Australian Government
Department of Agriculture and Water Resources

Heat Stress Risk Assessment

Issues Paper

September 2018

Live Animal Exports Branch

Cataloguing data

This publication (and any material sourced from it) should be attributed as: *Department of Agriculture and Water Resources 2018, Heat Stress Risk Assessment: Issues Paper*, Live Animal Exports Branch, Canberra, September. CC BY 4.0.

ISBN 978-1-76003-171-8

This publication is available at agriculture.gov.au/export/controlled-goods/live-animals/livestock/history

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Executive Summary

In response to confronting footage covering onboard treatment of sheep, over a series of voyages to the Middle East, the Australian Government commissioned a short, sharp review of the northern summer live sheep export trade. The *Independent Review of Conditions for the Export of Sheep to the Middle East during the Northern Hemisphere Summer* by Dr Michael McCarthy (McCarthy review), provided recommendations on conditions and actions required to assure health and welfare outcomes for sheep being transported to the Middle East during the northern hemisphere summer.

Given the short time available to Dr McCarthy to conduct his review and the far-reaching impact of some of his recommendations, the Department of Agriculture and Water Resources (the department) committed to conduct consultations and testing of key factors impacting the live sheep export trade. In particular, the development of a welfare-based approach to heat stress risk assessment (HSRA) in response to recommendations 3–5, 7 and 8 of the review. The department's response to the McCarthy review's HSRA-related recommendations is provided in Appendix A.

This issues paper seeks feedback on assessing heat stress risk in the sheep trade during the northern summer and to identify any additional relevant research and information. The paper will assist in informing stakeholder discussions and submissions on a new approach to HSRA based on animal welfare outcomes.

The department will use information received to support the development of effective measures to manage heat stress risk for sheep exported to the Middle East during the northern summer. Findings from the HSRA review will also be provided to the technical advisory committee for consideration in finalising the *Review of the Australian Standards for the Export of Livestock (ASEL)*.

1 Introduction

As part of its response on 17 May 2018 to the McCarthy review, the department committed to:

- undertake further public consultation and analysis to assess the specific HSRA settings
- test Dr McCarthy's analysis on adopting a HSRA approach to managing animal welfare outcomes to support changes to the industry HSRA model and
- investigate alternative ventilation measures, and the use of animal welfare indicators.

The terms of reference for the McCarthy review referred specifically to actions required to assure the health and welfare of sheep during the northern hemisphere summer period if the trade were to continue. Factors such as impacts on trading partners, broader implications for the trade and the farm gate price for Australian sheep were not taken into account in developing the findings and recommendations of the McCarthy review.

The department's full response to the McCarthy review's recommendations can be found at agriculture.gov.au/about/media-centre/media-releases/department-response-mccarthy-review. The department's response to the review's HSRA-related recommendations is provided in Appendix A. The department supports the recommendations from the McCarthy review and is implementing a process of public consultation and testing of the findings relating to HSRA (recommendations 3–5, 7 and 8). The government continues to support a sustainable live sheep export trade and remains committed to ensuring the welfare of animals is protected.

1.1 The process

The department has established a technical reference panel to advise on moving from HSRA based on mortality, to one based on the animal's physiological signs of excessive heat load. The panel, comprising of independent experts in animal welfare, heat stress and animal science (Professor Andrew Fisher, Professor Clive Phillips and Associate Professor Anne Barnes), has provided input to, and feedback on, this issues paper. The Australian Maritime Safety Authority (AMSA) is providing input on ship ventilation matters.

The panel will work closely with the ASEL review technical advisory committee and guide consultation on heat stress risk with; producer groups, livestock export industry organisations, animal welfare non-government organisations (NGOs), ship owners, researchers and academics, and other interested organisations.

The department notes the livestock industry also has related research underway on the HotStuff model (refer to Appendix B for details).

1.2 Make a submission

This issues paper encourages individuals and organisations to contribute to this review by making submissions through our online stakeholder engagement platform, Have Your Say, by **5pm on 19 October 2018**. For more information, contact the technical reference panel secretariat at HSRAreview@agriculture.gov.au.

You are invited to comment on any aspect of this issues paper, however, we are particularly seeking to:

- collect evidence and factual data on HSRA
- clarify possible impacts of implementing the McCarthy review recommendations related to HSRA.

We also welcome further information on:

- successful livestock health and welfare initiatives relevant to HSRA for sheep
- scientific papers describing relevant research findings
- details of perceived barriers and challenges to achieving effective HSRA during the export of sheep by ship.

In making a submission, please:

- be specific about the issues that are of concern to you
- note which page and section of the Issues Paper your comments relate to
- if you agree or support a particular part of the Issues Paper, please say so
- if you disagree, please tell us what you disagree with and why
- suggest any recommendations or solutions you may have
- provide a copy or link to any supporting evidence relevant to your submission.

Please include the following information in your submission:

- your name and title, contact address, telephone number
- your organisation, if applicable.

Table 1 Key consultation dates

Date	Activity
13 September 2018	Issues paper released—beginning of consultation period
19 October 2018	Submissions close—five-week consultation period ends

1.3 Publication of submissions

Submissions will ordinarily be available for public review at agriculture.gov.au, unless you request otherwise. Please indicate clearly on the front of your submission should you wish it to be treated as confidential, either in full or part.

The Australian Government reserves the right to refuse to publish submissions, or parts of submissions, which contain offensive language, potentially defamatory material or copyright infringing material.

A request may be made under the *Freedom of Information Act 1982* (Cth) for a submission marked confidential to be made available. Such requests will be determined in accordance with provisions under that Act.

Contact information, other than your name and organisation (if applicable) will not be published. Your name and organisation (if applicable), state or territory will be included on the department's website to identify your submission.

1.4 Other reviews

1.4.1 Australian Standards for the Export of Livestock

In a separate but related process, the department is currently undertaking a comprehensive review of ASEL. That review is being conducted by a technical advisory committee, chaired by Mr Steve McCutcheon. The public is able to participate in each stage of the ASEL review through a public submission process.

Section 4 of the *ASEL Review Stage 2: Issues Paper* deals with HSRA. The current ASEL standards identify additional risk management measures required during the months of May to October for exports to the Middle East. For example, stocking density requirements in ASEL provide specified (increased) space requirements for sheep exported to the Middle East departing from May to October. The department requires that a HSRA be applied to all voyages travelling through the Arabian Sea. This includes voyages that travel to and through the Red Sea.

More information about the ASEL review can be found at agriculture.gov.au/animal/welfare/export-trade/review-asel. Stakeholders wishing to make submissions about the standards applied to livestock exports including recommendations from the McCarthy review are encouraged to do so through the ASEL review.

1.4.2 The McCarthy review

In April 2018, footage was released showing live sheep in severe heat stress while being transported to the Middle East. The McCarthy review was announced by the Minister for Agriculture and Water Resources on 10 April 2018 as part of the Government's response to the incident. The McCarthy review was published on 17 May 2018.

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

In summary, key recommendations on heat stress and animal welfare include:

- that the industry moves away from using mortality as a measure to a focus on measures that reflect the welfare of the animal. Within the risk assessment model this replaces the mortality limit with a heat tolerance level
- that the risk settings on the HSRA are to be adjusted to better reflect community expectations
- that space allocation should embrace 'allometric' principles and adopt a *k*-value of 0.033, and this be utilised for any periods within the May to October period, unless overridden by the HSRA model's assessment
- that a vessel's pen air turnover (PAT) be independently verified, as part of the condition of an approved arrangement for sheep travelling to the Middle East during the northern hemisphere summer.

The department supports the recommendations from the McCarthy review while noting consultation and testing of analysis of the HSRA-related recommendations was not achievable in the short time allowed for the review. The department is implementing a process of public consultation and testing of the findings relating to HSRA (recommendations 3–5, 7 and 8). Developing a new approach to HSRA combines scientific review with broad consultation with the community, animal science and welfare experts, industry and animal welfare NGOs.

The McCarthy review recommended moving from a HSRA based on mortality to one based on animal welfare, with a risk threshold of less than a 2 per cent probability that 5 per cent of sheep on a voyage experience heat stress. Moving to a HSRA based on excessive heat load represents a significant shift from the current arrangements and will have implications for stocking densities.

The *Australian Meat and Livestock Industry (Export of Sheep by Sea to Middle East) Order 2018* (the order) imposes additional conditions on holders of export licences who export sheep by sea to the Middle East between May and October. These conditions require sheep export licence holders to adopt and implement actions that protect the health and welfare of sheep while travelling to the Middle East between May and October.

The order provides a legal basis for the implementation of several recommendations of the McCarthy review and measures to facilitate access to the Government's live animal export whistleblower hotline initiative.

In addition to the order, the department made immediate changes for voyages to the Middle East during the northern hemisphere summer including:

- significantly reducing stocking densities—with between 11 and 39 per cent more space given to sheep than prescribed under ASEL
- undertaking independent auditing of PAT to confirm the data entered into the industry HSRA model is accurate
- reducing the notifiable mortality level for sheep exported by sea to the Middle East from two to one per cent
- ensuring all live sheep export vessels have departed with an observer on board, noting the Minister for Agriculture and Water Resources has announced observers will be a feature on all live export voyages
- applying additional conditions to some exporters' licences, including reduced stocking densities and additional reporting.

1.5 Next Steps

The technical reference panel will:

- review feedback received through this process along with relevant research and literature
- consider onboard vessel data, daily and voyage reports from livestock export voyages including Australian Government Accredited Veterinarian (AAV) reports
- consult with: ASEL Review Technical Advisory Group, producer groups, livestock export industry organisations, animal welfare NGOs, ship owners, researchers and academics and other interested organisations
- prepare advice on HSRA for consideration by the department.

The department will consider advice provided by the technical reference panel as part of the process in developing HSRA settings for the export of sheep during future northern hemisphere summers.

2 Summary of Issues

The McCarthy review recommended the industry moves from a risk assessment based on mortality to one based on animal welfare. The McCarthy review proposes the HSRA model accommodate this by a move from the mortality limit to a heat tolerance level. To give effect to these recommendations, a robust scientific approach is needed in determining estimates for heat stress risk during export.

2.1 McCarthy review recommendations

The following recommendations from the McCarthy review directly relate to the HSRA model. We seek your views on assessing heat stress risk in the sheep trade during the northern summer, and assistance in identifying relevant research and information.

Please focus your response on the following McCarthy review recommendations and supporting information in this paper.

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.

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.
***Note:** *Table 1 (p.19) of the McCarthy review is provided at Table 2 in this paper.*

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.*

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.

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.

2.2 Heat Stress Risk Assessment

The following summary of the HSRA model comes from a LiveCorp paper dated 9 April 2018, provided to the ASEL technical advisory committee.

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. It combines historical and recent naval and land-based weather data, vessel configuration, voyage and livestock data. The model estimates the risks of mortality for livestock on voyages from Australia to the Middle East. The probability of animal mortality is described statistically as a function of wet bulb temperature by a distribution which is a function of the animal's characteristics (breed, condition, weight, coat and acclimatisation).

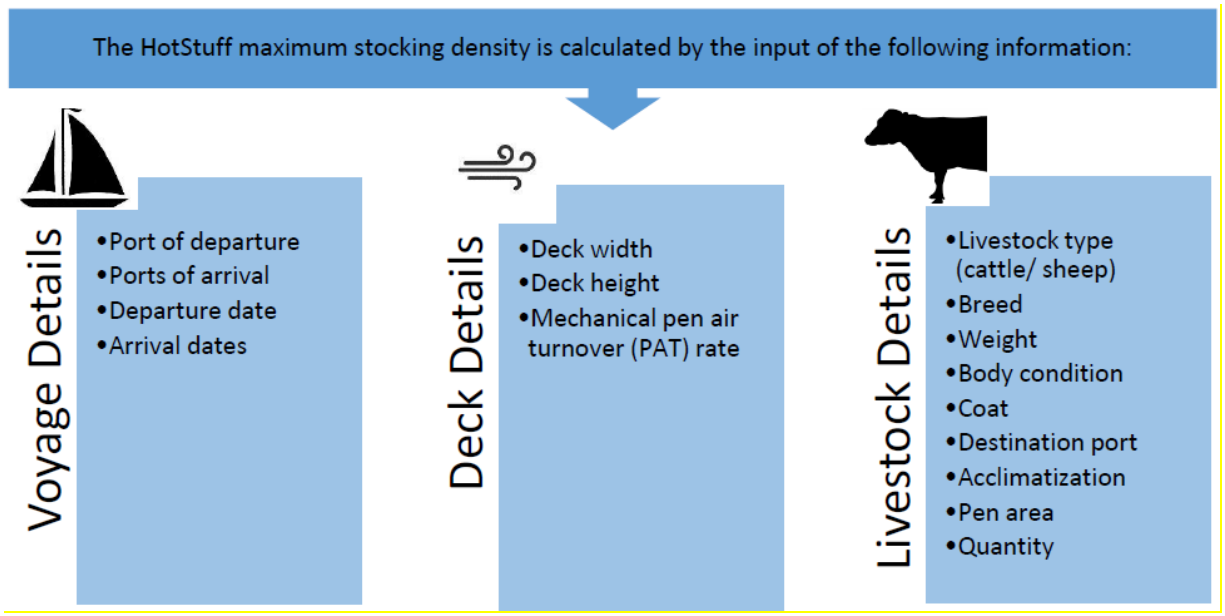
The model was designed based on the principle of altering stocking densities based on the time of year in order to limit metabolic heat production per unit area (and therefore limit the heat added to the incoming air).

The model factors in the heat generated by the animals themselves. Currently the heat stress risk probability for a voyage as calculated by the model must be below a 2 per cent chance of a 5 per cent mortality event. Use of the model in preparing export shipments has been a standard in the ASEL since 2004 and is required for any shipment to and through the Middle East.

The likelihood of reaching any given wet bulb temperature on a deck is also described by a probability distribution. First, the probability distribution of ambient wet bulb temperature has been assessed from weather observations for every voyage route for all twelve calendar months. Second, the ambient distribution is shifted hotter by an amount corresponding to the rise in wet bulb temperature on the deck. That rise is calculated from the heat output of the animals diluted by the fresh air flow rate. The result is probability distributions for both the deck wet bulb temperature (local environment) and the animal tolerance to the environment (mortality limit).

The intersection between the hot end of the deck wet bulb probability distribution and the cool end of the animal mortality limit gives the risk level. This is done for each line of livestock, on each deck of the vessel, for the particular discharge date.

Below is a diagrammatic representation of voyage, ship board and livestock inputs into the 'HotStuff' or HSRA model.



3 HSRA Model: Mortality limit and heat stress threshold

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*."

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."*

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).

The heat stress risk estimates in the model are derived from the integration of:

(i) wet-bulb temperature distributions en route and at port for the specific time of year

(ii) estimated animal mortality distributions for a given wet-bulb temperature adjusted for animal factors (liveweight, body condition, coat type (sheep) and acclimatisation zone)

(iii) ship and stocking density factors (i.e. that influence ventilation and therefore PAT) (Ferguson et al 2008).

The values currently used in the HSRA model for heat stress threshold and mortality limit taking account of body condition score, coat and acclimatisation factors for the 'standard animal' are identified in Table 1.

Table 1: Base Heat Stress Threshold and Mortality Limit Values for the 'Standard' Animals (temperatures in wet bulb °C)

Base Parameter	Merino		Awassi	
	adult	lamb	adult	lamb
Weight (kg)	40	40	40	40
Core Body Temperature (degrees C)	40	40	40	40
Condition (Fat Score)	3	3	3	3
Coat	shorn	shorn	hairy	hairy
Acclimatisation Wet Bulb Temp	15	15	15	15
Base heat stress threshold (degrees C)	30.6	26.7	31.9	28.6
Base mortality limit (degrees C)	35.5	35.2	36.1	35.9

Source: Adapted from Maunsell 2003 LIVE.116—Development of a Heat Stress Risk Management Model

Table 1 indicates a heat stress threshold of 30.6°C applied to a 40kg, body condition score 3, shorn adult Merino that is acclimatised to wet bulb temperature (WTB) of 15°C; the mortality limit for the same animal is set at 35.5°C (Maunsell 2003). Merino lambs in the model have a wet bulb temperature heat stress threshold of 26.7°C and mortality limit of 35.2°C (Maunsell 2003). Heat stress threshold is a dependant variable where the physiological response includes a slight rise in core body temperature.

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.

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.

Table 2. An amalgamation of heat stress indicators

Heat Stress Score	Panting Score	Respiratory Rate (RR)	Respiratory Character	Appearance or demeanour	Extrapolated percentage of ML within the HSRA model
0—Normal	0—Normal	25–80	Normal	Normal	0
1—Elevated respiratory rate	1—Normal (elevated RR)	80–100	Increased RR	Normal	0–35
2—Heat affected	2—Mild panting	100–160	Rapid RR	Discomfort	36–75
3—Onset of heat stress	3—Open mouth panting	160–220	Laboured	Extreme discomfort	76–85
4—Severe heat stress	4—Open mouth panting with tongue out	Usually second stage	Extremely laboured	Distressed	86–100

Source: Table 1 of the McCarthy review p.19

ASEL requires observation of respiratory character be included in the ship-board daily reports on livestock. In ASEL, respiratory character has a scale of 1–3 (normal, panting and gasping).
Dr McCarthy recommended using the five stage descriptor scale for respiratory character set out in Table 2 above. Respiratory rate can be measured and expressed in breaths per minute. Use of a panting score has been suggested because respiratory rate can be difficult to determine quickly and can subside with the onset of second stage panting. Although panting score is a subjective measurement it is relatively easy to use, is accurate and repeatable. This has led to the development of panting scores that appear to be well correlated with an animal's core body temperature.

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?

4 Stocking densities

4.1 McCarthy review recommendation 4

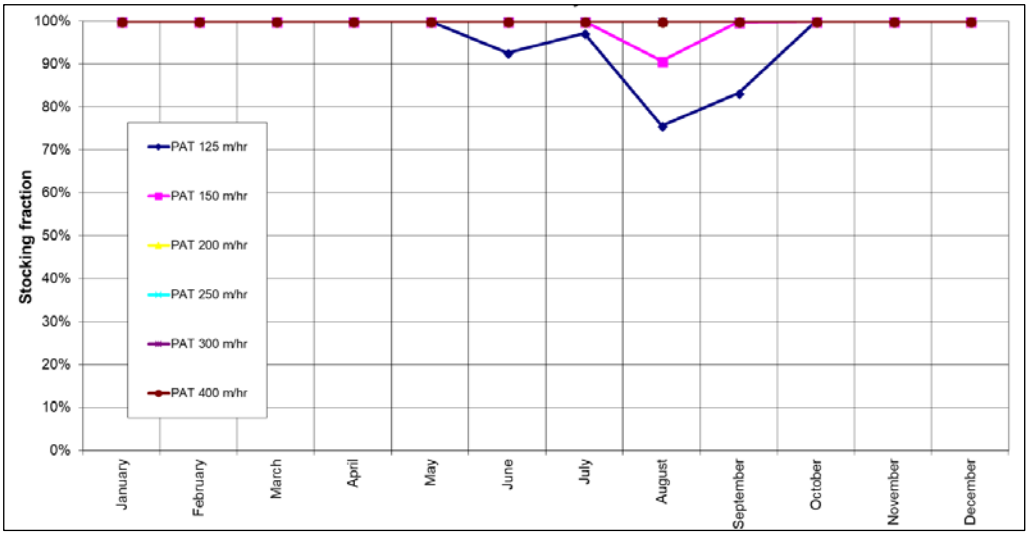
Recommendation 4 of the McCarthy review is "*As an interim measure, it is recommended that the risk be set at a 2 per cent probability of 5 per cent of the sheep becoming affected by heat stress (Heat stress score 3—refer *Table 1 of the McCarthy review). These settings should be reviewed by the ASEL 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.*

The heat stress scores referred to in the McCarthy review recommendation can be found in Table 2 on page 14 of this paper. The information in this section is based on work commissioned by MLA/LiveCorp for the McCarthy review, prepared by Stacey Agnew and entitled '*Effect of livestock heat stress risk standard on stocking densities for sheep on live export vessels*'.

Figure 1 below represents estimated stocking densities generated by the HSRA model based on the current risk criterion of a 2 per cent chance of a 5 per cent mortality incident. It shows that decks carrying 40kg adult Merinos will not be subject to destocking as a result of the risk of heat stress if the deck PAT is 200m/h or higher. Decks with PATs of 150m/h or less will need to be stocked at less than ASEL stocking densities during June to September.

In Figure 1, the 100 per cent stocking fraction refers to stocking up to the ASEL stocking requirements. ASEL minimum pen area per head can be found in ASEL Table A4.1.5, pp90–91. In Figures 1 and 2 the stocking fractions represent stocking levels below the ASEL limit. There is one curve plotted for each value of deck PAT, the data points are plotted at the mid-point of each month (Stacey 2018). All decks with PATs greater than 150 m/h can be stocked at 100 per cent of ASEL and are shown by a single line at 100 per cent in Figure 1 below.

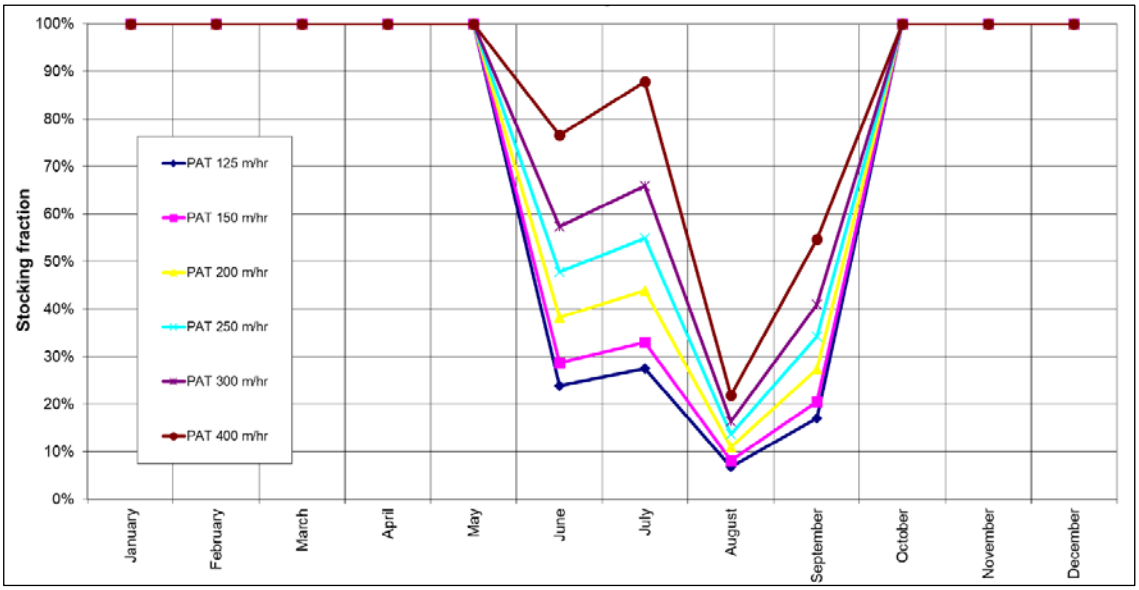
Figure 1: Allowable stocking fraction for a 40kg adult Merino (against ASEL) with curves for different deck PAT values



Source: Work commissioned by MLA/LiveCorp 'Effect of livestock heat stress risk standard on stocking densities for sheep on live export vessels'

The McCarthy review recommended a risk setting of a 2 per cent probability that 5 per cent of the sheep will become heat stressed or heat stress score 3 in table 2 of this report. The McCarthy review suggests this aligns with an allowable stocking fraction that can be estimated by using a 25 per cent reduction in the difference between the heat stress threshold and the mortality limit temperatures. For example, this means moving animal criterion for the model's standard 40kg adult Merino from the mortality limit toward the heat stress threshold by 1.2°C. The resulting effect on stocking fraction compared to ASEL requirements is shown in Figure 2 below.

Figure 2: The allowable stocking fraction for a 40kg 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'

The scenario in Figure 2 indicates the impact to onboard stocking densities during the northern hemisphere summer. In June and July, the decks with the highest PAT could be stocked to around 80 per cent of the current ASEL, but decks with lower PATs would be stocked at less than 60 per cent of the current ASEL. During August all decks would be stocked at less than 30 per cent of the current ASEL. This represents modelling that was undertaken for the McCarthy review.

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?

4.2 Allometric stocking densities

The *Australian Meat and Livestock Industry (Export of Sheep by Sea to Middle East) Order 2018* now requires that for the export of sheep by sea to the Middle East between May and October the minimum stocking density of sheep must be determined by either the allometric formula specified in the order, or a HSRA model, whichever provides the largest amount of pen space per animal.

Space allowances under ASEL are described in two dimensions (e.g. m^2) and is linked to an animal's weight, which exists in three dimensions. Therefore it is reasonable to relate space requirements not to weight per se, but weight to the power 0.66, which is referred to as an allometric equation. The *k*-value used in the allometric space allocation equation below can be used to compare space allocation for different postures and is not dependent on body weight. According to Petherick and Phillips (2009) a *k*-value of 0.033 appears to be the threshold below which there are adverse effects on welfare.

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. The space allocation calculated using allometric principles is 0.377 m^2 for a 40kg sheep. The allometric stocking density is equivalent to a stocking fraction of approximately 77 per cent of the ASEL limit based on a 40kg sheep.

Table 3 below compares the ASEL space allocation per sheep for sheep exports during the northern hemisphere summer against the use of allometric principles based on a *k*-value of 0.033. The formula for determining the space allocation for an animal using allometric principles is:

> $A = kW^{0.66}$ where A is area in m^2; k is a constant (0.033 in this case) and W is the weight of the animal (Source: Petherick 2007 and Petherick and Phillips 2009)

Table 3. A comparison of minimum ASEL area (May to October) to an allometric space allocation based on $k = 0.033$

Liveweight (kg)	ASEL minimum pen area (m^2) May–Oct	Allometric Allocation (m^2) $k = 0.033$	Percentage Change Allometric v ASEL May–Oct
30	0.265	0.311	18%
35	0.278	0.345	24%
40	0.290	0.377	30%
45	0.303	0.407	34%
50	0.315	0.436	39%
55	0.351	0.465	32%
60	0.381	0.492	29%
65	0.423	0.519	23%
70	0.468	0.545	16%
75	0.515	0.570	11%

Source: Table 2 of the McCarthy review p.22

The impact on stocking densities determined by allometric principles is the same for all decks regardless of PAT figures and whether they are open or closed decks. This approach does not take account of the fact that decks with higher PATs are capable of being stocked at higher densities than decks with lower PATs, depending on conditions.

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?

5 HSRA Model—future versions

5.1 McCarthy review recommendation 5

Recommendation 5 from the McCarthy review is "*That the required changes to the industry HSRA 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.*

The use of the HSRA model in preparing export shipments has been a standard in the ASEL since 2004 and is required for any shipment to and through the Middle East.

HotStuff v 4.0 (released in 2011/12) is the version HSRA model currently used by industry. The model calculates heat stress risk for both open and closed vessel configurations and identifies the heat stress risk for vessels while in transit and docked in port (Stacey 2011).

Industry has been developing a revised version of HotStuff (version 5.0). It is expected HSRA review panel findings will be taken into consideration. The revised version will include a platform upgrade to ensure the software is compatible with multiple computer operating systems, the addition of new ports and routes and refinements to the cross-wind parameters (Stacey 2017a).

The department will work with industry on future updates and implementing changes to the model.

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."

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).

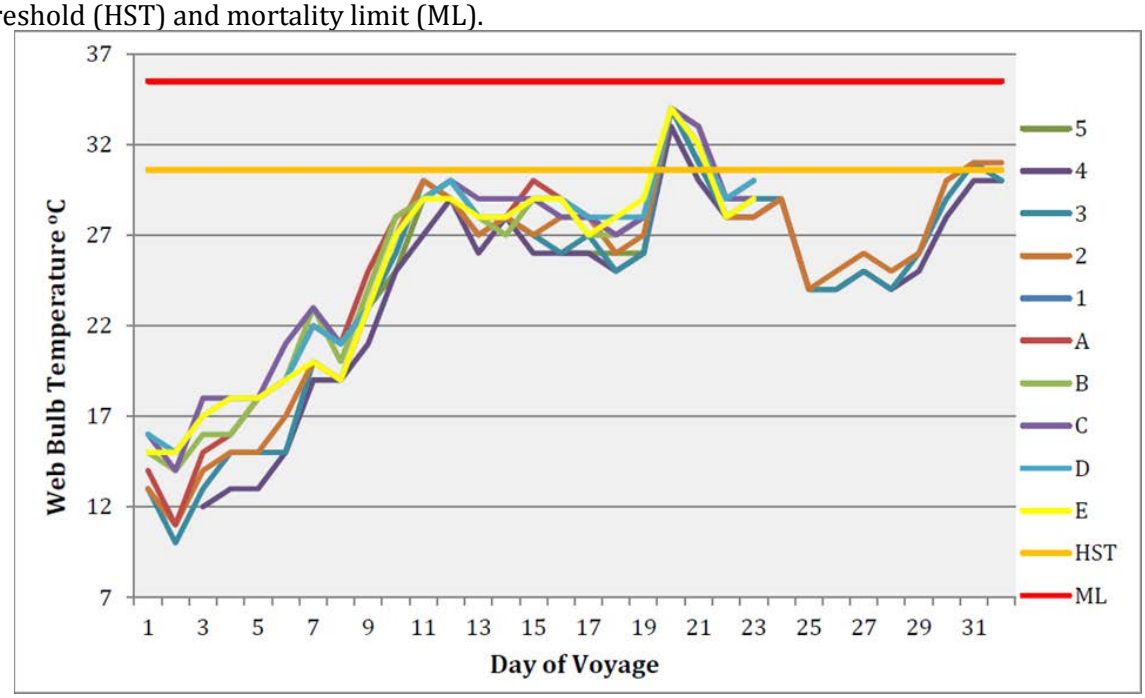
The study showed sheep do accumulate heat when exposed to continual high heat and humidity of up to 30°C wet bulb resulting in measurable changes in physiological parameters, including increased core temperature, respiratory rate (RR) and alterations in blood gas variables (Stockman et al 2011). The 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.

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.

Additional work reported by Stockman (2006) highlighted the effects on sheep of night time cooling (respite) versus no diurnal variation in environment. When sheep were exposed to hot, humid conditions during both day and night, there was an increase in daily mean, maximum and minimum core temperatures, to an extent greater than when the animals were exposed to cooler night-time temperatures.

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).

Figure 3. Mid-morning wet bulb temperatures by deck (see legend) and day of voyage, heat stress threshold (HST) and mortality limit (ML).



Source. Mortality Investigation Report 46, Sheep Exported to Qatar and the United Arab Emirates in September 2013

Figure 3 above shows the wet bulb temperature recorded for each deck on a voyage from Australia to the Middle East during August and September 2013. The current HSRA settings for the heat stress threshold (HST) and mortality limit (ML) are shown by the lines at 30.6°C and 35.5°C.

The main importing countries for Australian sheep in 2016 were Kuwait (36%), Qatar (30%) and UAE (9%), followed by Jordan, Israel and Oman. Sheep exported live by sea from Australia in 2016 were loaded at Fremantle WA (89.5%), Adelaide SA (8.3%) or Portland Vic (2.2%) (Norman 2017).

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).

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?

5.2.2 Vessel Configuration

The HotStuff software takes into consideration the configuration of the vessel when determining the appropriate stocking density for livestock. The details of every vessel used for livestock exports from Australia are loaded into the software program and include: the number of decks on the ship, the deck height and width, and the PAT rate or the speed at which air is circulated through the deck by the mechanical ventilation system. HotStuff also considers whether the vessel is closed or open decked to account for crosswind breezes experienced by open-decked ships whilst sailing or docked in port.

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. These ventilation reports provide evidence to AMSA that the ventilation on a ship meets the ventilation requirements in AMSA Marine Order Part 43 (MO43). A copy of each report is retained by AMSA as evidence the ship complied with MO43 on the day of testing. A copy is retained on board the vessel and is used to check ongoing compliance while the ship holds an Australian Certificate for the Carriage of Livestock.

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).

Ventilation and air quality are important when considering transport of livestock by ship, as their failure can result in mortalities. Recent industry research surveyed public and live export industry workers, with both groups rating ventilation as one of the most important welfare indicators (Wickham et al 2017). Adequate onboard ventilation is essential to remove excess heat, water vapour, microorganisms, dust, gases, provide a uniform distribution of air, and provide the correct air speed for stock.

Mechanical ventilation is used on closed and most open decks on export vessels to ensure air flow. PAT can be used to measure ventilation rates for closed decks (MAMIC, 2002). This is the ratio of actual ventilation flow (m^3/hour) to the pen area being ventilated (in m^2). Measurement of PAT on several export vessels reported values ranging between 100 to 300 m/hour (MAMIC, 2002). As PAT values increase, the wet bulb temperature, and therefore the humidity, of an enclosed deck decreases.

The MO43 define ventilation requirements in terms of complete volumetric air changes per hour, with no areas of still air (dead spots) permitted in pens. Air changes per hour are determined under MO43 by measuring the velocity in m/second of air at each inlet, with all inlet and outlet fans running and the spaces closed as they would be at sea. Each inlet area is measured, so the volume of air in m^3/hour provided from each inlet, and a total for each livestock space, can be calculated. Finally the volume of each livestock space is measured and calculated in accordance with MO43, allowing the number of complete volumetric air changes per hour in each space to be calculated.

Under MO43 a vessel's mechanical ventilation system must provide air from a source of supply, with a velocity across a pen of at least 0.5m/second. According to McCarthy (2018) this measure reflects both the mixing of air (i.e. air distribution) and indirectly predicates a minimum airflow. It is, however, a minimum and does not have the capacity to link to the animal (and/or stocking density) and provide any sort of risk assessment (McCarthy 2018).

MO43 stipulates a minimum of 20 air changes per hour for decks with a height of 2.3 metres or more, increasing proportionally to 30 air changes per hour for decks with a height of 1.8 metres or less. These requirements are equivalent to a PAT of between 50 and 100 m/hour respectively (MAMIC, 2001). Monitoring environmental temperatures (dry bulb, wet bulb), humidity and wind speed offers useful information for assessment of heat load. Wet bulb temperature is considered to have particular application onboard export vessels. Decks with livestock have a high relative humidity and require constant air flow under mechanical ventilation.

A variety of indices have been developed to reflect heat stress potential. These generally involve some combination of different forms of temperature measurement (dry bulb, wet bulb), humidity, and wind speed.

When there are heat stress conditions present, evaporative heat loss is the most important form of heat loss and this in turn is influenced far more by wet bulb temperature than by dry bulb temperature. In the likely range of values occurring on board export vessels, the simplest approach is to use wet bulb temperature alone as a practical measure of heat stress potential on board export vessels (MAMIC, 2002).

In practice the dry and wet bulb temperatures are measured on-board and the relative humidity can be calculated using standard charts. It is also possible to calculate wet bulb temperature from measurements of dry bulb temperature and relative humidity.

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.

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?

5.2.4 Open Decks

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

When there is a good crosswind, the effective PAT in open decks is very high. When there is no or little crosswind, the lack of any clearing air movement towards the centre or leeward side of the vessel can mean the conditions rely solely on the provided mechanical ventilation. MO43 has been changed so no ships with open decks will have reduced or no ventilation on open decks after 1 January 2020.

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?

6 Appendix A: Department's response to McCarthy review HSRA recommendations

McCarthy Recommendation	Department's Response
Recommendation 3—Heat Stress Risk Assessment Industry should move from a risk assessment based on mortality to a risk assessment based on animal welfare.	**Support:** The department agrees that mortality, in isolation, is an insufficient measure of animal health and welfare. The department proposes further public consultation and analysis to assess the specific heat stress risk assessment settings are required to give effect to this (see recommendation 4 below). Additional information is also becoming available from Independent Observers and there is research currently underway to identify animal welfare indicators that could be used for this purpose (see recommendation 6).
Recommendation 4—Heat Stress Risk Assessment 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.	**Support:** Subject to testing and consultation. The department will adopt a heat stress risk assessment approach to managing animal welfare outcomes. Dr McCarthy has not been able to consult and test his analysis on this issue in the short time available during his review, so the department will undertake that process over the next three months. This critical proposal by Dr McCarthy involves a new regulatory model and warrants an opportunity for all interested parties to contribute to the development of a new approach.
Recommendation 5—Heat Stress Risk Assessment That the required changes to the industry HSRA model be made immediately and then included in Version 5 of the HSRA model.	**Support:** Subject to further testing and consultation (see recommendation 4).

McCarthy Recommendation	Department's Response
Recommendation 7—Heat Stress Risk Assessment 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: c) the duration of time that sheep are exposed to high heat loads without respite d) ventilation design rather than assessing risk based on airflow alone In addition, the way in which the model manages open decks should be reviewed.	**Support:** Development of a future model should also consider additional inputs, including investigating alternate ventilation measures, and the use of animal welfare indicators. This will also be informed by the further consultation and analysis on heat stress risk assessment (see recommendation 4).
Recommendation 8—Heat Stress Risk Assessment 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.	**Support.** As per recommendation 7 the future model should also consider additional inputs, including investigating alternate ventilation measures, and the use of animal welfare indicators. This will also be informed by the further consultation and analysis on heat stress risk assessment (see Recommendation 4).

7 Appendix B: Selected LiveCorp/MLA research and development projects

Extract from LiveCorp Submission to the Review of Australian Standards for the Export of Livestock (ASEL)—Stage 1

HotStuff

Code	Project Title	Summary	Finish Date
LIVE.0116	Development of a Heat Stress Risk Management Model	The report outlines the data analysis, mathematical modelling and software development of 'HS' known as 'HotStuff' the program that is used to estimate the risk of mortality due to heat stress in livestock decks on voyages from Australia to the Middle East.	7/05/2003
LIVE.0230B	Independent advice on jetting inclusion in the HS model	The purpose was to study the final report on the development of the HS heat stress risk management model, attend a meeting on the most recent version of the HS model and review proposals from two different consultants to include an allowance for jetting to individual ship pens in the HS model.	25/02/2005
LIVE.0226	HS software further development to take version 2.2 to version 2.3	During the use of HS heat stress risk management software versions 2.1 and earlier, users identified additional features of the software that would improve its usability and effectiveness. Some of the features fell within the original scope of the development contract for the HS software (Live.116) and were included in HS version 2.2. A number of other features outside the scope of Live.116 were identified as being high priority items, ensuring that the needs of the software users continued to be met. These items were targeted for inclusion in HS version 2.3.	10/03/2005
LIVE.0234	Potential benefits of jetting to the 'Heat Stress' model	The study evaluated the potential benefits of including the effects of 'jetting' into the 'Hot stuff' (HS) model in place of the pen air turnover (PAT) parameter. Jetting refers to a component of the ships ventilation where a controlled and measurable air velocity is directed across a specified area. The report determined the typical velocity ratio of an average pen and compared the use of a velocity ratio and the standard PAT within the HS model.	29/04/2005

Code	Project Title	Summary	Finish Date
LIVE.0228	Upgrade of biological assumptions and parameters used in the HS risk management model version 2.3.	The overall objective of this project was to update and validate the animal parameters in the 'Hot stuff' model released in 2001. The report found additional data sets were consistent with the original heat stress data applied in the HS software and recommended a slight change to the heat stress threshold, mortality limit and coat factor for Bos taurus dairy (Friesian) cattle.	17/05/2006
B.LIV.0240	Assessing a method of incorporating jetting in the HS model and its commercial implications	This study was undertaken to further understand the effects of 'jetting' of a particular pen or deck might affect the heat stress risk for livestock in accordance with the recommendations of the report entitled 'Potential benefits of jetting to the HS model'. The report details how a normalised jetting factor may be incorporated into the 'Hot stuff' model to consider the effects of jetting and outlines the information required and the possible animal welfare and commercial outcomes.	29/01/2007
W.LIV.0264	Review of the Livestock Export Heat Stress Risk Assessment Model (HotStuff)	The aim of this study was to undertake a comprehensive review of the scientific basis of the core elements (animal physiology, engineering, climatology and statistics) that underpin the HotStuff model The report includes the panel's conclusion that the methodology and assumptions underpinning the HotStuff model are sound, reasonable and supported by scientific literature and further recommendations that aim to either engender greater confidence in the technical elements of the model or potentially improve the model's accuracy in the future.	31/01/2009
B.LIV.0249	HotStuff Version 3.0 Revision of the heat stress risk assessment methodology to properly incorporate risk of heat stress while at port	This study extends the existing methodology to address this issue. Risk estimates for both the sailing and discharge components of the voyage are incorporated in the revised methodology as well as the functionality for the separate treatment of each Middle Eastern port and for voyages discharging at multiple ports. As part of the study, the software has been moved to a more up-to-date development environment and updated to incorporate the new methodology, improve a range of features and fix a number of problems with the previous version.	30/06/2009

Code	Project Title	Summary	Finish Date
W.LIV.0277	HotStuff Version 4.0—Revised methodology and additional ports	The 'HotStuff' software for the assessment of heat stress risk on livestock voyages west from Australia has been revised, updated and expanded. The primary changes are: • the addition of ports in the Mediterranean, the Black Sea, West Africa and Russia route • inclusion of port risk as a parallel assessment of the risk during the discharge phase (actually introduced at Version 3)options via the Suez Canal or West Africa • inclusion of more voyage weather data and reanalysis of all voyage and port data • removal of the hard-coded limit of 5 knots on the assumed effective crosswind while sailing • updating the software programming environment (Version 4 to 5).	15/06/2014

Heat stress

Code	Project Title	Summary	Finish Date
LIVE.0104B	Use of electrolytes to alleviate stress: Desk top study	The study reviewed the scientific literature and live export industry practices in relation to electrolyte supplementation of sheep and cattle during sea transportation as a result of the previous studies 'Investigation of ventilation efficacy on livestock vessels'. The report identifies sea transport stress factors and considers the benefits of electrolyte supplementation in treating physiological clinical effects of the stress factors.	1/02/2001
LIVE.0209	Physiology of Heat Stress in Cattle and Sheep	This study was undertaken to define the physiology of clinical heat stress in cattle and sheep within an animal house through monitoring changes in body temperature, feed and water intake, respiratory and heart rates, and acid-base and electrolyte balance. The report details the findings of the experiments and assisted in the definition of the heat stress threshold for Bos taurus and Bos indicus heifers, Merino wethers and Awassi rams.	31/10/2002
LIVE.0210	Physiology of heat stress in cattle and sheep and the efficacy of electrolyte replacement therapy (Consultation with Murdoch University on LIVE.0209)	This consultancy was conducted with Murdoch University on Live.0209. Exploring the physiology of heat stress in cattle and sheep and the efficacy of electrolyte replacement therapy	31/10/2002
LIVE.0219	Wetting of Cattle to Alleviate Heat Stress on Ships	This study investigated the benefit of wetting heat stressed cattle by measuring the body temperature, respiration rate, feed intake and live weight change of cattle. The study found wetting cattle, using warm salt water reduced rectal temperature, respiration rate and panting score, increased cattle comfort, and did not result in worsening of the micro-climate.	31/08/2003

Code	Project Title	Summary	Finish Date
LIVE.0209B	Physiology of Heat Stress in Cattle & Sheep (Stage 2)—Efficacy of an Electrolyte Replacement Therapy and High Roughage Diet	The physiology of clinical heat stress in cattle and sheep was defined under experimental animal house conditions, considering particularly the physiological and biochemical changes that affect electrolyte balance in the animals, with a view to formulating appropriate supplementation of electrolytes. Changes in body temperature, feed and water intake, respiratory and heart rates, and acid-base and electrolyte balance were measured. An electrolyte supplement was proposed on the basis of measured changes in the cattle, and tested with positive results on urine pH indicating improved buffering capacity, and a body weight advantage.	30/11/2003
LIVE.0224 V1	Electrolyte supplementation of export cattle and further investigations in the heat stress threshold of sheep and dairy cattle	This study was conducted in an attempt to repeat the findings of the previous project entitled 'Physiology of Heat Stress in Cattle and Sheep' that reported a weight advantage of cattle supplemented with water based electrolytes. The project aimed to measure any animal performance and/or welfare benefits to cattle and sheep during and post electrolyte replacement therapy. The report found no evidence that conclusively supported the supplementation of electrolytes on board livestock vessels. However, the study identified heat stress thresholds for heavy rams, withers, ram lambs, and pregnant Friesian heifers.	27/02/2006
LIVE.010	Production of communication materials—wetting cattle heat stress tips & tools	This project developed tips and tools fact sheets to assist stockpersons, accredited seminarians and exporters understand appropriate use of wetting as a heat stress management technique	15/05/2006
B.LIV.0247	Respiratory heat and moisture generation	The aim of this project was to recommend values for respiratory exchange and heat production of deer and goats that are appropriate for use in a project aimed at determining the ventilation requirements during transport via aircraft. A literature search was conducted and recommendations made for carbon dioxide production, oxygen consumption, heat production, evaporative water loss and loss of water in urine and faeces for various sexes of goats and deer of various physiological states.	15/12/2008

Code	Project Title	Summary	Finish Date
W.LIV.0191	Environmental and heat risk assessment for live export holding facilities in NT	This project seeks to: a) ascertain the environmental risks associated with live export facilities in northern Australia and provide mitigation and management recommendations b) ascertain the risks associated with heat stress in live export facilities operating in northern Australia, including an assessment of HLI and AHL utilising collected weather data, and provide mitigation and management recommendations.	ONGOING

8 Glossary and acronyms

Term / acronym	Definition
AMSA	Australian Maritime Safety Authority
ASEL	Australian Standards for the Export of Livestock (Version 2.3) April 2011
HSRA	Heat stress risk assessment
HST	Heat stress threshold
MLA	Meat and Livestock Australia
ML	Mortality limit
PAT	Pen air turnover
NGO	Non-government organisation
WBT	Wet bulb temperature
Allometric	The relationship of body size to shape, anatomy, physiology and behaviour
Heat stress threshold	The maximum ambient wet bulb temperature at which heat balance of the deep body temperature can be controlled using available mechanisms of heat loss
HotStuff	Software program for the assessment of heat stress risk for live export voyages
K-value	*K*-values are used in allometric principles as a determinant of the threshold for all sheep to be able to either stand, sit or lie down at the same time.
McCarthy review	Review undertaken by Dr Michael McCarthy into the export of live sheep to the Middle East during the northern hemisphere summer
Mortality limit	The wet bulb temperature at which the animal will die
Pen air turnover	A measure of ventilation rate; it is the ventilation flow rate divided by the pen area
Northern summer	May to October
Wet-bulb temperature	The temperature read by a thermometer covered in water-soaked cloth over which air is passed.

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