panting will also be more easily communicated to the general community than use of the HSRA model or threshold wet bulb temperatures, will result in the acquisition of more knowledge in an area where knowledge is currently poor, and is likely to result in better welfare outcomes (since the outcome is directly regulated rather than regulations being framed around inputs or processes that may only be indirectly or partially associated with the outcome).

7.6 Possible modifications to the HSRA model

As stated in previous sections, it is LiveCorp's view that, given the significant knowledge gaps that exist with respect to the welfare impact on sheep of environmental heat, a cautious, staged, regulatory response is required. Within this setting, this section outlines possible changes to the HSRA model based on some of the concepts included in the TRP's draft report.

7.6.1 Setting of threshold temperatures

The objective the Panel's work is to transform the HSRA model from one with mortalities as the focus to animal welfare as the focus. This involves altering the probability distributions used in the model, threshold temperatures and adjustments for individual animal characteristics.

The discussion below addresses the following aspects of any adjustment to the HSRA model:

- Adjustments that are relevant for the "standard" sheep.
- Adjustments that are relevant for "non-standard" sheep.
- Adjustments to account for temperature fluctuations across time and the concept of respite.

7.6.1.1 Threshold temperatures for standard sheep

The temperature currently referenced in HSRA for anchoring probability distributions is the modal mortality limit. For the TRP's standard animal (56 kg adult, body condition score 3, zone 3, winter acclimatised, and recently shorn) this reference temperature is 34.6°C. The model uses this reference temperature to ensure that there is less than a 2% probability of mortalities due to heat stress reaching 5% of sheep loaded.

The Panel has recommended that instead of the modal mortality limit of 34.6°C for the standard sheep, a threshold temperature of 28°C be used. As has been noted throughout this submission, this recommendation of the Panel is based on what we believe is an erroneous view that substantial numbers of sheep start open mouth panting for long durations once the wet bulb temperature reaches 28°C on-board livestock vessels. We believe this view is erroneous since:

- no real world evidence has been produced by the Panel to support it, and
- the real world evidence we have seen suggests significant inconsistencies between what such an approach should predict and what is observed.

In a paper commissioned by LiveCorp in the preparation of this submission, one of Australia's foremost experts on thermoregulatory responses in animals, and an expert whose work the TRP extensively quote in the draft report, Professor Shane Maloney, disputes the use of a 28°C threshold. Professor Maloney argues that animal welfare is not compromised unless the wet bulb temperature is in excess of 33°C for 12 hours, 32°C for 24 hours or 30°C for 48 hours.

Professor Maloney openly concedes that the establishment of any temperature threshold in terms of animal welfare is based on limited research. Because of this, and given that real world data shows wet bulb temperatures well above even the levels advocated by Professor Maloney without animals excessively open mouth panting, there are strong arguments to increase any wet bulb temperature threshold to above the levels of Professor Maloney and adjust downwards if necessary.

In summary, for a standard sheep, if a reference temperature is to be included in an adjusted HSRA model this temperature should be significantly greater than the 28°C proposed by the Panel and, ideally, take into account duration. It is to be noted that any reference temperature likely to be set in a revised HSRA will be below model temperatures which currently apply. Setting temperatures above the levels proposed by Professor Maloney and adjusting downwards if required would be in line with the cautious regulatory approach that has been recommended.

7.6.1.2 Adjusting threshold temperatures for non-standard sheep

The recommendations of the TRP depend on not only the threshold temperature for the standard animal being accurate, but also on the accuracy of adjustments for non-standard animals.

The standard animal, as defined by the TRP, makes up only a very small proportion of total animals shipped from Australia to and through the Middle East. Last year about one-third of shipments were lambs, while most of the other two-thirds also comprised animals that did not align closely with the TRP's standard animal.

As has been noted, the TRP proposed that the same factors used in the HSRA model to adjust mortality limits across animal characteristics could also be used to adjust heat stress limits. However, adjustment factors in the HSRA model have never been validated in this context.

There is reason to conclude that the HSRA adjustment factors across animal characteristics, when applied to the HST, are erroneous. Certainly, the adjustment factors exhibit unusual features. For two types of animals (the TRP standard animal and a standard lamb), Table 7.1 provides the reference temperature used in the HSRA model for the mortality limit and the HST threshold temperature calculated applying the recommendations in the TRP draft report – including applying the HSRA adjustments for mortality limits to determine the HST threshold temperatures. In Table 7.1 a standard lamb is defined as weighing 40kg, body condition score 3, zone 3, winter acclimatised, and recently shorn (i.e. a coat of under 10mm).

Table 7.1: HSRA mortality limits and TRP threshold temperatures for the standard animal and a standard lamb

Animal characteristics	HSRA mortality limit reference temperature	TRP threshold temperature (using the HSRA adjustment factors)
TRP standard animal	34.6°C	28.0°C
Standard lamb	34.6°C	24.4°C

It can be seen from Table 7.1 that the mortality limits for the TRP standard animal and the standard lamb are identical, but there is a 3.6°C difference in the adjusted HST threshold temperatures between these two animals.

As shown in Chapter 2 the TRP's recommendation of a 28°C threshold temperature for a standard adult sheep is impossible to meet for most of the year, but the 24.4°C threshold for lambs is impossible to meet at any time of the year. Moreover, such a threshold temperature (applied at the 98 percentile level as per the TRP's recommendations) will be breached regularly in Australian domestic conditions.

The TRP provided no explanation of why such large differences should exist and an explanation is not obvious to LiveCorp – but this is an integral part of the TRP's recommendations and is just as vital to impact.

This suggests that not only does the TRP's recommendation regarding a 28°C wet bulb temperature threshold for the standard animal require examination (as Professor Maloney has recommended), but also the adjustment factors across animal characteristics. The TRP's recommendation to use the HSRA adjustment factors requires just as much supporting evidence as the recommendation to use a WBT threshold of 28°C for the standard animal – but the recommendation to use the HSRA adjustment factors receives virtually no attention in the draft report.

7.6.2 Incorporating duration

Material presented in Chapter 5 draws attention to diurnal variations in temperatures even at the equator. Professor Maloney's own work has also detected diurnal variations in temperatures which he believes are important. The scheme devised by Professor Maloney explicitly takes duration into account – and, by implication, respite. One of the recommendations of the TRP in the draft report is:

> *"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" (p5).*

It is LiveCorp's view that the work of the Panel is substantially incomplete while ever the question of how to incorporate duration into the HSRA model is left unanswered. As stated in the submission by LiveCorp to the HSRA Issues Paper:

> *"Duration is clearly an important element of tying any [temperature] threshold to welfare".*

If the policy objective is to tie environmental heat to animal welfare, no regulatory scheme should exist without taking into account duration – it would be deficient regulation since duration of exposure to adverse environmental conditions is integral to an assessment of welfare.

The question is: how can duration be incorporated into the HSRA model? In this section we outline one possible method for introducing duration into the HSRA model.

7.6.2.1 Incorporating duration if temperatures on successive days were independent

If temperatures on successive days were independent, it would be a *relatively* simple matter to incorporate duration into the HSRA model.

- Currently the HSRA model references maximum daily wet bulb temperatures – for instance, a probability distribution function for maximum wet bulb temperatures in July is shown in Figure 7.1, with the corresponding cumulative probability function shown in Figure 7.2[25].

[25] The distribution shown in Figure 7.1 contains an allowance of 2.0°C for heat generated by the animals themselves – this is added to the probability distribution for environmental wet bulb temperatures. For convenience, in conveying the concepts explained in this section, for environmental wet bulb temperatures, the idealised normal distributions used in the original HSRA report has been used.

Figure 7.1: Probability distribution for maximum voyage wet bulb temperatures in July

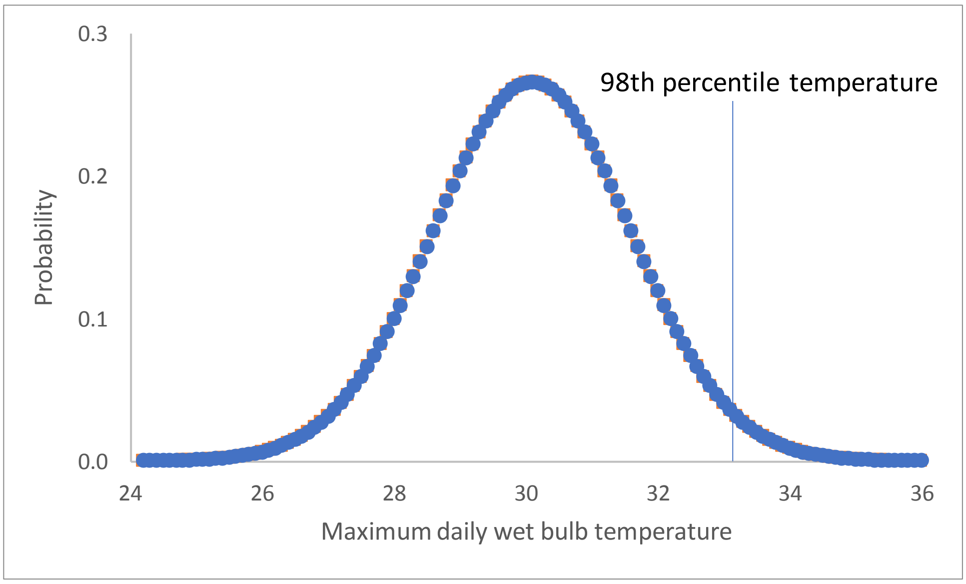
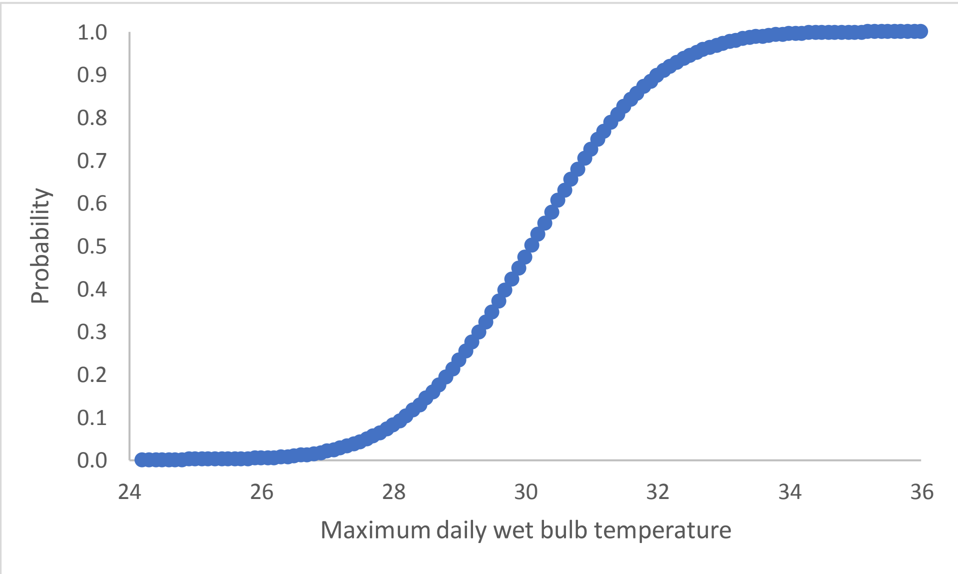


Figure 7.2: Cumulative probability function for maximum voyage wet bulb temperatures in July



- If temperatures were independent the probability of encountering a maximum wet bulb temperature of above 32°C two days in a row could be calculated by multiplying probability distributions. For instance, from Figure 7.2, the probability of a temperature above 32°C in July is 10.3%, so for two days in succession is $(10.3\%)^2$ = 1.1%.

If temperatures were independent the same process used above for calculation of maximum temperatures could also be used for calculating the probability of minimum temperatures. The probability of minimum temperatures is more relevant to the consideration of the welfare impacts from environmental heat, since it introduces the concept of respite.

The work of Professor Maloney, and the Panel itself, points to the criticality of respite. As temperatures drop an animal obtains relief from hot temperatures. With the considerable emphasis on respite from hot temperatures, in terms of animal welfare, there are strong arguments to suggest that the HSRA model should be recast to refer to minimum temperatures rather than maximum temperatures (as it does now). The Panel itself notes the importance of referring to minimum temperatures stating: "*The incorporation of daily minimum temperatures into the model is most desirable*" (p31). Under this recasting of the model what is important is not the probability of a maximum temperature being reached (as is the current focus of attention of the model), but the probability of the minimum temperature falling below a certain threshold that provides respite.

In demonstrating the concept of minimum temperatures, in the context of the existing HSRA probability distributions, we have assumed that:

- The minimum wet bulb temperature is 2.7°C below the maximum temperature. This assumption has been based on information presented in Chapter 5 including information from Singapore, that supplied by Dr Bruce Buckley, and that obtained from on-board temperature loggers.
- In other respects the distributional information is unaltered from that used for maximum temperatures – i.e. the distribution is shifted by the difference in means.
- An allowance of 2.0°C has been added to the environmental wet bulb temperatures probability distributions for heat generated by the animals themselves.

The resultant probabilities by month, assuming independence of temperatures across days in a month, is shown in Table 7.2. From Table 7.2 for example, based on the assumptions specified above, the probability of minimum temperatures being above 30°C for two successive days, in July, is 0.2% - i.e. the probability of the temperature falling below 30°C, thus providing respite, is more than 99%.

Table 7.2: Probability of various minimum WBTs being greater than a threshold temperature over a number of days.

Measure	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Two successive days												
Probability that minimum Deck WBTs > 28°C.	0.0%	0.0%	0.0%	0.0%	0.2%	4.9%	11.9%	15.3%	3.6%	0.0%	0.0%	0.0%
Probability that minimum Deck WBTs > 30°C.	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.7%	0.0%	0.0%	0.0%	0.0%
Probability that minimum Deck WBTs > 32°C.	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Three successive days												
Probability that minimum Deck WBTs > 28°C.	0.0%	0.0%	0.0%	0.0%	0.0%	1.1%	4.1%	6.0%	0.7%	0.0%	0.0%	0.0%
Probability that minimum Deck WBTs > 30°C.	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
Probability that minimum Deck WBTs > 32°C.	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

A further point needs to be made on the probabilities provided in Table 7.2. It needs to be appreciated that because of normal diurnal temperature patterns (hottest temperatures in the afternoon, coolest temperatures between midnight and dawn), the period between maximum and minimum temperatures over a selected period of time will be considerably less than the period selected. For example, the duration between maximum and minimum temperatures over a one day period will be less than one day – more like 12 hours. As a result, when a one day period is specified for calculation of maximum and minimum temperatures, respite will normally occur in about 12 hours. These considerations continue to apply when longer time periods are specified. For instance, using the Singapore data over 48 hours, the average time difference between maximum and minimum temperatures is 17.7 hours across all maximum temperatures and for 98 percentile maximum temperatures is 25.4 hours.

That is, respite occurs much more quickly than would be implied by simply referring to the period selected.

7.6.2.2 Incorporating duration when temperatures on successive days are allowed to be interdependent

As has been emphasised, the above analysis has been conducted under the assumption that temperatures on successive days are independent. Clearly, however, there will be a degree of dependency between temperatures on successive days. As a result, it is conceded that the assumption will be, to an extent, inaccurate.

To allow for dependency between temperatures on successive days conditional probabilities must be used:

$$Pr(T_d, W_{(d+1)}) = Pr(T_d) * Pr(W_{(d+1)} \mid T_d) \qquad \text{(Eqn 1)}$$

$$Pr(W_{(d+1)} \mid T_d) = f_1(T^{max}_d, X_{(d+1)}) \qquad \text{(Eqn 2)}$$

That is, the joint probability - $Pr(T_d, W_{(d+1)})$ - of a minimum temperature of T on day d and a minimum temperature of W on day d+1 is the probability of a minimum temperature T on day d multiplied by the probability of a minimum temperature W on day d+1 given that a minimum temperature T has occurred on day d. The conditional probability of a minimum temperature W on day d+1 can be expressed as a function of the maximum temperature T^{max} on day d and an array of other factors (X).

If respite is considered to occur once temperatures drop below a certain threshold, equations can be built for the probability of no respite (and, therefore, by simple arithmetic, the probability of respite) as follows:

$$Pr(T_d > Y, W_{(d+1)} > Y) = Pr(T_d > Y) * Pr(W_{(d+1)} > Y \mid T_d) \qquad \text{(Eqn 3)}$$

$$Pr(W_{(d+1)} > Y \mid T_d) = f_2(T^{max}_d, X_{(d+1)})$$

where Y is a threshold temperature. (Eqn 4)

The difficulty of applying these probability concepts to environmental temperatures on sheep voyages to and through the Middle East is not conceptual, but rather relates to availability of data.

- To estimate $Pr(W_{(d+1)} > Y \mid T_d)$ ideally requires recording of temperature data on successive days by the same ship and for that ship to be in relevant locations.
- Dealing with extreme temperatures also limits available data and accuracy in f( ) across the range of W in which there is interest. For example, if temperatures were recorded every day at a location for a particular month over 20 years, that would provide 20*30 = 600 data points, but

only 12 of these data points on average would be above the 98th percentile level. At the 98th percentile level (or even at slightly lower levels) we are dealing with VERY rare events.

In an exploratory sense, LiveCorp has attempted to estimate the probabilities shown above.

$Pr(T_d > Y)$ has been calculated by LiveCorp using the existing probability distributions in HSRA.

To estimate $Pr(W_{(d+1)} > Y \mid T_d)$ LiveCorp has:

- Traced the route taken by live export vessels travelling between Australia and the Middle East.
- For locations along this route extracted VOS data for ships recording temperatures on two successive days.
- Used logit models to estimate $f_2(T^{max}_d, X_{(d+1)})$.

In the logit models T^{max}_d was included in both linear and quadratic forms to allow for non-linearities in the dependency between temperatures on successive days. Additionally, seasonal binary variables were included with the seasons represented by:

- December, January, February;
- March, April, May;
- June, July, August; and
- September, October and November.

Estimations of f( ) will not be shown here, but are available on request. The linear and quadratic expressions of T_d were both significant in all equations estimated. Equations were estimated for $Y = 28°C$, $Y = 30°C$ and $Y = 32°C$.

The probabilities by month to be produced from this process are shown in Table 7.3. These probabilities are higher than those in Table 7.2 (because an allowance has been made for the dependency of temperatures between successive days – i.e. there will be a higher probability of tomorrow being hot if today is hot), but still shows that there is a high probability of relief from high environmental temperatures in most months.

The method outlined above would need to be further refined and an attempt made to address any data gaps. However, the method outlined above shows it should be possible to introduce duration into the HSRA model.

The estimated models involved only two successive days of temperature information (i.e. 48 hours). As explained previously, selection of a 48 hour period for analysis implies relief within a 24 hour period on most occasions from when the maximum temperature occurred – due to the diurnal fluctuation in temperatures.

7.6.3 Increasing the probability setting in HSRA

As was emphasised in Chapter 6 and at the beginning of this chapter, given that the consequence being modelled in HSRA has been very substantially changed, from mortalities to animals panting, compelling arguments exist to also change the probability objective. At the very least the probability setting in the model should be subject to just as much examination as the consequence setting – both are equally important. Very little attention has been provided in the draft report on the level to be assigned to the probability setting in HSRA.

Table 7.3: Probability of various minimum WBTs being greater than a threshold temperature over a number of days – allowing for dependencies between days.

Measure	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Two successive days												
Probability that minimum Deck WBTs > 28°C.	0.1%	0.1%	0.3%	0.8%	9.4%	30.2%	43.8%	45.2%	20.5%	2.6%	0.2%	0.0%
Probability that minimum Deck WBTs > 30°C.	0.0%	0.0%	0.0%	0.0%	0.0%	4.7%	7.7%	12.1%	0.0%	0.0%	0.0%	0.0%
Probability that minimum Deck WBTs > 32°C.	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.4%	1.5%	0.0%	0.0%	0.0%	0.0%

There is no scientific or regulatory justification for the simple application of the same risk probability (reflected in the 2% and 5 % thresholds) from the existing mortality model to a separate welfare-measure based model. All of these thresholds must be revisited and given consideration if the outcome measure is changed.

As explained in Chapter 6, the selection of an appropriate probability setting – because it is ultimately a reflection of what has been defined as an 'acceptable risk' – necessarily requires input from a wider audience and group than solely the TRP, or for that matter industry.

A process for examining the probability setting in the HSRA model was suggested in the ALEC submission to the HSRA Issues Paper.

> *"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. …. 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".*

7.7 Conclusion

The issue of how environmental heat impacts the welfare of animals is mired in complexity and a lack of precise knowledge.

With this is mind a cautious regulatory stance should be adopted.

Regulating to a single threshold temperature (even once adjusted for various animal characteristics), as has been recommended in the draft report, is an overly simplistic response - a response that does not reflect the complex interactions which exist between animal welfare, environmental heat, animal selection and conditions on-board a vessel. It will take time to refine and advance knowledge on these complex relationships and this needs to be acknowledged. It would be indifferent to the substantial community and economic impacts to introduce punitive regulations without addressing this complexity and improving the current state of knowledge which all concede is diminutive. In this regard it should also be noted that the PhD study from Stockman, that forms a large proportion of current knowledge, has been questioned in terms of its relevance to real voyage conditions.

On an interim basis, the work of Professor Shane Maloney and the indicative probability analysis of environmental temperatures contained in this chapter, suggests that the ALEC moratorium on shipments during June, July and August should be supported. It is in these months that risks are greatest.

During other months, on an interim basis, it is suggested that trade be allowed to continue under the revised conditions introduced last year. As identified in this submission, these revisions to the conditions of the trade have been significant and involve a fundamental shift in the regulatory and risk environment for the live-export trade. Importantly, continuing under the current conditions would allow more data to be collected and knowledge to be gained. Independent Observers would play a vital role in monitoring animal welfare conditions onboard vessels, including issues arising from environmental heat, providing an early warning of potential problems and informing further regulatory decisions.

It has been suggested in this chapter that panting might be regulated directly through the new third-party verification structure (i.e. the independent observers). This would be better regulation than preventing or closing a trade because of pre-emptive predictions to minimise a poorly understood risk defined based on threshold temperatures that have not been validated, and that do not seem to correlate with the available real-world evidence.

Approaches have also been suggested in this chapter on what would be required to redevelop the HSRA model with an animal welfare focus. Some of the steps involve:

- Exploring how to introduce duration and respite into the model, perhaps using some of the concepts outlined in this chapter
- Re-examining the animal adjustment factors under a new welfare objective
- Re-examining the probability settings to be included in the model.

To adequately undertake the above steps and more will take time.

8 Comments on other recommendations of the TRP

Most of this submission has been devoted to commenting on the Panel's recommendations that a threshold WBT of 28°C apply to the standard sheep and how this threshold should be adjusted to account for animals with other characteristics (i.e. Recommendations 2 and 3 in the draft report).

In this chapter we briefly comment on some of the other recommendations of the Panel.

- Recommendation 1: When the HSRA model was first developed three measures of environmental heat were considered for inclusion in the model. From this consideration wet bulb temperature was identified as the single most useful measure of environmental heat impacting on mortalities[26]. The authors of a review into the HSRA model in 2008 reached a similar conclusion: "*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*"[27]. If a decision is made, however, to change the objective of the HSRA model from mortalities to another welfare measure, there is good reason to revisit the question of which environmental measure should be used. LiveCorp notes that some academics, including one of the Panel members, has been critical of the use of wet bulb temperature in HSRA, advocating instead use of THI (the temperature humidity index), an alternative measure of environmental conditions.
- Recommendation 5: Based on the research presented in this submission, if the objective in HSRA is changed to a welfare measure, such as panting, it is essential that elements like duration and respite are introduced into the HSRA model. Material in this submission demonstrates that extreme model inaccuracies and misleading results would almost certainly occur if such modifications were not made to HSRA.
- Recommendation 6: Clearly there is a responsibility on exporters to care for the welfare of sheep welfare beyond the voyage period. Other than a moral responsibility, this responsibility is established under ESCAS. As Panel members would be aware, LiveCorp continues to conduct research into issues, including the impact of environmental heat, which may affect the welfare of animals in-market. This research has contributed to ALEC decisions on shipment moratoriums for certain months of the year.
- Recommendation 7: LiveCorp has several research projects in place to identify the best measures to use for animal welfare across the supply chain and the best mechanisms by which to collect this data. A key project for the livestock export industry in this area is "*Development and assessment of animal welfare indicators - Quantifying welfare improvements in the live export industry*", being delivered by Murdoch University. The aim of this project is to identify internationally accepted and current indicators of animal welfare for cattle, sheep and goats that could be used at each point along the livestock export supply chain. The adoption of an app based real time data collection platform is currently being piloted to capture the data and analysis. As well, the development of technologies to increase automation (both of the indicators and underlying data of relevance) is being explored. The project will ultimately result in a platform to benchmark performance and identify areas of improvement using an integrated welfare assessment.
- Recommendation 8: This submission has, on several occasions, highlighted the importance of a suite of factors that contribute to the extent with which environmental heat impacts on animal welfare. Stocking densities, that might be determined through use of the HSRA model, represent just one of these factors.

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[26] MAMIC Pty. Ltd., 2001, "Investigation of the ventilation efficacy on livestock vessels", *MLA Final Report, SBMR.002*, Sydney.
[27] Ferguson, D., Fisher, A., White, B., Casey, R., Mayer, B., 2008, "Review of the Livestock Export Heat Stress Risk Assessment Model (HotStuff)", *Report for Project Codes W.LIV.0262, W.LIV.0263, W.LIV.0264, W.LIV.0265*, Meat & Livestock Australia, December.

The Panel is right in drawing attention to other possible factors impacting on welfare, such as ammonia levels.

Better understanding and managing the on-board environment are priority areas for the Live Export Program (LEP) R&D program, funded jointly by Meat & Livestock Australia and LiveCorp, to ensure exporters have the information needed to pursue continued improvements to the welfare and comfort of animals during export. Ammonia is a key item identified in this regard.

The LEP has established a project to scientifically analyse the relationships between the different variables affecting bedding and the on-board environment (particularly ammonia) as well as the development of practical predictive tools and interventions to identify and manage risks. This project is a significant investment will be delivered by the University of New England through its project partnership with the LEP.

Appendix A: Report by Professor Maloney

Physiological review of the draft HSRA report

The following independent opinion is provided in response to a request from LiveCorp to analyse and provide my expert insight into physiological issues regarding the December 2018 draft report by the independent technical reference panel titled "Heat Stress Risk Assessment".

This opinion is provided under the auspices of a University Consultancy agreement between LiveCorp and The University of Western Australia.

Summary

The panel draft report supports a move away from a heat stress risk assessment model that is based on mortality to one based on welfare, arguing that the death of animals during live export is not acceptable under community standards.

The panel accepts the use of the wet-bulb temperature as an index of heat stress in sheep.

The proposed welfare measure is the expected transition from Panting Score 2 to Panting Score 3 (the transition from Phase I to Phase II panting).

Preliminary observations

From a physiological perspective, there are several important aspects of the draft report where my opinion differs from the conclusions of the panel, sometimes in the interpretation of data and sometimes in the methodology that was used to obtain those data. The most pertinent are summarised below and detailed in the body of this response:

- Quantitative physiological responses are more reliable than qualitative behavioural assessments, and so provide a more reliable, repeatable, and defendable basis for predicting and measuring welfare outcomes.
    - Core (or rumen) temperature is an objective reliable proxy for the PS2 to PS3 threshold. In my opinion it is better than respiratory frequency; the latter measure decreasing when a sheep transitions from Phase I panting (PS2) to Phase II panting (PS3).
    - There is a very robust relationship between the rumen temperature of sheep and the WBT.

- There is a mismatch between the 28°C WBT threshold and the desired welfare outcome of avoiding a change from PS2 to PS3.
    - The panel recommendation of a wet-bulb temperature threshold of 28°C is based on increases of sheep core body temperature of 0.5°C, which does not align with the panel's reference to the Phase II panting transition occurring when core temperature increases by between 0.5 to 1.0°C.

- For an individual animal, a shift from the prescriptive to the tolerance zone, or from PS2 to PS3, does not equate to immediate, irreversible physiological harm
    - In the parlance of Mitchell et al. (2017), the qualitative change in heat stress risk assessment moves the accepted conditions for sheep from the survival zone to the tolerance zone.
    - Exactly where the upper limit of the tolerance zone is for sheep is not known. Data collected during live export suggests that it is above the proposed 28°C.
    - A physiological response is not the same as physiological malfunction or harm.
        - Increases in any physiological response within the prescriptive zone are part of the animal's normal physiological responses and ability to thermoregulate, not an

    indication that welfare is compromised. Those responses are equivalent to a human sweating.
    - By using HST2 to define a welfare limit, the panel has acknowledged that it is acceptable to have sheep exposed to conditions that are above their prescriptive zone, and within their tolerance zone
    - Within the tolerance zone, and particularly towards the lower end, the animal remains able to thermoregulate (that is, to establish heat balance) via normal physiological mechanisms, but reaches heat balance at a slightly higher core temperature.
    - As above, this does not immediately or necessarily equate to physiological harm. Heart rate, peripheral perfusion, respiratory rate, and some behaviours, all change within the prescriptive zone, and continue to change within the tolerance zone.
  - The panel states that a wet-bulb of 28°C poses an unrelenting challenge to the homeostasis of sheep. Data collected during live-export shows that sheep do not develop uncontrolled hyperthermia at WBT of 28°C, but can thermoregulate for at least several days under those conditions.
  - Within the tolerance zone the "physiological malfunction" that Mitchell referred to was for functions such as long-term reproductive outcomes, not immediate physiological harm.

- The report, and the evidence that it relied upon, assumes that there is no material respite for animals on board livestock vessels near the equator. My analysis of those same materials shows the assumption to be erroneous.
  - The draft report makes several mentions, and cites several sources, to support the contention that there is no respite during live-export voyages. The literature on which that statement is based are summarised in this report, revealing that the sources, in fact, show that more than 2°C of respite is normal.
  - Data that were collected during export voyages shows that there is usually more than 2°C variation in the wet-bulb across a 24-h day, providing some respite for sheep as vessels near then cross the equator and enter the Gulf region.
  - The recommended threshold of 28°C is based on climate chamber experiments that were designed on the assumption that there is no respite, in terms of WBT, on board livestock vessels near the equator.
  - The draft report states that a lack of respite would lead to an underestimation of the WBT at which a given HST will occur (P26).
  - Thus the climate chamber experiments would have underestimated the WBT at which HST2 would occur during an actual voyage

- The evidence supports a move to a higher and variable threshold, based on the time of exposure to a given wet-bulb temperature, without compromising the ability to predict and prevent physiological harm. Illustrative testable scenarios are outlined, with a schematic for a heat stress risk assessment model that is based on WBT and time of exposure.

- Further details are given in the relevant sections below.

Preamble

The panel report agrees with Dr McCarthy that the criteria for the HSRA needs to move away from mortality risk to the risk of poor welfare, concluding that "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".

The proposal calls for a welfare-based assessment, revolving around the transition of sheep from Phase I (rapid shallow) panting, to Phase II (slow deep) panting. Yet the choice of the 28°C wet-bulb temperature (WBT) threshold in the draft report is not based on an assessment of panting or panting scores, but seems to be based on two findings, both given on P19 of the draft report.

- The first is work from Stockman (2006) on Poll Dorset x Merino weaners, and the finding that "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".
- The second is the finding, also from Stockman (2006), that the core temperature of 56 kg, recently shorn, four year old Merino wethers during winter "was significantly elevated 0.5°C above pre-heat values when the rooms were at 28°C WBT". The panel has proposed to use this value, called HST2, to define the welfare limit.

The conclusion to use a 28°C WBT threshold, based on increases in the core temperature of sheep of 0.5°C, does not align with the recommendation that the system be based on the transition from Phase I to Phase II panting (which is equivalent to the transition from Panting Score 2 to PS3).

- The draft report says on P21 that "there is a reasonably close association between animals panting at score 3 and their body temperature rising 0.5–1 degree above normal". Yet the panel then proceeded to use HST2, which accords to a 0.5°C increase in core body temperature.
- It seems overly restrictive to admit that the PS3 threshold occurs between 0.5 and 1.0°C above normal, but to then use the lower end of that distribution.

Part of the logic for the panel draft report to recommend a threshold of 28°C was because "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" (P7).

- From a physiological perspective, an unrelenting challenge would be an exposure to a stressor that overwhelms an animal's ability to maintain homeostasis.
- A WBT of 28°C does not present an "unrelenting challenge to homeostasis".

While data from climate chamber experiments are well-controlled, the design is necessarily restricted to small numbers, and thus the cohort represents a small fraction of the variation that exists in the population of sheep that are transported. The experiments of Stockman (2006) exposed relatively small cohorts of several sheep types (n=12 [chapter 3] or n=6 [chapter 4]) to various WBT. Data from real-world experiments are not as tightly controlled in terms of environmental exposure, but they can be conducted on larger cohorts (n = 20 to 48), and analysed to inform matters, such as the relationship between WBT and sheep body temperature.

Monitoring of sheep cohorts on vessels from Fremantle to the Gulf during the southern hemisphere winter showed that for days where the deck WBT was close to, or above, 28°C:

- There was no evidence that the sheep were unable to maintain homeostasis.
- The average daily rumen temperature of the cohort (n from 20 to 48) remained stable when the deck WBT was stable.
- If homeostasis, and in particular thermal homeostasis, had been challenged, then the sheep would have entered uncontrolled hyperthermia with an uncontrolled increase in core body temperature.
- There is no evidence that that was the case.
- On these voyages, the rumen temperature changed when the deck WBT increased or decreased, indicating that the sheep established a new steady state of homeostasis based on their heat balance, at the prevailing conditions.

There may be issues with an assessment system based on behavioural rather than physiological responses, such as panting, which can occur without an increase in core body temperature and is often assessed qualitatively, rather than quantitatively.

- For example, in discussing the implementation of Phase II panting in sheep, the authority on the subject, Bob Hales, states in Hales and Webster (1967) that "the present animals often commenced second phase breathing while rectal temperature was within the normal range".
- In addition, respiratory frequency decreases when the transition from Phase I (PS2) to Phase II (PS3) panting occurs.

Given uncertainty around the implementation of Phase II panting, and the somewhat subjective nature of qualitative behavioural data, it would seem prudent to base surrogate welfare measures on quantitative inputs. Given the sound relationship between deck WBT and the rumen temperature of sheep (a subject expanded on below), and the inferable threshold rumen temperature when the average sheep transitions from Phase I to Phase II panting, a testable and defendable threshold could be created at a given rumen temperature.

In one sense, notwithstanding the focus on qualitative panting scores, the panel has attempted to implement a quantitative measure by choosing to use HST2 (an increase in core temperature above baseline of 0.5°C). In my view, the panel chose an overly conservative HST. The HST3 (an increase in core temperature above baseline of 1.0°C) would be more appropriate to use in a welfare based risk model. However, there is also no evidence that exceeding HST3 is associated with immediate physiological harm.

- The core body temperature of fleeced sheep is 0.7°C higher than that of shorn sheep, even in benign conditions (Beatty et al. 2008). Yet no one would argue that a sheep suffers decreased welfare while it grows its wool over the year.

Three main issues are addressed in the remainder of this response:

- **i) How does WBT relate to physiological responses?**
- **ii) How much respite do the sheep generally experience at night when a ship nears and crosses the equator and then enters the Gulf?**
- **iii) Given ii, how should respite be factored into the HSRA model?**

How does WBT relate to physiological responses?

If the recommendation is to set the welfare threshold at the transition from Panting Score 2 (PS2) to PS3 (equivalent to the transition from rapid, shallow Phase I panting to deep, slow Phase II panting), then there is evidence to suggest that a WBT of 28°C is below that transition, and that therefore the threshold should be set at a higher level.

Data obtained from sheep during live export voyages show that the average daily rumen temperature of sheep on-board a livestock vessel is predictable from the average daily ventilated WBT measured on the deck.

- The panel flagged concerns about relying on a difficult to measure outcome like core body temperature.
- Measurement of environmental WBT can provide a sufficiently reliable surrogate measure of core body temperature in sheep.

The Phase I to Phase II panting transition in sheep occurs at a rumen temperature above 41.0°C.

- Data published by Hales and Webster (1967), and cited in the McCarthy report, show that the transition from Phase I to Phase II panting occurs when the core body temperature of sheep reaches 40.7°C.
- Beatty et al. (2008) simultaneously measured core temperature and rumen temperature in sheep and found that rumen temperature was always higher than the simultaneously measured core temperature by between 0.45°C and 0.75°C.
- Therefore the Phase I to Phase II transition occurs between a rumen temperature of 41.2°C (40.7 + 0.5) and 41.4°C (40.7 + 0.7).
- Based on measures taken during live export voyages, in winter-acclimated sheep, a daily mean rumen temperature of 41°C is reached when the daily mean of the deck ventilated WBT reaches 30°C.

The panel concluded that the welfare threshold should be set at the transition from Phase I to Phase II panting (PS2 to PS3 in the measures described by McCarthy). In that light, based on the evidence above, welfare should be managed by reference to a WBT around 30°C.

How much respite do the sheep generally experience at night when a ship nears and crosses the equator and then enters the Gulf?

Data collected during livestock export show that rumen temperature increase when the deck WBT increases, and decreases when the deck WBT decreases, supporting the panel's view that respite is beneficial.

As outlined in detail below, contrary to statements in the draft report, the evidence shows that WBT on board livestock export vessels, when they are close to the equator, typically varies across a day by between 0.7 and 9.0°C, with a mean of 2.9±1.6°C.

The draft report states (P18) "*Ship environments, especially travelling around the equatorial regions, provide little diurnal respite and therefore are more challenging*".

- The original experiments, on which the panel bases its proposal for a threshold of 28°C WBT (Stockman 2006), cites several studies in support of the notion that there is no respite in board livestock vessels.
- A close look at the cited publications does not support the notion.
    - Stockman (2006) on P23 cites two MLA reports in support of the statement that "Maximum wet bulb temperature on voyages ranges from 32 to 34°C, with sheep having little or no diurnal respite from high temperatures and humidity". Later, on P99, Stockman (2006) cites Norris and Richards (2003) in support of the statement that "Wet bulb temperature on board the ships commonly reaches 30°C with little diurnal relief from these high temperatures at night".
- The two MLA reports cited by Stockman, and relied on by the panel, are based on measurements made during two voyages to the Middle East.
    - The report for Voyage 1 (MAMIC 2002) does not analyse respite, or report its magnitude, but provides a couple of plots of environmental conditions, and makes a comment about one day; "*In particular, during the highest wet bulb (day 17) there may be no overnight respite from the oppressive conditions. Some respite is seen (during daylight hours) on days 18 and 19 (Figure 2)*".
    - I have taken the plot (their Figure 2) and analysed the data based on the measured number of pixels between the maximum and minimum each day, scaled by the y-axis number of pixels for a 5°C difference.

- Several logging locations are shown, the highest of the loggers displayed was analysed (that is, the hottest measured part of the ship, in this case the blue trace on their Figure 2, Logger 1556 Deck 4 Pen 25/26).
    - The WBT increased gradually as the ship sailed north-west for the first 10 days, then plateaued. I have analysed each day from day 11 to 20, identified the minimum and maximum WBT each day, and averaged those values to arrive at the average respite that the animals experienced.
    - The average daily range of WBT for those ten days was 2.4°C.

- The other report (MAMIC 2003) makes no mention of respite, and only says that environmental conditions were monitored and shown in Figure 2 to 4 (Figure 4 reports the WBT).
    - I applied the same procedure, as explained above, to analyse days 8 to 15 of that voyage, to arrive at an average daily range of WBT of 1.8°C.

- Norris and Richards (1989) compiled and analysed data from Ship Masters reports on 181 shipments. They make no specific mention of the subject of respite, but report (P99) that "*Temperature and relative humidity measured on the ships bridge were in the range 20 to 32°C and 70 to 90% respectively in most voyages. Comparison of temperature and relative humidity with daily death rate in 13 shipments selected to include different mortality profiles suggested that these factors per se were not closely related to mortality during the voyage*".
    - They make no mention of the issue of daily respite, or of the variation in conditions across the day during a voyage.

While discussing respite on P23, Stockman (2006) also cites Bailey and Fortune (1992) regarding the highest observations of WBT.

- In that paper, Bailey and Fortune (1992) provide a figure that shows the daily maximum and minimum temperatures during feedlotting (days 1-7) and a voyage (days 8 to 13) (Figure 2 in the cited paper).
    - It does not state explicitly whether the plot shows the dry-bulb temperature or the WBT, but they do state that the RH was relatively constant at around 85%. Therefore the difference between the maximum and the minimum is indicative of both.
    - As above, the analysis was based on the number of pixels between the maximum and minimum each day, scaled by the y-axis pixels for a difference of 5°C.
    - The average difference between the maximum and minimum temperatures from days 7 to 13 was 3.4°C.

Therefore, it has to be concluded that the references cited to support the notion that there is no respite on board livestock vessels either say nothing on the subject, or present data that shows that respite does exist, with an average value above 2°C (2.4, 1.8, and 3.4°C WBT).

The issue of respite is important to any setting of a welfare threshold that is based on either panting score or core temperature responses to WBT, because on P26 the draft report, the authors state; "*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*".

Given the uncertainty, I have analysed WBT data that were recorded every 15-minutes on occupied decks during 36 voyages from Fremantle to the Gulf region (between 4 and 11 voyages for each of five vessels).

The general pattern of WBT, measured using thirteen calibrated data loggers placed onto multiple decks of those 36 voyages, was quite uniform, with a gradual increase as the vessel sailed north-west from Fremantle across the Indian Ocean, and plateaued as the vessel neared and then crossed the Equator and entered the Gulf.

For each of the 36 voyages, data from that day that the WBT plateaued as the vessel neared the equator (usually around sailing day 6) to when the vessel reached the Gulf were analysed. Data were analysed from 375 days.

- On each vessel, for each 15-min, the highest recorded WBT from the 13 loggers (that is, the hottest part of the two decks) was used for analysis.
- For each 24-h day I calculated the mean daily WBT and the minimum and maximum WBT, and from those the daily range of WBT (maximum minus minimum).

There was no relationship between the mean-daily WBT and the range of WBT on the same day (R^2 = 0.02, n = 375, P = 0.67), that is, the mean daily range was independent of the daily mean WBT.

- The range across a day varied from 0.7 to 9.0°C, with a mean of 2.9±1.6°C. The distribution of the daily range is shown Figure 1. The most common range of variation was between 2.0 to 2.49°C.
- Thus it has to be concluded that, on average, sheep on board livestock export vessels near the equator receive 2.0 to 3.0°C WBT of respite in an average 24-h day.
- That value is consistent with the data mentioned above, from the publications by MAMIC (2002, 2003) and Bailey and Fortune (1992).

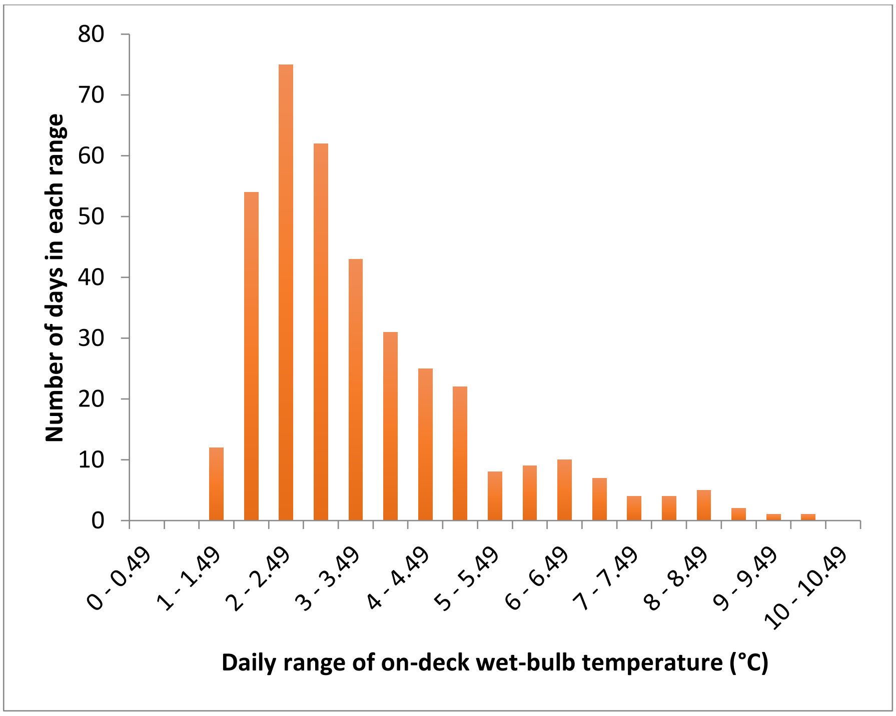

Figure 1. The distribution of the daily range of WBT on the decks of live export vessels on 375 days during 36 voyages, illustrating the extent of daily respite.

Given that the experiments on which the proposed 28°C threshold is based (Stockman 2006), were conducted with a constant WBT, and therefore no respite, but that the evidence suggests that during actual voyages 2 to 3°C WBT of respite is the norm, a question has to arise of how indicative were the climate room experiments of what occurs on-board a livestock vessel?

- Given that the threshold is based on HST2 (an increase in core temperature of 0.5°C), it is likely that the same increase in core temperature would not have been observed in the climate room experiments if the WBT had been varied 2 to 3°C on a 12-h cycle?

- The difference could help to explain the difference between the climate-room experiments and the measured rumen temperature in sheep during actual voyages.

The draft report suggests that 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" (Page 19).

The thinking is qualitatively similar to the reasoning in the paper cited in the report (Mitchell et al. 2018), which delineates zones for animal responses to various stressors, including thermal stress. The zones are referred to (each previous zone is contained within the subsequent zone), the thermoneutral zone, the prescriptive zone, the tolerance zone, and the survival zone.

The top end of the thermoneutral zone is where an animal can maintain its core body temperature without resorting to extra evaporative water loss.

- Contrary to what the draft reports states, an animal is always losing some heat by evaporation, even below the thermoneutral zone.
- Above the thermoneutral zone and within the prescriptive zone, an animal can maintain a constant core body temperature but uses physiological mechanisms to achieve heat balance. In the case of sheep exposed to conditions above the thermoneutral zone, those mechanisms include panting, sweating, and a redistribution of blood flow to the periphery.
- Within the prescriptive zone a sheep will use those mechanisms to maintain heat balance and therefore to maintain a constant core body temperature.

When a sheep cannot achieve heat balance at the same core body temperature as is maintained within the thermoneutral and prescriptive zones, it is by definition outside of its prescriptive zone, and enters the tolerance zone.

- Within the tolerance zone, an animal has an elevated core body temperature.
- As stated in the cited review by Mitchell et al. (2018) "Although some body functions may be compromised, the survival of an individual animal is not threatened because stable hypothermia and hyperthermia are not lethal".
- Arguably, the animal is using its standard physiological responses to thermoregulate in a manner that those mechanisms have been selected, by evolution, to achieve.
- The compromised "bodily functions" that the authors refer to are functions such as reproduction. It is arguable whether a decrease in reproductive function is a welfare issue.

Above the tolerance zone, in the survival zone, the survival of an individual is at risk; the physiological heat defence mechanisms that the animal has are insufficient to respond to the imposed stressor, and in the case of exposure to heat, heat stroke is likely. Evidence is limited on which to base judgments about how long an animal can avoid pathological changes in body systems once it is within the survival zone, but it is clear that exposure to conditions in the survival zone is not immediately pathological.

With regard to defining safe thermal limits, on P10 of their review, Mitchell et al. (2018) state that, "If it is the welfare of individual animals that are of concern, then it should be the lower and upper ends of the tolerance zone".

Exactly where the upper limit of the tolerance zone is for sheep unknown.

- The panel chose to use a readily observed measure of the response to heat, that is, the panting score. That panting score will be indicative of a physiological response to heat that does not compromise the individual animal.

- In using a mortality limit to determine risk, the initial incarnation of the HSRA attempted to define the survival zone for sheep.

By using HST2 (an increase in core body temperature of 0.5°C) to define an acceptable welfare limit, the panel acknowledge that welfare is not compromised when a sheep moves from the prescriptive zone to the tolerance zone.

The issue at hand is where, within the tolerance zone, should the focus be on limiting physiological impact and managing welfare outcomes?

The panel's view is that some sheep exhibiting PS3 is tolerable, but that welfare issues arise if PS3 is maintained without respite.

- Given that 2.0 to 3.0°C of daily respite generally occurs during a live export voyage (Figure 1), and that the HSRA HotStuff model uses a 12-h window to generate its assessment, it seems logical to create a welfare threshold that stipulates that the animals will be classified as heat stressed if they are exposed to multiple 12-h windows of conditions that exceed an acceptable limit.
- For example, that could be at least two nights in a row, when WBT exceeds the threshold for Phase II panting without respite.

The schematic immediately following illustrates this approach (Figure 2) assuming a threshold of 30°C, rather than the panel's recommended 28°C.

- Green coding indicates a combination of WBT and time that presents no adverse welfare outcomes
- Orange coding indicates a combination of WBT and time that begins to present adverse welfare outcomes
- Red coding indicates a combination of WBT and time that presents adverse welfare outcomes

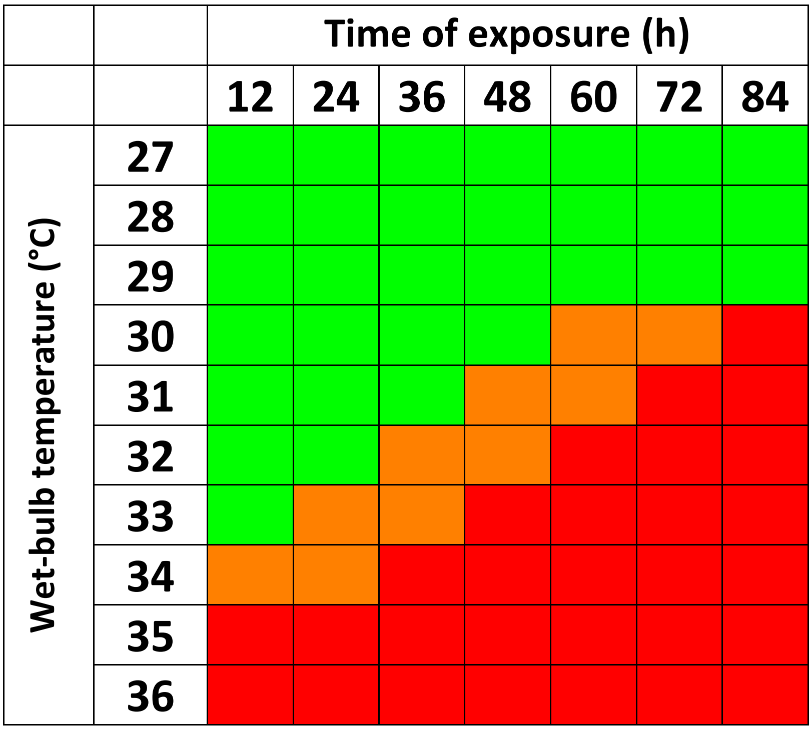

Figure 2. Schematic for a welfare threshold based on the environmental conditions (WBT) that result in Phase II panting (30°C) and the number of 12-h windows that the exposure is maintained

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February 2019

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Appendix B: Charts of temperature variations for latitudes 0 to 5°

This Appendix contains twelve charts showing wet bulb temperature variations recorded at latitudes 0 to 5° on vessels in the Indian Ocean on routes typically taken by live export vessels – one chart for each month of the year.

The following process has been used to derive data used to construct the charts contained in this Appendix:

- From VOS data voyages were identified containing wet bulb temperature recordings at latitude / longitude points matching routes typically taken by live export vessels traveling from Australia to the Middle East.
- For each voyage identified above, the maximum wet bulb temperature for each day was identified.
- For each maximum wet bulb temperature identified a minimum wet bulb temperature was also identified. This represented:
  - the minimum temperature recorded on the same day as the identified maximum temperature; or
  - the minimum temperature for the following day (assuming the maximum wet bulb temperature occurs mid-afternoon and the minimum wet bulb temperature occurs early hours of the morning);

  whichever is the less.
- Once 24-hour maximum and minimum wet bulb temperatures were linked for each day of each voyage, recordings were grouped within latitude bands. Although a series of charts exist, one set of 12 for each 5° latitude band from -25° to +20°, only the set of charts relating to latitudes 0 to 5° is shown in this appendix.

In the charts that follow for the latitude band 0 to 5° maximum recorded wet bulb temperatures and the next-24-hour minimum wet bulb temperature are plotted. Also shown on these charts are the 27.8 lines on both axes and the 98th percentile of maximum wet bulb temperatures.

If no difference existed between maximum and minimum temperatures all the plots would lie on a diagonal straight line. The fact that plots do not generally lie on a diagonal straight line indicates that even at latitudes 0 to 5° diurnal variations in temperatures exist.

Chart B1: 24 hour maximum and minimum wet bulb temperatures - latitude 0 to 5°, January

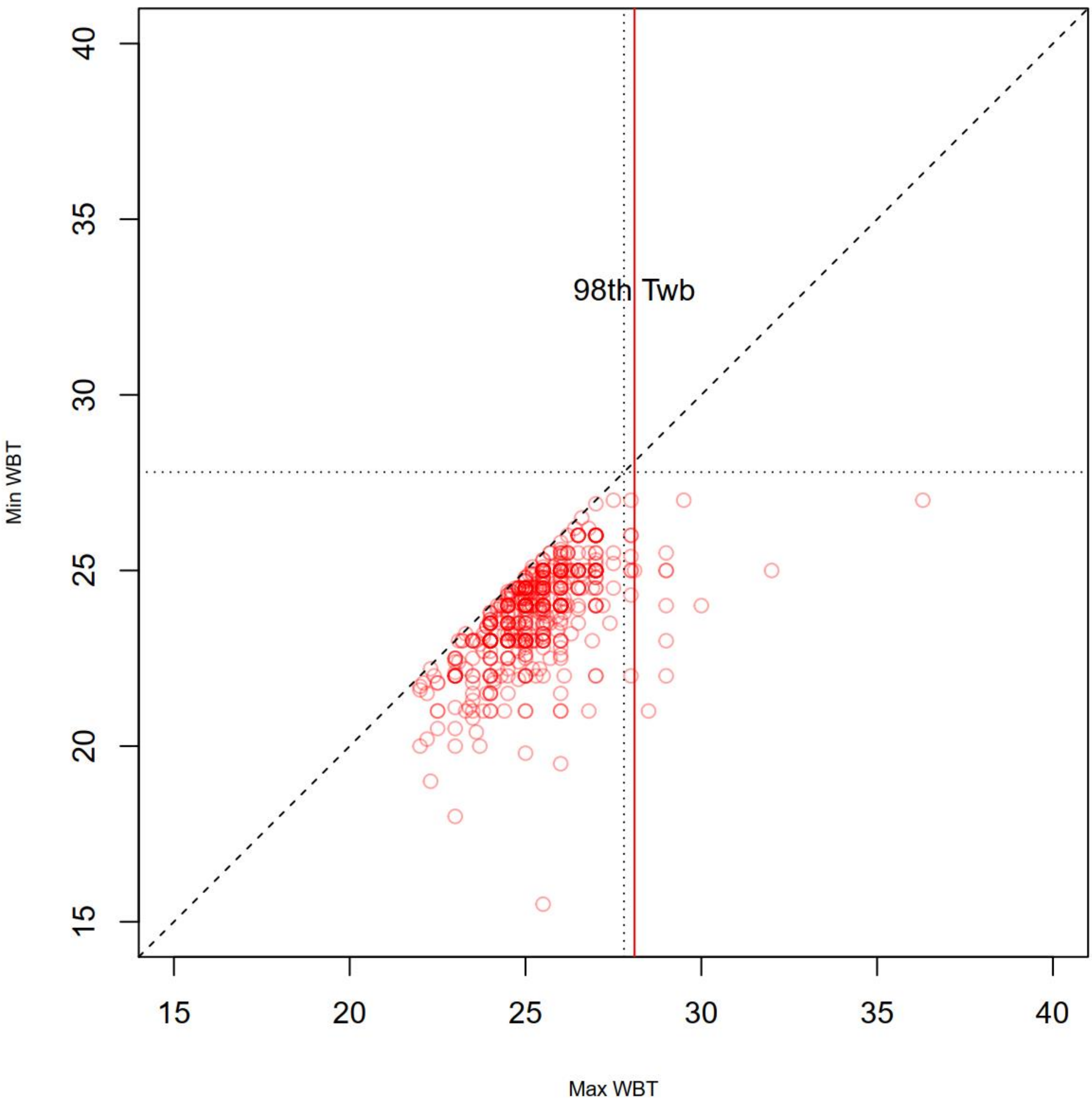

Chart B2: 24 hour maximum and minimum wet bulb temperatures - latitude 0 to 5°, February

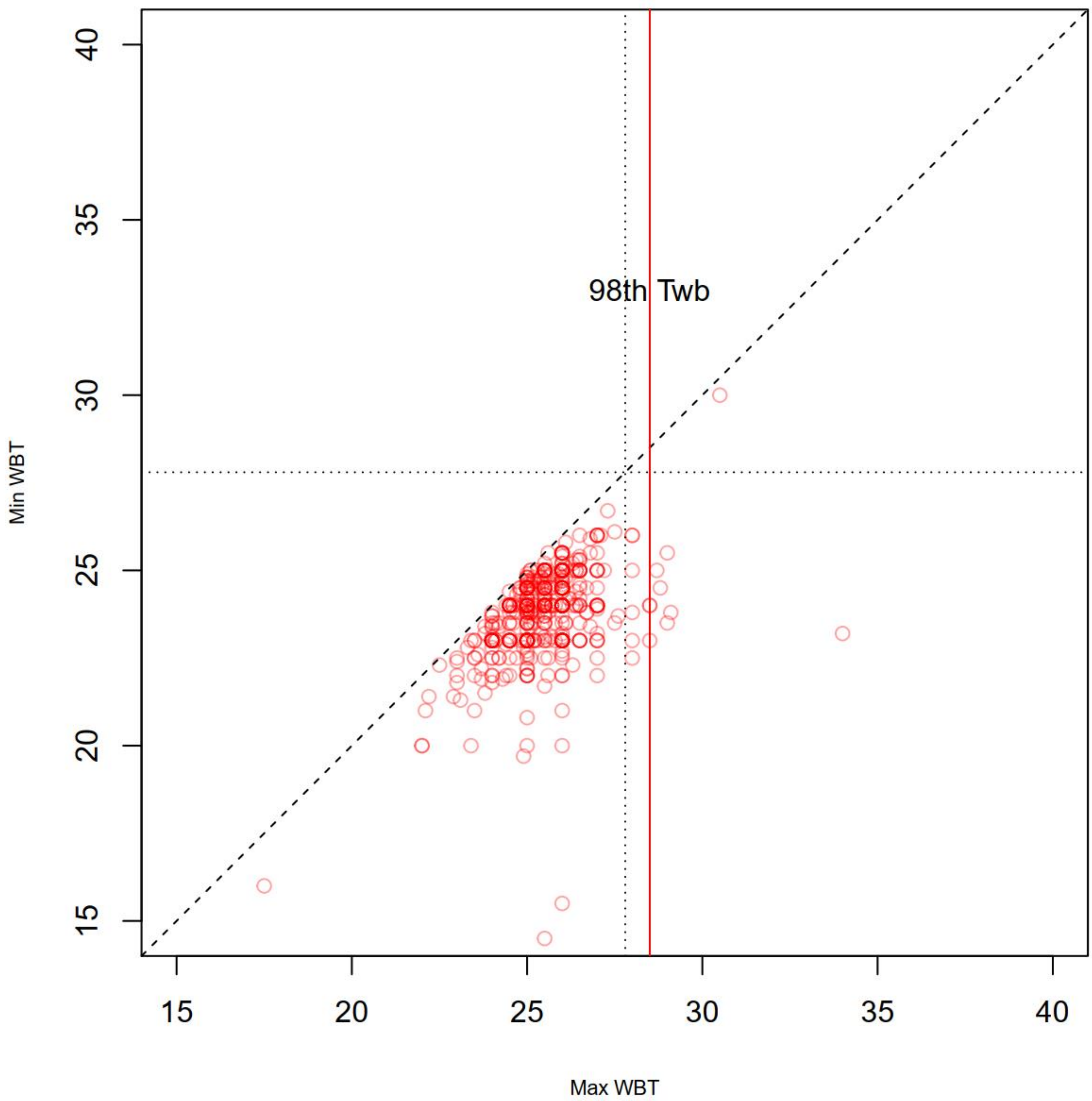

Chart B3: 24 hour maximum and minimum wet bulb temperatures - latitude 0 to 5°, March

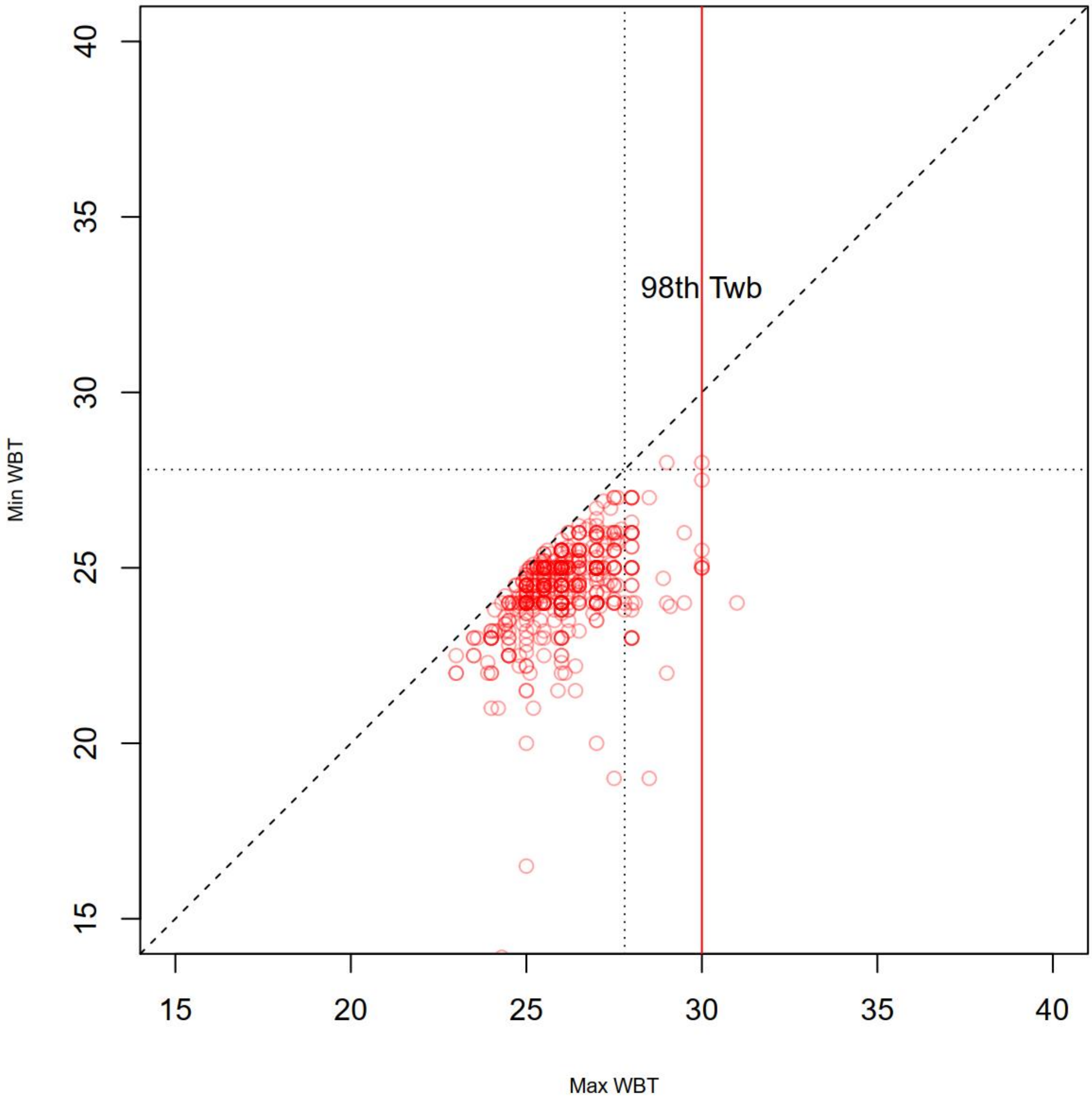

Chart B4: 24 hour maximum and minimum wet bulb temperatures - latitude 0 to 5°, April

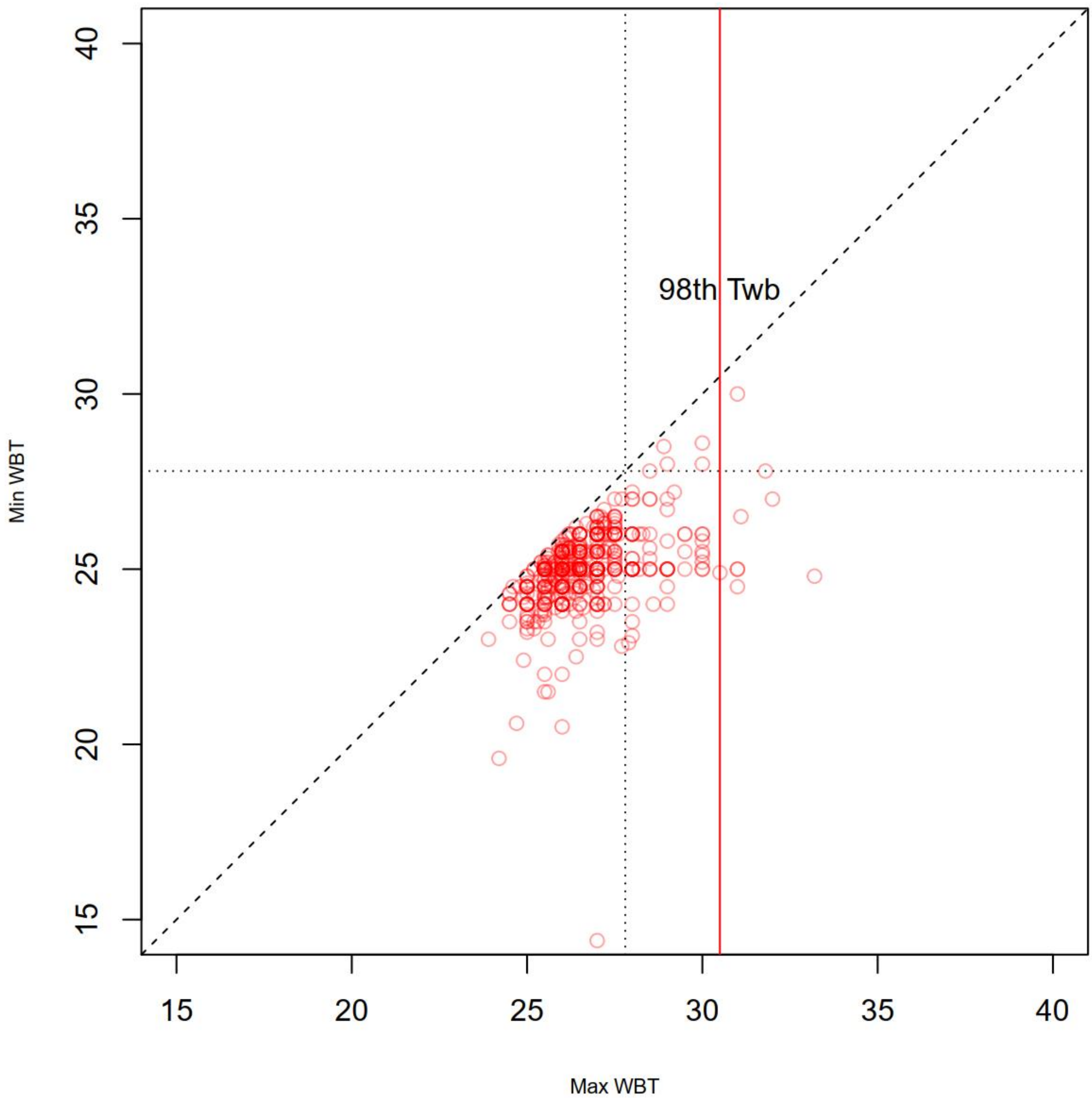

Chart B5: 24 hour maximum and minimum wet bulb temperatures - latitude 0 to 5°, May

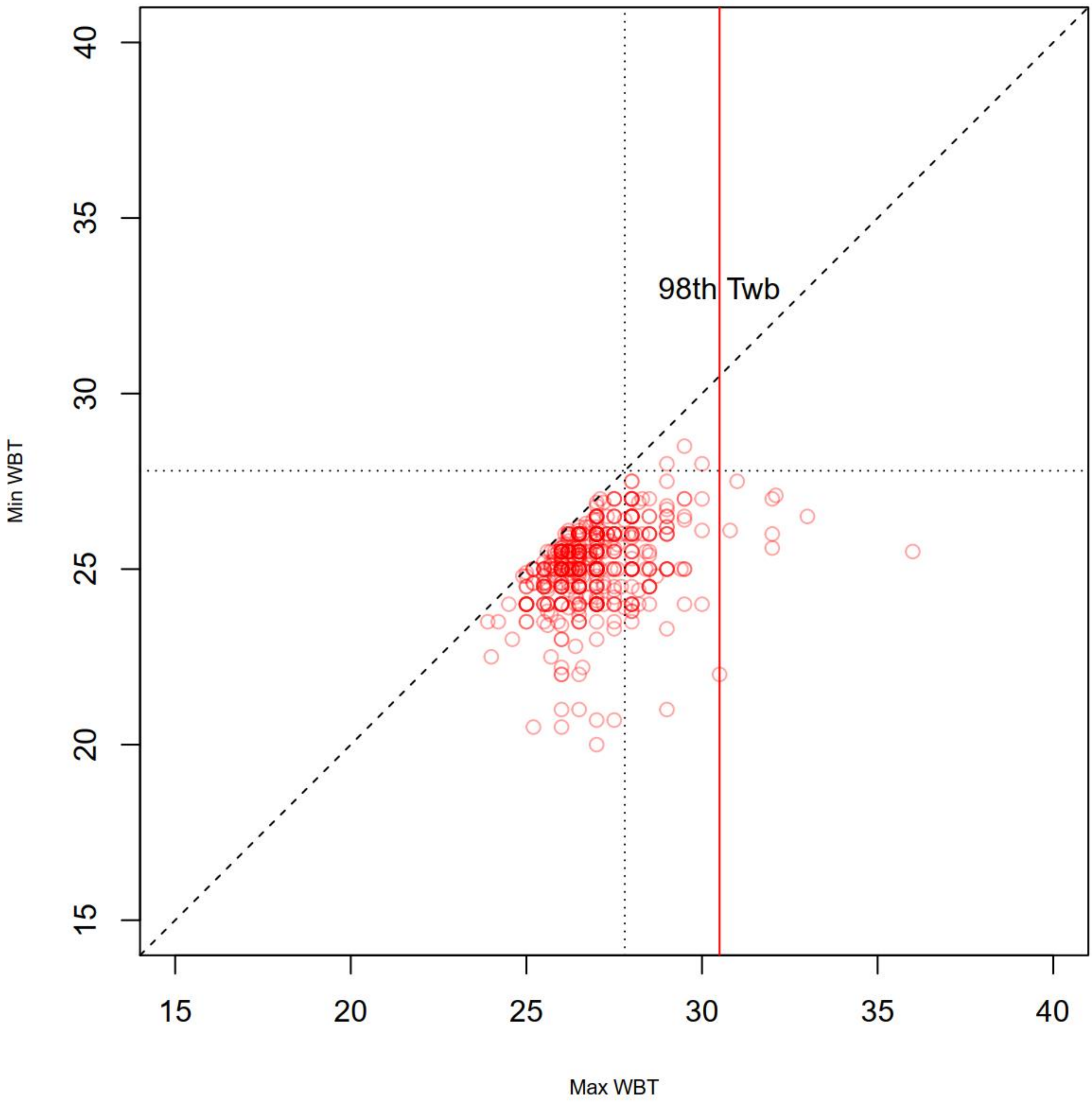

Chart B6: 24 hour maximum and minimum wet bulb temperatures - latitude 0 to 5°, June

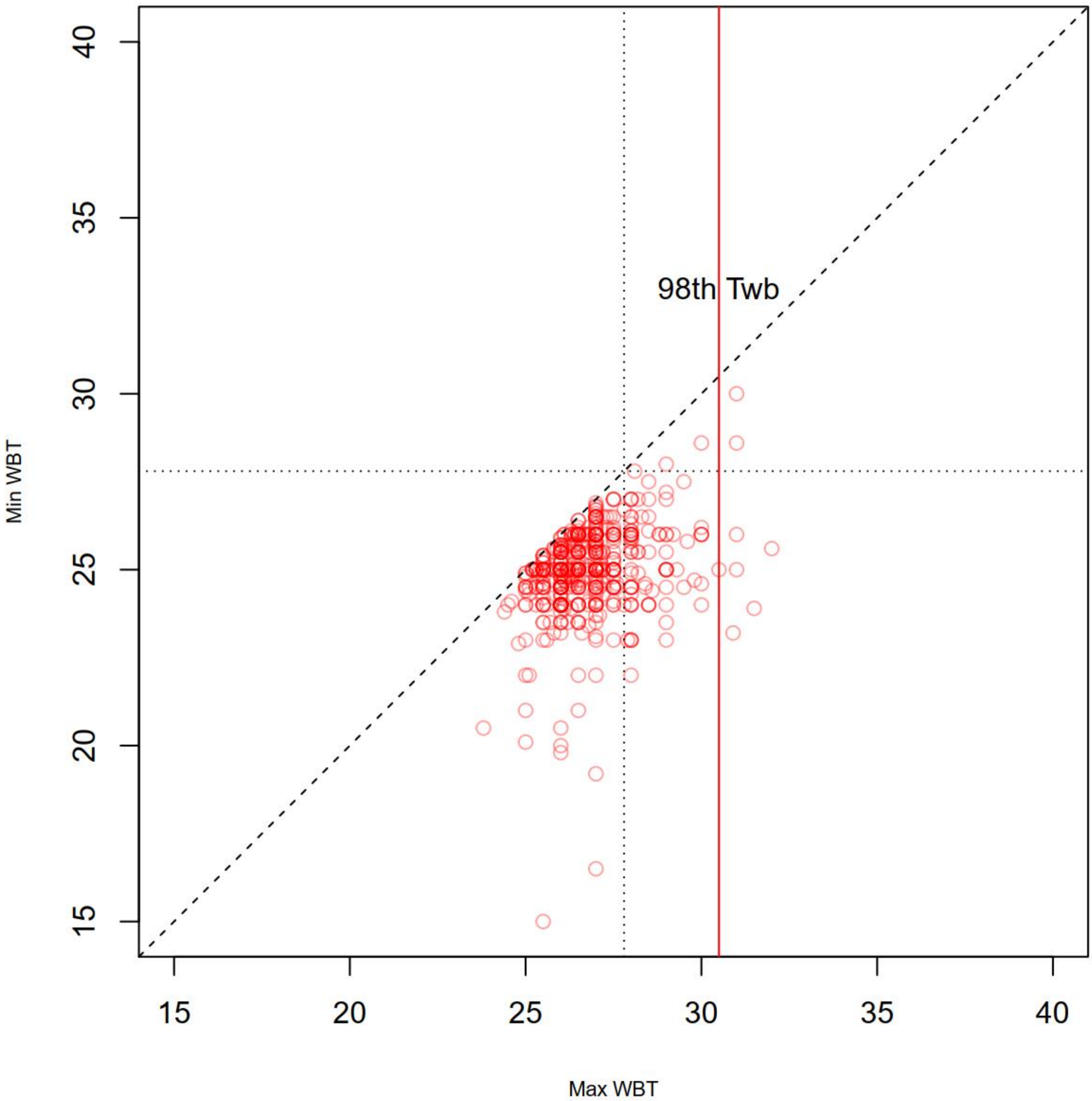

Chart B7: 24 hour maximum and minimum wet bulb temperatures - latitude 0 to 5°, July

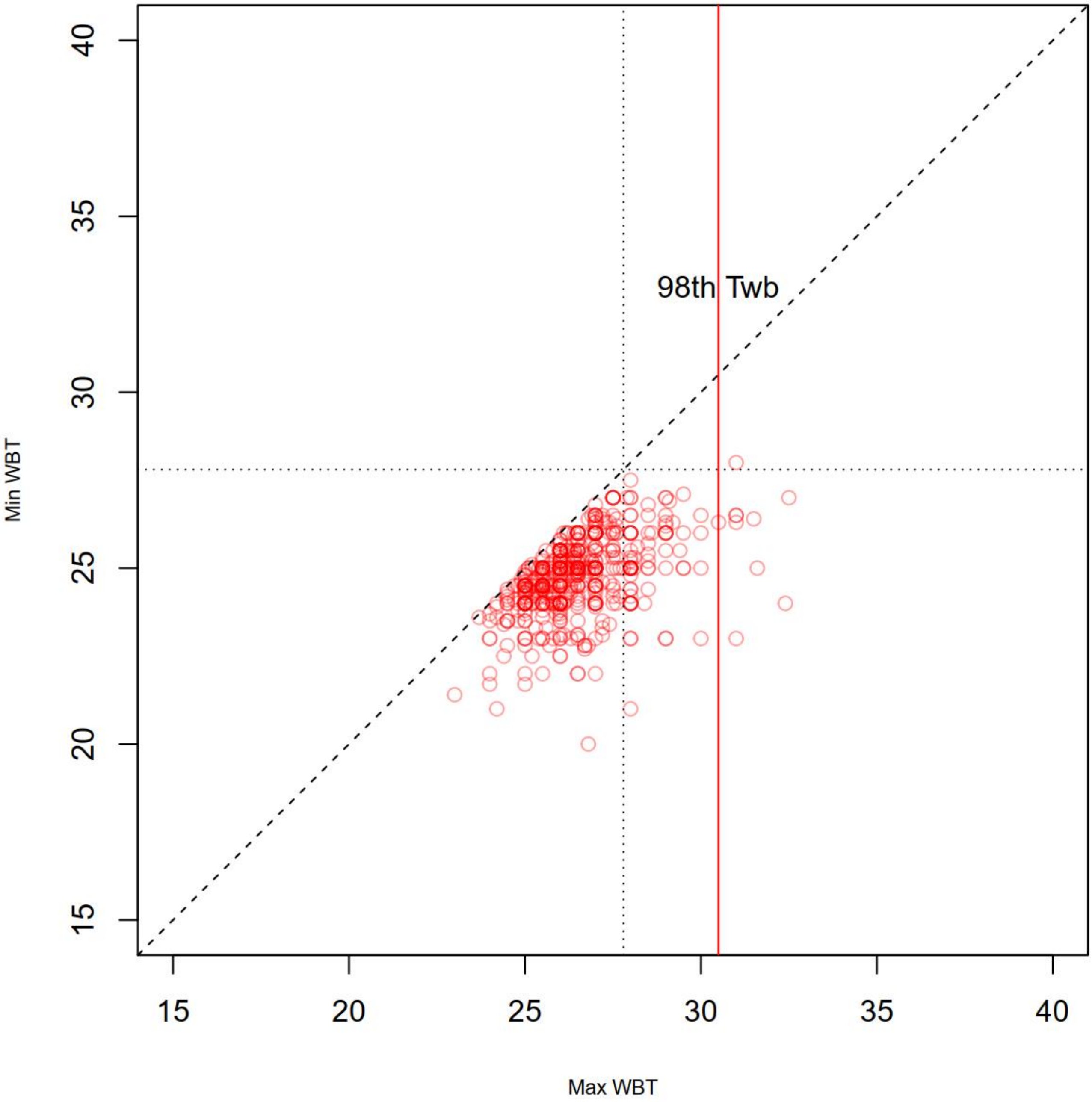

Chart B8: 24 hour maximum and minimum wet bulb temperatures - latitude 0 to 5°, August

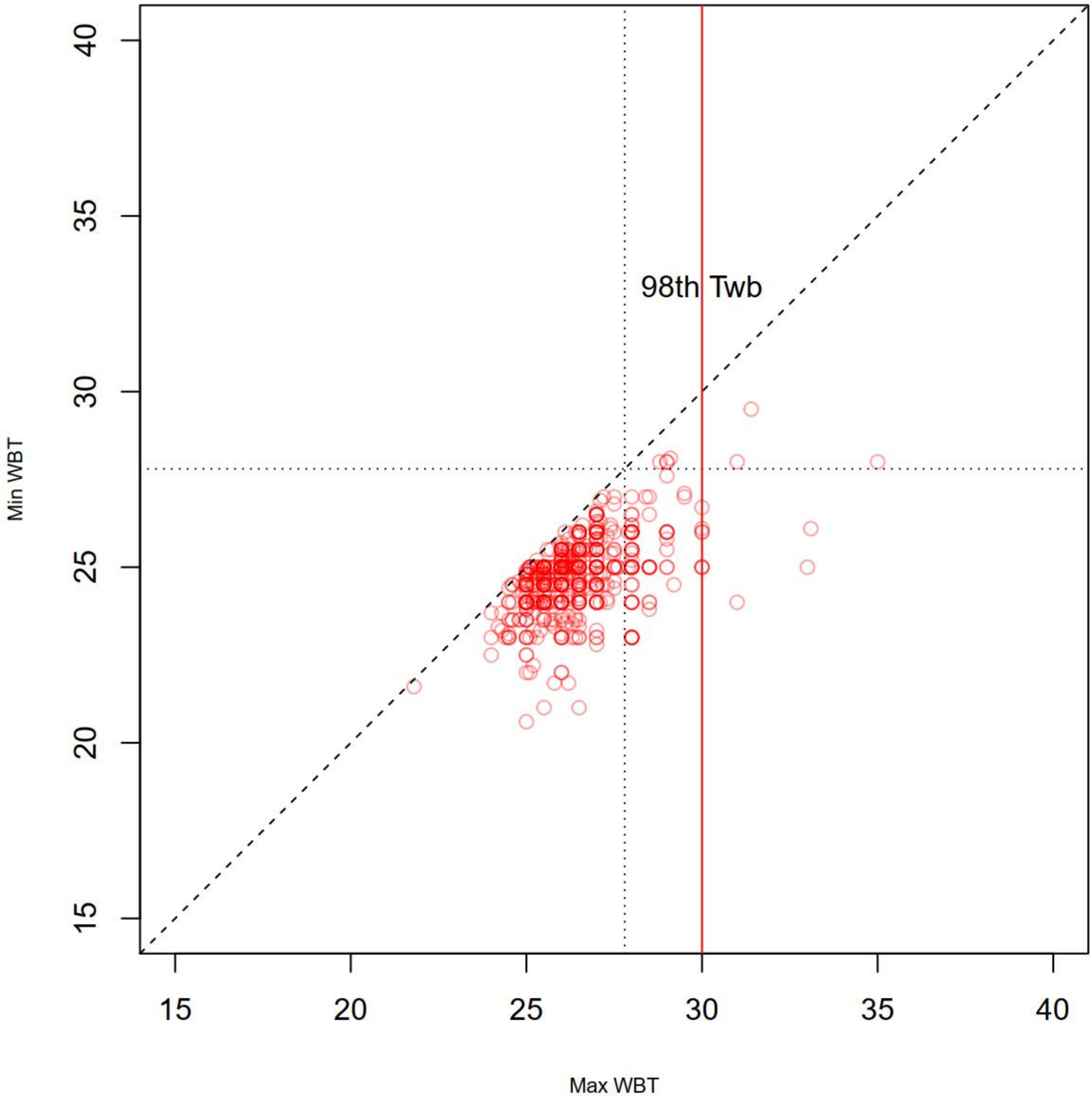

Chart B9: 24 hour maximum and minimum wet bulb temperatures - latitude 0 to 5°, September

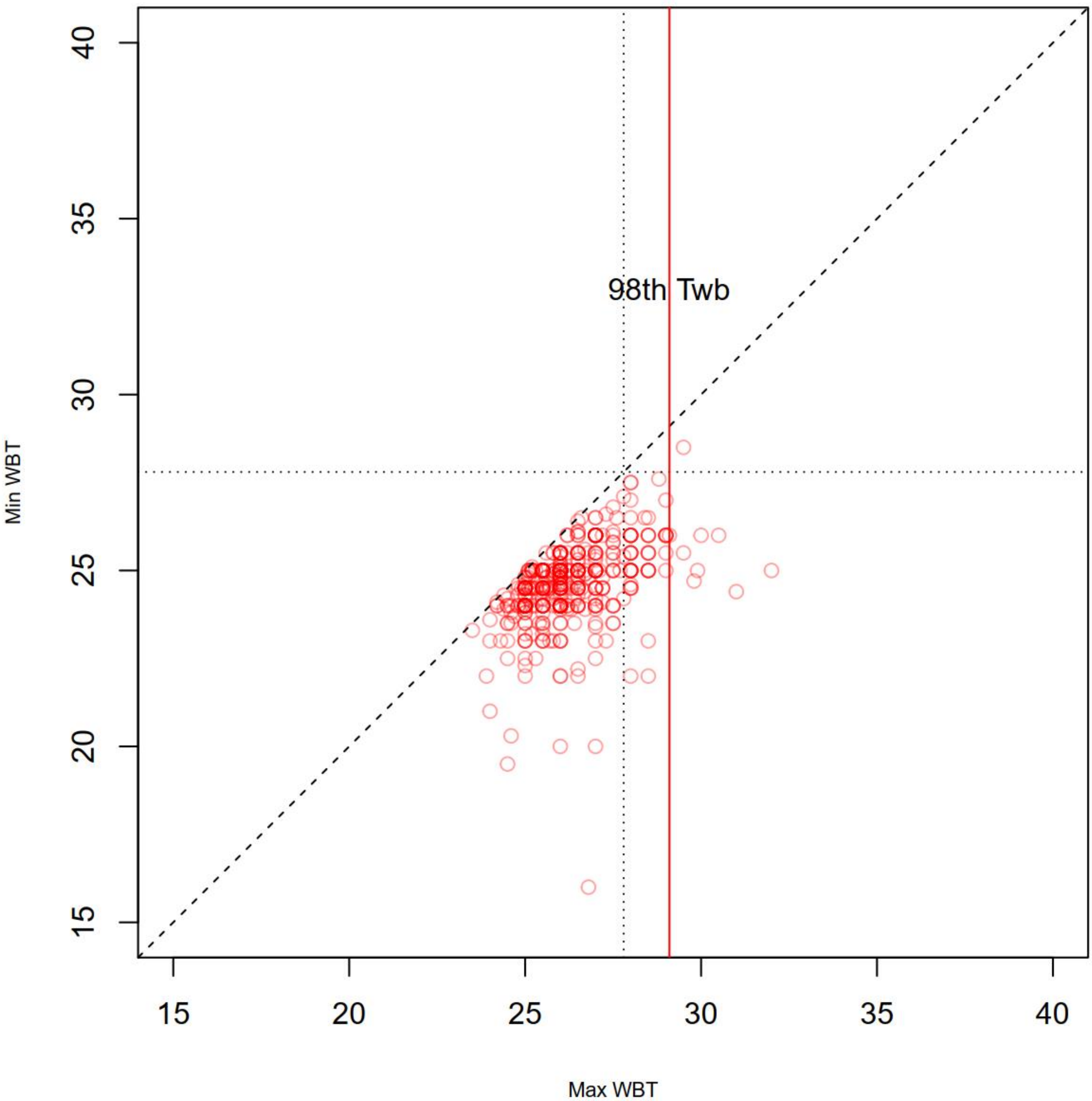

Chart B10: 24 hour maximum and minimum wet bulb temperatures - latitude 0 to 5°, October

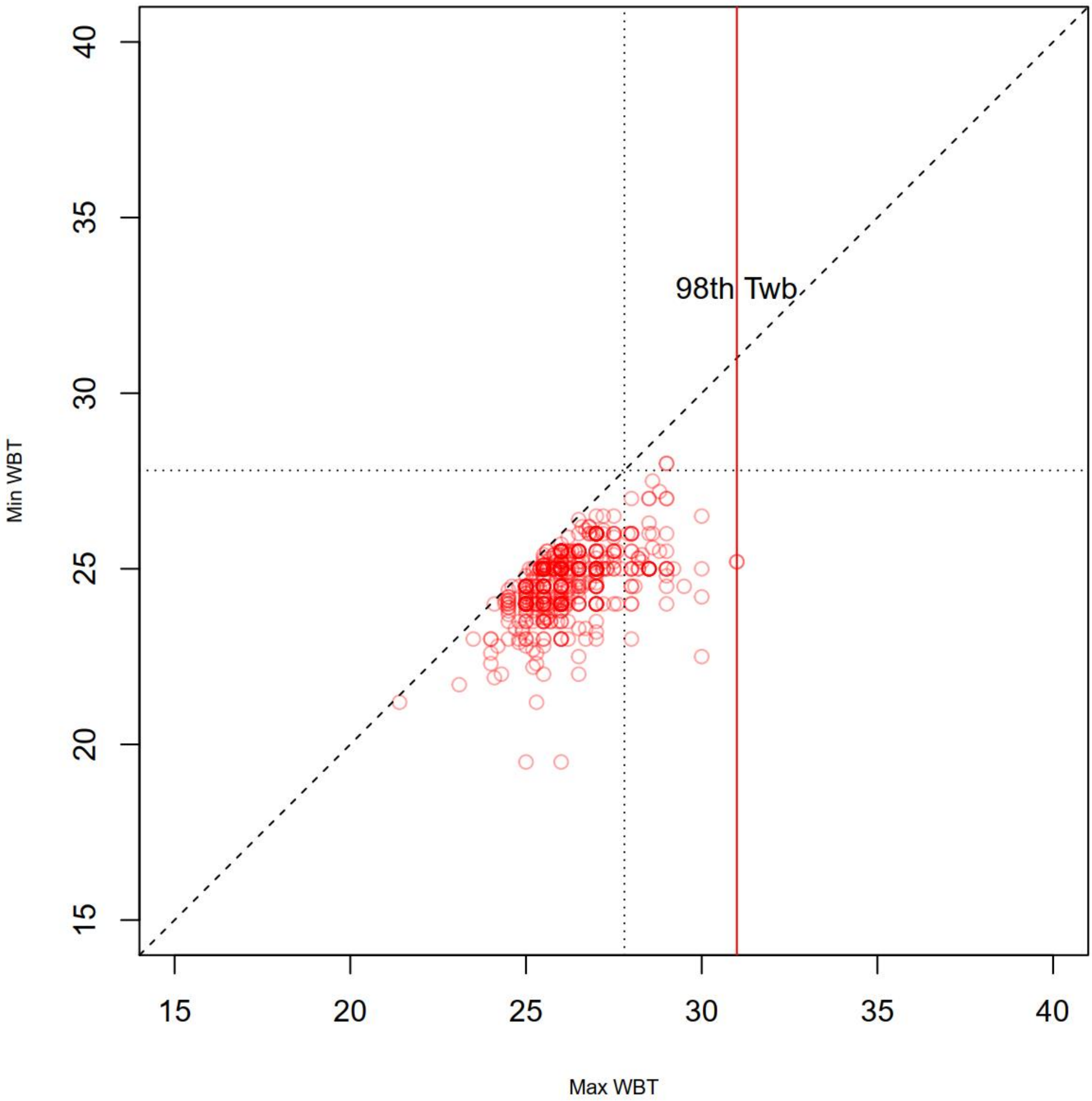

Chart B11: 24 hour maximum and minimum wet bulb temperatures - latitude 0 to 5°, November

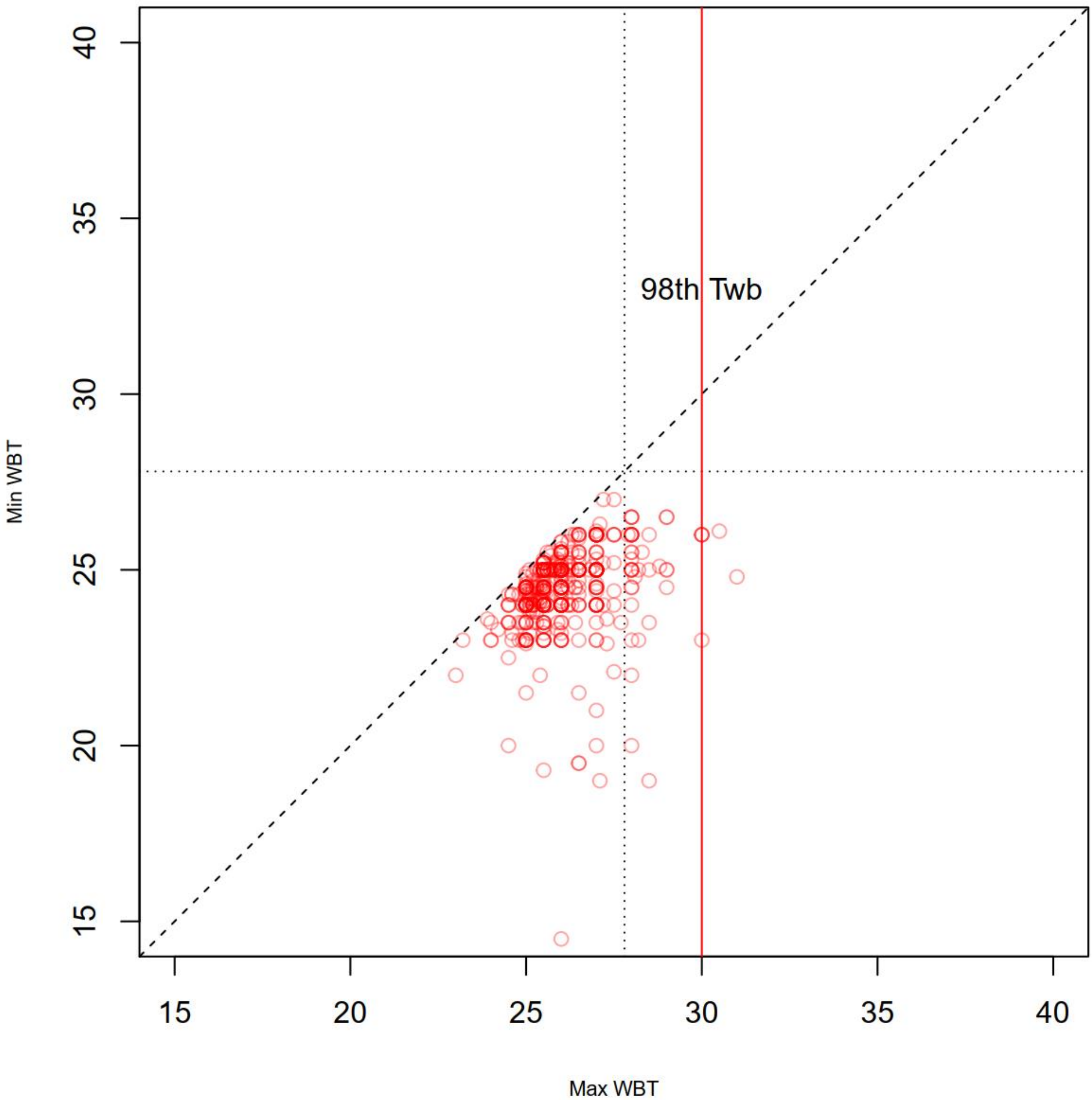

Chart B12: 24 hour maximum and minimum wet bulb temperatures - latitude 0 to 5°, December