LIVECORP SUBMISSION TO THE AUSTRALIAN GOVERNMENT HSRA PANEL

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LIVECORP
Level 1, 40 Mount Street, North Sydney

Contents

1. Introduction

LiveCorp and its research, development and extension

1. The Australian Livestock Export Corporation Limited (LiveCorp) is a not-for-profit industry body funded through statutory levies collected on the live export of sheep, goats and beef cattle, and a voluntary levy collected on live dairy cattle exports. LiveCorp is one of the 15 Australian rural Research and Development Corporations (RDCs).

2. LiveCorp is the only RDC focused solely on the livestock export industry and it works hard to achieve the right kind of change for industry by supporting exporters to meet their compliance and animal welfare requirements. This support is in part delivered by exploring and obtaining the best evidence possible to inform compliance and best practice.

3. LiveCorp delivers this by investing in research, development and extension (RD&E) and provides technical and marketing services and support to enhance the productivity, sustainability and competitiveness of the livestock export industry. LiveCorp operates across several program areas, often in close consultation with other industry stakeholders including the Australian Government, to continuously improve animal welfare, regulation, market access and supply chain efficiency.

4. LiveCorp does not engage in agri-political activity, rather its focus is on obtaining and providing the best information possible to inform policy makers in the setting of industry best practice and good regulation.

5. LiveCorp works in partnership with other RDCs, industry bodies and research providers to achieve strategic outcomes for the industry and leverage higher returns for investments that demonstrate value for money for livestock exporters.

6. In recognition of the benefit of livestock exports to businesses throughout the entire supply chain, including producers, much of LiveCorp's investment occurs in partnership with Meat and Livestock Australia (MLA), through the joint Livestock Export Program (LEP). The partnership with MLA to deliver the LEP is widely recognised as the most efficient mechanism for delivering RD&E and in-market technical support.

7. The LEP Research, Development and Extension (RD&E) Program is the primary mechanism for undertaking RD&E activities for the livestock export industry. The RD&E Program is focused on three key strategies:
    a. Improve animal health and welfare outcomes across the supply chain;
    b. Improve supply chain efficiency and regulatory performance; and
    c. Enhance market access conditions for existing and new markets.

8. The most significant area of investment for the RD&E Program is the delivery of animal health and welfare improvements, which receives 71% of the annual RD&E Program budget.

    a. Within that animal welfare strategic investment stream, heat stress research has accounted for several millions dollars over the last 15 years. This commitment to long-term research and funding has been required due to the well-recognised, inherent complexity and lack of other referrable science in the area.

9. The RD&E Program targets research to progressively identify, understand and seek to resolve key animal welfare risks, market access issues and supply chain inefficiencies. This is achieved through investment in projects to gather and analyse data, build knowledge, increase productivity and fill gaps in understanding, as well as to develop, trial and implement practical extension outputs.

10. Key focuses for the livestock export industry over the last 15 years have included the most significant causes of sheep mortality on-board vessels (salmonella, inanition and heat stress). In recent years, a range of projects aimed at improving data collection and developing welfare indicators have commenced and are now well-advanced. Some of these projects are summarised in Appendix 1 and others are detailed in this submission.

11. We also note that as part of the ongoing process to continually improve its R&D program and ensure its relevance and value, the LEP recently engaged an independent consultant to complete a systems review of the program in 2017 – 2018. This review has recently been completed and the recommendations are being considered within LiveCorp and MLA, with a view to finalising an implementation plan shortly.

    a. A focus of the review has been to ensure that extension and adoption of R&D are factored in more strongly at the front end of the program strategy and project initiation processes, to improve uptake by industry and address concerns over extension and adoption.

Process and comments on submission development

12. In responding to the HSRA Review Panel's issues paper and call for submissions, LiveCorp sought to bring together views from a group of multi-disciplinary professionals in the areas of modelling, animal physiology, regulation, and engineering.

13. These experts are not dissimilar to those that contributed to the development of the HSRA originally, although in the time-frames there are limitations on what could be achieved.

14. From this information, we have developed a number of propositions and proposals that we believe demonstrate the best way forward, and which are supported by the best information available and where relevant, fundamental principles of physiology and welfare outcomes.

    a. However, in the time-frames we have not been able to fully proof the concepts or complete full analysis.

15. If it would assist the Panel to have more supporting evidence please let us know and we will endeavour to obtain and provide that within the next few weeks / month. In the longer term we also hope to collaborate with the Panel, including to identify and refine the research that is needed (some of which are highlighted in this submission).

16. Finally, LiveCorp directs the HSRA Review Panel to the substantial body of research that the LEP has completed in the area of heat stress during livestock export.

17. We believe that the Australian industry's level of attention to research into heat and thermoregulation, particularly as it relates the combined heat and humidity risks is largely unprecedented.

18. Several million dollars have been committed to such projects and we have noticed in the policy debate on this matter to date, and we would expect again in the submissions to the Panel on its Issues Paper, that our projects and research are referenced strongly.

    a. We note that the Heat Stress Risk Assessment (HSRA) Panel pointed to many of these projects in an Appendix of its Issues Paper.

    b. Some additional projects completed by the LEP in the areas of heat stress and thermoregulation are included in the lists outlined in this submission.

19. We hope that the Panel will recognise the considerable effort, resources and time over the last 15 – 20 years that the LEP and the range of experts we have engaged, have committed to improving the knowledge of heat stress in the livestock export industry and developing and advancing the HSRA model.

2. Current HSRA model

Overview of development

20. The HSRA model was developed in 2003 following an investigation into the Becrux high mortality incident and in response to growing concerns about the welfare of cattle during export.

21. Experts from a diverse range of disciplines contributed to its development including engineers, statisticians, bio-metricians, veterinarians, animal physiologists, epidemiologists, meteorologists and programmers.

22. A lack of relevant data available in the scientific sphere necessitated the LEP's investment in a program of data collection on a series of voyages to the Middle East, coordinated by Maunsell Australia. These are detailed in the following reports:

    a. *Investigation of the Ventilation Efficacy on Livestock Vessel* (Maunsell Australia, 2001), SBMR.002

    b. *Investigation of Ventilation Efficacy on Live Sheep Vessels* (Maunsell Australia, 2004), LIVE.212

23. The development of the model is outlined in detail in the Maunsell Australia report of 2003, entitled *Development of a Heat Stress Risk Assessment Model* (LIV.116).

24. This report transparently outlines all of the assumptions made and the reasoning for these decisions, and the approaches and calculations used in the model. The LEP also engaged the HSRA developer (Stacey Agnew) in 2017 to produce an Addendum to the report for the development of the fifth HSRA version that again outlined the calculations behind the model.

    a. The HSRA review panel is referred to these reports for details on the design of the model.

25. Supplementing the voyage data there were further projects that the LEP funded that informed the animal parameters in the model and their refinement, including:

    a. *Physiology of heat stress in cattle and sheep* (Barnes, A et al, 2004)

b. *Electrolyte supplementation of export cattle, and further investigations in the heat stress threshold of sheep and dairy cattle* (Barnes, A et al, 2008)

c. *Pilot Monitoring of Shipboard Environmental Conditions and Animal Performance* (McCarthy, M, 2005)

d. *Upgrade of biological assumptions and parameters used in the HS risk management model version 2.3* (Stacey, 2006).

26. Since it was first developed, the model has been subject to a continual process of review and updating. This has included amendments that have incorporated cattle and sheep, closed and open decks, separate assessments of sailing and port risks and updated weather data and ports.

27. The model was also subject to an independent review managed through the CSIRO in 2008. This report made a number of recommendations and found that:

    a. "*Overall, the panel concluded that the methodology and assumptions underpinning the HotStuff model are sound, reasonable and supported by scientific literature. The model developers have followed well-defined and logical principles of adaptive management in the presence of uncertainty*."

28. Key projects outlining the details of the work completed to progress the HSRA are listed below:

    a. *Development of a Heat Stress Risk Management Model* (Maunsell Australia, 2003)

    b. *Potential benefits of jetting to the Heat Stress model* (Casey, 2005)

    c. *Upgrade of biological assumptions and parameters used in the HS risk management model version 2.3.* (Stacey, 2006)

    d. *Assessing a method of incorporating jetting in the HS model and its commercial implications* (Smith et al., 2007)

    e. *Review of the Livestock Export Heat Stress Risk Assessment Model (HotStuff)* (Ferguson et al., 2008)

    f. *Detailed Temperature and Humidity Climatology for Middle East Ports* (Buckley, 2009)

    g. *HotStuff version 3.0 – Revision of the heat stress risk assessment methodology to properly incorporate risk of heat stress while at port* (Eustace & Corry, 2009)

    h. *HotStuff version 4.0 – Revised methodology and additional ports* (Stacey, 2014)

    i. *HotStuff version 5.0 - Improvements to the Live Export Heat Stress Risk Assessment Method* (Stacey, 2017).

        i. The HotStuff version 5 report addendum also includes a restatement of details of the calculations behind the model.

Key features

29. The HSRA model was developed in 2003. It was and continues to be a model that is well-designed and evidenced against its objectives, and that deals with complex

interrelated factors based on the best available evidence in an area where there was, and still is, real gaps in knowledge.

30. Knowing the degree of uncertainty in the science, industry and the HSRA developers purposefully adopted a conservative approach in the assumptions and decisions made, including:

    a. Assessing heat stress risk against the probability objectives by line of livestock per deck (not at an aggregated consignment level);

    b. Using the 98th percentile for the worse 12 hours of a voyage as the overriding weather risk for the assessment; and

    c. Assuming zero wind for open decks when assessing port risk.

31. The model also achieved an impressive balance between incorporating the variability of the influencing factors for the separate lines of livestock and not introducing such complexity as to make it unusable or impractical. This is particularly noteworthy when it is considered that every voyage can be vastly different – with the animal, weather and potentially vessel factors changing.

32. The model was also tied to mortality because it was, and remains, the best objective measure of welfare available as it is dichotomous and there is no subjectiveness in interpretation. Further, mortality is instantly and repeatedly recognisable without any specialist skills, can only be counted once (i.e. it is permanent and does not change over time), and – as it does not have a duration influence – it does not require continuous monitoring to assess.

33. The specific thresholds used for the probability in the HSRA were independently derived for industry (Maunsell, 2003) to ensure that the model would operate as effectively and with as much certainty as possible.

34. In regards to the 2 % threshold, it reflects the application of a 98th percentile approach for voyage risk estimation which captures the 'worse case' / extreme weather scenario for any 12 hour period during a voyage. That 'worse case' 12 hour risk profile then becomes applicable to the whole voyage.

    a. "Worst case" is taken as the 250 nautical miles or approximately 12hrs of the particular voyage route that has the highest wet-bulb temperature probability distribution.

35. The 98th percentile of the normal weather distribution was selected for the weather probability because of the developer's assessment that trying to work above that point inherently had far too much uncertainty.

36. While statistically it was the highest sensibly used threshold, it is still recognised that it leaves a 2 per cent chance of an unwanted outcome.

37. The 5 per cent threshold for mortality was selected based on independent advice to the industry that it would not be possible to accurately distinguish between heat stress related mortality and other mortality causes (salmonella and inanition) clearly below this level. Or to put it another way, the advice was that above 5 per cent it would almost certainly be

mortality caused by a heat stress event, or if not, the cause would be very clearly identifiable (i.e. extreme, obvious incidents such as vessel breakdown / fire).

a. It is also important to note that the 5 per cent threshold is applied to each line on each deck / hold and not as an aggregated ship total.

38. Maunsell (2003) commented on the matter in the report of model's development:

a. "*The 'expected mortality', while statistically valid, is not necessarily the preferred measure for those seeking to judge acceptability of risk. The emphasis is normally on the likelihood of mortality exceeding a limiting level. The current reporting limits are 1% mortality for cattle and 2% for sheep. At these levels, it is difficult to verify from voyage reports, the importance of heat stress relative to other causes. It is preferable for assessing past events and future outcomes, to look at a higher mortality level with an appropriately lower likelihood (reduced probability). We have chosen 5% mortality. At this level and above, if heat stress is not a major cause, the alternative explanation will be obvious (fire, sinking, etc.). We also note that adopting a probability measure at a higher mortality level does not imply acceptance of greater risk. A single voyage will have different probability of 1% and 5% mortalities, but both will be a snapshot of the same risk profile. We note that the adoption of risk standards is not the role of this report, neither do we comment on the variation of risk standard with mortality level*."

39. More recent advice provided to LiveCorp from the HSRA developer noted that:

a. The 5% mortality event was chosen, as there were no robust data available to assess historical lower mortality events. At that time and earlier, inanition and salmonellosis were contributing to mortality in a way that low levels of heat stress mortality could not be distinguished.

40. Recognising the above, LiveCorp has still come to the belief in preparing this submission, that the 5 % level could be adjusted, within reason, to lower risk levels. We particularly based this position on our view that the regulator, through independent investigation into any voyage with mortality exceeding 1 per cent, should be able to provide an informed view on the probable causes.

a. However, in noting the above we also recognise the need to address the following caution provided to LiveCorp by the HSRA developer that "*the adopted distribution of animal susceptibility has only really been assessed at the 5th percentile. Consequently, moving away from these figures makes the method more conservative but less certain. We might not know whether it becomes optimistic or too conservative.*"

41. In considering the impact of the thresholds and assumptions selected in the development of the model, we believe that the historic records of mortality incidents (in terms of the numbers and the levels in any particular incident) demonstrate that the industry was successful in ensuring that the modelling and its settings were conservative.

42. Further, we believe that the model has clearly had a significant positive impact on welfare during livestock export since its adoption and note that it has been the overriding influence on the stocking rate and voyage decisions for exports to the Middle East.

43. This has been reflected in a dramatic and ongoing decrease in mortality, as can be seen in the graphs shown below.

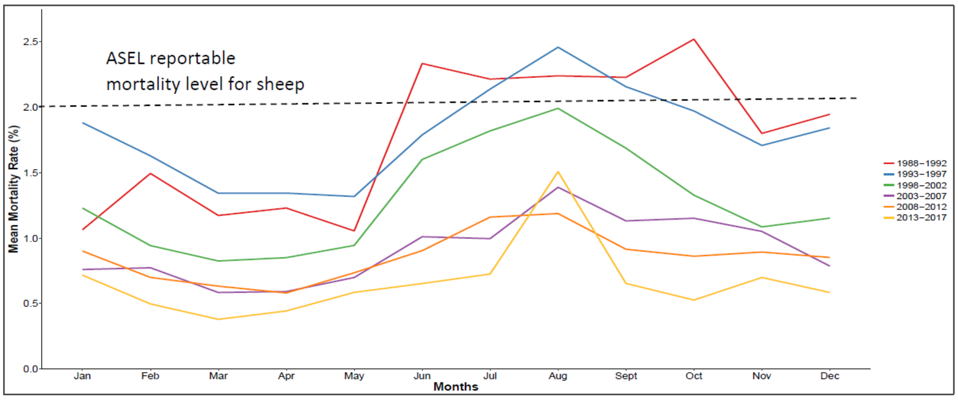


Figure 4. Performance of sheep exports by period (1995-2017)

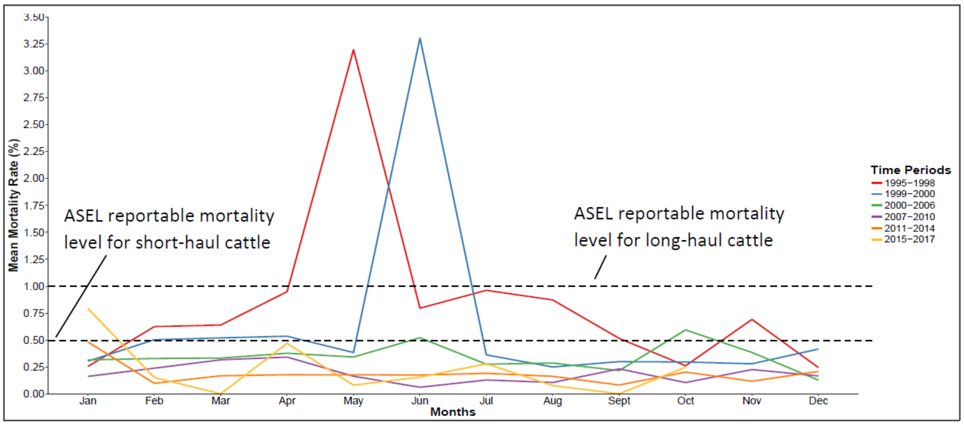


Figure 5. Performance of cattle exports by period (1995-2017)

44. For cattle, a recent long term study (LIV.252 – *Identifying the causes of mortality in cattle exported to the Middle East* (Perkins *et al*., 2015)) also demonstrated that heat stress no longer represents the most significant cause of mortalities for long haul shipments – other factors are now much more important. While there have been other changes within this period, the HSRA model has no doubt played a significant role. A graph produced for LiveCorp from the data collected through LIV.252 is included below and shows the changes before and after the implementation of the HSRA.

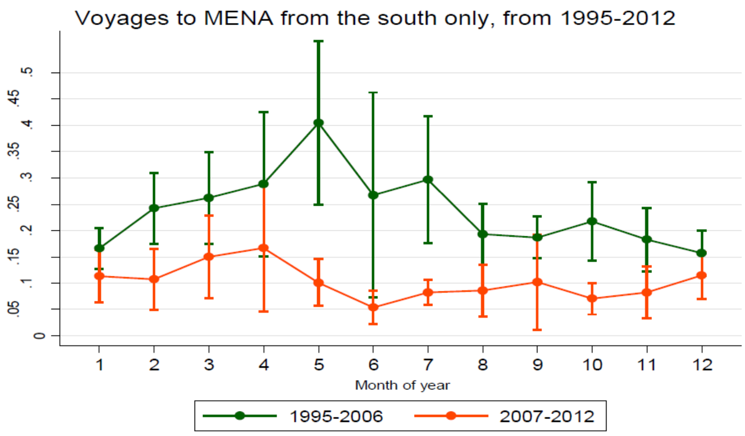


Figure 6. Average voyage cattle mortality (deaths per 1000 cattle days) by month of loading, for voyages involving cattle loaded in southern Australian ports and travelling to MENA. Bars represent 95% confidence intervals.

Context

45. Heat stress is an important factor with the potential to influence the mortality and welfare outcomes of a voyage, however it is not the only cause.

46. Enteritis and inanition are the most common cause of mortality during the livestock export of sheep – accounting for over 76 % of diagnosed mortality (Makin, K, 2010)[1]. In a multi-year study into the causes of mortality in sheep exported from Portland and Adelaide that reported in 2010 (Makin, K) it was found that enteritis was the most common cause of mortality (34.4%), followed by inanition (23.9%) and enteritis / inanition (18.2%). It noted that "*heat stress was recorded as the cause of death for 9.5 % of diagnosed mortality however, heat stress deaths were largely confined to two voyages that had heat stress events*."

    a. The report also identified significant line factors (in relation to mortalities from all causes) related to particular property of origins – "*Mortality was restricted to certain lines of sheep with 62.7% of lines having no recorded mortality and 74% of mortality being traced to 18% of lines*."

    b. Graphs from the Makin report (LIV.123) showing some of its findings are provided at Appendix 2.

47. It is important to note the potentially significant influences that issues such as salmonellosis, inanition and line effects can have in contributing to mortality and susceptibility to factors such as heat stress and the challenges that this presents for modelling and validation of predictive outcomes.

48. As noted previously, the data on the long-term performance of the industry shows that it has achieved substantial and ongoing reductions in the mortality rates for sheep over time.

    a. We expect that with the completion of the salmonella vaccine development in the next couple of years a further step change in these rates will be possible – both by addressing a direct, primary cause of mortality, as well as supporting the overall health and resilience of sheep to other challenges.

3. Opportunities to improve the approach

49. Below we expand on different opportunities to improve the management of heat stress risks within the livestock export supply chain, including identifying potential improvements to refine the HSRA model

Developing and integrating a welfare based continuous improvement system

50. Heat stress is a complex and multi-faceted issue, which we believe cannot be addressed by a singular focus on predictive risk assessments through the HSRA model.

51. The HSRA model achieves significant outcomes, but it does so bounded by the need to make evidence based assumptions that favour objectivity and certainty. Not focusing on these factors would result in a model that is detached and unrepresentative of the real world.

[1] Investigating mortality in sheep and lambs exported through Adelaide and Portland. Makin, K; House, J; Perkins, N et al. (2010), LIV.123

52. It also faces the pragmatic issue that no matter how effective a model is, it will never be able to take into account every factor or individual variance in a manner capable of absolutely predicting the actions, responses and outcomes of biological organisms and systems.

53. We hear this limitation within LiveCorp from engagement with practical people in the industry – veterinarians, exporters and stockpeople. They point to 'one-percenters', particularly in selection, preparation and rejection criteria, as the most important area to achieve the next level of improvements in animal welfare. Rarely do they see the HSRA model as the most important mechanism to achieve such improvements.

54. With the above in mind, Livecorp believes that an integrated approach featuring a refined HSRA model and a welfare based continuous improvement system is needed and offers real opportunities to improve heat stress risk management.

55. The implementation of a continuous improvement system offers the chance to achieve important structural changes in the industry by building strong, dynamic feedback loops into businesses.

56. Such structures are critical to improve the monitoring and collection of data, but also to ensure that that information is analysed and used on an ongoing basis to drive and demonstrate improvement and allow the proactive identification and response to issues (before they become significant problems).

57. These systems to encourage continuous improvement necessarily need to be used within industry based management frameworks, rather than used as regulatory measures or thresholds for punitive action.

58. Not surprisingly, the potential in this space is expanding due to the rapidly increasing availability of new technologies, and the re-purposing of existing technologies in other spheres into the livestock / agriculture space.

59. The LEP RD&E program is playing a significant role in the development of this continuous improvement structure and in supporting industry to transition from a performance structure based on mortality, to one with a greater focus on welfare.

60. The primary project through which the continuous improvement / benchmarking system is being advanced is the LEP project entitled Development and assessment of animal welfare indicators.

61. This critical project was commenced as part of an industry reform proposal initiated by ALEC in the last few years to develop meaningful indicators of welfare along the supply chain that would move performance measurement away from a focus on mortality, support transparency and reporting to the community, and develop a structure to enable exporters and the industry to access the information to use in a continuous improvement / benchmarking, and potentially early warning, system.

62. The project is being delivered by Murdoch University and, after an initial literature review and survey to identify potential indicators across the supply chain (available at the LiveCorp website), it is now actively progressing through a pilot and data collection phase.

63. In this phase a range of potential measures or indicators – including qualitative behavioural assessments – are being trialled on-board livestock vessels and throughout the supply chain (i.e. in registered premises and in-market feedlots).

64. The project has a final reporting date in 2021, although it should be noted that along the development pathway there are a range of steps that will be rolled out and its final reporting date does not preclude the interim adoption of approaches to mitigate risks identified in this submission.

65. We envisage from this research that a set of clear animal welfare indicators to underpin the industry structures and community reporting will be identified that:

   a. Are meaningfully linked to the welfare of the animal;

   b. Have scientifically set thresholds on which performance is measured;

   c. Can be collected and measured, and which have clear collection / sampling protocols;

   d. Are understood within the context of each other;

   e. The measurements against these indicators can be clearly interpreted in assessing the welfare of the livestock; and

   f. Can allow proactive identification of developing risks (i.e. early warning) to support interventions before issues arise.

66. The research challenge to achieve the above is significant and the selection of indicators is not an easy task. They need to underpin the collection of meaningful and comparable data – too many indicators will result in ambiguity and a lack of focus, while too few may not allow appropriate coverage of the range of animal welfare issues.

67. Some of the aspects of welfare that the project will need to consider include that:

   a. Welfare is multi-faceted – many different elements contribute, in varying degrees, to whether an animal is in a 'good welfare state'.

   b. Each element can have multiple degrees of variation that need to be considered and tied back to an acceptable welfare state (for example, there can be variations in the duration and severity of exposure / experience that are relevant, and the scale in terms of how many within a group are affected).

   c. The patterns and interactions of welfare need to be understood individually and collectively – for example, is panting at a high level for a short time worse than panting at a moderate level but for a longer period?

   d. Indicators have to be linked back to a welfare state through validated science.

   e. Indicators must be able to be assessed / measured consistently (can people easily recognise the differences, what level of training / education is needed)?

   f. Indicators need to have collection protocols that are meaningful – for example, welfare measures have to be based on sampling and if factors like duration are relevant then there needs to be consideration of how monitoring can occur continuously.

68. Importantly, indicators need to be understood across industry and community to form a common language and expectation and to build confidence and trust.

69. Part of ensuring the animal welfare indicators project can achieve its goal and be successfully implemented will be the availability of supportive collection and analytical technologies.

70. In this vein, one of the significant early developments to stem from the animal welfare indicators project has been the development and trialling of an app based, real time data collection platform.

71. This platform – known as LIVEXCollect – uses an app with a range of forms that allow different information to be collected and uploaded in real-time on areas including mortality, morbidity / treatments, daily reports and, particularly for the research trials, welfare indicators.

72. This platform will have an associated database and dashboard (currently being designed / developed) and will have the capacity to incorporate automation technologies, as they are trialled and adopted.

73. In this regard, we note that we believe automation will make a critical contribution to this system in the future to:

    a. Increase the reliability and reproducibility of the data;

    b. Reduce the reliance and workload impact on on-board personnel to collect data – particularly important under a welfare measurement system where there will be a reliance on sampling; and

    c. Enable the collection and rapid analysis of large volumes of information to allow for early warnings / alarms of potential issues to be alerted to on-board personnel and others that can check and respond.

74. Recognising the importance of integrating this technology into the industry and regulatory systems, the LEP also has a number of projects in this space that it has been pursuing alongside the welfare indicators project. Current projects and activities – which the LEP expects will expand as there is more clarity on the indicators that may need to be collected – include:

    a. Trials of automated environmental monitoring for ammonia, temperature, humidity and carbon dioxide (initially on-board aircraft);

    b. Development of automated sheep counting technology to provide irrefutable counts at loading and unloading (and in turn, irrefutable mortality figures); and

    c. Mapping and scoping of proof of concept trials with a university provider for technologies that could support the automated measurement of animal welfare indicators from the animal welfare indicators project (for example, behavioural measures such as panting).

    d. Scoping and trialling of automated environmental monitoring and other detection and response technologies relevant to reducing deck wet bulb temperature through the open innovation process.

75. There will of course be logistical challenges that need to be addressed in this process – including on-board power / battery, processing capacity, connectivity and transmission of data and ability of technology to withstand the environmental conditions (i.e. seawater).

76. LiveCorp believes that the above projects will provide rigorous, science based indicators and an effective continuous improvement and benchmarking structure / system to support animal welfare and transparency into the future.

77. As a further note, the continuous improvement system and associated data collection platforms will also provide the means and opportunity to narrow the confidence margins to improve, validate and refine the accuracy of the HSRA model.

    a. For example, continuous monitoring on voyages of temperature, humidity, location and actual sea surface temperatures in real time will allow validation against the predictions and assumed correlations.

    b. Each voyage would contribute to narrowing the confidence margin (which would improve static risk prediction) and illustrate the effectiveness of any dynamic risk management.

78. Noting all of the above, we believe that an integrated approach to heat stress risk that uses both an objectively based HSRA model and a welfare based continuous improvement system is needed and should be a fundamental consideration for the HSRA Panel.

Transitioning from static to dynamic risk assessment and response in the HSRA model

79. The above discussion of the integration of an interactive, animal welfare based continuous improvement system provides a good introduction to highlight the potential to adopt a more dynamic risk assessment and response approach into the HSRA model.

80. The current HSRA model is focused on maximising the predictive capacity prior to the voyage. This approach provides a static assessment based on historic data and reflects the limitations of the technology, in a number of areas, at the time of its development.

81. Such an approach works well in many circumstances and has served the industry well.

82. However, with a raft of new technologies available and emerging, and significant shifts in key fields (such as meteorology and climatology) since the HSRA model was developed there are now significant opportunities to consider if a dynamic approach to risk assessment and management is possible.

    a. Dynamic risk assessment and management is much more common in other sectors – for example, in aviation. The Australian feedlot industry also uses a more real-time forecasting model to support heat stress risk mitigation.

83. Some of the key technologies / changes that could support a more dynamic approach include the internet, wifi, the internet of things, expanded processing and storage capacities, modern meteorology and the accessibility of near real-time, high resolution satellite data.

84. While there are a number of steps to achieve dynamic risk management – including improving the sensitivity of inputs and adopting technology / automation, we believe that

this is a realistic option that would be a meaningful change for the livestock export industry.

a. One of the most significant opportunities to increase a dynamic risk assessment approach is in relation to the exposure / weather inputs – both in terms of using continually updating data to complement the historic assessment, and the potential of forecasts. To avoid duplication, this is not discussed further here and is outlined later in the submission.

85. The adoption of a more dynamic and proactive approach to risk assessment and management is also – as described earlier – closely aligned with the objectives of the animal welfare indicators project.

Delivering on the existing RD&E program of improvements to the HSRA model

86. The LEP RD&E program has consistently invested in research to support the improvement and refinement of the HSRA model and the underpinning science on heat stress.

87. A continuing program of work is in progress, which we believe will continue to significantly refine the model.

88. One of the most significant programs underway is the coordination of independent audits of the ventilation (the pen air turnover (PAT)) of vessels servicing the Middle East sheep trade. This worked commenced with the support of regulatory and industry initiatives, but has allowed us to now deliver against an existing RD&E recommendation.

89. In commencing these PAT audits, the industry has also been able to proactively implement a further RD&E recommendation by incorporating an assessment of a vessel's risk of re-ingestion.

a. Re-ingestion in this context is the potential risk for exhaust air to be sucked into the main fresh air inlets for the vessel. Re-ingestion is a potential risk factor for the effectiveness of ventilation at port if there is still air (sailing risk is virtually nil).

i. We note for completeness that re-ingestion between open decks is already incorporated into the calculations of port risk in the model.

b. Re-ingestion risk is assessed through a combination of desktop and on-site analyses, and refined through Computational Fluid Dynamic assessment.

90. We believe that the PAT and re-ingestion audit program is a particularly important project that will improve the accuracy and confidence in one of the core inputs applied in the model. The PAT values are particularly important given they directly influence the build-up or otherwise of the temperatures inside the vessel (and hence the animal environment). To date, more than ten vessels have been audited.

91. With access to, and confidence in, the PAT figures from these audits, the LEP is also in discussions with relevant researchers to undertake extensive validation work on the HSRA model.

92. We note that a previous project that was commenced to validate the HSRA model stalled because privacy concerns and other issues presented problems in obtaining ready access to PAT values. Even if these pre-audit PATs were available it appears likely that there may

have been variations in individual readings that would have affected the confidence in and usefulness of a validation exercise.

93. A further proposal that the LEP is assessing, which stems from the HSRA version 5 development research report, is that open decks be assessed as if they are enclosed decks (i.e. based solely on mechanical ventilation).

94. The LEP is considering this proposal in light of recent changes to Marine Order 43 that have amended the air change requirements for open and partially enclosed decks for new vessels (constructed from 1 July 2018) and existing vessels (coming into effect from 31 December 2019).

95. The LEP is also planning a significant upgrade to the HSRA model software to modernise its hosting / structure and improve its capabilities in terms of functionality, user friendliness and data capture. This upgrade will occur once there is greater clarity on broader refinements needed to the model.

96. In addition to the above, the LEP has developed and is progressing an R&D strategy with significant relevance to heat stress that builds upon existing and ongoing projects (of which some of those on the panel will be aware). Projects encompassed within this strategy include the following:

    a. Updating the weather data to improve the temporal and spatial estimates within the HSRA model and to investigate and if possible, implement more real-time weather forecasts for voyages (discussed in detail later in this submission).

    b. Undertaking climate controlled studies to better understand and define the animal response to heat exposure, including with consideration to duration.

    c. Aligning the Animal Welfare Indicators project with the heat stress research stream to assess the available science and develop meaningful, objective measures of welfare and protocols for collection on a sampling basis.

    d. Scoping technology that could automate the monitoring of welfare – including for heat stress – and support the move to an industry continuous improvement based on welfare.

        i. Automation is likely to be critical to support the proper collection of information in an objective manner with the least impact on animal carers (which is an important consideration when moving into the variability of welfare measures and a sampling approach).

        ii. While automation is being investigated, an app based voyage reporting tool and database have been developed alongside the Murdoch University indicators project. It is currently being used by Murdoch University for data collection in its project, and is being trialled with accredited veterinarians and stockpeople for wider use (e.g. for daily reporting).

    e. Scoping and trialling potential technologies that could automate the collection of environmental data on-board livestock vessels – particularly temperature and humidity.

    f. In-market heat stress risk assessment research.

97. Finally, LiveCorp has also initiated a further stream of heat stress related work outside of the LEP RD&E stream, using a new mode of research engagement. This work is using a skilled consultancy firm, Beanstalk AgTech, to manage an open innovation process to explore the existence and feasibility of new and developing solutions for managing the on-board environment, particularly wet bulb temperature. This open innovation approach is also much more aligned with trying to leverage the potential for a new dynamic risk assessment and intervention approach.

98. This new approach is providing the industry with the opportunity to tap into the global innovation and technology ecosystem to identify new or emerging technologies that may have shifted the feasibility of interventions previously considered impossible or unviable (e.g. dehumidification). So far, the project has scoped a wide range of technology 'territories' from health to military to identify potential solutions / elements of a solution – generally broken into 'detection' or 'response' technologies

    a. Areas investigated include dehumidification, targeted rapid cooling, environmental monitoring, weather data / improved voyage route planning and artificial intelligence.

99. LiveCorp is now commencing a trial phase to validate the effectiveness / viability of some technologies identified. While the approach is blue-sky and based on a fail-fast model, we believe it has the potential to further support new approaches to managing heat stress.

100. We believe that there is within the existing and planned program of RD&E work through the LEP and LiveCorp substantial projects that will improve the operation of the HSRA model and the approach to heat stress (and welfare) management generally.

4. Improving the sensitivity of the HSRA model exposure / weather inputs

101. As mentioned in the previous section, one of the significant areas where LiveCorp believes there is the opportunity to make transformative changes is in improving the sensitivity of the exposure / weather inputs in the HSRA model. In light of this, the following section outlines in detail the current and potential future modelling and forecasting approaches.

Current modelling and forecasting approach

<u>Current exposure inputs and analysis used in the HSRA</u>

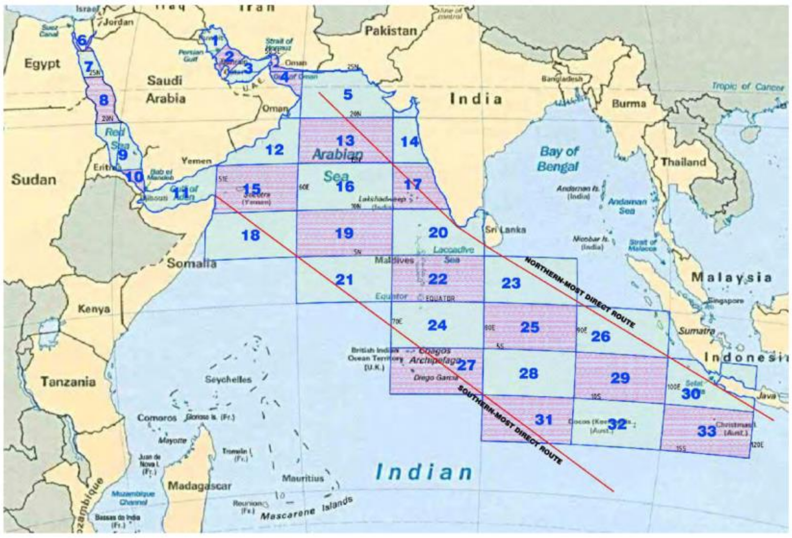
102. The probability function for various wet bulb temperatures likely to be experienced during a voyage was parameterised by Maunsell Australia using weather data from two sources:

    a. For all ports in the Persian Gulf and Red Sea to which Australian livestock are shipped, temperature and humidity data was obtained from official national meteorological observing stations closest to the port.

    b. Weather data along sea routes taken by live export vessels to the Middle East was obtained from the voluntary observing ships program and from drifting and moored buoys.

103. For ease of analysis, the oceanic regions studied by Maunsell Australia were subdivided into 33 separate zones (see below):

Zones used by Maunsell Australia in 2003 studying wet bulb temperatures



a. The Persian Gulf was divided into four zones, representing the northern, central and southern regions of the Gulf plus the Gulf of Oman;

b. The Red Sea was subdivided into four latitudinal zones, with an additional zone for the Gulf of Aden.

c. The open oceanic zones were generally divided into boxes of five-degree latitude and ten-degree longitude, increasing to ten-degree square latitude / longitude boxes south of 10 degrees S where the wet bulb regime was considered more benign.

104. Each of the zones had sufficient data (>1000 points/month) to generate a realistic probability distribution of wet bulb temperature within the zone for each month. Means and standard deviations were calculated for each zone by month and a normal distribution assumed.

105. There are separate assessments of the ambient weather for the voyage itself and also for the ports that the ship will visit to unload.

106. Further refinements of the weather modelling have also been undertaken over the years since its initial development and these are outlined in the reports on the LiveCorp website.

Choice of wet bulb temperature

107. The ability to accurately account for exposure is a critical component of the HSRA model, as is its relationship to the potential interventions that can be taken.

108. It is ultimately exposure to environmental conditions and their influence over the animal's capacity to exchange heat via different routes that partly determine changes in an animal's core temperature and subsequent physiological responses.

a. Animals (specifically homeo-therms) exchange heat with the environment by four routes; conduction, convection, radiation and evaporation.

109. Each of these routes can be modelled and estimated for any given set of environmental conditions using complex heat balance assessments that have equations for each route of heat exchange.

110. The influence / use of each of these routes of heat exchange will depend on different aspects of the environment. As such, heat balance can be impacted by any change in air temperature, wind speed, radiation temperature, or humidity.

    a. Under hot conditions, evaporative cooling methods assume greater importance, as the body tries to lose heat to maintain homeostasis through thermoregulation. Evaporative cooling methods include sweating and panting, in which heat is lost by increased amounts of air passing through the moisture-rich respiratory passages. Cattle are able to lose somewhat more heat through sweating than sheep, but both species are heavily dependent on panting.[2]

111. Thermal physiologists and biometeorologists have generally preferred to define some measure that incorporates all of these aspects of the environment into a single number that indexes the overall potential for heat exchange.

    a. For example, sports physiologists use the wet-bulb-globe-temperature-index, the cattle feedlot and dairy industries use the temperature-humidity-index, and architects use the thermal-comfort-index. Across a broad range, these indices all correlate reasonably well with each other.

112. The 2008 Review commented similarly on this consideration, stating:

    a. "*Because the effectiveness of evaporative cooling mechanisms declines rapidly as relative humidity increases, air temperature is not a good measure of the level of thermal challenge for livestock unless relative humidity is low to moderate. In addition, it is more common for heat stress in animals to arise through a combination of elevated temperature and humidity. Accordingly, environmental measures of heat challenge for animals typically include both temperature and humidity components.*"

113. The livestock HSRA model developers (Maunsell Australia) considered the different measures available and determined that the use of wet bulb temperature was most appropriate. This consideration is set out in SBMR.002 – Investigation into the ventilation efficacy of livestock vessels (Maunsell Australia, 2001) – in detail.

    a. The developers considered wet bulb temperature, temperature humidity index (THI) and a lesser known third indicator – the equivalent temperature index (ETI). The developers demonstrated that ETI generally conforms to the wet bulb temperature, while the THI (which is more commonly used) is closer to a midpoint between the wet bulb and dry bulb temperatures.

114. The use of the wet bulb temperature was considered by the independent review in 2008, which commented:

    a. *"Despite the THI [Temperature Humidity Index] being used more commonly, the developers' decision to use wet bulb temperature as the critical environmental measure for determining risk of heat mortality in livestock on board ships is sound."*

<u>Conservative risk threshold</u>

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[2] Ferguson, D., Fisher, A., White, B., Casey, R. & Mayer, B. 2008 Review of the livestock export heat stress risk assessment model (HotStuff). WLIV.0262/3/4/5. Meat and Livestock Australia. (North Sydney).

115. The model also focused on a predictive pre-voyage assessment based upon a worse-case scenario (defined as the 98th percentile on the worse 12 hours of the voyage) using global historical wet bulb temperature data extracted from the Voluntary Observing Ship (VOS) program. The program used an average monthly figure attributed to the mid-point on the month and scaled towards the next month's figure.

    a. The HSRA uses the 98th percentile of the **worse 12 hour period** of the voyage as the overriding risk for the whole voyage and hence it does not need to take into account the overall profile.

    b. Because the model focuses on predictions based upon the 98th percentile it was able to ignore the normal or more detailed weather patterns below that worse case situation.

116. Using the 98th percentile 12 hour 'worse-case' scenario works well when there is a focus on delivering a static, point-in-time pre-voyage assessment. However, its rigidity inhibits the adoption of more dynamic risk assessments or consideration of incorporating elements, such as duration risk.

<u>Limitations regarding duration</u>

117. The incorporation of duration into the HSRA model was considered in its original development, however it was identified that there were a number of limitations that would inhibit its inclusion.

118. Duration needs much more spatially and temporally sensitive information and much greater processing capacity to be modelled - something Maunsell noted in 2003[3]:

    a. *"An early ambition for the statistical assessment was to allow, in the estimation of risk, for duration of exposure in a particular zone……A far more sophisticated model of the weather involving comparison of weather time scales and ocean zone transition time scales would be required. The statistics then would most probably require a Monte-Carlo type simulation for each stocking entry as it was completed, requiring significant computing."*

119. The HSRA designers further looked at duration of exposure and commented that:

    a. *"In addition to the difficulty of implementation, there are very real limits on the benefits which may accrue from this approach [the adoption of the duration]. In particular, with heat at extreme levels, risk increases with duration, while heat at lower levels may generate some level of acclimatisation and protect against a subsequent, more severe, episode. That is; it is by no means clear how the animal parameters should be adjusted with duration. Other problems include:*

        i. Uncertainty about final route, with multiple ports of discharge changing during the voyage.

        ii. *Relaxation of stocking density after the first discharge port changes deck parameters."*

[3] *Development of a Heat Stress Risk Assessment Model* (Maunsell Australia, 2003), LIV.116.

120. We note that the model did take decisions that factor in some consideration of duration by:

    a. Using the probability distribution for the worse 12 hour period forecast for the shipment to derive the 98th percentile and making that the controlling risk over the entire voyage.

    b. Using data from voyages and climate control studies, where the exposure durations were for a longer period, to extrapolate the animal tolerances applied in the model.

121. This was further commented on by the 2008 Review, which stated:

    a. *The data and calculations used in the HotStuff model for identifying the critical values for heat-induced mortality and the distribution of the accompanying incidence of mortality are supported by biological knowledge and reasonable assumptions derived from existing knowledge. Although the model does not take duration of heat exposure directly into account, this is a reasonable position given that the temperature and humidity conditions when at their worst are unlikely to fluctuate greatly over a short time, the relative conservatism of the model in seeking to safeguard animal welfare, and the possibility of introducing greater error by attempting to build in duration of stress. Given that there is not a lot of data on mortality with heat stress for the model, there is even less data on duration effects for similar conditions.*

122. Noting that there are more options available now in terms of weather data, duration will still present a challenge to model which, if incorporated, will require detailed consideration to prevent undue complexity or outcomes that are not representative of reality.

<u>Focus on Delta T</u>

123. When sheep are present on the deck of a ship, their own metabolic heat production will modify the conditions on the deck compared to the outside ambient conditions. Because sheep are continually producing metabolic heat, which is lost to the environment via conduction, convection, radiation, and evaporation, the air surrounding the animals will be warmer and more humid than the air outside the ship. The extent to which the deck is warmer and wetter than the outside conditions is known as the wet-bulb-rise, or the delta-T.

124. As the heat and water that emanates from the sheep is carried away by the air that exits the deck, the extent to which the deck conditions are warmer and wetter than the outside air depends on the rate that air enters and leaves the deck – that is, the ventilation of the deck. The HSRA model uses a value referred to as the Pen-Air-Turnover (PAT) which is a measure of the number of times per hour that the air above a deck is changed.

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

126. The model adds the wet-bulb-rise to the expected ambient conditions to arrive at a probability distribution of the expected deck wet-bulb-temperature for a given voyage.

a. If the upper distribution of the expected deck wet-bulb-temperature exceeds the lower end of the beta-distribution of expected mortality, then the probability of mortality exceeding 5% for the line of livestock for the voyage is calculated.

127. Historically the focus of the HSRA model in terms of intervention or mitigation has been on reducing delta T.

 a. In the model, this can be achieved ultimately by two core means – increasing the ventilation (PAT) and decreasing stocking density. Depending on feasibility, there may also be the potential to change this through other methods in the future (e.g. dehumidification).

128. These intervention options will remain important and would continue to complement the dramatically improved ability to limit or reduce exposures to extreme ambient conditions through improvements in the sensitivity / resolution and forecasting of weather data (discussed below).

Opportunities to improve the exposure / weather inputs

129. In looking at the existing framework for risk assessment, the LEP has identified that there are significant developments that will greatly improve the sensitivity of the weather / exposure inputs related to the potential for modelling and forecasting and enable much more dynamic risk assessments and interventions.

130. These include the type and quality of data available, the ability to access data and use it to provide forecasts in real or near real time, and the ability to automate environmental measurements. All of these areas are the subject of R&D that is in progress or being commissioned.

Type, quality and access to alternative data

131. As noted earlier, the HSRA was designed around the best available source of wet bulb temperatures at the time.

 a. The HSRA developers considered a range of sources and determined that observations from the VOS data was the best information available. Further correlations with port / land based meteorological recordings were also conducted to validate that data where possible.[4][5]

132. The VOS data in the HSRA was updated in 2011[6] and recently the LEP has been considering undertaking a process of obtaining and analysing the subsequent tranche of available VOS data to update the figures in the HSRA.

 a. There is, similarly, newer land based data available that would enable an update of the port wet bulb climatologies.

133. However, there are some challenges with the VOS data. Basically, it is purchased by oceanic block and all of the data is provided without any or with very limited quality

[4] *Development of a Heat Stress Risk Assessment Model* (Maunsell Australia, 2003), LIV.116.
[5] *HotStuff V4, Improvements to the Live Export Heat Stress Risk Assessment Model* (Stacey Agnew, 2011), LIV.0277.
[6] Refer footnote 3.

control, and much of it tends to be encoded. As a result, the handling and cleaning process to develop this data into a meaningful input takes quite some time and resources.

134. Of course, the other aspect of the VOS data is that it presents a historical record that is then referred to in considering future risk. A better indicator of future risk may be weather forecasts or a combination of historic records and current forecasts.

135. The LEP has for several months been investigating alternative weather data sources and approaches that may provide the opportunity to improve the sensitivity of the weather data in the HSRA – both temporally and spatially, for a range of static and dynamic risk assessments.

    a. This includes the potential for the assessments to become more dynamic, with a combination of pre-export assessments based on predictions from both historical trend analysis and recent weather patterns, and during voyage forecasting (e.g. of 5 and 3 days and 24 hours or more to assist the avoidance of oceanic hot spots and to reduce the potential of entering a port during a higher-heat stress risk period).

    b. To achieve this would mean finding complementary data to the VOS collection.

136. While in 2003 and even more recently there were limited options, there has been a rapid advancement in the technology. In particular, modern meteorology has developed powered by the internet, open access to satellite data and a much better understanding of climate change and variability.

137. As a result, there are countries and organisations across Australia and globally that are gathering satellite data on daily or higher frequencies, completing quality control and making this information available to researchers, forecasters and others.

<u>Sea Surface Temperature; increased spatial and temporal resolution</u>

138. The information that is of particular interest from our perspective is the high resolution sea surface temperatures collected on a continuous basis via satellite.

139. Discussions we have had with relevant experts in the meteorological and climatological space provide a strong degree of confidence that the relationship between sea surface temperatures and the ambient wet bulb temperature (being the wet bulb temperature outside the vessel) can be mapped with reasonable accuracy. In turn, we are confident that you can then define / model the relationship with delta T which will support several things, including a better understanding of the effect of night time minimum temperatures (which are important for offloading heat and risk management).

140. This would open the HSRA model to a quality and history of data that has a much higher resolution than the VOS data in terms of the spatial and temporal temperatures. Many decades of sea surface temperature satellite data exists to support refined climate modelling and the continued frequent and focused collection and release of this data makes dynamic forecasting – to quite a high degree of specification – a very real possibility.

141. We acknowledge that there will be potential limitations in the Sea Surface Temperature extrapolation to wet bulb temperature – for example, understanding the effect of wind (and in particular the effect of land masses on wind measurements). However, preliminary work with our experts indicates that this analysis will provide significant extra information

and any limitations will not negate the improvements to the model. To the contrary, it will contribute to risk assessment and mitigation.

a. There may also be information obtainable from considering the differential between the immediate surface Sea Surface Temperature (skin) and the top one metre Sea Surface Temperature (which together help to define wind and night-time minimum ambient temperatures).

142. We also note that the ability to be much more responsive in incorporating trends and responding to existing patterns and weather information is going to become even more important with climate change and variability becoming significant challenges globally.

143. For the purposes of the HSRA predictions within this changing environment, a more dynamic historical weather assessment and forecasting approach will be a better means to incorporate and meaningfully address them.

Derivation and measurement of deck temperatures

144. The HSRA model and the associated research into animal physiology have focused on the correlations with wet bulb temperature. This is a sensible correlation and one that we continue to support. However, it is important to note that there are opportunities to improve how wet bulb temperature is measured.

145. Wet bulb temperature measurement can occur via three methods:

a. Natural wet bulb. When the bulb of a thermometer is covered by a sheath of muslin cloth that is continuously dampened via a water reservoir, the bulb of the thermometer will be cooled (and so register a lower temperature) whenever water evaporates from the cloth. The more air movement over the wet cloth, the more evaporation, and so the lower the thermometer will read. Because the rate of evaporation from the cloth is proportional to the humidity and the wind speed, the extent to which the wet-bulb reads lower than a dry-bulb thermometer (exposed to the same air) provides a measure of the humidity of the air. When the air is saturated with water vapour (100% relative humidity), the two bulbs will read the same temperature because no evaporation occurs from the wet-bulb. Ensuring the muslin is clean and changed frequently ensures greater measurement accuracy. Placement is also important and may affect its exposure to environmental ventilation or otherwise.

b. Ventilated wet bulb. A sling-psychrometer houses two identical thermometers in single housing. One of the thermometers is bare and so provides a measure of the dry-bulb-temperature. The bulb of the other thermometer is covered by a sheath of muslin cloth that is connected to a water reservoir that keeps the cloth wet, and so provides a measure of the wet-bulb-temperature. The psychrometer can be spun at a rate that ensures maximal wind speed across the thermometer bulbs. After the psychrometer is slung, the two thermometers are read, and the difference between the two readings can be used to derive the relative humidity from look-up tables, or computed.

c. Calculated wet bulb. Modern electronic devices measure the dry-bulb temperature and the relative humidity (using a capacitance hygrometer, wherein the electrical capacitance of a length of metal varies with the relative humidity) and derive the wet-bulb-temperature from those readings.

146. The above identifies three different measurement techniques – each with their own limitations and expectations of some degree of error.

   a. One implication is that there is variation between ventilated and natural wet bulb measures (in the same environmental conditions) that we understand can be several degrees in magnitude.

   b. As the natural wet bulb is routinely used on vessels (and was used to derive the original HSRA correlations) and the ventilated wet bulb is routinely used in research / experiments, comparisons between the real world and research will need to be adjusted to take this into account.

   c. Future refinement will include to help ensure consistency and validity in relevant extrapolations from or between those measures.

147. In the past, recordings on livestock vessels have focused on the manual recording of natural wet bulb measurements. For a range of reasons, accuracy and consistency in collection (and hence comparability) can add variance to these measurements.

148. Considering the importance of exposure in terms of heat stress risk and its assessment and management, we believe that an expansion in the environmental metrics collected would provide greater flexibility and redundancy.

149. While there will still be a need for an iterative process of self-validation to refine how they are incorporated to improve reliability and accuracy, we believe the following will be useful and important metrics for wet bulb temperature into the future:

   a. Derivation of the wet bulb temperature from the surrounding Sea Surface Temperature and delta T

   b. Direct environment measurement of dry bulb and humidity (automated collection, with calculated wet bulb temperature)

   c. Manual wet bulb thermometer measurement – noting likely variations between natural and ventilated readings.

150. In terms of deriving the deck level exposure from sea surface temperature, it is well recognised that ambient wet bulb temperatures can be modelled from sea surface temperature with some confidence. This data can be used to derive historic or forecast future wet bulb temperatures, with bridge wet bulb recordings providing a means of correlation / validation.

151. The next step – consistent with the current model – would then be to translate ambient wet bulb temperature into deck wet bulb temperatures to represent the exposure conditions of the animals. This is dependent on factors influencing delta T which are reasonably well characterised and can be incorporated into the model by reference to the more sensitive sea surface temperature data.

152. This derivation would be complemented by actual deck levels measurements using automated collection of calculated wet bulb temperatures and manual reading of natural

wet bulb temperatures. These would not only provide recordings in their own right but also provide the opportunity to try and better define or measure the relationship between the derived ambient wet bulb temperature and the estimated deck wet bulb temperature.

Research and development opportunities

153. As noted earlier, LiveCorp and the LEP have been investigating opportunities to improve the temporal and spatial sensitivity of weather data and to transition the use of those data sources into a more dynamic risk framework.

154. One of the important opportunities that this can present is the opportunity to incorporate risk management that is focused not just on changing the delta T, but also on changing the ambient temperature exposure.

    a. This includes the ability to limit exposure to temperatures that can have long term impacts on animals. Such an approach could mean delaying a departure, changing route, avoiding high risk oceanic hot spots, and identifying and moving into areas of respite if you happen into adverse conditions.

155. Ultimately, the above approach would allow a much more proactive assessment and management of the risks.

156. The reason that this approach would be enabled is that there are very discrete regional and localised variations – both spatially and temporally – in temperatures. And the information at this detail is available as a long term history (capable of identifying relevant trends, climatic patterns and correlations over time), short term history (immediate past temperatures on the route), and as forecasts at different scales (as with normal meteorological forecasts – on scales of weeks, to days, to hours each with a progressively improving accuracy).

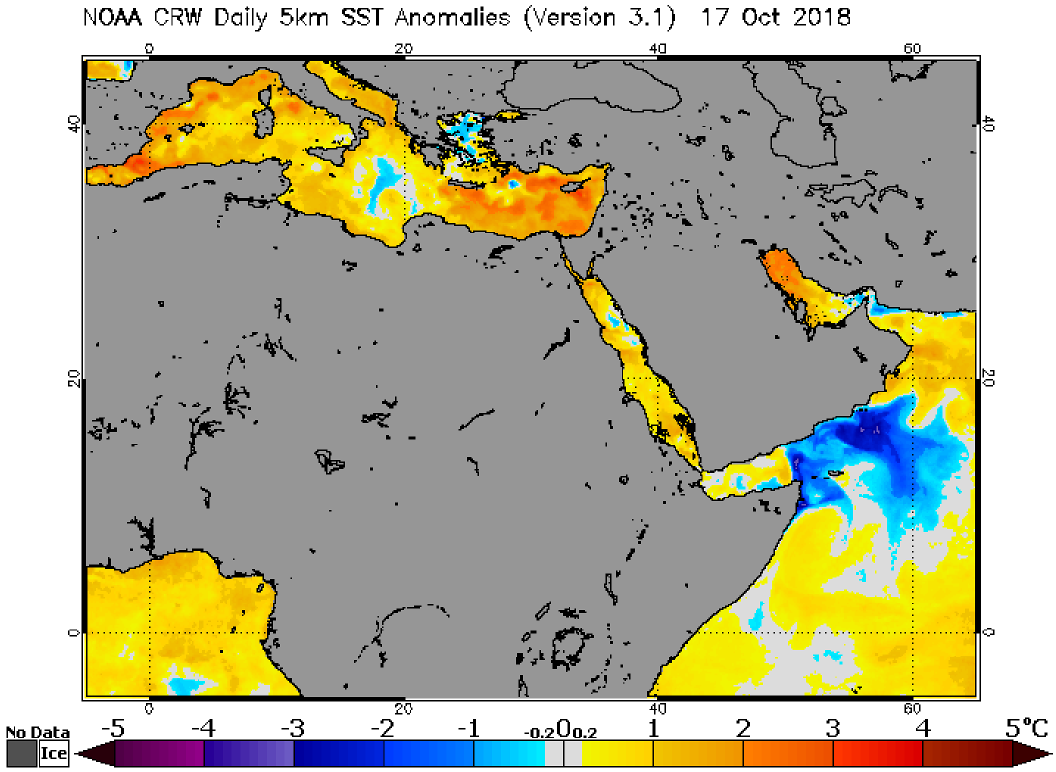
157. The diagrams immediately below provide illustrative examples of the type of information that can be generated to characterise or forecast those spatial and temporal changes (for the Arabian Gulf and Indian Ocean). These examples are of observations of recent trends in sea surface temperature (rather than forecasts or long-term historical information), but the same principles and capabilities apply to forecasting.

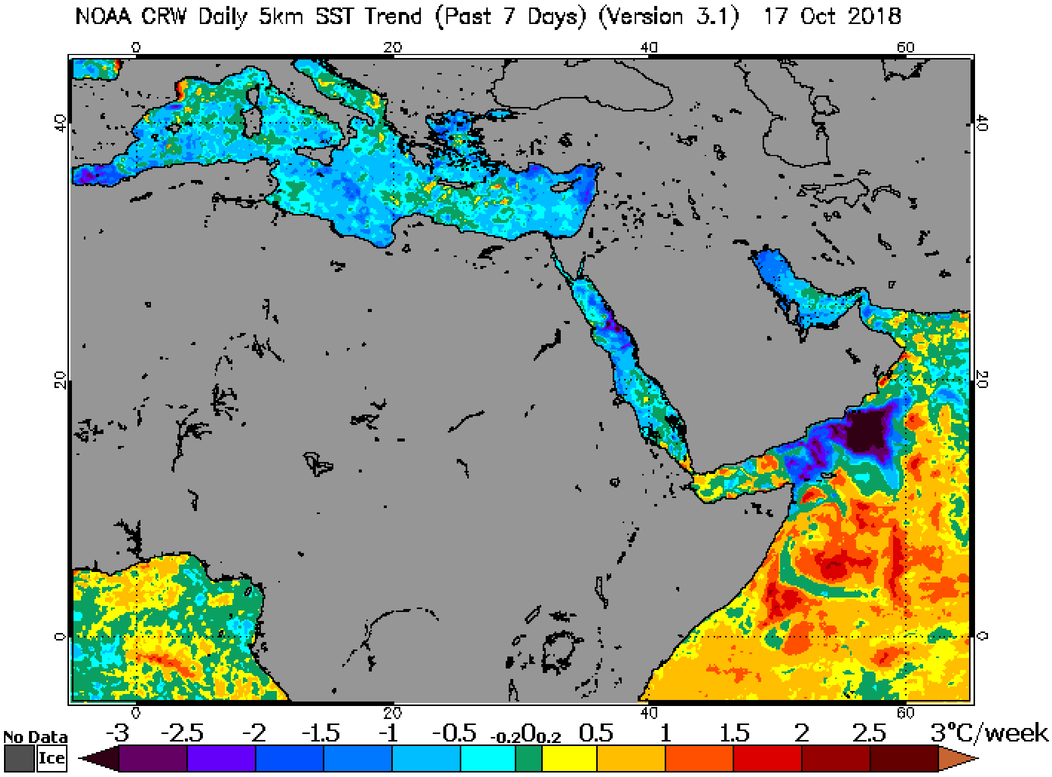
    a. The graphs of the daily 5 km anomalies illustrate the regional differences in sea surface temperature of 17 October 2018 compared with long-term trends for that region.

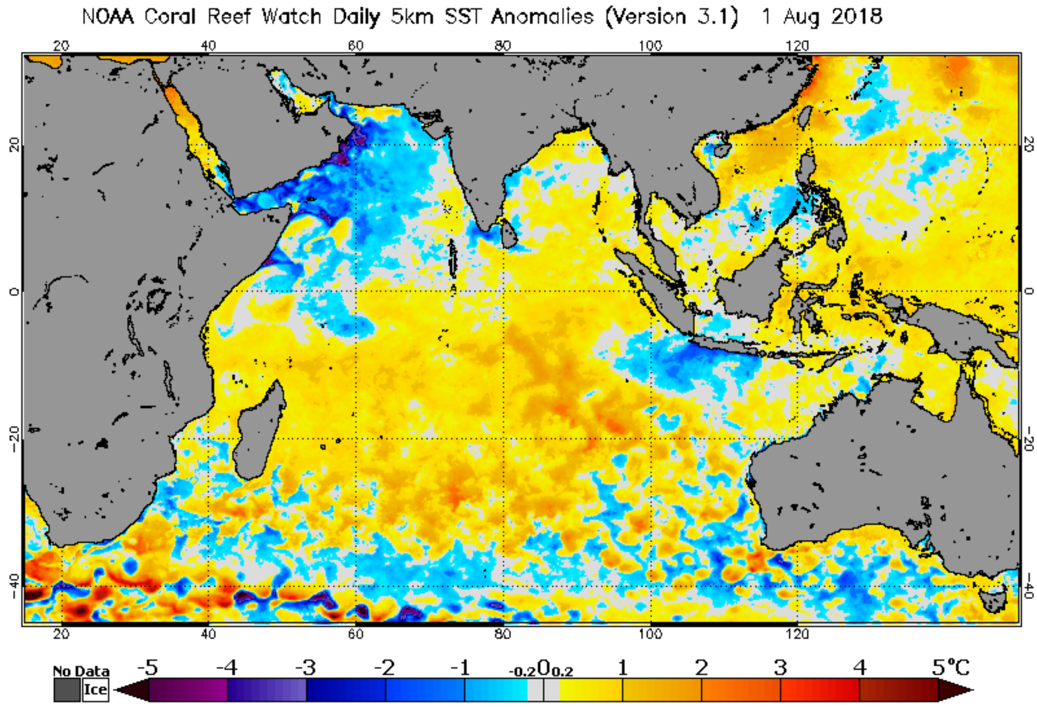
    b. The graphs of the daily 5 km SST trend (past 7 days) illustrate the change in temperatures over the week leading up to 17 October 2018 for that same region.

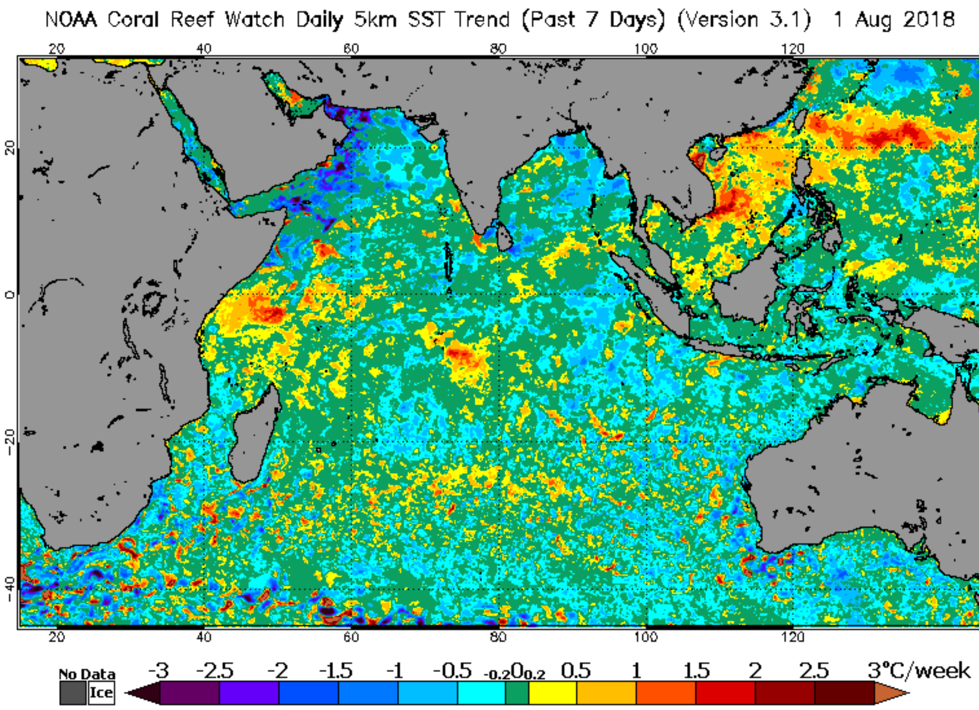
    c. It is immediately apparent how invaluable similar spatial and temporal information would be when applied to forecasting capabilities.

    d. We note that these are just illustrative examples and the relevance or application of these particular graphs should not be over-stated.


NOAA CRW Daily 5km SST Anomalies (Version 3.1) 17 Oct 2018
0
20
40
60
No Data
Ice
-5
-4
-3
-2
-1
-0.2
0
0.2
1
2
3
4
5°C


NOAA CRW Daily 5km SST Trend (Past 7 Days) (Version 3.1) 17 Oct 2018
No Data
Ice
-3 -2.5 -2 -1.5 -1 -0.5 -0.2 0 0.2 0.5 1 1.5 2 2.5 3°C/week


NOAA Coral Reef Watch Daily 5km SST Anomalies (Version 3.1) 1 Aug 2018
No Data
Ice
-5 -4 -3 -2 -1 -0.2 0 0.2 1 2 3 4 5°C



158. One of the main projects that is being considered that looks to capitalise on this is a two stage analysis, development and implementation project to improve the current predictive modelling and enable dynamic risk assessment / management – summarised below.

   a. Stage 1 – Defining the sea surface temperature, wet bulb temperature and ocean wind relationships, and completing historical climatology analyses to complement the use of the VOS data in the static risk assessments. This stage provides the opportunity to investigate the different Sea Surface Temperature measurements, the influence of wind, and incorporate climate change trends.

   b. Stage 2 – Using the stage 1 outcomes to investigate the introduction of a centralised forecasting service to provide dynamic risk assessments. This provides real-time continuing updating of the data underpinning the HSRA and to better assess risks based on recent weather and variability.

159. Further to the above and expanding on the section addressing measurement, the LEP and LiveCorp (through its open innovation program) have projects underway or being scoped to trial different technologies for automated collection of temperature and humidity data, which would support measurement and calibration of the temperature / exposure derivations.

160. Finally, we note that exposure / weather was not considered in the HSRA Panel Issues Paper. However, we hope that the Panel will recognise the principle importance of weather and exposure in relation to heat stress and the substantial opportunities that improvements in the sensitivity, quality and measurement of this input will provide to the model.

5. Rumen and / core temperature correlations underpinning risk assessment modelling

161. In the following section, we have sought to methodically work through the correlations that stem from the exposure / weather data through to the physiological responses and to identify any key observations or opportunities that may be of relevance.

Introductory comments on physiology

162. When an animal is capable of thermo-regulating, an increase in body temperature in response to continual metabolic heat production does not occur because the animal loses heat continually to the environment.

163. Animals exchange heat with the environment by four routes; conduction, convection, radiation and evaporation. The relative importance of these routes differs between species, however for obvious reasons this submission focuses on sheep.

164. Each of these routes is well defined, however the following is noted in regards to evaporation:

    a. Evaporation occurs when there exists a vapour pressure gradient from a wet animal surface to the air.

    b. Mammals exploit that physical property when they sweat or pant, both of which create wet surfaces on an animal that are exposed to the surrounding air. When water evaporates from those surfaces, heat is removed from that surface, and therefore from the body.

165. Heat exchange by each of the four routes noted above depend on different aspects of the environment. For example, the higher the humidity the less heat exchange by evaporation for a given air movement.

166. Animals can successfully thermo-regulate and maintain their core temperature using these mechanisms – and at this point, duration will not be relevant.

167. At extremes, thermal stress will occur, resulting in an increase in the animal's core body temperature. However, animals are able to cope with increases in core temperature while managing heat balance.

168. By definition, heat stress causes an increase in the core temperature of an animal. In many cases the animal can sustain that increase because the physical exchange of heat is driven by the core temperature to environmental temperature gradient, and therefore heat loss increases when core temperature increases. An increase in core temperature, in and of itself, does not necessarily equate to adverse physiological consequences for the animal.

169. We consider that heat stress is fundamentally about the impact of core temperature on animal physiology. In terms of monitoring or modelling these outcomes, the correlations that exist between wet bulb temperature and core temperature or rumen temperature to physiology / welfare are important.

170. In light of the previously discussed ability to predict and correlate exposure to wet bulb temperature, the two key correlations are:

    a. Wet bulb temperature to rumen temperature / core temperature

b. Rumen / core temperature to animal physiology / welfare

171. Each of these is explored below by reference to the best available evidence.

Wet bulb temperature to rumen temperature and core temperature

172. Core temperature is the key to understanding the status and physiological impacts on an animal from heat stress, because it is core temperature that affects the neurological and other systems that effect animal welfare, morbidity and mortality

173. Looked at as a whole, there are three key aspects to the wet bulb temperature to rumen temperature correlation being: exposure level, duration (and level), and respite.

174. In terms of exposure levels, it has been shown that when the dry-bulb-temperature exceeds body temperature, heat balance can be achieved if a sheep can lose heat by evaporative heat loss that is equivalent to that being produced by metabolism, plus that gained from the hotter environment.

175. While the maximal evaporative heat loss from sheep is not known, Merino sheep have been exposed to 40°C and they were able to maintain heat balance by panting[7]. Hales and Webster[8] exposed Merino sheep to 60°C and none are reported to have died, noting that the humidity was low in those experiments.

176. As indicated earlier, the evaporative heat loss capacity is reduced when the humidity increases. As such, when a sheep is exposed to both high temperature and high humidity, evaporative heat loss may not compensate fully for heat gain and body temperature will increase.

177. Core temperature and rumen temperature are closely and knowingly correlated – it is recognised that there is a reasonably predictable difference of just under a degree.

a. Beatty et al. (2008)[9] measured core temperature and rumen temperatures simultaneously in sheep and found that rumen temperature was always higher than the simultaneously measured core temperature by between 0.45°C and 0.75°C.

178. From our discussions with experts and review of available research there also seems to be an imperfect, but reasonable, correlation between wet bulb temperature and an animal's core body temperature -to be more precise, there seems to be a curvi-linear relationship between these two variables. However, we note that further data would be required to improve the confidence in this relationship.

179. Above a certain wet bulb temperature (which varies between animals) an animal's core body temperature will increase. The increase in core temperature is part of the response of many species to an increase in the environmental heat load when humidity increases. Because the physical exchange of heat is driven by the core temperature to environmental temperature gradient, heat loss increases when core temperature increases, and a new equilibrium of heat gain versus loss is established at a slightly higher core temperature. An

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[7] Vesterdorf, K., Blache, D. & Maloney, S.K. 2011 The cranial arterio-venous temperature difference is related to respiratory evaporative heat loss in a panting species, the sheep (Ovis aries). J. Comp. Physiol. B 181, 277-288. (doi:10.1007/s00360-010-0513-7).

[8] Hales, J.R.S. & Webster, M.E.D. 1967 Respiratory function during thermal tachypnoea in sheep. J. Physiol. (Lond.) 190, 241-260.

[9] Beatty, D.T., Barnes, A., Fleming, P.A., Taylor, E. & Maloney, S.K. 2008 The effect of fleece on core and rumen temperature in sheep. J. Therm. Biol. 33, 437-443.

increase in core temperature, in and of itself, does not necessarily equate to adverse physiological consequences for the animal.

180. If in the face of environmental challenge a new equilibrium is not maintained and core body temperature rises further, ultimately above a certain level death will occur.

181. Both Maunsell 2003 and Ferguson et al. 2008 commented on the relationship between wet bulb temperature and the heat stress mortality curve, including on the skewed beta distribution used in the HSRA model.

   i. "*We don't expect that we will ever see data which show mortality as a function of wet bulb temperature for a large group of one type of animal. Accordingly, we have had to synthesise the probability distributions of HST and ML. Appropriate to the nature of the problem, we chose a skewed beta distribution. This has the property that a small number of animals respond at lower temperatures but the distribution is more compressed above the 50 percentile. That is; no animals survive at wet bulb temperatures just a little above the temperatures that will kill half their number, whereas there are animals which are significantly 'softer' than most.*"[10]

   ii. "*From a biological perspective, the type of non-symmetric distribution chosen by the developers, with its longer tail toward the lower end of the wet bulb temperature axis, is not unreasonable. This is because in any sample, there are likely to be weaker animals that succumb earlier to heat stress, but there are unlikely to be many animals that can survive beyond certain limits - i.e. there is likely to be weakness at enduring heat stress, but there is unlikely to be "strength" in enduring temperatures beyond biological limits. This results in the shorter tail of the beta distribution towards the upper end of the wet bulb temperature axis - essentially the remaining animals would be dying en masse once the temperature increased beyond a certain point.*"[11]

182. Of course, it is also worth highlighting the further comments from these authors that – for the purposes of the current HSRA modelling – that the actual shape of the probability distribution, and in turn any point above the lower part of the beta distribution (i.e. including the specific Mortality Limits and Heat Stress Thresholds in the HSRA) are irrelevant because we are only interested in the lower portion of the graph.

   a. *"In selecting the beta distributions, greater attention has been paid to the low temperature end. The top end of the distribution is really only of academic interest as a 50% mortality rate is already a major problem and so arguments over prediction of 60% versus 75% mortality are not useful."*[12]

   b. "*the choice of a beta or a normal distribution actually matters relatively little in terms of the symmetry (or lack thereof) of the distribution curve, because it is not the entire distribution with which we are concerned in the application of the HotStuff*

[10] Maunsell Australia Pty Ltd. 2003 Development of a heat stress risk management model. Project LIVE.116. Meat and LIvestock Australia. (North Sydney)

[11] Ferguson, D., Fisher, A., White, B., Casey, R. & Mayer, B. 2008 Review of the livestock export heat stress risk assessment model (HotStuff). WLIV.0262/3/4/5. Meat and Livestock Australia. (North Sydney).

[12] Maunsell Australia Pty Ltd. 2003 Development of a heat stress risk management model. Project LIVE.116. Meat and LIvestock Australia. (North Sydney)

model. Specifically, we are not interested in the risk of 100% mortality (the whole distribution curve), or even of 50% mortality, both of which would be an animal welfare catastrophe. The limit chosen in the application of HotStuff is the risk of a 5% mortality rate for a livestock class. The selection of the 5% limit is outside the scope of this physiological review - it is more of an ethical, political and economic question as to what constitutes the mortality rate that one wants to have a significant probability of avoiding. However, the relevance of the 5% limit in the consideration of the probabilistic mortality model is that it is only the very left hand edge of the distribution curve that is relevant, and the key issues are the spread of that far left side of the curve, and its position on the wet bulb temperature axis."[13]

183. Finally, it should be acknowledged that the core body temperature / rumen temperature to wet bulb temperature relationship has not been fully characterised – particularly in relation to the impacts of high exposure levels, duration and respite. Increased sophistication in these areas will be an important capability need for any revised model.

Real-world impacts of wet bulb temperature on rumen temperature / core temperature

184. Discussion with experts suggests that there is some confidence that there is generally a reasonable association between an increase or decrease in wet bulb temperature and an increase or decrease in rumen temperature.

    a. This association reportedly holds true even after several days at the same, and relatively high, wet bulb temperature.

    b. There appears to be a slight delay between changes in wet bulb temperature and associated rumen temperature / core temperatures. However, we understand that this delay is significantly less than 24 hours and as such, for modelling purposes is not likely to be relevant.

185. The impact of duration, respite and repeated exposures on this association is important but less well characterised.

186. In regards to the first of these real world situations – **duration**, there is evidence that sheep can maintain the same or a slightly elevated rumen temperature over several days during exposure to the same wet bulb temperature.

187. For example, recent discussions with experts in this area indicated that sheep appear to be able to maintain moderately higher rumen temperatures for up to 7 – 8 days at temperatures of up to 28 – 29 degrees ventilated wet bulb temperature.

188. This indicates that while animals are unable to maintain their baseline core temperatures at these higher wet bulb temperatures, they can – through different thermoregulatory means – limit the increase and maintain a higher stable core temperature for long periods.

189. The next real-world influence of wet bulb temperature to rumen / core temperature to consider is **respite**.

[13] Ferguson, D., Fisher, A., White, B., Casey, R. & Mayer, B. 2008 Review of the livestock export heat stress risk assessment model (HotStuff). WLIV.0262/3/4/5. Meat and Livestock Australia. (North Sydney).

190. We understand from discussions with experts that the association between rumen temperature and wet bulb also holds true for respite and appears to be a reasonably correlated and roughly proportionate relationship.

191. The ability of sheep to maintain steady core temperatures – above baseline levels – for long durations and to rapidly reduce it when given respite is critical for better understanding the true risk of adverse physiological or animal welfare outcomes during long haul voyages.

192. The final real-world influence that can be considered is **repeated exposure**.

193. There is extremely limited information for sheep, particularly on the impact of repeated exposure on the correlations of rumen temperature and wet bulb temperature in light of its interrelationship with the duration and levels of both exposure and respite.

194. We note that the paper *A systematic review of heat load in Australian livestock transported by sea* (Collins et al., 2018) stated:

    a. *"We were unable to find any studies that empirically assessed the duration of respite periods required to protect livestock from harmful cumulative effects of repeated episodes of heat load."*

    b. The LEP is aware through its ongoing research program of these gaps in knowledge and is engaged in discussions with researchers on the potential to better understand duration, exposure / respite and response in sheep through renewed climate controlled studies. As the panel will be aware, planning for such research takes some time to ensure that it meets the needs of the relevant ethics committees.

195. A further significant point on the relationship between wet bulb temperature and rumen / core temperature is the scope for individual variability in tolerances based on individual animal or line factors.

196. Groups and individual livestock can have varying characteristics that may influence their tolerances.

197. These may include breed, body condition score, acclimation history, body weight and wool length – all of which are incorporated in the HSRA model (explained in Maunsell 2003 in detail).

198. Variations in the heat tolerance may also be driven by the less defined influences of factors such as gender, age, nutritional history, health (i.e. the potential for sub-clinical infection or disease), on-farm / transport / preparation factors and other underlying animal specific genetic influences.

199. Such individual variation introduces significant uncertainty in definitively predicting the correlations between heat exposure and response that needs to be recognised as a pragmatic limitation of modelling in the broader context of welfare management.

200. We believe the HSRA model has achieved an enviable balance and performance history given such variability and uncertainty.

201. Finally, the above points on individual variation are also directly relevant to the following section concerning the relationship of core temperature and / or rumen temperature with

physiological response / welfare. We understand that individual animals – like people – can both respond and experience heat exposure differently.

Rumen and core temperature to physiology and in turn to welfare

202. The final correlation that is critical to the extrapolation in the model is that of rumen and core temperature to physiology and welfare.

203. At the outset it is important to note that the correlation between physiology and core body temperature is imperfect and not fully characterised. As such, the following reflects a necessary degree of generalisation.

204. Further, it is also important to recognise that the correlation of a physiological response (for example open mouthed panting) to a welfare state will incorporate a values based assessment and judgment, and one that will vary subjectively depending on the individual perspective.

205. It is recognised that two phases of panting exist in sheep. When core body temperature increases slightly above normal, Phase I panting occurs, where breathing frequency increases but the volume of each breath decreases.

206. Available evidence suggests that immediately below a rumen temperature of around or just over 41 degrees, sheep will be engaging phase I panting for thermoregulation – that is their bodily functions are maintaining their rumen / core temperature.

    a. As noted earlier, 41 degree rumen temperature equates to a ventilated wet bulb of 30 degrees.

    b. Given that at that wet-bulb-temperature the animals are successfully thermo-regulating, there is no time component to the outcome.

207. Further, because they will maintain rumen / core temperature there are no adverse physiological outcomes at or below those temperatures.

208. The reduction in the volume of each breath during phase I panting restricts the increase in airflow mainly to the upper respiratory tract (known as 'dead space' because air in that space does not contribute to the exchange of oxygen or carbon dioxide with the blood in the lung).

209. By engaging in phase I panting there is no increase in ventilation of the gas exchange part of the lung (known as the alveolar ventilation) and so no increase in gas exchange. However, because there is increased airflow across the upper respiratory tract, especially the nasal mucosa, there is evaporation of water and loss of heat from the body but no change in gas exchange that could lead to acid / base disturbance.

210. When the core body temperature of a sheep increases further (above a core temperature of about 40.5°C in the experiments reported by Hales and Webster[14]), they will begin to progressively transition to phase II panting (open mouth panting).

[14] Hales, J.R.S & Webster, M.E.D. 1967 Respiratory function during thermal tachypnoea in sheep. J. Physiol. (Lond).

a. Based on the data from Beatty et al. (2008), that were cited earlier, a core body temperature of 40.5°C equates to a rumen temperature of higher than 41 – 41.25°C.

211. In light of the above, rumen temperatures above about 41 degrees are not immediately harmful in the short term. However, the efforts of the animals to thermoregulate do begin to have physiological consequences.

212. In the first instance, open mouthed panting starts to impact blood chemistry, and if sustained for long periods it can lead to acid base disturbances.

a. In phase II panting, breathing becomes slower and the volume of each breath increases. When this change in pattern occurs, alveolar ventilation increases, resulting in an increase in carbon dioxide excretion and eventually alkalosis (an increase of the pH of body fluid).

b. Stockman[15] in her thesis acknowledge also that animals open mouthed panting at 'Heat Stress Threshold 3' are at "high risk of developing respiratory alkalosis if exposure was prolonged."

c. In other words, transition to open mouthed panting does not immediately equate to irreversible physiological harm but rather to an increased risk of irreversible harm with extended duration without respite.

213. It is understood that over time sustained open mouthed panting and acid base disturbances can lead to kidney adaptations and in more extreme cases probably hypoxia in other tissues (that is because blood is redistributed to assist with heat loss and other tissues can then be deprived of blood and oxygen).

214. Accordingly, the mere fact that there is open mouthed panting and changes in blood chemistry does not equate to an immediate adverse physiological impact, and appears to be separated from causing irreversible harm to the animal by a reasonable duration (for example, as much as 5 – 7 days).

215. All of these things are reversible other than in extreme cases. For example, Hales (1967) exposed sheep to 60°C and induced Phase II panting that led to an average increase in arterial blood pH of 7.9 (from the normal 7.4). All sheep recovered.

216. Discussions with experts in preparing this submission did suggest that sheep may be able to maintain stable rumen temperatures at or above 41.5 for an extended period of up to a week without mortality.

217. There appears to be some evidence to suggest a likely minimum rumen temperature of around 42 degrees reflects a critical point to distinguish between reversible physiological impacts and more severe irreversible outcomes, assuming a sufficient duration.

a. It appears that duration starts to become important the closer rumen temperature is to around 42 degrees, although there is insufficient evidence to properly characterise the relationship.

[15] Stockman, C.A. 2006 The physiological and behavioural responses of sheep exposed to heat load within intensive sheep industries, PhD thesis. Murdoch University.

218. However, in noting the above it is important to recognise that the datasets and evidence of the relationship of duration, exposure levels and the escalating impacts of acid base disturbance from open mouthed panting is very limited.

219. At these as yet scarcely evidenced junctures between exposure, duration and outcomes, we expect that you start to enter the region where mortality risks arise (essentially the lower tail of the HSRA beta curve).

220. It is worth re-emphasising here that it will always be difficult to accurately demonstrate the relationship between different welfare or mortality outcomes or exposures because of ethical experimentation requirements, biological reasons and other reasons.

221. However, importantly this does not cloud or hinder industry from greatly refining its understanding of exposures and circumstances at lower levels, and specifically where they have begun to influence physiology – but which do not irreversibly harm animals.

222. In addressing the correlations between rumen temperature and physiology / welfare, it is important to make some final comments concerning the table of amalgamated measures included by McCarthy in his report.

223. This amalgamation includes a range of indicators – some of which are more recognised and have more accepted correlations than others.

224. The factors identified are subjective scores and there is an arbitrariness between the setting of the levels, which suggest a black and white split when in reality the transitions across levels are graded (i.e. why a score of pant score 3, rather than 3.25 or 3.5 in relation to the different levels).

225. A particular point that LiveCorp would like to make is that there is no validated correlation between the heat stress score levels (and the associated amalgamated indicators) and the assumed extrapolation of the mortality limit from the HSRA.

    a. The Heat Stress Scores that McCarthy has developed need to be linked to wet bulb temperatures/core temperatures, and in turn they need to reflect the non-linear relationship between wet bulb temperature and response.

    b. The amalgamation of these indicators does not incorporate any scientific validation against actual impact on the physiology on the animal.

    c. As a result, McCarthy's estimated alignment of 75 % of the extrapolated HSRA Mortality Limit to Heat Stress Score 3 has not been validated.

    d. Those values are subjective scores, not hard points and because the model needs some basis in objective measures, the outcome measure should be the wet bulb temperature / core temperature (or some other objective metric) rather than the heat stress scores simply being proportions of 'heat stress.'

226. A number of these points relate to the setting of probabilities in the model, which we address further below.

Future research and validation opportunities

227. In concluding this overall chapter on the correlations stemming from wet bulb temperature through to physiological response, we note that:

a. There appears to be a relatively consistent relationship between core and rumen temperatures and wet bulb temperature / exposure, but there is less confidence / certainty about this relationship at higher exposure levels and when the real-world influence and interaction with duration and respite is considered.

b. The correlation between physiology and core body temperature is imperfect and not fully characterised (again, particularly when duration and respite are considered), although there are some generalised relationships.

228. To use the above correlations with core temperature or rumen temperature as the basis for modelling would require expanded knowledge and calibration / validation over a larger dataset collected through real-world voyages.

229. As identified earlier, the LEP RD&E program currently has a program of work underway / being commissioned in this area to:

a. Undertake further climate controlled studies to better understand and define the animal response to heat exposure, including with consideration to duration.

b. Obtain greater clarity on appropriate indicators of welfare (including heat stress) within the welfare indicators project for the continuous improvement system.

230. Further, through the LEP and LiveCorp development of the data collection platform (LIVEXCollect) and trialling of automated technologies, the capacity to run improved validation and calibration is increasing.

6. Determining settings and selecting approaches

231. The interplay of an objective evidence based approach with values based judgments, including those that are reflected in community expectations from time to time, makes determining appropriate settings a particularly challenging issue.

232. LiveCorp firmly believes that the focus needs to remain on settings that are objective and evidence base. Community expectations should be taken into account to inform the approach, but they should not be the sole criteria that informs regulatory obligations or settings.

Community expectations and regulatory requirements

233. There is a link between the perceived physiological and welfare outcomes, and community expectations.

234. This is, not surprisingly, a very subjective connection and one that is fundamentally difficult to ascertain in the current structures where passionate and highly involved groups (including industry, interest groups, and activists) are the major voices and neither necessarily offer a reasonable reflection of the diverse community views on a particular issue.

235. This is particularly the case where a balance is sought between the competing interests, objectives or values in many socially sensitive industries. In many cases, these sectors contribute meaningfully to the economy, employment, and affordability and consumer choice.

236. In this space, a focus on any one aspect to the exclusion of others will result in an imbalance and a failure to achieve appropriate outcomes.

237. Community values including and beyond welfare concerns are diverse and must each be balanced with other objectives and values of the community and government.

    a. For example, it is unavoidable that threshold acceptable impacts on welfare – particularly when balanced with other outcomes, values and trade-offs – will reflect very personal values and views.

238. Millar, H offered several observations in this regard in a paper produced in July 2018[16]:

    a. *"… animal welfare is necessarily both science-based and values-based. In that sense animal welfare is like some other difficult public policy areas charged by often vocal individual and collective opinions – such as environmental sustainability – where the tools of science are used within a framework of values.*

    b. *In other words, animal welfare, though quite amenable to scientific study, is also founded in values based ideas about what people believe to be more or less desirable. There is no 'absolute truth'.*

    c. *….Indeed the frameworks can be seen as representing a spectrum, from a strongly science/evidence-based approach (biological functioning) to a currently more values-based approach (affective states), in which ethical judgements (moral values) will be increasingly brought into play."*

239. Millar, H also noted the challenge that this values and science based framework presents for regulation as follows:

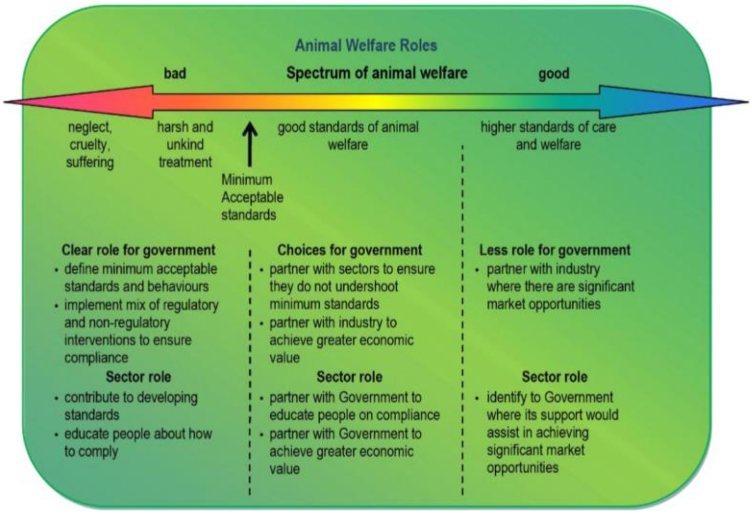
    a. As a result, regulation requires an evidence base and deals with a 'minimum community standard', explaining in part why legislation, for example mandatory animal welfare standards, often (and necessarily) falls short of meeting collective community (values-based expectations).

240. Further to the above Millar, H identified and supported the policy approach adopted by New Zealand and outlined in its Animal Welfare Strategy and shown in the figure below. This approach:

    a. recognises that there is an animal welfare spectrum, with cruelty/ suffering/neglect and harsh treatment being at one end, and high standards of care and welfare at the other end of the spectrum; and

    b. identifies that the greatest role for Government is in defining and regulating minimum acceptable standards of animal welfare with higher standards of welfare left to industry and commercial players.

[16] Millar, H (2018) *A review of animal welfare policy and assessment frameworks*, Australian Eggs Ltd



241. In essence, the position put forward by Millar reflects what we believe is generally accepted in Australia – albeit, there is a struggle to balance the pressure to regulate to values over evidence.

242. As a government appointed panel tasked with considering appropriate regulatory needs and thresholds, the focus must remain on appropriate evidence based minimum acceptable standards and good regulatory principles.

243. In light of the above and LiveCorp's research and development role, we have set out within this submission a science based proposal, relying on the best available evidence, which we are confident can help define and achieve the appropriate balance between welfare and economics.

Best practice regulation

244. Good regulation must be proportionate, consistent and achievable, which relies heavily on ensuring a defensible evidence base for relevant regulatory thresholds and how they are to be achieved and measured.

245. Notwithstanding the challenges, these principles apply equally to heat stress management and the thresholds of the model.

246. It is widely recognised that the best outcomes are achieved by focusing on and enabling continuous improvement rather than relying too heavily on sanctions to achieve compliance.

247. A balance must be struck to avoid being too risk averse. It is simply not possible to completely de-risk agribusiness or any other industry.

248. This extends in this case to the need for the HSRA panel to ensure that relevant metrics and thresholds have a defensible evidence base, including to sensibly accommodate uncertainty in that evidence.

    a. This includes to ensure that there is as much clarity and certainty as possible around the basis for those measures and how they are achievable, measurable and ultimately enforceable.

b. The approach and relevant thresholds should be broadly consistent with those used elsewhere across the livestock sector and society.

Practical modelling, validation and measurement

249. McCarthy's proposal effectively recommended a 'straight swap' from an existing mortality threshold based model, to application of the same probabilistic thresholds to a welfare metric.

250. As outlined in this submission, this is overly simplistic. It relies on a number of critical untested assumptions, such as the applicable distribution, the influence of duration and relevance to welfare and mortality outcomes. Accordingly, it is not appropriate, nor evidence based, to straight swap mortality to a pant score based model.

    a. To model risk against a 2 % chance of 5 % open mouth panting is divorced from and pre-empts any physiological impact. It fails to account for the well-recognised thermo-regulatory capacity of livestock and the importance of duration and respite to any adverse physiological outcomes.

    b. At this probability and without taking account of duration and respite, it is unnecessarily conservative.

251. An appropriate refinement of the model necessitates properly revisiting the evidence base and any relevant metrics and thresholds.

252. In particular, the assumed relationship between the extrapolation of the 'backing off' from Mortality Limit to pant score is not validated and speculative.

253. As we have outlined, open mouthed panting in of itself does not cause immediate, permanent physiological impacts on sheep. However, it is a flag that if it continues over a meaningful duration (that appears to be at least 5 – 7 days) that there may be irreversible or unacceptable harm.

    a. Duration is clearly an important element of tying any threshold to welfare and a minimum standard for regulation of preventing irreversible impacts / harm to the animals.

254. Practical modelling also requires a balance between complexity, usability and achievability to deliver a reliable outcome against a defined objective.

255. It is also essential that any model, particularly where used for a regulatory purpose, carefully considers the underlying assumptions and principles to constantly minimise the probabilities of error.

256. Not only do we believe that pant score is not an appropriate threshold metric against which risk should be modelled or the industry can be regulated, but it is difficult to see how the reliance on this metric could be implemented in practice.

257. In its submission ALEC has pointed to a number of concerns and limitations, which we share and have outlined a number of below:

    a. Pant scores cannot be collected on a census basis or practically measured at a population level;

    b. Significant subjective features;

c. Arguably arbitrary cut-offs (i.e. they are not 'black and white' measures, but rather based on a 'grey scale');

d. Greater difficulty and risk of bias in measure collection;

e. Impermanence (animals can move between levels);

f. Inability to reliably assess duration in individual animals;

g. Disconnected from short term adverse physiological outcomes;

h. It is difficult to avoid a disproportionate impact of individual animal or line factors (including those that cannot reasonably be considered in the model) on low threshold triggers (e.g. 5 %); and

i. There are multiple metrics of heat stress and heat stress is just one metric of welfare and mortality.

258. All of the above need to be viewed in the context of setting minimum acceptable standards as outlined earlier.

259. Noting the above, LiveCorp considers that in the future the insights gained from the indicators project may better characterise the above, define sampling and data collection processes (e.g. a pen score based on weightings) and allow for the incorporation of multiple measurable welfare metrics for the industry (beyond heat stress alone). This will allow for these more subjective measures to be better incorporated into industry continuous improvement / early warning systems.

260. We believe that other objective measures – such as wet bulb temperatures and core and / or rumen temperatures – may be more easily measurable, and most likely just need expanded metrics and a better capacity to avoid mismeasurement and inconsistency to be implemented in this structure.

261. The key factor that we highlight here is to not attempt to do with the HSRA model, what needs to be done through a welfare system.

262. The welfare systems, both the indicators and the open innovation approach, are being driven by industry – as identified by Millar – and the HSRA system we have identified provides ways to supplement such a system (i.e. with the forecasting)

263. But the HSRA model is a regulatory threshold. As such it needs to be set on objective measures, through application of the minimum evidence-based position, not to an aspirational or purely values based position.

264. This is critical if there is an intention to regulate against such a measure. It is necessary within regulation to have certainty and clarity on compliance and non-compliance – otherwise it inevitably becomes disputable and open to challenge.

265. In this regard, mortality remains the ultimate and most suited, reliable measure.

266. In contrast, we believe that the use or development of less objective measures, such as pant score or even multiple metrics, is suited to a dynamic risk model – where it helps to identify or warn of changing conditions – and as a feedback tool for validation.

7. Conclusion and proposed pathway forward

267. Heat stress is a complicated welfare issue where there is:

    a. Developing science, yet many gaps in knowledge that remain;

    b. Extensive, variable influencing factors at many different levels (vessels, decks, species, breed, line and individual); and

    c. Difficulties in establishing strong or absolute correlations or relationships.

268. Over-generalising, taking a simplistic view or assuming absolute correlations does not do justice to the complexity of the matter or the efforts and investments of the scientists and funders that have sought to better understand it.

269. Within this framework, the existing HSRA model reflects an unprecedented investment by industry into an internationally advanced and sophisticated model. It has been built over a more than 15 years with substantial, dedicated input from a number of experts, in what is a challenging area of science.

270. The fundamental assumptions and process in the HSRA model – as recognised by the 2008 review of the model – are sound and we are confident that it has delivered significant benefits to the industry and improved animal welfare.

    a. It is a testament to the developers that the model has operated with such impressive accuracy, despite the data sparse environment within which it was developed and has operated.

271. As identified earlier, industry has continued to refine the model for the last 15 years and has actively been looking at opportunities for continued improvement recently – including updates to the exposure (weather) inputs and animal physiology parameters.

272. These long-term efforts reflect the premise that we think is applicable to the Panel's work, that – given we are operating in an area of such uncertainty and limited data – we need to focus on creating certainty and reducing uncertainty wherever we can.

    a. By contrast, there needs to be particular care not to damage the model's capacity to continue to improve welfare by making decisions that increase uncertainty / reduce certainty – for example, by introducing subjectivity.

273. Despite the above, we have still attempted for the purposes of this submission to work through each aspect and correlation of relevance to the Panel's considerations. In doing so, we have ourselves relied on limited data-sets and generalised correlations to identify concepts or principles of relevance.

274. Understanding these correlations – for example, between rumen or core temperature and physiological responses – and their relative strengths and limitations is important to inform whether they have the capacity to support a regulatory objective in the model, or if they are better suited for use as 'flags' or indicators in alternative industry based measurement and improvement systems.

275. We believe that based on the available science in this space and the principles governing good regulation, there is a need for two integrated systems to operate in parallel to assess,

measure and continuously improve industry performance in mitigating heat stress risks. These systems would include:

a. An objectively based model for static and dynamic heat stress risk assessment; and

b. A continuous improvement / early warning based system for animal welfare.

276. There are several actions that are either in progress, being commissioned or under consideration through the livestock export R&D program to achieve these goals in regards to both the HSRA model and the animal welfare indicators structure. These are outlined in detail in the following sections.

277. We recognise that collaboration will be important in these initiatives and welcome the opportunity to engage further with the Panel.

278. Further detail on each of the HSRA model and the animal welfare system are outlined below.

Objectively based HSRA model

279. Within this submission we have outlined several key means of improving the HSRA model, including by:

a. Expanding the capabilities of the model to incorporate both static and dynamic risk assessments, including to inform relevant decision points for regulatory approval.

b. Integrating the regulatory based HSRA model with an industry / management based continuous improvement system.

c. Significantly improving the sensitivity – temporally and spatially – of the weather / wet bulb temperature data relied on for predictions and introducing the capacity for pre and during voyage forecasting.

d. Delivering the significant suite of projects currently underway or in planning, including in particular the:

i. PAT and re-ingestion audits to improve ventilation inputs (and in turn, improve the accuracy of the delta T calculation); and

ii. Further climate control studies, including to better understand the relevant correlations with regards to exposure levels, duration and respite.

e. Incorporating a structured and ongoing validation framework through improved metrics and measurements and the matching of predicted and observed outcomes.

280. These changes have the potential to have a transformative effect on the HSRA model (and heat stress risk management more broadly) and result in an approach to modelling and mitigating exposure to conditions capable of causing heat stress and heat stress outcomes that we are confident is dramatically more sophisticated and capable of dealing with those issues than anything that exists in any other agribusiness or animal husbandry industries that we are aware of.

281. Importantly to achieve the above, the HSRA model needs to continue to be focused on an evidence based and appropriately conservative correlation of exposure / weather with

objective measures that are meaningfully tied to actual and measurable physiological impacts.

282. In this regard, since its development the model has operated against a probabilistic outcome of a 2% chance of 5 % mortality. The reasons why these settings were used have been outlined early in the submission.

283. There has recently been a focus on changing these probabilities from reference to mortality to a welfare based measure.

284. However, any such move must still maintain the principles outlined earlier and ensure that the model, which is used as a regulatory threshold, remains objective, based on best evidence and represents the minimum regulation required to achieve the outcome.

285. In this regard, mortality was, and still is, the best objective measure of welfare available because:

    a. It is dichotomous (dead or not dead), there is no 'degrees' of mortality

    b. There is no subjectiveness in interpretation

    c. It is instantly and repeatedly recognisable without any specialist skills (i.e. it can be recognised regardless of education or literacy)

    d. It can only be counted once, as it is permanent and does not change over time; and

    e. It does not have a duration influence and as such, it does not require continuous monitoring to assess

286. There continue to be many good reasons for not abandoning mortality as the best objective measure of welfare outcomes in the HSRA model.

    a. This includes the fact that the HSRA model is built around the use of mortality, and it has proved to be quite effective, if not conservative, at providing certainty in the prediction of extreme events. A shift away from mortality would require the introduction of weaker, more subjective correlations into the model and potentially only serve to provide a model capable of predicting with less certainty lower impact events.

287. Notwithstanding the above, the McCarthy Review put forward a proposed change that would essentially reflect a 'straight swap' from mortality to an extrapolated representation of pant score 3 (using the HSRA mortality limit figure).

288. However, in our view McCarthy fails to achieve the necessary thresholds for incorporation into the model (and in this regard, we note that McCarthy had limited time to complete detailed validations and suggested further review).

289. Firstly, based on the available evidence relating to heat stress responses, the proposal to 'straight swap' from mortality to an extrapolated representation of pant score 3 (using the HSRA mortality limit figure) is not representative of the science.

    a. The extrapolation of a Mortality Limit percentage against Heat Stress Scores incorrectly suggests these linkages have been validated. They have not and caution is needed.

b. If a welfare basis is to be adopted the correlations between exposure, core temperature or rumen temperature, and physiological response need to be validated / calibrated and better understood. Such an approach needs to be taken afresh based on the science, not by arbitrary extrapolation from the existing model.

290. Secondly, based on the available evidence relating to heat stress responses the proposed thresholds are not tied to physiological consequences.

291. Our review of the available science suggested that:

a. Open mouthed panting in and of itself does not mean an animal is having physiological consequences and the available evidence strongly suggests that duration matters. Our understanding is that durations of open mouth panting (second phase) potentially in the order of a week are required for acid base disturbances to start to have physiological consequences (without necessarily impacting mortality).

b. In addition, the science shows that this is not irreversible and that physiology will return to normal if respite can be provided – consistent with fundamental physiological principles.

292. Importantly there is a substantial buffer between the exposures and core temperatures that are generally equated to commencement of open mouthed panting (as suggested by McCarthy as the threshold) and risk of increased mortality. In turn there is a strong duration and respite element, relative to exposure level, that would need to be understood and modelled to provide effective predictions.

293. Thirdly, the proposed threshold is extremely conservative and reflects a regulatory limit where shipments would be prevented from proceeding based on a prediction of the risk that within the worse-case 12 hours during a voyage a small proportion of animals would transition into open mouth panting.

a. The proposed setting of a maximum threshold of a 2 % chance of 5 % open mouth panting in any single 12 hour period is demonstrably and unnecessarily conservative.

b. At this probability, 95 % of the animals are still successfully thermo-regulating with no physiological impact and the remainder are transitioning to mechanisms that can impact on physiology but are highly unlikely to suffer any adverse consequences at those levels and at that duration.

c. Further, there is a significant risk / expectation that at such a level localised responses – for example, related to individual animal and line effects that cannot reasonably be factored into the model / or are not well understood or known – would be unreasonably generalised across a population and trigger this threshold.

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

295. Finally, it is subjective and impractical to measure or model in a meaningful manner. We have outlined in detail in the preceding sections of this submission a range of issues of subjectivity, and practicality with the proposal.

296. In the regulatory space in which the model operates, objective measures must take preference over easier to collect subjective measures.

297. Looking beyond the McCarthy recommendation, we have also closely investigated the potential objective measures that may be available and noted that the physiological impacts of heat stress, whether thermoregulatory responses or permanent harm, are ultimately related to core temperature.

298. We believe that open mouthed panting for a range of reasons outlined in earlier sections is not in of itself an appropriate measure because of its subjectivity and lack of clear correlation with physiological consequence (noting the importance of duration).

299. In preference, we believe that core temperature and rumen temperature are objective, and have a reasonably reliable correlation with exposure. Any welfare measure must be able to be reliably tied to core or rumen temperature to be effective.

300. However, even core and rumen temperature are difficult to measure and establishing the reliable, repeatable objective correlation between core temperature and recognised physiological outcomes, other than at a generalised level, presents difficulties. This is because the data-sets are limited and the evidence sparse on these relationships, particularly with regard to known areas of importance such as duration and respite.

301. As such, these correlations with core temperature or rumen temperature would need to be established with greater certainty and confidence in a variety of circumstances through further calibration and validation.

302. In the interim, mortality remains the most objective and appropriate measure and in this regard we note that consideration could be given to reducing the mortality threshold.

    a. In this regard, we note that – as expressed earlier in this submission – LiveCorp believes that it would be feasible to consider a reasonable adjustment in the 5 % mortality rate, if required. However, there would need to recognition of the need to be able to reliably distinguish between mortality caused by heat stress and other causes.

303. While we identified challenges with many of the available metrics that would make them difficult to model or use in an objective regulatory framework, we believe that measures – such as trends in the proportion and duration of open mouth panting – would be much more likely to provide a valuable mechanism to inform continuous improvement and validation.

304. In concluding, we believe the HSRA model needs to continue to be focused on an evidence based and appropriately conservative correlation of exposure / weather with objective measures that are meaningfully tied to actual and measurable physiological impacts.

305. While mortality remains the best objective measure at present, we believe there is enough evidence to support the adoption of key features that will result in transformative change and improved risk management to the model.

306. We also believe there will be a need for us to collaborate with the panel to help refine various aspects of the model.

Animal welfare indicators – continuous improvement and early warning

307. The opportunity and importance of considering the HSRA model in the context of an integrated framework with the animal welfare indicators based continuous improvement system was discussed in detail earlier in this submission.

308. In that section we identified that:

    a. Heat stress is a complex and multi-faceted issue that cannot be addressed by a singular focus on predictive risk assessments through the HSRA model.

    b. The HSRA model achieves significant outcomes, bounded by the need to make educated assumptions that favour objectivity and certainty to ensure the model is as accurate as possible and representative of the real world. It does so in a framework of significant variability where predictions can be challenging and never absolute given the reliance on forecasting the responses of biological systems.

        i. LiveCorp hears of this limitation through its engagement with veterinarians, exporters and stockpeople that highlight the one-percenters, particularly in selection, preparation and rejection criteria, as the area where the next level of improvements in animal welfare will be achieved. They rarely believe this will be delivered through the HSRA model.

    c. We therefore believe an integrated approach featuring a refined HSRA model and a welfare based continuous improvement system is needed and will offer real opportunities to improve heat stress risk management.

    d. We believe that this continuous improvement system will achieve significant structural change in the industry by building strong, dynamic feedback loops and early warning systems into exporter operations. These structures are critical both to improve the monitoring and collection of data, but also to ensure that that information is analysed and used on an ongoing to drive and demonstrate improvement and allow the proactive identification and response to issues before they become significant problems.

        i. They are also critical to supporting improved communication and transparency with the community to build confidence and trust in the performance of the industry.

309. Aligning with the principles outlined in the Millar, H paper and the advice of researchers involved in the project, the welfare based continuous improvement / benchmarking system needs to be an industry based management tool, rather than a government enforced punitive regulatory tool if it is to have the greatest impact. The system must encourage ownership and self-identification and response to welfare issues as they arise.

310. In addition to the industry structural changes, we believe that this system – and the associated enhancement in data collection – will also significantly contribute to informing research and future calibrations of correlations and models.

    a. For example, this could include the capacity to analyse data to better define and potentially understand the causes of line effects, enable performance based decisions through the supply chain, and the ability to strengthen and calibrate / validate the operation of the HSRA and enhance the confidence in the correlations between more objective measures (such as core temperature and rumen temperature) and

311. In conclusion, we believe that there is value in looking at both objective, more certain measures and more subjective or uncertain / yet to be validated measures in managing heat stress (and welfare more generally). However, they need to be incorporated into structures that can utilise them in the most meaningful way and provide the best outcomes in terms of welfare management.

312. Again, we would welcome the opportunity to discuss any aspect of our submission with the panel and to discuss and collaborate further.

8. Other areas of note

313. This submission has focused on the application of the model to sheep. As the panel will be aware, the outcomes and success from the HSRA model's assessment and mitigation of risks for cattle is different to sheep.

314. The physiological responses between the species differ significantly. Accordingly, the details in this submission should not be extrapolated or cross-referenced in the context of other species.

315. Separately, we note that any changes to the stocking density (proposed under the ASEL review) should be considered a 'first step' adjustment to the model prior to considering further changes due to the likely impact on 'wet bulb rise'.

9. Responses to HSRA questions

316. Recognising the HSRA panel has asked specific questions related to the HSRA, we have endeavoured to provide responses at Appendix 6. Where relevant, these relate back to concepts or elements earlier detailed in this submission.

317. LiveCorp would be pleased to expand on any of the responses to the questions.

10. Appendices

318. A range of additional information referenced in the above submission has been incorporated into appendices for the panel. These are detailed in the following pages.

Appendix 1 – Summaries of select research projects relevant to live sheep exports

1. Animal welfare indicators

A key project for the livestock export industry is the *Development and assessment of animal welfare indicators - Quantifying welfare improvements in the live export industr*y. It is being delivered by Murdoch University.

The project was commenced as part of an industry reform proposal initiated by ALEC to develop meaningful indicators of welfare along the supply chain that would move performance measurement away from a focus on mortality, support transparency and reporting to the community, and identify areas of improvement using an integrated welfare assessment.

It is a key part of defining the measurement of welfare moving forward and is the basis on which a move from mortality to welfare can be pursued on a scientifically rigorous basis.

The aim of this project is to identify internationally accepted and current indicators of animal welfare for cattle, sheep and goats that could be used at each point along the livestock export supply chain. To identify these indicators, the project conducted a literature review of standards and regulations, as well as a stakeholder survey. The survey of over 900 people from the community, animal welfare groups and the industry found a high level of agreement in the perception and importance of animal welfare.

From this research project, the researchers identified (54) candidate indicators. These included twenty indicators that are currently collected along the supply chain by the industry under regulation, including within voyage reporting and ESCAS auditing.

A comprehensive list of potential indicators – including qualitative behavioural assessments – are now in the process of being validated through supply chain pilots to determine a concise group of meaningful indicators of welfare that are practical, cost effective, efficient, repeatable, etc, and can:

- Provide the information to drive industry decision making, allow benchmarking of exporters and supply chain members, and enable planning for mitigation;
- Enable a system of early warnings to be built to enable proactive responses before issues occur; and
- Be understood across industry and community to form a common language and expectation.

The project will result in a framework for the industry to monitor, assess and report on its welfare performance and enable the introduction of a continuous improvement, benchmarking and, in conjunction with other projects, an early warning system.

2. Voyage Reporting

The LEP is well advanced in a research project that will allow the current voyage reports required under ASEL to be collected / recorded in an electronic / app based system. The project was initiated as a result of the livestock export industry and the regulator both identifying the need and opportunity to improve and standardise the on-board reporting framework under the Australian Standards for the Export of Livestock (ASEL). Its objectives include:

- Improving the quality, consistency and ease of data collection, collation and use on-board by providing Australian Accredited Veterinarians (AAVs) and stock people with better tools that support their day to day activities and responsibilities;

- Enabling the collation of data more effectively through the standardisation of data collection content and methods;
- Providing new tools for the users of the data (AAVs, exporters, the regulator) to easily access and interrogate information from a central point; and
- Streamlining and standardising regulatory conformance with the daily reporting requirements under ASEL.

In addition, the project will build the technical platform to allow the introduction of greater automation (e.g. of temperature / humidity data) and the implementation of animal welfare indicators, when this project concludes (noting that some welfare measures such as respiratory character and faecal description are already included). It is an important part of the industry's commitment to continuous improvement in animal welfare and supporting the regulatory objectives of the government.

The project has developed a smartphone app as the primary data collection tool to enable real time recording of mortality and animal health treatment records by AAVs and stockpersons. A centralised database with data analysis tools, and a user interface platform are also in pilot development. These tools will provide for a semi-automated data collection, analysis and reporting system that is more efficient, standardised and valuable than the current regulator managed framework. The system is currently being trialled and refined with input from AAVs.

3. Automated sheep counting

The LEP has partnered with researchers at the University of Technology in Sydney (UTS) to develop technology for the automated counting of sheep using video technology and algorithms. The initial focus of the project will be on receival / dispatch at livestock depots and loading / unloading of livestock vessels, but will have application throughout the whole supply chain.

Initial proof of concept tests, conducted of loading onto and off trucks and loading onto a livestock export vessel, have shown very high accuracy of the technology even at such an early stage of development. However, several practical challenges associated with environments encountered in the livestock export industry need to be addressed including such as weather, night, real-time count reports and camera positioning.

Machine led counting will provide a number of benefits to industry including independence of livestock counts, resolution of disputes or irregularities, and reduction of labour requirements. However, the development of these algorithms and the application of this technology will open the industry to a vast array of different opportunities for example, monitoring of animal behaviour and health.

4. Open Innovation Program

In May 2018, LiveCorp commenced an Open Innovation program to explore the existence and feasibility of new and developing solutions for managing the on-board environment, particularly wet bulb temperature.

While the LEP RD&E Program has invested in research to address the risk of heat stress to livestock during export (through risk assessment, management, planning, ventilation design, etc), interventions to change the ambient temperature or humidity in vessels (e.g. dehumidification / air conditioning) have traditionally been considered – based on expert advice – as almost impossible to achieve. The Open Innovation program has now provided the industry with the opportunity to tap into the global innovation and technology ecosystem to identify new and emerging technologies that may have shifted the feasibility of such interventions.

To date, the project / process has conducted a thorough scoping of a range of technologies that could support improved detection and responses for dealing with the risk of heat / humidity based on real time conditions / assessments, rather than solely predictive or historical approaches. Areas that have been investigated included dehumidification, targeted rapid cooling, environmental monitoring, weather data / improved voyage route planning and artificial intelligence. LiveCorp is now commencing a trial phase to validate the effectiveness and viability of the technologies identified.

Appendix 2 – Mortality graphs from LIVE.123

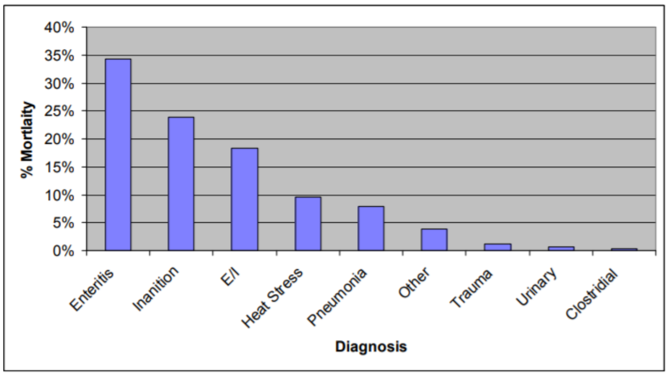


Figure 1 – Percentage of voyage mortality attributable to each of nine diagnostic categories across all 19 voyages on which post-mortem examinations were performed

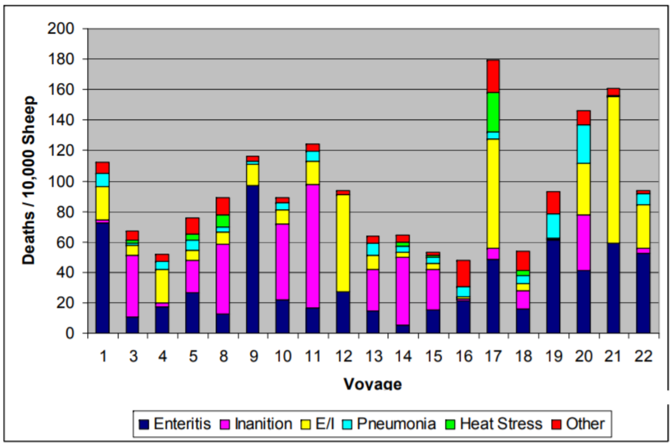


Figure 2 - Mortality per 10,000 sheep for 19 voyages. The height of each bar represents the number of mortalities/10,000 sheep and the coloured sections represent the proportion of mortality attributable to each of the 6 mortality categories

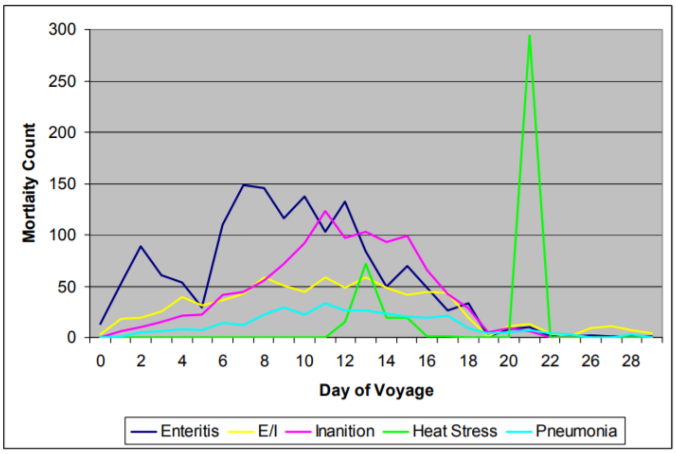


Figure 3 – Mortality count for each of four major diagnoses by day of voyage across all 19 voyages

Appendix 3 – Responses to HSRA Issues Paper questions

How should the effects of heat on animals be defined?

The effects of heat stress on animals should be defined by reference to the core and / or rumen temperature. It is ultimately the source of the impacts felt by the animal and is an objective measure on which further correlations to other physiological or welfare measures should be connected (through validated relationships). This is covered in detail in this submission.

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

Part of responding to this question necessitates understanding how 'heat load' is defined for the purposes of the Issues Paper. However, this submission covers in detail the different correlations. Further, it identifies the importance of the model being based on objective measures of heat stress, and the opportunity for more subjective/variable/impractical measures of heat stress to be incorporated into industry structures for continuous improvement and early warning.

We do note however that detection of 'heat load' should be defined by reference to core or rumen temperature, and should be differentiated from an animal that is successfully thermo-regulating. It has been noted that the detection of the point at which increased core temperature causes physiological consequences (being acid base disturbances), noting that even this appears to be reversible with respite, is a combination of exposure level (phase II open mouth panting) and duration (of at least 5 – 7 days).

Finally, we note that in terms of indicators for the detection of 'heat load' the Animal Welfare Indicators project has been initiated and is well underway to determining how welfare risks and outcomes can be measured holistically (and with regard to key factors) in the livestock export environment.

What level of heat load is tolerable / acceptable?

This submission addresses this question in the areas where LiveCorp is able to respond. We have outlined the science and evidence of where physiological consequences – in the form of acid base disturbances – begin to occur at particular core and rumen temperatures (generally reflecting the commencement of open mouth phase II panting) and durations (at least 5 – 7 days).

We have also outlined in the submission the community and regulatory considerations that are relevant and the importance of ensuring that any thresholds determined are evidence based and can be objectively measured (which we have identified as being mortality, core / rumen temperature and exposure levels).

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

As outlined in this submission, the HSRA uses a skewed beta distribution to describe mortality probability for the purposes of the model. The choice of a skewed beta distribution is justified on the basis that there is more likely to be more susceptible animals at the lower end of the distribution (leading to a lengthened left tail), and less likely to be a substantial degree of animals that can manage extreme conditions at the upper end of the distribution. As shown in the following diagrams taken from LIV.116, as the relative heat tolerance of the animal changes, so does the shape of the distribution, particularly the length of the tail.

Figure 3.6 Beta Function Probability Distribution – Merino - Adult

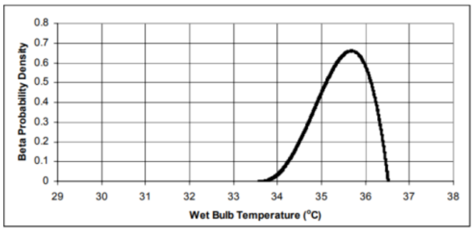
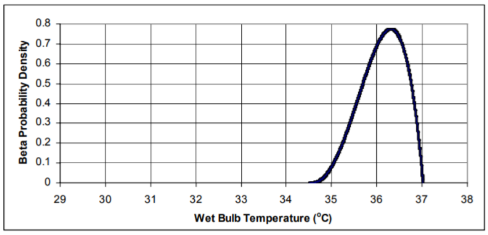


Figure 3.8 Beta Function Probability Distribution – Awassi - Adult



What is important and informs the probability distributions used in the HSRA model is the relatively good knowledge that exists at the left end of the tail where mortality in a population commences. For the mortality limit figure quoted of 35.5 degrees, the corresponding lower point of the beta is 33.58 degrees wet bulb and the upper point of the beta is 36.52. The 35.5 degree figure for mortality and the HST figure are figures that are derived and used for the purposes of producing the beta distribution and they generally reflect a point near to, but above the 50th percentile.

The critical area of interest, however, is the left hand side of the tail where the nominated probability is taken (at 5 % at present). This is where the strength of the science correlating the mortality curve to wet bulb temperature matters.

We also reiterate that these are base levels and they will shift depending on the different factors that are taken into account for the individual lines of animals. Again, these factors and how they are incorporated are outlined transparently and in detail in Maunsell, 2003 (LIVE.116).

The biological assumptions in the HSRA were also assessed in an LEP project in 2008 entitled *Upgrade of biological assumptions and parameters used in the HS risk management model* (LIVE.228). This project considered additional datasets that had come available since the original HSRA development including a series of observations from voyages (noting difficulties with accurate measurements), a literature review and a separate LEP project completed by Murdoch University (which suggested no need to revise the HST values for sheep from where they are set at now).

The 2008 review considered this report and other factors and concluded that:

> *The data and calculations used in the HotStuff model for identifying the critical values for heat-induced mortality and the distribution of the accompanying incidence of mortality are supported by biological knowledge and reasonable assumptions derived from existing knowledge.*

Since 2008 we are not aware of any new data that would suggest that the probabilistic beta distributions for mortality and the corresponding lower, upper and mode levels in the HSRA should be changed.

However, we certainly remain open to consideration of new research and data of relevance which has a high degree of confidence in its accuracy and comparable measures (i.e. it needs to be referrable to a measure incorporating humidity), and have been engaged in our own processes within the LEP to complete further informative research.

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?

This submission addresses in detail the science and evidence on physiological changes in sheep from increasing rumen and / or core temperature. We believe that it is essential that an objective measure – such as core and / or rumen temperature – form the basis of any physiological indicator in preference to any subjective or more variable physiological indicator (such as panting). This submission also outlines that the physiological indicators must represent more than an 'early warning' to be used as the threshold for the model, and instead must reflect a point where there are physiological consequences for the sheep. We have identified this point as being at or above the onset of acid base disturbance, where the combination and effects of exposure level, duration and respite must necessarily be considered, and mortality.

The use of other physiological indicators – for example, the onset of phase II panting (particularly where this is representative of the population's response to heat stress, rather than reflective of susceptible animals / individual variability / other contributing factors) – are best used in systems for continuous improvement, early warning, and validation.

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

Assuming that the indicators referred to in this question are differentiated from the above physiological indicators, we believe that 'animal welfare indicators' would be far too subjective to be appropriate in the model, and it would not be possible to reliably distinguish (for regulatory purposes) the contribution of heat stress over other factors.

However, we are not suggesting that there is not a role for animal welfare indicators (i.e. based on animal behaviour / affective states). We simply do not believe that it is in this framework.

The Animal Welfare Indicators project is working to define the appropriate animal welfare indicators for the live export supply chain and this holistic look at welfare (rather than solely heat stress) and the correlated development of a continuous improvement / early warning structure is the best place for this to be considered. We note in this regard that the project is analysing the benefits and limitations of using qualitative behavioural assessments.

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

The probability settings for a regulated model must be objective and evidence based.

We have outlined in detail in this submission the issues with McCarthy's proposal to 'straight swap' from mortality to open mouthed panting, and have highlighted how it is disconnected from welfare, significantly and unnecessarily conservative and not an appropriate basis on which to base the model.

As the submission deals with this issue in detail we won't go too much further other than to note that it is critical that if the probability settings are reviewed that they are considered holistically as a representation of risk and animal welfare (for example, simply because the settings are 2 % of a 5 % risk for mortality does not equate to applying those same settings to a different, lower threshold). This includes taking into account more difficult, but highly significant areas of duration and respite.

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

As we have noted, strictly speaking a change is not necessary to incorporate high core temperatures causing physiological consequences into the model as it is encompassed in mortality and the low risk settings used in the model (which as noted we believe could reasonably be adjusted lower, and drastically improved by new and more sensitive exposure inputs).

Beyond mortality, we note that any change from mortality in the model must be based on an objective measure (mortality or core / rumen temperature) and a clearly defined and evidenced relationship.

We recognise that there are few suitable measures that provide the certainty required for a regulated model (i.e mortality and core / rumen temperature). For this reason, it is important to recognise that the outcome that is desired is best achieved by a combination of a HSRA model based on objective, evidence based settings and an early warning / continuous improvement welfare system (which would also support validation exercises) that incorporates welfare indicators that – subject to a scientific basis – are more variable / subjective measures.

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

Noting all of the above comments, we merely note that the probability settings as a whole need to be considered as they reflect risk and statistical significance and they must relate to an objective welfare outcome. Were this to change from mortality, duration and respite become critical factors that cannot be ignored.

How can allometric stocking densities most effectively be used?

Allometric stocking densities have been considered by the Technical Advisory Committee (TAC) for the Australian Standards for the Export of Livestock (ASEL). LiveCorp notes that submissions have been made on this item in response to the ASEL TAC's issues paper and on this basis note that it appears to be duplicative for the HSRA panel to address it also.

Allometric stocking densities are most appropriately used within ASEL to set the minimum space allowance requirements for livestock. The allometric density should not attempt to take into account thermoregulation or heat stress. Rather, the HSRA model – in providing a more meaningful and sophisticated assessment of the relevant factors – should identify where further stocking density reductions are required based on heat stress risks.

We also believe that the allometric stocking density also should not vary between periods of the year. It should, as noted above, be set based on minimum space requirements for the voyage, excluding considerations of heat stress. Applying a higher stocking density through ASEL separate to the HSRA in the norther summer would cause perverse outcomes and ultimately only increase the impact on those exporters and ship-owners that have invested in better ventilation.

Finally, we note that any stocking density change determined by the ASEL TAC will be incorporated into the HSRA model, which will basically just amend the baseline from which any de-stocking occurs. The recent Middle East Sheep Order specifies how the HSRA and the allometric stocking densities should be interpreted that between May and October and this appears appropriate (i.e. the minimum stocking density must be determined by whichever provides the greater space of the HSRA or the allometric equation).

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

Significant effort has been made by different groups – including the Australian Livestock Exporters' Council – to address stocking densities and the relevant k-value (constant) that should be used in the allometric equation, including incorporating the scientific basis for this choice, in their submissions to the ASEL TAC. Consistent with our comments above, we believe that allometrics and k-values are rightly a matter for ASEL, not for the HSRA.

However, for the avoidance of doubt, we note the following comments from our second submission to the ASEL review:

- Stocking density has a critical influence over the welfare of livestock exported from Australia and is one of the primary determinants over the productivity / profitability of the trade. However, it is a complex area with many factors interacting from an animal, infrastructure and journey perspective to influence the likely risks and outcomes. Please refer to LiveCorp's submission to ASEL Review – Stage 1 for further detail and discussion of stocking densities and the available science on allometrics.
- A number of key projects conducted by the LEP are relevant in this regard and which LiveCorp would be pleased to provide further details of if required during the ASEL Review process:
- Quantitative assessment of cattle behaviours on-board livestock ships (Stockman, 2009) – this project analysed video footage of a shipment to the Middle East. It aimed to provide an informed estimate of what proportion of time animals spend performing certain basic behaviours on-board.
- Refining Stocking Densities (Ferguson & Lea, 2013) – this project assessed a range of welfare and performance indicators (including weight change, time spent lying, environmental conditions, etc) for two long haul sheep and one short haul cattle shipments against the following stocking densities – ASEL, ASEL + 10 per cent (or the space provided using an allometric K-coefficient of 0.027, whichever was greater), and ASEL - 10 per cent. The report noted that:
  - Any reductions in the ability of the animal to eat its normal feed allowance or rest for 6-8 hours / day will result in a profound compromise to their welfare.
  - The current ASEL stocking densities are appropriate based on the animal welfare indicators applied in these investigations but a 10 per cent increase should be further investigated. It was also noted that the project only considered voyages during periods when climatic conditions were relatively benign and the benefits of an increase (10%) may be more evident under warmer, more humid voyage conditions.
  - However, it was recognised that under such conditions, it would also be likely that stocking density reductions would be required based on the HSRA model predictions.
- Following this earlier research, a project has commenced between the LEP and the University of New England as part of a project partnership to conduct detailed research into stocking densities so as to expand and inform the scientific understanding of space use by groups of sheep and cattle on-board livestock export vessels. A consultative committee has been established to inform and support this project, entitled "*Effects of stocking density on behaviour and group dynamics of cattle and sheep exposed to differing export conditions*". The project will look at quantifying the extent and cause of variation in response to differences in climate conditions, stocking density and other stressors (e.g. availability of bedding, trough space and sequential feeding, etc), and how they affect the distribution,

behaviour, welfare and performance of livestock. It will include land based studies, as well as on-board trials / data collection (in collaboration with the "*Development and assessment of animal welfare indicators - quantifying welfare improvements in the live export industry*" project). The UNE project will ultimately provide robust science and information to the industry on optimal stocking densities for both sheep and cattle, which we expect will inform industry and regulatory standards.

We also note in relation to the comments made in the HSRA issues paper that Petherick and Philips identified that uncertainty surrounds the use of specific allometric coefficients and many have been extrapolated from intensive animal industries where animals spend their lives in confinement. The situation for live export, simply by virtue of duration, is different to intensive animal industries and is a consideration for the ASEL TAC and the subject of the detailed research with UNE.

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

This is discussed in detail throughout the submission, both in terms of the known correlations with rumen temperature and animal physiology and exposure levels. Duration – and respite – are critical considerations for determining when thermo-regulatory responses, such as open mouth panting, will begin to have physiological consequences.

We have highlighted the importance of improving the sensitivity of the exposure information – both spatially and temporally – if these factors are to be taken into account.

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

Noting the above comments highlighting the importance of respite, we also note that the potential to incorporate minimum daily temperatures is covered in detail in the discussion on the potential opportunity to improve the spatial and temporal sensitivity of the exposure inputs and their measurement. The model would need to be changed substantially to incorporate factors such as minimum temperatures / respite.

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

The model currently assesses the voyage and port heat stress risks to the first port. This reflects the fact that once unloading has occurred the sheep are generally stocked at a much lower rate than originally loaded. It would be possible to identify a structure to take multiple ports and continued voyages into account, although some thought would be require to minimise complexity and allow for consolidated / simple reports and advice.

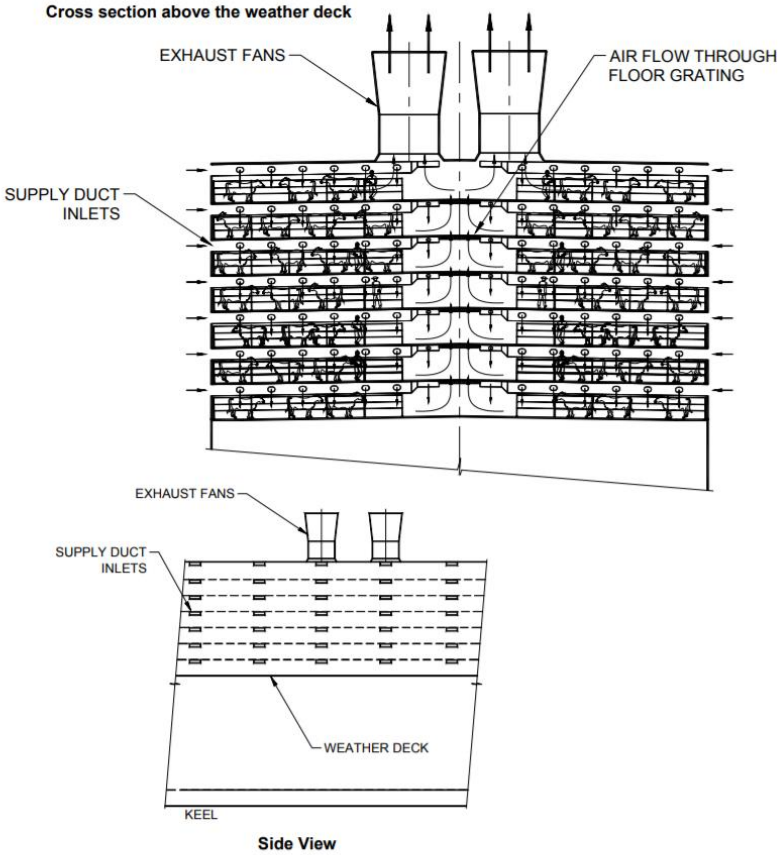
What elements or factors contribute to good ventilation performance on a vessel? And, how might ventilation performance be incorporated into the HSRA model?

Ventilation performance is incorporated into the HSRA model and has been since its inception.

The model developed and implemented Pen Air Turnover, or PAT, as the preferred measure of ventilation rate. It is the ratio of the ventilation flow (typically in m^3 /hr or m^3 /s) to the pen area in the ventilated section (in m^2). PAT has the dimensions of a velocity and can be most conveniently written in metres per hour (m/hr). To relate PAT to the dimensions of the livestock housing, it may also be explained as follows: If the fresh air could be introduced evenly through the floor of each pen and be extracted evenly through the ceiling above each pen, then the vertical air velocity through the floor and ceiling would be the PAT. Because of the relationship between beast weight and stocking density and between liveweight and the production of heat and CO_2, PAT is a direct measure of the average effectiveness in controlling heat and pollutant build-up. On vessels monitored for the 2001 ventilation study report, PAT fell in the range of 100 to 300m/hr. The traditional measure 'air changes per hour' relates flow to deck volume. With the same stocking density and heat load, a space with twice the deck height requires twice the flow to have the same 'air changes'. This treatment of deck height is the principal reason why 'air changes per hour' is not as relevant as PAT.

As noted earlier, audits of the PATs of vessels – including their risk of re-ingestion – are being conducted of all vessels shipping sheep to the Middle East. These audits will help refine and improve the accuracy of this important input towards to the Delta T.

We also note that Maunsell Australia produced the report – *Practical Ventilation Measures for Livestock Vessels* (LIVE.211) – in 2003 for MLA / the LEP after completion of the practical ventilation investigation project, *Investigation into the ventilation efficacy on livestock vessels* (MAMIC Pty Ltd, 2001).



Livestock vessels are also required to comply with the regulations set by the Australian Maritime Safety Authority. These regulations – set out in Marine Order 43 – identify minimum ventilation requirements for vessels, including that:

- All vessels must comply with the minimum air change requirements set out for enclosed or partially enclosed areas as set out in the Order, from 31 December 2019 (grandfathering earlier exceptions).
- All new vessels must only be single tiered and from 31 December 2019 no existing vessels will be able to carry livestock on more than one tier.

The Marine Order also specifies the following in relation to air distribution requirements:

2.4 Mechanical ventilation system — air distribution requirements

(1) A mechanical ventilation system must distribute air so that the whole of any livestock space is efficiently ventilated.

(2) For a vessel constructed or converted for the carriage of livestock after 26 May 2004 — the mechanical ventilation system must provide air from a source of supply, with a velocity across a pen of at least 0.5 ms-1.

(3) For a vessel constructed or converted for the carriage of livestock before 27 May 2004 — the mechanical ventilation system must, after 31 December 2019, provide air from a source of supply, with a velocity across a pen of at least 0.5 ms-1.

(4) However, if a solid structure or the vessel's side impedes the flow of air in an area of the pen, AMSA may approve, for up to 4% of the area of the pen, a velocity less than 0.5 ms-1 but more than 0.2 ms-1.

(5) For a livestock space, the livestock operator of the vessel must ensure that:

(a) the air is as clean and fresh as practicable; and

(b) there is minimal recirculation of intake and exhaust air.

Note A vertical high velocity exhaust system may help prevent recirculation of exhaust and intake air.

These requirements are regulated checked by AMSA and we believe that they are complementary to the HSRA ventilation approach. However, we are also aware that there are a diversity of views on ventilation.

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

As identified earlier in this submission, ventilation and PATs are one of the main interventions for reducing the delta T (the difference between ambient and on-board temperature). Further outlined in that chapter is the concept of expanding the metrics and measurements of the wet bulb temperatures relevant to the animal environment. Such improved data collection, particularly if it can be implemented at an appropriate distribution across a vessel, is likely to provide an improved indication of the delta T relationship on-board individual vessels (and in turn, provide for a reflection on the performance of the ventilation in effectively reducing delta T).

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

The HSRA model has spent considerable time modelling open decks for the purposes of incorporating their assessment. This is outlined in detail in the Maunsell and Stacey Agnew reports and further information or presentations on this aspect can be provided if requested.

Ferguson et al. also assessed open decks and ventilation in their review of the model in 2008, included at pages 15 – 22 of that report. Some relevant notes from that report are included below:

- *"The benefits of cross wind ventilation to open pens en-voyage appear self evident from data presented in LIVE.212. It is also apparent from information presented in LIVE.116 at section 5.4.2 where it is noted that crosswinds in excess of 1 m/s overwhelm most mechanical effort, for open decks.*

- *En-voyage, cross wind ventilation would have some element of controllability to it, in that it would generally be possible to navigate the vessel in such a way as to generate significant cross winds. As such, cross wind ventilation is a controllable parameter. This allows ship's personnel to react to adverse conditions that can affect the mortality rate during the voyage. However, it is not possible to control cross wind ventilation in-port, as it would be entirely dependent on the prevailing direction and strength of winds occurring at the port, as well as the direction of the ship when it is tied up alongside a dock. Therefore, cross wind ventilation in-port is not a controllable parameter. Moreover, the aim of the HotStuff model is to provide a prediction of the probability of mortality of animals, prior to departure from Australia. If the mortality rate on open decks can be significantly affected by cross wind ventilation in port, and cross wind ventilation in port cannot be relied upon, it would be prudent to make no reliance on cross wind ventilation in port. This is a strategy that would err on the side of caution, and aligns with conservative engineering practice and lends support for Maunsell's decision to not attempt to account for cross winds in port for open deck vessels within the HotStuff model.*

- *The Computational Fluid Dynamic (CFD) modelling described in section 5 of LIVE.116 appears exhaustive.*

- *Two very important points arise from the CFD work. Firstly, the relative effect of cross wind ventilation on open deck air flow is clearly demonstrated, in Figure 5.1 of LIVE.116. There it supports earlier experimental conclusions that good cross winds have the potential to overwhelm mechanical ventilation. Secondly, a lower limit to air flow is established via natural convection. That is, even when no mechanical ventilation is present, the buoyancy driven air flow will result in some air movement, albeit at very low effective PAT, as shown in Figure 5.2 of LIVE.116."*

As noted above, considerable research has been conducted on the incorporation of cross-winds during sailing on open decks. Likewise, consideration was given to how to treat open decks at port and it was determined that – because it is assumed that 98th percentile wet bulb temperatures are likely to be associated with still air – there is no cross-wind in port. In addition, the HSRA also accounts for the risk of re-ingestion between open decks in its calculations.

Most recently, through the independent PAT audits being coordinated for vessels carrying sheep to the Middle East the risk of re-ingestion via main inlets is also being assessed. This risk is almost entirely a port risk where exhaust air can hover and be re-ingested into inlets. Given the assumption of still air at 98th percentile these assessments are very conservative and have had an impact on stocking densities. To complete the re-ingestion assessments, the engineer conducted the audits is using a conservative interpretation of desktop analysis (i.e. of ventilation and ship design) and physical inspection, followed – where required – by further computational fluid dynamics to better refine the estimates.

Re-ingestion risk is also being assessed in this process for the voyage – however, because only a small amount of air movement is required to remove the risk, and because it is relatively easy to achieve air movement when sailing / during a voyage – it is largely irrelevant.

Marine Order 43 also include requirements that the operator of the vessel must ensure that the air is as clean and fresh as practicable, and that there is minimal circulation of intake and exhaust air. It notes that a vertical high velocity exhaust system may help prevent recirculation of exhaust and intake air.

We note that an item identified through LEP research, and outlined in the HSRA 5 report, is a proposed amendment to change the requirements for open decks in the model so that they are assessed as per closed decks.

We note in this regard that the Australian Maritime Safety Authority (AMSA) recently amended Marine Order 43 and included a new provision that any vessel constructed or converted for the carriage of livestock after 1 July 2018 that has a livestock space that is not enclosed, must have a mechanical ventilation system that can meet specified air change requirements.

Further, the Marine Order identifies that after 31 December 2019, any vessel with a livestock space that is either partially enclosed or not enclosed must have a mechanical ventilation system that is able to meet specified air change requirements.

The LEP will review the changes needed for how the HSRA model assesses open decks in the future, in light of the above changes.

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

Refer to above question and previously specified reports on the HSRA development, refinement and review.