AVA Submission:

Heat Stress Risk Assessment (HotStuff): Issues Paper

October 2018

Submission from the Australian Veterinary Association Ltd

www.ava.com.au

AUSTRALIAN VETERINARY ASSOCIATION

About us

The Australian Veterinary Association (AVA) is the national organisation representing veterinarians in Australia. Our 9,500 members come from all fields within the veterinary profession. Clinical practitioners work with companion animals, horses, farm animals and wildlife. Government veterinarians work with our animal health, public health and biosecurity systems while other members work in industry for pharmaceutical and other commercial enterprises. We have members who work in research and teaching in a range of scientific disciplines. Veterinary students are also members of the AVA.

Executive Summary

1. The AVA contends that a major shift in thinking is required in the application of the HotStuff model.

Currently, the model is used only to determine space allocation for the intended voyage, in order to reduce mortality risks. The Heat Stress Threshold (HST) values that are generated by the HotStuff calculations are not being utilised to predict the likelihood of sheep suffering clinical heat stress, and we feel this is a fundamental flaw in the process. The AVA believes that the HotStuff model should be used as a preventative tool: to predict the risk of heat stress occurring during the proposed voyage, and thus determine *if indeed the ship should sail*.

Livestock attributes (species, breed, age, body weight, body condition, coat length, month and district of origin) and route climatology (average/predicted wet bulb temperatures *en route* and in destination ports) can be entered into the model to predict the wet bulb temperature (WBT) at which livestock will suffer heat stress during any voyage.

Where calculations show that environmental WBTs are likely to exceed the calculated HST for the particular group of animals, the conclusion should be that the voyage does not proceed.

2. The HotStuff model estimates for HST and mortality limit (ML) appear reasonable when sheep are exposed to a certain wet bulb temperature for a short time, and then are returned to a thermoneutral wet bulb temperature which allows shedding of heat load and restoration to normal physiological state. However, the model does not take into account *duration* of exposure to heat, nor lack of diurnal variation nor potential for repeat high WBT challenges and thus the impacts of *cumulative* heat load. It is beyond the capacity of the AVA to say how this is mathematically incorporated into the HotStuff model but the model must integrate historical and predicted climate observations to predict likely duration of exposure to HST for different lines of sheep.

3. It is inappropriate for sheep or any other animals to be exposed to long periods of heat stress, due to the impact of cumulative heat load on normal physiological processes. Sheep should never be exposed to HST 3, even for short periods. Sheep should not be exposed to HST 2 for more than 3 consecutive days where there is no diurnal variation in temperature. Diurnal variation allows sheep to return to their thermoneutral zone and for respiratory rates to return to resting range at night. Otherwise, sheep can start dying within 3 days of being exposed to hot, humid weather, as heat load is cumulative. This duration of permissible exposure should be further reduced in the presence of other welfare imposts and/or co-morbidities as these will further reduce the animal's ability to cope. This is consistent with the 5 Domains approach to assessing welfare which looks at *severity* and *duration* of welfare compromise, as well as the anticipated *integrated* impact of the combined welfare impacts on the animal's mental state.

4. A detailed explanation of the pathogenesis of heat stress is provided in this submission, including pictorial illustration of the complex and multifactorial inputs leading to hyperthermia and ultimately death from multi-organ dysfunction where heat cannot be dissipated through normal physiological mechanisms.

5. A number of Ship-board Daily reports are provided to illustrate changing conditions during a typical voyage to the Middle East in the Northern Hemisphere summer, including ambient and deck WBTs, sea temperatures and respiratory rates of sheep as the ship approaches and crosses the equator.

6. The AVA has completed a series of desk-top exercises, using data from real voyages, to illustrate the use of HotStuff to calculate heat stress thresholds in various classes of sheep. These show that between May and October environmental wet bulb temperatures increase as ships sail to the Middle East, and sheep demonstrate varying levels of elevated respiratory rates and heat stress. The examples demonstrate that winter-acclimatised, mature Merino sheep from southern Australia exhibit heat stress when the wet bulb temperature is approximately 28°C and lambs at approximately 26-27°C.

7. Death of sheep secondary to heat stress during live shipping is not just of concern during "heat wave conditions" but a major cause of mortality during all shipments of sheep across the Equator. It is apparent that even on low mortality shipments, there are extended periods where sheep are suffering significant and prolonged heat stress, which is not acceptable. Further, this can occur at any time of the year when shipments cross the equator, and for that reason the HotStuff Model should be applied to all voyages to the Northern Hemisphere, in all months of the year. Even summer-acclimatised sheep travelling in the cooler months of the Northern Hemisphere are at risk of heat stress crossing the Equator.

8. Heat stress is not just a phenomenon in sheep. In this submission the AVA refers to a high mortality event involving cattle travelling to China in 2018, and thus a heat stress risk assessment must be completed for all classes of livestock travelling to any destination requiring the ship to cross the Equator. This is because wet bulb temperatures at which heat stress occurs in sheep and cattle are found (a) in equatorial regions in all months of the year and, (b) in regions other than the Middle East.

9. Until now, prolonged exposure of sheep and cattle to relentless heat and humidity has been accepted as being part of a "normal" voyage because mortality rate was the only trigger for investigation on any voyage. A paradigm shift is required to look at the accumulated morbidity data and realise that this extended exposure to prolonged heat stress over days to weeks is an issue in and of itself, irrespective of mortalities.

10. Space allocation per animal must be based on allometric principles and increased by at least 30% for sheep that weigh 40 to 60 kg (based on a *k*-value of 0.033). The typical sheep sent to the Middle East is an adult Merino wether in this weight range. This increase in space ($k = 0.033$) is the minimum amount needed to alleviate adverse welfare outcomes, and must be implemented across all body weights and all months of the year.

11. The recommended approach for heat stress risk assessment going forward is to determine likely WBTs for locations throughout the voyage including discharge points, based on historical and predicted meteorological data. If the predicted environmental WBTs are likely to exceed the calculated HST for the particular group of animals, the conclusion should be that the voyage does not proceed. Where there is insufficient or inconclusive meteorological data, the precautionary principle should always be employed to ensure the welfare of the animals is prioritised. Certain times of the year are a known risk (May to October) and thus voyages carrying sheep to the Middle East during this period cannot be recommended. Similarly, extreme caution should be employed when assessing the risk of any shipment of any species of livestock across the equator, in all months of the year.

Introduction

Previous submissions

The AVA has tendered two previous detailed submissions which provide background information for this current document. The first of these was the AVA's submission to the McCarthy review, which contains information on space allocation, thermoregulation and heat stress in sheep (AVA 2018a). The second is the AVA's submission to the ASEL Stage 2 Issues Paper, in which the AVA has recommended recording of more environmental and animal data on each voyage with a view to making immediate, continuous and ongoing improvements to animal welfare on every future voyage (AVA 2018b).

Current submission – data sources

Export of livestock from Australia by ship has been occurring since the 1960s. Nevertheless, it has been observed that there is "*insufficient independent science*" examining heat stress during shipping of sheep from southern Australia, and "*high mortality events associated with heat load continue to occur*" (Collins, Hampton et al. 2018). In light of this, the AVA has used primary evidence from shipboard daily reports and end of voyage reports available through freedom of information (FOI)[1], Mortality Investigation Reports[2], peer-reviewed literature, and reports funded by the livestock industry to inform this response.

Heat Stress Risk Assessment Model (HotStuff)

When voyages are being planned from Australia to or through the Middle East, a Heat Stress Risk Assessment (HSRA) is undertaken using the HotStuff model, as part of the export application process. Inputs include predicted weather conditions, animal physiology, ship design, ventilation and proposed route. Output from the model is used to manipulate space allocation on ships to provide a less than 2% probability of a 5% *mortality* on the voyage. As the model is currently applied, it is strictly concerned with probability of mortality, so does not account for true suffering due to heat. Currently there is no consideration of the heat stress that animals suffer *in the process leading up to death,* nor does it account for the number of animals that do suffer adverse welfare due to heat stress during the voyage, but do not actually die *en route* (or that do not die immediately, but die of renal failure 5 days after the heat event).

The McCarthy Review[3] has made many recommendations to address these short-comings, including:

- Recommendation 3: Industry should move from a risk assessment based on mortality to a risk assessment based on animal welfare.
- Recommendation 4: As an interim measure, it is recommended that the risk be set at a 2% probability of 5% of the sheep *becoming affected by heat stress* (Heat stress score 3—see **Table 1**). 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.
- Recommendation 7: 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.
- Recommendation 8: 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.

[1] Source: http://www.agriculture.gov.au/about/reporting/foi/disclosure_log

[2] Mortality Investigation Reports source: http://www.agriculture.gov.au/export/controlled-goods/live-animals/livestock/regulatory-framework/compliance-investigations/investigations-mortalities

[3] Source: http://www.agriculture.gov.au/SiteCollectionDocuments/biosecurity/export/live-animals/mccarthy-report.pdf

The AVA contends that a major shift in thinking is required in the application of the HotStuff model.

Currently, the model is used only to determine space allocation for the intended voyage, in order to reduce mortality risks. The Heat Stress Threshold (HST) values that are generated by the HotStuff calculations are not being utilised to help predict likelihood of sheep suffering clinical heat stress, and we feel this is a fundamental flaw in the process. We note a similar observation was made by Ferguson et al. (2008):

"*Consideration should also be given to utilising the HST values that have been developed, but not actually applied in the output and use of the HotStuff model*".

The AVA believes that the HotStuff model should be used as a preventative tool: to predict the risk of heat stress occurring, and determine *if indeed the ship should sail*. **Put simply, where calculations show that environmental Wet Bulb Temperatures (WBTs) are going to exceed the calculated HST for the particular group of animals, the conclusion should be that the voyage does not proceed.**

This concept is expanded later in this document.

The remainder of this submission addresses the sequential questions posed *en bloc* in the Issues Paper.

Issues Paper Section 3: Questions about mortality limit and heat stress threshold:

Note: Please provide rationale and evidence to support your position.

How should the effects of heat on animals be defined?

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

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?)

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?

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?

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

Answer

Table 1 below provides definitions of heat stress categories according to the AVA, and empirical measures of heat stress in sheep.

The level of heat load that is acceptable will depend on the severity and duration of the heat stress event, as well as the influence of other stressors that sheep may be exposed to concurrently. Based on principles of thermoregulatory physiology, the AVA recommends that the line dividing Heat Stress Scores 2 and 3 is the point beyond which sheep should not be exposed during any voyage. In other words, sheep should never be exposed to HST 3. Sheep should not be exposed to HST 2 for more than 3 consecutive days where there is no diurnal variation during any voyage. This duration of permissible exposure should be further reduced in the presence of other welfare imposts and/or co-morbidities. This is expanded in the next section – "Discussion".

Table 1. The AVA's proposed method to define effects of heat stress in sheep, modified from (McCarthy 2018) and (Stockman 2006). The line dividing Heat Stress Scores 2 and 3 is the point beyond which sheep should not be exposed during any voyage. Sheep should not be exposed to Heat Stress Score 2 for more than 3 days during any voyage.

Heat Stress Score (Heat Stress Threshold/HST*)	Panting Score & Respiratory character	Respiratory Rate (RR)	Approximate body temperature (°C)	Extrapolated percentage of ML within the HSRA model
0—Normal resting➔active	0—Normal respiration resting➔active	15–35➔70	39	0
1—Mild heat stress (HST 1)	1—Increased respiratory rate	70–100	39.5+	0–35
2—Moderate heat stress (HST 2)	2—Panting	100–160	40+	36–75
3—Severe heat stress (HST 3)	3—Open mouth panting; laboured respiration	160–220	40.5+	**76–85**
4—Near death	4—Open mouth panting with tongue out; Extremely laboured respiration	Usually second stage	41+	86–100

***See Table 2 for definitions of HST.**

Discussion

The HotStuff model estimates for *heat stress threshold* (HST) (Maunsell-Australia 2003, Stacey 2006, Stockman 2006) and *mortality limit* (ML) (Ferguson, Fisher et al. 2008) appear reasonable when sheep are exposed to a certain wet bulb temperature for a short time, and then are returned to a thermoneutral wet bulb temperature which allows restoration of normal physiological functions through innate thermoregulatory mechanisms (AVA 2018a). However, the model does not take into account duration of exposure to heat, nor lack of diurnal variation and thus the impacts of cumulative heat load. Further, the HotStuff model is not currently applied as intended, to predict risk of heat stress during a voyage; instead it is used to assess *heat stress mortality risk* in order to determine space allocation on ships.

McCarthy's summary of heat stress definitions and indicators [Table 1 of the McCarthy Review (McCarthy 2018)] requires modifications (as set out in **Table 1** above) in consideration of the following:

- The resting respiratory rate for sheep ranges between 16 and 34 breaths per minute (Fielder 2016).
- As a practical indicator of the onset of heat stress, respiratory rates in sheep will exceed 70 breaths per minute (Radostits, Gay et al. 2007).
- Results of studies performed in sheep under controlled conditions (Stockman 2006) which are explained in more detail below.

Findings from Doctoral research: The physiological and behavioural responses of sheep exposed to heat load within intensive sheep industries (Stockman 2006)

Figure 1 following shows results from exposure of ***winter-acclimatised*** mature Merino wethers to prolonged periods of elevated temperature and humidity (Stockman 2006).

Two out of 6 sheep reached HST3 within a day of continual exposure to at least 28°C (i.e. nil diurnal variation). At this stage, respiratory rates were 140-220 breaths/minute, sheep were open-mouth panting, and some had tongues hanging out. The rectal temperature in the two worst affected sheep reached 40.5°C and they were removed from the climate-controlled room on the evening of the same day "*in consideration of the well-being of the animal*", as directed by the Murdoch University Animal Ethics Committee. One wether was removed 3 days after the beginning of exposure and three wethers were removed 4 days after WBT first reached 28°C. This clearly demonstrates that there is variation amongst sheep in their ability to compensate for increasing WBT.

Note that the sheep used in this study were housed in individual pens with individual feed and water buckets, good ventilation, on land rather than at sea. Sheep had room to turn around and lie down (e.g. 56 kg sheep, 0.88 m^2 pen size gives *k* value of 0.062), wool length was < 25 mm and they were winter acclimatised. Sheep on a ship are not individually penned, under ASEL (version 2.3, 2011) have approximately half the space allocation of the studies described by Stockman (2006), the decks are variably ventilated and the ship is moving. Australian sheep being shipped to the Middle East in May-October are similarly *winter*-acclimatised.

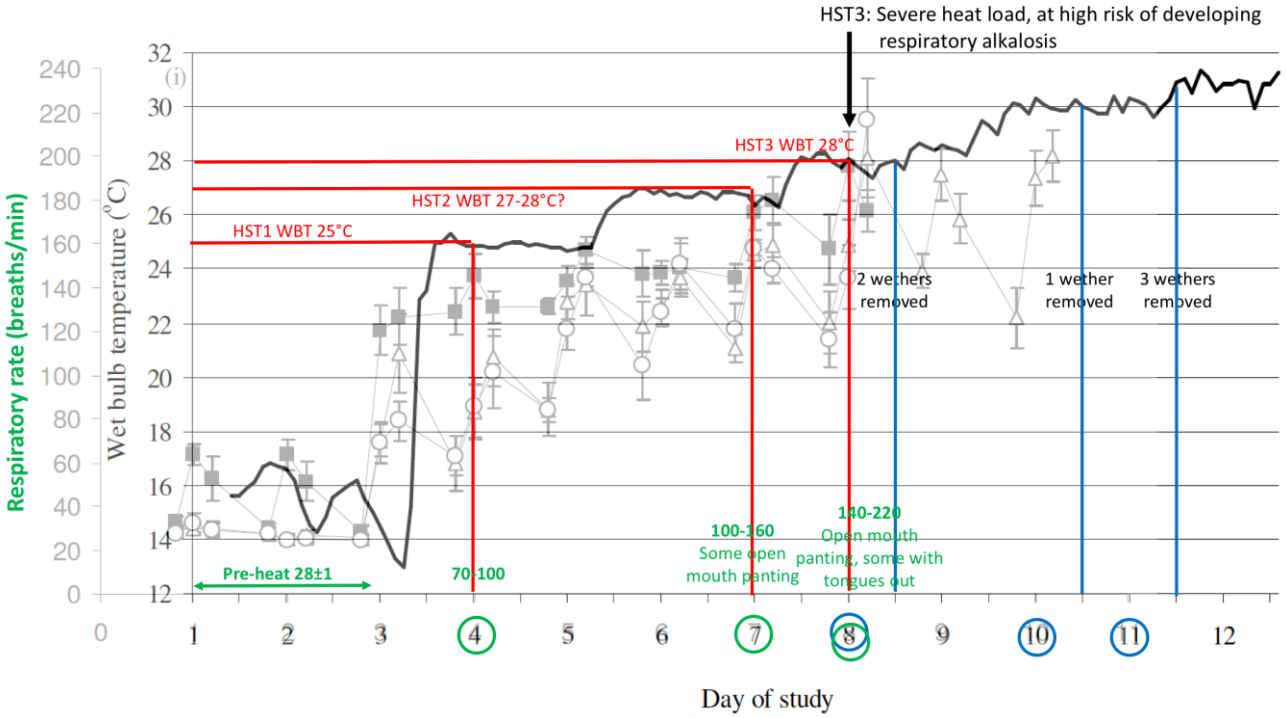


Figure 1. Environmental wet bulb temperature (WBT; °C; solid black line) measured 2-hourly, and mean respiratory rate (breaths/minute; O ; mean±SEM) measured at 0700, 1300 and 1600 hours in winter-acclimatised mature Merino wethers (n=6, approx. 4 years old, 56 kg) housed individually in a climate-controlled room with space allocation *k*-value of 0.062. Red lines indicate the wet bulb temperature and day at which heat stress thresholds (HST) 1, 2 and 3 were reached (terms defined in Table 2 below). Green numbers/circles indicate respiratory rates on particular days described in the experiment. Wethers were removed from the controlled-climate room on the evening of the day when rectal temperature reached 40.5°C (blue lines/circles), "in consideration of the well-being of the animal" (adapted from Stockman 2006). Other grey markers (Δ and ■) belong to adult and lamb Merino rams respectively. The two graphs used in this figure were taken from Stockman (2006), superimposed, and comments and coloured lines added.

Table 2. Definitions of heat stress thresholds (HST; based on Stockman 2006) that align with Table 1 above.

	Heat stress threshold definition
HST 1	The daily mean wet bulb temperature on the day that the daily mean core body temperature first significantly increases over pre-heat values
HST 2	The daily mean wet bulb temperature on the day that the daily mean core body temperature first significantly increases 0.5°C above pre-heat values
HST 3	The daily mean wet bulb temperature on the day that the daily mean core body temperature first significantly increases 1°C above pre-heat values

What is a reasonable duration of exposure to mild, moderate and severe heat stress?

Sheep should never be exposed to HST 3 during any voyage. Sheep should not be exposed to HST 2 for more than 3 consecutive days where there is no diurnal variation in temperature. Diurnal variation allows sheep to return to their thermoneutral zone and for respiratory rates to return to resting range at night. Otherwise, sheep can start dying within 3 days of being exposed to hot, humid weather, as heat load is cumulative. This duration of permissible exposure should be further reduced in the presence of other welfare imposts and/or co-morbidities.

It is inappropriate for sheep or any other animals to be exposed to long periods of heat stress as it interferes with normal physiological processes. The pathogenesis of heat stress is summarised in **Figure 2**. In the field, sheep which are exposed to heat stress require early and vigorous intervention to reduce body temperature and replace lost fluids and electrolytes. This sort of treatment is unrealistic on a ship travelling from Australia to the Middle East carrying 70,000 sheep.

Additionally, less than optimal conditions during any voyage (including stressors such as inappropriate space allocation, feed and water accessibility, ventilation and air quality, bedding, deck instability) and any other co-morbidities (e.g. concurrent diarrhoea and/or respiratory disease) will have an additive effect and sheep will be even more susceptible to heat stress. This will result in a lowering of their heat stress threshold, and also reduce the duration of exposure that they can endure. Hence these additional welfare imposts must be considered when assessing risk of any voyage.

This is consistent with the 5 Domains approach to assessing welfare which looks at animals' needs in 5 domains of potential welfare compromise (Mellor and Beausoleil 2015). Based on the 5 Freedoms, but an expansion of this concept, the 5 Domains looks at the **severity** of the welfare compromise, and **how long** the animals might experience it. It also assesses the anticipated **integrated** impact of the combined insults from each domain on the animal's mental state. Domains 1-4 assess functional compromise (nutrition, environment, health and behaviour, based on physiological measurements). Based on the severity and duration of functional disruption in the first 4 domains, it is possible to assess the likely intensity of negative experiences in the mental domain (Domain 5), which represents the summation of the animal's experience.

The 5 Domains approach recognises that elements of good welfare may co-exist with elements of reduced or poor welfare:

- Animals that have a good welfare status because needs are being met in most of the 5 domains are likely to tolerate relatively minor compromise in another domain
    - E.g. short term hunger in an animal that is otherwise healthy
- Conversely, strong negative sensations elicited in one domain may completely dominate those from other domains e.g. severe breathlessness, severe pain.

An animal suffering mild to moderate heat stress may cope if the duration of the stress is limited (and particularly if there is diurnal variation that gives periodic respite), and there are no other welfare impacts affecting the animal (e.g. an animal in its normal environment that is otherwise healthy). However, where there is additional welfare compromise due to the abnormal ship-board environment (deck movement, poor air quality and ammonia, feed and water restrictions, behavioural stressors from mixing with unfamiliar animals with low space allocation, fear of humans, inanition, illness, inability to rest etc.) the combined impact may be far greater. The animal's experience is determined by the integrated impact of all these imposts on the animal.

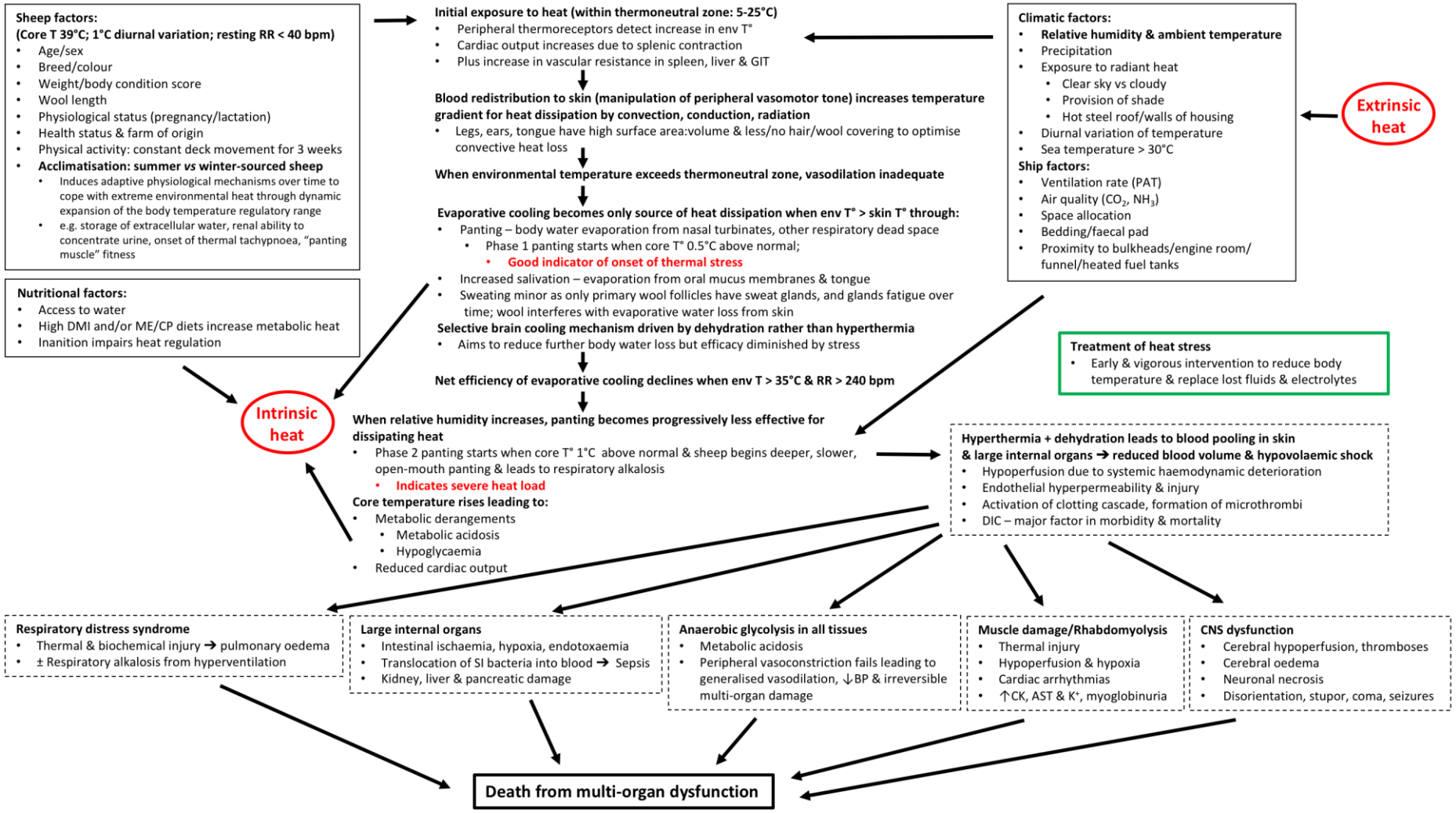


Figure 2. Pathogenesis of heat stress in sheep.

The HotStuff model does not take into account (a) duration of exposure to high WBT nor (b) lack of diurnal WBT variation nor (c) potential for repeat high WBT challenges (e.g. known high risk zones include sailing through the Strait of Hormuz and discharge of livestock at Qatar, UAE and Oman). The model needs to be modified to predict prolonged exposure to elevated wet bulb temperatures but it is beyond the capacity of the AVA to comment how mathematically this may be achieved in the HotStuff model.

In **Table 1** above, the line dividing Heat Stress Scores 2 and 3 is the point beyond which sheep should not be exposed during any voyage. When winter-acclimatised mature Merino wethers are exposed to HST3 in a climate controlled room or on a ship, they exhibit clinical signs of severe heat stress (extended head and neck, open mouth breathing, with or without protruding tongue) within approximately 24 hours (**Figure 1** above). Respiratory rates are likely to exceed 160 breaths/minute and body temperature increases by at least 1°C above the normal range (Stockman 2006), consistent with significantly impaired health (Radostits, Gay et al. 2007). Some sheep may take some days longer to show clinical signs consistent with HST3 (**Figure 1** above). These clinical signs are indicative of pathophysiological disturbances due to adverse environmental conditions and result in a significantly compromised welfare state.

Additionally, sheep should not be exposed to Heat Stress Score 2 for more than 3 days during any voyage. Three days of Heat Stress Score 2 is only acceptable if there is diurnal variation which allows some reprieve and for respiratory rates to drop back to normal (35) at night. Otherwise, sheep can start dying within 3 days of being exposed to hot, humid weather. This is likely to be sooner where other welfare insults and/or co-morbidities exist.

An example recorded in Mortality Investigation Report (MIR) 65

It was observed that "*the first heat related death*" on a ship travelling from Australia to the Middle East in July 2016 occurred 3 days (Day 7) after the onset of "*the first hot and humid weather … encountered*" (Day 4 of voyage from Fremantle, as reported in MIR 65)[4]. For this journey, mean wet bulb temperatures across all decks of the ship for the days leading up to and including the first deaths from heat stress are shown in **Table 3**. The End of Voyage Report for this voyage noted "*heat stress levels rising to high 2 scores at night from day 4 onwards until the Arabian Gulf (day 13)*" (FOI 2016/17-75 Document 24), *prior to* the heat stress event that precipitated an investigation (mortalities > 2%). In other words, sheep were dying from heat stress for a week before the high mortality event that triggered the investigation. This voyage is described more fully in **Table 5** and **Figure 15** in the section on "HSRA Settings".

Table 3. Mean wet bulb temperature (WBT, °C) across all decks of a ship during a voyage from Fremantle to the Middle East in July 2016. The Mortality Incident Report 65 stated that "*The first hot and humid weather was encountered on Day 4. Sheep were visibly affected and began to pant… The first heat related death was reported on Day 7.*"[1] The End of Voyage Report for this voyage noted "*heat stress levels rising to high 2 scores at night from day 4 onwards until the Arabian Gulf (day 13)*" (FOI 2016/17-75 Document 24).

Day of voyage	Mean WBT (°C)	Comments
1	18.3	Ship departed Fremantle
2	22.8	
3	24.9	
4	28.5	Sheep first visibly affected by hot humid weather
5	28.3	
6	28.7	
7	28.7	First heat-related death recorded

[4] Source: http://www.agriculture.gov.au/export/controlled-goods/live-animals/livestock/regulatory-framework/compliance-investigations/investigations-mortalities/sheep-qatar-kuwait-uae-oman-report-65

What is happening on any voyage?

Sheep being shipped to the Middle East between May and October are exposed to many consecutive days of temperatures at or exceeding their heat stress thresholds. The following sections are included to illustrate the general route of ships from Australia to the Middle East and examples of wet bulb temperatures outside (ambient) and on the decks, sea temperature, respiratory rates in sheep on different days of the voyage.

Figure 3 is included to roughly illustrate the course and duration of any live animal export ship from Adelaide and Fremantle to the Middle East (Maunsell-Australia 2004).

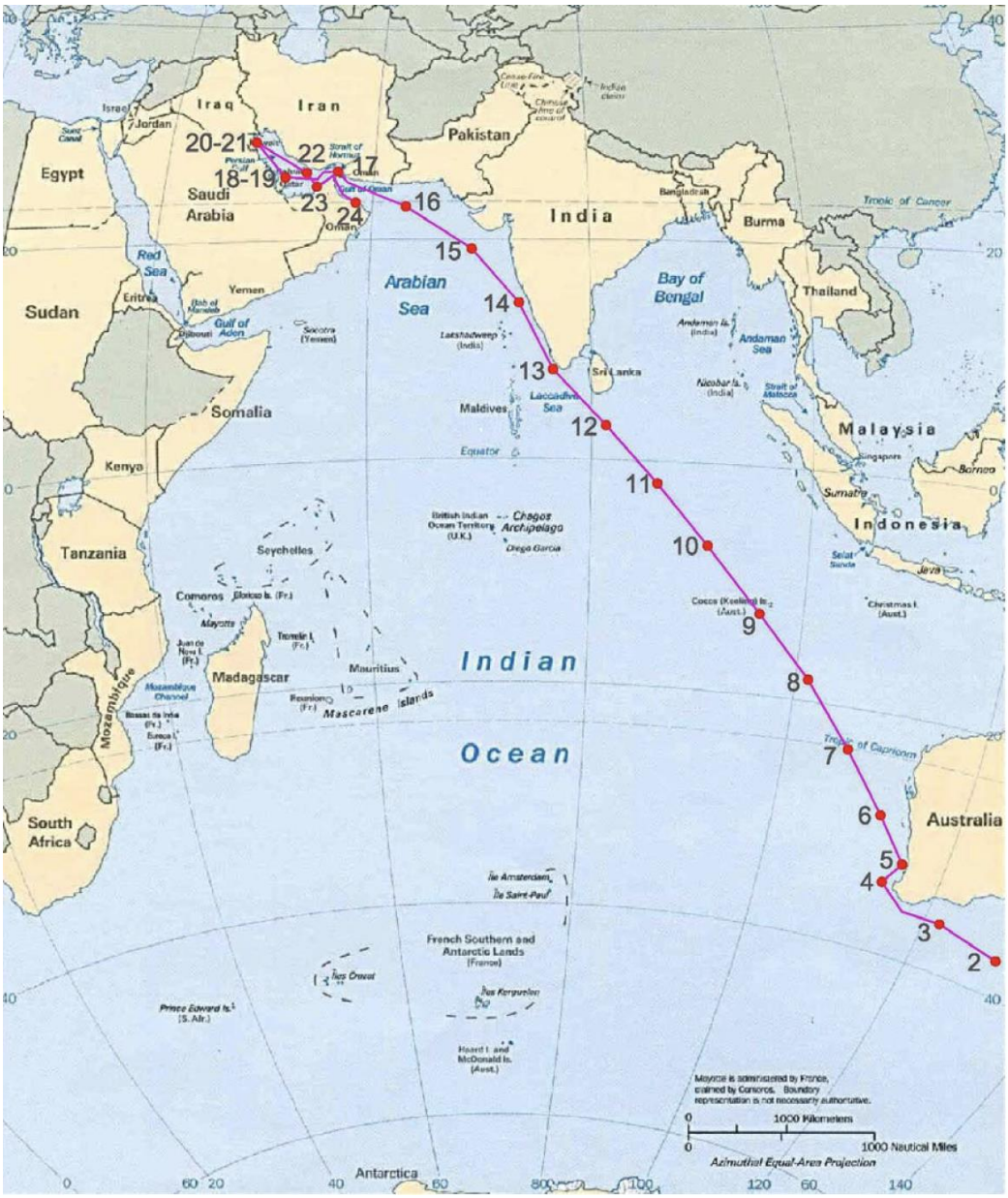
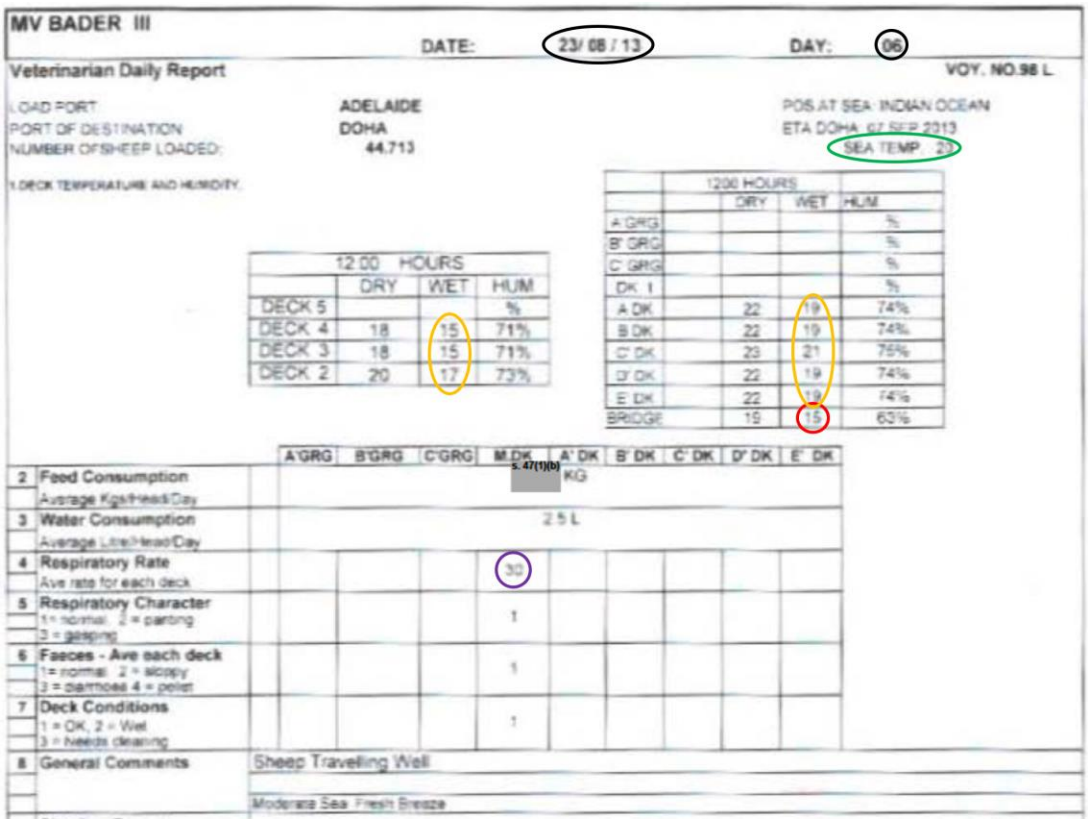


Figure 3. Example of daily noontime positions of a ship used for live export of stock from Adelaide and Fremantle to the Middle East in June-July 2002 (Maunsell-Australia 2004).

Extracts of Veterinary Daily Reports follow to illustrate changing conditions during a voyage

Figures 4-9 following are from a different voyage to that described in **Figure 3** above, and show sea temperatures, ambient (bridge) and deck wet bulb temperatures and sheep respiratory rates as each ship approaches the Equator from Fremantle (Source: FOI2013/14-51). Sea temperature is important because it impedes diurnal variation on any ship as the steel hull is immersed in a vast thermal sink of the Indian Ocean. Unfortunately, better quality images are not available.

Use the map above to get a rough idea of where a ship is during its journey across the Indian Ocean on any particular day, when reading the reports below (remember that they are different voyages). Note the increasing ambient and deck WBTs, sea temperatures and respiratory rates of sheep as the ship approaches and crosses the Equator.



MV BADER III

DATE: 23/ 08 / 13 DAY: 06

Veterinarian Daily Report

VOY. NO.98 L

LOAD PORT: ADELAIDE
PORT OF DESTINATION: DOHA
NUMBER OF SHEEP LOADED: 44,713

POS AT SEA: INDIAN OCEAN
ETA DOHA: 07 SEP 2013
SEA TEMP: 23

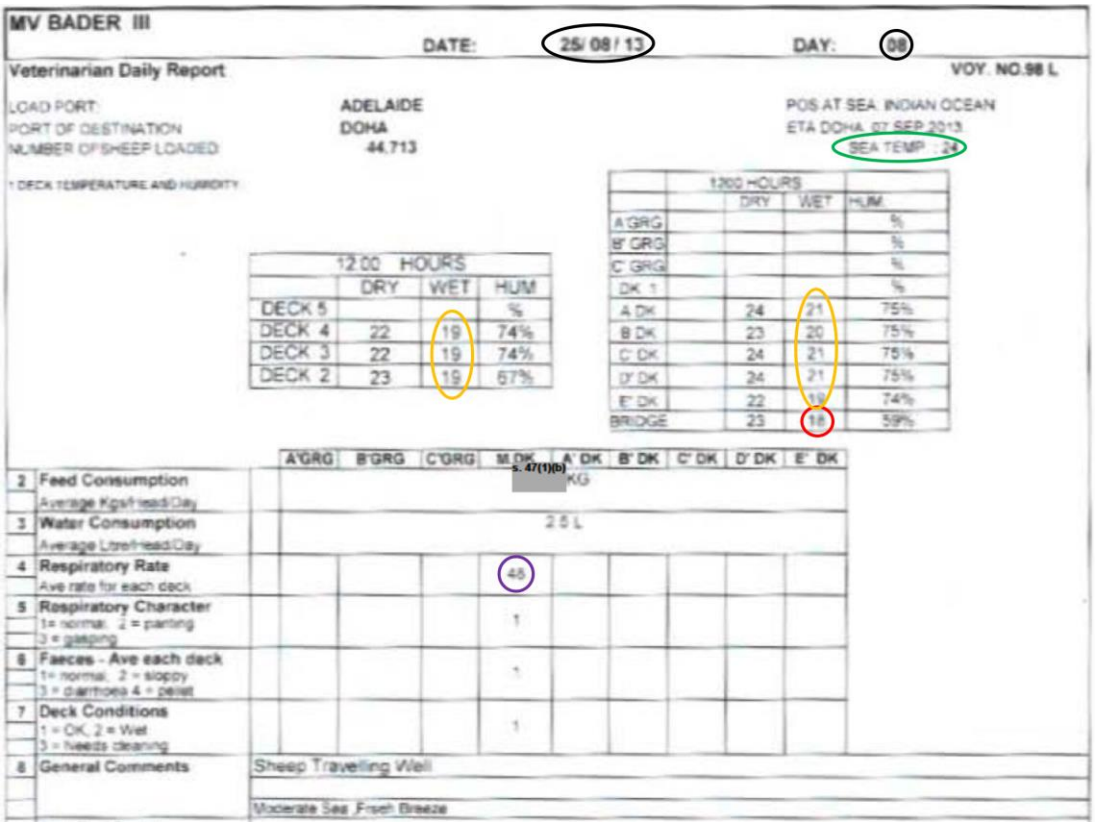
1 DECK TEMPERATURE AND HUMIDITY

12.00 HOURS	DRY	WET	HUM
DECK 5			%
DECK 4	18	15	71%
DECK 3	18	15	71%
DECK 2	20	17	73%

1200 HOURS	DRY	WET	HUM
A GRG			%
B GRG			%
C GRG			%
DK 1			%
A DK	22	19	74%
B DK	22	19	74%
C DK	23	21	75%
D DK	22	19	74%
E DK	22	19	74%
BRIDGE	19	15	63%

		A'GRG	B'GRG	C'GRG	M.DK	A' DK	B' DK	C' DK	D' DK	E' DK
2	Feed Consumption Average Kgs/Head/Day				s. 47(1)(b) KG					
3	Water Consumption Average Litre/Head/Day				2.5 L					
4	Respiratory Rate Ave rate for each deck				30					
5	Respiratory Character 1= normal 2 = panting 3 = gasping				1					
6	Faeces - Ave each deck 1= normal 2 = sloppy 3 = diarrhoea 4 = pellet				1					
7	Deck Conditions 1 = OK, 2 = Wet 3 = Needs cleaning				1					
8	General Comments	Sheep Travelling Well Moderate Sea Fresh Breeze								

Figure 4. Day 6 data from a live export ship sailing from Adelaide to Doha in August-September 2013, showing sea temperature (20°C; green circle), wet bulb temperature on the bridge (15°C; red circle), wet bulb temperatures on open (2-5) and enclosed (A-E) decks (orange circles) and respiratory rates of sheep (30 bpm; purple circle) (source FOI2013/14-51).



MV BADER III

DATE: 25/ 08 / 13 DAY: 08

Veterinarian Daily Report

VOY. NO.98 L

LOAD PORT: ADELAIDE
PORT OF DESTINATION: DOHA
NUMBER OF SHEEP LOADED: 44,713

POS AT SEA: INDIAN OCEAN
ETA DOHA: 07 SEP 2013
SEA TEMP: 24

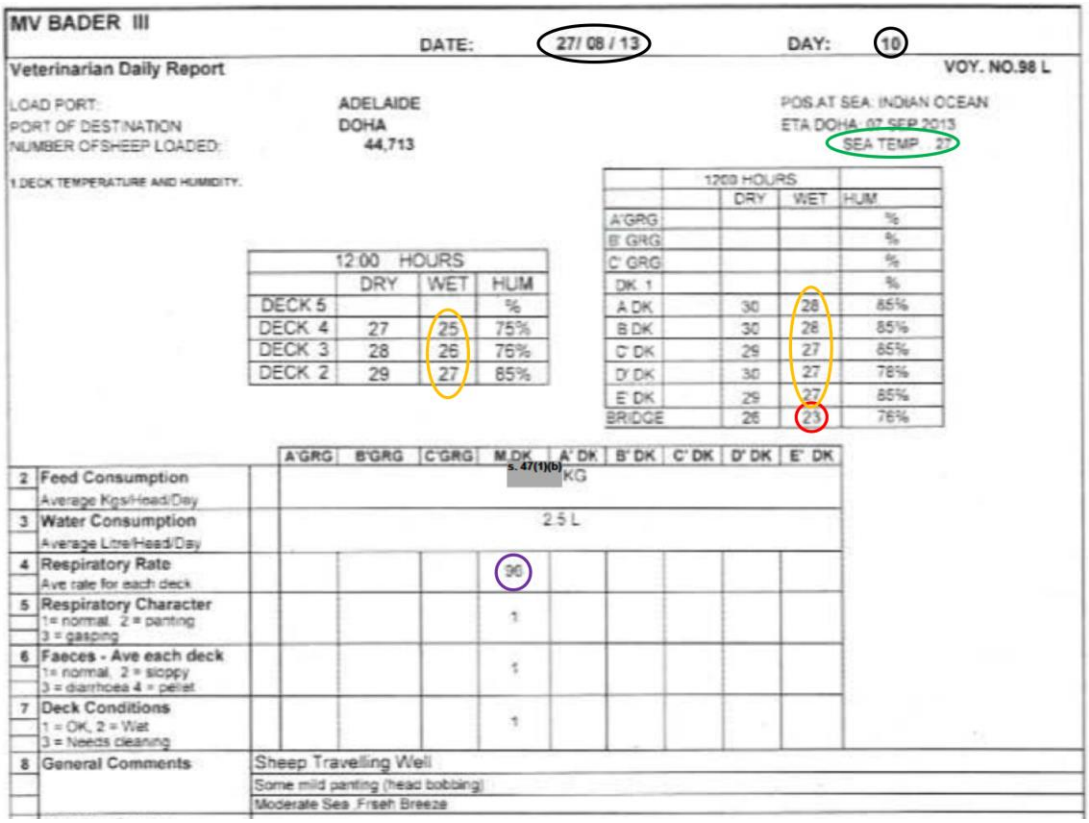
1 DECK TEMPERATURE AND HUMIDITY

12.00 HOURS	DRY	WET	HUM
DECK 5			%
DECK 4	22	19	74%
DECK 3	22	19	74%
DECK 2	23	19	67%

1200 HOURS	DRY	WET	HUM
A GRG			%
B GRG			%
C GRG			%
DK 1			%
A DK	24	21	75%
B DK	23	20	75%
C DK	24	21	75%
D DK	24	21	75%
E DK	22	19	74%
BRIDGE	23	18	59%

		A'GRG	B'GRG	C'GRG	M.DK	A' DK	B' DK	C' DK	D' DK	E' DK
2	Feed Consumption Average Kgs/Head/Day				s. 47(1)(b) KG					
3	Water Consumption Average Litre/Head/Day				2.5 L					
4	Respiratory Rate Ave rate for each deck				48					
5	Respiratory Character 1= normal 2 = panting 3 = gasping				1					
6	Faeces - Ave each deck 1= normal 2 = sloppy 3 = diarrhoea 4 = pellet				1					
7	Deck Conditions 1 = OK, 2 = Wet 3 = Needs cleaning				1					
8	General Comments	Sheep Travelling Well Moderate Sea Fresh Breeze								

Figure 5. Day 8 data from a live export ship sailing from Adelaide to Doha in August-September 2013, showing sea temperature (24°C; green circle), wet bulb temperature on the bridge (18°C; red circle), wet bulb temperatures on open (2-5) and enclosed (A-E) decks (orange circles) and respiratory rates of sheep (48 bpm; purple circle) (source FOI2013/14-51).



MV BADER III

DATE: 27/ 08 / 13 DAY: 10

Veterinarian Daily Report VOY. NO.98 L

LOAD PORT: ADELAIDE
PORT OF DESTINATION DOHA
NUMBER OFSHEEP LOADED: 44,713

POS.AT SEA: INDIAN OCEAN
ETA DOHA: 07 SEP 2013
SEA TEMP : 27

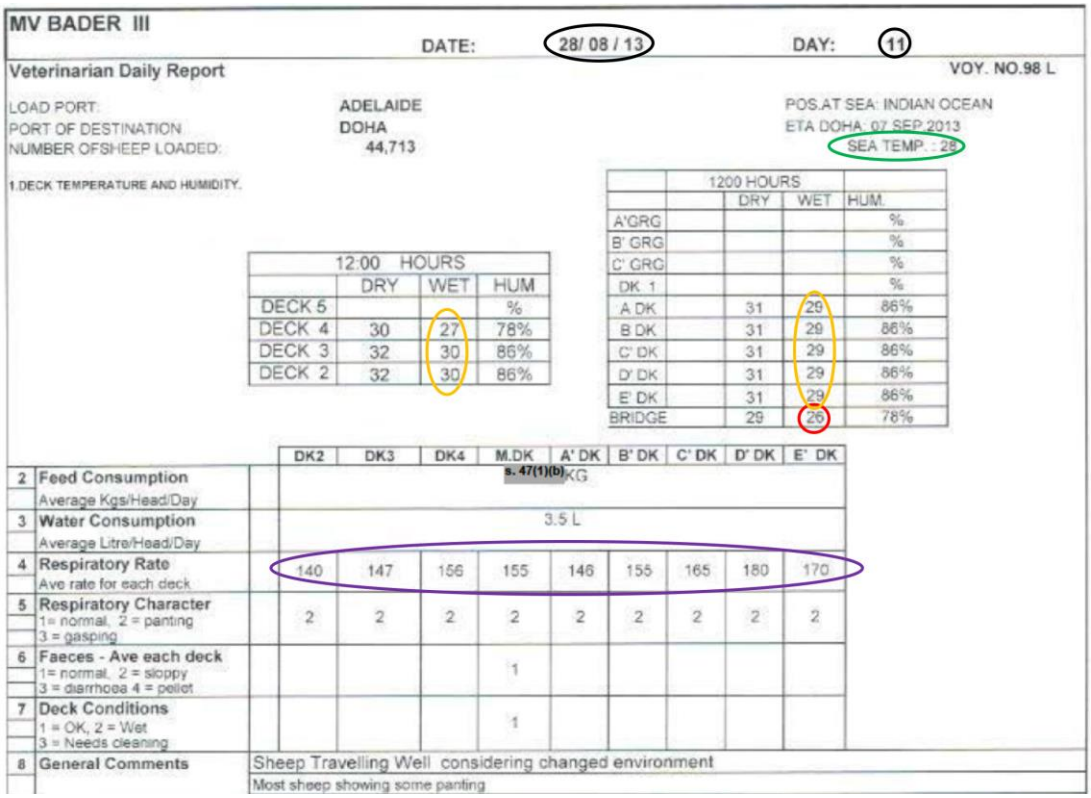
1.DECK TEMPERATURE AND HUMIDITY.

12:00 HOURS	DRY	WET	HUM
DECK 5			%
DECK 4	27	25	75%
DECK 3	28	26	76%
DECK 2	29	27	85%

1200 HOURS	DRY	WET	HUM
A'GRG			%
B' GRG			%
C' GRG			%
DK 1			%
A DK	30	28	85%
B DK	30	28	85%
C' DK	29	27	85%
D' DK	30	27	78%
E' DK	29	27	85%
BRIDGE	26	23	76%

		A'GRG	B'GRG	C'GRG	M.DK	A' DK	B' DK	C' DK	D' DK	E' DK
2	Feed Consumption Average Kgs/Head/Day				s. 47(1)(b) KG					
3	Water Consumption Average Litre/Head/Day				2.5 L					
4	Respiratory Rate Ave rate for each deck				96					
5	Respiratory Character 1= normal, 2 = panting 3 = gasping				1					
6	Faeces - Ave each deck 1= normal, 2 = sloppy 3 = diarrhoea 4 = pellet				1					
7	Deck Conditions 1 = OK, 2 = Wet 3 = Needs cleaning				1					
8	General Comments	Sheep Travelling Well Some mild panting (head bobbing) Moderate Sea ,Fresh Breeze								

Figure 6. Day 10 data from a live export ship sailing from Adelaide to Doha in August-September 2013, showing sea temperature (27°C; green circle), wet bulb temperature on the bridge (23°C; red circle), wet bulb temperatures on open (2-5) and enclosed (A-E) decks (orange circles) and respiratory rates of sheep (96 bpm; purple circle) (source FOI2013/14-51).



MV BADER III

DATE: 28/ 08 / 13 DAY: 11

Veterinarian Daily Report VOY. NO.98 L

LOAD PORT: ADELAIDE
PORT OF DESTINATION DOHA
NUMBER OFSHEEP LOADED: 44,713

POS.AT SEA: INDIAN OCEAN
ETA DOHA: 07 SEP 2013
SEA TEMP : 28

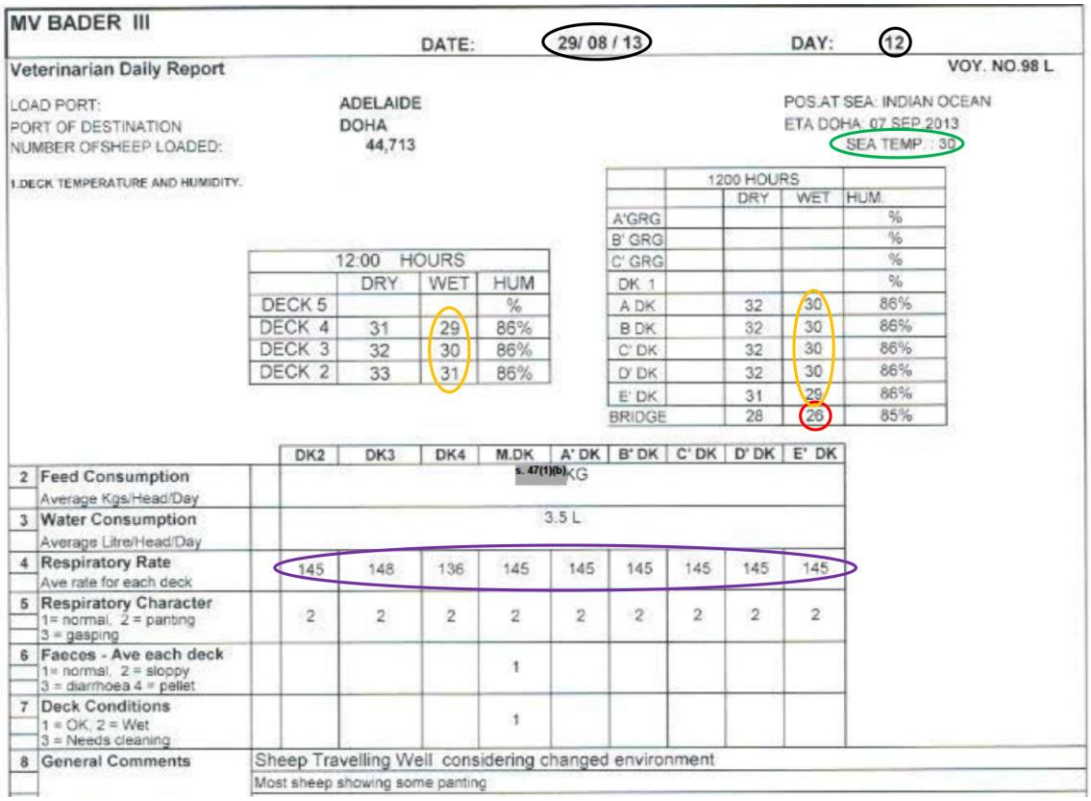
1.DECK TEMPERATURE AND HUMIDITY.

12:00 HOURS	DRY	WET	HUM
DECK 5			%
DECK 4	30	27	78%
DECK 3	32	30	86%
DECK 2	32	30	86%

1200 HOURS	DRY	WET	HUM
A'GRG			%
B' GRG			%
C' GRG			%
DK 1			%
A DK	31	29	86%
B DK	31	29	86%
C' DK	31	29	86%
D' DK	31	29	86%
E' DK	31	29	86%
BRIDGE	29	26	78%

		DK2	DK3	DK4	M.DK	A' DK	B' DK	C' DK	D' DK	E' DK
2	Feed Consumption Average Kgs/Head/Day				s. 47(1)(b) KG					
3	Water Consumption Average Litre/Head/Day				3.5 L					
4	Respiratory Rate Ave rate for each deck	140	147	156	155	146	155	165	180	170
5	Respiratory Character 1= normal, 2 = panting 3 = gasping	2	2	2	2	2	2	2	2	2
6	Faeces - Ave each deck 1= normal, 2 = sloppy 3 = diarrhoea 4 = pellet				1					
7	Deck Conditions 1 = OK, 2 = Wet 3 = Needs cleaning				1					
8	General Comments	Sheep Travelling Well considering changed environment Most sheep showing some panting								

Figure 7. Day 11 data from a live export ship sailing from Adelaide to Doha in August-September 2013, showing sea temperature (28°C; green circle), wet bulb temperature on the bridge (26°C; red circle), wet bulb temperatures on open (2-5) and enclosed (A-E) decks (orange circles) and respiratory rates of sheep (140-180 bpm; purple circles) (source FOI2013/14-51).



MV BADER III

DATE: 29/ 08 / 13 DAY: 12

Veterinarian Daily Report VOY. NO.98 L

LOAD PORT: ADELAIDE
PORT OF DESTINATION DOHA
NUMBER OFSHEEP LOADED: 44,713

POS.AT SEA: INDIAN OCEAN
ETA DOHA: 07 SEP 2013
SEA TEMP : 30

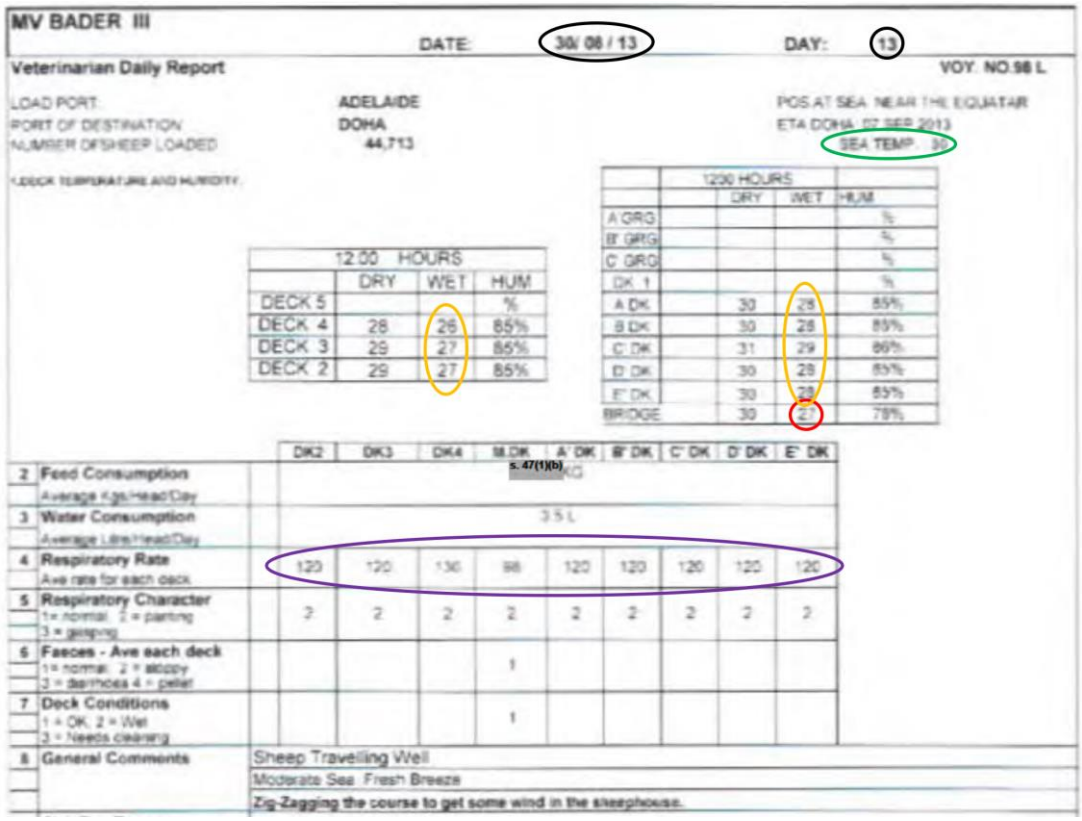
1.DECK TEMPERATURE AND HUMIDITY.

12:00 HOURS	DRY	WET	HUM
DECK 5			%
DECK 4	31	29	86%
DECK 3	32	30	86%
DECK 2	33	31	86%

1200 HOURS	DRY	WET	HUM
A'GRG			%
B' GRG			%
C' GRG			%
DK 1			%
A DK	32	30	86%
B DK	32	30	86%
C' DK	32	30	86%
D' DK	32	30	86%
E' DK	31	29	86%
BRIDGE	28	26	85%

		DK2	DK3	DK4	M.DK	A' DK	B' DK	C' DK	D' DK	E' DK
2	Feed Consumption Average Kgs/Head/Day	s. 47(1)(b) KG								
3	Water Consumption Average Litre/Head/Day	3.5 L								
4	Respiratory Rate Ave rate for each deck	145	148	136	145	145	145	145	145	145
5	Respiratory Character 1= normal, 2 = panting 3 = gasping	2	2	2	2	2	2	2	2	2
6	Faeces - Ave each deck 1= normal, 2 = sloppy 3 = diarrhoea 4 = pellet				1					
7	Deck Conditions 1 = OK, 2 = Wet 3 = Needs cleaning				1					
8	General Comments	Sheep Travelling Well considering changed environment Most sheep showing some panting								

Figure 8. Day 12 data from a live export ship sailing from Adelaide to Doha in August-September 2013, showing sea temperature (30°C; green circle), wet bulb temperature on the bridge (26°C; red circle), wet bulb temperatures on open (2-5) and enclosed (A-E) decks (orange circles) and respiratory rates of sheep (136-148 bpm; purple circles) (source FOI2013/14-51).



MV BADER III

DATE: 30/ 08 / 13 DAY: 13

Veterinarian Daily Report VOY. NO.98 L

LOAD PORT: ADELAIDE
PORT OF DESTINATION DOHA
NUMBER OFSHEEP LOADED 44,713

POS.AT SEA: NEAR THE EQUATAR
ETA DOHA: 07 SEP 2013
SEA TEMP : 30

12:00 HOURS	DRY	WET	HUM
DECK 5			%
DECK 4	28	26	85%
DECK 3	29	27	85%
DECK 2	29	27	85%

1200 HOURS	DRY	WET	HUM
A'GRG			%
B' GRG			%
C' GRG			%
DK 1			%
A DK	30	28	85%
B DK	30	28	85%
C' DK	31	29	86%
D' DK	30	28	85%
E' DK	30	28	85%
BRIDGE	30	27	78%

		DK2	DK3	DK4	M.DK	A' DK	B' DK	C' DK	D' DK	E' DK
2	Feed Consumption Average Kgs/Head/Day	s. 47(1)(b) KG								
3	Water Consumption Average Litre/Head/Day	3.5 L								
4	Respiratory Rate Ave rate for each deck	120	120	120	88	120	120	120	120	120
5	Respiratory Character 1= normal, 2 = panting 3 = gasping	2	2	2	2	2	2	2	2	2
6	Faeces - Ave each deck 1= normal, 2 = sloppy 3 = diarrhoea 4 = pellet				1					
7	Deck Conditions 1 = OK, 2 = Wet 3 = Needs cleaning				1					
8	General Comments	Sheep Travelling Well Moderate Sea Fresh Breeze Zig-Zagging the course to get some wind in the sheephouse.								

Figure 9. Day 13 data from a live export ship sailing from Adelaide to Doha in August-September 2013, showing sea temperature (30°C; green circle), wet bulb temperature on the bridge (27°C; red circle), wet bulb temperatures on open (2-5) and enclosed (A-E) decks (orange circles) and respiratory rates of sheep (120 bpm; purple circles) (source FOI2013/14-51).

Assessing heat stress using physiological parameters

Physiological data has been collected during shipping of sheep and cattle from southern Australia to the Middle East for some years, and has been used to create and update the HotStuff model. The figures below are from industry-generated project reports and are included to illustrate shipboard observations and to direct interested parties to these references. Nevertheless, more data must be collected and collated to improve welfare outcomes for livestock travelling by ship. See the AVA submission to the Stage 2 ASEL Review Issues Paper for further details of recommended welfare indicators (AVA 2018b).

The next three graphs illustrate how rectal temperature and respiratory rates increase with increasing WBT so can be used to assess heat stress in sheep (see **Table 1** above).

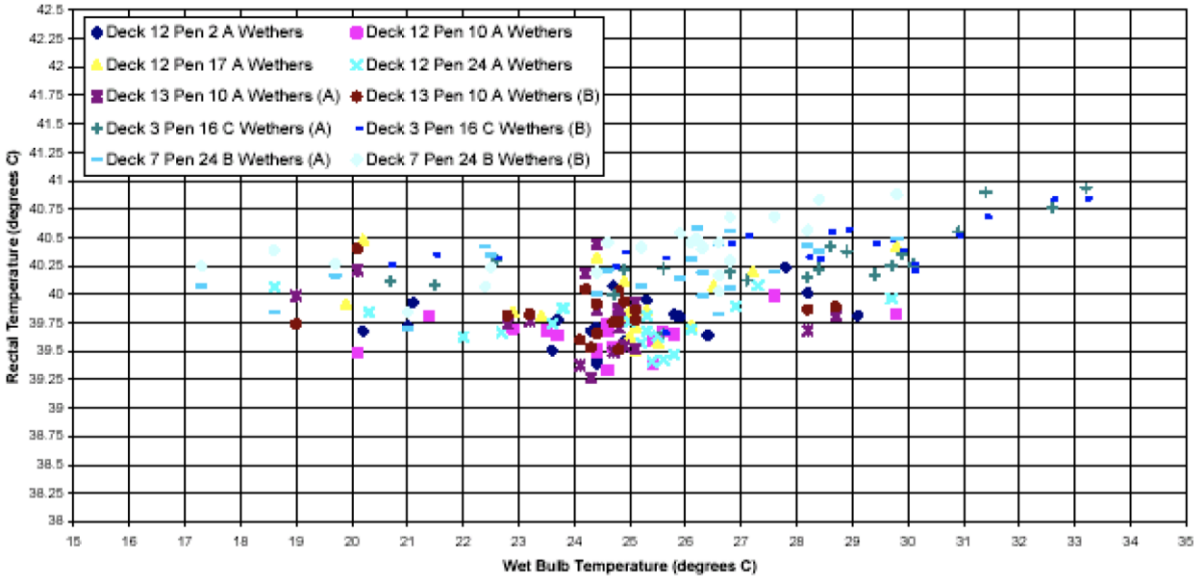


Figure 10. Comparison of rectal temperature with deck wet bulb temperature in a range of winter acclimatised Merino wethers (voyage September 2002) (Maunsell-Australia 2003). This demonstrates that at 28°C WBT, rectal temperatures in sheep ranged from 39.7-40.6°C on this voyage.

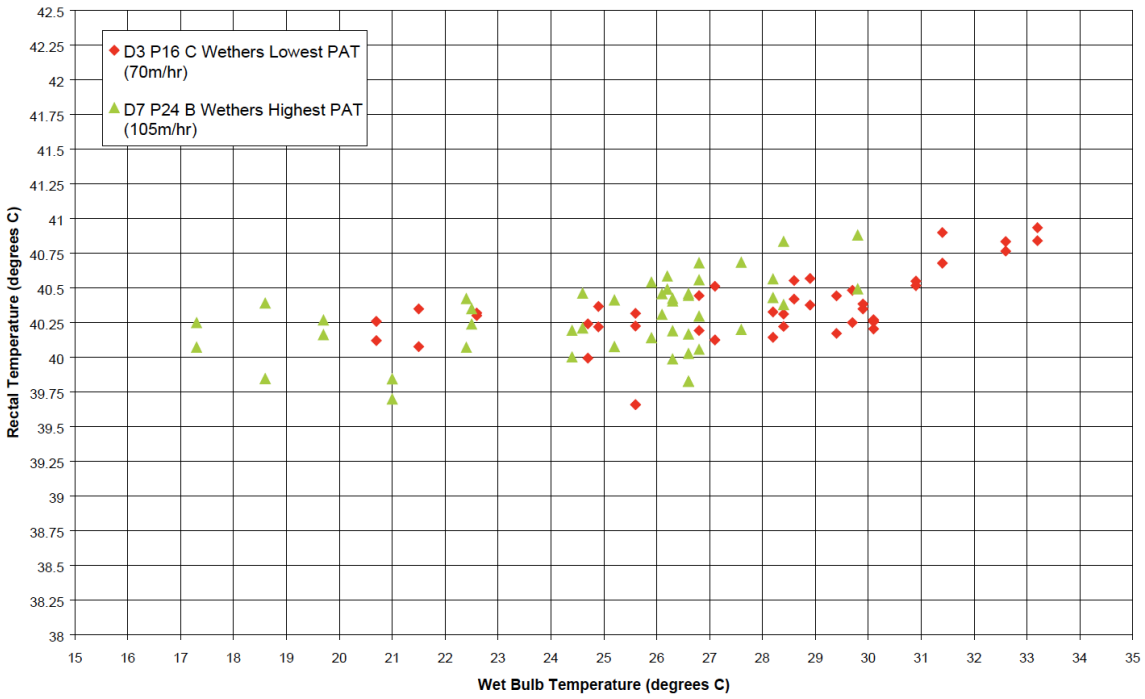


Figure 11. Comparison of rectal temperature with deck wet bulb temperature by pen air turnover (PAT) in a range of winter acclimatised Merino wethers (voyage September 2002) (Maunsell-Australia 2004). This demonstrates that at 28°C WBT, rectal temperatures in sheep ranged from 40.1-40.6°C on this voyage.

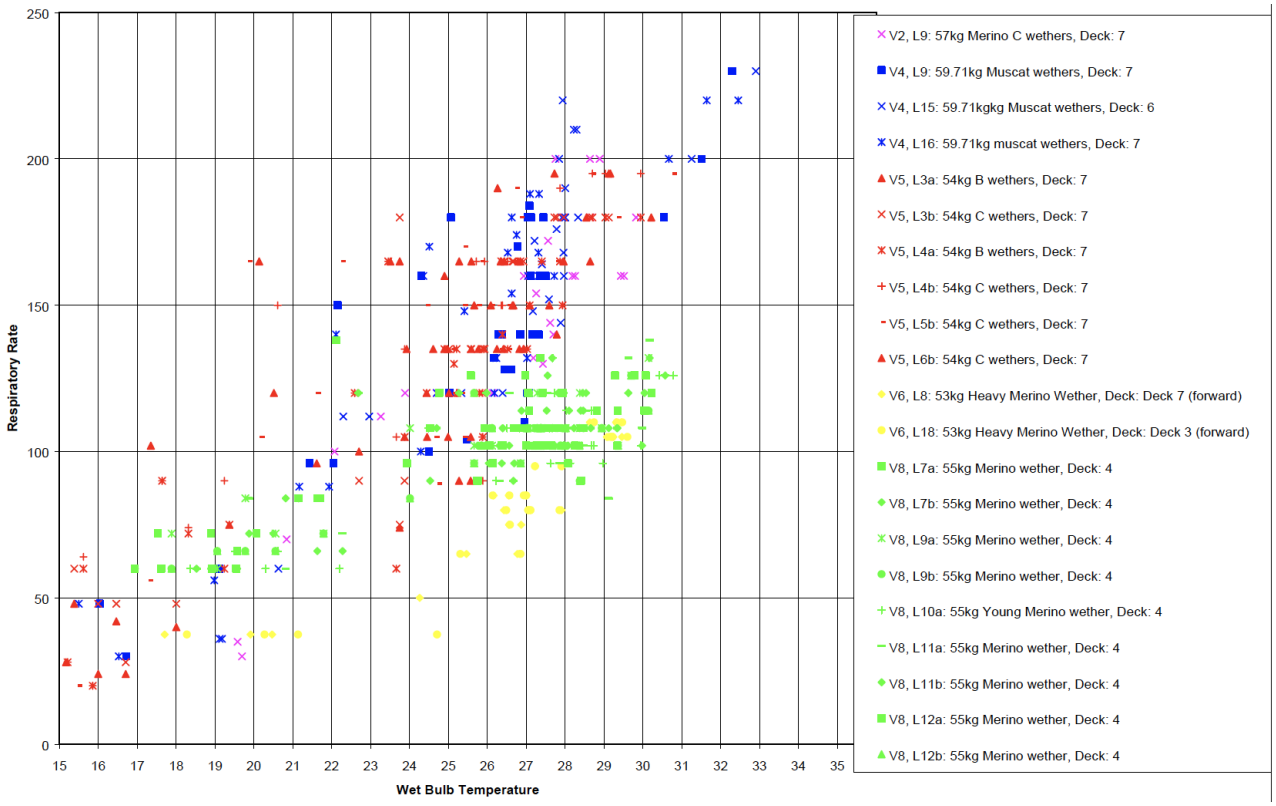


Figure 12. Comparison of respiratory rate with deck wet bulb temperature in a range of winter-acclimatised Merino wethers > 50 kg (Stacey 2006). This demonstrates that at 28°C WBT, respiratory rates in sheep ranged from 80-220 breaths per minute on this voyage.

Issues Paper Section 4.1: Questions about HSRA settings:

Note: Please provide rationale and evidence to support your position.

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

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

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

Answer

The Heat Stress Risk Assessment model, HotStuff, was designed to assess the risk of heat stress occurring in livestock being shipped from Australia; however, this is a misnomer as it is currently only used to assess risk of *mortality*. Nevertheless, the HotStuff model *does* have the capacity to assess risk of heat stress during any voyage and should be used to do so. Livestock attributes (species, breed, age, body weight, body condition, coat length, month and district of origin) and route climatology (average/predicted wet bulb temperatures *en route* and in destination ports) may be entered into the model to predict the wet bulb temperature at which livestock will suffer heat stress during any voyage.

The model does not take into account **duration of exposure** to elevated WBT, **lack of diurnal WBT variation** and **potential for repeat high WBT challenges**, thus the model needs to be modified to cater for prolonged exposure to elevated wet bulb temperatures. Additionally, less than optimal conditions during any voyage (including stressors such as inappropriate space allocation, feed and water accessibility, ventilation and air quality, bedding) as well as any co-morbidities will have an additive effect on lowering the heat stress threshold and duration of exposure that can be endured, and must be considered when evaluating any voyage and discharge period.

It is beyond the capacity of the AVA to say how this is mathematically incorporated into the HotStuff model but the model must integrate historical and predicted climate observations to predict likely duration of exposure to HST for different lines of sheep.

Discussion

The Heat Stress Risk Assessment model, HotStuff, is based on controlled scientific studies (Stockman 2006) and shipboard data gathered on multiple voyages from Australia to the various countries north of the Equator including the Middle East (MAMIC 2001, Maunsell-Australia 2003, Stacey 2006, Stacey 2017). Maunsell-Australia (2003) and Stacey (2017) describe the development of the HotStuff model and how the mortality limits (ML) and heat stress thresholds (HST) for “standard” animals were chosen, and explain how ML and HST are adjusted in livestock that have different attributes from the “standard” animals.

The HotStuff model was designed to assess the risk of heat stress occurring in various species, breeds and ages of livestock being shipped from Australia. However, it is currently only used to assess risk of *mortality* (set at determining a 2% probability of a 5% mortality event) in order to determine space allocation on ships. Nevertheless, the HotStuff model does have the capacity to calculate the HST for a particular class of animals and should be used to do so. Livestock attributes (species, breed, age, body weight, body condition, coat length, month and district of origin) and route climatology (average/predicted wet bulb temperatures *en route* and in destination ports) may be put into the model to predict the wet bulb temperature at which livestock will suffer heat stress during any voyage. In other words, once the HST is known it is possible to calculate the risk of heat stress during any voyage based on historical averages and forecast climatic conditions for the weeks of the voyage in question.

Any mature Merino sheep that is:

- heavier than 40 kg and/or
- in body condition > 3 and/or
- carrying wool > 10 mm in length (but less than 25 mm as per current ASEL) and/or
- is sourced from a district (zone) in a month where the WBT is < 15°C

will have an adjusted heat stress threshold lower than the standard Merino sheep that is described in Table 1 of the Heat Stress Risk Assessment Issues Paper (2018)[5].

Based on Stockman's studies on heat stress in sheep under controlled conditions (Stockman 2006) the AVA has recommended that "*irrespective of stocking density, thermoregulatory physiology indicates that sheep on live export voyages to the Middle East during May to October will remain susceptible to heat stress and die due to the expected extreme climatic conditions during this time. Accordingly, voyages carrying live sheep to the Middle East during May to October cannot be recommended*" (AVA 2018a).

Practical application of HotStuff to calculate HST

The AVA has completed a desk-top exercise, using data from real voyages, to illustrate the use of HotStuff to calculate heat stress thresholds in various classes of sheep (**Tables 4-8, 10**, following).

The examples of sheep are typical of the classes of sheep that are exported, and based on data available from the relevant voyage. Shipboard data from Mortality Investigation Reports (MIR) and Freedom of Information (FOI) data have been graphed showing daily sheep mortality numbers, ambient and mean deck WBTs, sea temperature and mean deck relative humidity. Comments which appear on graphs in inverted commas are direct quotes from the daily reports. Against this information, the AVA plotted the HST as a horizontal line showing how WBT relates to HST during the voyage. The five examples that follow show Merino sheep shipped from southern Australia across the Equator between May and October suffered heat stress (**Figures 13-18**). It must be remembered that there are variations in sheep factors (some of which are described in HotStuff), environmental factors and ship factors (space allocation, air temperature and quality, bedding, feed and water quality and quantity) that will contribute to variation in sheep showing clinical signs of heat stress across different decks on any ship. Additionally, it has been demonstrated that people that regularly work with sheep are more likely to use a smaller range of scores when performing qualitative behavioural assessments of various industry-relevant practices (Fleming, Clarke et al. 2016) so sheep behaviour during any voyage may have been under-estimated.

Between May and October environmental wet bulb temperatures increase as ships sail to the Middle East (Stacey 2017) and sheep demonstrate varying levels of elevated respiratory rates and heat stress. Whether HotStuff (**Tables 4-8, 10**) or Stockman's studies (Stockman 2006) are used, **winter-acclimatised, mature Merino sheep from southern Australia exhibit heat stress when the wet bulb temperature is approximately 28°C and lambs at approximately 26-27°C.**

The tables and figures illustrate a recurring pattern that sheep tend to have a resting respiratory rate (recorded as "normal" on daily shipboard reports) for the first 4 days of any voyage from Fremantle, and then show "elevated" or "high" respiratory rates and mild to severe heat stress as the ship approaches the Equator and temperature and humidity increase. For example, the End of Voyage Report for a July 2016 voyage stated "*heat stress levels rising to high 2 scores* (mild-severe heat stress) *at night from day 4 onwards until the Arabian Gulf (day 13)*" (**Figure 15**; FOI 2016/17-75 Document 24) prior to the heat stress event that precipitated an investigation (sheep mortalities > 2%) and corroborated in MIR 65: "*The first hot and humid*

[5] Source: https://haveyoursay.agriculture.gov.au/39528/documents/87365

weather was encountered on Day 4. Sheep were visibly affected and began to pant… The first heat related death was reported on Day 7".[6]

Figures 18 and 20 show "daily autolysed carcasses" rather than daily sheep mortality numbers. In these two voyages, cause of death/reason for euthanasia was recorded on each Shipboard Daily Report as either inanition (accounted for approx. 63% of all mortalities), autolysed (32%), enteritis, enterotoxaemia, wound, fracture, abscess, foot abscess, arthritis, pneumonia, pleurisy, flystrike or dermatophilosis (which accounted for the remaining 5% of mortalities). Given that sheep are being checked on a regular basis during any voyage, and obvious causes of death have been reported, it appears reasonable to equate the finding of a rapidly decomposed carcass with death secondary to heat stress for those where cause of death is reported as "autolysed".

In this exercise, every attempt has been made to accurately record sheep numbers and mortalities however there are discrepancies between numbers of livestock loaded onto any ship and discharged at the port of destination, plus numbers of mortalities recorded amongst various documents. This observation further supports the AVA recommendation that "*sheep must be individually identified with electronic ear tags to assist with data collection and for traceability*" in its submission to the McCarthy Review on heat stress in sheep (AVA 2018a).

[6] Source: http://www.agriculture.gov.au/export/controlled-goods/live-animals/livestock/regulatory-framework/compliance-investigations/investigations-mortalities/sheep-qatar-kuwait-uae-oman-report-65

MV Bader III voyage: 18 August 2013 – 18 September 2013 (MIR 46, FOI2013/14-51)

Table 4. Adjusted heat stress threshold (HST) wet bulb temperatures (WBT) for examples of sheep that could have travelled from Adelaide and Fremantle to Qatar and the United Arab Emirates in *August-September 2013* as described in Mortality Investigation Report 46[7] where 4,179 sheep died and the main cause of death was heat stress (F = factor applied in HotStuff model calculations, BCS = body condition score, std = standard).

	Body weight (kg)	F wt (kg)	Core temp (°C)	Condition (BCS)	F BCS	Coat	F coat	Zone	Zone WBT (°C)	F zone	Base HST (°C)	Tcore -HST (°C)	Adj. HST WBT (°C)
Standard Merino adult sheep	40	1.00	40	3	1	shorn	1	std	15	1	30.6	9.40	**30.60**
Adult Merino from Zone 1 to Qatar & UAE, Sept 2013	50	1.05	40	3	1	10-25 mm	1.08	1	9	1.15	30.6	12.21	**27.79**
Adult Merino from Zone 2 to Qatar & UAE, Sept 2013	60	1.08	40	3	1	shorn	1	2	11	1.10	30.6	11.21	**28.79**
Standard Merino lamb	40	1.00	40	3	1	shorn	1	std	15	1	26.7	13.30	**26.70**
Merino lambs from Zone 2 to Qatar & UAE, Sept 2013	35	0.97	40	3	1	shorn	1	2	11	1.10	26.7	14.24	**25.76**

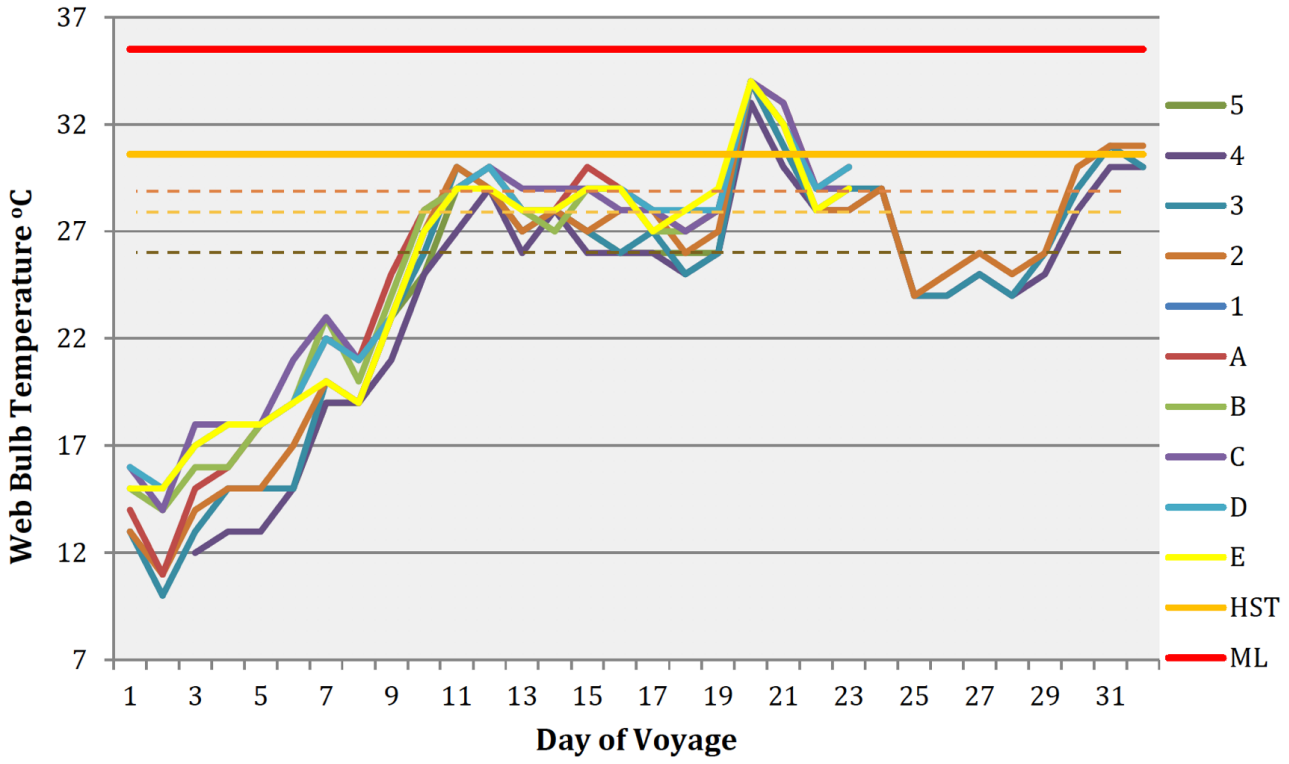


Figure 13. Mid-morning wet bulb temperature by deck and day for a voyage undertaken in *August-September 2013* from Adelaide and Fremantle to Qatar and United Arab Emirates as described in Mortality Investigation Report 46[1] where 4,179 sheep died and the main cause of death was heat stress, showing mortality limit (ML, solid red line) and heat stress threshold (HST 30.6°C, solid orange line) for a "standard" sheep (Stacey 2017), and calculated adjusted heat stress thresholds for mature Merino wethers (27.8°C WBT; dotted orange line and 28.8°C WBT; dotted tan line) and Merino lambs (25.8°C WBT; dotted brown line) according to assumptions described in Table 4. This figure appears as Figure 3 in the Heat Stress Risk Assessment Issues Paper (2018).

[7] Source: http://www.agriculture.gov.au/export/controlled-goods/live-animals/livestock/regulatory-framework/compliance-investigations/investigations-mortalities/report-46

Figure 14 focusses on sheep loaded in Adelaide, and sourced from New South Wales, Victoria and South Australia during July. The mortality rate for this consignment was 7.3% (3,256 mortalities of 44,713 sheep loaded) compared with 3.0% for sheep sourced from Fremantle (923 sheep died of 30,795 sheep loaded)[8]. 3180 sheep died in this consignment on Day 21. This is different to what was recorded in the Daily Shipboard Reports so the blue columns in the graph are incorrect. Contrary to what is written in the MIR that sheep were only exposed to WBT greater than HST on days 20 and 21 (solid green line), sheep sourced from Zone 1 would have been exposed from day 10 (dotted green line). The mean respiratory rates for all sheep on the ship are also depicted on the graph and show sheep reached HST 2 (100 breaths per minute) on day 11 and continued panting at rates associated with HST 2 until they disembarked the ship on days 21-23.

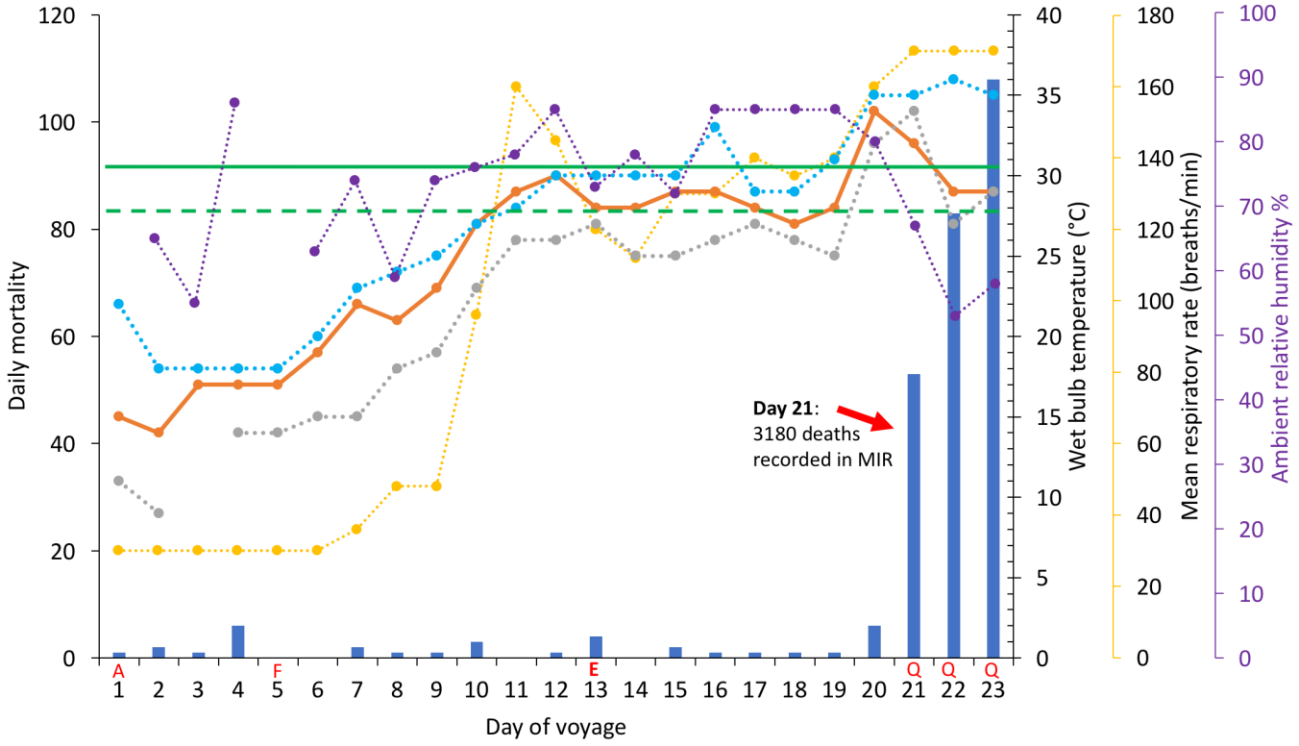


Figure 14. Approximated mean mid-morning wet bulb temperature (WBT, °C; solid orange line) across single tiered, enclosed decks (Decks A-E), ambient WBT (dotted grey line), sea temperature (dotted blue line), ambient relative humidity (dotted purple line and purple axis), mean respiratory rate (dotted yellow line and yellow axis) and understated daily sheep mortalities (blue columns) by day for a voyage undertaken in *August-September 2013* for a line of sheep sourced from Adelaide (A), that were shipped via Fremantle (F) to Qatar (Q). In all, 4,179 sheep died of 75,508 sheep loaded (5.5%) and the main cause of death was heat stress. The Adelaide consignment had 3,256 mortalities of 44,713 sheep loaded (7.3%). Horizontal lines show the heat stress threshold (HST 30.6°C, solid green line) for a "standard" sheep (Stacey 2017), and the adjusted heat stress threshold for adult Merino sheep from Zone 1 (27.8°C WBT; dotted green line) according to assumptions described in Table 4. The ship crossed the Equator (E) on day 13. Any deaths occurring after 11 am are included in the following day's mortalities. The data and comments were obtained from Mortality Investigation Report (MIR) 46[8] the Shipboard Daily Reports of the voyage (FOI 2013/14-51). Missing data points and approximations are due to illegibility of reports.

[8] Source: http://www.agriculture.gov.au/export/controlled-goods/live-animals/livestock/regulatory-framework/compliance-investigations/investigations-mortalities/report-46

The following graphs do not contain respiratory rates because they were not recorded on the Shipboard Daily Reports. Nevertheless, the graphs demonstrate how mean deck WBT meets or exceeds adjusted HST, as calculated by the Hotstuff model, approximately 4-5 days out of Fremantle, for the duration of the voyage. Until now, this prolonged exposure of sheep to relentless heat and humidity has been accepted as being part of a “normal” voyage because mortality rate was the only trigger for investigation on any voyage. The paradigm shift now is to look at morbidity data and realise that the extended exposure to prolonged heat stress over days to weeks is an issue in and of itself, irrespective of mortalities.

Al Messilah voyage: 4-25 July 2016 (MIR 65, FOI 2016/17-75)

Table 5. Adjusted heat stress threshold (HST) wet bulb temperatures (WBT, °C) for examples of sheep that could have travelled from Fremantle to Qatar, Kuwait, the United Arab Emirates and Oman in *July 2016* as described in Mortality Investigation Report 65[9] where 3,027 sheep died and the main cause of death was heat stress (F = factor applied in HotStuff model calculations, BCS = body condition score, std = standard).

	Body weight (kg)	F wt	Core temp (°C)	Condition (BCS)	F BCS	Coat	F coat	Zone	Zone WBT (°C)	F zone	Base HST (°C)	Tcore -HST (°C)	Adj. HST WBT (°C)
Standard Merino adult sheep	40	1.00	40	3	1	shorn	1	std	15	1	30.6	9.40	**30.60**
Adult Merino from Zone 3 in July	55	1.07	40	2	0.95	shorn	1	3	10	1.13	30.6	10.71	**29.29**
Adult Merino from Zone 2 in July	60	1.08	40	3	1	shorn	1	2	9	1.15	30.6	11.72	**28.28**

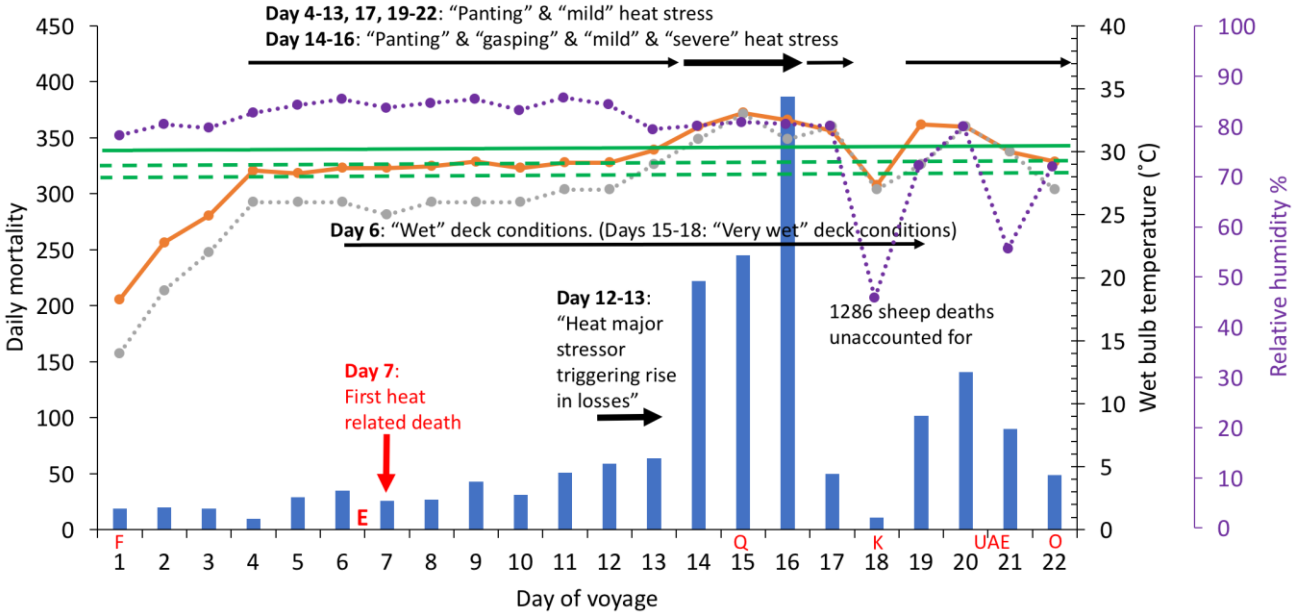


Figure 15. Mean mid-morning wet bulb temperature (WBT, °C) of all decks (solid orange line), ambient WBT (dotted grey line), mean deck relative humidity (dotted purple line) and daily sheep mortalities (blue columns) by day for a voyage undertaken on ship with 10 single tier, fully enclosed decks in *July 2016* from Fremantle (F) to Qatar (Q), Kuwait (K), the United Arab Emirates (UAE) and Oman (O) as described in Mortality Investigation Report 65[2] where 3,027 (4.36%) of 69,322 sheep died (not all shown on the graph) and the main cause of death was heat stress, showing heat stress threshold (HST 30.6°C, solid green line) for a "standard" sheep (Stacey 2017), and the heat stress threshold for two lines of mature Merino wethers (28.3°C and 29.3°C; dashed green lines) according to assumptions described in Table 5. The ship crossed the Equator (E) on day 6-7. Sea temperatures not available. The horizontal black arrows and comments were obtained from the Shipboard Daily Reports and End of Voyage Report (FOI 2016/17-75 Documents 1-24). The End of Voyage Report for this voyage noted "*heat stress levels rising to high 2 scores at night from day 4 onwards until the Arabian Gulf (day 13)*" (FOI 2016/17-75 Document 24), *prior to* the heat stress event that precipitated an investigation (mortalities > 2%). Any deaths occurring after 11 am are included in the following day's mortalities.

[9] Source: http://www.agriculture.gov.au/export/controlled-goods/live-animals/livestock/regulatory-framework/compliance-investigations/investigations-mortalities/sheep-qatar-kuwait-uae-oman-report-65

Awassi Express voyage: 15 August 2016 – 8 September 2016 (FOI2017/18-28)

Table 6. Adjusted heat stress threshold (HST) wet bulb temperatures (WBT, °C) for examples of sheep that could have travelled from from Adelaide (Zone 1) and Fremantle (Zone 3) to Oman and Kuwait in *August-September 2016*. Data was derived from Heat Stress Risk Assessments performed prior to the voyage (FOI2017/18-28 Document 28).

	Body weight (kg)	F wt	Core temp (°C)	Condition (BCS)	F BCS	Coat	F coat	Zone	Zone WBT (°C)	F zone	Base HST (°C)	Tcore-HST (°C)	Adj. HST WBT (°C)
Standard Merino adult sheep	40	1.00	40	3	1	shorn	1	std	15	1.00	30.6	9.40	**30.60**
Adult Merino from Zone 1 in August	52	1.05	40	3	1	shorn	1	1	7.5	1.19	30.6	11.76	**28.24**
Adult Merino from Zone 3 in August	52	1.05	40	3	1	shorn	1	3	10.74	1.11	30.6	10.96	**29.04**

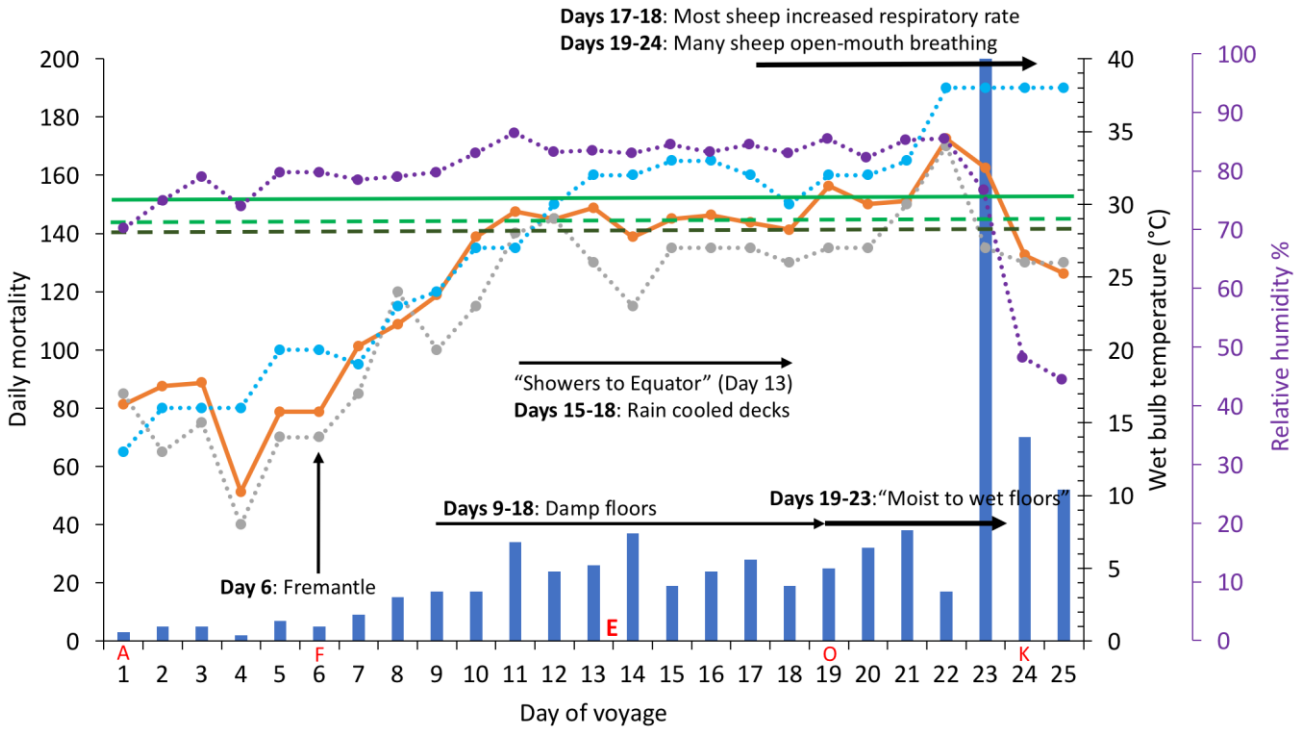


Figure 16. Mean mid-morning wet bulb temperature (WBT, °C) for Decks C-F (solid orange line), ambient WBT (dotted grey line), sea temperature (dotted blue line), mean deck relative humidity (dotted purple line) and daily sheep mortalities (blue columns) by day for a voyage undertaken on a ship with fully enclosed decks in *August-September 2016* from Adelaide (A) and Fremantle (F) to Oman(O) and Kuwait (K) where 748 (1.26%) of 59,364 sheep died, showing heat stress threshold (HST 30.6°C, solid green line) for a "standard" sheep (Stacey 2017), and the heat stress thresholds for mature Merino wethers from Zone 1 (28.24°C; dashed dark green line) and Zone 3 (29.04°C; dashed green line) according to assumptions described in Table 6. The ship crossed the Equator (E) on day 13-14. Sea temperature was ≥ 30°C after day 11 of the voyage. Data was derived from Shipboard Daily Reports and the End of Voyage Report (FOI2017/18-28 Documents 1-32). Any deaths occurring after 11 am are included in the following day's mortalities.

Awassi Express voyage: 2-22 August 2017 (MIR 69, FOI2017/18-27)

Table 7. Adjusted heat stress threshold (HST) wet bulb temperatures (WBT, °C) for examples of sheep that could have travelled from from Fremantle (Zone 3) to Qatar, Kuwait and the United Arab Emirates in August 2017. Data was derived from Heat Stress Risk Assessments performed prior to the voyage (FOI2017/18-27 Document 24).

	Body weight (kg)	F wt	Core temp (°C)	Condition (BCS)	F BCS	Coat	F coat	Zone	Zone WBT (°C)	F zone	Base HST (°C)	Tcore -HST (°C)	Adj. HST WBT (°C)
Standard adult sheep from HotStuff model	40	1.00	40	3	1	shorn	1	std	std	1	30.6	9.40	**30.60**
Adult Merino to UAE in August	60	1.08	40	3	1	shorn	1	3	10.3	1.12	30.6	11.39	**28.61**
Lamb standard from HotStuff model	40	1.00	40	3	1	shorn	1	std	std	1	26.7	13.30	**26.70**
Merino lamb to UAE in August	37	0.98	40	2	0.95	shorn	1	3	10.3	1.12	26.7	13.90	**26.10**

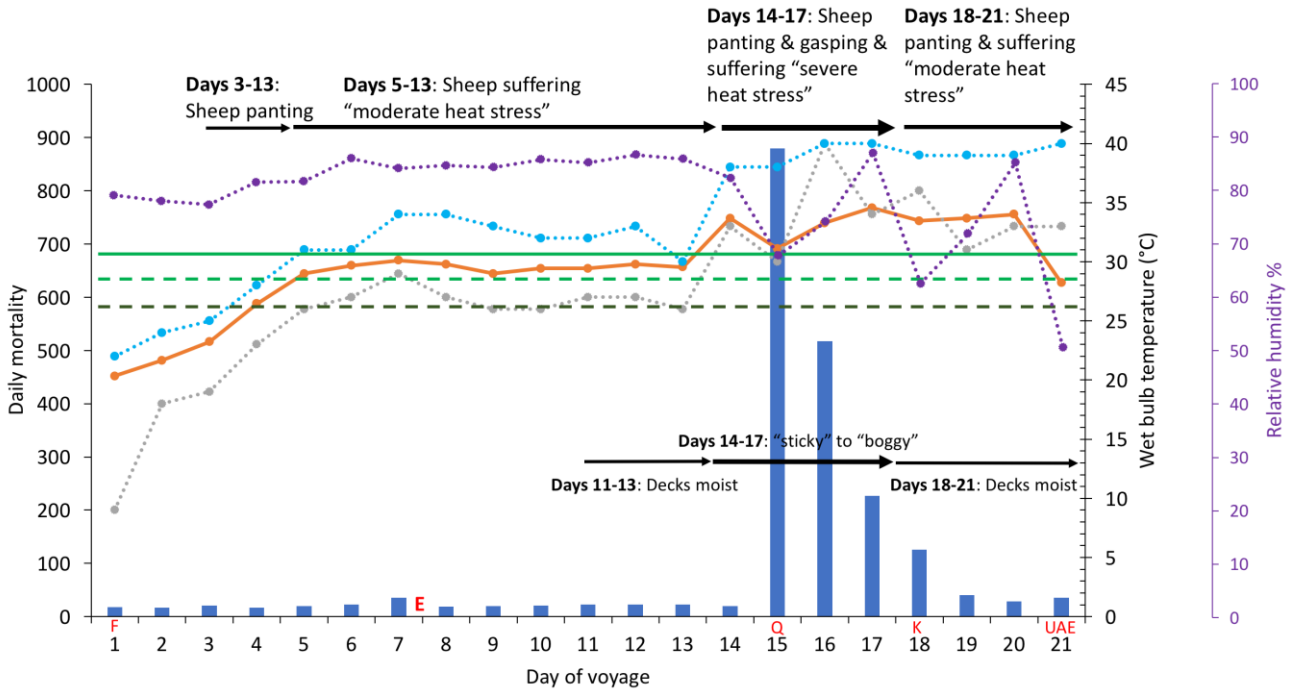


Figure 17. Mean mid-morning wet bulb temperature (WBT, °C) of all decks (solid orange line), ambient WBT (dotted grey line), sea temperature (dotted blue line), mean deck relative humidity (dotted purple line) and daily sheep mortalities (blue columns) by day for a voyage undertaken on ship with 10 single tier, fully enclosed decks in *August 2017* from Fremantle (F) to Qatar (Q), Kuwait (K) and the United Arab Emirates (UAE) as described in Mortality Investigation Report 69[10] where 2,400 (3.76%) out of 63,804 sheep died (discrepancy of 195 sheep) and the main cause of death was heat stress, showing heat stress threshold (HST 30.6°C, solid green line) for a "standard" sheep (Stacey 2017), and the heat stress thresholds for mature Merino wethers from Zone 3 (28.6°C; dashed green line) and Merino lambs from Zone 3 (26.1°C; dashed dark green line) according to assumptions described in Table 7. The ship crossed the Equator (E) on day 7-8. The horizontal black arrows and comments were obtained from the Shipboard Daily Reports of the voyage (FOI 2017/18-27 Documents 1-26). Any deaths occurring after 11 am are included in the following day's mortalities.

[10] Source: http://www.agriculture.gov.au/export/controlled-goods/live-animals/livestock/regulatory-framework/compliance-investigations/investigations-mortalities/sheep-qatar-kuwait-uae-report-69#investigation-findings

Mortality Investigation Reports 37 (July 2010), 38 (August 2010) and 40 (June/July 2011) also demonstrate how mean deck WBT meets or exceeds adjusted HST as calculated by the Hotstuff model approximately 4-5 days out of Fremantle, for the rest of each voyage[11].

Death of sheep secondary to heat stress during live shipping is not just of concern during "heat wave conditions" but a major cause of mortality during all shipments of sheep across the Equator. It is possible that decreased welfare during high mortality voyages could be the result of atypical conditions. However, in shipments where overall mortality rate is considered low it is apparent that animals experience heat stress even during what have been regarded as "typical" voyages (Caulfield, Cambridge et al. 2014). McCarthy (2005) collected temperature and relative humidity data on 9 voyages between April and October, and significant heat stress was observed on 3 voyages and mild heat stress occurred on an unspecified number of the other six voyages (McCarthy 2005).

The issue of heat stress in sheep during live export from Australia to the Middle East has been associated with legislated investigations to date because:

(a) The mortality limit has exceeded 2% for a line and/or entire shipment of sheep during a "heat wave"
(b) Causes of mortality on voyages where ML < 2% are not publicly available
(c) Heat stress morbidity data during any voyage is minimal and not publicly available.

This could be interpreted as heat stress and associated mortality not being a problem in voyages where the ML is less than 2%. However, in Shipboard Daily Reports from two voyages where mortality rate was below the reportable limit (e.g. 0.82-0.84%; **Figures 18 & 20**) the cause of death/reason for euthanasia was recorded on each Shipboard Daily Report as either inanition (accounted for approx. 63% of all mortalities), autolysed (32%), enteritis, enterotoxaemia, wound, fracture, abscess, foot abscess, arthritis, pneumonia, pleurisy, flystrike or dermatophilosis (which accounted for the remaining 5% of mortalities). Given that sheep are being checked on a regular basis during any voyage, and obvious causes of death have been reported, it appears reasonable to equate the finding of a rapidly decomposed carcass with death secondary to heat stress for those where cause of death is reported as "autolysed". Therefore, in the scant data available, clinical heat stress and mortality from heat stress is important during all voyages carrying sheep over the Equator, not just those to the Middle East in May to October.

Even though **Figure 18** depicts what has historically been regarded as a low mortality shipment (0.84%), it is not acceptable to subject sheep to prolonged and relentless heat stress as shown from days 5 to 16 and 19 to 24. Sheep are exceedingly stoic *but* heat-stressed sheep suffer up until to the point of death. Though fewer animals may have succumbed in this example, this does not negate the fact that the surviving animals suffered the prolonged effects of heat stress.

[11] Mortality Investigation Reports source: http://www.agriculture.gov.au/export/controlled-goods/live-animals/livestock/regulatory-framework/compliance-investigations/investigations-mortalities

Al Shuwaikh voyage: 26 September 2017 – 12 October 2017 (FOI2017/18-60)

Table 8. Adjusted heat stress threshold (HST) wet bulb temperatures (WBT, °C) for examples of sheep that could have travelled from from Fremantle (Zone 3) to Kuwait, Qatar, UAE and Oman and in September-October 2017. Data was derived from Heat Stress Risk Assessments performed prior to the voyage (FOI2017/18-60 Document 48).

	Body weight (kg)	F wt	Core temp (°C)	Condition (BCS)	F BCS	Coat	F coat	Zone	Zone WBT (°C)	F zone	Base HST (°C)	Tcore -HST (°C)	Adj. HST WBT (°C)
Standard adult sheep	40	1.00	40	3	1	shorn	1	std	std	1	30.6	9.40	**30.60**
Adult Merino to Doha in September	60	1.08	40	3	1	shorn	1	3	12.96	1.05	30.6	10.71	**29.29**
Lamb standard	40	1.00	40	3	1	shorn	1	std	std	1	26.7	13.30	**26.70**
Merino lamb to Doha in September	37	0.98	40	2	0.95	shorn	1	3	12.96	1.05	26.7	13.07	**26.93**

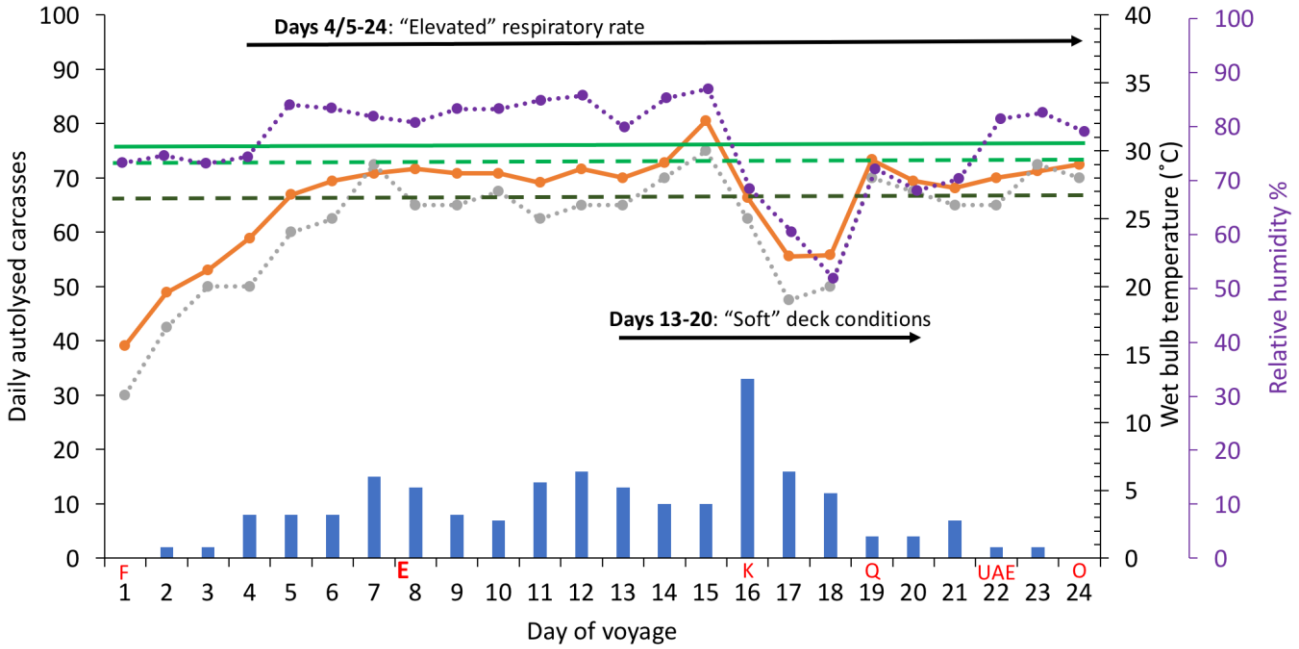


Figure 18. Mean mid-morning wet bulb temperature (WBT, °C) of all decks (solid orange line), ambient WBT (dotted grey line), mean deck relative humidity (dotted purple line) and daily sheep mortalities recorded as "autolysed" (blue columns) by day for a voyage on a ship with open and enclosed decks undertaken in *September/October 2017* from Fremantle (F) to Kuwait (K), Qatar (Q), the United Arab Emirates (UAE) and Oman (O) where 659 (0.84%) of 78,057 sheep died, showing heat stress threshold (HST 30.6°C, solid green line) for a "standard" sheep (Stacey 2017), and the heat stress thresholds for mature Merino sheep from Zone 3 (29.3°C; dashed green line) and Merino lambs from Zone 3 (26.9°C; dashed dark green line) according to assumptions described in Table 8. The ship crossed the Equator (E) on day 8. The horizontal black arrows and comments were obtained from the Shipboard Daily Reports of the voyage (FOI 2017/18-60 Documents 1-50). Any deaths occurring after 11 am are included in the following day's mortalities.

It is clear from the above examples, sheep being exported from southern Australia to or through the Middle East in the months of May to October suffer varying degrees of heat stress for *many* consecutive days (**Figures 13-18**). In Mortality Investigation Report 69 it states "*The humidity and temperature experienced from day 5 to day 13 and associated deck conditions, prior to arrival in Qatar is likely to have contributed to the severity of the mortality event.*"[12] The HotStuff model does not take into account duration of exposure to heat, lack of diurnal temperature variation and cumulative heat load or potential for repeat high WBT challenges thus the model needs to be modified to cater for prolonged and/or repeated exposure to elevated wet bulb temperatures.

Additionally, less than optimal conditions during any voyage (including stressors such as inappropriate space allocation, feed and water accessibility, ventilation and air quality, bedding) will have an additive effect on lowering the heat stress threshold and duration that can be tolerated, and must be considered when evaluating the risk of any voyage.

The desk-top exercise used the HotStuff model and "standard" sheep in good faith and clearly shows sheep being subjected to temperatures higher than HST. The reality is likely worse than the figures show because:

a) Using 40°C core temperature as the base parameter in HotStuff calculations (Table 1 of the HSRA Issues Paper) results in a falsely elevated HST. Core temperature for a normal sheep is approximately 39°C (Beatty, Barnes et al. 2008). In sheep, 40°C represents the critical point above which hyperthermia can be said to be present (Radostits, Gay et al. 2007). The AVA contends that the use of 40C as the core body temperature base parameter is incorrect
b) Deck WBT readings are taken at 11 am thus not recorded reliably during the hottest part of the day
c) The position of thermometers on decks may not record the hottest part of any deck
d) Experienced animal handlers tend to employ a narrow range of descriptors which may underestimate severity of heat stress reported (Fleming, Clarke et al. 2016).

Therefore, the recorded WBTs on each deck are likely underestimated, and the HST is falsely elevated, so cross-over between the two is probably more pronounced and prolonged than is depicted in these comprehensive illustrations of shipboard reports.

Furthermore, this is supported by the early work performed during the development of the HotStuff model showing that sheep are in danger of suffering heat stress when WBT is > 29°C (**Table 9**).

Table 9. Preliminary wet bulb temperature risk criteria for heat stress in several livestock lines (Maunsell 2003).

	Wet Bulb Temperature Risk Range		
Livestock Line	**Safe**	**Caution**	**Danger**
Bos indicus	< 28°C	28 - 31°C (non acclimatised) 30 - 33°C (well acclimatised)	> 31°C (non acclimatised) >33°C (well acclimatised)
Bos taurus	< 26°C	26 - 30°C	> 30°C
Sheep	< 26°C	26 - 29°C	> 29°C

[12] Source: http://www.agriculture.gov.au/export/controlled-goods/live-animals/livestock/regulatory-framework/compliance-investigations/investigations-mortalities/sheep-qatar-kuwait-uae-report-69

How can we alter HotStuff from assessing ML to HST?

Table 2 in the Heat Stress Risk Assessment Issues Paper[13] suggests that to determine the "onset of severe heat stress", HotStuff can be reduced 25% of the way from the heat stress mortality threshold to determine space allocation (**Figure 19**). If we accept that the right column in **Table 1** is reasonable ("Extrapolated percentage of ML within the HSRA model") then a 25% reduction correlates with "severe heat stress (HST 3)" and is not acceptable. However, the basis of the extrapolated percentage of ML derivation in unclear.

A simpler way to achieve this outcome is to calculate HST, compare against historical and predicted weather conditions for the duration of the voyage, and if the WBT is likely to exceed HST3 for any part of the journey or HST 2 for 3 consecutive days, sheep are not to be exported in that period.

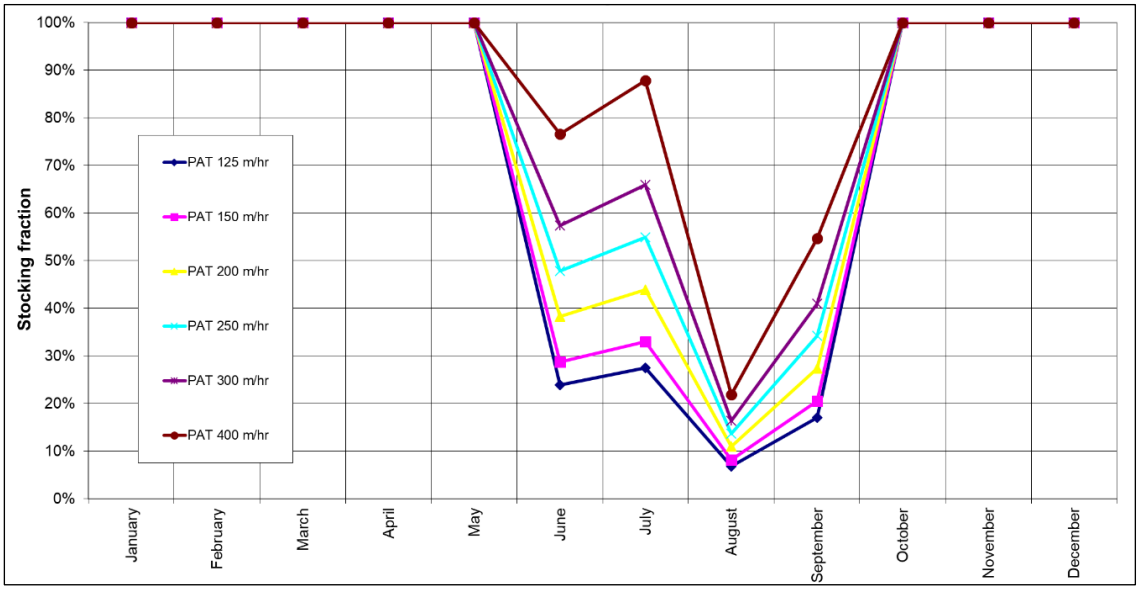


Figure 19. The allowable stocking fraction for a 40 kg adult Merino with the animal criterion reduced from mortality limit 25 per cent of the way to the heat stress threshold. (Source: McCarthy Review Figure 1 p17; Work commissioned by MLA/LiveCorp 'Effect of livestock heat stress risk standard on stocking densities for sheep on live export vessels'. Note that this paper has not been made publicly available so the figure is being interpreted in isolation from the discussion by the author.)

[13] Source: https://haveyoursay.agriculture.gov.au/39528/documents/87365

What about voyages between November and April?

The data in **Table 10** and **Figure 20** which follow are included to demonstrate why HST should be calculated on every voyage that crosses the Equator, in every month of the year. Even summer-acclimatised sheep travelling in the cooler months of the Northern Hemisphere are at risk of heat stress crossing the Equator.

Al Shuwaikh voyage: 14 November 2017 – 1 December 2017 (FOI2017/18-59)

Table 10. Adjusted heat stress threshold (HST) wet bulb temperatures (WBT, °C) for examples of sheep that could have travelled from from Fremantle (Zone 3) to Kuwait, Qatar and UAE and in November-December 2017. Data was derived from Heat Stress Risk Assessments performed prior to the voyage (FOI2017/18-59 Document 49).

	Body weight (kg)	F wt	Core temp (°C)	Condition (BCS)	F BCS	Coat	F coat	Zone	Zone WBT (°C)	F zone	Base HST (°C)	Tcore -HST (°C)	Adj. HST WBT (°C)
Standard adult sheep	40	1.00	40	3	1	shorn	1	std	std	1	30.6	9.40	**30.60**
Adult Merino to UAE in November	52	1.05	40	2	0.95	shorn	1	3	16.61	0.96	30.6	9.03	**30.97**
Lamb standard	40	1.00	40	3	1	shorn	1	std	std	1	26.7	13.30	**26.70**
Merino lamb to UAE in November	37	0.98	40	3	1	shorn	1	3	16.61	0.96	26.7	12.57	**27.43**

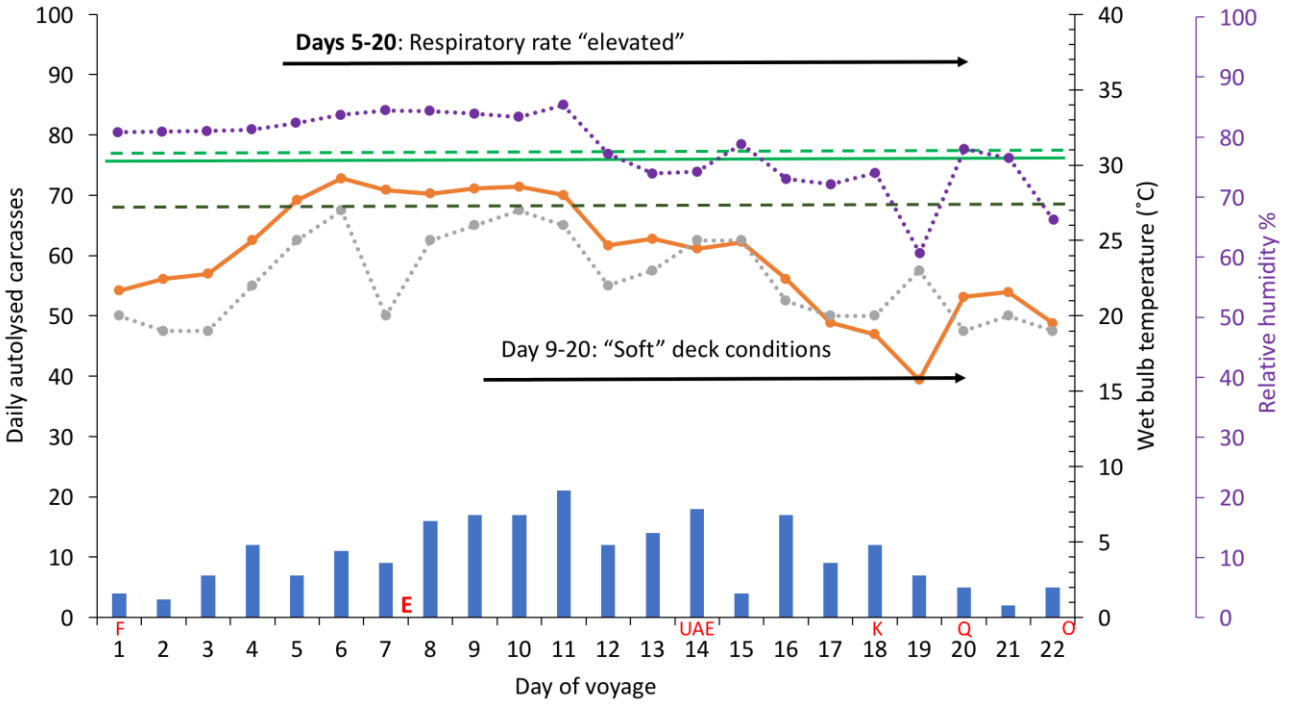


Figure 20. Mean mid-morning wet bulb temperature (WBT, °C) of all decks (solid orange line), ambient WBT (dotted grey line), mean deck relative humidity (dotted purple line) and daily sheep mortalities recorded as "autolysed" (blue columns) by day for a voyage on a ship with open and enclosed decks undertaken in *November-December 2017* from Fremantle (F) to the United Arab Emirates (UAE), Kuwait (K), Qatar (Q) and Oman (O) and where 695 (0.82%) of 84,917 sheep died, showing heat stress threshold (HST 30.6°C, solid green line) for a "standard" sheep (Stacey 2017), and the heat stress thresholds for mature Merino sheep from Zone 3 (31.0°C; dashed green line) and Merino lambs from Zone 3 (27.4°C; dashed dark green line) according to assumptions described in Table 10. The ship crossed the Equator (E) on day 7-8. The horizontal black arrows and comments were obtained from the Shipboard Daily Reports of the voyage (FOI2017/18-59 Documents 1-51). Any deaths occurring after 11 am are included in the following day's mortalities.

What about other species of livestock?

A heat stress risk assessment must be completed for all classes of livestock to any destination where a ship crosses the Equator. This is because wet bulb temperatures at which heat stress occurs in sheep and cattle are found (a) in equatorial regions in all months of the year and, (b) in regions other than the Middle East.

Figure 21 below illustrates how cattle died during a shipment to China in 2018 in spite of meeting pre-export conditions. It provides an excellent example of why any shipment that crosses the Equator should be assessed for risks. It should be noted in the last two paragraphs that industry wants to better manage any future shipments (see section 3.1) and HSRA should be implemented on every shipment, not just those to the Middle East.

"Deaths spiked when the ship was near the equator, there were 12 lost on one day."

All pre-export conditions had been met and an Australian accredited vet and accredited stockmen were aboard the independently chartered vessel, Mr Meerwald said. Exporters are required to report any voyages on which more than one per cent of cattle die on board.

Mr Meerwald said Harmony was working with DAWR to investigate the circumstances.

"We are terribly disappointed at the outcome," Mr Meerwald said. "But it's not through neglect or irresponsible behaviour. This signals further respiratory work needs to be done when taking cattle from southern Australia across the equator.

"We hope to get a credible insight into what caused the issues and determine how to better manage future shipments."

He said Harmony had recommended to industry the adoption of the heat stress risk assessment model, adopted for the Middle East, be implemented on all shipments.

Figure 21. Excerpt from an article discussing cattle deaths during shipment to China published in the West Australian newspaper on 19 June 2018 (Source: https://thewest.com.au/business/agriculture/deaths-mar-china-cattle-trade-ng-b88870012z).

Issues Paper Section 4.2: Questions about allometric stocking densities:

Note: Please provide rationale and evidence to support your position.

How can allometric stocking densities most effectively be used?

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

Answer

Space allocation should be determined using a *k*-value of at least 0.033 in all classes of stock in all months of the year to reduce adverse welfare outcomes.

The AVA recommendation to the McCarthy Review was "*Space allocation per animal must be based on allometric principles and increased by at least 30% for sheep that weigh 40 to 60 kg (based on a k-value of 0.033). The typical sheep sent to the Middle East is an adult Merino wether in this weight range. This increase in space (k = 0.033) is the minimum amount needed to alleviate adverse welfare outcomes, and must be implemented across all body weights and all months of the year*." See the AVA submissions to the McCarthy Review (AVA 2018a) and ASEL Issues Paper Stage 2 (AVA 2018b) for further details.

Issues Paper Section 5 .2.1: Questions about heat load exposure and destination ports:

Note: Please provide rationale and evidence to support your position.

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

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

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

Answer

Duration and repeated exposure to high WBTs

The level of heat load that is acceptable will depend on the severity and duration of the heat stress event, as well as the influence of other stressors that sheep may be exposed to concurrently. Based on principles of thermoregulatory physiology, the AVA recommends that the line dividing Heat Stress Scores 2 and 3 **(Table 1)** is the point beyond which sheep should not be exposed during any voyage. In other words, sheep should never be exposed to HST 3. Sheep should not be exposed to HST 2 for more than 3 consecutive days where there is no diurnal variation in temperature. Diurnal variation allows sheep to return to their thermoneutral zone and for respiratory rates to return to resting range at night. Otherwise, sheep can start dying within 3 days of being exposed to hot, humid weather, as heat load is cumulative. This duration of permissible exposure should be further reduced in the presence of other welfare imposts and/or co-morbidities, as these will further reduce their ability to cope.

Sheep being shipped to the Middle East between May and October are exposed to many consecutive days of temperatures at or exceeding their heat stress thresholds. In fact, this can occur at any time of the year when shipments cross the equator, and for that reason the HotStuff Model should be applied to all voyages to the Northern Hemisphere, in all months of the year. Even summer-acclimatised sheep travelling in the cooler months of the Northern Hemisphere are at risk of heat stress crossing the Equator.

The risk is not just restricted to sheep, and the example given on page 33 shows that cattle are also at risk of heat stress morbidity and mortality in voyages to the Northern Hemisphere. A heat stress risk assessment must therefore be completed for ALL classes of livestock to any destination where a ship crosses the Equator. This is because wet bulb temperatures at which heat stress occurs in sheep and cattle are found (a) in equatorial regions in all months of the year and, (b) in regions other than the Middle East.

How to factor in daily WBTs, route and discharge locations

Historical and predicted WBTs for locations throughout the voyage including discharge points (see map on page 12, **Figure 3**) should be used to determine whether any proposed voyage should proceed. If the predicted environmental WBTs are going to exceed the calculated HST for the particular group of animals, the conclusion should be that the voyage does not proceed. Where there is insufficient or inconclusive meteorological data, the precautionary principle should be employed to ensure the welfare of the animals is prioritised: in other words, where there is a high likelihood of heat stress events based on timing of proposed journey (May to October), voyages carrying live sheep to the Middle East during this period cannot be recommended.

For further detail, see answers to "**Questions about mortality limit and heat stress threshold"** and **"Questions about HSRA settings"** above and previous AVA submissions (AVA 2018a, AVA 2018b).

It is beyond the capacity of the AVA to offer mathematical methodology.

Issues Paper Section 5.2.3: Questions about ventilation:

Note: Please provide rationale and evidence to support your position.

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

How might ventilation performance be incorporated into the HSRA model?

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

Answer

Figure 22 (next page) summarises sheep, ship and environmental factors that affect ship ventilation capacity. This figure shows the range of inputs that affect temperature load in any ship, and it must also be noted that the presence of sheep themselves increase deck wet bulb temperature by an average of 3.2°C.

If ambient WBT is 28°C (i.e. "bridge WBT"), regardless of ventilation capacity, winter-acclimatised Merino sheep sourced from southern Australia are likely to suffer varying degrees of heat stress. This is because "*the ventilation system … can only deliver the outside temperatures to the decks*" (End of Voyage Report FOI2017/18-27 Document 22).

For example, in the MIR 65 report it states that "all livestock services were operating satisfactorily during the voyage with no apparent factors associated with Marine Order 43 that may have contributed to the high mortality rate."[14] Despite adequate ventilation, the environmental temperature was just too hot.

In the literature, a Pen Air Turnover (PAT) of 50 m/h is regarded as adequate, but assumes that only fresh air is being drawn into the ship. Many ships have inadequate ventilation systems (MAMIC 2001, MAMIC 2002) because they re-ingest exhaust air containing heat, water vapour, carbon dioxide and ammonia rather than fresh outside air. This confounds calculations in HotStuff because recorded PATs may be overestimating the volume of fresh air that is being delivered to decks. Recommendations 9 and 11 of McCarthy Review have addressed this issue with respect to independent auditing of PATs. This independent auditing must occur on decks fully loaded with livestock as the presence of animals and noxious gases/water vapour may obstruct/alter airflow across decks.

If HotStuff model calculations predict that ambient WBT is greater than the calculated HST for that particular line of sheep then the conclusion reached is that the voyage does not proceed because the risk of heat stress is too high.

[14] [14] Source: http://www.agriculture.gov.au/export/controlled-goods/live-animals/livestock/regulatory-framework/compliance-investigations/investigations-mortalities/sheep-qatar-kuwait-uae-oman-report-65

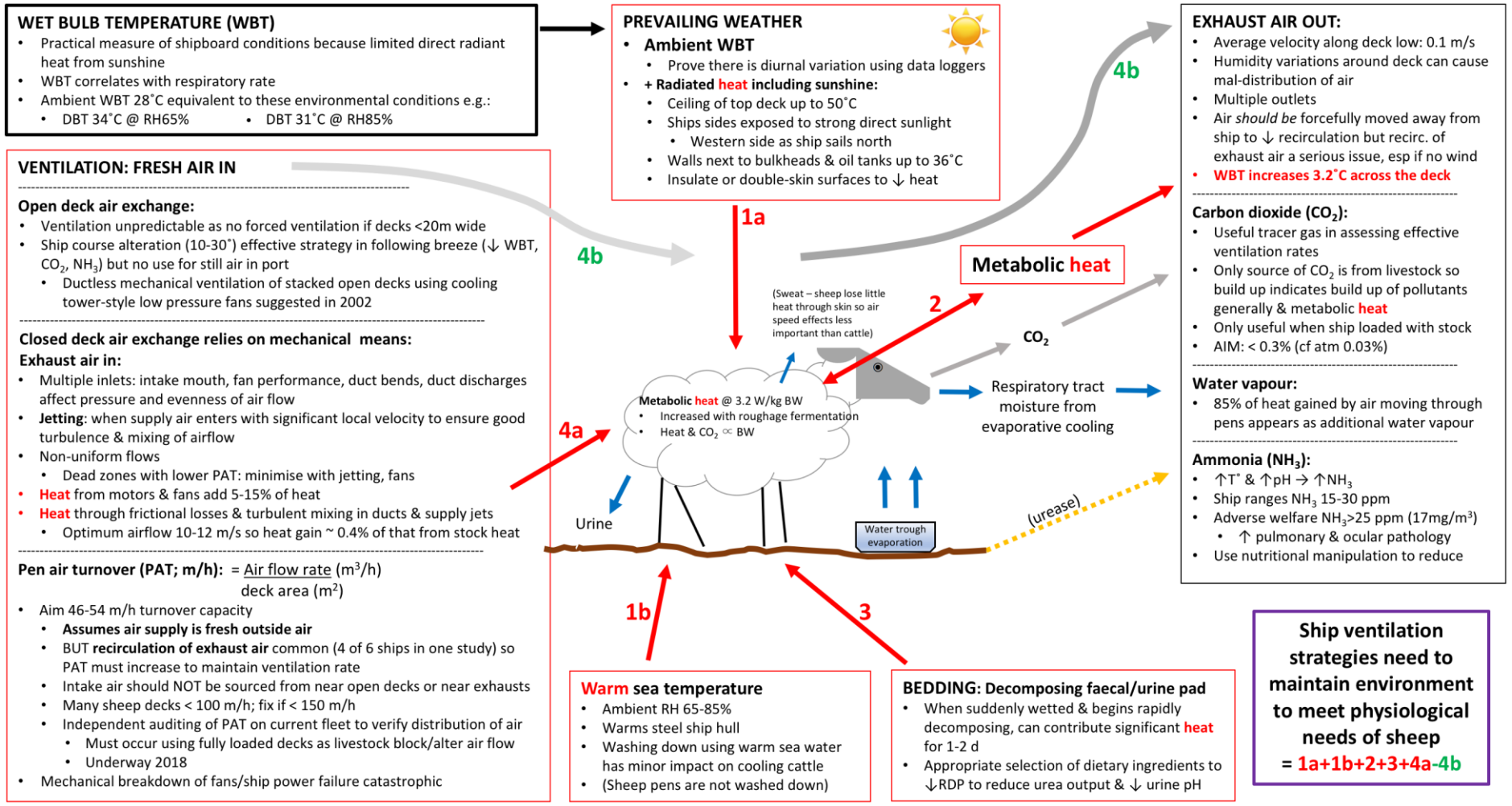


Figure 22. Sheep, ship and environmental factors that affect ship ventilation capacity.

Issues Paper Section 5.2.4: Questions about open decks:

Note: Please provide rationale and evidence to support your position.

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

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

Answer

All open decks should be treated as closed decks and adequate, reliable, forced ventilation provided.

Discussion

Ventilation of open decks with no forced ventilation is unpredictable (MAMIC 2002), so it is untenable that natural ventilation without mechanical ventilation is the method allowed to maintain air temperature and quality on open decks of ships. There are two very high risk periods for livestock being shipped on open decks:

1. When a ship is underway, in the presence of a following wind blowing at similar wind speed to ship speed, essentially the air surrounding the animals is still and the exhaust air from the decks is not being dissipated but instead being re-ingested and recirculated. The only method available to provide some relief is “zig-zagging” where the ship must alter course to port and starboard, making deviations back and forth over the direct route to ensure adequate ventilation of livestock (MAMIC 2002).
2. It can take 2 or more days at any port to discharge livestock depending on facilities. When ships are in port they are stationary, and livestock on open decks are at high risk of heat stress as hot, humid days coincide with days of no wind, and will result in “outbreaks” of death due to heat stress.

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