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Department of Agriculture, Water and the Environment

Heat and cold stress in *Bos taurus* cattle from southern Australia during long-haul export by sea

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Draft report

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Department of Agriculture, Water and the Environment
GPO Box 858 Canberra ACT 2601
Telephone 1800 900 090
Web awe.gov.au

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Contents

Tables

Figures

Maps

Summary

The Department of Agriculture, Water and the Environment has prepared this draft report of its review of heat and cold stress in *Bos taurus* cattle from southern Australia during long-haul export by sea.

The review builds on the 2018-19 review of the Australian Standards for the Export of Livestock (ASEL) by sea (ASEL sea review) by the Technical Advisory Committee (TAC), which made recommendations identifying temperature stress as an issue for the welfare of exported cattle (and buffalo) on long-haul voyages (voyages of 10 days or more).

In preparing the draft report we reviewed voyage reports for the export of 1,019,563 head of cattle on 214 long-haul voyages over 5 years from 1 January 2016 to 31 December 2020. We reviewed voyages from 5 ports of departure, to 4 destination regions, 9 destination countries and 34 destination ports.

We considered scientific literature, industry research, voyage reports by stockpersons and shipmasters, Accredited Veterinarians (AAVs) and IOs, the ASEL sea review, data from the Bureau of Meteorology, internal and external stakeholder feedback and other relevant information.

We engaged an independent technical expert group to review the draft report and provide feedback. Formal public consultation is now being conducted via the department's 'Have Your Say' website. All feedback will be considered before publication of the final report.

This draft report provides evidence-based advice on improvements to current export arrangements to support animal welfare during preparation and transport of *Bos taurus* cattle consignments from southern Australian ports during long-haul export by sea.

Heat stress findings

The review determined that evidence of increased heat load can occur during long-haul *Bos taurus* voyages from southern Australia in all classes of cattle (breeder, feeder or slaughter):

- to all destinations
- from all departure ports and
- departing during both the northern hemisphere winter and summer.

Within this, it was found that *Bos taurus* slaughter cattle voyages have a significantly greater risk of increased heat load compared to voyages of feeder cattle and breeder cattle.

This review found the overall voyage mortality rate for the 214 voyages was 0.21%, which is below the notifiable level of 0.5% as defined in ASEL 3. Within this context, it was identified that *Bos taurus* slaughter cattle voyages have a significantly greater risk of heat stress-related mortality compared to voyages of other classes of cattle. Our review identified that two-thirds of heat stress-related mortalities occurred in combination with other diseases, primarily respiratory disease. This finding suggests that susceptibility to heat stress may be exacerbated by other health conditions.

A seasonal pattern was found in the frequency of heat load and heat stress-related mortality voyages, with a higher incidence occurring in the northern hemisphere summer compared to the northern hemisphere winter. The analysis found that approximately 1 in 10 voyages departing in the northern hemisphere summer resulted in at least 1 heat stress-related mortality. This incidence was approximately 1 in 30 for voyages departing in the northern hemisphere winter. Within the 6-month northern hemisphere seasons, our analysis also found that voyages departing in April, May and June had 2.6 times the odds of a heat load or heat stress-related mortality than voyages departing during other months of the year.

Important factors for the monitoring and management of the risk of heat stress during export voyages of *Bos taurus* cattle from southern Australian ports include:

- improved shipboard monitoring and collection of environmental data
- the use of heat stress risk assessment (HSRA) modelling all year round to all destinations, particularly for *Bos taurus* slaughter cattle
- identifying hot spots in vessels along with appropriate husbandry and management of cattle
- appropriate selection of animals and the use of preventative disease measures.

Cold stress findings

Our review analysed the impact of cold conditions on the welfare of cattle up to the conclusion of unloading at the destination port. The review found there were no recorded mortalities attributed to cold stress.

The review demonstrated the risk of cold conditions for cattle was greatest during the northern hemisphere winter particularly for exports departing from December to February. The final 5 days of the voyage were typically the coldest period with lowest recorded temperatures commonly coinciding with unloading at the destination port.

The review found that 20 of the 214 voyages were identified as having evidence of cold conditions based on either reported environmental signs such as temperatures of ≤5°C or frozen water in troughs, or behavioural or physiological signs. Thirteen voyages recorded temperatures between 5°C and −3°C but reported no evidence of cold stress. Three voyages reported cattle showing behavioural or physiological signs of cold stress (1.4%). Lack of awareness of how to recognise and mitigate the impacts of cold conditions could be a factor in the low incidence of cold stress reporting.

Road transportation and housing conditions in the importing country were beyond the scope of the review. Potential impacts of extreme cold conditions on welfare during road transportation after disembarkation and beyond may be an area for further research.

Impact of ASEL 3

ASEL 3 was implemented on 1 November 2020, changing the requirements and conditions under which live cattle are exported. It includes new reporting requirements that will allow for rigorous scrutiny of voyage outcomes. We have tried to acknowledge the impact of ASEL 3 when discussing findings and recommendations throughout our report.

Some initial submissions to this review suggested it would be prudent to wait until substantial data on ASEL 3 shipments becomes available before making further recommendations or changes to conditions. Our approach is to be proactive in identifying risk factors in this trade and in seeking improvements in animal welfare outcomes when issues of concern are identified.

Changes under ASEL 3 include:

- increased space allocation particularly for lighter cattle. There is no alternative (reduced) space allocation option for heavier cattle over 390kg during the northern hemisphere summer
- cattle more than 500kg must not be sourced for export or exported unless a heavy cattle management plan is approved in writing by the department
- southern-sourced pregnant *Bos taurus* cattle crossing the equator from May to October must be accompanied by a management plan approved in writing by the department
- changes to pregnancy requirements so that livestock must not be exported in the last third of their pregnancy
- increased time in registered establishments prior to export in most circumstances
- a requirement that a sufficient quantity of bedding is carried, applied and monitored to ensure good animal welfare outcomes for livestock
- increased requirements for reporting on animal welfare from registered premises and on-board vessels
- the introduction of LIVEXCollect (a data collection and management system administered by Livecorp) to improve consistency in the way livestock observations and other measurements are recorded and reported.

Findings and recommendations

The following findings and recommendations relate to the export of southern-sourced *Bos taurus* cattle voyages departing from southern Australian ports:

Findings

Heat load and heat stress-related mortalities

1. Increased heat load during long-haul *Bos taurus* voyages from southern Australia can occur in all classes of cattle (breeder, feeder or slaughter), to all destinations, from all departure ports and departing during both the northern hemisphere winter and summer.
2. *Bos taurus* slaughter cattle on voyages departing from southern Australian ports are at a higher risk of increased heat load than other classes of cattle.
3. *Bos taurus* slaughter cattle on voyages departing from southern Australian ports are at a higher risk of heat stress-related mortality than breeder cattle.
4. Two-thirds of heat-stress related mortalities were identified as 'combined' with an underlying disease. This was most commonly respiratory disease.
5. Heat stress mitigation strategies employed during the voyages were reported.

Other heat stress factors

Hot spots:

6. Voyage reporting rarely provided any detail on hot spot monitoring and management.

Bedding and pad management:

7. Welfare consequences of inappropriate pad management were noted on some voyages. The most common pad issue related to wet, sloppy pads in humid conditions.
8. ASEL 3 has implemented additional requirements regarding bedding use, application and monitoring.

Pregnant cattle:

9. There was no clear seasonal trend to the occurrence of heat stress risk in pregnant cattle.
10. The frequency of voyages reporting premature lactation is small which makes it difficult to determine its significance.

Reporting heat stress:

11. Daily deck temperature recordings may not accurately reflect actual conditions.
12. Evidence of increased heat load (elevated respiratory rates, altered respiratory character, increased panting score or heat stress score) was not consistently recorded or reported.

Cold exposure and cold stress

13. Twenty of the 214 voyages were identified as having evidence of cold conditions based on either environmental signs such as temperatures of ≤5°C or evidence of relevant behavioural, physiological signs.
14. There were no recorded primary mortalities due to cold stress.

15. The cold tolerance of Australian cattle exported to cold climate destinations is not well established.
16. Wet conditions are an important consideration on board a livestock vessel when animals are exposed to direct windchill (open decks) and high ventilation rates.
17. Mitigation measures for managing cattle in cold conditions are not well established.

Recommendations

Heat load, heat stress-related mortalities and other heat load factors

1. A suitable HSRA should be employed all year round for *Bos taurus* slaughter cattle to all destinations.
2. Consideration should be given to providing *Bos taurus* slaughter cattle exported from southern Australian ports during the northern hemisphere summer additional pen space.
3. Vaccination against bovine respiratory disease may be valuable in decreasing its incidence and should be considered for voyages of *Bos taurus* slaughter cattle departing Australia from southern ports between 1 May and 31 October.
4. Ongoing examination of *Bos taurus* slaughter cattle outcomes should occur to assess the benefit of this preventative measure.
5. Further investigation beyond the scope of this review is warranted to explain why slaughter cattle voyages departing in late autumn and early winter have substantially higher mortality rates than during other months of the year.
6. Further investigation beyond the scope of this review is warranted to explain why voyages departing from Portland having greater odds of heat load compared to voyages departing from Fremantle.
7. Further research should be undertaken into the effectiveness and appropriate employment of heat stress mitigation measures.
8. Hot spots on vessels should be identified and monitored using standardised and well-maintained data loggers to support the management of cattle in these areas.
9. Exporters should implement proactive pad management during voyages. These should include specific contingencies for addressing sloppy pads in hot, humid conditions.
10. The next ASEL review should investigate the adequacy of ASEL bedding requirements for long-haul voyages out of southern Australia.
11. In addition to reporting on abortions and births, daily reports should also require reporting on premature lactation.
12. On board data loggers should be used to improve the monitoring of deck temperatures.
13. The use of and reporting of cattle panting scores should be consistent. A discussion between AAVs, stockpersons, exporters, heat stress technical experts, welfare groups and the department would promote this.

Cold exposure and cold stress

14. Further research should be undertaken to determine appropriate critical temperatures that relate to compromised animal welfare for Australian cattle exported to cold climate destinations.

15. Consideration should be given to timing and method of deck washing to allow time for cattle coats to dry before the vessel encounters cold conditions.
16. Industry should develop guidance for appropriate mitigation measures on board vessels for cattle in cold conditions.
17. Measures to mitigate the risk of cold stress on board vessels should be incorporated into exporters' 'adverse weather contingency plan'.
18. The 'cold climate destination checklist' for cattle should be completed prior to the export of cattle to cold climate destinations.

1 Introduction

The Australian live cattle export trade provides over $800 million in annual export revenue to the Australian economy and supports the livelihood of many people in regional and rural communities (DAWE 2021). Recognising this, the Australian Government is committed to supporting a sustainable livestock export trade whilst maintaining high standards of animal welfare.

The Review of the Regulatory Capability and Culture of the Department of Agriculture and Water Resources in the Regulation of Live Animal Exports (Moss 2018) recognised the importance of the livestock export industry to the Australian economy. However, it also acknowledged the welfare of exported animals is of significant interest to the Australian community.

In April 2020 the *Bos taurus* review was initiated by the department to examine heat and cold stress in *Bos taurus* cattle from southern Australia during long-haul export by sea. The review builds on the 2018 - 19 review of the Australian Standards for the Export of Livestock (ASEL) by sea (ASEL sea review) by the Technical Advisory Committee (TAC), which made recommendations identifying temperature stress as an issue for the welfare of exported cattle (and buffalo) on long-haul voyages (voyages of 10 days or more). The recommendations were informed by Independent Observer (IO) voyage reports, which identified some incidents of temperature stress.

In conducting the *Bos taurus* review, the department has assessed issues relating to heat and cold stress in *Bos taurus* cattle from southern Australia during long-haul export by sea on 214 long-haul voyages over five years from 2016 to 2020. We reviewed scientific literature, industry research, voyage reports (by stockpersons, shipmasters, AAVs and IOs), the ASEL sea review, data from the Bureau of Meteorology, targeted stakeholder feedback and other relevant information.

1.1 Purpose of the review

This review assesses the adequacy of current export arrangements in protecting the welfare of *Bos taurus* cattle from southern Australia, with regards to temperature stress during export by sea and provide evidence-based advice to the department on improvements to animal welfare during sourcing, preparation and export.

Several shipboard issues relating to *Bos taurus* cattle exports were identified by the TAC in the ASEL sea review. The TAC noted that *Bos taurus* cattle sourced from southern Australia are at greater risk of heat stress than *Bos indicus* cattle and that there will be some risk of heat stress (for any livestock) on any voyage that crosses the equator headed for northern hemisphere ports. Recommendations 1, 2 and 3 from the ASEL sea review addressed animal welfare concerns relating to export of *Bos taurus* cattle crossing the equator while Recommendation 27 addressed the need for updating the HSRA model:

- **Recommendation 1** stated that the revised ASEL should prevent *Bos taurus* cattle from an area of Australia south of latitude 26° south (southern ports) being sourced for export on voyages that will cross the equator between 1 May to 31 October (inclusive), unless an agreed livestock HSRA indicates the risk is manageable.

Currently only cattle exported to the Middle East are required to have a HSRA under ASEL 3. Until the HSRA model has been further developed to include all destinations across the equator, the provision should continue to apply to the Middle East. Once industry has updated the existing HSRA model to enable its application to voyages to any destination that requires equatorial crossing (not just the Middle East), ASEL will be revised to meet this recommendation.

- **Recommendation 2** stated that the ASEL prevent pregnant *Bos taurus* cattle from southern ports being sourced for export on voyages that cross the equator from 1 May to 31 October (inclusive).

Prior to implementation it was determined that there was insufficient evidence to implement a complete prohibition, so a requirement was introduced to allow high performing exporters to export pregnant breeder cattle during this period under an approved management plan (ASEL 3, Standard 1.4.3).

- **Recommendation 3** stated that the ASEL prevent *Bos taurus* cattle with a body condition score of 4 or more out of 5, or 5.5 or more out of 6 for dairy cattle, being sourced for export from, or exported through, any area of Australia north of latitude 26° south from 1 October to 31 December (inclusive).

This recommendation was implemented in full (ASEL 3, Standard 1.4.4).

- **Recommendation 27** stated that the ASEL be revised over time to require the application of an agreed HSRA to all livestock voyages that cross the equator, at all times of the year, from all Australian ports.

This recommendation is yet to be implemented pending industry improvement of the existing HSRA to incorporate destinations other than the Middle East.

In addition, animal welfare issues relating to temperature stress have been noted in a number of publicly available IO voyage reports and raised in correspondence from RSPCA Australia to the government.

1.2 Scope of the review

This review considered voyages transporting animals described as *Bos taurus* breeds or cross-bred *Bos taurus* cattle with phenotypical *Bos taurus* characteristics, sourced and exported from southern regions of Australia (ports south of latitude 26° south) from 1 January 2016 to 31 December 2020. Long-haul voyages are those to 'far' markets that take over 10 days. Except for 2 months (November and December 2020), all voyages analysed for this review were governed by standards in ASEL 2.3. ASEL 3, which introduced the term 'far' markets, was introduced on 1 November 2020.

Under ASEL 2.3, day 1 of the voyage referred to the first day at sea after leaving the first port of loading. Whilst ASEL 3 introduced a new definition of voyage length, this did not impact our voyage analysis as all the voyages within the scope of this review were defined as long-haul.

The review covers *Bos taurus* cattle exports from 5 ports of departure, to 4 destination regions, 9 destination countries and 34 destination ports. The ports of departure reviewed are Fremantle, Portland, Geelong, Geraldton, and Port Adelaide. The destination countries reviewed are China, Israel, Jordan, Kuwait, UAE, Oman, Qatar, Pakistan, and the Russian Federation. Japan is excluded as a destination from the review because no consignments were exported from the southern Australian focus ports.

1.3 Consultation

1.3.1 Key stakeholders

Our process identified the key groups for consultation. These stakeholders will be engaged with at varying stages during the review process to ensure all have had an opportunity to provide feedback. Stakeholders include:

- animal welfare organisations
- Australian Maritime Safety Authority
- livestock exporters
- general public
- peak industry and industry-related bodies
- research organisations and academics
- state and territory governments
- veterinarians, including accredited veterinarians.

1.3.2 Targeted consultation

We undertook targeted consultation with a range of stakeholder groups to inform the review, including:

- a round of teleconferences with targeted stakeholder groups to inform the scope of the review and its process. Stakeholder groups included animal welfare groups, industry groups, researchers, AAVs and state and territory representatives.
- a written submission process for targeted stakeholder groups to inform the draft report. We received 7 written submissions during this targeted consultation process.

1.3.3 Independent technical expert group

An independent technical expert group (TEG) was contracted to provide advice and feedback to the department about the content of the review before release of the draft for comment and its finalisation. The panel includes:

- Associate Professor Anne Barnes—Associate Professor in the School of Veterinary Medicine, Murdoch University. An experienced researcher in the livestock export trade particularly heat stress physiology. Other areas of expertise include animal reproduction, thermal and appetite physiology, and animal welfare and behaviour.
- Professor Andrew Fisher—Director, Animal Welfare Science Centre, University of Melbourne. Clinical veterinary experience followed by research programs in livestock health, management and welfare. Formerly head of the CSIRO's livestock welfare research group based in Armidale, NSW.
- Dr Hugh Millar—member of the ASEL committee; former Executive Director Biosecurity Victoria and Chief Veterinary Officer for Victoria. Dr Millar has over 40 years' experience as a

veterinarian and biosecurity professional, in areas including animal and plant health, veterinary public health, animal welfare and biosecurity management in the invasive pests sector.

The TEG provided comments on a preliminary draft of this report. The TEG's comments, and the department's response, can be viewed at Appendix D: Feedback from the technical expert group.

1.4 Australia's live cattle export industry

Australia is one of the largest exporters of live cattle by sea in the world, shipping animals for slaughter and breeding (including dairying) purposes. In 2020, Australia exported 1,082,207 live cattle by sea to 16 destinations on 170 export voyages. Of these 978,000 were classified as feeder and slaughter cattle, valued at over $1.3 billion. The remaining 131,000 head were classified as breeder and dairy cattle valued at $298 million (Comtrade 2021).

In the 5 years to 2019-20, Indonesia and Vietnam were the 2 largest export destinations for live cattle by both value and volume. China ranked 3rd followed by Israel and the Russian Federation (Table 1).

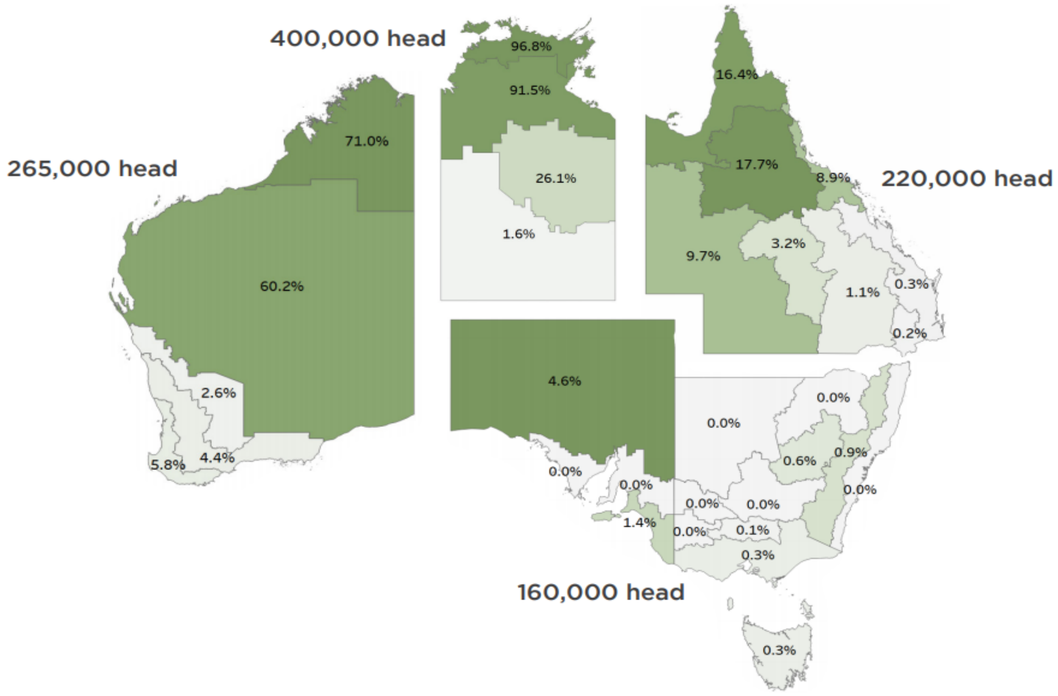
Table 1 Australian live cattle export destinations by value and volume - five years to 2019 to 2020

Destination	Volume (head)	Value ($m)
Indonesia	2,892,329	3,122
Vietnam	1,171,810	1,810
China	609,399	1,202
Israel	315,138	249
Russian Federation	155,522	355
Total	5,775,136	7,502

Source: DAWE (2020)

The majority of live cattle are exported from northern Australia, including from the Northern Territory, Western Australia and Queensland. Figure 1 shows the 'head' number of cattle exported through the adjacent port. For example, 400,000 head of cattle per annum are exported through the Port of Darwin. The percentages indicate the proportion of cattle sold in that region that are sold to live export (Dalgleish, Agar & Herrmann 2018).

Figure 1 Proportion of cattle sourced from different regions (WA, NT, QLD, other) entering the live cattle trade (2018)

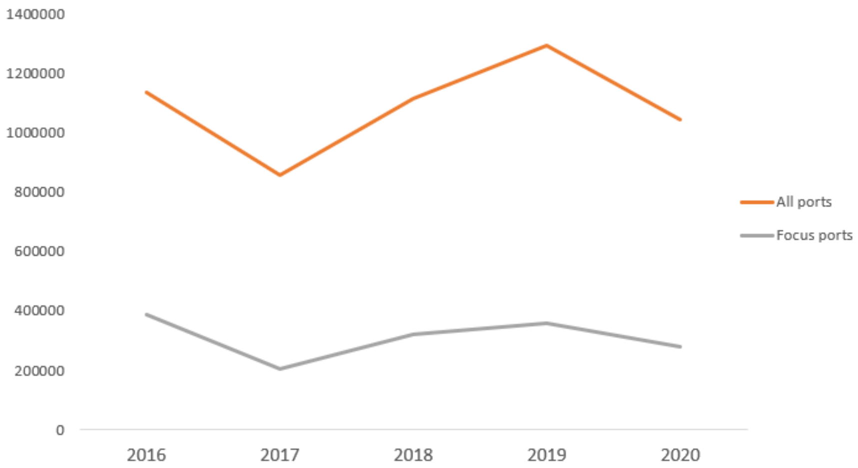


Source: Dalgleish, Agar & Hermann (2018)

In 2020, 72.3% of live cattle exports were on voyages from northern Australia to markets in Southeast Asia, notably Indonesia and Vietnam (DAWE 2020). These markets typically import *Bos indicus* slaughter and feeder cattle. *Bos indicus* breeds are suited to warmer and tropical climates and primarily sourced from Queensland and the Northern Territory. Distance to processing plants and the high cost of processing cattle in Australia's remote north leaves few viable alternatives to live export when marketing cattle from northern Australia (MLA 2020).

Smaller by comparison is Australia's export of *Bos taurus* type cattle which are mostly sourced from southern Australia and exported on long-haul voyages. In 2020, 27% of live cattle exports originated in the review's southern focus ports (Figure 2). *Bos taurus* beef cattle exports are a mix of lightweight feeders, slaughter cattle, and breeding cattle. *Bos taurus* dairy breeds are also exported from Australia, predominantly from southern Australia. These are usually high-value animals exported by both air and sea, depending on the destination. The most common markets include China and Japan.

Figure 2 Cattle exported from all Australian ports vs. southern focus ports, 2016-2020



Source: DAWE (2021b)

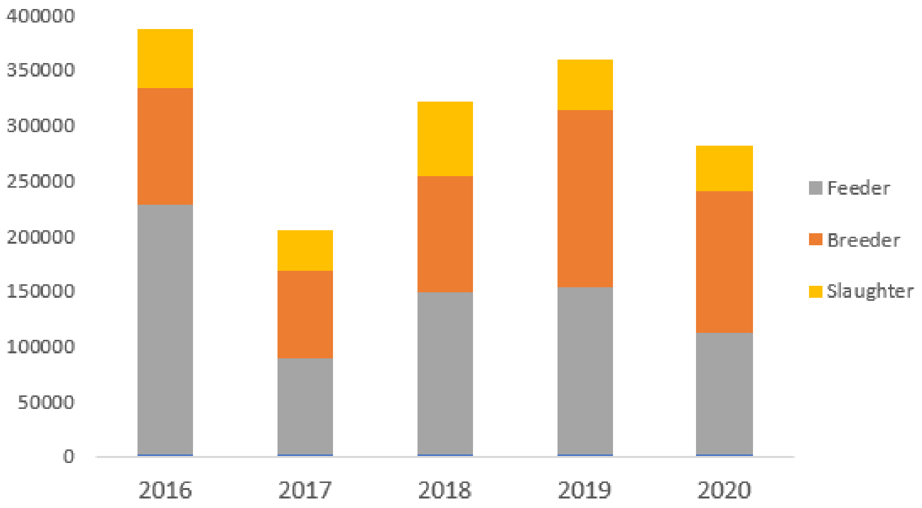
Long-haul voyages from southern focus ports have exported cattle to 9 destinations. China, Israel and the Russian Federation have dominated the long-haul trade, representing 95% of total exports by volume for the 5 years to 2020 (Table 2). Table 2 shows recent destination and volume data (2020) as well as destination and volume data for the 5 year period analysed in this review.

Table 2 Long-haul export destinations from Australian focus ports, 2020 and 2016 to 2020

Destination	2020 Volume (head)	2016-2020 Volume (head)
China	129,637	593,273
Israel	37,475	277,437
Russian Federation	30,973	137,021
Jordan	4,074	19,926
Qatar	2,963	10,156
Pakistan	2,729	6,025
Oman	2,625	5,278
Kuwait	1,179	4,617
United Arab Emirates	560	4,318
Total	212,215	1,058,051

A high proportion of cattle exported from southern focus ports are breeder cattle, including dairy cattle. In 2020, 60% of exports from southern ports were classified as breeders. (Figure 3). By comparison, breeders only make up 14% of all cattle exported from Australia in that year.

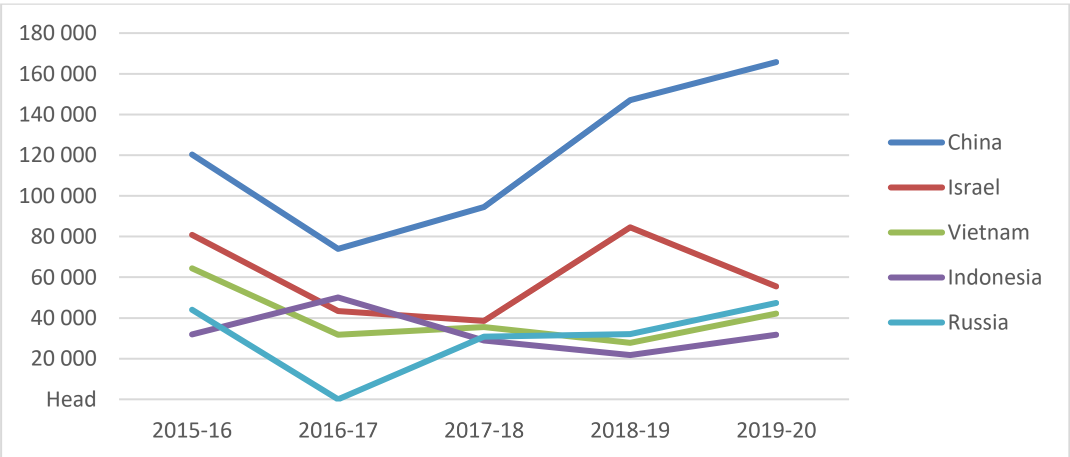
Figure 3 Cattle exported from Australian focus ports according to class, 2016-2020



There are two main reasons why there is a high proportion of breeder cattle exported from southern Australia. Firstly, Victoria is a productive dairy region due to the cool temperate climate being suited to British and European high milk yielding dairy breeds. The temperate, mostly tick-free, climate of southern Australia also allows the production of *Bos taurus* cattle that grow more rapidly, mature earlier and in some opinions, produce superior quality meat compared with *Bos indicus* animals (Moore et al. 2015). The region has fertile soils and moderate to high annual rainfall which supports growing fodder crops on farm, reducing the requirement for purchasing feed.

Secondly, importers seeking quality beef and dairy *Bos taurus* breeding animals will source from southern Australia where supply is greatest. The cost of long-haul transport from southern ports is high, relative to shorter journeys from northern Australia. However, some importers are willing to pay the higher cost as a necessary part of the investment they are making in their herds. China's interest in increasing the genetic profile of its national cattle herd, combined with its growing demand for European-style beef via feeder/slaughter cattle, has seen it continue to grow as a major destination for southern Australian cattle (Figure 4). Supply to other destinations has remained largely unchanged over the past 5 years.

Figure 4 Export destinations for live cattle



1.5 *Bos taurus* and *Bos indicus* cattle types

Bos taurus typically refers to British and European breeds of domestic cattle, and in Australia they are most often raised in southern regions. *Bos taurus* cattle are used for beef or milk production and breeds include Angus, Charolais, Hereford, Holstein-Friesian, Jersey, Limousin, Shorthorn and Simmental breeds. *Bos taurus* are most commonly exported on long-haul voyages for feeder, slaughter or breeder purposes (Sartori et al. 2010).

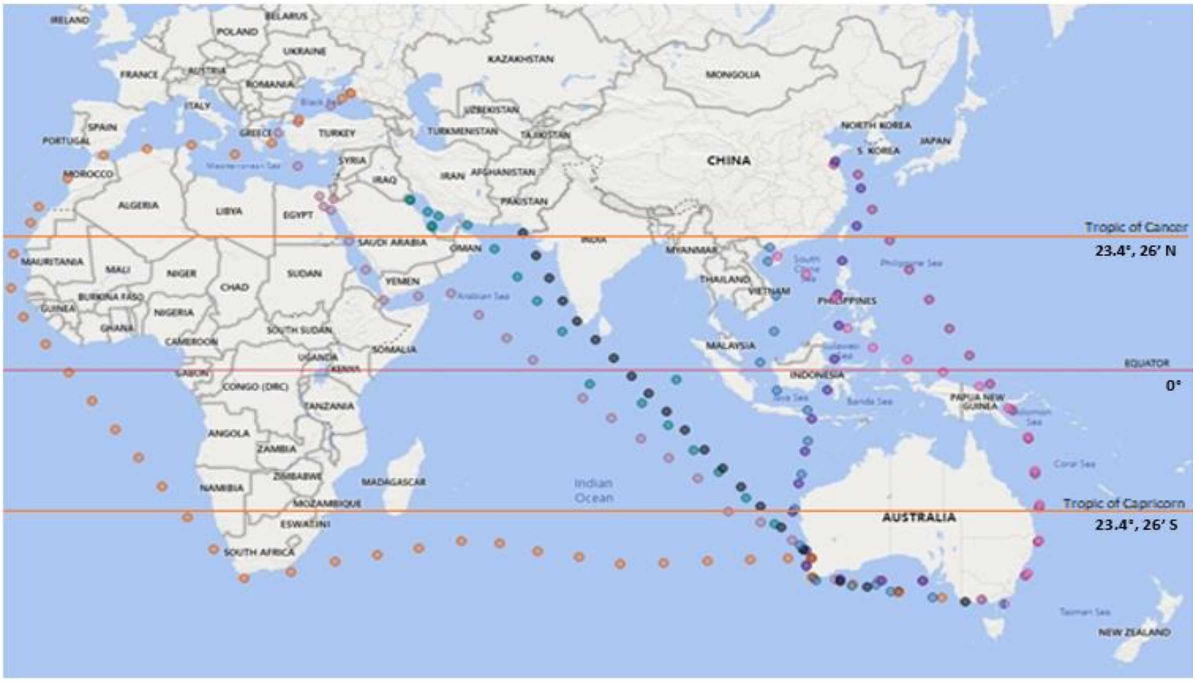
Bos indicus refers to hot or sub-tropical tolerant cattle, which originate in the Indian subcontinent. *Bos indicus* cattle are well suited to northern Australian climatic conditions due to their increased tolerance for heat. This is attributed to thinner hair coats, generally leaner body condition scores and more skin surface area for evaporative heat loss. *Bos indicus* cattle exported from Australia are largely composed of Brahman, Brahman crosses and composite breeds. *Bos indicus* breeds and their crosses are exported to markets in Southeast Asia as beef feeder or slaughter cattle (Sartori et al. 2010).

2 Overview of voyages

From 1 January 2016 until 31 December 2020 there were 214 long-haul voyages, consisting of 245 consignments carrying 1,019,563 *Bos taurus* cattle from southern ports of Australia.

Five ports of departure, 4 destination regions, 9 destination countries and 34 destination ports were identified. Focus ports of departure were Fremantle, Portland, Geelong, Geraldton, and Port Adelaide, with destination countries being China, Israel, Jordan, Kuwait, UAE, Oman, Qatar, Pakistan, and the Russian Federation. Typical voyage routes are outlined in Map 1.

Map 1 Typical voyage routes from southern Australian ports to destination countries



Destination countries were grouped by region to reflect similar voyage routes and environmental conditions likely to be experienced by cattle during voyages by sea (Table 3). As Pakistan-bound export vessels take a similar voyage route as those to Persian Gulf countries, Pakistan has been included in this region. One voyage in 2016 exported animals to both Israel and the Russian Federation and has been included in the Russian region due to the voyage length and route.

Table 3 Destination regions, countries and ports

Region	Country	Port
China	China	Beihai, Caofeidian, Dafeng, Dalian, Dongying, Fuzhou, Huanghua, Jingtang, Lianyungang, Macun Port, Ningbo, Qingdao, Qinhuangdao, Qinzhou, Rizhao, Shidao, Tangshan, Tianjin, Weifang, Xiamen, Yantai
Red Sea	Israel, Jordan	Ashdod, Eilat, Haifa, Aqaba
Persian Gulf	Kuwait, Oman, Pakistan, Qatar, UAE	Kuwait, Shuwaikh, Muscat, Sohar, Sultan Qaboos, Karachi, Doha, Jebel Ali
Russian Federation	Russian Federation	Novorossiysk

From 2016 to 2020, 31 vessels were used to export *Bos taurus* cattle from southern Australian ports to the specified regions. Frequency of use was variable, with one vessel undertaking just one voyage whilst another vessel undertook 20 voyages. On average, each vessel sailed 7 times.

2.1 Overview by class of cattle

Live export cattle are categorised according to end use. Feeder cattle are generally lighter as they will be fattened in the importing country prior to slaughter. In comparison, slaughter cattle are generally heavier with higher body condition scores, as they are slaughtered a short period after arrival at destination country. Breeder cattle include cows, heifers and bulls intended to be used for breeding. Voyage data indicates the average weights for breeder and slaughter cattle are around 300kg and 550kg respectively. While exact figures are not available it is estimated that over 80% of breeder exports are dairy breeders.

Feeder and slaughter cattle are exported under the same ASEL conditions. There are additional conditions and pregnancy testing requirements for pregnant cattle outlined in Appendix A.

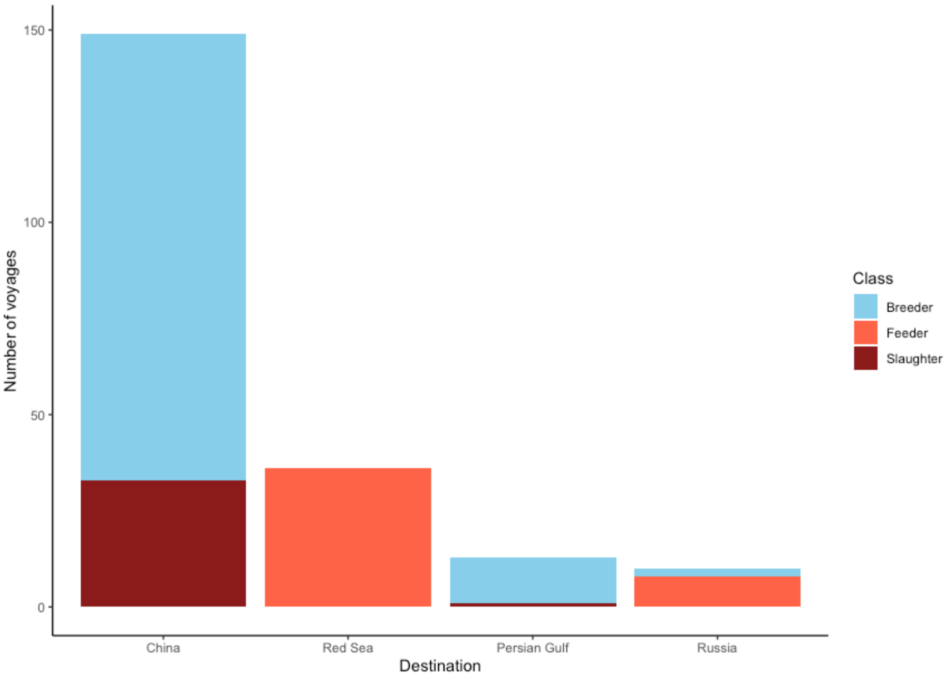
The majority of voyages (60.7%) during the scope period of this review carried breeder class cattle, with fewer voyages carrying feeder (20.1%) and slaughter (15.9%) classes (Table 4). Seven voyages carried more than one class of cattle.

Table 4 Review voyages by cattle class

Cattle class	Count of class	Percentage
Breeder	130	60.7%
Feeder	43	20.1%
Slaughter	34	15.9%
Combined feeder and slaughter	5	2.3%
Combined feeder and breeder	2	0.9%
Total	214	100%

Each destination tends consistently to import the same classes of cattle (Figure 10). China has imported *Bos taurus* breeder cattle since 2001. Within the review period, an average of 23 breeder voyages to China occurred yearly. The export of slaughter cattle to China by sea is relatively new. It started in 2017 with 4 voyages of slaughter cattle. This increased to 12 slaughter voyages in 2018. Within the review period, all voyages of *Bos taurus* cattle to the Red Sea region carried feeder cattle, with 5 voyages carrying both feeder and slaughter cattle and 1 voyage carrying both feeder and breeder cattle. Exports to the Russian Federation are typically feeder cattle. All shipments to Persian Gulf countries, with one exception, carried breeder cattle (Figure 5).

Figure 5 Overview of cattle class by destination



2.2 Overview by northern hemisphere season (northern hemisphere summer and northern hemisphere winter)

Of the 214 voyages, 123 (57.5%) of voyages departed Australia in spring and summer from warmer conditions in Australia to northern hemisphere winter (NHW) (November to April inclusive). Exports to the Persian Gulf region and to the Russian Federation, only occurred during this period. The remainder of voyages (42.3%) departed Australia in colder conditions and travelled to the northern hemisphere summer (NHS) (May to October inclusive).

2.3 Overview by destination region

The average voyage duration for all regions was 21 days. Voyages to China were typically the shortest (average 18 days), with Red Sea and Persian Gulf voyages only slightly longer in duration (23 and 24 days respectively). Voyages to the Russian Federation, whether via the Suez Canal or around southern Africa, were significantly longer in duration (average 38 days, longest 44 days).

Table 5 Number of voyages, cattle exported, voyage duration and mortality rates by region for the period 1 January 2016 to 31 December 2020

Factor	China	Red Sea	Persian Gulf	Russian Federation	Total
Voyages	149	41	13	11	214
Cattle exported	594,087	270,816	29,074	143,093	1,019,563
Average loaded	3,987	6,605	2,236	13,008	4,764
Average duration (days)	18	23	24	38	21
Average mortality rate	0.20%	0.20%	0.18%	0.28%	0.20%

The smallest voyage in the period consisted of 230 head of cattle to the Persian Gulf. The largest voyage carried 17,507 cattle to the Russian Federation. Exports to China accounted for 69.6% of voyages and 58.3% of total head loaded. Voyages to China averaged 3,987 head compared to an average of 4,764 head for all voyages. Exports to the Red Sea region accounted for 19.2% of voyages and 26.6% of total head exported, averaging 6,605 head per voyage. The Persian Gulf region and the Russian Federation imported *Bos taurus* animals the least often, accounting for 2.9% and 14% of exported cattle, and were 6% and 5.1% of total voyages, respectively.

Table 6 Number of voyages, cattle exported, voyage duration and mortality rates for China by year for the period 1 January 2016 to 31 December 2020

Factor	2016	2017	2018	2019	2020	Total
No. of voyages	25	19	36	38	31	149
Cattle exported	92,629	75,487	130,221	162,753	132,997	594,087
Average duration (days)	19	19	19	18	18	18
Average mortality rate	0.15%	0.12%	0.31%	0.18%	0.18%	0.20%
Mortality rate range	0 to 0.64%	0.03 to 0.33%	0 to 1.51%	0 to 1.36%	0.05 to 0.67%	0 to 1.51%
Voyages with no reportable mortalities	3	0	1	3	0	7

In 2016 to 2017, the number of *Bos taurus* cattle exported to China decreased due to short supply and high price of cattle. Trade volumes almost doubled in 2018 due to strong market demand for the recently established slaughter trade. The volume of cattle exported continued to increase in 2019 but reduced in 2020 due to the impact of COVID-19.

Table 7 Number of voyages, cattle exported, voyage duration and mortality rates for the Red Sea by year for the period 1 January 2016 to 31 December 2020

Factor	2016	2017	2018	2019	2020	Total
No. of voyages	6	6	11	11	7	41
Cattle exported	51,200	28,902	60,803	72,788	39,616	253,309
Average duration (days)	24	21	23	22	21	22
Average mortality rate	0.38%	0.13%	0.14%	0.22%	0.17%	0.20%
Mortality rate range	0.16 to 0.66%	0 to 0.3%	0.03 to 0.34%	0.03 to 0.8%	0.02 to 0.38%	0 to 0.8%
Voyages with no mortalities	0	1	0	0	0	1

Export trends to the Red Sea region were similar to China. The number of *Bos taurus* cattle exported decreased significantly from 2016 to 2017 due to supply and price. In 2018, the volume of cattle exported doubled as supply eased and demand increased. In 2020, volumes exported to the region almost halved due to COVID-19 affecting trade.

Table 8 Number of voyages, cattle exported, voyage duration and mortality rates for the Persian Gulf by year for the period 1 January 2016 to 31 December 2020

Factor	2016	2017	2018	2019	2020	Total
No. of voyages	4	3	1	3	2	13
Cattle exported	5,719	6,672	1,397	9,353	5,933	29,074
Average duration (days)	24	24	25	23	26	24
Average mortality rate	0.13%	0.30%	0.14%	0.13%	0.15%	0.18%
Mortality rate range	0 to 0.33%	0.12 to 0.46%	0	0.09 to 0.21%	0.1 to 0.2%	0 to 0.46%
Voyages with no mortalities	1	0	0	0	0	1

In 2016 to 2020, exports to the Persian Gulf region sourced from southern Australia only occurred during the NHW. Exports to the Persian Gulf region increased from 2016 to 2017. In 2018, they significantly decreased to less than a third of the previous year. Exports peaked in 2019 but significantly declined in 2020 due to COVID-19.

Table 9 Number of voyages, cattle exported, voyage duration and mortality rates for the Russian Federation by year for the period 1 January 2016 to 31 December 2020

Factor	2016	2017	2018	2019	2020	Total
No. of voyages	2	0	3	4	2	11
Cattle exported	34,319	0	40,962	36,839	30,973	143,093
Average duration (days)	36	0	34	42	38	38
Average mortality rate	0.43%	0	0.27%	0.16%	0.38%	0.28%
Mortality rate range	0.41 to 0.44%	0	0.17 to 0.44%	0.08 to 0.22%	0.34 to 0.41%	0.08 to 0.44%
Voyages with no mortalities	0	0	0	0	0	0

Despite no exports of *Bos taurus* cattle to the Russian Federation in 2017, exported cattle numbers increased from 2016 to 2018 then declined steadily in 2019 and 2020 with exports only occurring from November to May.

3 Science of heat stress

3.1 Physiology of heat stress

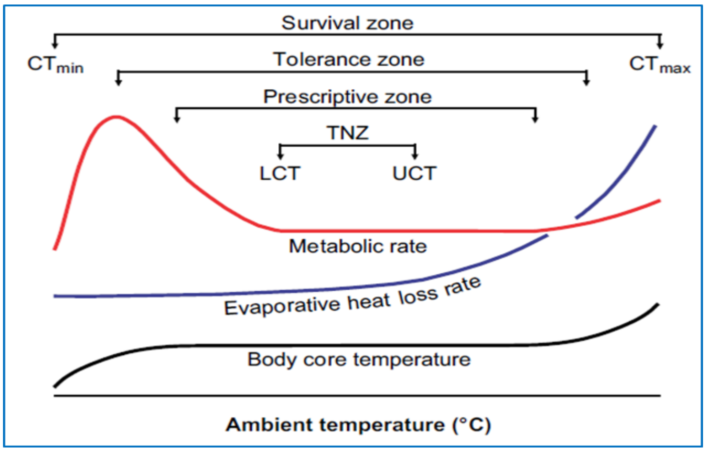
High thermal heat load occurs when animals are subject to hot environmental conditions, especially when accompanied by high humidity, and cannot remove heat generated by metabolic processes in the body (Collins, Hampton & Barnes 2018). A possible outcome of excess heat load is heat stress, for which various definitions are available in scientific papers. According to De Rensis et al. (2015) heat stress occurs when an animal's normal biological responses to hot conditions can no longer maintain body temperature at its resting level. The Meat and Livestock Australia Veterinary Handbook describes heat stress as a state where animals are responding to excessive heat load (Jubb & Perkins 2019). A definition is also provided by Barnes et al. (2004):

> Heat stress is a term used to denote a state where an animal is responding to adverse hot conditions. Under such conditions an animal can respond to the heat by making physiological changes and adjustments within the body, so that it can survive in that environment. These changes will act to keep critical systems and mechanisms within the body functioning. However, if the heat load experienced by the animal becomes excessive, the critical functions may no longer be maintained, and clinical disease, collapse and even death can result. Such a situation may be described as severe or clinical heat stress.

An animal's behavioural and physiological response to high heat load seeks both to increase heat loss and decrease heat gain. The type and magnitude of the physiological and behavioural adjustments influence how well the animal is able to respond to hot conditions.

There is a relationship between the ambient temperature and core body temperature, evaporative heat loss rate, and metabolic rate of mammals as noted in Figure 6 (HSRA Technical Reference Panel 2019). The authors identified four zones of ambient temperature, with the narrowest being the thermoneutral zone (TNZ). Wider than this is the prescriptive zone, in which mammals are fully functional and can maintain their core temperature but as the temperature increases, evaporative water loss must increase to reduce thermal heat load. In the zones outside the prescriptive zone, body temperature is no longer maintained with escalating hypothermia and hyperthermia.

Figure 6 Relationship between ambient temperature and body core temperature, evaporative heat loss rate and metabolic rate of mammals



Source: Adapted from Figure 5 Mitchell et al. (2018) and cited in the HSRA Technical Reference Panel (2019)

Sparke et al. (2001) describe four means for animals to lose heat including radiation, conduction, convection and evaporation. When environmental temperatures increase toward animal skin temperatures, evaporation becomes the only route for heat loss.

The initial physiological responses in cattle to heat load aim to increase heat loss. These include redirecting blood to the periphery, vasodilation of skin blood vessels and vasoconstriction of vessels supplying internal organs. Evaporation occurs from the skin most effectively as sweat (Sparke et al. 2001). If the loss of heat from the skin is not sufficient to maintain a stable core temperature, additional heat can be lost from the respiratory membranes as the animal pants. The temperature at which panting is initiated to supplement the other heat loss mechanisms will depend on several factors, such as humidity or ventilation, and the effectiveness of initial physiological responses (Barnes et al. 2004). Panting is of particular importance when the humidity increases along with temperature because the effectiveness of evaporative heat loss from the skin is reduced. When the temperature of inspired air rises to near body temperature, heat loss from panting also becomes limited (Sparke et al. 2001). Prior acclimatisation to heat will also affect how well the animal is able to use means other than panting to maintain normothermia.

In response to increased heat load, cattle will also seek to reduce heat production. Cattle voluntarily decrease feed intake in response to hot conditions. This may be by as much as 25% if fed high energy grain diets (Sparke et al. 2001), although some research suggests this reduction may be up to 100% in extreme heat (Barnes et al. 2004). A decline in dry matter intake (DMI) has been reported to commence when ambient temperature reaches approximately 25°C to 27°C. However, this threshold is also influenced by diet type and composition (Lees et al. 2019).

Bos indicus cattle are known to be more heat tolerant than *Bos taurus* cattle. Heat tolerance varies between different genotypes of the same species of Bovidae (section 3.4.1).

Behavioural and physiological changes associated with heat stress in cattle vary according to the severity of the heat stress (Table 10).

Table 10 Behavioural and physiological responses to heat stress in cattle

Mild to moderate heat stress	Severe heat stress
Agitation/distress	Frothy discharge from mouth or nose (pulmonary oedema)
Depression	Ataxia
Tendency to seek shade	Refusal to move
Refusal to lie down or lying in any wet areas	Collapse
Crowding around water troughs	Convulsions
Increased water intake	Coma
Reduced feed intake	Death
Increased respiratory rate	
Open mouth panting	
Increased heat rate	
Elevated rectal temperature	
Excessive salivation	

Source: Jubb & Perkins (2019); Parkinson et al. (2019)

The department notes that there are differing views on what constitutes whether an animal is 'heat stressed'. Despite much scientific research over many years on the subject of heat stress in livestock, there is yet to be any scientific consensus that clearly identifies the point when an animal changes from responding to increased heat (being heat affected) to being 'heat stressed'. Heat stress at the extremes appears to be clearly identified, however, the transition point and the impact of duration remain undefined.

In the recently completed Animal Welfare Indicators Pilot for the Livestock Export Industry Supply Chain (Collins et al. 2021), industry proposed a range of indicators to assess the ability of livestock to cope with periods of heat and humidity and to better understand the welfare impact of heat. Indicators included panting scores, feeding behaviour score, posture, resting, drinking and ruminating. This pilot proposed twice daily recording of panting scores and other measures during voyages, as this would improve the 'understanding of the welfare impacts of thermal loading in a live export context, as well as the degree and duration of heat that types of livestock can cope with and respond to'.

3.2 Assessing heat load

3.2.1 Measuring heat load in the environment

Thermal load can be measured through WBT, temperature humidity index, heat load index, and equivalent temperature index. As noted by Collins, Hampton, Barnes (2018), numerous studies have used WBT as the measurement to assess heat load in live animal exports as WBT incorporates both air temperature and humidity. This is relevant because an animal's ability to dissipate heat via evaporative means is highly dependent on the level of moisture in the air.

The Temperature Humidity Index (THI) has been widely used to assess heat load in animals (Beatty 2005). According to Collins, Hampton & Barnes (2018) the THI is a calculated index which weights dry bulb and wet bulb temperatures for comparison with animal performance. Its effectiveness in the live export setting is questioned, however, because it does not include important climatic variables, such as airflow and solar load, or animal factors (Gaughan et al.

2008). The THI is not currently used by industry or the department in assessing the risk of heat stress during live export.

The Heat Load Index (HLI) was developed for use by the feedlot industry to assess thermal stress (Gaughan et al. 2008). The base HLI defines a threshold for a reference animal – a black Angus steer, 100 days on feed, Body Condition Score (BCS) 4+ and no access to shade. The HLI threshold for the reference animal is adjusted up (more heat tolerant) or down (less heat tolerant) for variables such as breed, physiological state, type of feed and temperature of drinking water. It is not currently used to assess heat on live export vessels but provides a simple means to compare heat tolerance.

The Australian feedlot industry uses a web-based service providing weather and heat load forecasts to feedlot operators, called The Cattle Heat Load Toolbox. The model integrates weather station data to predict the Accumulated Heat Load Units (AHLU). The AHLU give an indication of the amount of heat that is accumulated by an animal when it is exposed to hot environmental conditions. AHLU incorporate factors such as intensity and duration of heat, the opportunity to dissipate heat, animal factors and mitigation measures (Burchill et al. 2021). This model is not currently used to assess heat load on live export vessels.

The Equivalent Temperature Index (ETI) is a mathematically derived, environmental measure of heat load. It is referenced in the MLA Veterinary Handbook (Jubb & Perkins 2019) and described in an industry publication on ventilation in export vessels (MAMIC 2001). ETI incorporates dry bulb temperature (DBT), relative humidity and wind speed. The ETI is highly correlated with WBT, whereas the THI may be considered as closer to an arithmetic average of DBT and WBT. While ETI is a potentially useful measure of heat stress, the relative complexity of the index against the simple measurement of WBT alone, and the close agreement between ETI and WBT for the regions of interest during export voyages, mean that WBT alone is preferred as a single, practical measure of heat stress potential on board export vessels (MAMIC 2001).

3.2.2 Duration of increased heat load

Duration is important in defining heat stress but is currently not well defined. Heat stress can result from short periods of extreme heat or extended periods of hot conditions (Collins, Hampton & Barnes 2018) Diurnal and day-to-day variation in deck WBT means that periods of heat stress might be interspersed by respite periods, such as overnight, during which an animal’s physiology can recover. The welfare impacts for cattle experiencing periods of increased WBT are likely to be more severe if there is no respite. However Collins, Hampton & Barnes (2018) and the HSRA Technical Reference Panel (2019) noted that no studies have been conducted on the necessary duration of respite periods needed to protect livestock from heat stress.

The department was unable to assess the effect of duration of increased heat load in this review because daily voyage reports only require a single daily temperature measure. The full range of temperatures experienced in any 24 hours is not available for analysis. It is possible that cattle experienced periods of respite from hot conditions between daily temperature measurements.

3.2.3 Measuring increased heat load in animals

The assessment of increased heat load is best determined from the effects of heat on the animal’s behavioural and physiological responses. An obvious method is the measure of core body temperature, but this is impractical for shipped animals. Panting score is a frequently used practical measure, although panting is both a response to increased thermal exposure and an indication that the animal continues to require heat loss to maintain homeostasis (HSRA Technical Reference Panel 2019).

With increasing heat load, Jubb & Perkins (2019) explain that cattle will sweat, drink more water and increase their respiratory rate. On board export vessels, animals may move towards ventilation fans and away from ship structures that radiate heat near pen areas. Feed intake and rumination is often decreased which may assist in lower metabolic heat output. These physiological and behavioural signs can be useful in assessing livestock response to heat.

Panting scores are a non-invasive, non-intrusive visual tool that may be used in conjunction with respiratory rate and effort as an index of heat stress (HSRA Technical Reference Panel 2019). Gaughan et al. (2008) outlined a panting score table for cattle. A slightly modified version is provided in the MLA veterinary handbook and was recommended for continued use by the TAC (Table 11). According to the MLA Veterinary Handbook (Jubb & Perkins 2019) in assessing cattle, if more than 10% of animals have a panting score of 3.5 or higher, then there is a potential for serious losses if steps are not taken quickly to allow animals to dissipate heat'.

Table 11 Panting score used in the assessment of heat stress in cattle

Breathing pattern	Panting Score	Respiratory Rate (breaths per minute)
Normal – no panting, difficult to see chest movement.	0	<40
Slight panting, mouth closed, no drool or foam. Easy to see chest movement.	1	40–70
Fast panting, drool or foam present. No open mouth panting.	2	70–120
As for 2, but occasional open mouth panting. Tongue not protruding.	2.5	70–120
Open mouth + some drooling. Neck extended and head usually up.	3	120–160
As for 3 but with tongue out slightly and occasionally fully extended for short periods. Excessive drooling.	3.5	120–160
Open mouth with tongue fully extended for prolonged periods + excessive drooling. Neck extended and head up.	4	>160
As for 4 but head held down. Cattle "breathe" from the flank. Drooling may cease.	4.5	Variable – RR may decrease

Source: MLA Veterinary Handbook (Jubb & Perkins 2019) adapted from Gaughan et al. (2008)

3.3 Managing increased heat load

3.3.1 Stocking density and pen space allocation

Stocking density considerations relevant to Australian livestock exports were discussed extensively by the TAC in section 3 of the 2018 ASEL sea review:

> It is universally accepted that the amount of space provided to animals during periods of confinement is critically important for their health and welfare. Stocking density governs important elements of body posture and behaviour, including social interaction. It also affects access to fodder and water, influences

> susceptibility to disease and has a strong influence on heat load experienced by confined animals. (ASEL Review Technical Advisory Committee 2018)

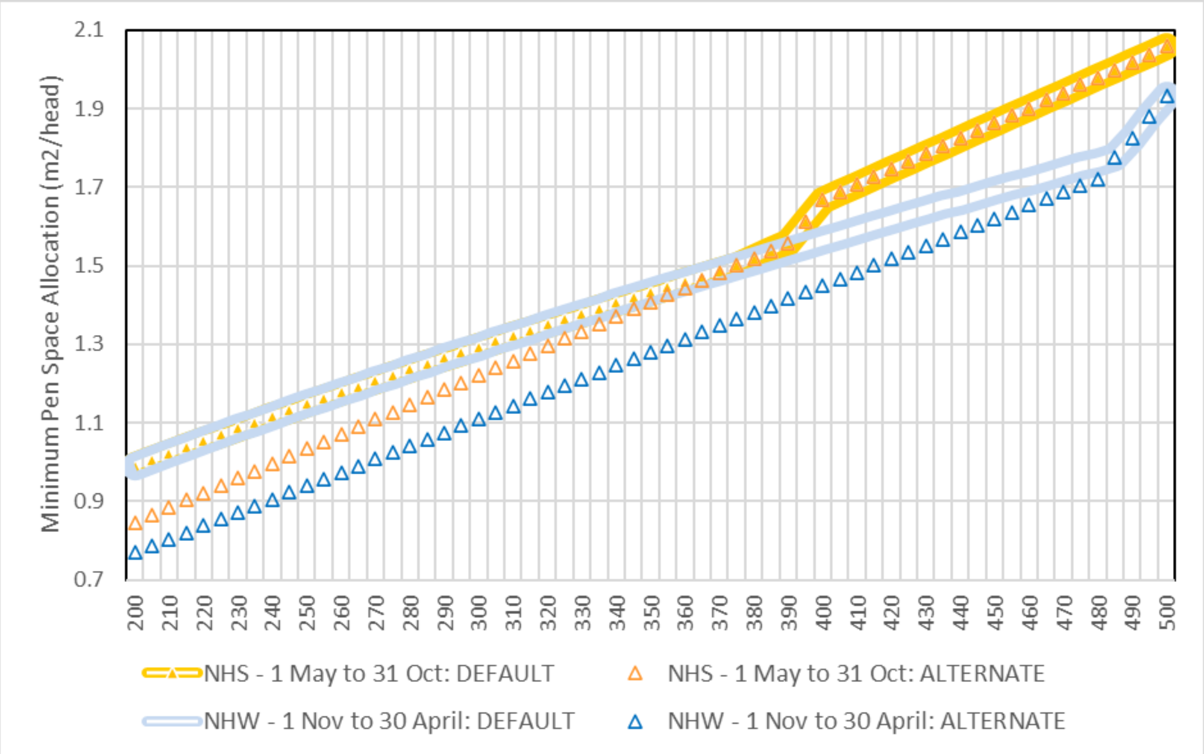
Allometry is the study of the relationship between body size to animal shape and behaviour. The TAC recommended that allometric principles were incorporated into ASEL 3 for calculating pen space allocations, with the proviso that no animal will receive less space than under ASEL 2.3.

For cattle, the TAC determined that animal welfare outcomes on most export voyages could be improved if animals are provided with more space. The TAC recommended that the default pen space allocation for cattle voyages be based on a “k” value of 0.030.

Other considerations also impacting pen space allocations for cattle exported from Australia include latitudes of departure and discharge ports, the time of year, pregnancy status, breed, horn length, weight thresholds and exporter performance. These are managed by the provision of date and destination-specific space allocation tables and the requirement for specific management plans for heavy (over 500kg), pregnant and horned cattle.

For pen space allocation purposes, Australian departure ports are divided up into ports north of the latitude 26 deg South (northern ports) and those south of latitude 26 deg South (southern ports). Figure 7 shows the relationships between the pen space allocations for voyages that depart southern Australian ports during NHS and those that depart during the NHW.

Figure 7 ASEL 3 pen space allocations for voyages departing from south of latitude 26 deg south - northern hemisphere summer vs northern hemisphere winter with alternative pen space options included



Alternative pen space allowances are available to exporters who meet the criteria set out in department’s Alternative Minimum Pen Space Allocation Policy. For cattle sailing from 26°

south, the alternative pen space allowance tables under ASEL 3 have been sourced, unchanged from ASEL2.3. This means:

- During the NHS, the **alternative** pen space allowances for cattle under ASEL 3 are the same as the **standard** pen space allowances for cattle during the NHS under ASEL 2.3
- During the NHW the **alternative** pen space allowances for cattle under ASEL 3 are the same as the **standard** pen space allowances for cattle during the NHW under ASEL 2.3.

For exports departing in the NHS, the default and alternative pen space allowances are the same for cattle over 370kg. For exports departing in the NHW, the default and alternative pen space allowances are the same for cattle over 485kg. This is a result of the minimum pen space allowances under ASEL 2.3 for heavier cattle being greater than the pen space allowance calculated using the allometric formula with a constant of k=0.030. The department applies the principle of using whichever pen space allowance that gives the most room for the individual animal.

Default and seasonal space allowances also make some provision for a normal range of climatic conditions, but not for exposure to periods of high heat and humidity. Efforts to manage this welfare risk factor have been made through the application of a HSRA model. MLA developed a proprietary HSRA model called 'HotStuff' which manipulates stocking densities depending on a variety of inputs. It relies on climatology from the specific export routes and destinations. The most recent version in use, 'HotStuff' Version 4 released in 2012, has been applied to sheep and cattle exports to the Middle East. 'HotStuff' Version 4 does not include climatology for non-Middle East countries so is not applicable to many of the destinations considered in this draft report. The TAC recommended 'HotStuff' be upgraded to cover all destinations for Australian livestock exported by sea. The recommendation was accepted by the Australian Government, however, at the time of writing an updated version of 'HotStuff' has not been released.

Impacts of stocking density on heat stress

There are direct and indirect impacts of stocking density on heat stress. The more cattle that are in a pen or on the deck of a ship:

- the more metabolic heat is produced per cubic metre of pen/deck space which drives up the wet bulb temperature of the immediate environment – called 'wet bulb rise'
- the more the bodies of the cattle physically obstruct the flow of air through the pen, reducing the removal of metabolic heat and humidity generated from respiration and the pad
- the more urine and faeces per square metre is added to the pad leading to higher humidity and associated WBTs
- the less space there is for cattle to adopt an optimum posture for heat loss, typically standing and physically separated from animals around them
- the more difficulty cattle may have freely accessing water when required.

3.3.2 Mitigation measures

Voyage reports frequently acknowledged crew proactively and reactively used a variety of mitigation measures for hot conditions, to improve livestock welfare. These measures included washing decks, wetting cattle, alternating vessel path, deploying fans, opening hatches on decks, rearranging/moving animals, minimising unnecessary handling and altering the provision and type of fodder. Industry publications including the MLA Veterinary Handbook (Jubb & Perkins 2019) and the LiveCorp Shipboard Stockies Guide (LiveCorp 2020) detail mitigation measures to assist livestock in hot conditions.

Lees et al. (2019) state 'the provision of alleviation strategies is paramount in supporting animals to achieve comfort'. They note that environmental modification to mitigate heat load has traditionally focused on reducing solar radiation by using shade structures and increasing air movement around livestock. The department understands that while shade provision to reduce solar radiation may be an important strategy in the feedlot industry, it is of less relevance in the live export setting where cattle are housed on decks, and is therefore not discussed further in this review.

Mitigation measures employed during a voyage can be grouped into the following categories:

- modification of the environment surrounding livestock (changing stocking densities, provision of air movement, wetting cattle and pad management)
- nutritional management
- reducing other stressors.

Risk management measures were occasionally noted to begin at loading with the placement of higher risk cattle in the best ventilated pens. Adjustments to stocking densities were frequently reported where cattle were rearranged or moved in response to hot conditions or 'hotspots', such as proximity of the vessel's engine. For example, '[The crew] reduced density in pens by spreading animals between pens and opening gates between pens to create more space' and 'crew moved animals from closed decks to open decks where possible.' On occasion, movement of animals was noted prior to expected hot conditions, presumably to minimise handling during peak heat load. These measures aimed to reduce stocking densities and therefore reduce the impact of metabolic heat production.

Voyage reports noted that crew often deployed fans to increase air movement during hot conditions. An independent observer noted 'there was a specific equatorial plan for high temperature periods involving zig-zagging the vessel to increase air flow through the decks, the installation of fans for some pens and a program of washing down cattle decks and pens.' One AAV reported 'extra fans were placed in 'hotspots' and in front of higher risk animals … after recognising some areas as being hotter than others.' The LiveCorp Shipboard Stockies Guide (LiveCorp. 2020) suggests ensuring ventilation systems are functioning to full capacity and identifying ventilation dead-spots such as bulkheads, as strategies for heat mitigation.

Wetting cattle during a voyage was occasionally noted in voyage reports. Wetting enhances the impact of air movement in cooling animals, with the benefit coming from the evaporation of water from the skin surface (Brown-Brandl & Tami 2018). This paper states that to maximise heat loss when wetting cattle, the hair coat of the animal must be saturated to the skin surface and then allowed to dry completely. Misting tends to set on the top of the hair coat and does not have the same effect as saturation. Voyage reports did not contain detail on whether this degree of wetting was achieved or its efficacy as a mitigation measure. A study by Gaughan et al. (2008) investigated the effectiveness of water application and air movement as a heat mitigation tool for cattle. It concluded that actively cooling cattle *after* maximum ambient temperature occurred was more effective than cooling when ambient temperatures peaked. Combined wetting and ventilation as key management strategies were confirmed in this study.

Deck washing is a routine husbandry practice during long-haul voyages to manage the pad. It is employed as a mitigation strategy as a wet pad can contribute to lameness problems and also be a source of heat and humidity. During warm, humid conditions, cattle drink more and urinate more which means pads may become wet and sloppy with limited ability to dry. Deck washing removes the pad and may have an added benefit of directly cooling deck infrastructures, depending on the extent that water temperature is below deck temperatures (MAMIC 2001). An early submission to the *Bos taurus* review stated that strategic cleaning of pens reduces the amount of wet manure and can lower relative humidity within the pen microclimate.

The frequency of deck washing varied from every second day to a couple of times during a voyage. Washes were commonly employed as the vessel neared the equatorial region. The effectiveness of washing decks as a mitigation strategy during hot conditions was occasionally reported. One voyage report stated 'all pads remained firm until the equator, where increased humidity caused the pens to become clay or mud-like, to sloppy. Three day wash cycles, for most of the voyage, ensured the health and welfare of the animals.'

Control over both the provision of water and feed are potentially important in managing heat stress risk. One early submission to the *Bos taurus* review claimed cattle can drink up to 20% of their body weight as water a day when hot, stressing the need for *ad libitum* water during voyages. Voyage reports have noted crew regularly assessing the number and placement of water troughs during hot periods. Savage et al. (2008) stated that offering chilled water to animals may be a useful method to decrease body temperature during times of high heat load but noted that cattle will drink greater volumes of warm water. The department would welcome feedback on the efficacy and practicality of chilled water as a heat mitigation measure on board live export vessels.

Altering the energy content of feed and the timing of feeding has been shown to influence body temperature and heat tolerance (Mader et al. 2015; Barnes et al. 2008). Cattle are known to reduce feed intake during hot conditions, which reduces the heat of metabolic digestion (Sparke et al. 2001). One voyage report stated a temporary feed reduction was used effectively to manage heat load in equatorial zones. Reducing the energy content of feed, usually by increasing the roughage component, was commonly noted. Lees et al. (2019) discuss dietary management strategies for cattle during hot conditions, particularly in the feedlot and dairy industries. Strategies include use of feed additives such as betaine, probiotic yeast supplements and antioxidants, as well as managing the proportion of roughage in the diet and altering feeding time to reduce metabolic heat loads during the hottest hours of the day. Lees et al. (2019) state there is considerable variability in the success of these techniques during heat load and that further studies are required to ensure the appropriateness of nutritional supplements as a heat load mitigation tool.

The use of electrolytes was noted on a couple of voyages. Electrolytes are generally found in water and feed in sufficient quantities to meet physiological needs. Studies by Barnes et al. (2004) and Barnes et al. (2008), showed that the use of electrolytes resulted in a moderate, short-term increase in water and feed intake in some classes of animals. However, results have been difficult to replicate with other studies indicating there is little benefit above offering palatable water (Beatty 2005). Further, a study by Banney et al. (2009) indicated that the use of electrolytes may increase urination, making their use an additional consideration for bedding management.

Voyage reports often mention minimising unnecessary handling and disturbance of animals to avoid unnecessary physical exertion. This management practice, particularly if used in combination with other practices outlined above, could reduce the impact of hot conditions.

Determining the effectiveness and appropriate use of mitigating measures is outside the scope of this review. Further analysis to determine the most effective mitigation strategies to manage heat stress risk is encouraged.

3.4 Animal factors influencing heat tolerance

The review of the literature and information from early submissions to this review have highlighted the animal factors that may influence an animal's ability to tolerate heat.

3.4.1 Genotype (*Bos indicus* vs. *Bos taurus*)

Bos indicus cattle are more heat tolerant than *Bos taurus* cattle. This has been demonstrated extensively in scientific studies (Barnes et al. 2004; Gaughan et al. 2010; Islam et al. 2020)(Barnes et al. 2004; Gaughan et al. 2010; Islam et al. 2020) where, under similar conditions, *Bos taurus* showed more clinical signs of increased heat load compared to *Bos indicus*. This is attributed to *Bos indicus* having thinner and shorter coats, generally leaner body condition scores, lower metabolic rates and greater skin surface area for evaporative heat loss (Adams & Thornber 2008).

Field studies in Australian feedlots have shown pure and crossbred *Bos taurus* cattle have higher panting scores at the same HLI compared to *Bos indicus* cattle (Gaughan et al. 2010). Islam et al. (2020) also examined panting as an indicator of heat stress in cattle. No effect of sex, body weight or docility score was found for individual cattle, however, panting duration was less for *Bos indicus* and *Bos indicus* crosses (>50% *Bos indicus*).

A voyage stocking both *Bos taurus* and *Bos indicus* cattle in 1995 reported a mortality rate of >28.4% and identified heat stress as a significant cause (More, Stacey & Buckley 2003). All mortalities were *Bos taurus* type cattle suggesting genotype was a significant heat stress risk factor. Data from this voyage formed part of the body of evidence used to create industry's HSRA software, 'HotStuff'.

3.4.2 Body condition score and fat deposition

Larger animals with higher body condition scores have more difficulty dissipating heat (McCarthy & Banhazi 2016). Approximately 70 to 80% of evaporative cooling in cattle occurs through the skin. The greater the surface area, the more effective the evaporative cooling process. In relative terms surface area decreases as an animal becomes fatter. Consequently, larger animals have a reduced capacity and smaller animals have an increased capacity for heat loss from the body (Adams & Thornber 2008).

Obesity or fatness is also recognised as a risk factor because fat has strong insulating properties. Fat has low thermal conductivity and lower blood supply therefore there is less ability for heat to dissipate from and via fatty tissues (Adams & Thornber 2008).

3.4.3 Acclimatisation

Animals are capable of modifying their behavioural, physiological, and morphological characteristics, or a combination of these, in response to the thermal environment (Lees et al. 2019). Acclimatisation is the process of adaptation by an animal to certain environmental conditions. According to Barnes et al. (2004), it involves changes to the animal's metabolic rate as well as changes to the skin surface and the animal's coat. Significant differences in heat production from acclimatised versus non-acclimatised cattle have been demonstrated (Robinson, Ames & Milliken 1986). Literature indicates that acclimatisation in cattle starts within 2 weeks of exposure to conditions and takes 4 to 7 weeks to complete (Adams & Thornber 2008). Bianca (1959) demonstrated that exposure of calves to either a hot-dry or hot-humid environment for various daily periods over 3 weeks resulted in acclimatisation with increased rates of sweating and lower metabolic heat production. Long-haul voyages in this review from southern Australian ports take around 3 weeks, except for voyages to the Russian Federation, which are longer. This is unlikely to be sufficient time for acclimatisation particularly because of the variability of climate conditions over the course of a voyage. Collins, Hampton & Barnes (2018) suggest acclimatisation to heat or cold should be in place before voyage departure.

3.4.4 Coat colour and length

Coat colour will influence the extent to which an animal absorbs solar radiation and is a major factor in heat tolerance (Gaughan et al. 2008). The influence of coat colour on heat tolerance was studied by Islam et al. (2020) who found that white coloured cattle panted less during the day than dark or tan coloured cattle. Coat colour is less important in the live export setting except where cattle on open decks are exposed to direct sunlight.

Coat length can adversely affect an animal's ability to shed heat through evaporative heat loss (McCarthy & Banhazi 2016). Therefore, cattle with longhair coats are more likely to accumulate heat (Jubb & Perkins 2019). Longer coats can be a breed characteristic of *Bos taurus* breeds or typical of animals acclimatised to cooler conditions.

3.4.5 Concurrent illness

Sick and recovering cattle are more susceptible to heat stress (Gaughan et al. 2008). Lees et al. (2019) noted that 'The health status of an animal can significantly influence the ability to cope with heat load conditions.' A study by Brown-Brandl et al. (2006) reported that animals with a previous treatment history for pneumonia, anytime from birth to slaughter, had respiration rates that were on average 10.5% higher compared to those never diagnosed or treated. The net effect of fever related to illness, and concurrent exposure to heat load increases the risk of adverse outcomes including death.

The most common cause of mortality during live export was reported as bovine respiratory disease (BRD) (Moore et al. 2015). BRD negatively impacts an animal's ability to utilise evaporative cooling via the respiratory tract which may increase their susceptibility to heat stress.

3.4.6 Diet

Cattle voluntarily decrease feed intake in response to hot conditions. Sparke et al. (2001) found that cattle fed a high energy grain diet decreased their feed intake by as much as 25%. Barnes et al. (2004) noted that in hot conditions (WBT 32°C) *Bos taurus* cattle were 'eating virtually nothing'. A decline in dry matter intake (DMI) has been reported to commence when ambient temperature reaches approximately 25°C to 27°C. However, this threshold is also influenced by diet type and composition (Lees et al. 2019).

The energy density of feed can influence heat tolerance. One study demonstrated that cattle fed a highly fermentable diet exhibited more signs of heat stress compared to cattle fed a slowly-fermentable diet under the same environmental conditions (Kennedy 2008). The HLI studies indicate that cattle on grain fed diets are more susceptible to heat however McCarthy & Fitzmaurice (2016) suggests that this is 'a proxy for both bodyweight and fatness. Both bodyweight and fatness are likely to increase with days on feed.'

Early submissions to the review also raised the influence of a grain fed diet on thermal tolerance. One submission indicated that slaughter cattle are often fully or partially grain-fed, and this practice likely increases for this class when exported in autumn and winter. Another submission cited Idris et al. (2021) stating that cattle susceptibility to heat stress is increased for those 'kept on high levels of nutrition for the purpose of maximising growth rates'.

The influence of diet on heat tolerance is well recognised within the live export industry. A common mitigation measure during times of high heat load is to 'temporarily reduce or cease feeding of concentrate and consider a higher roughage proportion in ration' (Jubb & Perkins 2019). One submission suggested that further research could be undertaken to enhance the understanding of the role of diet in heat stress. It noted that 'research, to better define metabolic heat outputs directly relevant to diets and feed intakes typically encountered on livestock vessels, and their impact on individual animals and on deck temperatures …may improve management of…heat stress on livestock vessels.'

3.4.7 Age

Very old or very young animals have reduced ability to tolerate heat due to impaired or immature thermoregulatory systems. As stated in ASEL 3, cattle less than 200kg sourced for export require a light cattle management plan approved in writing by the department. The management plan must outline measures to manage health and welfare of light cattle. ASEL 3 requires that cattle are a minimum of 200kg at the time of export. The export of very old or very young cattle rarely occurs.

3.4.8 The Heat Load Index (HLI)

The HLI threshold demonstrates differences in heat tolerance of different genotypes and the influence of other factors such as health status, days on feed, acclimatisation and drinking water temperature. The HLI threshold at which an animal gains heat was defined for a reference animal: a grain fed, healthy, black *Bos taurus* steer with a body condition score of 4+, with no access to shade. Adjustments to the reference HLI threshold for different variables are also defined (Table 12). Some variables, such as *Bos indicus* breed, can increase heat tolerance, shown as a positive adjustment in the table, whereas some factors such as illness or lack of acclimatisation can reduced tolerance, showing as a negative adjustment.

Table 12 Animal and management adjustments to the heat load index threshold of the reference animal (healthy, unshaded Angus steer, 100 days on feed)

Item	Relative effect on HLI threshold of reference steer
Bos taurus (British)	0
Bos taurus (European)	+3
Bos indicus 50%	+7
Bos indicus 100%	+10
Healthy	0
Sick/recovering	−5
Acclimated	0
Not acclimated	−5
Days on feed 0–80 days	+2
Days on feed 130+ days	−3
Drinking water temperature: 15–20°C	−1
Drinking water temperature: 21–30°C	0
Drinking water temperature: 31–35°C	−1

Source: Gaughan et al. (2008)

The HLI shows that sick, unacclimatised and grain-fed animals (>130 days) are more susceptible to heat stress. The influence of drinking water is also noted and is discussed in more detail in section 3.3 .

3.5 Cattle thermoregulation

Thermoregulation is the mechanism by which animals, in this case cattle, maintain a stable core body temperature independent of external temperature variation. Thermoregulation utilises a range of physiological and behavioural mechanisms that assist an animal to maintain its core body temperature within a narrow range for optimal functioning of body processes. For cattle, the core body temperature range is between 36.7°C and 39.1°C (Cunningham 2002).

Cattle are most productive when the temperature of their environment stays within the thermoneutral zone (TNZ). The TNZ is the range of ambient temperatures within which an animal can maintain its body temperature, with no requirement to either increase heat production or heat loss. Bounding the TNZ is the lower critical temperature (LCT) and the upper critical temperature (UCT). Mitchell et al. (2018) state the LCT and UCT are not tolerance limits but rather, they are points beyond which animals must use active physiologic responses to maintain thermoregulation. In addition, the TNZ and its boundary points may be quite variable and will depend upon many factors including wind chill, wet or dry coat, coat length, Body Condition Score (BCS), age, concurrent illness, nutrition and acclimatisation. In this sense, the TNZ is an elastic zone with flexible upper and lower boundaries (Wagner 1988).

Section 3.2 discusses the TNZ and other thermoregulatory zones.

3.6 Heat stress thresholds

Maunsell Australia Pty Ltd (2003) described the HST as 'the maximum ambient WBT at which heat balance of the deep body temperature can be controlled using available mechanisms of heat loss.' This would suggest that the HST itself is not a measure of poor welfare but rather the maximum temperature at which an animal maintains homeostasis. Barnes et al. (2004) state the HST is the WBT at which cattle are no longer able to maintain their normal body temperature.

For this review, we did not seek to determine temperatures for HSTs for exported live *Bos taurus* cattle. The literature review identified a range of WBTs that could be considered too hot and may contribute to poor welfare. This guided our analysis. The assessment of increased heat load was not specific to recorded WBTs but based on voyage reports of physiological and behavioural responses to heat. This section of the draft report provides a summary of *Bos taurus* cattle HSTs reported in the literature.

Barnes et al. (2004) conducted a series of experiments to describe the physiology of heat stress in cattle and sheep. The experiments held *Bos taurus* cattle, weighing between 300–400kg, in temperature controlled-rooms where the WBT was gradually increased to a peak of 32°C and then maintained for 5 days. The experiments showed that the mean body temperature of 39.5°C was consistently exceeded at ambient temperatures between 28°C and 30°C WBT. At 32°C WBT, cattle demonstrated clinical signs of heat stress including depression, inappetence, drooling, increased respiratory rates and open mouth panting.

More, Stacey & Buckley (2003) investigated the maiden voyage of the MV Becrux carrying sheep and cattle from Australia to the Middle East. Cattle mortality rate was >28.5% with all mortalities being *Bos taurus* cattle. While *Bos indicus* cattle may have experienced heat stress during this voyage, they did not die. The authors estimated the HST of the cattle was 'probably no greater than 27°C WBT, and possibly lower, for many of the cattle due to a range of factors including complete lack of acclimatisation, high condition scores.' The HST of the *Bos taurus* cattle on this voyage was estimated to be 7.3°C WBT lower than *Bos indicus* cattle.

An industry paper describing the development of the heat stress risk assessment model 'HotStuff', provides a table of HSTs for various breeds of cattle (

Table 13) (Maunsell Australia Pty Ltd 2003). According to this research, a 300kg *Bos taurus* beef breed, with body condition score of 3, mid-season coat, spring/summer acclimatised for southern Australia has a HST of 30°C WBT. A *Bos taurus* dairy breed with the same characteristics has a HST of 28.2°C WBT. *Bos indicus* and *Bos indicus* crosses by comparison have higher HSTs.

Table 13 also lists mortality limits (MLs) which are described as the WBT at which an animal will die. It is important to note that the difference between the base HST and the base ML ranges from 3.2°C to 4.7°C WBT.

Table 13 Base heat stress threshold and mortality limit values

Base Parameter	*Bos taurus*		*Bos indicus*		
	Beef	Dairy	Beef	25% indicus	50% indicus
Weight (kg)	300	300	300	300	300
Core temperature (°C)	40	40	40	40	40
Body condition score	3	3	3	3	3
Coat	Mid	Mid	n/a	n/a	n/a
Acclimatisation (WBT)	15	15	15	15	16
Base HST (WBT)	30	28.2	32.5	31.25	31.875
Base ML (WBT)	33.2	32.9	36.0	34.6	35.3

Source: Maunsell Australia Pty Ltd (2003)
*n/a Not applicable.

The MLA Veterinary Handbook (Jubb & Perkins 2019) provides guidance on WBTs with regards to heat stress (Table 14). It notes that *Bos taurus* cattle are comfortable below 26°C WBT but that over 30°C WBT is considered a ‘danger’ zone.

Table 14 WBT risk criteria for heat stress on export vessels

	Safe	Caution	Danger
Bos indicus cattle	< 28°C	28–31°C (non-acclimatised) 30–33°C (acclimatised)	>31°C (non-acclimatised) >33°C (acclimatised)
Bos taurus cattle	<26°C	26–30°C	>30°C

Source: Jubb & Perkins (2019)

4 Heat load voyage analysis

Industry submissions, the literature review and the data available from end-of-voyage, daily and IO reports identified 4 possible risk factors that may be associated with increased heat load and heat stress-related mortalities. These were:

- cattle class (breeder, feeder, slaughter)
- season of departure (ASEL season either NHW or NHS or April, May, June season (AMJ season))
- destination region (China, Persian Gulf, Red Sea, the Russian Federation)
- departure port (Portland, Geelong, Port Adelaide, Fremantle and Geraldton)

The objective of this analysis was to adopt an epidemiologically-sound approach to determine any association between these risk factors and increased heat load or heat stress-related mortalities on long-haul voyages of *Bos taurus* cattle from southern Australia. The partitioning of the effect of these 4 factors (class, season, destination and departure port) on increased heat load and heat stress-related mortalities was to allow the exploration of increased heat load and heat stress-related mortality separately, rather than relying only on mortality as a welfare indicator.

The department collated data from voyages which reported signs of increased heat load and/or heat stress-related mortality.

Our **case definition for heat load voyages** was 'any voyage where daily reports recorded behavioural and physiological responses to increased heat.' The behavioural and physiological signs that indicated cattle were thermoregulating included any combination of the following: reports of increased water consumption, decreased feed consumption, increased respiratory rate/character, increased panting score/heat stress score or heat stress-related morbidity/death. Alterations in food or water consumption alone were not considered conclusive evidence of a physiological response to heat. The department's analysis of heat load voyages is discussed in section 4.2.1.

Our **case definition for heat stress-related mortality** was 'any mortality where the cause of death was reported by the AAV or stockperson to be due to heat stress or associated with heat stress.' The department's analysis of heat stress-related mortality voyages is discussed in section 4.2.3.

We found that determining the occurrence of heat stress as distinct from a normal physiological response to heat was challenging:

- Science has not yet determined the explicit moment or threshold that cattle become heat stressed, and existing views among interested stakeholders in the live export trade vary significantly. This moment or threshold varies between a species of cattle for reasons discussed in section 3.4
- Under ASEL 2.3, reporting requirements for daily voyage reports were limited. A single measure per voyage per day of respiratory character (normal, panting or gasping) was the

minimum heat stress-related requirement. In some cases this may have been presented as a single measure per deck. Around 2018/2019 some exporters voluntarily included daily deck heat stress measures and/or panting scores in voyage reports. Rankings were not necessarily consistent and it is unclear what panting score system was used (possibly that described in the MLA Veterinary Handbook)

- A single measure of respiratory character or panting score per voyage or per deck per day means the reporter provided an 'averaged' reading even if it applied across species. This measure does not provide any information about the range of behaviours across the vessel. It also does not provide visibility about what happened in between daily reports
- Voyage reporting also only provided a single deck temperature per day. This means we have limited knowledge of the effect of duration of high temperatures and limited ability to determine if the cattle were experiencing periods of respite.

4.1 Evidence of hot conditions

Voyage reports under ASEL 2.3 provide a single daily deck temperature as well as ambient temperatures and bridge temperatures. The time that temperatures are recorded is assumed to be at the same time each day but this was not reported. The department was therefore unable to assess daily temperature ranges.

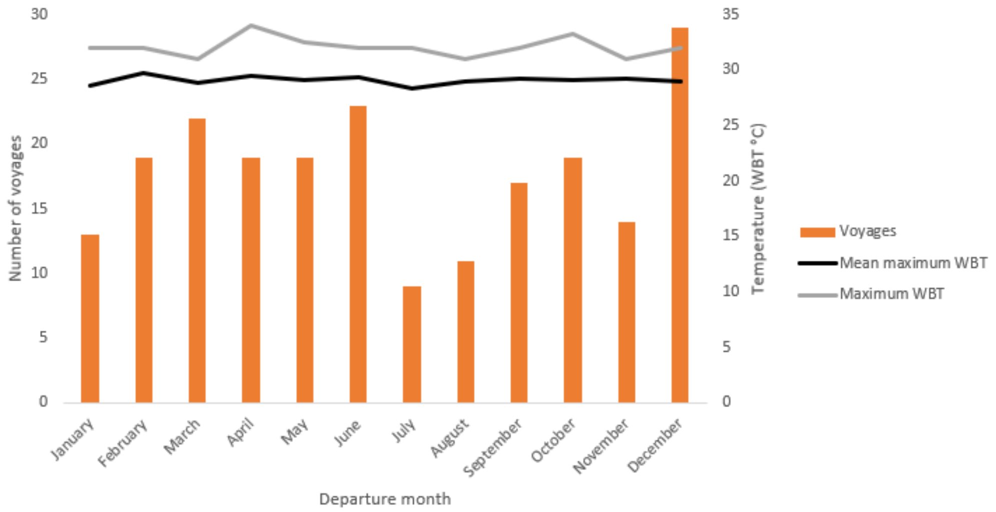
The department collated maximum WBTs reported for each voyage. The average maximum daily WBT across all voyages was 29.2°C WBT with a range of 25°C WBT to 34°C WBT. The highest maximum of 34°C WBT was recorded on one voyage in April (Table 15). Out of 214 voyages, 213 (99.5%) voyages recorded at least one day of 26°C WBT or greater while 75 voyages (35%) recorded a maximum of 30°C WBT or greater (Table 15).

Table 15 Maximum voyage wet bulb temperature from 214 voyages (2016 to 2020)

Maximum temperature on voyage (°C WBT)	Voyages with at least 1 day at or above maximum temperature
26	213 (99.5%)
28	189 (88.3%)
30	75 (35.0%)
32	16 (7.5%)
34	1 (0.5%)

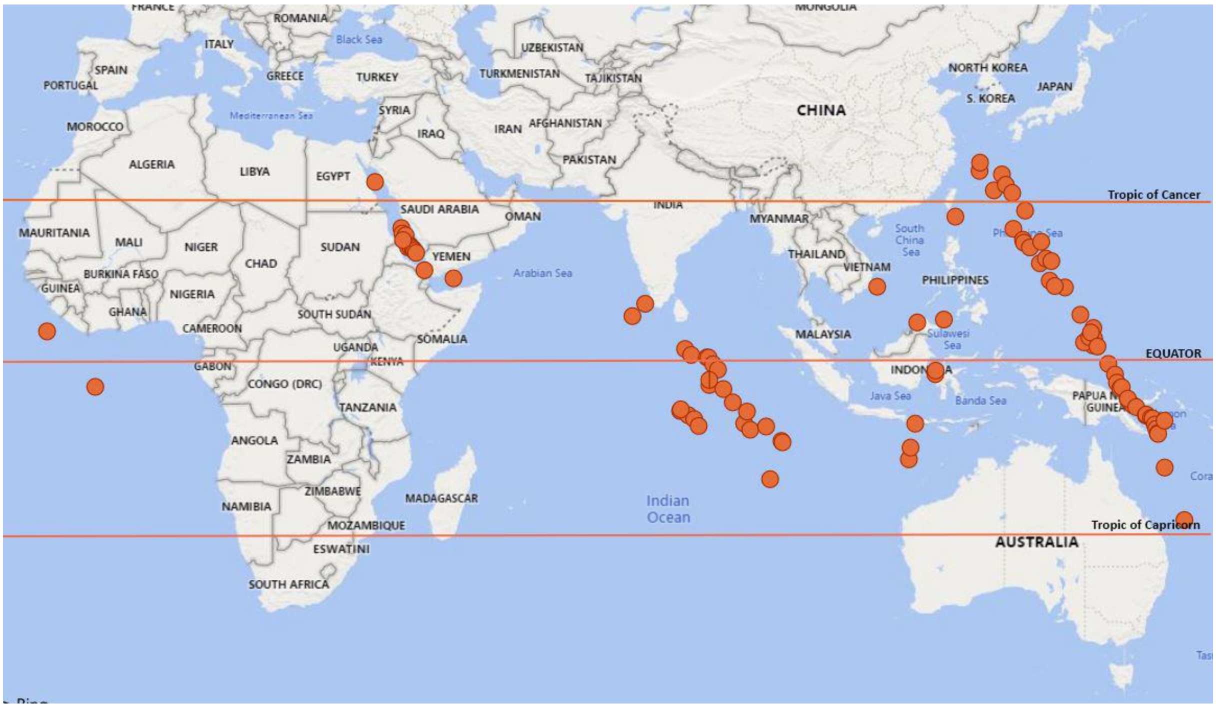
The average maximum WBT was similar for vessels departing from Australian ports in the NHW (29.1°C WBT) compared to the NHS (29.3°C WBT). The mean maximums for all voyages calculated for each month are displayed in Figure 8 along with the hottest voyage for each month. The monthly average maximum ranged from 31°C to 34°C WBT (Figure 8) reflecting the relatively consistent equatorial temperatures across the year.

Figure 8 The number of voyages and temperature (mean and mean maximum WBT °C) by month



The geographical location (latitude and longitude) of the first day of the maximum deck temperature (°C WBT) for each voyage is shown in Map 2. The equatorial region is known to be a location where hot, humid conditions occur. However, this depiction shows that the hottest part of a voyage may occur at other locations along voyage routes.

Map 2 Location of maximum deck wet bulb temperature for voyages that recorded at least 1 day at 28 WBT °C or above (2016 to 2020)



4.1.1 Voyages recording evidence of increased heat load

We collated data on voyages which reported evidence of increased heat load in the cattle (heat load voyages or heat load events). As stated in section 4 of this draft report, our case definition for heat load voyages was 'any voyage where daily reports recorded behavioural and physiological responses to increased heat.'

Variations in respiratory rate and character offer stronger evidence of increased heat load. Under ASEL 2.3, daily reporting required an assessment of the respiratory character ranked from 1 to 3 by deck (1=normal, 2=panting, 3=gasping). Some exporters also include a heat stress score ranked from 1 to 3 (1=normal (no stress), 2=mild stress, 3=severe stress). Respiratory character (2 or 3) and heat stress score (2 or 3) were recorded as evidence of a response to increased heat load. Commentaries on the responses of cattle to hot conditions were also assessed from the general comments sections of daily reports, end of voyage or IO reports.

In the 214 voyages reviewed:

- Fifty-three voyages (24.8%) documented either elevated respiratory rate/character of 2 or 3 or elevated heat stress score of 2 or 3. These voyages are defined as 'heat load voyages'
- Heat-associated behaviours were documented in 49 (22.9%) voyages. They were noted as an increase in water consumption (31 voyages), decrease in feed consumption in (12 voyages) or both (6 voyages)

4.1.2 Summary of heat load voyages

- Approximately 1 in 4 long-haul *Bos taurus* voyages from southern Australia reported evidence of increased heat load (heat load voyages)
- These voyages covered all classes of cattle, to all destinations and from all departure ports in the review and departed during both the NHW and NHS.

4.1.3 Voyages recording heat stress-related mortality

We collated data on voyages which reported at least one mortality related to heat stress. Our case definition for heat stress-related mortality was any mortality where the cause of death was reported by the AAV or stockperson to be due to heat stress or associated with heat stress. Each heat stress-related mortality was classified as either primary, 'combined' or other. A primary heat stress mortality was recorded where the reporting clearly identified heat stress as the cause of death. A 'combined' heat stress mortality was recorded where the cause of death was not attributed to heat stress alone but often listed as a differential diagnosis with other diseases. The 'other' heat stress mortality category included deaths associated to heat stress in the reports that were unable to be classified as primary or combined. Due to limited detail provided in the voyage reports, the analysis could not question the accuracy of the reported causes of death.

Fourteen of the 214 voyages (6.5 %) reported mortalities related to heat stress. The average maximum temperature on these 14 voyages was 30.3°C WBT with a range from 27.6°C WBT to 34.0°C WBT. A total of 85 head of cattle, ranging from 1 to 42 cattle mortalities per voyage, were identified as heat stress-related mortalities during the period (Appendix A: ASEL 3 standards applicable to heat and cold stress).

Primary heat stress-related mortalities accounted for 17.6% mortalities (n=15) and 'other' heat stress-related mortalities constituted 16.5% (n=14). Two-thirds of the heat stress-related mortalities were classified as combined heat stress-related deaths (65.8%; n=56). Respiratory disease represented 85.7% (48 of 56) of the comorbidities (diseases reported in the combined heat stress-related mortalities). Other examples of documented comorbidities included 'infection', 'gastro-enteritis' and 'bloat'.

Eleven voyages with heat stress-related mortalities occurred in 2018 while one voyage with heat stress-related mortalities occurred in each of 2016, 2017 and 2020. The reason for these annual variations is beyond the scope of this review. While unconfirmed, issues raised by the Awassi footage released in 2018 may have increased awareness and reporting of heat stress in 2018. Additionally, the export of slaughter class cattle to China commenced with 4 voyages in 2017 and 12 voyages in 2018. Eleven of the 2018 voyages reported evidence of increased heat load. By comparison only 6 voyages in each of 2019 and 2020 reported evidence of increased heat load.

4.1.4 Summary of heat stress-related mortality

- 6.5% of voyages recorded at least one heat stress-related mortality
- Approximately two-thirds of heat stress-related mortalities were reported to be associated with another condition, most commonly underlying respiratory disease.

4.2 Analysis of risk factors for increased heat load and heat stress related mortality

Although 214 voyages were reviewed for this report, only 204 voyages were included in the statistical analysis. Ten voyages were removed from the total of 214 to simplify the analysis because they contained consignments by two exporters or two departure ports. The occurrence of heat load events or heat stress-related mortality could not be accurately split by exporter or departure port based on the available data.

In reviewing the 204 voyages, voyage destinations included China (72% of voyages, n = 147), the Persian Gulf (6.4%, n = 13), the Red Sea (16.7%, n = 34) and the Russian Federation (4.9%, n = 10). Voyages departed from 5 departure ports including Portland (58.3%, n = 119), Fremantle (32.8%, n = 67) and Geelong (8.8%, n = 18). Most voyages had only one departure port (90.2%, n = 184) but some recorded two (9.8%, n = 20). Classes of cattle were categorised as breeder (63.2%, n = 129), feeder (20.6%, n = 42) or slaughter (16.2%, n = 33). Season was categorised as AMJ season or ASEL season (either NHW or NHS). The ASEL season reflects the variation in stocking density on voyages according to season of departure. NHW voyages were 57.8% of total voyages (n = 118) and NHS voyages were 42.3% of total voyages (n = 86). Voyages departing in the AMJ season made up 27.4% of total voyages (n = 56). The mean duration of voyages was 20.3 days (sd = 5.29 days). Voyages were operated by 23 different exporters using 31 unique vessels with each vessel undertaking between 1 to 20 voyages.

The methodology performed in our analysis is outlined in Appendix C: Methodology. We performed initial univariable and subsequent multivariable analyses. The univariable analyses compared each of the 2 possible outcomes (presence or absence of heat load events and heat stress-related mortality) with each of the 5 potential risk factors (class of cattle, ASEL season, AMJ season, destination and departure port). Acknowledging the complexities of voyages and that many variables may impact voyage outcomes, a multivariable analysis was then performed. Multivariable analyses were undertaken to assess the significance of more than one variable at once on the occurrence of heat load voyages and heat stress-related mortality voyages. The multivariable model was developed using standard model building strategies to assess the effect of cattle class, departure port, ASEL season and AMJ season on the occurrence of heat load and heat stress-related mortality voyages. Outcomes of the multivariable analyses are discussed below.

4.2.1 Collinearity

An association was identified between destination and class (P < 0.001) as visualised in Figure 9. This is because the same class of cattle is typically exported to the same destination. Similarly, associations were identified between destination and departure port (P < 0.001) and class of cattle and departure port (P < 0.001). Variable selection for the multivariable models was guided by this collinearity.

4.2.2 Cattle class

Of the 214 voyages reviewed 60.7% were breeder cattle (n=130), 20.1% feeder (n=43) and 15.9% slaughter (n=34) voyages. Evidence of a response to increased heat load was reported in approximately 1 in 3 slaughter cattle voyages, while approximately 1 in 4 slaughter cattle voyages reported at least one heat stress-related mortality. Heat load voyages for feeder and breeder cattle were less frequent than for slaughter cattle. For breeder cattle, 1 in 10 voyages reported evidence of increased heat load while heat stress-related mortalities were rare (1 in 66 voyages). For feeder cattle approximately 1 in 5 voyages reported evidence of increased heat load and 1 in 14 voyages reported a heat stress-related mortality (Table 16).

Table 16 Summary of voyages with evidence of increased heat load and heat stress-related mortalities according to cattle class

	Breeder	Feeder	Slaughter	Mixed voyages	Total
Total voyages	130	43	34	7	214
Voyages with evidence of increased heat load	31/130 (10.0%)	7/43 (16.3%)	13/34 (38.2%)	2/7 (28.6%)	53/214 (24.8%)
Voyages with heat stress-related mortality	2/130 (1.5%)	3/43 (7.0%)	9/34 (26.5%)	0	14/214 (6.5%)

Of the 204 voyages included in the statistical analysis, 129 voyages carried breeder cattle, 33 voyages carried slaughter cattle and 42 voyages carried feeder cattle. 6.4% of voyages (n = 13) reported heat stress-related mortality events, and 25% (n = 51) of voyages reported increased heat load and/or heat stress-related mortality events. Voyages recording heat load by cattle class and heat stress-related mortality by cattle class are shown in Figure 10 and Figure 11.

Figure 9 Distribution of class of cattle by destination

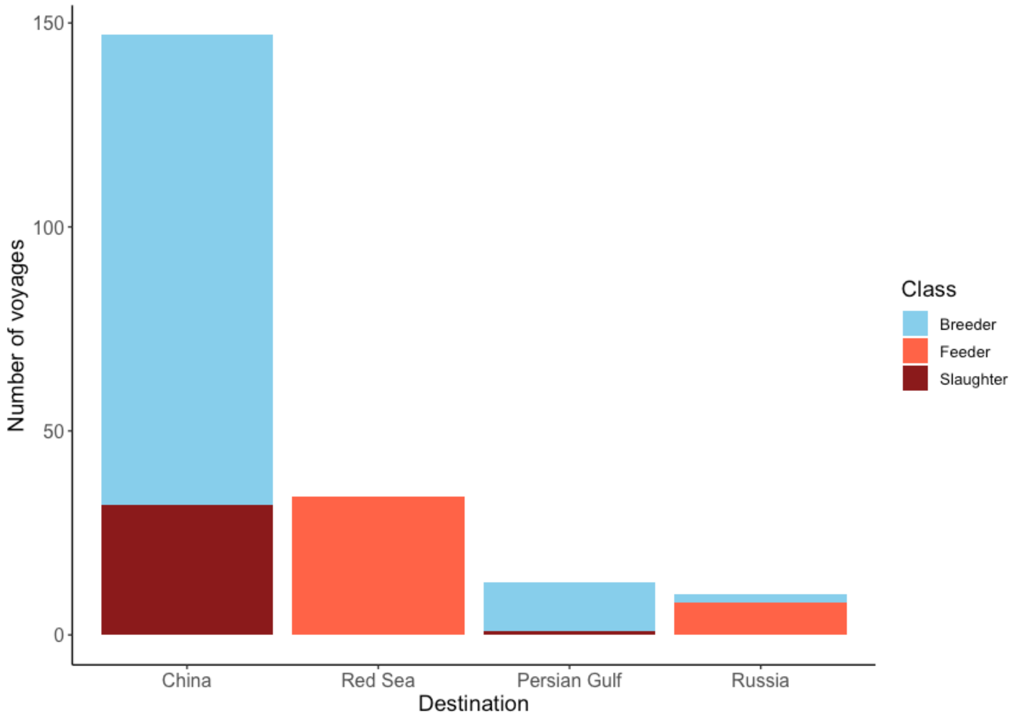


Figure 10 Voyages recording heat load by cattle class

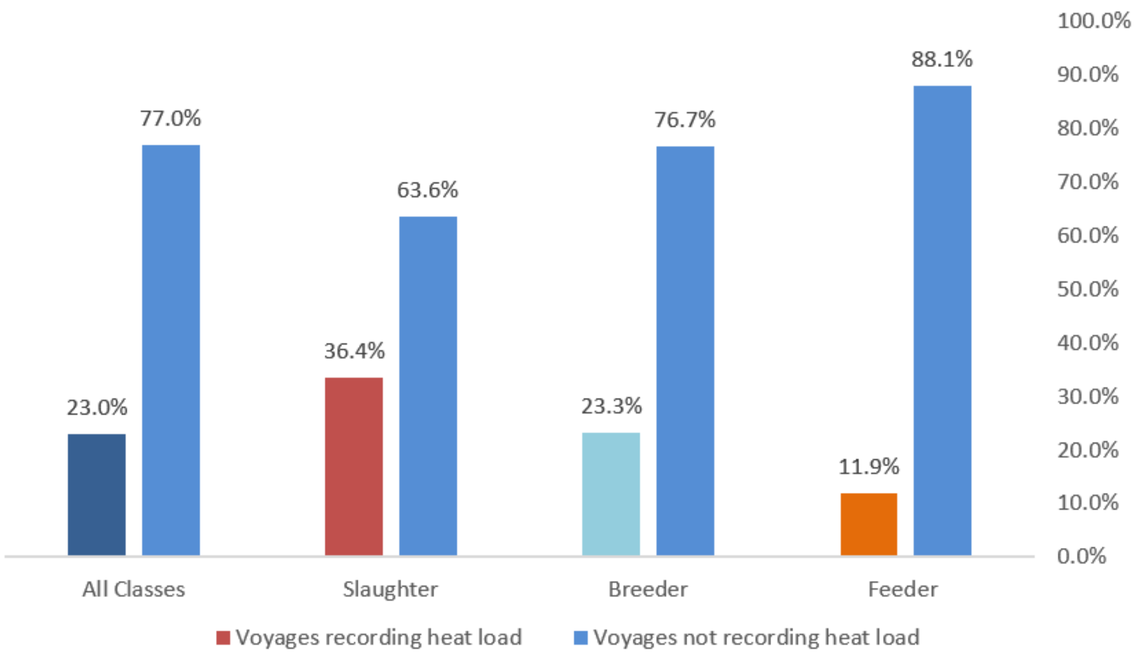
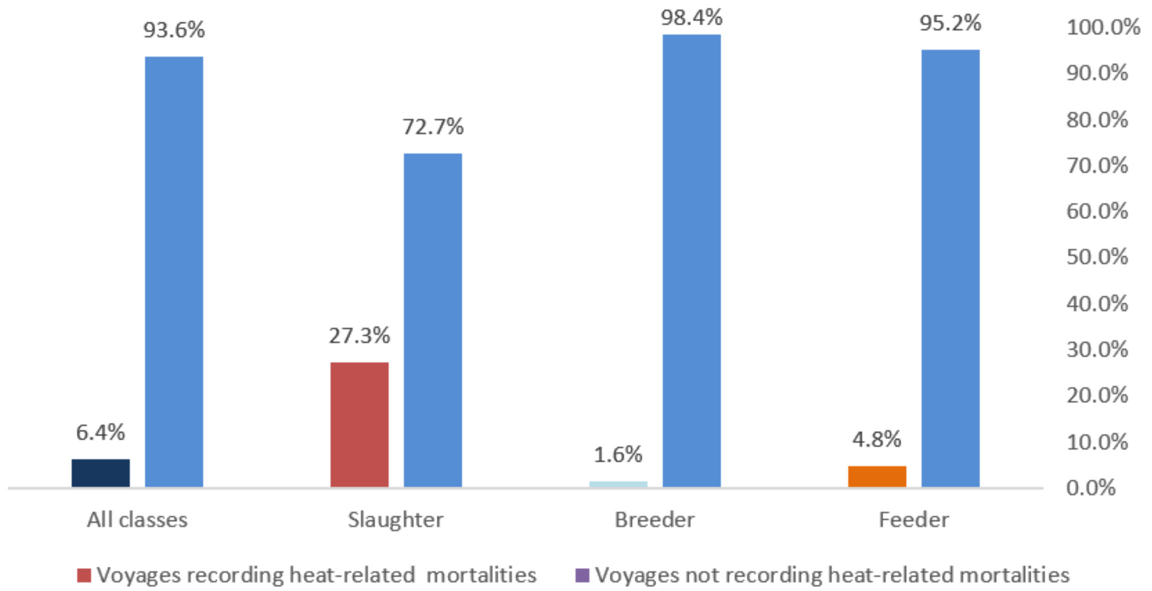


Figure 11 Voyages recording heat stress related mortality by cattle class



For the outcome of increased heat load, analysis identified a significant association between cattle class (P = 0.041), departure port (P = 0.048) and AMJ season (P = 0.025). In this model there was no significant effect of ASEL season (P = 0.025). Slaughter cattle voyages were found to have a significantly greater risk, with 4.0 times the odds (95% CI 1.42 – 12.05) of experiencing increased heat load than breeder cattle voyages (P = 0.010) and 4.33 (95%CI 1.34 – 15.95) than feeder cattle voyages (P = 0.018). The only significant departure port difference was between Portland and Fremantle, where 3.38 times the odds of heat load was identified in voyages departing Portland, compared to Fremantle (P = 0.023). A significant effect of AMJ season was also identified, with voyages departing in April, May and June associated with 2.43 the odds (95%CI 1.12 – 5.33) of heat load than those departing at other times of the year (P=0.025).

For the outcome of heat stress-related mortality, analysis identified a significant effect of heat load (P < 0.001) and cattle class (P < 0.001). In this model, there was no significant effect of ASEL season, AMJ season or departure port (however, it should be noted that the effect of some of these variables are likely mediated through the effect of the presence of heat load in this model). Within this model, it was found that the presence of increased heat load is associated with 7.28 (95%CI 1.65 – 37.13) times the odds of mortality than voyages without increased heat load. It was also found that slaughter class animals have 38.8 times the odds (95%CI 4.80 – 561.10) of heat stress-related mortality compared with breeder class animals (P = 0.02) but do not have significantly different odds of heat stress related mortality compared with feeder animals (P = 0.077; 95%CI 0.93 – 40.98).

4.2.3 Summary of cattle class analysis

- Over 1 in 3 slaughter class voyages (33.4%) experienced heat load and over 1 in 4 slaughter class voyages (27.3%) reported at least 1 heat stress-related mortality
- A significant association was identified between cattle class and the occurrence of a heat load voyage

- Slaughter cattle voyages have 4.0 times the odds (95% CI 1.42 – 12.05) of experiencing increased heat load than breeder cattle voyages (P = 0.010) and
- Slaughter cattle voyages have 4.33 times the odds (95%CI 1.34 – 15.95) of experiencing increased heat load than feeder cattle voyages (P = 0.018).
- Slaughter cattle voyages are significantly more at risk of heat stress-related mortality compared to voyages carrying breeder cattle, independent of the effect of increased heat load.
- Slaughter cattle voyages have 38.8 times the odds (95%CI 4.80 – 561.10) of heat stress-related mortality compared with breeder cattle voyages.

4.2.4 Season of voyage departure

Fewer of the 214 voyages departed Australia in the NHS (42.5%; n=91) compared to the NHW (57.5%; n=123). A greater proportion of voyages with evidence of heat load occurred during the NHS (28.6%; n=26) compared to NHW (22.0%; n=27).

Ten of the 14 voyages with heat stress-related mortalities occurred in the NHS. This equated to about 1 in 10 voyages during the NHS (11%). Voyages during the NHW resulted in heat stress-related mortalities less frequently (3.3% of voyages) (Table 17).

Table 17 Summary of voyages with evidence of increased heat load and heat stress-related mortality according to season

Type	northern hemisphere summer	northern hemisphere winter	Total
Total voyages	91	123	214
Voyages with evidence of increased heat load	26/91 (28.6%)	27/123 (22.0%)	53/214 (24.8%)
Voyages with mortalities due to heat load	10/91 (11.0%)	4/123 (3.3%)	14/214 (6.5%)

The relationship between season and heat load and heat stress-related mortality was explored further in our analysis. Partitioning the analysis by 6-month ASEL seasons reduces the ability to assess significance of weather determined seasonality. In part, the analysis of the effect of ASEL season reflects the variations in stocking density on voyages departing in each season (NHW v NHS). As noted in Figure 12 and Figure 13, when the analysis is looked at by month there appears to be a seasonal pattern in the frequency of heat load voyages and heat stress-related mortality voyages that depart in late autumn/early winter, particularly in the months April, May and June, particularly for slaughter cattle (Figure 14 and Figure 15).

When analysing the effect of the AMJ season, we found that even accounting for the changes to stocking density in accordance with the ASEL season, there is still a significant effect of AMJ season on the outcomes of heat load. While no effect of AMJ season was found on mortality independent of the effect of heat load, the significant effect of heat load on mortality that was identified includes an effect of AMJ season, as reported above (Figure 16 and Figure 17).

Figure 12 Presence of heat load distributed by month for all voyages

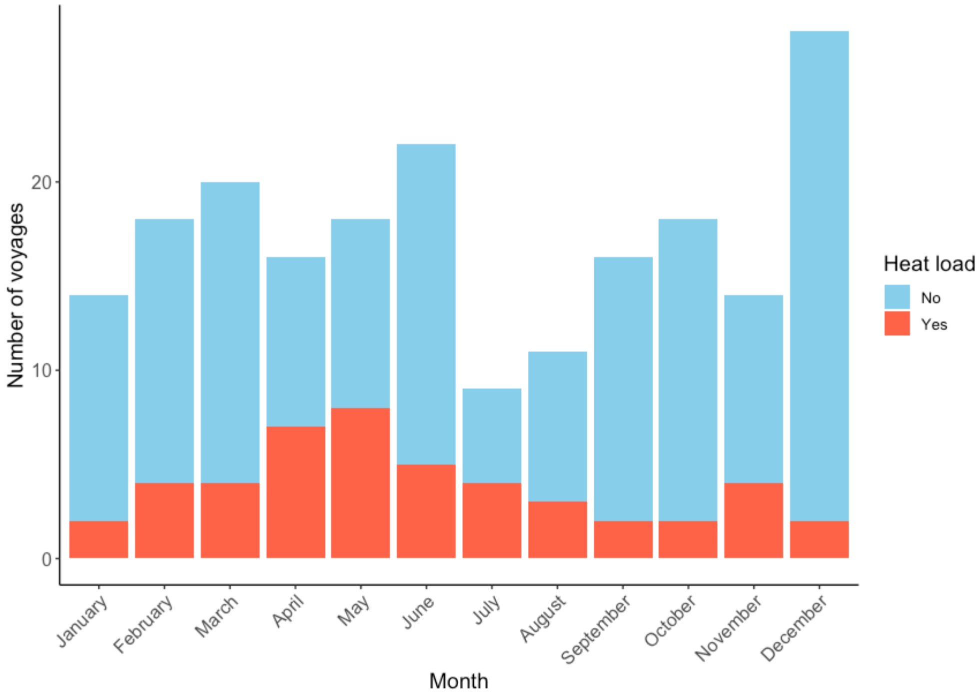


Figure 13 Heat stress-related mortalities distributed by month for all voyages

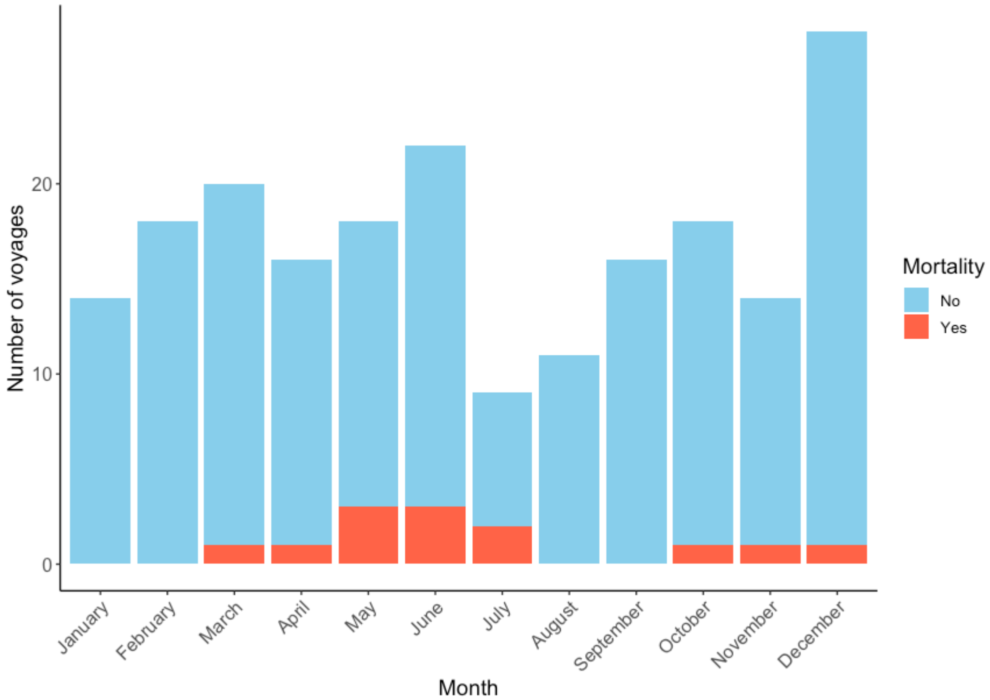


Figure 14 Presence of heat load for slaughter class only

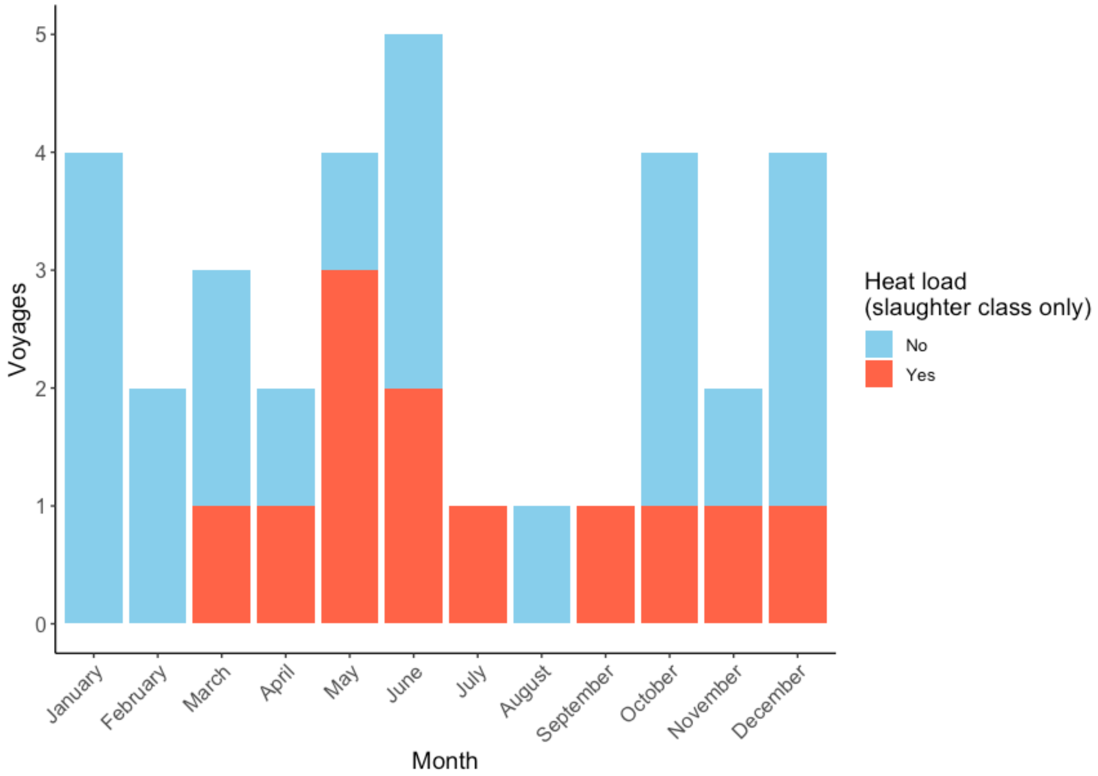
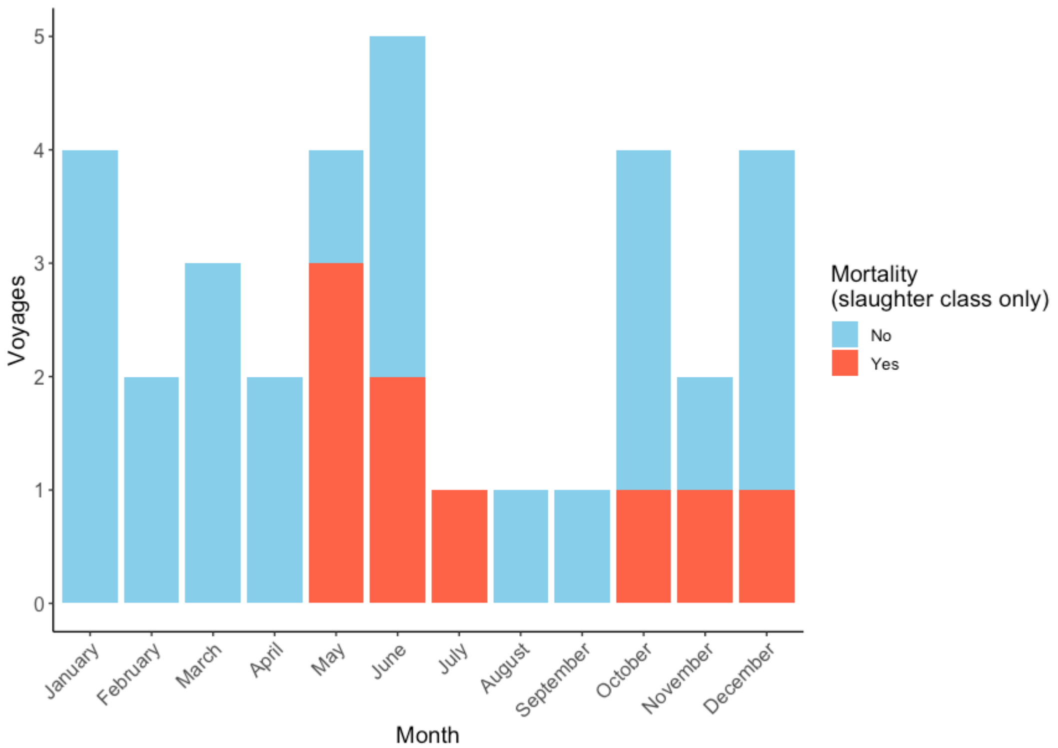


Figure 15 Heat stress-related mortalities for slaughter class only



One submission noted a similar finding from an analysis of voyage mortality rates (as distinct from heat stress-related mortalities in this analysis). The submission identified a strong seasonal pattern in mortality rates for slaughter cattle voyages. Mortality rates were substantially higher for autumn and winter departures, than for the spring and summer. The high mortality rates for slaughter cattle voyages in the autumn were strongly influenced by May departures. The submission did not attempt to attribute cause to this seasonal pattern. Further investigations into the reasons for this trend are warranted.

Figure 16 Voyages recording heat load – by AMJ season

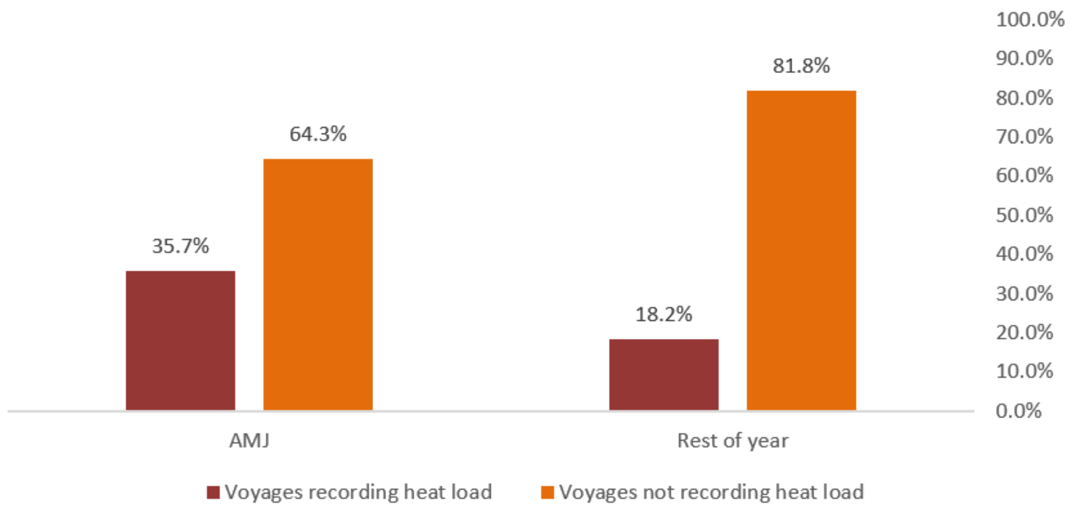
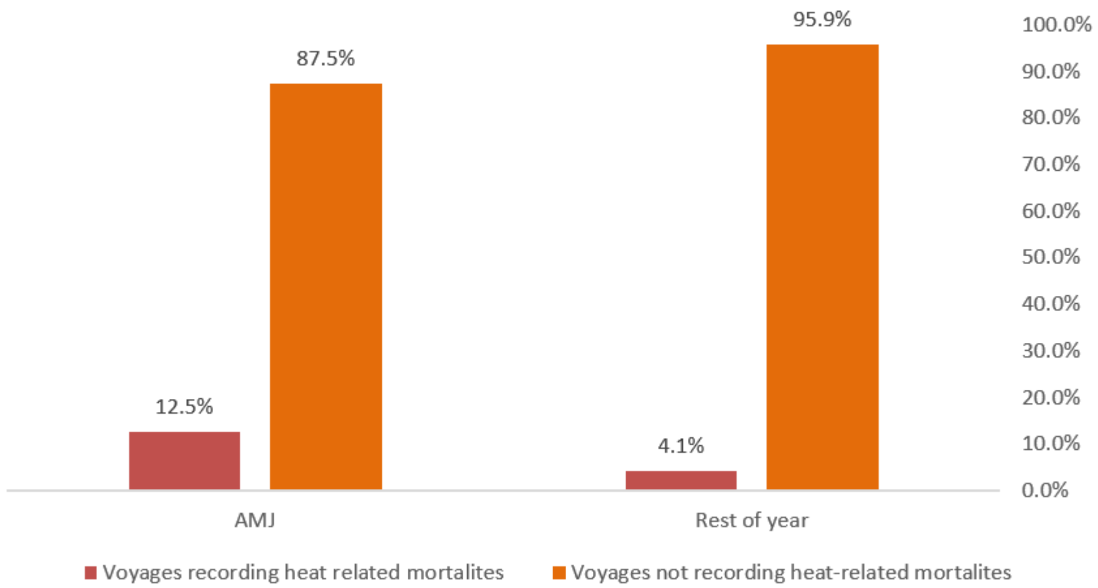


Figure 17 Voyages recording heat stress-related mortality – by AMJ season



4.2.5 Summary

- A greater proportion of voyages with evidence of increased heat load occurred during the NHS (28.6%; n=26) compared to NHW (22.0%; n=27)
- Approximately 1 in 10 voyages departing in the NHS resulted in at least 1 heat stress-related mortality. A lower proportion of departures in the NHW resulted in heat stress-related mortality (1 in 30)
- Voyages that departed in April, May or June had 2.43 times (95%CI 1.22 – 5.63) the odds of heat load or mortality than those departing during other months of the year
- There was no independent effect of voyages departing in April, May or June on mortality, but the significant effect of heat load on mortality includes an effect of AMJ season
- Further investigations into the substantially higher mortality rates for slaughter cattle on voyages departing in late autumn and early winter would be useful to explain the trend.

4.2.6 Voyage destination region

The proportion of voyages with evidence of increased heat load by destination region ranged from 18.2% (the Russian Federation) to 46.2% (Persian Gulf), however these 2 destination regions recorded the smallest sample sizes (Table 18). China and Red Sea, with larger voyage numbers, accounted for 24.2% and 22.0% of voyages with evidence of increased heat load, respectively.

The 14 voyages with heat stress-related mortalities occurred on voyages to China (n=11) and the Red Sea (n=3). These 2 destination regions accounted for 88.8% of the in-scope voyages (190/214). Heat stress-related mortalities did not occur on voyages to the Persian Gulf and the Russian Federation, however few voyages went to these locations overall and only departed during the NHW (Table 18).

Univariable statistical analyses found no significant association between destination region and heat load (P = 0.166), mortality (P = 0.94) or heat load and/or mortality (P = 0.258). Destination was not able to be analysed at the multivariable level due to collinearity with other variables (see methodology in Appendix C: Methodology).

Table 18 Summary of voyages with evidence of increased heat load and heat stress-related mortalities according to voyage route

	China	Red Sea	Persian Gulf	Russian Federation	Total
Total voyages	149	41	13	11	214
Voyages with evidence of increased heat load	36/149 (24.2%)	9/41 (22.0%)	6 (46.2%)	2/11 (18.2%)	53/214 (24.8%)
Voyages with heat stress-related mortalities	11/149 (7.4%)	3/149 (2.0%)	0	0	14/214 (6.5%)

4.2.7 Summary of destination analysis

No significant association between destination region and heat load voyages or heat stress-related mortality voyages was found.

4.2.8 Departure port

The review analysed departures from 5 southern Australian ports: Portland, Geelong, Port Adelaide, Fremantle and Geraldton.

Table 19 Summary of voyages with evidence of increased heat load and heat stress-related mortalities according to departure port

Port	Total voyages	Voyages with evidence of increased heat load	Voyages with heat stress-related mortalities
Fremantle	61	12	7
Fremantle, Portland	10	0	0
Geelong	16	5	1
Geelong, Fremantle	2	0	0
Geraldton	1	1	0
Port Adelaide, Fremantle	4	3	1
Portland	111	30	5
Portland, Fremantle	9	2	0
Total	214	53	14

The significance of departure port was analysed for the risk of experiencing increased heat load or heat stress-related mortality. Port Adelaide and Geraldton were removed from the analysis because of the small number of departures (n = 3 for Port Adelaide and n = 1 for Geraldton). All departures from these ports were associated with heat load events, potentially introducing bias for associations with other departure ports which recorded much greater numbers of voyage departures.

Figure 18 Distribution of departure port by destination

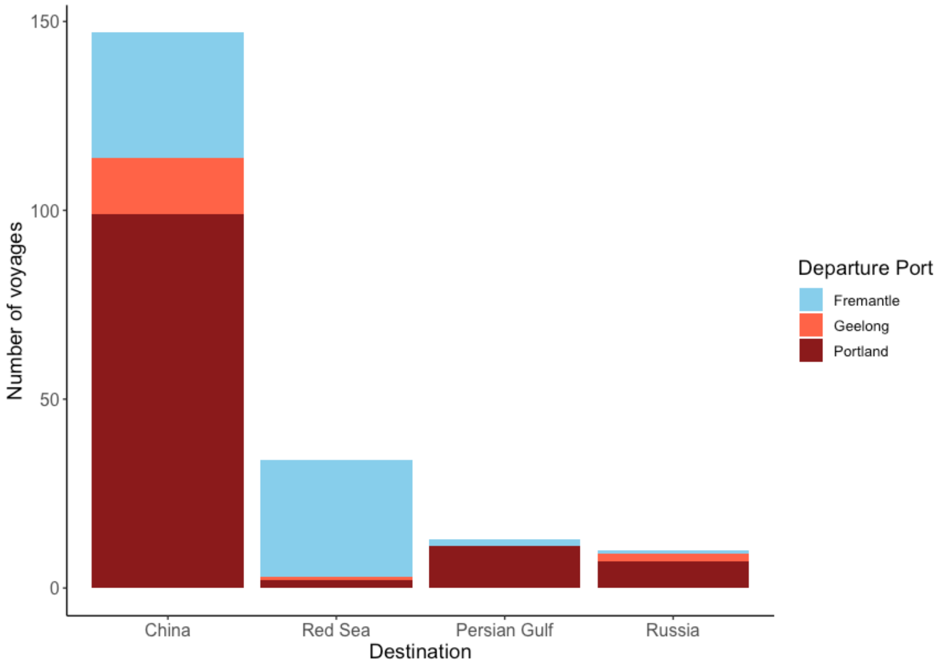
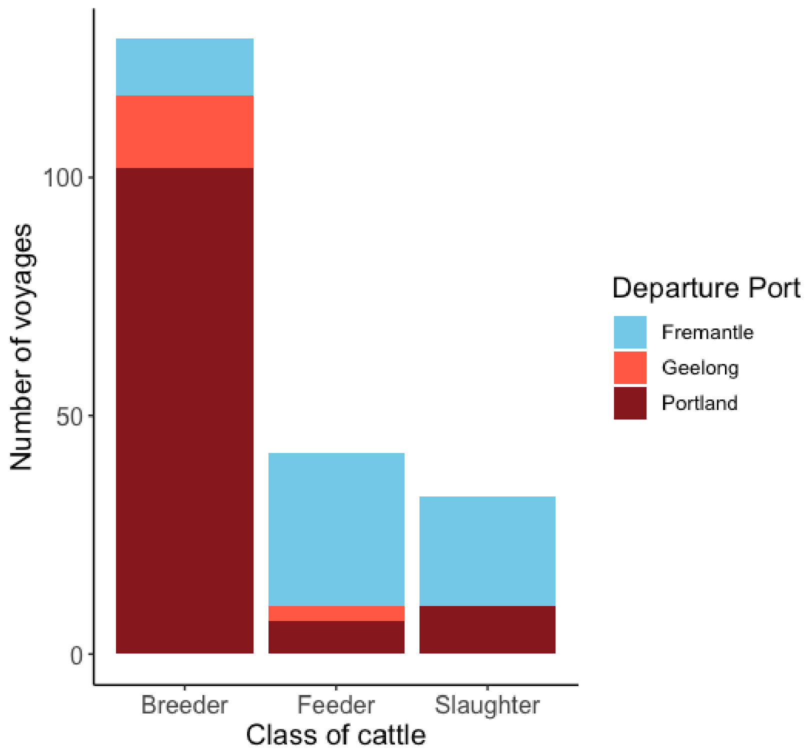


Figure 19 Distribution of class of cattle by departure port



The significant effect of departure port found in the multivariable analysis with heat load as the outcome identified Portland to have greater odds of heat load compared with Fremantle with a trend towards greater odds of heat load from Geelong compared to Fremantle. Further investigation beyond the scope of this review is warranted to explore this potential association.

4.2.9 Summary of departure port analysis

- A significant association was found between the occurrence of heat load voyages and departure port.
- Voyages departing from Portland have 3.38 times the odds of heat load compared with voyages departing from Fremantle (P = 0.023).

4.2.10 Vessel

The analysis reviewed the evidence of increased heat load or heat stress-related mortalities on vessels. Thirty-one unique vessels performing between one and 20 voyages were identified as having an occurrence of heat stress or heat stress-related mortalities.

Evidence of increased heat load was recorded on 74% of vessels (n=23). Eleven of these vessels recorded more than 1 heat load voyage (Figure 20). Nine vessels were associated with heat stress-related mortalities (Figure 21). Three vessels reported more than one mortality event (Table 19).

Figure 20 Heat load voyages distributed by vessel

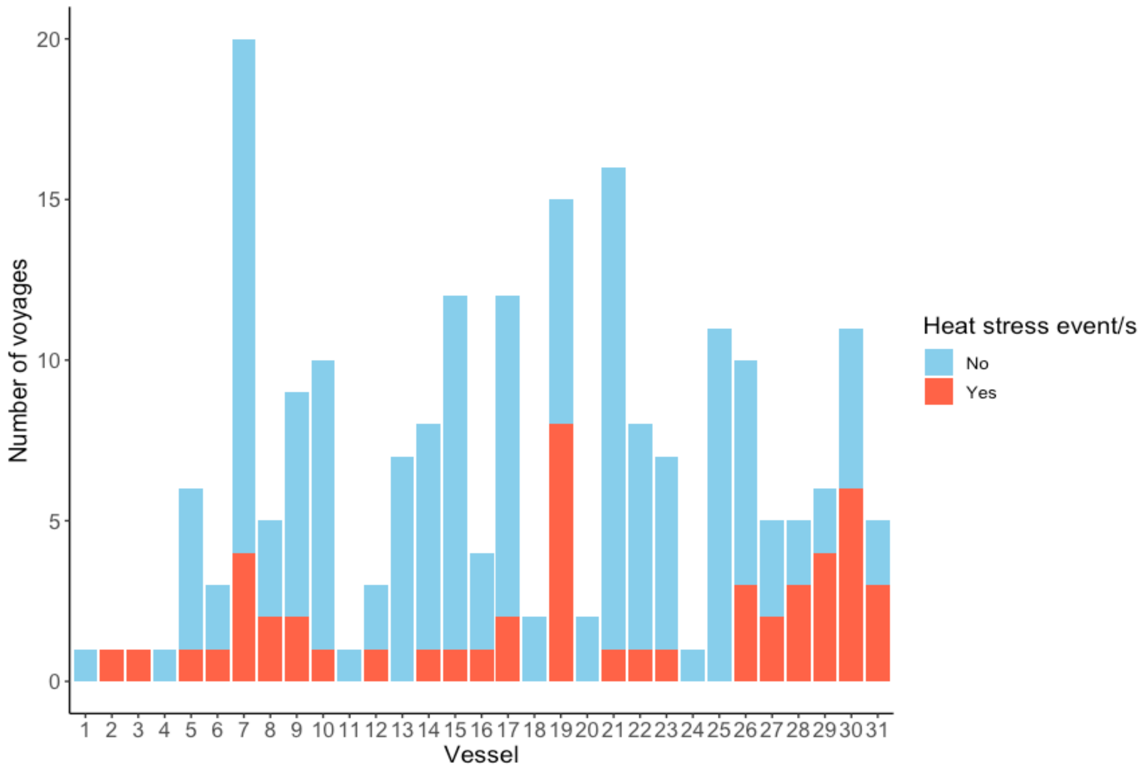
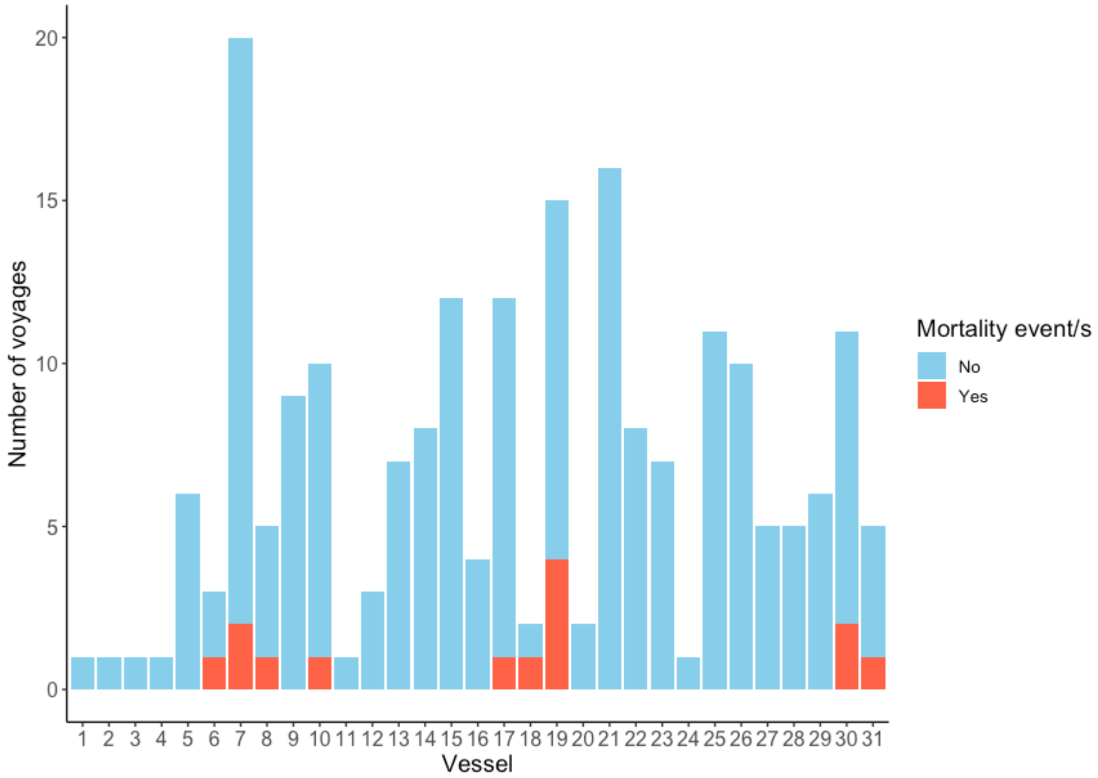
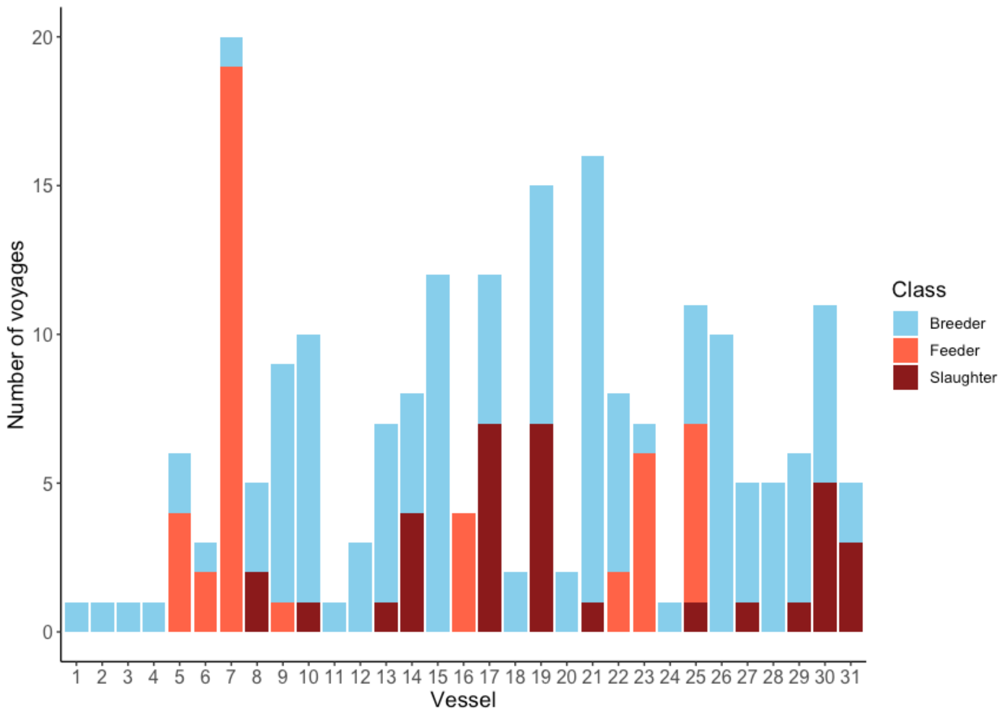


Figure 21 Heat stress-related mortality voyages distributed by vessel



The analysis also showed that some vessels tend to export the same class of cattle, as visualised in Figure 22.

Figure 22 Distribution of class of cattle by vessel



For each vessel, we analysed the ratio of voyages which reported heat stress-related mortality to total voyages undertaken. This ratio was between 1 in 2 (50%) and 1 in 12 (8%). However, some of these vessels only conducted a small number of voyages during the review period so significance is unclear. Table 20 shows vessels that experienced a heat stress-related mortality. Vessel 'F' reported 1 voyage with heat-stress related mortalities from a total of 2 voyages (50%). In contrast, vessel 'G' reported 4 voyages from a total of 15 voyages with heat stress-related mortalities (27%). There are factors relating to vessels, such as ventilation rates and the impact of changes to air flow requirements which had to be implemented by 1 January 2020 under Marine Order 43 (2018), that may influence voyage outcome. Further analysis of the influence of vessel on heat stress outcomes is necessary to determine significance.

Table 20 Summary of voyages with heat stress-related mortalities according to vessel

Vessel (de-identified)	Total number of voyages included in the scope of this review (of 214)	Frequency of voyages with at least 1 mortality due to heat stress (of 14)	Ratio
A	3	1	1:3
B	20	2	1:10
C	5	1	1:5
D	10	1	1:10
E	12	1	1:12
F	2	1	1:2
G	15	4	1:3.75
H	11	2	1:5.5
I	5	1	1:5

4.2.11 Summary of vessel analysis

- Some vessels appear to be overrepresented in terms of increased heat load and heat stress-related mortalities, noting that some vessels may more often carry slaughter cattle, which are at increased risk of heat stress-related mortalities.
- The analysis did not establish the significance of any particular vessel to the occurrence of heat stress outcomes.

4.3 Summary of key findings

Heat load:

- Approximately 1 in 4 long-haul *Bos taurus* voyages from southern Australia reported signs of increased heat load in 1 or more animals.
- These voyages covered all classes of cattle, to all destinations and from all departure ports in the review and departed during both the NHW and NHS.

Heat stress-related mortality:

- 6.5% of voyages recorded at least one heat stress-related mortality
- Approximately 2 in 3 heat stress-related mortalities were in combination with another issue. This issue was most commonly respiratory disease.

Class of cattle:

- There is a significant association between heat load voyages and class of cattle (P = 0.044), with slaughter cattle voyages at a greater risk of increased heat load.
- There is a significant association between heat stress-related mortality and class of cattle (P < 0.001), with slaughter cattle voyages at increased risk of heat stressed-related mortality.
- Slaughter cattle voyages have 38.8 times the odds (95%CI 4.80 – 561.10) of heat stress-related mortality compared with breeder cattle voyages.

Season:

- Approximately 1 in 10 voyages departing in the NHS resulted in at least 1 heat stress-related mortality.
- A lower proportion of departures in the NHW resulted in heat stress-related mortality (1 in 30).
- Voyages that departed in April, May or June had 2.6 times (95%CI 1.22 – 5.63) the odds of heat load or heat stress-related mortality than those departing during other months of the year.

Destination:

- The analysis did not establish a significant association between destination region and heat load voyages or heat stress-related mortality voyages

Departure port:

- A significant association was found between the occurrence of heat load voyages and departure port (P = 0.048).
- Voyages departing from Portland have 3.38 times the odds of heat load compared with voyages departing from Fremantle (P = 0.023).

Vessel:

- The analysis did not establish the significance of any vessel to the occurrence of heat stress outcomes.

4.4 Discussion and recommendations

4.4.1 Challenges faced

One of the challenges encountered during this review was that the analysis was highly dependent on voyage reports and therefore limited by the quality and quantity of available data in these reports. Determining the reliability of the reported data for accuracy and completeness was also challenging. There were some inconsistencies in voyage reporting which could not be explained. For example, some voyages recorded high deck temperatures, where historical studies suggest the cattle should have been showing evidence of increased heat load, but no evidence was reported. It is not known if this was a true occurrence or inaccurate reporting. Indeed, two voyages included reports of at least one mortality documented as heat stress, but with no reports that other cattle were showing signs of responding to increased heat. This seems illogical and raises questions about the accuracy and completeness of the dataset. This is further discussed in section 5.5.

Under ASEL 2.3, reporting requirements for daily voyage reports were limited. For example, a single measure per voyage per day of respiratory character or panting score was the minimum heat stress related requirement. This means the reporter provided an 'averaged' reading which does not provide any information about the range of cattle behaviours observed across the vessel. It also does not provide visibility about what happened in between daily reports. Voyage reporting also only provided a single deck temperature per day, meaning we have limited knowledge of the effect of duration of high temperatures and limited ability to determine if cattle were experiencing periods of respite. Where exporters voluntarily included daily deck heat stress measures and/or panting score, it is unclear whether the rankings within these were consistent and it is unclear what panting score system was used (possibly that described in the MLA Veterinary Handbook).

The timing and nature of changes introduced on 1 November 2020 under ASEL 3 made it challenging to determine how many pertinent factors may change or improve through ASEL 3 alone. The department notes that changes introduced under ASEL 3 may address some of the welfare issues raised in this export supply chain. We have tried to acknowledge these improvements when discussing findings and recommendations throughout our report.

Some voyage data was complex or limited and unable to be included in the analysis. For example, of the 214 voyages reviewed, only 204 voyages were included in the statistical analysis. Ten voyages were removed from the total of 214 to simplify the analysis because they contained consignments by two exporters or two departure ports. The occurrence of heat load events or heat stress-related mortality could not be accurately split by exporter or departure port based on the available data. Departure ports Port Adelaide and Geraldton were removed from the analysis because of their small number of departures but significance with regards to heat load and heat stress-related mortality. Their inclusion could have biased significance. In another example, the large number of vessels meant that it was not possible to include vessels as a variable in the analysis.

There was significant interaction and 'confounding' by inter-relating voyage factors which made the analysis challenging. For example, some vessels tended to carry the same class of cattle, and the same class of cattle were typically exported to the same destination. These collinearity issues constrained any reasonable analysis that considered the significance of both variables. We acknowledge it may not be possible to fully 'correct' for some of these confounding factors.

4.4.2 Discussion

The department's analysis shows that increased heat load can occur in across all classes of cattle, exported to any destination, from any departure port and in any season. For this reason it is recommended that heat stress risk management measures should be employed all year round for all classes of cattle to all destinations. This concurs with the TAC recommendation that heat stress risk assessment should apply to all *Bos taurus* cattle exports from southern Australian ports on voyages that will cross the equator with the additional recommendation that measures should be conducted all year, not just between 1 May to 31 October (inclusive).

There was a significant association of heat stress-related mortality with timing of departure. Voyages that departed in April, May or June had 2.6 times (95%CI 1.22 – 5.63) the odds of heat load or mortality than those departing during other months of the year. This finding contrasts with one submission that suggested there was little evidence of seasonal difference in mortality rates. This may be due to the assessment of cause of death in this review, which focused on heat stress-related mortalities, as opposed to all cattle mortalities.

In addition to the season of departure, there was a significant association of heat stress-related mortality with class of cattle with slaughter cattle voyages having significantly higher odds of heat stress-related mortality. One submission analysed mortality data from Reports to Parliament. This submission highlighted that voyages carrying slaughter cattle, departing southern ports in Australia during May to July appeared to have higher overall voyage mortality rates when compared with other months. This observation is supported by the findings of this review.

The increased risk of heat load in slaughter class cattle may be explained by a number of factors. The smaller surface area-to-mass ratio of these animals make it more challenging to dissipate heat. Slaughter cattle are usually heavier and fatter that other classes of livestock. Additional risk management measures for heat stress should be considered for long-haul slaughter cattle exports. Providing cattle additional space during the voyage, particularly during the AMJ season, may allow slaughter cattle to reduce heat load by evaporative losses. This could be achieved by providing cattle with more space in line with the HSRA model or a suitable allometric calculation.

Another potential risk factor for slaughter cattle is their diet, often grain or high in grain, which may increase metabolic heat production. As acknowledged in section 3.4 cattle fed a highly fermentable diet to increase growth rates are at greater risk of heat stress. One early submission to this review stated that slaughter cattle are often on high levels of nutrition for the purpose of maximising growth and to ensure they retain optimal bodyweight for slaughter. Another submission stated concern that 'grain-assisted' feeding practices prior to export may lead to subclinical or clinical gastrointestinal problems during the voyage that are exacerbated by heat stress.

The department does not have oversight on the feeding strategy of cattle prior to their entry into a registered establishment. Once there, we understand that all cattle are adjusted to the shipboard ration. A common mitigation measure on live export ships during times of high heat is to 'temporarily reduce or cease feeding of concentrate and consider a higher roughage proportion in ration' (Jubb & Perkins 2019). One submission to the review did suggest that further research could be undertaken to enhance the understanding of the role of diet in heat stress. It noted that 'research, to better define metabolic heat outputs directly relevant to diets and feed intakes typically encountered on livestock vessels, and their impact on individual animals and on deck temperatures … may improve management of … heat stress on livestock vessels.'

Two thirds of heat stress-related mortalities were identified as occurring in combination with other diseases, primarily respiratory disease. This suggests that concurrent illness may exacerbate susceptibility to heat stress. The high prevalence of respiratory disease in conjunction with reported heat stress-related mortality in our analysis is consistent with findings documented in literature (Lees et al. 2019) Cattle that are transported are at risk of BRD. A vaccination is available that provides protection from the most common aetiological agents of BRD. Vaccination of cattle, particularly slaughter cattle, may therefore reduce heat stress mortalities by reducing the occurrence of underlying disease.

We documented heat stress mitigation strategies employed during voyages, discussed in detail in section 3.3.2. These include washing decks and wetting animals, altering navigation strategies such as zig-zagging vessels, managing hot spots and the manure pad, and feeding an increased proportion of chaff. In addition, 1 submission highlighted other possible mitigation strategies that were beyond the scope of this review, including genomic selection of cattle. It is not clear how these strategies are used as a planned approach to mitigate heat stress. It is also not clear how effective these strategies are. We suggest that further research into heat stress mitigation strategies by industry is warranted.

Heat load and heat stress-related mortalities

Findings

1. There was evidence of increased heat load during long-haul Bos taurus voyages from southern Australia can occur in all classes of cattle (breeder, feeder or slaughter), to all destinations, from all departure ports and departing during both the northern hemisphere winter and summer.

2. *Bos taurus* slaughter cattle on voyages departing from southern Australian ports are at a higher risk of increased heat load than other classes of cattle.

3. *Bos taurus* slaughter cattle on voyages departing from southern Australian ports are at a higher risk of heat stress-related mortality than breeder cattle,

4. Two thirds of heat-stress-related mortalities were identified in combination with an underlying disease, primarily respiratory disease.

5. Heat stress mitigation strategies employed during the voyages were reported. While mitigation strategies are applied it is not clear if these are a planned or reactive approach.

Recommendations

1. A suitable HSRA should be employed all year round for *Bos taurus* slaughter cattle to all destinations.

2. Consideration should be given to providing *Bos taurus* slaughter cattle exported from southern Australian ports during the NHS additional pen space.

3. Vaccination against bovine respiratory disease may be valuable in decreasing its incidence and should be considered for voyages of *Bos taurus* slaughter cattle departing Australia from southern ports between 1 May and 31 October.

4. Ongoing examination of *Bos taurus* slaughter cattle outcomes should occur to assess the benefit of this preventative measure.

5. Further investigation beyond the scope of this review is warranted to explain why slaughter cattle voyages departing in late autumn and early winter have substantially higher mortality rates than in all other months of the year.

6. Further investigation beyond the scope of this review is warranted to explain why voyages departing from Portland having greater odds of heat load compared to voyages departing from Fremantle.

7. Further research should be undertaken into the effectiveness and appropriate employment of heat stress mitigation measures.

5 Other heat stress factors

5.1 Ventilation and hot spots on decks

The OIE Terrestrial Animal Health Code Chapter 7.2 Transport of Animals by Sea (OIE 2016) includes a generic requirement that the ventilation system must be adequate to meet the thermo-regulatory needs of the animals being transported. Details regarding how to achieve this are not explained and minimum requirements for air change rates, air flow rates over livestock pens or air quality parameters are not stipulated.

Australian ventilation requirements, efficacy and auditing are the responsibility of the Australian Maritime Safety Authority (AMSA). Standards applicable to ventilation of live export vessels are detailed in Marine Order 43 and

Appendix A: ASEL 3 standards applicable to heat and cold stress. ASEL 3 also requires daily and end of voyage reports to include any issues relating to ventilation.

MAMIC (2001) noted that the major source of deck heat is livestock-derived, from metabolic heat output. Adequate ventilation is necessary to maintain ambient conditions on decks to support welfare and physiological needs of livestock. It is also necessary to remove deck-side pollutants such as carbon dioxide and ammonia.

Additional heat sources on decks are from inefficient air intake systems (motor and fan inefficiencies) blowing frictional heat into the decks and radiated heat from walls (near engine rooms and fuel tanks), and ceilings (especially uppermost deck). Inefficient intake systems can add as much as 15% of the heat produced by livestock. Radiated heat can be significant in specific locations, also adding an amount of heat equivalent to 15% of the heat produced by cattle (MAMIC 2001).

5.1.1 Voyage analysis of ventilation and hotspots

We analysed daily and end of voyage reports for comments relating to ventilation and hot spots. Voyage reporting on ventilation was varied. Reports for:

- 65/214 (30.4%) voyages included no comment about the ventilation
- 104/214 (48.6%) voyages included subjective comments such as ‘good’, ‘excellent’ and ‘adequate’ regarding the effectiveness of the ventilation
- 45/214 (21%) voyages included objective comments on functionality of the ventilation system, such as whether it worked throughout the voyage without issues or disruptions.

Reporting for 2 voyages provided actual airflow measurements. It was not clear in either case whether these were real time measurements or reporting of the vessel’s known capability. The department understands that real-time airflow and air quality measurements during the voyage are possible.

Comments regarding issues with ventilation were generally rare. This may be because the ventilation generally worked well or may be due to under-reporting. Twenty-one out of the 214 voyages (9.8%) reported hot spots particularly near the engine room and on closed decks (Table 21).

It was not uncommon for the same vessel to receive both good comments on ventilation for 1 voyage and poor comments for another voyage. Reasons for this may be factors such as different ambient conditions, class of stock, stocking levels and competency/experience of the reporter.

The AAV on 1 voyage suspected that temperature readings on some decks were not representative of the whole deck because thermometers were placed near ventilation outlets or located centrally. Two IO reports noted that the wet bulb thermometers were not working accurately.

In a number of reports, it was noted that hot spots were destocked or lightly stocked if conditions became too warm. Rarely further detail was provided however in 1 report, the AAV made the following recommendation about stowage near a hot spot:

> It is strongly recommended that at this time of the year, the most heat tolerant cattle (ex-pastoral or *Bos Indicus* infused) be stowed in Hold 3 (on this vessel) particularly in the areas adjacent to the exhaust vents.

Only 1 voyage report provided a description of the temperature of the hot spot compared to surrounding pens. It noted that radiation heat from the engine room increased temperatures next to the engine room walls by 2°C compared to surrounding pens. The actual temperature was not noted.

Table 21 Hot spots identified in voyage reports

Vessel*	Location	Comment from reports
A	'aft section near engines'	'High temperatures'
B	Aft Deck 4 hold 2	'some known hot spots stocked lightly' 'Inadequate airflow to most pens in this location'
C		'additional fans for slow extraction areas'
D	Deck 5 hold 3	This location was noted to be hotter than other decks
E		'some known hot spots lightly stocked'
F	Deck 4 Deck 5–7	'pens under exhaust fans destocked' 'ventilation intake tower near engine room caused nearby pens to be up to 2°C warmer'
G		'areas of higher humidity had lower stocking density'
H		'one intake tower close to engine room doors can result in hot air intake'
I		'Some deficiency in airflow to small areas relative to outside conditions'
J		'Few hot spots, nearby pens lightly stocked'
K	Deck 4 hold 3	Hottest deck due to proximity to engine room
L	Deck 4 hold 3	AAV noted hot spots near engine room
M	Decks 4 & 5, hold 3	Highest heat loads observed in these areas
N	Hold 3	Hottest area
O	Deck 2 and Deck 4	'Hottest areas were deck 2 near the engine room and the whole of deck 4'
P	Decks 1–3	Increased heat load noted on these decks

*vessel labels in Table 21 do not match other lists of vessels

5.1.2 Summary of ventilation and hotspots

- Issues with vessel ventilation systems were rarely noted
- Sixteen vessels reported hot spots with 9.8% of voyages reporting hot spots
- Voyage reporting rarely provided any detail on hot spot monitoring and management unless conditions were warm enough to warrant movement of animals
- It is not clear from voyage reports how closely hot spot conditions are monitored, the extent of hot spot temperature differences with surrounding pens and whether there is any pre-determined approach or guidelines to managing hot spot areas.

5.2 Bedding and pad

ASEL 3 sets out the minimum requirements with regards to bedding on voyages. The standards require that bedding provisions be:

a) applied in a sufficient quantity that allows pens to be maintained in a manner that ensures the health and welfare of the livestock and minimises slipping, injuries, abrasions, lameness, pugging and faecal coating; and

b) applied prior to and during loading and unloading to minimise slipping during loading and unloading; and

c) be monitored routinely (at least daily) to ensure consistency and depth is appropriate to mitigate risks to the health or welfare of the livestock (Standard 5.1.10).

Bedding provides comfort and traction for livestock, improves air quality, absorbs moisture on decks and reduces humidity. The manure pad develops over pen flooring and is made up of bedding material, faeces, urine and environmental moisture. In most environmental conditions the ship's ventilation system draws moisture out of the pad allowing a firm to tacky layer to develop (Jubb & Perkins 2019).

With regards to heat stress, the main welfare risks relate to wet, sloppy pads and the amount of faeces. High ambient temperatures on a deck will cause an increase in the amount of water consumed by the livestock and when water consumption increases, urine output will also increase. The manure pad will deteriorate when animals are producing more liquid waste than the bedding can absorb and the ventilation system can evaporate. The evaporation of moisture from the manure pad will also make conditions more humid on decks (McCarthy & Banhazi 2016).

Wet pads can result in poor welfare conditions (Banney, Henderson & Caston 2009; McCarthy & Banhazi 2016) including:

- coat contamination which particularly affects medium to heavy-coated animals; when marked, this can impact the animal's ability to dissipate body heat
- limited mobility and access to all areas of a pen
- lameness and abrasions due to soft feet
- poor air quality due to ammonia
- unhygienic conditions which support the spread of disease

- reluctance to lie down, drink and feed.

Feedback during industry consultation has described differences in the way the manure pad is managed at different times of the year. In the NHW, it may be possible to undertake a final wash 3–4 days prior to arrival, with the pad remaining dry and in good condition. In the NHS, undertaking a deck wash as closely as possible to arrival is ideal, as the pad is likely to deteriorate very quickly at this time of year.

The importance of pad management has been noted in industry publications (Banney, Henderson & Caston 2009; McCarthy & Banhazi 2016). These relay the importance of pre-determined deck washing plans and use of an appropriate substrate in sufficient amounts to assist pad development and moisture absorption.

Banney, Henderson & Caston (2009) noted that:

> Based on current mortality rates and estimates of poor health attributable to bedding management, the cost of bedding is not likely to be recouped by a reduction in mortality rates alone. However, while the cost of bedding may not be justified purely in commercial terms through reductions in mortalities, lameness and possible live weight loss, addressing the welfare issues through bedding management will have a positive impact on the animal welfare image of the industry, assisting its long-term viability.

5.2.1 Voyage analysis of bedding and pad

Deck washing was regularly noted in voyage reports. This was often implemented as the vessel neared humid conditions around the equator as well as at other times. The frequency of deck washes varied from not at all (n=2) to as often as every second day. Most voyage reports noted that deck washing, and substrate (sawdust or wood shavings) application was readily and appropriately used to support pad management.

It was rarely clear whether the approach to deck washing was pre-determined or ad hoc. Issues with deck washing included inadequate water pressure, poor drainage resulting in flooding of pens or wet pads, and inadequate frequency.

The most common pad issue related to wet, sloppy pads (n=44). This was related to humid conditions or issues with flooding or leaking pipes and troughs. A small number of voyages noted that the pad was poorly managed. This was observed or noted to be because deck washing was not frequent enough (n=6), there was insufficient substrate or substrate was sparingly used (n=8). Reported welfare consequences of inadequate pad management included coat contamination (n=1), lameness (n=4), and ammonia build up in the environment (n=2).

5.2.2 Summary of bedding and pad

- Sloppy pads were noted on 44 of 214 voyages (20.6%)
- Pad management was usually reported to be adequate with appropriate use of substrate and deck washing
- Fourteen of 214 voyages (6.5%) reported inadequate pad management
- Welfare consequences of inappropriate pad management included coat contamination, lameness and ammonia build up.

5.3 Water provision

Clinical observations of animals subject to high environmental heat and humidity include an increase in evaporative heat loss and an increase in water consumption (Barnes et al. 2008; Beatty 2005; Stockman 2009). It is imperative that cattle have an adequate source of clean drinking water during periods of high environmental temperatures.

5.3.1 Voyage analysis of water provision

The analysis identified voyages that recorded minor and major water provision issues and the corresponding actions taken during these voyages. Many of these issues were found to be minor and short-term and were addressed during the voyage. Examples are given below.

Displaced water troughs

There were accounts of poorly secured water troughs being knocked off railings on 3 voyages. In these instances, IOs reported that the issues were addressed by the crew through regular monitoring and reinstalling displaced troughs. On all 3 voyages IOs onboard reported that sufficient water was available throughout the voyage.

Water supply system issues and empty water troughs

Issues with water supply were noted on 15 (7% of) voyages. Minor and temporary issues included broken floats or valves (n=3), troughs knocked off railings (n=3), cessation to water supply for cleaning (n=4) or unknown (n=2). These issues were rectified without any reported impact to health and welfare of cattle.

More significant issues with water supply were noted on 3 (1.4% of) voyages:

- The IO report for one voyage noted issues with empty water troughs. There were several non-systemic causes. Two pens did not have water for a period when water valves were not turned on after cleaning. Empty troughs were also caused by float valves being incorrectly set. Two decks were out of water for 45 minutes when higher demand for water could not supply upper decks. These issues were addressed by the crew at the time they were noted
- On one voyage the IO report noted that drinking water to the upper decks was not supplied *ad libitum* on days 5, 7, 10, 11, 12, 13, 15, 17 and 18 as evidenced by the presence of empty water troughs. Remedial action by the crew was undertaken on each occasion to resolve the issue and supply water. After longer outages, the cattle were queuing to drink. The department referred the water supply issue to the exporter and AMSA
- Another voyage reported issues with *ad libitum* water supply. Water and feed troughs were not properly secured to the rails and were regularly pushed off the rails by cattle. Several issues were identified relating to hose connections, broken isolating switches and a lack of spare parts. These issues meant it was not possible to leave the deck water on without supervision. Many troughs were disconnected each day when staff were not on the deck. This issue was referred to AMSA which applied conditions to the vessel's Australian Certificate for the Carriage of Livestock (ACCL), preventing it from undertaking long-haul voyages (i.e. >10 days) until actions were taken to address the drainage and trough issues. Subsequent reporting by IOs on this vessel noted only minor issues which were readily fixed.

Water quality

Issues with water quality were identified on 9 voyages. Most of these were readily addressed by the crew. Issues with rust or rusty discolouration were noted on 2 voyages. On 1 of these voyages the IO reported water lines were flushed to clear the contamination. The other voyage did not carry an IO, but the voyage report noted that the water supply needed regular attention due to rust, although no disruption to water supply was reported.

Difficulty in operating nose bowls

On 2 voyages it was noted that animals were experiencing initial difficulties in operating nose bowls. On 1 voyage the cattle took 1 to 2 days to become accustomed to using the nose bowls. A number of voyages noted that the use of nose bowls was monitored closely.

5.3.2 Summary of water provision

- Issues with the provision of water were reported on 7% of voyages, while 1.4% of voyages reported more significant water supply issues
- Water issues were generally non-systemic in nature, and usually rectified at the time
- More significant issues raised by IOs were addressed with the exporter or AMSA.

5.4 Pregnant cattle

Scientific literature describes that increased heat load impairs numerous functions associated with fertility and establishing and maintaining pregnancy (Lees et al. 2019). Heat stress may be detrimental to early-stage pregnancy and the period prior to full establishment of the placenta (De Rensis, Garcia-Ispierto & Lopez-Gatius 2015). Heat stress is also of concern in late gestation when its influence can affect milk yield after calving and have long term negative impacts on calves (Hansen 2019).

Appropriate heat stress thresholds for pregnant cattle have not been clearly defined. A study of 6 pregnant dairy heifers at 3–5 months gestation (average weight 420 ± 19kg) found the heat stress threshold to be 27°C to 28°C WBT (Barnes et al. 2008). This was based on an increase in mean daily body temperature up to 1°C and clinical signs of heat stress such as open mouth panting. Further literature on the influence of breed, weight, class, acclimatisation, duration of hot conditions and influence of live export conditions specific to pregnant cattle was not found.

Some submissions raised concerns about the export of pregnant cattle. The risks associated with heat stress in pregnant cattle mainly referred to the risk of abortion and, to a lesser extent, premature lactation in pregnant and non-pregnant dairy heifers. Gaps in evidentiary knowledge on heat stress were also highlighted, as outlined in Collins, Hampton & Barnes (2018) such as 'experimental manipulation of variables that influence heat load, further assessment of the HSRA and development of a suite of animal welfare indicators to identify at risk animals before severe heat stress occurs'. These gaps pose challenges to policy development.

5.4.1 Australian Standards for the Export of Livestock

Except for 2 months (November and December 2020), all voyages analysed for this review were governed by standards in ASEL 2.3. The ASEL 3 standards include requirements relating to the export of pregnant cattle (Appendix A).

These include:

- pregnancy testing
- the maximum gestation period permitted for exported cattle at the time of arrival at the destination

- that an AAV must accompany voyages with pregnant cattle (unless otherwise agreed)
- 15% extra space
- additional feed requirements
- additional veterinary medicines
- a pregnant cattle management plan for southern sourced *Bos taurus* voyages crossing the equator from 1 May to 31 October.

There are some important changes to the management of pregnant cattle within ASEL 3 that may reduce the risk of heat stress in pregnant cattle. This includes providing additional space and the use of a pregnant cattle management plan.

There is a provision for 15% additional space for pregnant cattle over the default and alternative space requirements. Under ASEL 3 pregnant cattle will receive 15–34% additional space compared to ASEL 2.3 depending on body weight. For example, pregnant heifers weighing between 280kg and 320kg exported between 1 May and 31 October on default space allocation will be provided 24% to 20% (respectively) additional space compared to the allocation under ASEL 2.3.

ASEL 3 requires that southern sourced pregnant *Bos taurus* cattle crossing the equator from May to October are exported under a management plan approved in writing by the department. This was not a requirement under ASEL 2.3. The management plan must include details of how the exporter intends to manage animal health and welfare risks associated with sourcing and exporting. Particular focus is placed on mitigation measures to address risk of injury and stresses (that may lead to heat stress, abortion and early births, premature lactation and other health and welfare issues).

5.4.2 Voyage analysis of pregnant cattle

Of the 214 voyages analysed for this review, 132 loaded cattle classified as 'breeders'. It was found that at least 41 of these voyages included pregnant cattle.

Prior to the introduction of ASEL 3, exporters were not required to disclose whether a consignment included pregnant cattle. This posed a challenge for the analysis of thermal stress in pregnant cattle. The known pregnant cattle voyages were determined by searching TRACE (Tracking Animal Certification for Export) documents for any confirmation of pregnant cattle. A load plan is not a core document so in most voyages, the location of pregnant cattle is unknown which limits the ability to attribute deck-specific observations.

These data challenges limited the validity and depth of this analysis and it is uncertain to what degree it is representative of pregnant cattle export voyages. The introduction of LIVEXcollect under ASEL 3 is expected to significantly improve reporting on pregnant cattle. LIVEXcollect requires reporting of whether a pregnant cattle management plan has been implemented, the occurrence of abortions and births and any relevant details.

Noting reporting limitations, a summary of the 41 voyages is provided below:

- Twenty-one of 41 (51%) voyages departed during the NHS

- Destination countries included China (35), Oman/Pakistan (1), Oman/UAE (1) and Pakistan (4)
- The mortality rates for these voyages ranged from 0.00% to 0.46% with a mean voyage mortality rate of 0.16%
- Forty of 41 voyages recorded a maximum WBT of 26°C or more for at least 1 day. The highest WBT, 32°C, was recorded on 2 voyages. The mean maximum WBT was 29.0°C
- Nineteen of 41 (46%) voyages recorded evidence of cattle responding to hot conditions
- These nineteen voyages noted increased water consumption (n=14) and/or a decrease in feed consumption (n=7)
- Twelve of 19 voyages noted alterations to respiratory character (11) and/or increased panting score/heat stress score (n=5)
- Eleven of the 19 voyages departed during the NHS while 8 departed during the NHW
- There were no reports of mortalities of pregnant adult cattle attributed to heat stress
- Ten of 41 (24%) voyages recorded abortions.

Of the 10 voyages that recorded abortions, 1 voyage recorded 3 abortions with the main differential diagnosis noted as heat stress. Two voyages recorded 2 abortions and 7 voyages recorded 1 abortion. No reasons were provided for the abortions reported on the latter 9 voyages. Of these 9 voyages, 5 also reported physiological responses to increased heat load (increased respiratory character or panting score). The remaining 4 voyages did not include reports of any cattle response to heat load. This information is tabulated below (Table 22).

Table 22 Relationship of the occurrence of abortions on 10 long-haul *Bos taurus* voyages from southern Australian ports to voyages with reported response to increased heat load

	Voyages including reports of cattle response to heat load and abortions	Voyages with no reports of cattle response to heat load and abortions
Destination	China (4); Oman/UAE (1); Pakistan (1)	China (3); Pakistan (1)
Multiple abortions (3)	1	0
Multiple abortions (2)	1	1
Single abortions	4	3
Abortion reported to be related to increased heat load	1	0
No reason provided for abortion	5	4
Departure during NHS	4	1
Departure during NHW	2	3

Source: DAWE (2020); NHS = northern hemisphere summer (1 May to 31 October); NHW = northern hemisphere winter (1 November to 30 April).

The one voyage that reported abortions with the main differential diagnosis noted as heat stress, departed Portland in March bound for Pakistan transporting *Bos taurus* dairy cattle with an average weight of 365kg. Two cattle mortalities unrelated to heat stress were recorded on this voyage. From day 13 until discharge on day 24, deck temperatures ranged from 27°C WBT to 29°C WBT. From day 13 until day 22 (10 days), respiration was noted to be 'generally normal with intermittent panting.' The exception to this was day 21 when 'some open mouth panting' was noted. The abortions occurred on day 17, day 22 and day 24. The extended duration of hot conditions and the heavier body condition are likely to be factors associated with the abortions.

There is no clear seasonal effect on abortions. Five of the 10 voyages where abortions were reported departed during the NHS, and 5 departed during the NHW. Of voyages that reported responses to heat load and noted abortions, 4 departed during the NHS and 2 departed during the NHW. The sample is small and no clear seasonal influence can be deduced with regards to heat stress related risk to pregnant cattle. This concurs with the general findings of the heat load analysis.

Premature lactation is a poorly understood and rarely documented condition in live exported dairy cattle. Mansell et al. (2012) state that premature lactation has been reported in live exported dairy breeds of cattle but not in beef breeds. The syndrome involves the rapid development of the udder and the commencement of lactation not associated with calving. One submission stated that 'it is likely to be associated with feeding management and thermal conditions during transport'.

Premature lactation was reported on 2 of the 41 voyages analysed. Both of these voyages reported signs of increased heat load in cattle. One departed during the NHS and recorded a maximum temperature of 28.6°C WBT. The other departed during the NHW and recorded a maximum of 31°C WBT. In both cases the cattle were managed by feeding chaff and moved to cooler areas of the vessel where possible.

The frequency of voyages reporting premature lactation is small which makes it difficult to determine its significance. One submission recommended that 'documentation of the occurrence of premature lactation during voyages, accompanied by detailed information regarding livestock factors, environmental conditions and resource management could improve our understanding of this issue'. We agree that further information is required to better understand the disease and its welfare significance and encourages further industry driven research on the matter.

5.4.3 Summary of pregnant cattle

- Ten of 41 voyages carrying pregnant cattle reported abortions
- One voyage recorded abortions related to heat stress
- There was no clear seasonal trend to the occurrence of heat stress risk in pregnant cattle
- Under ASEL 3, pregnant cattle are receiving additional space
- Improved reporting on pregnancy, abortions and premature lactation could assist future analyses.

5.5 Reporting of heat stress

The assessment of 214 voyages for evidence of heat load noted some reporting anomalies. Four of the 14 voyages with reports of heat stress-related mortalities did not report any other evidence of hot conditions, such as increased respiratory rate or heat stress score in any other cattle on board the vessel. It would be reasonable to deduce that if a voyage reported a heat stress-related mortality, other cattle on the voyage would likely have demonstrated elevated respiration rates or other signs of heat stress. Inconsistences in the reporting of respiratory character were also raised in a submission.

Voyages with WBTs that would be considered hot (based on literature of HSTs) did not always report evidence of heat stress. In total, 15.4% (n=33) of voyages reported maximum deck WBTs of 30°C or greater with no reported evidence of heat stress. One voyage carrying feeder and slaughter cattle reported a mortality rate of 1.8% for lines of cattle housed on 1 particular deck (overall voyage mortality rate was 0.8%). This voyage recorded 9 consecutive days with maximum deck WBTs at ≥28°C. This period included 3 consecutive days of maximum deck WBTs at 30°C. Mortalities were mostly attributed to pneumonia or 'unknown' causes, with no mention of hot conditions contributing to mortalities. In addition, every daily report recorded the same respiratory rate and a respiratory character rating of '1' ('normal'). Examples such as this raise the possibility that reporting could be limited or inaccurate.

Some inconsistencies may be attributed to the fact that reporting requirements under ASEL 2.3 were limited. Historical reporting only allowed for a single entry per deck per day for relevant physiological and behavioural signs. This means daily reports recorded a single rank of respiratory character or heat stress score per deck, with no ability to capture the number of animals displaying these signs. This would result in the reporter 'averaging out' symptoms for each deck. Additionally, records were often abbreviated or with vague statements, meaning it was not always possible to determine their accuracy and completeness.

This issue may be alleviated by the introduction of LIVEXCollect on 1 November 2020. LIVEXCollect is a data collection and management system administered by LiveCorp for use on livestock export vessels to improve consistency in the way livestock observations and other measurements are recorded and reported. The LIVEXCollect forms standardise data entry and reporting in accordance with ASEL, allowing for improved data aggregation and analysis. Daily and end of voyage reporting is then provided to the department in a consistent form. This aligns with findings in the Inspector-General of Live Animal Exports report on monitoring and reporting during livestock export voyages (March 2020). The Inspector-General recommended improvements to the quality, standards and analysis of reported data.

The Moss review noted that inconsistencies may be attributed to an unwillingness to raise concerns by the person reporting. Moss noted that 'AAVs appear have an inherently conflicted role. While they are required to report to the department on animal welfare issues, they are either employed, or engaged by exporters or contracted on a consignment by consignment basis'.

Another issue relates to the fact that daily deck temperature recordings may not accurately reflect actual conditions. Data loggers on live export voyages to the Middle East regularly record variations in WBT of 6°C within a 24-hour period, especially near the start and end of voyages when the distance from the equator is greatest. Closer to the equator, daily WBT fluctuations are more typically 1–3°C in a 24-hour period. Several voyage reports note that some of the wet bulb thermometers were not reading accurately. A number of voyages might record 1 temperature in the daily report but note temperatures exceeding these in reporting commentary. This indicates that having a set time each day to note temperatures in daily reports does not capture the actual range experienced for that day. Having an appreciation for diurnal temperature variations and the extent of respite periods during hot conditions can provide important information to AAVs and stockpersons monitoring a voyage where cattle are at risk of heat stress (HSRA Technical Reference Panel 2019).

5.5.1 Summary of reporting of heat stress

- Evidence of heat stress (elevated respiratory rates, altered respiratory character, increased panting score or heat stress score) was not consistently recorded or reported
- The maximum temperature recording may be inaccurate in some voyage reports.

5.6 Discussion on other heat stress factors

Voyage reporting indicates that many vessels have hot spots. It is possible that stockpersons and crew are monitoring these areas more closely, but this is not clear from voyage reports. Only 1 voyage reported a temperature difference between a hot spot and surrounding areas, but otherwise actual conditions in these areas are not reported. It is difficult to assess specifically how hot spots should be monitored and managed without an understanding of temperatures experienced. Improved accuracy and recording of diurnal ranges of deck temperatures could be assisted by the use of data loggers on all long-haul cattle voyages. Placement and maintenance of these data loggers is also of critical importance.

Reducing stocking rates in affected pens assists airflow around animals to support evaporative cooling and provides cattle with easier access to water troughs. However, if conditions are hot enough, a single animal in a hot pen will still be at risk of heat stress. This highlights the value of using data loggers to continually record temperatures in affected areas. This will assist decision making around the use of pens in hot spots and appropriate mitigation measures.

In this analysis, 20.6% of voyages reported sloppy and wet pads. We encourage exporters to include pad management plans in their approved arrangements. This should include instructional material for stockpersons and AAVs. The pad management plan should include an intention to discuss pad management during the daily meeting, the provision of highly absorbent bedding substrate and clear instructions for the use of substrate on board vessels.

We acknowledge that under ASEL 3 there are additional requirements regarding bedding application and monitoring. This may influence pad management outcomes in the future. Accurate reporting on pad issues will assist when making assessments regarding adequacy of bedding requirements. The next ASEL review should investigate the adequacy of bedding required under ASEL 3 for long-haul voyages from southern Australian ports. The appraisal of 41 voyages of pregnant (and non-pregnant) *Bos taurus* breeder cattle from southern Australian ports noted the occurrence of abortions on 10 voyages. Six of these voyages also reported evidence of heat stress, while 4 voyages reported no evidence of heat stress. Voyages reporting abortions were split evenly between NHS departures (n=5) and NHW departures (n=5). Of the 6 voyages with abortions and evidence of heat stress, 4 departed in the NHS and 2 departed in the NHW. Although case numbers are small, these findings do not show a strong association between the risk of abortion and any particular northern hemisphere season.

ASEL 3 Standards applicable to pregnant cattle provides additional pen space for pregnant cattle which may mitigate the risk of heat stress and associated abortion. As there does not appear to be as seasonal trend in heat stress risk in pregnant cattle, we the department recommends pregnant cattle management plans for *Bos taurus* cattle departing from southern ports and crossing the equator, should be employed for all months of the year.

The inconsistent reporting of heat stress signs warrants attention. Clarifying the use of and appropriateness of cattle panting scores through discussion with users could unearth issues with existing reporting methodologies. Such a discussion should include AAVs, stockpersons, exporters, heat stress technical experts, welfare groups and the department. A review of cattle panting scores has been incorporated in the department's forward plan.

Issues with water quality and supply during voyages were not systemic. In general, minor issues were associated with mechanical problems and corrective measures were taken immediately. Issues concerning water delivery interruptions and water quality were vessel specific. Reports indicate that where significant issues were identified the necessary corrective measures were taken by the crew. Exporters were notified of any major repairs or improvements that were needed before future voyages. Significant water provision issues were not noted as a systemic failure on long-haul *Bos taurus* voyages from southern Australian ports.

Some aspects of thermal stress that were raised in early submissions are beyond the scope of this review, including vessel design and infrastructure, training and experience of veterinarians and stock people. We encourage ongoing research and discussion into the issue of heat stress in cattle.

Other heat stress factors

Findings

Hot spots:

6. Voyage reporting rarely provided any detail on hot spot monitoring and management.

Bedding and pad management:

7. Welfare consequences of inappropriate pad management were noted on some voyages. The most common pad issue related to wet, sloppy pads in humid conditions.

8. ASEL 3 has implemented additional requirements regarding bedding use, application and monitoring.

Pregnant cattle:

9. There was no clear seasonal trend to the occurrence of heat stress risk in pregnant cattle.

10. The frequency of voyages reporting premature lactation is small which makes it difficult to determine its significance.

Reporting heat stress

11. Daily deck temperature recordings may not accurately reflect actual conditions.

12. Evidence of heat load (elevated respiratory rates, altered respiratory character, increased panting score or heat stress score) was not consistently recorded or reported.

Recommendations

8. Hot spots on vessels should be identified and monitored using standardised and well-maintained data loggers to support the management of cattle in these areas.

9. Exporters should implement proactive pad management during voyages. These should include specific contingencies for addressing sloppy pads in hot, humid conditions.

10. The next ASEL review should investigate the adequacy of ASEL bedding requirements for long-haul voyages out of southern Australia.

11. In addition to reporting on abortions and births, daily reports should also require reporting on premature lactation.

12. On board data loggers should be used to improve the monitoring of deck temperatures.

13. The use of and reporting of cattle panting scores should be consistent. A discussion between AAVs, stockpersons, exporters, heat stress technical experts, welfare groups and the department would promote this.

6 Cold stress

6.1 Physiology of cold stress

Cold stress has been described in a number of ways in scientific literature. According to Abbas et al. 2020, temperatures below the thermoneutral zone (TNZ) threshold can result in cold stress. Wagner (1988) states that as the temperature declines below the lower critical temperature (LCT), cold stress on an animal increases.

When ambient temperature drops below the LCT, cattle exert extra energy and increase heat production to maintain normothermia. The main physiological response of animals under cold stress is to up-surge heat production and decrease heat dissipation to maintain a constant body temperature. Cattle increase heat production by increasing their metabolic rate and cardiac output, redistributing of blood flow (including by cutaneous vasoconstriction), and a mobilising of fat stores and glucose for metabolism (Broucek et al. 1991). Wagner (1988) states the increase in metabolic rate during cold periods can be as much as 20–30%.

Cattle increase feed intake in order to meet the increased energy demand and a failure to do so results in weight loss (Wagner 1988). A decrease in water intake has also been noted (Anderson et al. 2011).

6.2 Assessing cold stress

6.2.1 Measuring cold stress in animals

As noted in section 3.3.3 of this draft report, measuring core body temperature is an accurate method for assessing response to both hot and cold conditions. However, as this remains impractical during live cattle voyages, assessing behavioural and physiological responses to cold conditions may be more appropriate. Behavioural and physiological signs of cold stress in cattle include (Barnes et al. 2018; EFSA 2011; European Commission 2017; Young 1983):

- low core body temperature less than 35°C
- increased appetite/feeding
- reduced water consumption
- reduced movement
- grouping or huddling
- shivering
- weight loss / reduced body condition
- increased respiratory effort and increased heart rate
- erratic behaviour
- collapse / inability to rise from a lying position
- death.

6.2.2 Measuring cold stress in the environment

There is minimal literature directly relating to cold environmental conditions and the export of livestock by sea. Scientific articles on cold stress found during our literature review were predominantly from North America, Europe or the Russian Federation. General literature and descriptions of cold stress use dry bulb temperature (DBT) as a measure, as well as identifying windchill and moisture (rain, snow) as being critical factors influencing the ability of cattle to tolerate cold temperatures (Wagner 1988, Young 1983). Rain and wind are influential, especially in combination, due to the rapid cooling effect of air movement on wet surfaces.

The impact of windchill on the 'effective' temperature experienced by the cattle is likely to be significant (Marston et al. 1998; Tarr 2007). For example, at wind speeds of 16 km/h, 'effective' temperatures may be lowered by 6–7°C.

An early stakeholder submission noted that 'the department should develop a Cold Stress Risk Assessment model, equivalent to the HSRA model, and that this should also factor in additional stressors associated with extreme temperature variations'. We note that industry has developed information manuals including the *Beef Breeder Manual for cold winter climates* (Miller, Cobiac & Inerbaev 2015) and the *Cold Climate Destination Checklist for Cattle* (LiveCorp. & MLA. 2020).

6.3 Animal factors influencing cold tolerance

Beef cattle that are composed primarily of *Bos taurus* genetics are adapted to cool climates and are known to tolerate cold temperatures remarkably well. Young (1983) stated that:

> cold-adapted adult ruminants on full feed and with substantial thermal insulation are very cold hardy and have generally very low LCTs such that in dry, cold, agricultural regions they rarely experience direct cold stress.

This description, however, acknowledges the variety of animal factors in play. Animal factors influencing cold tolerance include breed, acclimation, nutrition, age, BCS and coat condition.

6.3.1 Cattle breed and age

Bos taurus have a better ability to adapt to cold conditions than *Bos indicus.* Brahman calves have, for example, been shown to experience more difficulties adapting to cold environments compared with crossbred calves (Roland et al. 2016). In a study by Godfrey et al. (1991) Brahman calves showed reduced ability to respond to cold conditions and impaired thermoregulation compared to crossbred calves. The Brahman calves had lower rectal temperatures and were less able to use energy-containing blood constituents (glucose, triglycerides, fatty acids) to increase their body temperature when exposed to cold conditions (4°C).

Ferguson et al. (2008) state that:

> older, reasonably well-grown animals…are more tolerant of cold weather than thinner, younger animals. This is partly due to increased muscle and fat and a greater body volume: surface area ratio which lessens heat loss to the environment.

Phillips (2008) and Wagner (1988) suggest that adult cattle in good condition can tolerate cold stress due to their size and the heat of food digestion. Morignat et al. (2018) showed that cattle of all ages were at risk of mortality if cold exposure was prolonged.

While cattle under 200kg can be sourced for export by sea under a 'light cattle management plan', cattle must be at least 200kg at the time of export.

6.3.2 Body condition score

Cattle with lower BCS are much more susceptible to cold stress than cattle with a higher BCS (Tarr 2007). Large fat deposits in cattle with higher BCS provide insulation and energy reserves when exposed to cold conditions (Anderson et al. 2011).

ASEL 3 (standard 1.4.4) requires that cattle sourced for export must have: 'a BCS of 2 to 6 (inclusive) (on a scale of 1 to 7), unless they are *Bos taurus* cattle sourced for export from, or exported through, any area of Australia north of latitude 26° south between 1 October and 31 December (inclusive), then they must have a BCS of 2 or more but less than 5 (on a scale of 1 to 7).'

Noting that the ASEL BCS scale starts at 1, literature indicates that cattle of BCS 2 will be significantly more susceptible to cold exposure than cattle of BCS 6. The susceptibility of leaner animals to cold conditions should be taken into account by exporters when assessing any request to export animals under a light cattle management plan and vessel load plan.

6.3.3 Coat thickness and condition

An animal's coat plays an important role in an animal's tolerance of cold conditions (LiveCorp. & MLA. 2020). This is dependent on coat thickness, moisture content and windchill factors. One stakeholder submission noted that 'cold stress is largely moderated by coat thickness, insulating fat cover and metabolic heat increment of digestion'.

Coat thickness varies depending on season, climate, breed and genotype. Cattle with thicker coats have been identified as having lower LCTs (Marston et al. 1998). Cattle adapted to colder climates prior to export are likely to have thicker coats, impacting their susceptibility to heat stress and tolerance of cold conditions.

Mader & Griffin (2015) describe that an animal's energy requirements to maintain normothermia in cold conditions might double if the coat is wet and muddy, particularly if there is no protection from wind. Anderson et al. (2011) also noted the compounding impact of wind chill exposure in developing the cold stress.

Wet conditions are an important consideration on board a livestock vessel when animals are exposed to direct windchill (open decks) and high ventilation rates. To ensure coats are not wet as a vessel nears cold conditions, consideration should be given to timing and method of deck washing to avoid wetting of livestock and allow time for coats to dry.

The publication *Cold Climate Destination Checklist for Cattle* (LiveCorp. & MLA. 2020) indicates that cattle with a heavy winter coat have a much lower LCT (−8°C) than non-adapted cattle with a slick summer coat (+15°C). Cattle exported from an Australian summer to a northern winter will not have the insulation of a heavy winter coat. The LCT is also affected by wet and muddy coats and by the insulation provided by subcutaneous fat, cattle in lower body condition have less subcutaneous fat.

6.3.4 Acclimatisation

Acclimatisation is discussed in relation to heat tolerance in section 3.4.3. The same principles are relevant to an animal's tolerance of cold conditions.

Examples of seasonal acclimatisation to cold include increased thickness of hair coat, fat deposition and increased feed intake (Roy & Collier 2012). Young (1981) and Brown-Brandl et al. (2003) state that metabolic rate and heat production increase with cold climate and decrease with warm climate. Animals kept permanently under cold climatic conditions exhibit and increased basal metabolic rate and a reduced upper and lower critical temperature (Webster et al. 1970; Young 1983; Robinson et al. 1986).

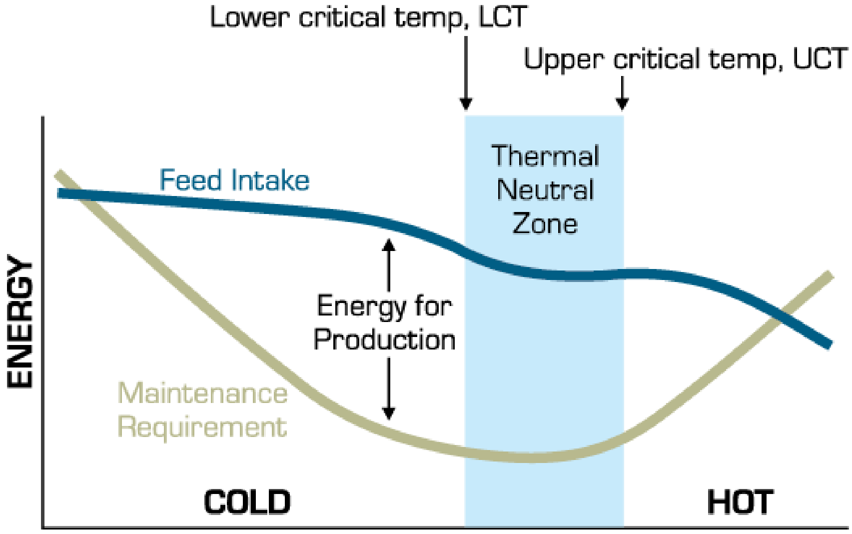
6.3.5 Diet

Maintaining feed quality and quantity is essential for cattle to maintain, or gain, body weight during exposure to cold conditions. Adequate energy from a quality diet, supports metabolic heat production to maintain normothermia during cold stress conditions. This was noted in 2 stakeholder submissions.

Maintenance energy requirements for cattle can increase dramatically with increasing coldness below the TNZ. Feedlot studies by Bourdon et al. (1984) showed increases in maintenance requirements of up to 25–37%. Tarr et al (2007) cited that the general rule for every degree that ambient temperature is below the LCT, cattle require approximately 2% increase in energy requirement. The cold climate checklist (LiveCorp. & MLA. 2020) states a higher requirement of 1.8 to 2% increase for every 1°C drop in effective temperature below their LCT.

Beef cattle subjected to conditions below the LCT will voluntarily increase feed intake subject to feed accessibility and availability. This may be by as much as 5 to 10% above thermoneutral maintenance for ambient temperatures ranging from −5°C to −15°C (Anderson et al. 2011). The higher feed intake raises body heat production in response to cold exposure by increasing metabolic rate (heart rate, respiration, and blood flow). Figure 23 Relationship of feed intake and maintenance requirements to temperature (adapted from NRC 1981)Figure 23 shows the correlation between feed intake and maintenance energy requirements at different ambient temperatures.

Figure 23 Relationship of feed intake and maintenance requirements to temperature (adapted from NRC 1981)



Source: Anderson et al. (2011)

Timing of feeding influences the timing of heat output. Konandreas, Anderson & Addis (1982) noted that during severe cold conditions, feeding cows later in the day ensured that feed-related increases in metabolic heat production coincided with colder conditions at night.

One submission noted that cold stress in cattle may only become evident upon arrival at the importing country when, under cold conditions there may be inadequate feed available to meet the increased metabolic demands of the thermoregulatory system. Conditions on arrival are outside the scope of this review.

Studies of feedlot cattle in winter have shown that cattle benefit from diets that are higher in energy when wind chill index increases (Mader & Griffin 2015; Wagner 1988).

Wagner (1988) noted that drinking excessively cold water or being unable to access water because it is frozen can exacerbate cold stress by reducing feed intake. In cattle, feed intake is linked to water intake and, in cold weather, warming the water will increase feed intake (Petersen et al. 2016).

6.4 Cold stress thresholds

The literature on cold stress mostly relates to northern hemisphere conditions with a general focus on appropriate management of production animals through winter and extreme cold conditions. Conditions described in literature can be significantly colder (as low as −35°C) than those experienced on livestock vessels during export from southern Australia.

A wide range of LCTs are described in literature such as 0°C (Broucek, Letkovicová & Kovalcuj 1991), 4°C for dairy breeds (Abbas et al. 2020) 5°C for dairy breeds (De Rensis, Garcia-Ispierto & López-Gatius 2015) and −21°C for acclimatised beef cattle in northern United States (Anderson et al. 2011). According to Young (1983) ‘lactating and fattening cattle are extremely cold-hardy and rarely experience climatic conditions below their lower critical temperature’.

A guidance paper by LiveCorp. & MLA. (2020) aims to address the unique risks to the health and welfare of cattle associated with their delivery into conditions below cattle TNZ. The paper noted that cattle with summer coats have an LCT of 15°C, while cattle with thick winter coats may have an LCT of −8°C. While these temperatures were not referenced in the guidance paper, they appear to match those outlined in a report by Marston et al. (1998) which provided guidelines for LCTs for beef cattle in Kansas (Table 23Table 23). The same thresholds are also noted by the Ontario Ministry of Agriculture, Food and Rural Affairs (Tarr 2007).

Table 23 Estimated lower critical temperatures for beef cattle

Coat description	Critical temperature °C
Summer or wet coat	15°C
Dry autumn coat	7°C
Dry winter coat	0°C
Dry heavy winter coat	−8°C

Source: Marston et al. (1998)

It is difficult to interpret the significance of these LCTs. Marston et al. (1998) do not provide information on the research undertaken to determine the LCTs, nor the relevant animal factors such as age, breed, class and BCS that influenced the findings. As such, cattle in Victoria might be accustomed to mean monthly minimum temperatures in summer ranging from 13°C to 14.6°C (BOM 2021) of which an LCT of 15°C for a dry summer coat appears high.

6.5 Cold stress voyage analysis

6.5.1 Description of voyages

Twenty of the 214 voyages (9.3%) were identified as reporting ambient temperatures of ≤5°C DBT or included evidence of cold conditions based on behavioural, physiological, or environmental signs. The average minimum temperature for these 20 voyages was 3.2°C DBT, while the lowest minimum was −7°C DBT (Table 24).

Thirteen of these 20 voyages did not report evidence of cold stress, despite 11 voyages reporting minimum DBT between 2°C and 5°C and 2 voyages reporting DBT of −0.3°C and −3°C.

Table 24 Summary of voyages and minimum reported DBT

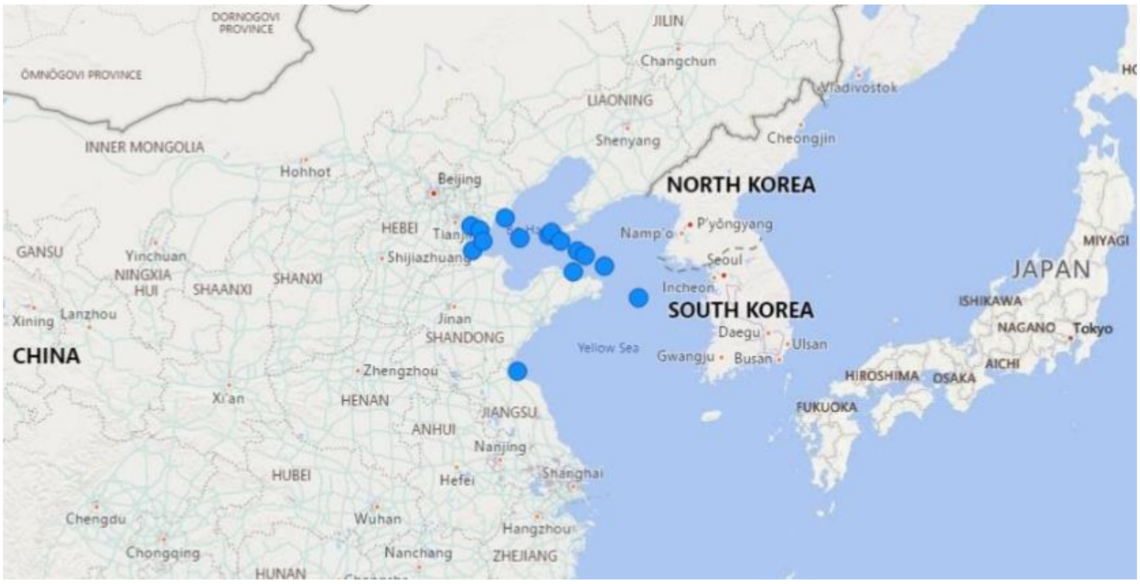
Minimum temperature (°C DBT)	Voyages with at least 1 day at or below the minimum temperature
≤−7	1
−6 to −3	2
> −0.3 to 0	2
>1 to 5	15
Total	20

Some voyage reports recorded a wide temperature variation during the course of the voyage with the average difference of 17.6°C between minimum and maximum WBTs.

Eighteen of the 20 voyages were destined for ports in the northern half of China and 2 voyages to Israel, with 1 voyage additionally discharging cattle in the Russian Federation (Map 3

Location of the coldest recorded DBT for voyages to China). Four of the 5 voyages reporting the coldest temperatures departed during December 2018, December 2020 and early February 2016, coinciding with the NHW.

Map 3 Location of the coldest recorded DBT for voyages to China



Source: DAWE (2020)

All voyages recording DBTs of 5°C or less departed Australia between the months of October and April (inclusive).

Increasingly cold temperatures were most often recorded in the final 5 days of the voyages. The temperature profile of the final 5 days for cold voyages with complete daily reports (n=9) was assessed. The average change in temperature between 5 days prior to arrival and the final temperature recorded was 16°C, with a range of 2°C to 24°C.

6.5.2 Observations of cold conditions

Seven of the 20 voyages reported evidence of cold conditions, either reporting animal responses to cold or environmental issues associated with cold. Of these 7 voyages 2 carried feeder cattle, 2 carried breeder cattle and 3 carried slaughter cattle. The 7 voyages recorded a minimum of 5°C DBT (n=5), 10°C DBT (n=1) and 16.9°C DBT (n=1).

Three of the 7 voyages reported behavioural or physiological signs of cold conditions including:

- shivering when the minimum deck DBT was −1°C
- decreased water consumption when DBT was 10°C
- cattle reported to be 'cold, wet and windblown' with temperatures of 13.6°C WBT/17.2°C DBT after rough seas and high winds flooded the lowest open deck in the Great Australian Bight. Excluding this voyage, the average minimum was 2.5°C DBT.

Another 3 of the 7 voyages, on 3 different vessels, documented environmental issues with frozen water troughs or pipes with minimum deck DBT of 0°C, −1°C and −7°C. In these instances water was provided manually by the crew.

One of the 7 voyages reported cattle were euthanased as their BCS was too low to support the environment they were entering.

6.6 Summary of key findings

Cold stress:

- Twenty of the 214 voyages were identified as having evidence of cold conditions based on either reported temperature of ≤5°C or environmental signs such as frozen water in pipes, or behavioural and physiological signs.
- Of the 20 voyages:
    - 13 recorded cold temperatures between 5°C and −3°C DBT but reported no evidence of cold stress
    - 3 reported behavioural or physiological signs of cold conditions (1.4% of voyages in this review)
- Average minimum temperature was 3.2°C DBT and the average difference between minimum and maximum WBTs was 17.6°C
- During the final 5 days there was an average decrease of 9.1°C DBT over a 24-hour period
- All voyages recording DBT ≤5°C departed Australia between the months of October and April (inclusive)
- There were no recorded primary mortalities due to cold stress.

6.7 Discussion and recommendations

The analysis demonstrated that the risk of cold conditions in all classes of cattle is greatest during the NHW particularly for exports departing from December to February. The coldest part of the journey appears to be during unloading in northern ports.

The scope of this review ends at unloading. There is very little reporting of environmental conditions and the management of cattle beyond this point including the suitability of transportation and feedlot infrastructure to protect cattle from cold stress. These aspects may also be important in terms of welfare outcomes.

One submission raised concerns about the welfare impact of temperature variations. We have not identified scientific research discussing the significance of wide temperature variation on cattle welfare (or other species).

Another submission noted that conditions can be so cold as to impact normal watering operations on vessels, for example the freezing and fracturing of water lines. No feeding issues due to cold conditions were reported in the voyage reports analysed by the department in this review. However, the reports noted that crew undertook manual watering if water pipes were frozen.

Extremely cold drinking water could be a welfare concern, particularly if cattle reduce or cease drinking. While reduced drinking was reported on 1 voyage (at deck DBT of 10°C), the impact on welfare was not recorded. Further research into the impact of drinking water temperatures on cattle behaviour might help to improve animal welfare.

Increased availability of dietary energy when cattle experience cold conditions could present a simple mitigation measure. Other measures such as the adjustment to the temperature of the water, timing and method of deck washing if a vessel is approaching cold conditions should also be considered. Further examination of mitigation measures employed on vessels is encouraged.

At one port the AAV euthanased 10 “skinny/depressed” cattle prior to discharge on welfare grounds. The AAV determined that the cattle were not in sufficient body condition to survive transportation to the feedlot. This highlights the importance of a cattle body score condition and susceptibility to cold stress.

More reporting and data collection regarding cold stress should take account of the LCTs described in the LiveCorp cold climate checklist noted in section 6.3.5. Lack of awareness of how to recognise and mitigate the impacts of cold conditions could be a factor. Establishing the bounds of the TNZ for Australian cattle across different seasons could be an area for future research. We note that the MLA Veterinary Handbook and the LiveCorp Stockies Guide (Jubb & Perkins 2019) released in November 2020 contain limited information about cold stress.

ASEL requires that written contingency plans be prepared to address a number of animal welfare challenges including adverse weather conditions. It is not clear to what extent appropriate management of cattle in cold conditions is incorporated into the contingency plans.

Cold exposure and cold stress

Findings

13. Twenty of the 214 voyages were identified as having evidence of cold conditions based on either environmental signs such as temperatures of ≤5°C or evidence of relevant behavioural, physiological signs.

14. There were no recorded primary mortalities due to cold stress.

15. The cold tolerance of Australian cattle exported to cold climate destinations is not well established.

16. Wet conditions are an important consideration on board a livestock vessel when animals are exposed to direct windchill (open decks) and high ventilation rates.

17. Mitigation measures for managing cattle in cold conditions are not well established.

Recommendations

14. Further research should be undertaken to determine appropriate critical temperatures that relate to compromised animal welfare for Australian cattle exported to cold climate destinations.

15. Consideration should be given to timing and method of deck washing to allow time for cattle coats to dry before the vessel encounters cold conditions.

16. Industry should develop guidance for appropriate mitigation measures on board vessels for cattle in cold conditions.

17. Measures to mitigate the risk of cold stress on board vessels should be incorporated into exporters’ ‘adverse weather contingency plan.’

18. The ‘cold climate destination checklist’ for cattle should be completed prior to the export of cattle to cold climate destinations.

Appendix A: ASEL 3 standards applicable to heat and cold stress

Heat stress

The following standards relevant to heat stress are currently implemented under ASEL 3 (DAWE 2020):

Standard 1.4.2: Cattle sourced for export must have an individual liveweight of 200kg to 500kg. Animals outside of these weights must not be sourced for export, unless otherwise provided:

a) for cattle less than 200kg, in a light cattle management plan approved in writing by the department, or

b) for cattle more than 500kg, in a heavy cattle management plan approved in writing by the department.

Standard 1.4.3: *Bos taurus* cattle sourced for export from any area of Australia south of latitude 26° south must only be exported on voyages that cross the equator and depart between 1 May and 31 October (inclusive) if:

a) they have been determined in accordance with the conditions in Standard 1.4.5, or Standard 1.4.6 and 1.4.7, to be not detectably pregnant, unless otherwise provided in a pregnant southern sourced *Bos taurus* cattle crossing the equator from May to October management plan approved in writing by the department; and

b) for cattle to or through the Middle East, a heat stress risk assessment indicates that the risk is manageable (less than 2% risk of a 5% mortality).

Standard 1.4.4: Cattle must not be sourced for export or exported unless they have been assessed by a competent stock handler against the cattle body condition scoring in Table 2 and have a body condition score of 2 to 6 (inclusive) (on a scale of 1 to 7), unless they are *Bos taurus* cattle sourced for export from, or exported through, any area of Australia north of latitude 26° south between 1 October and 31 December (inclusive), then they must have a body condition score of 2 or more but less than 5 (on a scale of 1 to 7).

Standard 3.4.2: The minimum length of time that cattle must remain in a registered establishment prior to departure for the port is 2 clear days for short or long–haul voyages, or 3 clear days for extended long–haul voyages. For any clear day on which animals are subject to a feed or water curfew, an additional clear day is required.

Standards applicable to ventilation and air quality

The requirements for ventilation on livestock vessels from AMSA are in Marine Order 43, s21 (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}

Sch 2 pt 2 s2.3(4):

- 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}

Sch 2 pt 2 s2.4(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}

The following standards relevant to ventilation are currently implemented under ASEL 3:

Standard 5.1.19: When livestock for export are loaded on vessels with enclosed decks, the ventilation system must be run continuously from the commencement of loading until the last animal has been unloaded.

Standard 5.1.20: Ammonia levels in a representative number of pens must be measured daily. If ammonia levels exceed or are likely to exceed 25ppm in any livestock spaces, appropriate reduction measures must be implemented.

a) Compliance with this standard will be delayed for a 12-month period (from the date this version is in force) while the use of available ammonia detection devices on vessels is tested.

ASEL 3 also requires reporting with regards to ventilation. Daily reports must include any notes about ventilation issues including:

- Detail of issue(s)
- Period of time of issue(s)
- Deck(s) affected
- Impact on animals

End of voyage reports should provide a summary of any ventilation issues.

Standards applicable to feed provision

The following standards relevant to feed provision are currently implemented under ASEL 3:

Standard 5.1.10: Feed and water provisions must be appropriate for the species, class, weight and age of livestock, voyage length and expected weather conditions.

Standard 5.1.11: All livestock must be provided with adequate trough space during the voyage to ensure each animal can meet its daily requirements for feed and water without risk to their health or welfare.

Standard 5.1.12: Livestock must have access to suitable feed and *ad libitum* water:

a) as soon as possible and no more than 12 hours after being loaded on the vessel; and
b) for water, within maximum water deprivation times equal to those set out in the Land Transport Standards; and

c) of a quality to maintain good health, hydration and welfare and satisfy energy requirements for the duration of the voyage, including loading and unloading, and in the event of delay.

Standard 5.1.14: The ration fed on the vessel must comply with these conditions:

a) the ration must not contain more than 30% by weight of wheat, barley or corn, unless the livestock have been adapted to the ration over a period of at least 2 weeks prior to export; and

b) all pelleted feed must be accompanied by a manufacturer's declaration that states it is manufactured in accordance with the Australian Code of Good Manufacturing Practice for the Feed Milling Industry (2009); and

c) all Australian-origin feed from a previous voyage that is suitable for livestock consumption may remain in a feed storage tank provided that:

I. each tank is completely emptied, and feed discarded at least once in every 90 days; and

II. all feed that is no longer suitable for livestock consumption is emptied in its entirety before further feed is loaded; and

III. records are maintained of the emptying of feed storage tanks and are available for inspection.

Standard 5.1.15: All voyages (noting this includes the days of loading and unloading) must carry adequate reserves of feed to ensure livestock can continue to be fed in accordance with the minimum daily requirements even if delays occur. The additional reserve that must be carried on the vessel to be used only in the event of delay is a minimum of 3 days of feed for cattle, buffalo, sheep and goats.

Standard 5.3.7: Feed loaded and provided to cattle exported on voyages of: 30 days or less, must include at least 1% of the required feed as chaff and/or hay; and

a) 31 days or more and where an exporter has approval under Standard 5.1.17to export cattle on extended long-haul voyages, must include at least 2% of the required feed as chaff and/or hay.

Standard 5 of ASEL 3 addresses the feed requirements for cattle including minimum quantities/head/day for different classes of cattle and dictates the provision of supplementary feed types for in appetent animals.

Standards applicable to water provision

(In addition to the reference to water in the standards related to feed).

Standard 5.1.13: There must be no water curfew applied prior to unloading of livestock at ports in the Middle East between 1 May and 31 October (inclusive).

Standard 5.1.16: The minimum additional reserve of water that must be carried on the vessel to be used in the event of delay is 3 days of daily water maintenance requirements for all livestock on board. Allowance may be made for fresh water produced on the vessel while at sea.

Standards applicable to pregnant cattle

Standard 1.1.7: Female livestock must not be treated with a prostaglandin drug:

a) within the 60 day period prior to export unless they have been pregnancy tested immediately before prostaglandin treatment and declared to be in the first trimester of pregnancy or not detectably pregnant; nor

b) within 14 days prior to export.

Standard 1.4.3 *Bos taurus* cattle sourced for export from any area of Australia south of latitude 26° south must only be exported on voyages that cross the equator and depart between 1 May and 31 October (inclusive) if:

a) they have been determined in accordance with the conditions in Standard 1.4.5, or Standard 1.4.6 and 1.4.7, to be not detectably pregnant, unless otherwise provided in a pregnant southern sourced *Bos taurus* cattle crossing the equator from May to October management plan approved in writing by the department; and

b) for cattle to or through the Middle East, a heat stress risk assessment indicates that the risk is manageable (less than 2% risk of a 5% mortality).

Standard 1.4.5 Female cattle sourced for export as feeder or slaughter animals must:

c) be pregnancy tested within 30 days prior to export, by registered veterinarian or competent pregnancy tester who must certify in writing that the animal is not detectably pregnant and include with the certification the date of the procedure; and

d) undergo the above pregnancy testing by a registered veterinarian if the animal is too small to be manually palpated, who must base the certification on assessment of the animal by a method other than manual palpation.

Standard 1.4.6 Female cattle sourced for export as breeder animals must be no more than 190 days pregnant at the scheduled date of discharge in the importing country. In order to demonstrate this, the cattle must be pregnancy tested:

a) by a registered veterinarian using an approved blood test; and

   I. if the test result is negative, be certified in writing as not detectably pregnant; or

   II. if the test result is positive, undergo testing as per b) or c) below; or

b) by a registered veterinarian that attests to current experience and competency in cattle pregnancy diagnosis, using manual palpation and only if the voyage is less than 10 days; and

   I. if the test result is negative, be certified in writing as not detectably pregnant; or

   II. if the test result is positive, be certified in writing as pregnant with number of days pregnant stated; or

c) by a registered veterinarian that is accredited under the PREgCHECK (NCPD) Scheme, using manual palpation or an alternative method if the veterinarian determines that the animal is too small to be manually palpated safely; and

I. if the test result is negative, be certified in writing as not detectably pregnant; or

II. if the test result is positive, be certified in writing as pregnant with number of days pregnant stated; and

d) with the certification stating the animal's individual NLIS identification number and date of the procedure, and where accredited PREgCHECK tester is used, the name of the accredited tester, their accreditation number and a statement of their accreditation.

Standard 1.4.7 Pregnancy test certification for Standard 1.4.6 is valid for:

a) 30 days for pregnant cattle, unless an exporter has applied for a certification validity extension, and received approval in writing from the department, prior to loading; and

b) 60 days for not detectably pregnant cattle, from the date of the procedure or collection of blood sample.

Standard 4.1.9 Unless the exporter has approval under Standard 4.1.10, an AAV must accompany each consignment of livestock and must remain with the consignment until the last animal has been unloaded at the final port of disembarkation in these circumstances:

a) if the voyage is expected to be an extended long-haul voyage; and

b) on voyages with pregnant livestock; and

c) any other voyage when directed by the department.

Standard 5.3.1 The minimum pen space allowances for cattle exported by sea are contained in Table 9, Table 10a, Table 10b, Table 11a, Table 11b, Table 12a and Table 12b. These penning criteria apply:

a) where a curfew of more than 12 hours will be undertaken at the registered establishment prior to transport to the port of embarkation, a curfew factor of an additional 5% must be applied when calculating liveweight (cumulative with other additional space requirements and must be calculated first); and

b) the weight of each animal in a pen must not vary from pen average weight by 50kg. The pen average weight is calculated by dividing the total weight of the cattle in the pen by the number of cattle in the pen; and

c) for pregnant cattle, a minimum additional 15% space must be provided; and

d) cattle without horns may be penned with cattle with horns up to 12cm in length and where the horns are tipped (blunt); and

e) cattle outside of the weights shown in Table 9, Table 10a, Table 10b, Table 11a, Table 11b, Table 12a and Table 12b must only be sourced for export or exported in accordance with a light or heavy cattle management plan where an exporter has approval under Standard 1.4.2.

Table 25 Feed requirements for cattle

Class of cattle	Minimum feed allowance/head/day (% liveweight)
Cattle weighing less than 250kg	2.5
Breeding heifers with 6 or fewer permanent incisor teeth (regardless of pregnancy status)	2.5
Pregnant cows	2.5
Other classes of cattle	2.0

Standard 5.3.9 The minimum veterinary medicines and equipment to be carried on the vessel are in Table 14. Additional veterinary medicines and equipment to be carried on voyages with pregnant cattle are in Table 15. Additional veterinary medicines and equipment may be necessary if there are other classes of cattle in the voyage.

Table 26 Additional minimum veterinary medicines and equipment for pregnant cattle

Medicines and equipment	Minimum requirement
Obstetrical lubricant	5 litres per 2,000 cattle
Calving ropes	1 set per vessel
Obstetrical gloves	1 box per vessel
Oxytocin	50 ml per 1,000 cattle
Additional chlorohexidine (or equivalent)	5 litres per vessel
Iodine (umbilical treatment)	1 litre per vessel
Uterine pessaries	10 per 2,000 cattle
Surgical equipment	Adequate to conduct a caesarean section

Cold stress

The following standards relevant to cold stress are currently implemented under ASEL 3:

Standard 1.4.2: Cattle sourced for export must have an individual liveweight of 200kg to 500kg. Animals outside of these weights must not be sourced for export, unless otherwise provided:

a) for cattle less than 200kg, in a light cattle management plan approved in writing by the department, or

b) for cattle more than 500kg, in a heavy cattle management plan approved in writing by the department.

Standard 4.1.18 Contingency plans, including procedures for contacting the exporter, must be prepared in writing for each consignment that address:

a) mechanical breakdown of the vessel or functionality relevant to maintaining the livestock's health and welfare; and

b) a feed and/or water shortage during the voyage; and

c) the satisfactory tending, feeding and watering of the livestock in the event of a malfunction of the automatic feeding or watering systems, without compromising the safe navigation of the vessel; and

d) an outbreak of a disease during the voyage; and

e) adverse weather conditions during the voyage; and

f) rejection of the consignment by the overseas country.

Appendix B: Heat load mortality table

Vessel	Exporter	Departure month	Departure year	Voyage Duration (days)	Destination	Cattle class	Average cattle liveweight (kg)*	Max WBT (°C)	Voyage mortalities (head)	Voyage mortality rate (%)	Heat stress-related mortalities				Comorbidities
											Total	Primary	Secondary	Other	
A	B	April	2018	30	Red Sea	Feeder	300	34.0	15	0.26	3		3		infection, clostridia, bloat
B	A	June	2018	22	Red Sea	Feeder	300	29.5	1	0.03	1		1		none stated
B	D	March	2018	22	Red Sea	Feeder	n/a	27.6	13	0.28	1		1		respiratory disease (BRD)
C	C	December	2018	22	China	Slaughter	571	30.1	2	0.14	1			1	none stated
D	E	May	2018	17	China	Slaughter	n/a	33.0	46	1.45	42		42		respiratory disease (BRD)
E	F	May	2020	14	China	Slaughter	510	29.0	10	0.54	4	1	3		gastroenteritis
F	A	April	2018	21	China	Breeder	n/a	32.0	11	0.48	2		2		pneumonia
G	C	October	2018	15	China	Slaughter	540	30.0	1	0.05	1			1	none stated
G	C	May	2018	14	China	Slaughter	n/a	30.0	10	0.56	8			8	none stated
G	C	June	2018	20	China	Slaughter	562	28.5	13	0.67	4			4	none stated
G	E	July	2016	18	China	Breeder	n/a	29.0	3	0.07	1		1		respiratory compromise
H	E	Novembe r	2017	18	China	Slaughter	n/a	29.0	5	0.21	1		1		lameness
H	E	July	2018	18	China	Slaughter	598	32.0	33	1.51	15	14	1		none stated
I	E	June	2018	17	China	Slaughter	n/a	31.0	17	0.67	1		1		respiratory disease

*n/a Not applicable.

Appendix C: Methodology

Data was collected from various forms of voyage reports for departures during the time period 1 January 2016 to 31 December 2020. Data sources included daily and end of voyage reports from AAVs and stockpersons, Australian Maritime Safety Authority (AMSA) master's reports, IO reports, exporter documents and reportable mortality report.

For each voyage general information was recorded, including:

- vessel
- exporter
- voyage start and end date
- voyage duration
- departure port and destination port and country
- the cattle breed and or class
- number of cattle loaded
- pregnancy status (where information was available)
- total mortalities and mortality rate

Observations for each voyage were also captured to ascertain the presence and extent of heat or cold stress. These included:

- maximum and minimum recorded temperatures on cattle decks, and total range experienced
- geographical location of maximum and minimum deck temperatures when maximum WBT ≥26°C or minimum WBT ≤5°C, respectively
- cattle behaviour attributed to or typically representative of increased heat load or cold conditions (as defined in relevant sections below)
- ventilation and hot spot issues
- mortalities attributed to heat or cold stress
- management strategies implemented to decrease the effects of or prevent heat and cold stress, including effectiveness of strategy if reported
- additional relevant observations provided by reporting persons.

A statistical analysis was conducted for voyages that reported evidence of increased heat load or heat stress-related mortalities. These voyages were analysed for associations with class of cattle, season, destination, departure port and number of departure ports (single or multiple).

Descriptive Analysis

A descriptive analysis was performed in the first instance to describe each variable independently in terms of distribution and to visualise relationships between two variables where possible.

All voyages with the exception of one recorded a single destination. Seven voyages recorded two classes of cattle on board, whereas the rest recorded only one. For the purpose of analysis, the single voyage with two destinations was treated as two voyages – one for each destination. This decision was made because the overlapping nature of the voyage route of the second destination with the first and the lack of mortality or heat load on this voyage, allowed accurate categorisation for both destinations. Conversely, the records with multiple classes of cattle were excluded from the statistical analysis, due to lack of capacity to identify which class was affected by heat load or mortality from the data available. Post-hoc repeated analyses with these records duplicated was performed to ensure that results did not differ significantly through exclusion of these records.

Where multiple ports of departure were listed only the first was used in analysis. In addition, the data associated with departure ports of Port Adelaide and Geraldton were removed for further analysis as there were small numbers recorded (n = 3 for Port Adelaide and n = 1 for Geraldton) and all were associated with heat load events. This potentially introduces bias for associations with other departure ports (which recorded vastly greater number of voyage departures

Univariable Analysis

Univariable analyses were performed, comparing outcome variables (evidence of increased heat load, heat stress-related mortality, and heat load and/or heat stress-related mortality) with potential explanatory variables (class of cattle, season, AMJ season, destination, departure port and number of departure ports (single or multiple)). All variables were categorical in nature therefore Chi square tests were used for these.

Heat load as an outcome

The analysis explored the significance of voyage characteristics that may contribute to the occurrence of increased heat load (heat load voyages). Univariable analyses identified a significant association between heat load voyages and class of cattle ($P = 0.044$) and AMJ season ($P=0.014$). No significant association was identified between heat load voyages and destination ($P = 0.166$), season (NHW vs NHS)($P = 0.570$), departure port ($P = 0.136$) or whether single or multiple departure ports were used ($P = 0.173$).

Heat stress-related mortality as an outcome

This analysis explored the univariable association of heat stress-related mortality voyages with cattle class, season of departure (NHS or NHW), destination and departure port. A significant association was identified between heat stress-related mortality and cattle class ($P < 0.001$) and AMJ season ($P=0.048$) but not with destination ($P = 0.94$), departure port ($P = 0.229$), number of departure ports ($P = 0.622$) or season (NHW vs NHS) ($P = 0.078$).

Multivariable Analysis

Multivariable analyses were specified, using generalised linear models with binomial link functions. Two Directed Acyclic Graphs (DAG) was used to identify variables for inclusion in the models (Figure 24 and Figure 25). Variables were assessed for inclusion in the final model by forwards and backwards stepwise selection. Model comparison was performed using likelihood ratio tests, with models with significantly lower residual deviance favoured. Significance was set at $P < 0.05$. All statistical analyses were performed in R.

The large number of categories in the vessel variable meant that it was not possible to include this variable in the analyses, however class, season and departure port were all considered for inclusion as identified in the methods. The decision to exclude destination from all models was made due to the collinearity issues identified above.

Figure 24 Outcomes of heat load and/or mortality

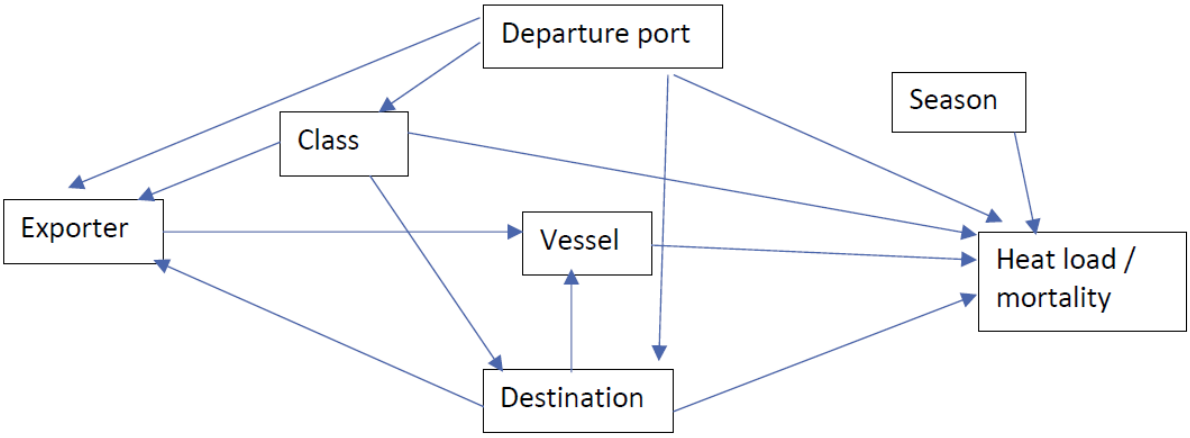
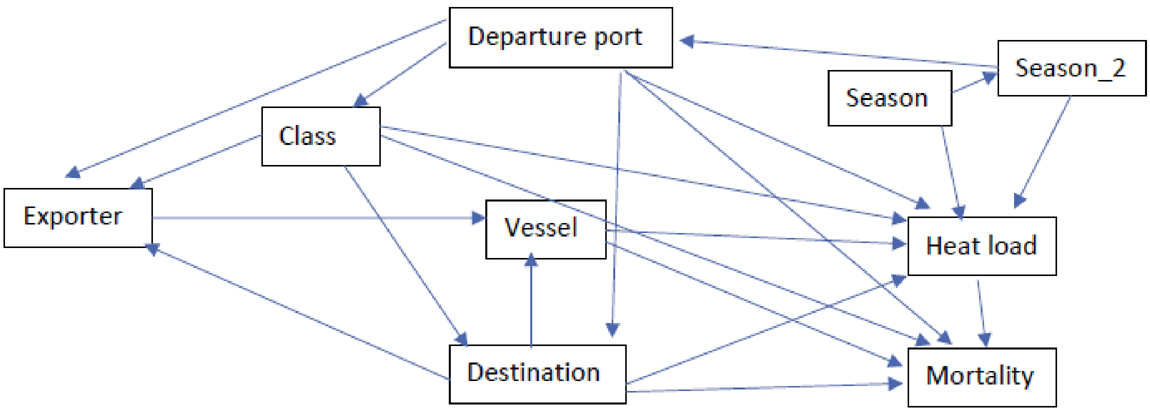


Figure 25 Outcome of mortality, including heat load as an explanatory variable



Appendix D: Feedback from the technical expert group

The technical expert group

An independent technical expert group (TEG) was contracted to provide advice and feedback to the department about the content of the review before release of the draft for comment and its finalisation. The panel includes:

- Associate Professor Anne Barnes – Associate Professor in the School of Veterinary Medicine, Murdoch University. An experienced researcher in the livestock export trade particularly heat stress physiology. Other areas of expertise include animal reproduction, thermal and appetite physiology, and animal welfare and behaviour.
- Professor Andrew Fisher—Director, Animal Welfare Science Centre, University of Melbourne. Clinical veterinary experience followed by research programs in livestock health, management and welfare. Formerly head of the CSIRO's livestock welfare research group based in Armidale, NSW.
- Dr Hugh Millar – member of the ASEL committee; former Executive Director Biosecurity Victoria and Chief Veterinary Officer for Victoria. Dr Millar has over 40 years' experience as a veterinarian and biosecurity professional, in areas including animal and plant health, veterinary public health, animal welfare and biosecurity management in the invasive pests sector.

Feedback on the draft report

The TEG was complimentary of the structure and content of the draft report, describing it as a 'substantive' piece of work. The TEG provided general formatting and editorial suggestions which were incorporated into the draft report.

The TEG also provided written feedback focusing on a number of key points. The department supported all suggestions made by the TEG and addressed every suggestion in the relevant section of the draft report, with increased commentary, evidence and explanation. This feedback is outlined below.

Comments and suggestions on the Summary and Recommendations

The TEG stated that for understandable reasons much of the focus of the draft report was on heat stress but suggested that we include more content about cold stress findings in the summary.

The TEG recommended we include increased justification and explanation for some recommendations, stating in some cases it was not clear how recommendations were developed out of the findings. Numbering recommendations would also help readability.

Comments on discussion of ASEL

The TEG commented that the timing and nature of the introduction of ASEL 3 made it difficult to determine how many factors may change or improve through ASEL 3 alone. They acknowledged the report does highlight where recent or proposed ASEL 3 changes may be relevant to the findings and recommendations and were pleased to see that a number of ASEL review recommendations were borne out by the analysis in the draft report. The TEG suggested we ensure we clearly identify what is expected to change in response to ASEL 3 and what will not change. Analysis of the impact of changes introduced under ASEL 3 could be included in a future review of ASEL.

Need for a clear case definition of a heat load event and heat stress related mortality

The TEG noted the analysis in the draft report hinges upon the definition of a heat load event and a heat stress-related mortality. The draft report would benefit from increased clarity on how we have defined these 2 terms. The TEG recommended greater explanation of causes of death, and a clear case definition for what we included as a primary heat stress death, or any other type of mortality. They commented that we should include some discussion on the weaknesses and strengths of this approach, and acknowledgment that it may not be possible from voyage reports to determine when animals had moved from a physiological response to heat to an overly stressed response.

Comments on the statistical analysis

The TEG stated that overall, our findings seem reasonable based on the analysis, accepting data limitations, and that the recommendations follow logically. The TEG suggested we provide more information on the methodology used in the statistical analyses, to enable an informed person to evaluate the robustness of that methodology and to be able to theoretically replicate the process. This information would be acceptable in an appendix. The TEG commented the analysis was highly dependent on voyage reports and thus limited by the available data. Further explanation of constraints and limitations would be useful to give some context. The TEG acknowledged the presence of many interacting and confounding factors which made the analysis difficult. The report does endeavour to address this issue, but it could indicate it was not always possible to ‘correct’ for some confounding factors.

Comments and suggestions to include analysis of port of departure

The TEG suggested our report could be improved by including an analysis based on port of departure. We have identified that southern Australian ports are part of the problem faced on long-haul voyages, and the TEG suggest we investigate this further. This may identify significant differences in the way animals are prepared at different ports. The TEG noted that departure port is an important factor influencing outcomes during live sheep exports.

Comments on voyage reports

The TEG identified that voyage reports available within the scope of this review, had significant limitations regarding their usefulness for analysis of heat and cold stress. There could be a recommendation to improve voyage reporting in relevant ways to provide more robust data going forward. Collection of better data is recommended but also to make that data accessible and available for future analysis. Extra recommendations were included in the draft report, focusing on heat load reporting and deck temperature records.

Glossary

Term	Definition
ad libitum	The availability of food and water at all times with the quantity and frequency of consumption being the free choice of the animal (DAWE 2020)
adverse weather	Temperature and climatic conditions (such as rain, hail, snow, wind, humidity, heat, storms, cyclones, heatwaves and drought) that either individually or in combination, are likely to expose livestock to heat or cold stress, cause injury and/or result in other unfavourable animal health or welfare outcomes (DAWE 2020)
allometry	Visual assessment of an animal's weight based on relative proportions of muscle and fat.
Accredited Veterinarian (AAV)	A veterinarian who is accredited under the Export Control (Animals) Rules 2021 to carry out duties in relation to the export of livestock (DAWE 2020)
Australian Maritime Safety Authority (AMSA)	Australia's national agency responsible for maritime safety, protection of the marine environment, and maritime aviation search and rescue.
Australian Standards for the Export of Livestock (ASEL)	The set requirements for exporting livestock from Australia by sea and air.
collinearity	A statistical correlation between 2 or more variables.
confidence interval	A range of values based on the observed data which are likely to contain the true unknown value for a specified proportion of the time.
consignment	A group of cattle that are under export preparation by one exporter and are destined for export or have been exported from a single seaport or airport.
body condition score (BCS)	Visual assessment of an animal's weight based on relative proportions of muscle and fat.
dry bulb temperature (DBT)	The temperature of air measured by a thermometer freely exposed to the air but shielded from radiation and moisture (BOM 2021).
excessive heat load (EHL)	The increase of temperature above normal due to lack of ability to dissipate body heat effectively (MLA 2021).
'effective' temperature	The actual temperature experienced by cattle during cold conditions. The contributory factors to determine the effective temperature include ambient temperature, wind, and humidity.
far markets	All other export destinations not designated as 'near markets' (see near markets below).
feeder cattle	Cattle that are exported to be fattened prior to slaughter.
heat stress risk assessment (HSRA)	An assessment performed using a heat stress model that combines weather statistics, vessel parameters and animal heat tolerance factors to determine the pen space allocation for the livestock for an intended voyage to predict the risk of mortality or heat stress.
heat load	An animal's thermal balance incorporating the cumulative effects of animal factors and environmental conditions on thermal comfort
heat load voyage	Any voyage where daily reports recorded behavioural and physiological responses to increased heat.
heat stress threshold	The wet bulb temperature when the animal's core temperature is 0.5°C above when it would otherwise have been (Maunsell 2003).

Term	Definition
independent observer (IO)	Authorised officers under the live animal exports legislation, acting in a regulatory capacity to undertake specific regulatory monitoring activities aimed at ensuring compliance.
long-haul voyage	A voyage that is 10 days or more in duration, but less than 31 days.
lower critical temperature (LCL)	The lowest temperature an animal can tolerate before it will need to increase its metabolic rate to increase body temperature
mortality limit (ML)	The wet bulb temperature (WBT) at which the animal will die
multivariable analysis	The type of statistical model used to assess the relationship between several variables; An assessment of independent relationships while adjusting for potential confounders
near markets	Export destinations located south of latitude 15° north, east of longitude 90° east, and west of longitude 180°
NHS	Northern hemisphere summer (1 May to 31 October).
NHW	Northern hemisphere winter (1 November to 30 April).
odds	The probability that an event will occur over the probability that the event will not occur (e.g. the likelihood of heat stress occurrence when cattle are exposed to hot conditions)
odds ratio	A measure of association between an exposure and an outcome
slaughter cattle	Cattle that are exported for slaughter upon arrival at destination port.
Technical Advisory Committee (TAC)	The technical group that reviewed the Australian Standards for the Export of Livestock (ASEL) (ASEL sea review) and in Independent Observer (IO) voyage reports.
temperature humidity index (THI)	An indicator of heat load risk. Calculated by combining the measurement of environmental temperature and humidity.
thermoneutral zone (TNZ)	The range of environmental temperatures at which metabolic rate is basal, with no requirement to either increase heat production or use additional processes to lose heat (HSRA final report).
upper critical temperature (UCT)	The highest temperature an animal can tolerate before it will need to decrease its metabolic rate to reduce body temperature.
wet bulb temperature (WBT)	The temperature read by a thermometer with the bulb covered by a water-soaked cloth other which air is passed.
wind chill	The cooling effect of skin exposure to wind and low temperature.

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