Heat Stress Risk Assessment Issues Paper

VALE Submission

October 2018

VETS AGAINST LIVE EXPORT

C/- LADY BARRON POST OFFICE, FLINDERS ISLAND, TAS 7255

INFO@VALE.ORG.AU

Technical Advisory Committee
C/- Department of Agriculture and Water Resources
GPO Box 858
CANBERRA ACT 2601

Dear Committee,

Thank you for the opportunity to make a submission to the **Heat stress Risk Assessment Issues Paper**

Vets Against Live Exports (VALE) was established in 2011. It currently has over 200 members. Since its establishment, VALE has sought to provide informed and factual comment on the live export industry, especially with respect to heat stress.

VALE published a significant peer-reviewed scientific paper on heat stress (Caulfield et al. Heat stress: A major contributor to poor animal welfare associated with long haul live export voyages. *The Veterinary Journal* 2014;199:223-228). With more voyage reports being available since that publication, VALE's understanding of the science and its correlation with shipboard conditions has continued to advance.

Heat stress remains one of VALE's most significant concerns regarding the live export of both sheep and cattle. We welcome the opportunity to comment on this critical issue in sheep being transported to the Middle East as per the Issues Paper. We have confined our comments to the Middle East sheep trade as per the Issues Paper but believe that heat stress risks should be reassessed for both sheep and cattle exported to any location at any time of the year.

Yours sincerely

Dr Sue Foster BVSc MVetClinStud FANZCVS
VALE Spokesperson
[redacted]

TABLE OF CONTENTS

1. VALE'S HEAT STRESS RISK ASSESSMENT

1.1 Heat Stress Risk in Exported Sheep and Cattle

Heat stress has been reported as a major factor causing poor animal welfare and high mortalities on live export voyages (Caulfield et al 2014). Two government reviews of the live export industry have also highlighted heat stress as a significant issue (Keniry 2004, Farmer 2011). Experimental studies (Beatty 2005, Stockman 2006) have been performed under optimal conditions (ie healthy sheep and cattle, on land, with greater than shipboard space allowances and individual pens). The findings of these studies, including the established "heat stress thresholds" (HSTs) have never been incorporated appropriately into welfare and risk assessments, such as the heat stress risk assessment (HSRA) model, Hotstuff. Further, the government definition of HST for sheep and cattle respectively has been set at wet bulb temperatures (WBTs) higher than those demonstrated to cause significant heat stress in experimental animals in optimal conditions (Beatty 2005, Beatty et al 2006, Stockman 2006, Stockman et al 2011).

Despite the HSRA, high mortality incidents due to heat stress continue to occur on a near annual basis. The frequency of these does not appear to have substantially changed since the inception of Hotstuff. Hotstuff is only designed to limit the probability (<2%) of a very extreme mortality event (>5% mortality). It was never designed to prevent heat stress per se.

In addition, National Livestock Export Shipboard Performance Reports published by the government (eg Norman 2017) have consistently demonstrated much higher mortality in animals, particularly sheep, transported from the Australian winter to the Middle Eastern summer but also cattle from Northern Australia during "the wet season". It is very likely that the increased mortality rates are directly or indirectly due to heat stress regardless of whether a high mortality incident is registered.

1.2 Analysis of Shipboard Reports for Middle East Voyages

Most of the voyage information available to the public is from voyage reports from high mortality voyages, obtained under the *Freedom of Information Act* (1982). There has been a consistent pattern of high mortality events in the Middle East. Since 2009, each high mortality voyage to the Middle East has occurred in a peak heat period: August 2009, June 2010, July 2010, August 2010, June 2011, September 2013, July 2016 and August 2017. Thus, 8/8 Middle East high mortality voyages in 8 years occurred in the "northern summer period".

Of concern with respect to animal welfare is that the few available reports of voyages in which the ASEL mortality limit of 2% was not exceeded indicate that animals experience heat stress during typical voyages but do not necessarily die (Maunsell Australia 2003; Voyage Reports[1]). VALE analysed two routine mortality voyages from 2017 on the Al Shuwaikh[2] which can be summarised as follows:

[1] See: http://www.vale.org.au/high-mortality-voyages.html Two Routine Voyages. Accessed 12 October 2018

[2] See: http://www.vale.org.au/high-mortality-voyages.html. Two Routine Voyages (accessed 12 October 2018)

1. Fremantle to Kuwait, Hamad, Jebel Ali, Muscat 23.9.17: 0.84% sheep mortality. Sheep panting from Day 5-6 to Day 24 (19-20 consecutive days) due to WBT equalling or exceeding the experimentally established HST for these sheep classes (Stockman 2006) for all but two of those 19-20 days. There was no mention of heat stress in the report.
2. Fremantle to Jebel Ali, Kuwait, Hamad, Muscat 11.11.17: 0.84% sheep mortality. Sheep panting from Day 5-20 (16 consecutive days). No mention of heat stress in the report. This voyage was not in the northern summer period.

Likewise, on a voyage through the Middle East in 2011, a cattle consignment with acceptable mortality had respiratory rates in excess of 70 bpm for 19 consecutive days with respiratory character scored as normal throughout.[3] Heat stress was only recorded on three of those days, in each case being classified as mild despite average respiratory rates for cattle on most decks being 90-95 bpm.

It is likely that heat stress is under-recorded on the voyage reports. Careful scrutiny and analysis of all voyage reports using appropriate HSTs as established by Stockman (2006) would demonstrate just how many "routine" sheep voyages to the Middle East are affected by mild to severe heat stress (HST 1-3 as defined by Stockman for both winter- and summer-acclimatised Merino sheep). Similar analysis should be performed for cattle voyages, especially for *Bos taurus* cattle.

1.3 Heat Stress Thresholds

As indicated in the Issues Paper 2018, the HSRA modelling is performed using the defined mortality limits and not using HSTs. Thus the only parameter used for modelling has been risk of death and not risk of poor animal welfare. The HSRA model was developed by the industry to assess heat stress risk and has never been independently validated or assessed against industry performance (namely the desired reduction in extreme mortality events). A recommendation for revision of the current model and space allowances was made as far back as 2011 (High Mortality Investigation Report 38)[4] but this did not occur. The HSRA is now being revised because the public were made aware of what heat stress actually looks like via shipboard footage shown on 60 Minutes in April 2018.[5] The McCarthy review made the recommendation that the heat stress risk assessment be changed from a <2% chance of >5% mortality to <2% chance of >5% sheep being affected by heat stress.

In the Department's[6] high mortality investigation reports, HST is defined as the maximum ambient wet bulb temperature at which the heat balance of the deep body temperature can be controlled using available mechanisms of heat loss. The Mortality Limit (ML) is defined as the wet bulb temperature at which animals will die.

Between 2006 and 2018, the defined HSTs and MLs for live export voyages have remained

[3] See: http://www.vale.org.au/high-mortality-voyages.html. Voyage 39 (FOI 2011/12-52) (accessed 12 October 2018)
[4] See: hthttp://www.vale.org.au/high-mortality-voyages.html Voyage 38 (accessed 12 October 2018)
[5] See: https://www.9now.com.au/60-minutes/2018/extras/latest/april/liam-bartlett-sheep-ships-and-videotape (accessed 12 October 2018)
[6] The term Department has been used to indicate the Department of Agriculture. The name of this department has changed on multiple occasions between 2006 and 2018 eg AQIS, DAFF, DAWR

unchanged:
Standard Merino sheep: HST 30.6ºC; ML 35.5ºC
[Adult *Bos taurus* beef cattle: HST 30ºC; ML 33.2ºC
Adult *Bos indicus* cattle: HST 32.5ºC; ML 36ºC]

These figures were purportedly based on a 2003 industry publication (Maunsell 2003). Key points in that document include the following direct quotes:

- The HST of *Bos taurus* animals lies between 28 ºC and 30ºC
- The HST of *Bos indicus* animals is probably greater than 32ºC wet bulb, but will reduce to this level if heat exposure is prolonged
- During voyage 1[7], the UCwbT [defined in the document as HST] for *adult sheep* varied between 28 ºC and 30ºC
- During voyage 2[8], this parameter was estimated to lie between 26ºC and 30ºC, with the lower end of this range possibly being extended by animals that were compromised for other reasons (including disease)
- For *young sheep*, the UCwbT [HST] may be lower

It is concerning that despite these key points, the Department's HSTs for sheep and *Bos taurus* cattle were set at the upper limit or higher than HSTs supported by available data in 2003 (Maunsell 2003). It would appear to be more than an interesting coincidence that the HST for sheep was set 0.1ºC higher than the upper average shipboard WBT from 181 voyages from Australia to the Middle East (Norris and Richards 1989). On board WBT in that paper was reported as averaging between 16.4ºC and 30.5ºC. It seems plausible that the HST of 30.6ºC was not chosen on science or animal welfare grounds but rather on the upper limit of expected mean shipboard WBTs.

Even more concerning is that the HSTs from 2003 have never been revised despite industry-funded, studies on heat stress in sheep and cattle (Beatty 2005; Stockman 2006; Beatty et al 2006; Stockman et al 2011).

The PhD thesis of Catherine Ann Stockman (2006) is the most comprehensive experimental study of heat stress in sheep in simulated live export conditions. As such, it should be the key document used for HST determination. Chapters 3 and 4 describe experiments that simulate some of the conditions experienced by sheep on ships travelling to the Middle East. The study in Chapter 3 details an experiment performed on summer-acclimatised Merino and Awassi sheep. The study in Chapter 4 details an experiment performed on different classes of winter-acclimatised Merino sheep. In the experimental studies for this thesis, animals were housed individually in pens, with free access to feed and water, in rooms with good ventilation. The space allowances were greater than those prescribed under ASEL v 2.3. The heat stress thresholds were designated as HST 1 (the temperature at which the daily mean wet bulb temperature significantly increased above pre-heat values), HST 2 (the daily mean wet bulb temperature on the day that daily mean core body increased 0.5ºC above pre-heat

[7] Voyage data is from two voyages used to study investigate the effect of ventilation on heat stress in sheep during long-haul voyages to the Middle East. Voyage 1 was conducted during June/July 2002.
[8] Voyage data is from two voyages used to study investigate the effect of ventilation on heat stress in sheep during long-haul voyages to the Middle East. Voyage 2 was conducted during September 2002.

values) and HST 3 (the daily mean wet bulb temperature on the day that daily mean core body temperature first increased 1ºC above pre-heat values). For winter-acclimatised sheep (ie modeling for the situation that occurs transporting sheep from Australia to a northern summer), the relevant HSTs were recorded in Table 4.3 of the thesis. These can be summarised as follows:

Adult merino wethers: HST1 25ºC; HST 2 28ºC; HST 3 28ºC
Merino Ram lambs: HST 1 25ºC; HST 2 26ºC; HST 3 27ºC;
Adult merino rams HST 1 25ºC; HST 2 28ºC; HST 3 29ºC.

HST1 (25ºC in winter-acclimatised sheep) best fits the Department's definition of HST, namely, the wet bulb temperature at which core temperature can no longer be controlled by available mechanisms of heat loss. This HST is appropriate for all three classes of Merino sheep studied and should be regarded as "incipient heat stress" (Stacey 2018 as cited in The Issues Paper 2018). It is evident from the study that once HST 2 and HST 3 are attained, substantial alterations to core temperature have taken place.

These HSTs, scientifically demonstrated in best-case scenarios, are all lower than those currently used by the Department in analysing high mortality voyages. On live export voyages, space allocations are less, the stocking density is higher and the ventilation rate is variable in addition to other complicating variables (sheep disease, ship movement, restricted access to food and water etc). In the absence of other data, HST 2 of the experimental models should be the absolute maximum used by the government in their definitions of HST for each class of sheep. Given a) the government's own definition of HST and b) that a significant increase in core body temperature is consistent with failure to thermoregulate, a much better option would be to use Stockman's HST 1 as the government's HST.

One of the recent high mortality voyage reports (Voyage 69)[9] provides practical evidence that these experimental figures (HST 2 26-28ºC) should be the maximum-accepted HST and not the current government defined figure of 30.6ºC. The veterinarian on that voyage described moderate clinical heat stress from days 5 to 13, i.e. from a wet bulb temperature of 29ºC.

VALE believes that all field data in the public domain confirms the validity of the HSTs established in Stockman's thesis (2006). The Department's HST for merino sheep must be urgently revised and lowered. Heat stress thresholds should not only take into account best-case scenarios but should be applicable to all animals on a voyage (e.g. HST for adult sheep is higher than that for lambs; Maunsell 2003, Stockman 2006) and be adequate for animals that may already be stressed and/or diseased. In addition, duration of heat exposure must be assessed.

1. 4 Effect of Shipboard Space Allowance on Heat Stress

The only precautions that have been taken by the government and industry to alleviate heat stress have been to reduce stocking density based on a HSRA model during high-risk

[9] See: http://www.agriculture.gov.au/export/controlled-goods/live-animals/livestock/regulatory-framework/compliance-investigations/investigations-mortalities/sheep-qatar-kuwait-uae-report-69 (accessed October 12 2018)

periods. The HSRA model was designed to alter stocking densities based on the time of year in order to "limit metabolic heat production per unit area (and therefore limit the heat added to the incoming air)" (Issues Paper 2018). Whilst alterations to space allowances will limit the heat rise that occurs on deck due to the heat generated by the animals, it can never change the ambient WBT of the incoming air.

It is evident that when adverse heat and humidity conditions occur in predictable locations in the Middle East (eg Qatar and Straits of Hormuz), nothing can be done on ships to prevent "heat crashes". Veterinarian and stockmen routinely attempt to increase space for each sheep during the voyage during conditions of high heat and humidity (see High Mortality Voyage Report 65)[10] indicating that a) space allowances under Hotstuff are clearly recognised by the exporters and shipboard veterinarians as inadequate (High Mortality Voyage Reports 37, 38 and 65)[11] and that b) increasing space for all sheep (either by altered configurations or substantial reduction in sheep numbers due to death or discharge) has failed to prevent extreme mortality events (High Mortality Investigation Reports 37, 38 and 65).[12] This is not surprising. When ambient temperature data for the region frequently exceed even HST 3 for winter acclimatised sheep (Stockman 2006), no amount of increased space allowance will prevent heat stress morbidity or mortality. At the very best, increasing space allowance may help prevent heat stress when the ambient wet bulb temperature is a few degrees below HST 1 as defined by Stockman (2006).

In summary, reducing space allowance is highly desirable both for animal comfort and to reduce heat stress when temperature and humidity conditions are not extreme. However, it must be acknowledged that no amount of space increase will prevent heat stress once the ambient temperature reaches HST 1-2 as defined by Stockman (2006).

Stockman (2006) indicated that exceeding HST 3 for any prolonged period is not conducive to the "well being" of sheep. Evidence-based assessment indicates that exceeding scientifically established HSTs for sheep, for prolonged periods of time, is routine on voyages to the northern summer. As such, evidence-based data supports the fact that there is a high probability that sheep on voyages to the Middle East in the northern summer will typically experience a level of heat stress that is not conducive "to the well being of sheep" ie an adverse animal welfare state. VALE supports increased space allowances to improve comfort and animal welfare but similar to the Australian Veterinary Association (2018), does not believe that increasing space allowances will prevent unacceptable heat stress in the northern summer.

Based on all available science, live export sheep shipments from Australia to the Middle East from May to October should not be permitted by the Australian government. In addition, heat stress risks should be reassessed for both sheep and cattle exported to any location at any time of the year.

[10] See: http://www.agriculture.gov.au/export/controlled-goods/live-animals/livestock/regulatory-framework/compliance-investigations/investigations-mortalities#consignment-65-sheep-exported-by-sea-to-qatar-kuwait-uae-and-oman-july-2016 (accessed 12 October 2018)
[11] See: hthttp://www.vale.org.au/high-mortality-voyages.html Voyage Reports 37,38, 65 (accessed 12 October 2018)
[12] See: hthttp://www.vale.org.au/high-mortality-voyages.html (Voyage Reports 37.38. 65 (accessed 12 October 2018)

2. SPECIFIC COMMENTS ON ISSUES PAPER 2018

Numbering throughout is as per the Heat Stress Risk Assessment Issues Paper September 2018 (referred to as Issues Paper 2018)

2.1.1 Recommendation 3 from the McCarthy review

"Industry should move from a risk assessment based on mortality to a risk assessment based on animal welfare. "

COMMENT: See Section 1.2 for evidence of poor animal welfare despite "acceptable" mortality rates.

VALE agrees with this recommendation. In addition to the examples given for routine mortality voyages, one can also examine high mortality voyages. In one voyage report, in which mortality was 2.04% (just over the acceptable limit at the time), maximum WBT levels of 34–35ºC and severe heat stress were recorded in all sheep (over 69,000 animals) for at least 7 days.[13] Using the voyage reports and correlating these with the established HST parameters from Stockman's thesis (2006), there is no doubt that on both routine and high mortality voyages many surviving sheep experience an adverse welfare state for prolonged periods. To date, their welfare has been ignored because mortality was the only indicator assessed.

2.1.2 Recommendation 4 from the McCarthy review

"As an interim measure, it is recommended the risk be set at a 2 per cent probability of 5 per cent of the sheep becoming affected by heat stress (Heat stress score 3—refer *Table 1 of the McCarthy review). These settings should be reviewed by the ASEL Review Technical Advisory Committee at the end of this northern hemisphere summer period and again, annually by an independent taskforce."

COMMENT: VALE concurs with the Australian Veterinary Association (AVA) and does not believe that sheep should be transported from Australia to the Middle East between May and October (AVA 2018). For other months of the year, and for cattle, VALE would agree with the recommendation of the McCarthy review.

2.1.3 Recommendation 5 from the McCarthy review

"That the required changes to the industry heat stress risk assessment model be made immediately and then included in Version 5 of the HSRA model. Note: *The department accepted this recommendation in principle, subject to more testing and consultation through this process.* "

COMMENT: VALE agrees with the McCarthy Review recommendation that these changes should be made immediately. Delaying implementation is not appropriate given the identified limitations of the HSRA model (see Section 1.1).

[13] See: http://www.vale.org.au/high-mortality-voyages.html Investigation into the reportable sheep mortality level on a sea voyage from Fremantle, Western Australia to Bahrain, Kuwait and the United Arab Emirates (UAE) Report 38 (accessed 12 October 2018)

2.1.4 Recommendation 7 from the McCarthy review

"A future version of the industry heat stress risk assessment model to be developed, adopted and used by industry during the northern hemisphere summer of 2019 should have the capacity to assess:

a) the duration of time that sheep are exposed to high heat loads without respite

b) ventilation design rather than assessing risk based on airflow alone.

In addition, the way in which the model manages open decks should be reviewed."

COMMENT: VALE concurs with the AVA and does not believe that sheep should be transported from Australia to the Middle East between May and October (AVA 2018). Sheep should not be sailing to the Middle East in the northern summer of 2019.

2.1.5 Recommendation 8 from the McCarthy review

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

a) the 'heat tolerance' level

b) the probability risk settings."

COMMENT: VALE concurs with the AVA and does not believe that sheep should be transported from Australia to the Middle East between May and October (AVA 2018). Sheep should not be sailing to the Middle East in the northern summer of 2019.

2.2 Heat Stress Risk Assessment

"The HSRA model provides a scientific approach for determining the risk of heat stress for export voyages to the Middle East and estimating any required increase in space allowance."

COMMENT: The HSRA model has never provided a scientific approach as:

a) the HSTs were never based on the best available evidence (Stockman 2006) (Section 1.3 in this document)
b) the model aims to limit metabolic heat production per unit area and therefore limit the heat added to the incoming air. It fails to acknowledge that the incoming air may already be exceeding the HST for sheep as demonstrated by Stockman (2006)
c) a 5% mortality event is catastrophic and has rarely happened in history, even prior to 2003. There is no indication that the HSRA has ever improved or even prevented high mortality incidents due to heat stress. In addition, the repetitive failure to avert crises by increased space allowance on board (End of Voyage reports from shipboard veterinarians)[14] has provided evidence that no amount of space will stop animals dying when the ambient conditions are extreme and above HST 2-3 as defined by Stockman (2006).

3.1 McCarthy review recommendations 3 and 8

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

[14] See: http://www.vale.org.au/high-mortality-voyages.html Voyage Reports 37, 38, 65 (accessed 12 October 2018)

COMMENT: VALE agrees. Mortality is the crudest instrument for measuring animal welfare (see Section 2.1.1). This is not acceptable in 2018.

“Recommendation 8 from the McCarthy review is “*A future version of the industry heat stress risk assessment model to be developed, adopted and used by industry during the northern hemisphere summer of 2019 should reassess:*
-the ‘heat tolerance level
-the probability risk settings.”

COMMENT: VALE concurs with the AVA and does not believe that sheep should be transported from Australia to the Middle East between May and October (AVA 2018). For other months of the year, and for cattle, VALE would agree with recommendation 8 of the McCarthy review.

“In the HSRA model, mortality limit is the wet bulb temperature above which the animal will die. An additional dependent variable is the ‘heat stress threshold’ (HST). This is defined as the maximum wet bulb temperature at which the heat balance of the animal’s core body temperature could be controlled by bodily heat loss mechanisms, although the heat stress threshold is not used in the HotStuff model.
As the local air wet bulb temperature approaches an animal’s heat stress threshold, the animal is on the verge of becoming stressed. Incipient stress is the first uncontrolled rise in core body temperature, this is taken as being 0.5°C above what the core temperature would otherwise have been (Stacey 2018).”

COMMENT: VALE notes that incipient stress as defined by Stacey 2018 (as cited in The Issues Paper 2018) actually corresponds to HST 2 as defined by Stockman (Stockman 2006). However, the definition of “incipient” is “beginning to happen/develop” so, on the evidence available, it should in fact correspond to HST 1 (Stockman 2006). Regardless, even the HST 2 values for Merino adults and lambs (Stockman 2006) have not been used in Table 1 of Issues Paper (2018).

Table 1 (Issues Paper 2018)
COMMENT:
There are numerous flaws in this table:

a) normal body weight for Merino and Awassi adults and lambs are identical. Clearly this is not the case. A standard average adult Merino wether weighs more than 40kg (eg approximately 53-56kg in the studies on live export voyage simulation by Stockman (2006))
b) the core body temperature for merino sheep is listed as 40.0ºC. It is uncertain whether this temperature is supposed to represent normal body temperature or body temperature at the onset of heat stress. Normal body temperature of sheep is usually regarded as being about 39ºC (Radostits et al 2007). Forty degrees Celsius is regarded as being a “critical point” by Radostits and others (2007). The normal rectal temperatures in the West Australian Merino sheep in both relevant Stockman studies (Chapters 3 and 4) ranged from 38.3ºC to 39.3ºC for both winter and summer

acclimatised Merino sheep

c) the “base HST” is inappropriate as per Section 1.3.

“Ferguson et al (2008) undertook an industry funded review of the scientific basis of the core elements (animal physiology, engineering, climatology and statistics) that underpin the HotStuff model. The authors concluded that the methodology and assumptions underpinning the model were sound, reasonable and supported by scientific literature.”

COMMENT: the study was industry funded and given the failure to integrate the findings of Stockman (2006), one has to question the conclusions of this study.

“The McCarthy review recommends the industry move from a risk assessment based on mortality to one based on animal welfare. The McCarthy review proposes the HSRA model accommodates this by a move from the mortality limit to a heat tolerance level.
The McCarthy review suggests the existing settings of a less than 2 per cent probability of a 5 per cent event remain the same, but that the mortality limit be replaced by a tolerance limit corresponding to a heat stress score of 3 in Table 2 below.”

COMMENT:
If the studies by Stockman are used as being representative of West Australian sheep (the majority of sheep exported), then the respiratory rates of Merino sheep range from 26-77 bpm (Stockman 2006). Thus, the normal respiratory rates of 25-80 bpm appear accurate although textbooks certainly give much lower resting respiratory rates for sheep eg 10-20 bpm (Radostits et al 2007). Respiratory rates over 70 bpm are reported as being representative of heat stress (Radostits et al 2007).

Panting Score 1 in Table 2 is defined as being “elevated” at 80-100 – this panting score could occur in exercise or heat exposure. Sheep will pant in an attempt to thermoregulate and can control their core temperature in the face of heat load by panting for a period of time before core body temperature starts to rises (dependent on actual heat load applied). As such a Panting Score of 1 in sheep that are not being exercised should be deemed as “Heat Affected”.

Panting Score 2 in Table 2 (RR of 100-160 bpm) is defined as being “Heat Affected” and sheep are described as showing “discomfort”. Unfortunately, this Panting Score designation is not based on the available science. In Stockman’s Study (2006; Figure 4.5), the mean respiratory rate for winter-acclimatised Merino wethers, ram lambs and adult rams that experienced mild to moderate heat stress (ie increased core body temperature) nearly all fell below 160 bpm; slightly above 160 bpm for adult rams in HST 3). This clearly demonstrates that sheep exposed to HST 3 (severe heat stress with temperatures exceeding core body temperature by 1ºC) had respiratory rates that were not regarded as consistent with “heat stress” by McCarthy’s Panting Score (Table 2). Respiratory rates of 100-160 bpm clearly indicate that the HST has been exceeded in winter-acclimatised Merino sheep and should not be regarded as being merely “heat affected”. An evidence-based “bold black” line on McCarthy’s scale would (and should) be drawn between Panting Scores 1 and 2.

The only scientifically validated panting score relevant in the assessment of HST in live export sheep is that assessed by Stockman (2006). The panting score used by McCarthy is slightly different from that used by Stockman (2006). The Panting Score used by Stockman (2006) was:
1 Slight panting
2. Fast panting and open grin
3. Open mouth panting
4. Open mouth panting, tongue out

At neither HST 2 nor HST 3 in the winter-acclimatised sheep did the **mean panting score** exceed 2.5 This means that sheep in the Stockman study that were failing to thermoregulate on average demonstrated mainly past fast panting. With severe heat stress (HST 3) the adult rams and wethers had a **mean maximum panting** score of 3. These figures will have been lowered by the study design which required that sheep be removed at 1700 hours on the day their temperatures exceeded 40.5ºC "**on consideration of well-being of the animal**." All sheep did progress to Panting Score 3 (and some to Panting Score 4) before being removed from the room. HST 3 is well below the current government HST of 30.6ºC.

It is notable that winter-acclimatised Merino ram lambs (40kg approximately) had a considerably lower mean maximum panting score of 2, again indicating the inappropriate designations of the McCarthy Panting Score in assessing heat stress.

Stockman (2006) stated that for winter-acclimatised Merino sheep "The use of HST is an effective measure of thermal strain as in [it] indicates the point when an animal is unable to maintain thermal balance, as evidenced by increasing core body temperature….An increase in core temperature above normal in this study was associated with increased respiratory rate and panting score in adult rams and lambs. However, rapid phase panting (Panting Score 2) was not reached in sheep until core temperatures were significantly above those at HST 2. At HST 2 sheep were generally not observed to be open mouth panting."

A consistent panting score of 3 on Stockman's scale implies that HST 3 has been reached or exceeded (Stockman 2006). Sheep will have lost thermoregulatory ability well before they reach this panting score (Stockman 2006) and in fact Panting Score 2 (essentially identical for Stockman and McCarthy) was not reached until HST 2 was exceeded. Thus, sheep in Panting Score 3 as defined by McCarthy will definitely have exceeded HST 3 and should be regarded as having severe heat stress rather than "onset of heat stress". It is quite clear, based on science that not only onset of heat stress but also moderate heat stress occur at McCarthy's Panting Score 2 not Score 3.

McCarthy's Panting Score needs to be revised with the bold black line differentiating heat stress placed between Panting Scores 1 and 2. Panting Scores 3 and 4 should designate severe heat stress.

Use of McCarthy's Panting Score 3 could only be used if the model estimating probability of having <2% chance that <5% of animals having heat stress implied that the heat stress was severe for that 5%. McCarthy's scores could replace the current scale in ASEL but only if the "bold line" was shifted from its current position to a position between Panting Scores 1 and 2.

Questions about mortality limit and heat stress threshold:

Q "How should the effects of heat on animals be defined?"

COMMENT: The current definition of HST is scientifically valid. However, the current temperatures designated as HST by the government are not supported by the scientific literature available. The effects of heat on animals should be assessed against the best available scientific evidence. For sheep, the best experimental evidence is that from Stockman (2006). For individual sheep, a scientifically validated Panting Score should be used. Currently, the only validated Panting Score is that used by Stockman (2006).

Effects of heat stress should be assessed by both HST and duration of exposure. HST 1, as defined by Stockman (2006) to be the WBT at which there is a significant core temperature increase, is clearly undesirable but if exposure is limited to one day, then welfare effects are likely to be minimal. However, if animals are at HST 1 (or higher) for many days with no respite (which is often the case based on weather data and voyage reports), then clearly that is a significant welfare issue. HST 1 may not result in massive mortality but would be expected to cause marked morbidity. As such, duration of exposure is required as an additional measure of assessment.

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

COMMENT: in an individual penned sheep, one would check rectal temperature, count respiratory rate, observe respiratory pattern, measure food and water intake and consider blood and serum biochemistry. This is not practical on a ship. Panting score is a useful heat stress indicator for intensively housed sheep. However, one must also note the duration of exposure in any assessment. In addition, there should be assessment of the faecal pad (bogging occurs on ships as documented visually and in high mortality voyage reports).[15] Bogging results in increased stress and energy expenditure (with likely increased heat production) and is an adverse animal welfare state.

In addition, one should use qualitative behavioural assessment (QBA) scores (Fleming et al 2016). Farmers can identify sick sheep without being able to explain exactly how they know they are sick (Fleming et al 2016). Likewise, a Pakistani naval officer and the Australian public who watched his footage, did not need to count respiratory rates to know that sheep with heat stress on the Awassi Express[16] were suffering – essentially they were using "qualitative behavioural assessment". Ideally, CCTV footage of each deck should be available and footage assessed by independent observers. It is very evident that conditions which shipboard veterinarians consider "normal" are "normal for voyages" and certainly not "normal for the animals". An example of this would be the shipboard veterinarians' classification of normal respiratory rate for cattle as up to 80 bpm (McCarthy 2005). No cattle textbook or Australian land-based cattle veterinarian would accept that range as being

---

[15] See: http://www.vale.org.au/high-mortality-voyages.html Voyage Reports 65, 69 (accessed 12 October 2018)

[16] See: https://www.9now.com.au/60-minutes/2018/extras/latest/april/liam-bartlett-sheep-ships-and-videotape (accessed 12 October 2018)

normal and it would appear to indicate that shipboard veterinarians are inured to the conditions onboard and that shipboard “normals” alter those veterinarians’ perceptions of “normal”.

However, from a practical standpoint, Stockman (2006) stated that “the use of HST is an effective measure of thermal strain as it indicates the point when an animal in [is] unable to maintain thermal balance, as evidenced by increasing core body temperature.” As the WBTs for HST were defined by Stockman (2006), one could simply use the average daily deck WBTs to assess whether HST1-3 is likely to have been exceeded for winter or summer-acclimatised sheep. This would require multiple WBT measurements not just the single WBT measurement for each deck measured between 9 and 11am as is routine practice on live export ships (Lynn Simpson and other shipboard veterinarians Pers Comm; Fazal Ullah Pers Comm).

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

COMMENT: This is a non-scientific and inappropriate question. Heat stress in the scientific literature is always defined by any rise in core body temperature ie when the animal fails to thermoregulate and thus cope with its environment. This was defined by Stockman (2006) as HST 1. The study by Stockman (2006) then describes what can be expected for HST 1 and higher WBTs. It should not be a matter of opinion – it must be based on the best scientific evidence available, which is Stockman’s thesis (2006). The limitations of the McCarthy Panting Score have already been discussed but it should be noted that HST 1 is already exceeded when sheep are only considered “heat affected” ie McCarthy’s Panting Score 2. In general terms, heat affected sheep (eg McCarthy Panting Score 1) and sheep at HST 1 (Stockman 2006) can cope, for some periods of time, but this does not mean that coping/suffering is acceptable, especially when heat load is applied for many days. From voyage reports, it is apparent that many sheep can survive with continual heat and conditions above HST 1 but this does not mean that such conditions are acceptable welfare states. Australia should not be sending animals to the Middle East in the northern summer where there is a high probability that conditions will be exceeding HST 1 (often exceeding HST 3) for winter-acclimatised sheep (as defined by Stockman 2006). Risk at other times of the year for both cattle and sheep should be based on animal type and projected weather forecasts at the time of the voyages.

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

COMMENT: See Section 1.3 for a detailed analysis
A HST of 30.6°C WBT has never been a scientifically valid definition for Merino sheep. HSTs for winter-acclimatised Merino sheep of various classes have been established in the study by Stockman (2006). Even HST 3 (the WBT that causes a 1°C increase in body temperature) is lower than the government’s arbitrary, non-evidence-based HST. The mortality limit (ML)

presumably has been defined as the point that all sheep would die. Extreme mortality events, such as that on the Bader III (High Mortality Voyage 46[17]; Figure 3 in the Issues Paper 2018) show that 7.28% sheep died despite the fact that the recorded WBTs were still many degrees below the ML. The ML appears to be some statistical figure used for probability monitoring but of little relevance to the sheep that die well before this temperature is reached.

Q "Are there other physiological indicators linked to the effects of excessive heat on sheep that could be measured and considered for inclusion in the HSRA model?"
COMMENT: QBA tools could be used.

Q "What animal welfare indicators could be considered in assessing the effects of heat on animals? "
COMMENT: sheep that are subjected to heat and humidity for any period of time, when already in a reasonably hostile environment (intensive housing, ammonia, ship movement, tight space allowances, high stocking density, unfamiliar rations etc) will be experiencing an adverse welfare state regardless of whether the HST is exceeded or not. Conditions of continuous high environmental heat and humidity with no diurnal variation comprise a serious adverse welfare state regardless of whether the HST is exceeded. Even if core temperatures are maintained, having to pant for prolonged periods to thermoregulate is a negative welfare state. Breathlessness for example is now considered to be an adverse welfare state (Beausoleil and Mellor 2015) and continuous panting for prolonged periods (as recorded on daily voyage reports) cannot be considered acceptable animal welfare.

4.1 McCarthy review recommendation 4

"Recommendation 4 of the McCarthy review is "*As an interim measure, it is recommended that the risk be set at a 2 per cent probability of 5 per cent of the sheep becoming affected by heat stress (Heat stress score 3—refer *Table 1 of the McCarthy review). These settings should be reviewed by the ASEL Review Technical Advisory Committee at the end of this northern hemisphere summer period and again, annually by an independent taskforce.*"
Note: *Table 1 (p.19) of the McCarthy review is provided at table 2 on page 14 in this paper."*

COMMENT: VALE concurs with the AVA (AVA 2018) and does not believe that sheep should be transported from Australia to the Middle East between May and October. For other months of the year, and for cattle, VALE would agree with the change suggested in the McCarthy review.

4.2 Allometric stocking densities

"During May to October, ASEL provides 0.29m^2 for a 40kg sheep. As outlined above, the department has already implemented the McCarthy Review's Recommendation 2, that 'allometric' principles with a *k*-value of 0.033 be used to determine stocking densities during May to October, unless overridden by the HSRA model's assessment."

COMMENT: See Section 1.4

[17] See: http://www.vale.org.au/high-mortality-voyages.html Voyage Report 46 (accessed 12 October 2018)

VALE has analysed ASEL space allowances for live export voyages. For cattle and sheep, the space allowances are almost unchanged since 1978 (AVA 2018). A table of space allowances from 1983 has been included for cattle (VALE Table 1). It is evident that apart from some minor increases in allowances for cattle travelling from southern latitudes in an Australian winter, all allowances are unchanged or even decreased. There were no scientific studies on space allowances performed prior to 1983. As such, these allowances are entirely arbitrary designations with no scientific or animal welfare basis. The current on-board space-allowances do not conform to OIE recommendations and are less than any similar Australian land standards (see VALE Table 2). They also do not conform to any allometric principles (Petherick and Phillips 2009) and do not permit free movement of animals or easy access to food and water. The tight space allowances pose a considerable risk to animals with respect to injury, inanition and, heat stress. In addition, these space allowances do not permit easy inspection of animals in pens, impeding the capacity to identify and treat sick or injured animals.

Questions about allometric stocking densities:

Q How can allometric stocking densities most effectively be used?

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

VALE COMMENT: VALE concurs with the AVA (AVA 2018) and does not believe that sheep should be transported from Australia to the Middle East between May and October. VALE believes a *k*-value of 0.033 should be an absolute minimum for any time of year when calculating space allowances (Petherick and Phillips 2009; AVA 2018).

It is important to recognise, as per previous comment, that the space allowances provided by ASEL had no basis in science. The space allowance on live export ships is the least of all the Australian sheep codes (VALE Table 2) including indoor housing despite the extreme nature of conditions that can be encountered on ships. As such, the space allowances would always have been considered unacceptable for Australian sheep on land.

The only study that has been done to assess actual space allowances on live export ships (Ferguson and Lea 2013) was industry-funded and fundamentally flawed (Phillips and Petherick 2014). Only two sheep voyages were assessed, neither of which were to the Middle East in high summer. In addition, the study used minimally increased and decreased space allowances thus had limited ability to demonstrate welfare benefits. In addition, despite some descriptions of improved animal welfare with increased space allowances in the study, the authors concluded that there was no benefit in increasing space by 10% ie the conclusions were inconsistent with their observations..

VALE believes that sheep on live export voyages should have space allowances increased to a *k*-value of >0.033. A k value of >0.033 is the best **minimum** estimate we have currently from the scientific literature (Petherick and Phillips 2009). A *k*-value of 0.033 might provide some level of comfort and increased ease of accessing food and water troughs but is hardly generous (as VALE Figure 1 shows) and thus not really likely to be adequate for good animal welfare over a 3 week period.

Figure 2.2 Sheep in individual pens inside climate controlled room

VALE Figure 1: a photo from Stockman's thesis (2006; Figure 2.2 Sheep in individual pens inside climate controlled room) illustrating pen size of 0.880 m^2. This illustrates the space available to individually penned sheep with 0.88 m^2 ie over double the current ASEL space allowance for a 53 kg sheep and over double the allometric allocation of k = 0.033 for a 50 kg sheep as per Table 3 in the Issues Paper 2018).

5.2 McCarthy review recommendation 7

"Recommendation 7 from the McCarthy review is "*A future version of the industry HSRA model to be developed, adopted and used by industry during the northern hemisphere summer of 2019 should have the capacity to assess:*
a) the duration of time that sheep are exposed to high heat loads without respite
b) ventilation design rather than assessing risk based on airflow alone
In addition, the way in which the model manages open decks should be reviewed."

COMMENT: VALE does not believe that sheep should be transported to the northern hemisphere in summer. However, in principle,(ie if voyages to the northern summer occur), VALE agrees with the recommendation.

5.2.1 Prolonged High Heat Load Exposure and Destination Ports

"Stockman et al (2011) stated that a good understanding of the physiological responses of sheep to continuous exposure to high temperature and humidity is required to optimally manage the animals during live shipment. Their experiment aimed to quantify the physiological responses of sheep to the cumulative effects of high wet bulb temperature with no diurnal relief. The study examined sheep during simulated exposure to commonly seen environmental temperatures during live shipment (Stockman et al 2011)."

COMMENT: Stockman studied both winter- and summer- acclimatised sheep. The peer-reviewed study cited above (Stockman et al 2011) pertains to the summer-acclimatised sheep study. It is not known why Stockman never published the study on winter-acclimatised sheep (Stockman 2006). The methods of each were similar.

“The study showed sheep do accumulate heat when exposed to continual high heat and humidity of up to 30°C wet bulb resulting in measurable changes in physiological parameters, including increased core temperature, respiratory rate (RR) and alterations in blood gas variables (Stockman et al 2011). The authors indicated the sheep recovered quickly after the heat exposure and these variables returned to normal. The sheep maintained feed intake during exposure to hot conditions, and there was little alteration in blood electrolyte concentrations or acid-base balance. “

COMMENT: the sheep in the published study (Stockman et al 2011) were healthy summer-acclimatised sheep housed, in well-ventilated rooms with very low stocking density and over double the ASEL space allowance. This should have been considered a best-case scenario. It should be noted that whilst the sheep maintained their feed intake in this study, 25% of the sheep in one room ate poorly whether the rooms were hot or not ie they already had reduced food intake. Stockman specifically states in the thesis discussion (p138) that “If feed had been available ad libitum in this study, sheep may have been feeding above maintenance in the ambient conditions and a decrease in feed intake back to maintenance may have occurred during the heat periods.” Stockman noted that reduced feed intake had been noted in studies where sheep were fed in excess of requirements.

“Stockman et al (2011) noted sheep can infrequently be exposed to more severe environmental conditions during live shipment and it would be expected physiological responses to these conditions would be more severe. However, it was evident in this study that assessment of the effect of heat on sheep needs to consider not only how hot it gets, but also the duration and therefore the accumulation of heat.”

COMMENT: this is likely to be correct but it must also be noted that the Stockman studies occurred in ideal environments that are not representative of the low space allowances and high stocking density of export vessels.

“The wet bulb temperature (WBT) of the environment experienced by ships rises during the trip from Australia to the Middle East, depending on the season and the route travelled. During the winter months, the WBT rarely approaches 26°C, while during the summer months, between June and September, the WBT averages around 28°C, and maxima above 33°C have been recorded over the western approaches to the Straits of Hormuz. There is little diurnal variation in WBT during shipping through these regions (MAMIC/Maunsell 2003; LIVE.116).”

COMMENT: between June and September the average WBT of 28 exceeds the HST of winter-acclimatised Merino sheep as defined by Stockman (2006) – see Section 1.3

“According to MAMIC/Maunsell (2003) the heat and humidity levels increase rapidly across

all Middle East ports during the period from May through to June. First affected are the southern-most ports of Muscat and Fujairah where heat and humidity climb quickly during May. The heat and humidity extend northwards with central Gulf ports from Dubai to Doha, Bahrain and Dhahran becoming consistently hot and humid from June onwards (MAMIC/Maunsell 2003). Further summary voyage and discharge port weather data can be in Stacey (2017b) W.LIV.0277 addendum.
The peak of heat and humidity sets in for the northern most ports of Kuwait in the Gulf and Aqaba in the Red Sea (Gulf of Aqaba) towards the end of June into early July. The high heat and humidity levels continue through until the end of September, except for the southern Persian Gulf ports where the high humidity levels linger into October (MAMIC/Maunsell 2003)."

COMMENT: the weather data for the region is well documented and it is evident from all available information and the HSTs ascertained in ideal conditions (Stockman 2006) that sheep should not be subject to export to the Middle East between May and October. Adverse conditions will also occur at other times of year and in other locations, including at the Equator for both sheep and cattle.

Questions about heat load exposure and destination ports:
Q How might potential duration and repeated exposure to high heat loads be incorporated into the HSRA model?
Q How might minimum daily temperatures be factored into the HSRA model?
Q How might multiple discharge ports be taken into account when assessing heat stress risk?

COMMENT: these questions are irrelevant given that the weather data for the Middle East between May and October indicate that there is a high likelihood for sheep being exposed to multiple days of WBTs exceeding the scientifically defined HSTs (Stockman 2006) with no respite.

5.2.2 Vessel Configuration
"In line with recommendation 9 of the McCarthy review, industry is now implementing a process of verifying PATs for vessels currently servicing the trade. The ventilation measurements necessary to calculate the PAT records for each vessel are included in the ventilation reports provided by ship owners to AMSA. "

COMMENT: VALE supports this initiative

5.2.3 Ventilation and air quality
"McCarthy (2018) indicates the industry heat stress risk assessment model is based on the principle of the wet bulb rise. This is the rise in wet bulb temperature that occurs between the time the air comes into the hold and the time it leaves and reflects the heat and water vapour added to the air in the course of cooling the animal. The higher the PAT the lower the wet bulb rise. Doubling the PAT halves the wet bulb rise (McCarthy 2018)"

COMMENT: VALE agrees with this statement but is concerned that it overlooks the fact that if the air entering the hold is already at a WBT that exceeds the HST for sheep, then no matter how high the PAT, heat stress will not be avoided.

"The McCarthy review also recommended that vessels travelling to the Middle East should be fitted with automated continuous environmental monitoring equipment. It is argued that temperature and humidity data loggers would improve understanding of the link between environmental conditions, the role of on-board ventilation systems and animal performance. Further work is required to investigate the feasibility and practicality of current and emerging technology in monitoring and reporting on environmental conditions on-board."

COMMENT: VALE agrees with the McCarthy Review. McCarthy recommended this in an industry-funded study in 2005 (McCarthy 2005) and it is not acceptable that it has taken 13 years and explosive footage to potentially implement a recommendation from 2005. Recommendations from both government reviews and industry-funded studies are rarely implemented in the live export trade.

Questions about ventilation:
Q What elements or factors contribute to good ventilation performance on a vessel?
Q How might ventilation performance be incorporated into the HSRA model?
Q How might we ensure ventilation design delivers efficiency/performance/output requirements?

COMMENT: appropriate ventilation is important to reduce heat rise across the decks and to limit accumulation of noxious gases such as ammonia also. As such, ventilation should be incorporated into all assessments of live export voyages regardless of the time of year or HSRA. Ventilation can potentially prevent WBT shifting above the HST however, no matter how high the PAT, heat stress will still occur if the ambient temperature is already at the HST.

5.2.4 Open Decks
Questions about open decks:
Q How should open decks be treated for the purposes of assessment in the model?
Q What other things need to be considered in assessing heat stress risk on open decks?

COMMENT: to the best of VALE's knowledge, the HSRA for open deck ships has always assumed a minimum 5 knot cross wind (Ferguson and Fisher 2008). This is not necessarily present eg when ships are stationary or when there is a following breeze (McCarthy 2005). Zig-zagging (McCarthy 2005) has been used to try and artificially create a crosswind (eg High Mortality Voyage Report 46[18]) but this manoeuvre is not necessarily performed (Lynn Simpson Pers Comm) and is not always possible (eg in confined spaces such as the Suez Canal or ports). The model is flawed in this regard.

VALE notes that the open-decked ships will not be permitted to operate without ventilation after 1 January 2020 and does not believe that they should be permitted to operate in the northern summer of 2019 given that their inherent problems have already been recognised.

[18] See: http://www.vale.org.au/high-mortality-voyages.html. Accessed 12 October 2018

REFERENCES

Australian Standards for the Export of Livestock (Version 2.3) 2011 and Australian Position Statement on the Export of Livestock. 2011

Australian Veterinary Association. AVA Submission: A short review of space allocation on live export ships and body temperature regulation in sheep. 2018

Beatty DT. Prolonged and continuous heat stress in cattle: physiology, welfare and electrolyte and nutritional interventions. PhD Thesis, Murdoch University 2005

Beatty DT, Barnes A, Taylor E et al. Physiological responses of *Bos taurus* and *Bos indicus* cattle to prolonged, continuous heat and humidity. *Journal of Animal Science* 2006;84: 972-985

Beausoleil NJ, Mellor DJ. Introducing breathlessness as a significant animal welfare issue. *New Zealand Veterinary Journal* 2015;63:44-51

Caulfield MP, Cambridge H, Foster SF, McGreevy P. Heat stress: A major contributor to poor animal welfare associated with long haul live export voyages. *The Veterinary Journal* 2014;199:223-228

Farmer B. Independent review of Australia's live export trade. Commonwealth of Australia, Canberra ACT. 2011

Ferguson D, Fisher A, White B, Casey R. Review of the livestock export heat stress risk assessment model (HotStuff). W.LIV.0262, W.LIV.0263,W.LIV.0264, W.LIV.0265. Meat and Livestock Australia, Sydney, NSW, Australia. 2008

Ferguson D, Lea J. Refining stocking densities. W.LIV.0253. Meat and Livestock Australia Limited, Sydney, NSW, Australia 2013

Fleming PA, Clarke T, Wickham SL et al. The contribution of qualitative behavioural assessment to appraisal of livestock welfare. *Animal Production Science* 2016;56:1569-1578

Keniry J. Livestock Export Review. A final report to the Minister for Agriculture, Fisheries and Forestry. 2004

Maunsell Australia. Development of a heat stress risk management model. LIVE .116. Meat and Livestock Australia, North Sydney, NSW, Australia 2003

McCarthy M. Pilot Monitoring of shipboard environmental conditions and animal performance. LIVE.223. Meat and Livestock Australia Limited, Sydney, NSW Australia 2005

Norman GJ. National livestock export industry sheep, cattle and goat transport performance report 2016. W. LIV.0291. Meat & Livestock Australia Limited, Sydney, NSW Australia 2017

Norris RT, Richards RB. Deaths in sheep exported by sea from Western Australia – analysis of ship Master's reports. *Australian Veterinary Journal* 1989;66:97-102

Petherick JC, Phillips CJC. Space allowances for confined livestock and their determination from allometric principles. *Applied Animal Behaviour Science* 2009;117:1-12

Phillips CJC, Petherick JC. The Ethics of a Co-regulatory Model for Farm Animal Welfare *Research Journal of Agricultural Environmental Ethics*; 2014; DOI 10.1007/s10806-014-9524-9

Radostits O, Gay CC Hinchcliff KW, Constable PD. *Blood Radostits Veterinary Medicine 10th Edition*. Elsevier Edinburgh 2007

Stockman CA. The physiological and behavioural responses of sheep exposed to heat load within intensive sheep industries. Thesis, Doctor of Philosophy, Murdoch University 2006

Stockman CA, Barnes AL, Maloney SK et al. Effect of prolonged exposure to continuous heat and humidity similar to long haul live export voyages in Merino wethers. *Animal Production Science* 2011;51:135-143

VALE TABLES

VALE Table 1: Space allowances for cattle 1983 to 2018. Figures in blue indicate the largest space allowance, figures in red are the smallest space allowances. Figures in black indicate space allowances between the greatest and smallest allowances.

Cattle weight	**1983**	**1999 >10 days**	**1999 <10 days**	**ASEL 2011 >10 days**	**ASEL 2011 <10 days**	**ASEL** port south of latitude 26° **May-Oct**	**ASEL** port south of latitude 26° **Nov-April**
200kg	0.90	0.77	0.77	0.77	0.77	0.847	0.77
300 kg	1.175	1.110	1.110	1.110	1.110	1.221	1.110
400kg	1.45	1.45	1.45	1.45	1.45	1.668	1.45
500kg	1.790	1.790	1.725	1.790	1.725	2.060	1.932

VALE Table 2: Space allowances in ASEL v 2.3 compared to space allowances in codes relating to other intensive housing systems.

Sheep (for a weight of 47kg)	Space allowance m^2 per animal
On board ship (ASEL 4.12)	0.308
In a live export pre-export feedlot (ASEL 3.11)	0.33-0.6
Saleyard selling – holding pens (Model Code of Practice – Saleyards)	0.47-0.8
Feedlots (shipping assembly – outdoor) (Model Code of Practice – Sheep)	1.3-1.5
Intensive indoor systems (Model Code of Practice – Sheep)	0.5-0.9

Cattle (for a weight of 330kg)	
On board ship (ASEL 4.12)	1.212-1.333 (depending on time of year)
In a live export pre-export feedlot (ASEL 3.11)	2.64
Saleyard selling pens (Model Code of Practice – Saleyards)	2.25-2.7
Feedlots (Model Code of Practice – Cattle)	9 (outside) 2.5 (shedded)