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

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Submission from RSPCA Australia

3 December 2021

Introduction

The Department of Agriculture, Water and the Environment's (DAWE) October 2021 Draft Report considers heat and cold stress specifically in *Bos taurus* cattle during long-haul export by sea (voyage duration 10-30 days) with voyages originating from southern Australian ports (DAWE, 2021b). Publicly available documents do not always include cattle species so data in this submission may by necessity be drawn from *B. indicus* cattle and/or their crosses. Southern ports include Fremantle and Geraldton in WA, Adelaide SA and Geelong and Portland in Victoria. Despite the Draft Report looking at long-haul voyages (10-30 days duration), Vietnam has been excluded from the data, because the majority of the cattle exported there are *B. indicus*.

The never-ending battle to obtain and evaluate data collected from livestock observations and their immediate environment during live export voyages continues to make it difficult to achieve positive improvements for livestock during export by sea.

Regardless, the sentience of livestock must continue to be considered above and beyond mortality benchmarks that the livestock export industry still focusses on. For example, Norman (2020) states that the annual national livestock export industry transport performance reports for sheep, cattle and goat provide "ongoing evidence of the industry's willingness to fully expose its performance to public scrutiny", however the reports only summarise mortalities, and make no mention of livestock morbidity in transit (Norman, 2020).

The technical expert group (Barnes, Fisher and Millar) invited by DAWE to provide advice and feedback to the Draft Report also requested collection of better data and to make that data accessible and available for future analysis (DAWE, 2021b). The Australian Veterinary Association has previously requested that all morbidity and mortality should be recorded and reviewed on every voyage, with a view to making immediate, continuous and ongoing improvements to animal welfare on every future voyage (AVA, 2018a). The RSPCA hopes these requests are heeded to facilitate optimising animal welfare during future live export shipments.

This submission has been set out to respond to the recommendations made in the Draft Report. We have based our response to the report on information from a range of sources including:

- Papers published in peer-reviewed journals.
- Industry-funded, non-peer reviewed reports on livestock export available at https://livecorp.com.au/researchAndDevelopment#Research-reports.
- Mortality statistics from live export of cattle, sheep and buffalo by sea, which are tabled in both houses of parliament every six months and can be sourced from; www.awe.gov.au/biosecurity-trade/export/controlled-goods/live-animals/live-animal-export-statistics/reports-to-parliament.
- Mortality Investigation Reports - In the event of a notifiable mortality incident during live export, a desk-top investigation is undertaken by the DAWE. Each resultant Mortality Investigation Report (MIR) is numbered individually and can be sourced from www.awe.gov.au/biosecurity-trade/export/controlled-goods/live-animals/livestock/regulatory-framework/compliance-investigations/investigations-mortalities. MIRs are not footnoted when cited in this submission.
- Independent Observer Report Summaries - Independent observers (IO) were placed on ships during voyages between 2018 and 2020 [commenced (DAWR, 2018b) after footage of heat stressed sheep on multiple voyages aired on television on 8 April 2018 and ceased at the onset of the COVID-19 pandemic (DAWE, 2020). The IO reports are not published

publicly (unless under FOI), instead they are perfunctorily summarised by DAWE prior to public scrutiny. Each Independent Observer Report Summary (IORS) can be sourced from www.awe.gov.au/biosecurity-trade/export/controlled-goods/live-animals/livestock/regulatory-framework/compliance-investigations/independent-observations-livestock-export-sea and are not footnoted when cited in this submission.

Summary response to the recommendations

1. A suitable HSRA should be employed all year round for all classes of *Bos taurus* cattle to all destinations, as cattle can suffer heat stress crossing the Equator in all months of the year.
2. *Bos taurus* cattle, especially slaughter class, pregnant and high body condition score cattle, should not be shipped on long-haul voyages from southern Australian ports across the Equator between April and October as they are at risk of heat stress and death. This risk is especially high for winter-acclimatised *B. taurus* cattle.
3. Vaccination of cattle against two of the organisms associated with the BRD complex should be implemented for all cattle exported by sea from southern Australian ports in all months of the year as cattle are at risk of death during live export in all months of the year.
4. All cattle should be vaccinated on-farm, as per label instructions prior to entry to feedlot/registered premises (RP) while cattle are still naïve to many of the organisms they could be exposed to upon entry into feedlot or RP prior to export.
5. A veterinarian should be on every voyage carrying livestock from any Australian port to any destination port. Where this is not mandated, a veterinarian must, at the very least, accompany all long-haul (10-30 day) voyages and voyages with the heaviest class of cattle (slaughter) that are more prone to heat stress and lameness.
6. Heavy slaughter cattle (>500 kg) must not be shipped at any time.
7. Sufficient information derived from research and previous reviews exists to negate the need for further investigation in relation to:
   - Higher mortality rates during the highest risk period (April to October).
   - Greater odds of higher heat load for cattle departing Portland compared to Fremantle.
   - Effectiveness of heat stress mitigation measures for high-risk cattle at high-risk times as shipments should be rejected (ongoing monitoring and evaluation of measures at all other times is essential).
8. Where HotStuff calculations show that environmental WBTs are likely to exceed the calculated HST for the particular group of animals, the conclusion should be that the voyage does not proceed. Under these circumstances, wet-bulb rise across decks and multiple concurrent stressors risk tipping livestock into unstable hyperthermia and risk of death either directly from heat stress or co-morbidity such as Bovine Respirator Disease (BRD).
9. Hotspot areas must be required to have improved ventilation using permanent measures to ensure ships are equipped to help safeguard animal welfare. Where this is not in place, hotspot areas must not be stocked.
10. Auditing of ship ventilation under fully stocked conditions must occur on a regular basis to ensure ongoing maintenance of fans and motors to ensure that ventilation is at maximum capacity during equatorial crossings and voyages in the Northern Hemisphere Summer (NHS).

11. Additional research is required to determine optimal types and volumes of bedding for all voyages, especially for those ≥10 days in duration. Once determined, the bedding must be used appropriately to safeguard animal welfare during voyages.
12. Bedding must be provided throughout all voyages, regardless of duration/port of origin/port of destination to minimise foot and leg trauma (lameness and skin abrasions) at loading, during the voyage and at discharge.
13. Standards should be amended to include the current allowance of bedding per square metre of deck, for every 4 days of voyage.
14. Premature lactation should be included in the daily reports. Additionally, southern-sourced pregnant *B. taurus* cattle should not be exported on voyages which cross the Equator from April to October.
15. Onboard data loggers are essential to collect good quality data including WBT, DBT and RH on the proviso that they are placed in appropriate locations and that daily strategic recordings are obtained and analysed which reflect a true indication of the conditions being endured by all cattle on the voyage.
16. Monitoring of panting scores in cattle must be implemented as soon as practicable.
17. The requirement for more data collection during voyages must be implemented as soon as practicable and data interpreted at the completion of every voyage to update ASEL in a timely manner and on an ongoing basis to optimise animal welfare.
18. Further research into cold stress is essential and should include examination of temperature range as well as absolute temperatures for the voyage duration.
19. Until further research can be undertaken into cold stress in cattle, the precautionary principle should prevail by implementing the following recommendations between December and February to cold climate destinations:
    - Only *B. taurus* feeder, breeder and slaughter cattle >250 kg with body condition score ≥3 (out of 5) should be exported to cold climate destinations between December and February (inclusive) to ensure adequate body size, subcutaneous fat reserves that will insulate against the cold and support an increased metabolic rate. Summer-acclimatised cattle lack homeorhetic winter adaptations including insulation from a heavy winter coat and adequate level of feed intake.
    - Minimum loaded rations to be increased by 5% to allow for 10% increased energy requirements in second half of any voyage to a cold destination port.
    - Second feed of the day as late as possible to coincide with feed-related increases in metabolic heat production with colder night conditions.
    - Provision of wind-chill prevention by:
        - consideration of timing and method of deck wash-downs so cattle are not wetted in the last 5 days of voyages between December and February.
        - destocking open decks susceptible to inundation in wet weather/rough seas between December and February.
    - Provision of twice the volume of bedding in ASEL 3.2 to provide adequate bedding across Equator and in the last 5 days of the voyage.

Detailed response to the recommendations

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

A suitable HSRA should be employed all year round for <u>all classes</u> of *B. taurus* cattle, not just slaughter cattle, to all destinations, once the HotStuff HSRA model has been updated to incorporate all destinations, as cattle can suffer heat stress crossing the Equator in all months of the year ((DAWE, 2021b), Figure 1.1., Tables A.1 & A.2).

> **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).

Figure 1.1. Excerpt from *Heat load voyage analysis* Section 4.4.2 Discussion in Draft Report (DAWE, 2021b).

Winter-acclimatised sheep from southern Australian ports have been removed from ships destined to the Middle East from mid-May to mid-September (destination port dependent) because it is too hot. *Bos taurus* cattle, especially slaughter class, pregnant and high body condition score cattle (as acknowledged in Recommendations 1, 2 and 3 of the ASEL sea review), should not be exported from Australia across the Equator between April (see Section 5) and October as their thermoregulatory physiology indicates that they will remain susceptible to heat stress. Section 5.6 of the Draft Report states: "*if conditions are hot enough, a single animal in a hot pen will still be at risk of heat stress*". The statement of "*the exporter arrangements were observed to be implemented during the voyage and to be compliant with ASEL requirements*" or similar at the conclusion of many IORSs in spite of the occurrence of heat stress and heat-related deaths in stock during the voyage (e.g. IORS 12, 127, 136, 173 comments in Table A.2) illustrates how DAWE must prevent cattle boarding vessels if heat stress is predicted by modelling, as cattle suffer heat stress in spite of satisfying current ASEL requirements (DAWE, 2021a).

It is recommended to avoid the transfer of farm animals from a relatively cool to hot environment (Silanikove, 2000) because acclimatisation to heat augments thermoregulation by increasing evaporative capacity (Mitchell et al., 2018). Cattle sourced from southern Australia in April to October are not adapted to the hot and humid conditions experienced during the voyage. Homeostatic physiology (homeostasis) allows livestock to mostly survive voyages across the Equator and into the northern hemisphere summer by establishing a "physiological hyperthermia" using radiation, conduction and convection whilst there is a temperature difference between the surface of the animal and that of the environment, and then using evaporative cooling to maintain thermal balance at a higher core body temperature, placing them into the "tolerance zone" (Figure 1.1) (Beatty et al., 2006; Mitchell et al., 2018). The consequences for an animal placed into a hot environment that is unable to access sufficient water to facilitate evaporative cooling is potentially fatal, so too are the consequences for that animal if the environment does not allow the water produced by the animal to evaporate (Mitchell et al., 2018).

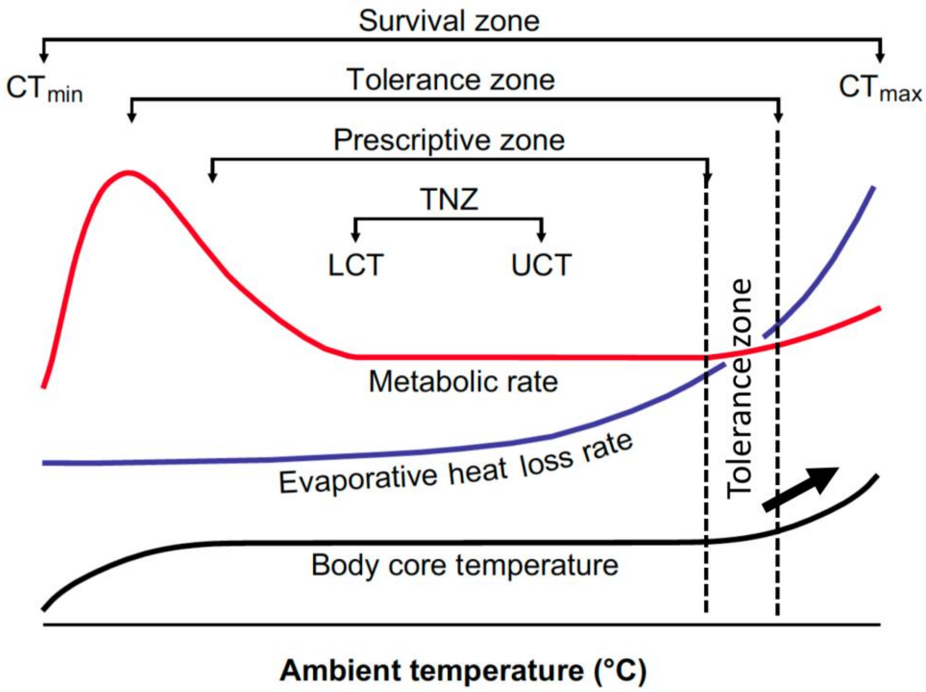


Figure 1.2. Steady-state relationship between ambient temperature and body core temperature, evaporative heat loss rate and metabolic rate of mammals (adapted from Figure 5 (Mitchell et al., 2018)). Animals can establish a physiological hyperthermia to keep body core temperature stable in hot dry conditions, but which may deteriorate into a pathological hyperthermia (black arrow) if the environment does not allow the water produced by the animal to evaporate.

Additionally, the hormonal and metabolic adaptations to heat (or cold) that mammals make as seasons change (homeorhesis) do not have time to occur to any significant extent during a long-haul voyage (Adams and Thornber, 2008) resulting in a lower heat stress threshold (HST) wet bulb temperature (WBT) in winter-acclimatised livestock (Hing et al., 2021). Summer-acclimatised cattle have made homeorhetic changes, and therefore have a higher heat stress threshold and more resilience to heat during equatorial crossings.

There needs to be sufficient difference between core body temperature and environmental WBT in the immediate microclimate of any healthy animal to allow it to shed body heat sufficiently (Mitchell et al., 2018). The lower the HST of the animal and the higher the WBT of the immediate environment, the more poorly the animal will cope with shedding heat. Figure 1.3 shows that equatorial weather conditions range from 22.5-26.5°C WBT (Stacey, 2017b). Table 1.1 demonstrates standard HSTs for beef and dairy *B. taurus* cattle, and adjusted HSTs for cattle that could have travelled from southern ports across the Equator in Mortality Incident Reports (MIRs) 62, 73, 74 and 79 (Maunsell-Australia, 2003; Ferguson et al., 2008; Stacey, 2011; 2017a; b). Some classes of cattle being shipped in April, May, June and July all had adjusted HSTs lower than 26.5°C WBT and would have been at great risk of heat stress crossing the Equator. (It is acknowledged that HotStuff only includes climatology for Middle Eastern ports but this is the only version currently available.)

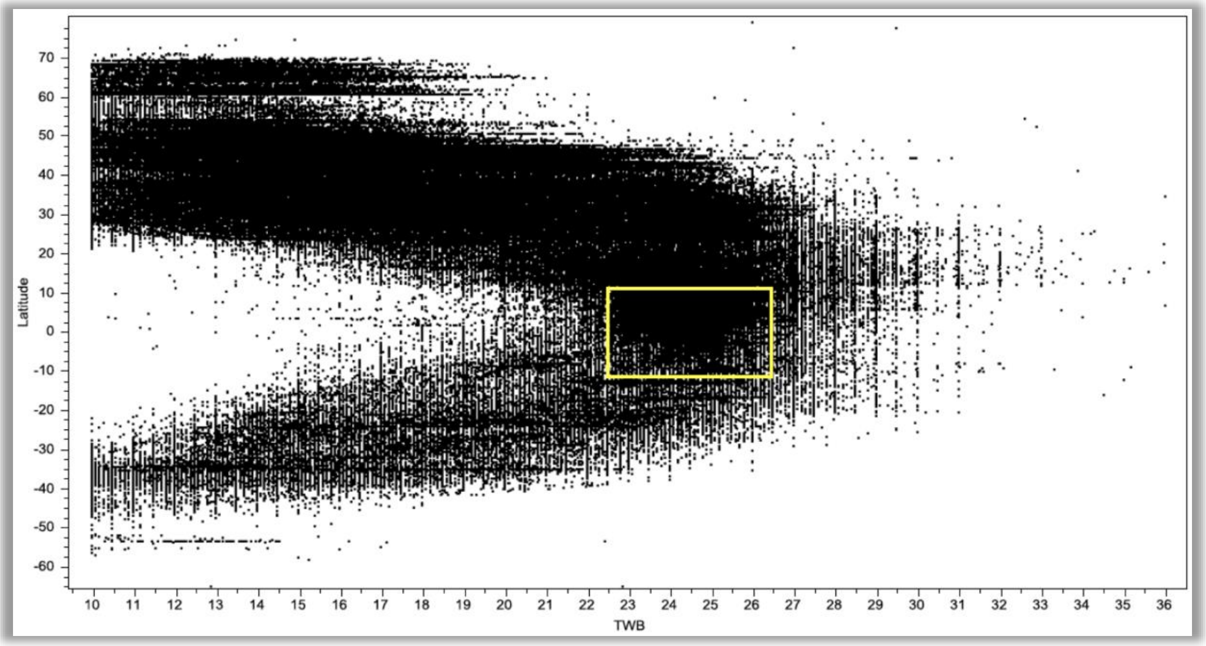


Figure 1.3. Wet bulb temperature (TWB °C) distribution by degree of latitude, with the equatorial region (10°S to 10°N latitude marked by yellow box) ranging predominantly between 22.5-26.5°C TWB (Stacey, 2017b).

Table 1.1. Heat stress thresholds in slaughter cattle that travelled to Mexico (MIR 62) and China in 2018 (MIRs 73, 74) and 2019 (MIR 79) (Maunsell-Australia, 2003; Stacey, 2006; 2011; 2017a; b). Heat stress played a role in the reportable mortality incidents on voyages described in MIR 73, 74 and 79 – which carried heavy, late autumn/winter-acclimatised cattle with low HSTs. It has been noted that the current version of HotStuff only includes climatology for Middle Eastern ports.

Parameter	Body weight (kg)	Condition (fat score)	Coat length	Climate Zone (°C)	Adjusted HST WBT (°C)
Standard *Bos taurus* beef	300	3	mid	15 (std)	**30.00**
Standard *Bos taurus* dairy	300	3	mid	15 (std)	**28.20**
Dairy heifer, zone 1, April (MIR 62)	290	3	mid	11	**27.23**
Dairy bull, zone 1, April (MIR 62)	430	3	mid	11	**25.46**
Beef heifer, zone 1, April (MIR 62)	290	3	mid	11	**29.18**
Beef bull, zone 1, April (MIR 62)	430	3	mid	11	**27.68**
Beef steer, zone 2, May (MIR 73)	588	3	mid	11	**26.34**
Beef steer, zone 2, May (MIR 73)	704	3	mid	11	**25.50**
Beef steer, zone 2, July (MIR 74)	597	3	winter	9	**24.25**
Beef steer, zone 2, June (MIR 79)	582	4	winter	9.5	**23.00**

As an example, Figure 1.4 shows the relationship between daily mortality and mean WBT and panting score across all decks in cattle during a voyage from Portland to China in July 2018 where 33 of 2192 (1.51%) slaughter cattle died (MIR 74). The HST for 597 kg cattle could have been 24.25°C WBT (assumptions shown in Table 1.1). The mean deck WBT exceeded the adjusted HST between days 7-17 of the voyage and the Australian-Government Accredited Veterinarian (AAV) reported all cattle were uncomfortable during this time in conditions of 29°C WBT and 92% relative humidity (RH). Unsurprisingly, heat stress was found to be the main cause of mortalities.

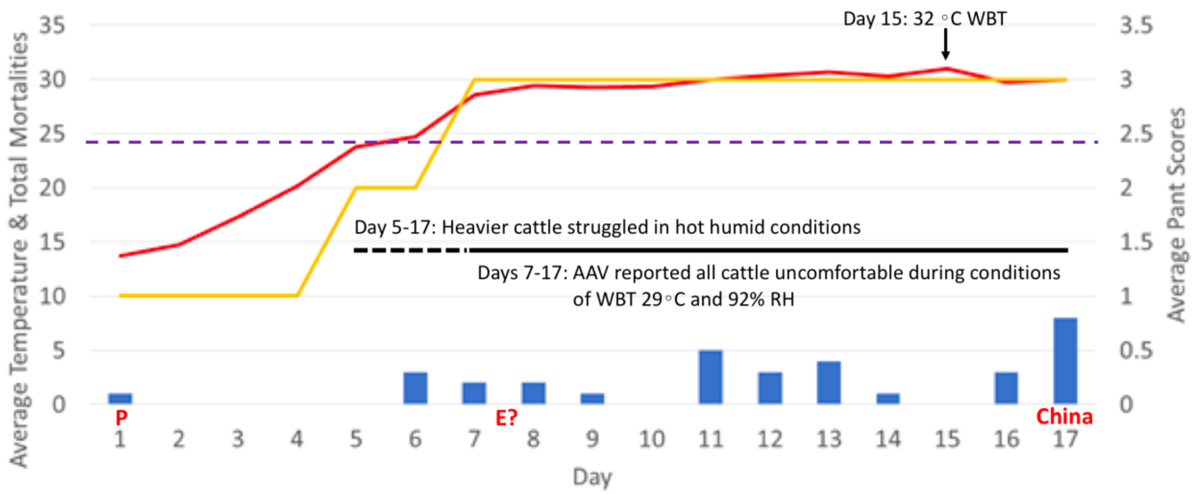


Figure 1.4. Daily mortality (blue bars), mean wet bulb temperature (solid red line) and panting score (solid yellow line) across all decks, for a 17-day voyage from Portland (P) to China, in July 2018 that crossed the Equator (E) on an unstated day, carrying 2192 slaughter cattle from NSW and SA where 33 died (1.51% mortality rate; MIR 74). The adjusted heat stress threshold for cattle weighing 597 kg (24.25°C WBT; dotted purple line) is shown (assumptions in Table 1.1).

The prevailing weather conditions determine minimum heat and humidity on ship decks at ventilation inlets. Livestock make the decks hotter through production of heat (metabolism, evaporative cooling) resulting in wet bulb rise across livestock decks. If prevailing weather approaches the heat stress threshold of cattle, they should survive this hyperthermia using physiological mechanisms (Beatty et al., 2006). However, the multiple stressors that exist on the ship (low space allocation impeding air flow, unstable deck, 24h light and loud noise, suboptimal bedding, ammonia, variable quality and quantity of feed and co-morbidities such as bovine respiratory disease and lameness) could impede evaporative cooling and lead to pathological hyperthermia. That is, the extra stressors push cattle from the tolerance zone into the survival zone (Figure 1.2) greatly increasing risk of dying from heat stress.

Figure 1.5 shows the daily mortality across all decks for a 17-day voyage from Fremantle to China in June 2019 where 25 of 1832 (1.36%) slaughter cattle died (MIR 79). The adjusted HST for cattle that could have been on the voyage was lower than prevailing weather conditions on Days 5-10 of the voyage (assumptions in Table 1.1). Investigation of the reportable mortality event revealed that the primary cause of death was gastroenteritis, however, "*the AAV made note that there was a correlation between the number of mortalities and the hottest part of the voyage*" and "*it seemed very likely that the heat stress was a contributing factor to the mortalities*" (MIR 79).

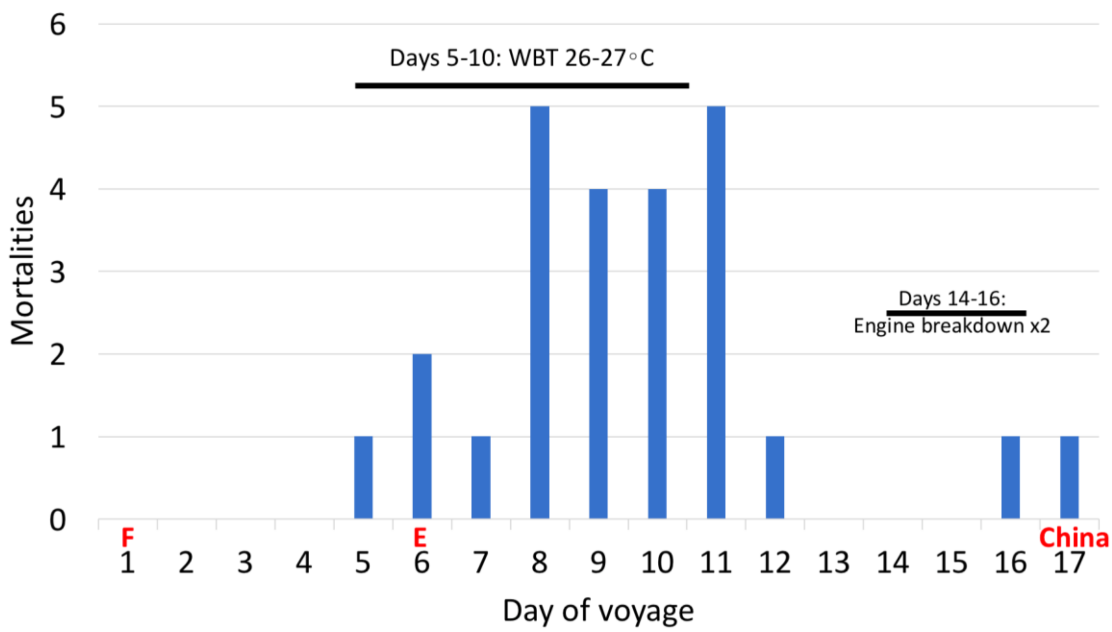


Figure 1.5. Daily mortality (blue bars), across all decks, for a 17-day voyage from Fremantle (F) to China, in June 2019 that crossed the Equator (E) on Day 6 (IORS 136), carrying 1832 slaughter cattle from SE WA where 25 died (1.36% mortality rate; MIR 79). The HST for cattle weighing 582 kg was 24.54°C WBT (assumptions in Table 1.1).

***Bos taurus* cattle, especially slaughter class, pregnant and high body condition score cattle, should not be shipped on long-haul voyages from southern Australian ports across the Equator between April and October for the following reasons:**

- Winter-acclimatised cattle are exposed to elevated WBTs as they approach and cross the Equator, then exposed to prolonged elevated WBTs of the northern hemisphere summer for the duration of any voyage from April to October. Examples of *typical* winter conditions in southern Australia include:
    - MIR 73: Lake Preston (120 km south of Fremantle port), WA, in late May temperature range 17.5-20°C, rain and wind.
    - MIR 74: Portland, Vic, in July daily temperature 14°C, rain and wind (which is not "extreme weather", as described by DAWE in the report).
- Cattle are subjected to heat-load accumulation resulting from little diurnal variation in WBT (Beatty et al., 2006) which may occur from south of the Equator for the duration of any voyages between April and October (e.g. Figures 1.4 and 12.1).
- For the duration of any voyage, cattle are exposed to the stressors of constant loud noise, 24h exposure to light, a moving deck, suboptimal pen conditions (variable ventilation, low space allocation, faecal pad as bedding), variable ammonia levels, variable quality and quantity of feed and concurrent diseases (Hing et al., 2021).
    - MIR 79: The primary cause of death was gastroenteritis. "*The AAV made note that there was a correlation between the number of mortalities and the hottest part of the voyage*" (Figure 1.5).

Whilst some acclimatisation to the various stressors listed above may occur during any voyage, the accumulated effects of these also place cattle at risk of irreversible heat stress and death.

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

"*It is universally accepted that the amount of space provided to animals during periods of confinement is critically important for their health and welfare*" (TAC, 2019). Space allowance for cattle loaded at southern Australian ports for long-haul (10-30 days) export by sea at *any* time of the year requires a minimum *k*-value ≥ 0.033 to reduce risk of adverse welfare outcomes (Table 2.1) (Petherick and Phillips, 2009). It is unclear why ASEL v3.2 (2021) includes a *k*-value of 0.030 as the default settings as this space allocation does not necessarily allow cattle the ability to rise and of free movement to feed/water troughs.

Table 2.1. Space allocation for different postures displayed by livestock during transport, where area, A (m^2) = k x $W^{0.66}$ and W is body weight in kg and *k* is a constant in the equation that defines the space allowance for animals exhibiting various postures (Petherick, 2007; Petherick and Phillips, 2009).

Posture	*k*-value
Standing (short-term transport) or lying on sternum with legs folded beneath	0.020
Lying semi-laterally (legs folded against body)	0.025
All stock lying simultaneously (without necessarily allowing ability to rise or free movement to feed/water)	0.027
Threshold below which there are adverse effects on welfare in intensive housing	0.033
Area to allow animal to move between lying and standing (equivalent to lying laterally with legs extended)	0.047

Table 2.2 outlines the minimum space allocation for consignments of 200-500 kg cattle exported by sea that are loaded at a port south of latitude 26°S, and the voyage crosses latitude 15°S (DAWE, 2021a). The *k*-value is included to demonstrate that between May and October, only cattle weighing 425-500 kg are stocked at or beyond the threshold (*k* = 0.033) which is considered to alleviate adverse welfare outcomes. If the exporter has an approved alternative arrangement, cattle weighing 200-350 kg have reduced space allocation and concomitant higher likelihood of adverse welfare outcomes. Between November and April, all cattle weighing 200-500 kg have a space allocation at which there will be adverse welfare outcomes under default and alternative settings (Table 2.2).

It is unfathomable that there is an alternative arrangement at all times of the year that allows for "exporter performance" to the detriment of space allocation and animal welfare, bearing in mind that voyage durations average 18 days to China, 23 days to the Red Sea, 24 days to the Persian Gulf (and 38 days to the Russian Federation in extended long-haul voyages). This reduction in space allocation ensures cattle suffer poorer welfare on every voyage under the alternative arrangement because there is:

- more metabolic heat produced per square metre of deck and thus greater wet bulb rise, which is relevant for every Equator crossing
- more bodies to physically obstruct flow of air through pens which hinders removal of hot, humid air
- more urine and faeces per square metre of deck
- less space for cattle to adopt any posture, let alone an optimum posture for heat loss away from others in the pen
- greater difficulty in accessing feed and water troughs
- influences susceptibility to disease.

Table 2.2. Space allocation for cattle loaded at a port south of latitude 26° S in ASEL v3.2 (2021).

ASEL 3.1	May-Oct (default)		May-Oct (alternative)		ASEL 3.1	Nov-Apr (default)		Nov-Apr (alternative)	
Live weight (kg)	**Min pen area (m^2/head)**	***k*-value**	**Min pen area (m^2/head)**	***k*-value**	**Live weight (kg)**	**Min pen area (m^2/head)**	***k*-value**	**Min pen area (m^2/head)**	***k*-value**
200	0.99	0.030	0.847	**0.026**	200	0.99	0.030	0.77	0.023
205	1.007	0.030	0.866	**0.026**	205	1.007	0.030	0.787	0.023
210	1.023	0.030	0.884	**0.026**	210	1.023	0.030	0.804	0.024
215	1.039	0.030	0.903	**0.026**	215	1.039	0.030	0.821	0.024
220	1.055	0.030	0.922	**0.026**	220	1.055	0.030	0.838	0.024
225	1.07	0.030	0.941	**0.026**	225	1.07	0.030	0.855	0.024
230	1.086	0.030	0.959	**0.026**	230	1.086	0.030	0.872	0.024
235	1.102	0.030	0.978	**0.027**	235	1.102	0.030	0.889	0.024
240	1.117	0.030	0.997	**0.027**	240	1.117	0.030	0.906	0.024
245	1.132	0.030	1.016	**0.027**	245	1.132	0.030	0.923	0.024
250	1.148	0.030	1.034	**0.027**	250	1.148	0.030	0.94	0.025
255	1.163	0.030	1.053	**0.027**	255	1.163	0.030	0.957	0.025
260	1.178	0.030	1.071	**0.027**	260	1.178	0.030	0.974	0.025
265	1.193	0.030	1.09	**0.027**	265	1.193	0.030	0.991	0.025
270	1.207	0.030	1.109	**0.028**	270	1.207	0.030	1.008	0.025
275	1.222	0.030	1.128	**0.028**	275	1.222	0.030	1.025	0.025
280	1.237	0.030	1.146	**0.028**	280	1.237	0.030	1.042	0.025
285	1.251	0.030	1.165	**0.028**	285	1.251	0.030	1.059	0.025
290	1.266	0.030	1.184	**0.028**	290	1.266	0.030	1.076	0.026
295	1.28	0.030	1.203	**0.028**	295	1.28	0.030	1.093	0.026
300	1.294	0.030	1.221	**0.028**	300	1.294	0.030	1.11	0.026
305	1.308	0.030	1.24	**0.028**	305	1.308	0.030	1.127	0.026
310	1.323	0.030	1.258	**0.029**	310	1.323	0.030	1.144	0.026
315	1.337	0.030	1.277	**0.029**	315	1.337	0.030	1.161	0.026
320	1.351	0.030	1.296	**0.029**	320	1.351	0.030	1.178	0.026
325	1.364	0.030	1.315	**0.029**	325	1.364	0.030	1.195	0.026
330	1.378	0.030	1.333	**0.029**	330	1.378	0.030	1.212	0.026
335	1.392	0.030	1.352	**0.029**	335	1.392	0.030	1.229	0.026
340	1.406	0.030	1.371	**0.029**	340	1.406	0.030	1.246	0.027
345	1.419	0.030	1.39	**0.029**	345	1.419	0.030	1.263	0.027
350	1.433	0.030	1.408	**0.029**	350	1.433	0.030	1.28	0.027
355	1.446	0.030	1.427	0.030	355	1.446	0.030	1.297	0.027
360	1.46	0.030	1.445	0.030	360	1.46	0.030	1.314	0.027
365	1.473	0.030	1.464	0.030	365	1.473	0.030	1.331	0.027
370	1.486	0.030	1.483	0.030	370	1.486	0.030	1.348	0.027
375	1.502	0.030	1.502	0.030	375	1.5	0.030	1.365	0.027
380	1.52	0.030	1.52	0.030	380	1.513	0.030	1.382	0.027
385	1.539	0.030	1.539	0.030	385	1.526	0.030	1.399	0.028
390	1.558	0.030	1.558	0.030	390	1.539	0.030	1.416	0.028
395	1.613	0.031	1.613	0.031	395	1.552	0.030	1.433	0.028
400	1.668	0.032	1.668	0.032	400	1.565	0.030	1.45	0.028
405	1.688	0.032	1.688	0.032	405	1.578	0.030	1.467	0.028
410	1.707	0.032	1.707	0.032	410	1.591	0.030	1.484	0.028
415	1.727	0.032	1.727	0.032	415	1.603	0.030	1.501	0.028
420	1.746	0.032	1.746	0.032	420	1.616	0.030	1.518	0.028
425	1.766	**0.033**	1.766	**0.033**	425	1.629	0.030	1.535	0.028
430	1.785	**0.033**	1.785	**0.033**	430	1.641	0.030	1.552	0.028
435	1.805	**0.033**	1.805	**0.033**	435	1.654	0.030	1.569	0.028
440	1.824	**0.033**	1.824	**0.033**	440	1.666	0.030	1.586	0.029
445	1.844	**0.033**	1.844	**0.033**	445	1.679	0.030	1.603	0.029
450	1.863	**0.033**	1.863	**0.033**	450	1.691	0.030	1.62	0.029
455	1.883	**0.033**	1.883	**0.033**	455	1.704	0.030	1.637	0.029
460	1.902	**0.033**	1.902	**0.033**	460	1.716	0.030	1.654	0.029
465	1.922	**0.033**	1.922	**0.033**	465	1.728	0.030	1.671	0.029
470	1.94	**0.033**	1.94	**0.033**	470	1.741	0.030	1.688	0.029
475	1.961	**0.034**	1.961	**0.034**	475	1.753	0.030	1.705	0.029
480	1.98	**0.034**	1.98	**0.034**	480	1.765	0.030	1.722	0.029
485	2	**0.034**	2	**0.034**	485	1.777	0.030	1.775	0.030
490	2.019	**0.034**	2.019	**0.034**	490	1.827	0.031	1.827	0.031

495	2.039	**0.034**	2.039	**0.034**	495	1.88	0.031	1.88	0.031
500	2.06	**0.034**	2.06	**0.034**	500	1.932	0.032	1.932	0.032

Winter-acclimatised *B. taurus* cattle must not be exported from Australia across the Equator between April and October as they are at risk of heat stress and death (see Section 1).

Any amount of room does not alleviate the risk of heat stress. Introducing an alternative arrangement for all months of the year with lower *k*-values and therefore proportionally reduced space allocation under ASEL v3.2 (2021) compromises animal welfare.

Based on OIE recommendations and the Five Domains theory of animal welfare, cattle being exported by sea should be given space allocation with at least an allometric *k*-value of 0.033 during all voyages to alleviate adverse welfare outcomes (Beausoleil and Mellor, 2015; Mellor and Beausoleil, 2015; OIE, 2019a; b).

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.

It has been known for decades that bovine respiratory disease complex (BRD) is a particular problem in long-haul, southern-sourced ships carrying *B. taurus* animals (More, 2002). Cattle being prepared for export are exposed to the stress factors of BRD which include weaning, saleyards, transport, injury, dehydration, co-mingling, pen competition, pen "add-ons", handling, weather extremes, dust and feed and water changes (MLA, 2006) prior to any voyage.

The infectious agents associated with BRD include viruses [infectious bovine rhinotracheitis herpes virus 1 (IBR), bovine viral diarrhoea virus (BVDV), bovine respiratory syncytial virus (BRSV), and parainfluenza virus (PI3)] and bacteria [(*Mannheimia haemolytica*, *Pasteurella multocida*, and *Haemophilus somnus*)].

Currently available commercial BRD vaccines in Australia protect against IBR and *M. haemolytica*. Commercially available vaccines include:

- Rhinogard® IBR vaccine (Zoetis), which is a single-dose, live intranasal vaccine
- Bovi-Shield® MH-One *M. haemolytica* Vaccine for Cattle (Zoetis) which is an inactivated bacterin-toxoid and a single dose confers protection within 7 days and for at least 17 weeks
- Bovilis MH + IBR® (Coopers) combined vaccine which is a killed vaccine and *requires 2 doses* 14-180 days apart.

Some importing countries do not allow use of live vaccines and it is important to follow on-label instructions. For example, only one dose of killed IBR vaccine was administered to cattle in pre-export quarantine in Portland in 2016, and 149 beef and dairy breeder cattle died of BRD during export (MIR 62).

Vaccination of cattle against two of the organisms associated with the BRD complex should be implemented for all cattle exported by sea from southern Australian ports *in all months of the year* as cattle are at risk of death during live export in all months of the year (Figure 3.1).

All cattle should be vaccinated on-farm, as per label instructions prior to entry to feedlot/registered premises (RP) while cattle are still naïve to many of the organisms they could be exposed to upon entry into feedlot or RP prior to export.

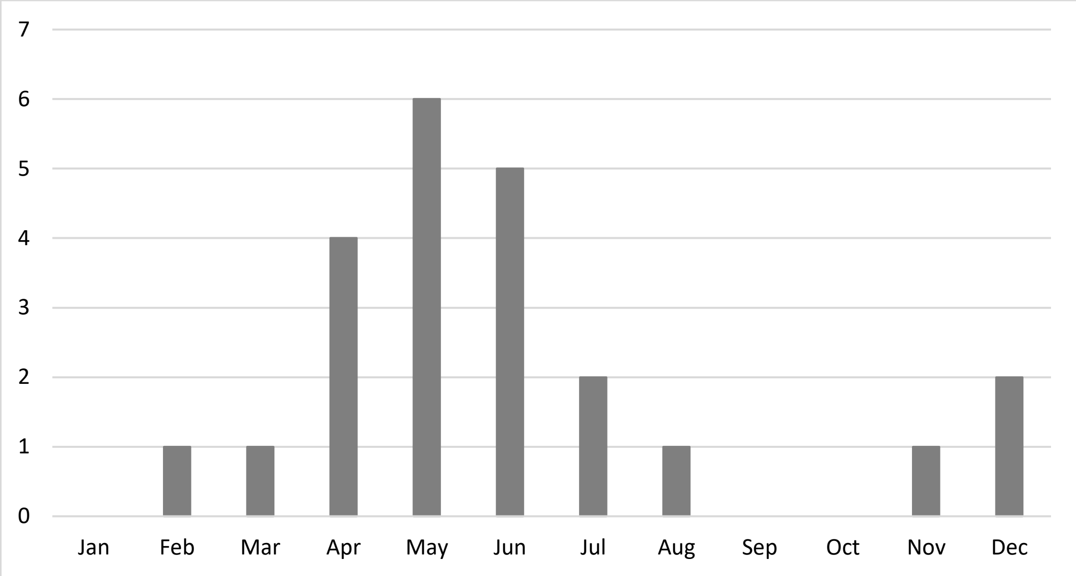


Figure 3.1. Distribution by month of loading of number of long-haul voyages (n = 23) that had a mortality > 0.4% in cattle exported by sea from southern Australian ports that crossed the Equator between 2016 and 2020 inclusive to China/Middle East/Mexico (Source: www.awe.gov.au/biosecurity-trade/export/controlled-goods/live-animals/live-animal-export-statistics/reports-to-parliament).

Some of the many and severe stressors during preparation/voyages include:

- Cattle are sourced from multiple farms of varying vaccination status (MIR 62 sourced cattle from 61 properties, MIR 73 cattle sourced from 222 vendors via 3 feedlots, MIR 79 cattle sourced from 22 properties).
- Cattle are drafted into groups at RP based on weight rather than farm of origin.
- Bad weather in RP.
- Vaccines may not be administered as per label instructions in feedlots (MIR 73)/RPs (MIR 62):
  - Whereas, in MIR 74: "*A different BRD vaccination regime (*as opposed to the voyage reported in MIR 73 but not stated in the report*) … was implemented for this voyage. BRD did not appear to be a major contributing factor to the mortalities on this voyage*".
- Rough seas, high winds and rain on ships (MIR 62).
- Equatorial zones are hot all year and cattle therefore need healthy lungs to assist with shedding heat load through panting:
  - MIR 73: "*AAV reported all mortalities showed lung pathology consistent with BRD, exacerbated by heat stress… the highest number of mortalities occurred on the days when the temperature and pant scores peaked*" describes how 40 out of 46 mortalities were attributed to pneumonia and heat stress while crossing the Equator.

Vaccination against respiratory organisms will also assist protection against infectious bovine keratoconjunctivitis (pink eye). It has been shown that a multitude of organisms, especially in the live export supply chain, can affect cattle eyes. These include IBR, PI3, BRSV and BVD viruses. These "viral initiators" cause conjunctivitis and damage to the cornea and predispose the animal to infection with the bacteria that cause pinkeye. In the live export supply chain, these diseases should be considered when trying to minimise eye disease (Laurence, 2019).

Information from MIR 62 concerning a shipment of *breeder* cattle exported by sea over 23 days from Portland to Mexico on 27 April 2016 where 155/6677 cattle died (mortality rate of 2.32%;

Figure 3.2) and "*bovine respiratory disease (BRD) was the main factor contributing to the mortalities*", include:

- Cattle sourced from 61 properties
- 21-day isolation in RP in Portland
- One dose of Bovilis MH + IBR® (Coopers) despite label instructing 2 doses 14-180 days apart
- Drafted multiple times for selection in week prior to voyage
- 6571 heifers averaged 290 kg, and could have had an adjusted HST of 27.23°C if Jersey, or 29.18°C if Angus/Hereford
- 106 bulls averaged 430 kg, and could have had an HST of 25.46°C if Jersey, or 27.68°C if Angus/Hereford
- Space allocation determined by ASEL 2.3, where *k*-value < 0.033, and deemed too low to avoid adverse welfare outcomes
- Rough seas, high winds and rain on days 6-8 and day 18 with open forward decks (Decks 5-8) covered in water
- Majority of deaths were younger, lighter Angus and Angus-cross heifers.

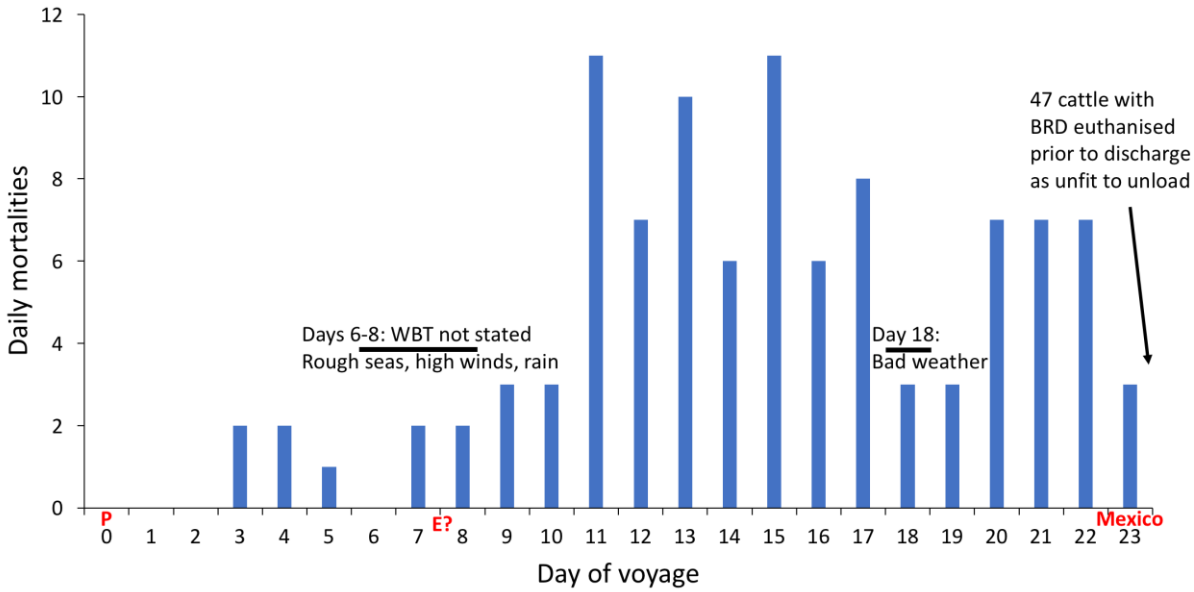


Figure 3.2. MIR 62 concerning a shipment of breeder cattle exported by sea over 23 days from Portland (P) to Mexico on 27 April 2016 where 155 of 6677 cattle died (mortality rate of 2.32%). It is not known when the vessel crossed the Equator (E).

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

Ongoing examination cannot occur if there is no veterinarian on board the vessel carrying livestock. "*The Department does not routinely require an AAV to be on board for slaughter cattle exports to China*" (MIR 79). In 2018-2019, 22 of 37 voyages (59%) carrying cattle to China, ranging from 14-25 days duration, did not carry a veterinarian on board (Hing et al., 2021).

A veterinarian should be on every voyage carrying livestock from any Australian port to any destination port (AVA, 2018a). Where this is not mandated, a veterinarian must, at the very least, accompany all long-haul (10-30 day) voyages and voyages with the heaviest class of cattle (slaughter) that are more prone to heat stress (Maunsell-Australia, 2003) and lameness (Banney et al., 2009; Simpson, 2012; AVA, 2018b).

Heavy slaughter cattle >500 kg must not be shipped at any time.

ASEL 3.2 requires that cattle >500 kg "*must only be sourced for export or exported in accordance with a … heavy cattle management plan*" (DAWE, 2021a) as it acknowledges the higher risk of shipping cattle >500 kg. Heavy ("slaughter") cattle suffer poor welfare on during sea voyages, as illustrated in reportable mortality events reported in MIRs 73 & 74.

Wet bulb temperature risk criteria for heat stress on export vessels (Table 4.1 taken from www.veterinaryhandbook.com.au) generalises safe, cautionary and dangerous WBT ranges for different species of livestock but does not take into account animal body weight, body condition, coat length, time of year and location of sourcing. When these conditions are also considered, it can be seen that cattle > 500 kg from Zones 1, 2 or 3 (Figure 6.1) have adjusted HSTs less than 30°C WBT at all times of the year (Table 4.2) (Maunsell-Australia, 2003; Stacey, 2011; 2017a; b).

Beef cattle > 500 kg in fat score 3 or more, from Zones 1-3 all have an adjusted HST < 26°C WBT in June, July and August and < 28°C WBT in April, May, September and October and therefore are at greater risk of heat stress during voyages from southern Australian ports across the Equator during these months.

Table 4.1. Wet bulb temperature risk criteria for heat stress on export vessels (Table 14.1 in www.veterinaryhandbook.com.au).

		Wet bulb temperature risk range	
Animal type	Safe	Caution	Danger
Bos indicus	<28°C	28–31°C (non-acclimatised) 30–33°C (acclimatised)	>31°C (non-acclimatised) >33°C (acclimatised)
Bos taurus	<26°C	26–30°C	>30°C
Sheep	<26°C	26–29°C	>29°C

Table 4.2. Adjusted heat stress threshold (HST) wet bulb temperatures (WBT) for *Bos taurus* cattle weighing 500 kg, in fat score 3, in different coat lengths and geographical zones by month of the year based on HotStuff calculations (Maunsell-Australia, 2003; Stacey, 2011; 2017a; b). In any category, cattle heavier than 500 kg will have a lower adjusted HST and be more at risk of heat stress for any given WBT. It has been noted that the current version of HotStuff only includes climatology for Middle Eastern ports.

Parameter	**Body weight (kg)**	**Coat length**	**Zone**	**Adjusted HST WBT (°C)**	**Zone**	**Adjusted HST WBT (°C)**	**Zone**	**Adjusted HST WBT (°C)**
Standard *Bos taurus* beef	**300**	**mid**	**std**	**30.00**	**std**	**30.00**	**std**	**30.00**
Sourced in Jan	500	summer	1	28.99	2	29.51	3	30.03
Sourced in Feb, Dec	500	summer	1	28.86	2	29.38	3	29.87
Sourced in Mar, Nov	500	mid	1	27.61	2	28.16	3	28.66
Sourced in Apr, Oct	500	mid	1	27.05	2	27.61	3	28.02
Sourced in May, Sep	500	mid	1	26.49	2	27.05	3	27.41
Sourced in Jun, Aug	500	winter	1	24.69	2	25.30	3	25.63
Sourced in July	500	winter	1	24.53	2	25.14	3	25.45

Information from MIR 73 concerning *slaughter* cattle exported by sea over 17 days from Fremantle to China on 31 May 2018 (under ASEL 2.3 space allocation; note retrograde step of introducing an "alternative" reduced space allocation for cattle being shipped in May to October under ASEL 3.2 which follows ASEL 2.3) where 46 of 3180 cattle died (mortality rate 1.45%; Figure 4.1) demonstrates how the mean WBT across all decks was greater than the adjusted HST of cattle that could have been on board from Day 5-13:

- 3033 cattle were predominantly Angus, weighing 588 kg, could have had an HST of 26.34°C (dotted red line in Figure 4.1), and given space allocation under ASEL 2.3 (*k*=0.031).
- 147 steers and heifers weighing 704 kg, could have had an HST of 25.50°C (dotted purple line in Figure 4.1), and given space allocation under ASEL 2.3+15% (*k*=0.038; compared to Beatty et al. *k*-value = 0.05 for Angus-cross cattle under controlled conditions).
- "*AAV reported there was a spike in temperature passing through the equator which affected all decks, particularly the enclosed decks (4, 4A, 5). During this time, the majority of cattle on decks 1-5A had a pant score of 2 (mild panting) with 1% of cattle reaching a pant score of 4 (open mouth panting with tongue out).*"

Figure 4.1 illustrates why *B. taurus* heavy slaughter cattle >500 kg should not be shipped from southern Australian ports across the Equator at any time of the year.

Equally, in January 2020 on a voyage carrying cattle and sheep from Fremantle to Israel it was noted in IORS 212: "The highest recorded wet bulb temperature reached 29.5°C on Day 8 as the vessel crossed the equatorial region. A second peak in wet bulb temperatures up to 27.5°C was reported on Day 16 as the vessel entered the Red Sea. During both these occasions, … cattle displayed a maximum heat stress score of 1". Cattle in fat score ≥ 3, weighing > 500 kg sourced in January (summer-acclimatised), have an adjusted HST < 29.5°C WBT if sourced from Zone 2, and < 30°C WBT if sourced from Zone 3 (Table 4.2).

Additionally, cattle > 380 kg will incur more leg injuries than other cattle, depending on the pen floor and stability of the ship (Banney et al., 2009). Larger animals are more likely to suffer from lameness on board ship, and the lesions typically seen are extremely painful conditions. Foot lesions include claw abrasions, sloughing of claw or hoof wall exposing the sensitive hoof tissues, and exteriorisation of the pedal bone (P3), due to slipping and abrasion on rough or raised flooring. Animals develop swelling and open sores on their fetlocks and carpi due to trauma during lying or rising. Affected animals become unable to rise and will lie in prolonged lateral recumbency once it becomes too painful to stand. This predisposes to development of further abrasions and pressure sores (AVA, 2018a).

Australian-Government accredited veterinarians (AAVs) have reported that the presence of lame cattle on board ship is extremely problematic, not only because the animals suffer severe pain but also because of the consumption of veterinary and stockperson time. These animals are inevitably culled (rather than undergoing commercial slaughter) at their destination (AVA, 2018a).

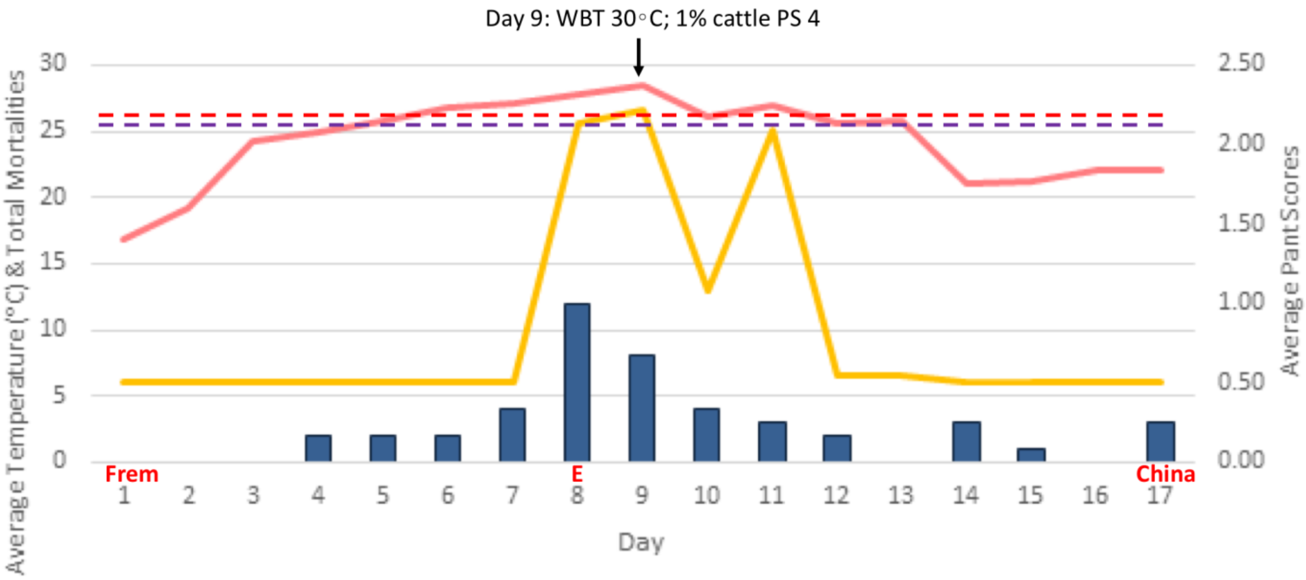


Figure 4.1. Daily mortality (blue bars), mean wet bulb temperature (solid pink line) and panting score (solid yellow line) across all decks, for a 17-day voyage from Fremantle (Frem) to China, in May 2018 that crossed the Equator (E) on Day 8, carrying 3180 slaughter cattle where 46 died (1.45% mortality rate; MIR 73). Heat stress thresholds for cattle weighing 588 kg (26.34°C WBT; dotted red line) and 704 kg (25.50°C WBT; dotted purple line) are shown. Assumptions for HST calculations are shown in Table 1.1.

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.

Further investigation is not required as there is sufficient evidence to show that slaughter cattle should not be exported between April and October.

Risk of heat stress in livestock crossing the Equator exists all year, and peaks in April-June (Figures 3.1 and 5.1) (Maunsell-Australia, 2003). South of 5°S latitude there are periods between March and May where the WBT is elevated to 26-28°C. The near-equatorial region (latitudes 5°S-5°N) is characterised by a relatively uniform WBT of 25-26°C and there is a risk of higher WBTs between April-June when the trade winds tend to be weaker (Figure 5.1). "*There are quite a few periods of time when the wet bulb temperature reaches 28°C*" (Maunsell-Australia, 2003). Table 4.2 summarises adjusted heat stress thresholds for *B. taurus* cattle weighing 500 kg at all times of the year. Any cattle weighing > 500 kg sourced from April to October have an adjusted HST < 28°C WBT.

The open oceanic waters of the Indian Ocean are characterised by generally lower mean wet bulb temperatures than experienced in the Persian Gulf and the Red Sea, as well as the Gulfs of Oman and Aden. However, there are times of the year when there can be sizeable areas with raised wet bulb temperatures. The region between 15°N and 10°N from 50°E to 70°E experiences a period from May to June when the mean wet bulb temperature exceeds 26°C – peaking at 26.7°C in June. The 98th percentile reaches 30°C in June. This is the time of northward transit of the sun and it coincides with prolonged periods of light wind conditions. The May to June period is also very humid over the approaches to the Gulf of Oman, although wet bulb temperatures are generally not quite as high as in the regions immediately to the south and west. The region between 5°N and 10°N between 70°E and 80°E to the west of the southern tip of India also warrants a mention. This region experiences mean wet bulb temperatures above 26°C early in the season – during April and May – as the sun traverses overhead and reaches 29°C on 2% of occasions.

The near equatorial region – from 5°N to 5°S is characterised by a relatively uniform wet bulb temperature distribution – mostly around 25°C to 26°C. There is a slight peak in the period from April to June as the southeast trade winds tend to be weaker at this time of the year and the SW monsoon is yet to develop. It is notable that although there is a strong tendency for most wet bulb temperature to fall within the 25 to 26°C range there are quite a few periods of time when the wet bulb temperature reaches 28°C. Although they are scattered throughout the year there is a preference for them to occur in June. They tend to coincide with periods of time when the SE trade winds are weak and there are large areas of light winds lasting several days. The voyage of the Becrux encountered one such period of elevated wet bulb temperature – reaching 28°C in Late June 2002. It is possible to avoid these areas on most occasions by changing the route to stay over regions where the wind is stronger, although this is not a practice currently followed.

South of 5°S there are periods of time between March and May when the mean wet bulb temperature is elevated close to 26°C. In April the wet bulb temperature reaches 28°C on 10% of occasions and there are occurrences in other months of the year when the temperatures reach 28°C.

Figure 5.1. Excerpt from HSRA model, HotStuff, development project (Maunsell-Australia, 2003).

Most cattle diseases manifest as a result of a combination of stressors and micro-organisms. Stressors that cattle may be exposed to on land at any time of the year include weaning, transport, mixing in saleyards and introduction to intensive farming (feedlot/RP). On ships, they are also exposed to constant loud noise, 24-hour fluorescent lighting, variable movement of ship decks, suboptimal pen conditions (insufficient space, variable ventilation, faeces as bedding), ammonia generated by decomposing bedding, poor quality and/or quantity of feed, engine breakdowns and extreme weather conditions (heat/cold/rough seas) (Hing et al., 2021).

After prolonged dry spells (late summer/early autumn), pre-export cattle may be exposed to higher concentrations of and prolonged exposure to dust, which will contribute to development of BRD and pink eye complexes (Norris et al., 2001; More, 2002; MLA, 2006; Perkins, 2008; Laurence, 2019). There may be more cattle entering RPs with subclinical disease at this time of the year, which can readily develop into clinical disease when exposed to the multiple stressors of live export.

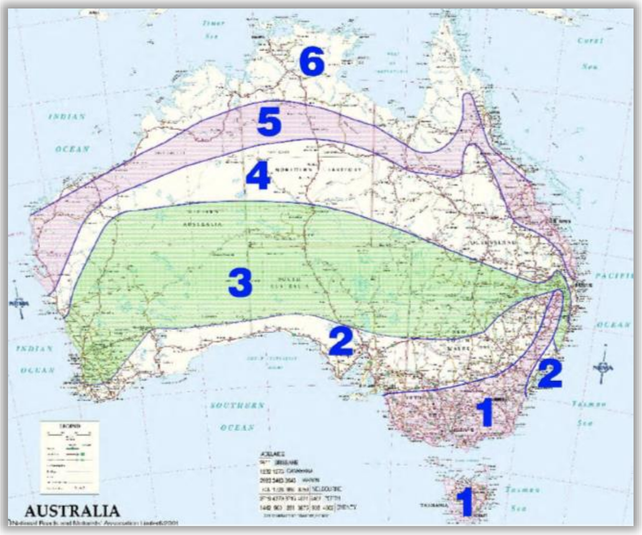
Additionally, cattle may be grazing high fibre pastures/dry-standing stubbles prior to the autumn break then placed on high energy, low effective fibre rations in feedlots/RPs/on ships. The minimum time cattle must remain in an RP prior to departure to the port is 2 clear days for long-haul voyages (DAWE, 2021a) but cattle must be exposed to shipboard rations for many more days than this to ensure smooth adaptation of rumen microflora to the new ration. Adequate fibre in the ration is essential to minimise ruminal acidosis and appropriate rumen degradable protein to minimise atmospheric ammonia. The physical formulation of pelleted feed used during preparation and shipping has also been problematic with regard to formation of fines (pelletised feed tending to disintegrate to powder).

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.

Further investigation is not required as there is already sufficient evidence to show why there is a greater odds of heat load for voyages departing from Portland compared to Fremantle. To address this, high-risk cattle (i.e., dairy breeds, areas sourced) should not be exported during high-risk times of the year, (i.e., April to October).

Cattle exported from Portland are likely sourced from Zones 1 and 2 (Figure 6.1) whereas cattle exported from Fremantle are likely sourced from Zones 2 and 3. Cattle from more southern latitudes are less acclimatised to equatorial crossings at all times of the year (Tables 4.2 and Fig 6.1) (MAMIC, 2001; 2002; McCarthy, 2002; Maunsell-Australia, 2003; Barnes et al., 2004; McCarthy, 2005; Stacey, 2006; 2011; 2017a; b).

Additionally, cattle exported from Portland are more likely to be dairy cattle, that have a lower HST than beef cattle (Table 1.1).



	ZONE					
	1	**2**	**3**	**4**	**5**	**6**
Jan	**15**	**17**	**19**	**21**	**23**	**25**
Feb	14.5	16.5	18.4	20.4	22.3	24.3
Mar	13	15	16.8	18.6	20.5	22.3
Apr	11	13	14.5	16.3	18	19.5
May	9	11	12.3	13.9	15.5	16.8
Jun	7.5	9.5	10.6	12.1	13.7	14.7
Jul	**7**	**9**	**10**	**11.5**	**13**	**14**
Aug	7.5	9.5	10.6	12.1	13.7	14.7
Sep	9	11	12.3	13.9	15.5	16.8
Oct	11	13	14.5	16.3	18	19.5
Nov	13	15	16.8	18.6	20.5	22.3
Dec	14.5	16.5	18.4	20.4	22.3	24.3

Figure 6.1. Australian weather map zones used in the HotStuff model for predicting heat stress in livestock and HotStuff HSRA model acclimatisation wet bulb temperatures by zone and month (Stacey, 2017a)(Maunsell-Australia, 2003).

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

If the HSRA model, HotStuff, predicts that the adjusted HST for cattle destined for export exceeds the predicted deck WBT, then those cattle should not be exported at that time of the year. Mitigation strategies employed reactively during transit are not significantly beneficial, assuming space allocation and ventilation meet ASEL standards. For example, on a 24-day voyage carrying cattle and sheep from Adelaide and Fremantle to Israel in May 2018 (IORS 3), the AAV commented on Day 17 "*today we were in the very severe heat stress areas of the heat curves on the verge of the dying animals section … They had room and no amount more would have made much difference*" (FOI LEX-755 page 382).

The HotStuff HSRA model is based on data collected during commercial live export voyages and research undertaken in controlled climate rooms under the guidance of animal ethics committees over the past twenty years (MAMIC, 2001; 2002; Maunsell-Australia, 2003; 2004; Beatty, 2005; McCarthy, 2005; Beatty et al., 2006; Stacey, 2006; Stockman, 2006; Smith et al., 2007; Beatty et al., 2008; Stacey, 2011; Stockman et al., 2011; Stacey, 2017b; a). It is acknowledged that HotStuff only includes climatology for Middle Eastern ports but this is the only version currently available. The model considers the following:

- Environmental factors including long-term and immediate weather predictions, ports of origin and destination
- Ship factors including ventilation capacity of ship, space allocation
- Animal factors including species, breed, body weight, body condition score, hair/wool length and month and district of sourcing.

Regardless of the ventilation efficiency on any ship transporting livestock, there is a rise in WBT across all decks during voyages. Heat inputs include:

- Ambient air drawn from outside onto each deck
- Heat generated by the ventilation system caused by friction/motors

- Metabolic heat produced by livestock including digestion and evaporative cooling
- Heat from evaporation and decomposition of faeces and urine in the faecal pad
- Elevated sea temperature crossing the Equator at all times of the year, and during April to October north of the Equator.

Livestock are exposed to multiple stressors during live export including constant loud noise, 24-hour fluorescent lighting, variable movement of ship decks, suboptimal pen conditions (variable ventilation, insufficient space, faeces as bedding), ammonia generated by decomposing bedding, variable feed quality and quantity, engine breakdowns and extreme weather conditions (heat/cold/rough seas) (Hing et al., 2021). Shipboard crew understand that livestock are in the precarious position of hyperthermia in hot conditions as "*voyage reports often mention minimising unnecessary handling and disturbance of animals to avoid unnecessary physical exertion*" (DAWE, 2021b) (of both animals and crew). This means any livestock requiring veterinary attention must wait. For example, the Independent Observer noted on a voyage in April 2018, that it was too hot to move sheep with pinkeye "*due to the stress of the weather conditions at the present*" (FOI LEX-755 page 343).

Fodder quality and quantity were reviewed in 2011 and the fundamental needs for high roughage, high performance and high safety rations with minimal adaptation were discussed (Willis, 2011). A live export project called "Fodder on Board" was initiated in late 2017 (Norman, 2019). The results of this study should identify appropriate chemical and physical constituents of pellets (fibre/energy/protein/additives/minimisation of metabolic heat) and livestock adaptation periods and will hopefully play an integral role in reducing livestock morbidity and mortality during shipping if findings are incorporated into ASEL 3.

Where HotStuff calculations show that environmental WBTs are likely to exceed the calculated HST for the particular group of animals, the conclusion should be that the voyage does not proceed. Under these circumstances, wet bulb rise across decks and multiple concurrent stressors risk tipping livestock into unstable hyperthermia and risk of death either directly from heat stress or co-morbidity such as BRD.

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.

The recommendation to monitor environmental conditions for the entire voyage through the use of data loggers during export from Australia by sea appeared in a pilot study nearly 2 decades ago (Maunsell-Australia, 2004; McCarthy, 2005).

Multiple, well-maintained data loggers must be added to every deck, including hotspots, of every ship carrying livestock, as requested by the Australian Veterinary Association:

> "*Aggregated voyage data, including key animal welfare indicators, can and must be measured and collated using up-to-date technologies such as blockchain*" (AVA, 2018c)

and McCarthy in 2018:

> "*Automated continuous environmental monitoring equipment installed as a condition of any approved arrangement*" (McCarthy, 2018).

The accuracy of the single shipboard thermometer on each ship deck is unreliable. For example:

- The IO on a voyage carrying cattle and sheep from Adelaide and Fremantle to Turkey in April 2018 noted that: "*the Dry and Wet bulb temperatures recorded at some stages in this* *voyage were questionable … they need regular cleaning to maintain their accuracy*" (FOI LEX-755 page 17 of 845).

- The IO on a voyage carrying cattle and sheep from Fremantle to the Persian Gulf in June 2018 noted that: "*Toward the end of the voyage I came across several thermometers where the wet bulb temperature was as high as and in one case higher than the dry bulb reading…*" (FOI LEX-755 page 722 of 845).
- The IO on a voyage carrying cattle and sheep from Fremantle to Israel in June 2018 noted that: "*not all of the wet/dry bulbs were in working order so humidity levels … unlikely to be reliable*" (FOI LEX-755 page 805 of 845).

A mid-morning reading of the single shipboard thermometer on each ship deck does not necessarily indicate the maximum WBT reached during any particular day nor does it describe the amount of WBT variation in any 24-hour period, nor does it represent the WBT across the entire deck. For example:

- The IO on a voyage carrying cattle and sheep from Adelaide and Fremantle to Turkey in April 2018 noted that: "*The readings are routinely taken 4 times each day at 6 hourly intervals from midnight… Extra reading (5th) … taken … at 3pm…were often hotter and more humid than the 12 noon readings"* (FOI LEX-755 page 19 of 845).
- IORS 10 noted on a voyage carrying cattle and sheep from Fremantle to Israel in June 2018 that: "*The IO felt that given the average was being reported that this did not reflect the daily maximum temperature and humidity levels*".

A mid-morning reading of the single shipboard thermometer on each ship deck does not necessarily represent the WBT across the entire deck. For example:

- MIR 73 noted on a ship carrying cattle from Fremantle to China in May 2018 that: "*The AAV noted most of the readings were taken in areas where there was good ventilation*".
- IORS 166 noted on a voyage carrying cattle from Portland to China in August 2019 that WBT was measured once daily on each deck and was not representative as relative hot spots existed across decks.
- IORS 9 noted on a voyage carrying cattle and sheep from Fremantle to the Middle East in June 2018 that: "*Each of the decks has just one thermometer. These are located in a position that is generally central and handy to access for reading, but are unlikely to be representative of the worst environmental conditions on the particular deck*".

Location of hot spots on any livestock vessel are known and likely identified in their first few voyages carrying livestock loaded from southern Australian ports across the Equator, at any time of the year, as some degree of heat stress occurs in livestock at every equatorial crossing. For example, this comment was made in IORS 206, during a voyage carrying cattle and sheep from Fremantle to the Persian Gulf in December 2019: "*The ventilation system was supported with ancillary fans to cover known hotspots and areas prone to containing stagnant air*".

It is incomprehensible that DAWE has not yet mandated that hotspot areas must have improved ventilation using permanent measures (as opposed to reactive use of portable fans) to ensure ships are equipped to help safeguard animal welfare.

It should not be up to stockpersons in transit to ensure "*ventilation systems are functioning to full capacity and identifying ventilation dead-spots such as bulk heads, as strategies for heat mitigation*" (LiveCorp, 2020). Hotspot pens should not be stocked and instead be used for storage use only (fodder/bedding etc.) unless it is deemed too much of a fire hazard (risk of spontaneous combustion) to store fodder/bedding in these zones. Hotspot pens could also be used as hospital pens for livestock suffering cold stress during northern hemisphere winter voyages.

Hotspot areas must be required to have improved ventilation using permanent measures to ensure ships are equipped to help safeguard animal welfare. Where this is not in place, hotspot areas must not be stocked.

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

Livestock should not be on ships in conditions under which sloppy "pads" are able to develop as housing livestock on/in liquid faeces/urine/bedding significantly compromises animal welfare. (See Section 1 about use of HSRA model HotStuff to predict when it is unsafe to export livestock.) Faecal pad management should not just be about image: "*a positive impact on the animal welfare image of the industry*" (Banney et al., 2009).

There were 53 of 214 (24.8%) voyages with evidence of increased heat load in the Draft Report and sloppy pads were noted on 44 of 214 [20.6% of voyages (DAWE, 2021b)]. No association was made between the two in the Draft Report, but this requires further investigation and analysis.

Degree of sloppiness of bedding is an excellent indicator of heat stress in livestock during export (when not due to leaking water pipes/troughs, rain, sea water). Briefly, as WBT rises on decks, livestock drink more water to augment evaporative cooling via sweating and panting (85% of heat gained by air moving through pens appears as additional water vapour). However, the water vapour pressure gradient between animals and the environment is not sufficient for evaporation to occur, so livestock are less able to regulate core body temperature (and move from tolerance zone to survival zone in Figure 1.2), urinate more and the bedding becomes more and more sloppy.

Additionally, as stated in Section 5.3 of the Draft Report: "*It is imperative that cattle have an adequate source of clean drinking water during periods of high environmental temperatures*" (DAWE, 2021b). Paradoxically, faeces become sloppier as deck WBT rises and increasing faecal liquidity poses an ever-greater risk of water spoilage via splashing of faeces into water troughs, which could then impede water intake and increase exposure to pathogens.

For example, IORS 207 states "Cattle pads were soft to muddy with depths ranging from heel to hock", IORS 211 states "Pad depth and moisture levels in cattle pens increased steadily and pads became muddy by day 6" and 214 states "all pads remained firm until the equator, where increased humidity caused the pens to become clay or mud-like, to sloppy". See more comments about pad conditions made in IORS in Table A.2.

It was stated by Banney et al. (2009):

> *"According to industry observations, when wet bulb temperatures reach approximately 31.5°C (dry bulb temperature approximately 33°C and the relative humidity approximately 90%) bedding will increase in moisture and the incidence of pugging will increase with the corresponding increased consumption of water by cattle. Wet bulb temperature of 32°C was quoted as a common rule of thumb for action as animals may become susceptible to heat stress at these temperatures."*

Whilst the WBT range around the Equator is usually 22.5-26.5°C (Figure 1.3), the WBT rise across any deck averages 3.2°C (MAMIC, 2001; 2002; Maunsell-Australia, 2004; Smith et al., 2007). Deck WBT is therefore determined by:

- prevailing weather which determines wet bulb temperature of air being forced onto each deck by mechanical ventilation
- radiant heat from sunshine on steel roof/west side of ship as sails north, bulkheads next to engines/heated oil tanks
- mechanical ventilation motors and fans and frictional losses in pipes add up to 15% of heat
- warm sea temperature
- decomposing bedding/faeces
- metabolic heat from livestock.

Consistent, even ventilation of decks is required to continually lift water vapour and heat from decks to ensure cattle can continue to thermoregulate. High environmental WBT and wet bulb rise across decks combines with high livestock densities and infrastructure impeding and altering air flow, so hotspots develop to a lesser or greater degree, 32°C WBT is reached and decks become sloppy as water vapour increases and cattle struggle to control body core temperature using evaporative cooling.

Auditing of ship ventilation under fully stocked conditions must occur on a regular basis to ensure ongoing maintenance of fans and motors to ensure that ventilation is at maximum capacity during equatorial crossings and voyages in the NHS.

In December 2019, on a voyage carrying cattle from Portland to China, it was noted in IORS 210 that on day 6 (maximum WBT of 28°C recorded for two days as the vessel crossed the Equator), a considerable decline in the lower deck pad conditions was observed. Relatively higher humidity was noted on these decks with animals consequently demonstrating signs consistent with a heat stress score of 1, with increased water consumption and urine production observed. This, along with the environmental conditions, was determined to be contributing to the decline in pad conditions. It was subsequently identified that the ventilation system had been running at less than full capacity since departure on those decks.

Additionally, sloppy pads lead to a reluctance to lie down/drink/eat, an increased risk of disease [lameness (infected feet, slipping injuries), abrasions, mastitis, enteritis (contaminated feed and water troughs) and pulmonary irritation secondary to ammonia build up] and cause faecal contamination of skin which can further impede thermoregulation. Figures 9.1-9.5 illustrate faecal pad conditions on voyages from southern Australian ports across the Equator.

Figure 9.1. Firm faecal pad with "no issues identified", day 3, IORS 12, July 2018. Cattle have dry feet and little faecal contamination of their coats when the ship's ventilation system draws moisture out of the faecal pad.

Figure 9.2. Unhygienic, sloppy conditions, day 6, IORS 40, November 2018. Cattle are producing more liquid waste than the bedding can absorb and the ventilation system can evaporate.

Day 12 Cattle in pen—no issues identified

Figure 9.3 This photograph was taken on day 12 of a voyage from Adelaide and Fremantle to Turkey in April 2018, with bridge WBT 28.2°C, a liquid faecal pad and soiling of skin (IORS 1).

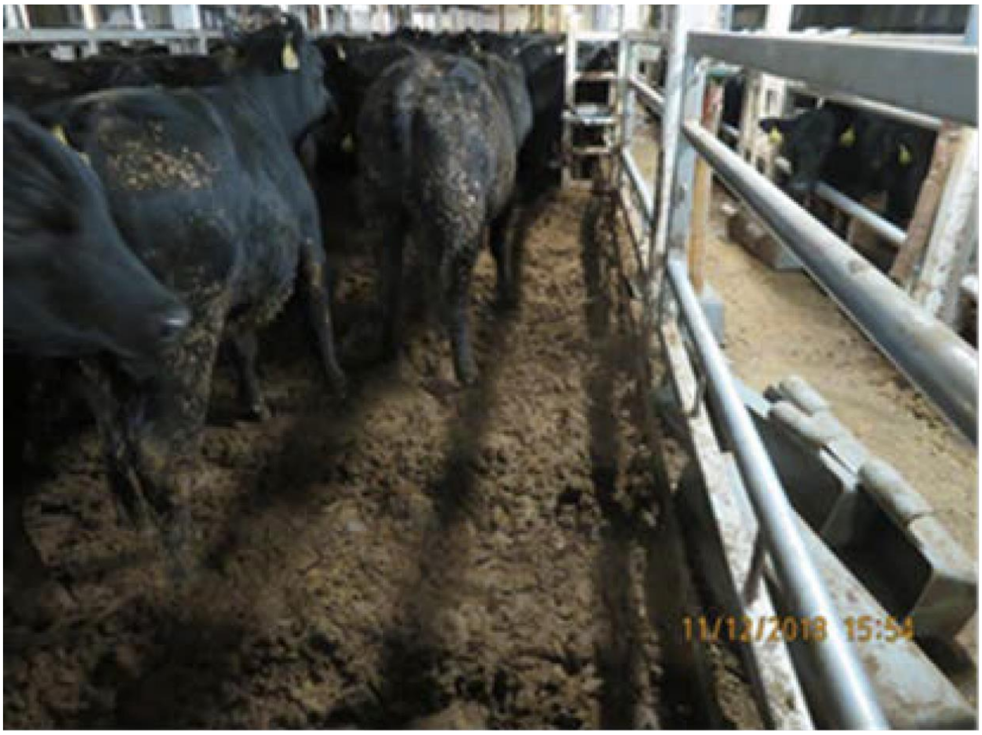


Figure 9.4. This photograph, taken on day 18 of a November 2018 voyage described in IORS 40, is inscribed with "no issues identified", in spite of the fetlock-deep faeces in the picture and the IORS stating "*overall the environment and vessel factors appeared to result in some lameness and subsequent mortalities, poor condition of the pad ... and some loss of condition of shy feeders and lame cattle*."

Figure 9.5. Cattle cheek-by-jowl resting in their faeces, but annotated as "*representative photograph*" with "*no issues identified*" taken on day 5 from IORS 127, May/June 2019. The pictures do not represent cattle in internal pens on open decks (which are not mechanically ventilated) nor hot spots on any deck, nor on "*days with the highest WBT (32°C)*" which were observed from Day 24.

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

Additional research is required to determine optimal types and volumes of bedding for all voyages, especially for those ≥10 days in duration. Once determined, the bedding must be used appropriately to safeguard animal welfare during voyages.

ASEL 3.2 (2021): Section 5.3.9 states: "*Cattle exported on long and extended long haul voyages must be provided with additional sawdust, rice hulls or similar bedding material to be used exclusively for bedding at a rate of at least 7 tonnes or 25 m^3 for every 1000 m^2 of cattle pen space. This additional bedding requirement does not apply to cattle loaded from a port north of latitude 26°S and exported to South-East Asia*." The volume of bedding has not been changed from ASEL 2.3 (2011).

Bedding must be provided throughout all voyages, regardless of duration/port of origin/port of destination to minimise foot and leg trauma (lameness and skin abrasions) at loading, during the voyage and at discharge (Banney et al., 2009),

Bedding must not be withheld until the end of the voyage to create an impression that the faecal pad has been maintained to this standard throughout the voyage. (e.g., IORS 40, Table A.2). The benefits of adequate bedding (a) ensure better welfare of all stock on board, including the reduction of abrasions and lameness (Figure 10.1), and (b) time saved with reduced injury treatments allows crew to spend more time attending all other livestock (Banney et al., 2009).

Day 17 Cattle in pen—no issues identified

Figure 10.1. This photograph was taken on day 17 of a voyage from Adelaide and Fremantle to Israel and Jordan in May 2018, with WBT 30°C, a liquid faecal pad, apparently "*no issues identified*" and a comment from the IO stating on 11 May "*they are deeply asleep in excrement and perfectly happy*" but on 14 May states "*there has been the expected increase in foot issues in the cattle. 35 are under treatment for mild lameness or general malaise*" (IORS 3; FOI LEX-755 pages 339, 353).

Figure 10.2 illustrates that the minimum ASEL 3.2 bedding requirements allow for a total of 25 mm bedding on cattle decks for voyages ≥ 10 days. More must be loaded to cover ramps and walkways during loading and discharge, but clearly, this is inadequate from a welfare perspective.

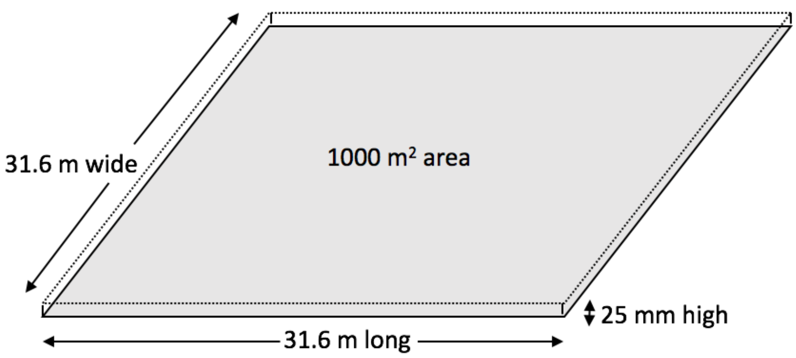


Figure 10.2 The ASEL 3.2 bedding requirement for voyages ≥ 10 days' duration is 25 m^3 for 1000 m^2 cattle pen space or a depth of 25 mm, for voyages of any duration ≥ 10 days (not to scale).

DAWE already understands the importance of bedding. MIR 52 describes the maiden voyage of a new livestock export ship in April 2017, where 95 of 1236 cattle died (7.69% mortality rate) during an 8-day voyage as a result of cattle slipping over on slippery deck floors and not being able to rise. The Department considered applying the following additional condition to the next livestock export consignment using the same vessel:

- Bedding must be loaded onto the vessel, at a minimum quantity of 25 m^3 for every 1000 m^2. (Bedding is not required under ASEL on voyages shorter than 10 days).

In spite of a recommendation being made in 2009 and reiterated in 2016 to develop a scoring system for bedding condition, abrasions, lameness, body faecal contamination and time spent lying/standing to assist industry benchmark and improve health and welfare outcomes associated with bedding (Banney et al., 2009; McCarthy and Banhazi, 2016), there is apparently still no data to understand what benefits 25 m^3 bedding per 1000 m^2 cattle pen space (independent of voyage length) provides cattle on any voyage.

Australian-Government accredited veterinarians report that available bedding on long haul voyages is generally insufficient (AVA, 2018a). Quantities should not be token but should be of a quantity that ensure animals can rest comfortably, to manage faecal pads in humid conditions, and for management of lame and pregnant livestock. There must be adequate volume and changes of bedding to absorb moisture from faeces and urine to stop caking of animals and contamination of feed and water troughs. Additives to bedding could be considered to help reduce ammonia production (McCarthy, 2002; Lean, 2003; Tudor et al., 2003; Banney et al., 2009; McCarthy and Banhazi, 2016).

Standards should be amended to include the current allowance of bedding per square metre of deck, for every 4 days of voyage (e.g., IORS 1 & 8 state cattle deck washing procedures were performed on a four-day cycle; IORS 2 a 5-day cycle).

Bedding should be in a form that does not predispose to respiratory diseases (Perkins, 2008) and pink eye (Laurence, 2019) and there should be extra to support care of hospital cattle as well as load and discharge requirements (AVA, 2018a).

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

Premature lactation is a considerable welfare issue in exported dairy heifers (Mansell et al., 2012). Structured data collection was recommended in 2015 (Mansell et al., 2015).

The RSPCA welcomes the change under ASEL 3.2 (2021) with respect to pregnancy requirements so that livestock must not be exported in the last third of their pregnancy.

Premature lactation should be included in the daily reports. Additionally, southern-sourced pregnant *B. taurus* cattle should not be exported on voyages which cross the Equator from April to October.

The risks of premature lactation and mastitis before parturition increase considerably, secondary to (a) warm weather, and (b) serious environmental contamination from liquid faecal bedding (see Sections 5 and 10) (McCarthy, 2002; Lean, 2003; Mansell et al., 2012). Anecdotally, udder development becomes noticeable a week or more into a journey and becomes a problem once the animals are subjected to more significant heat stress (Mansell et al., 2012).

Factors which may alter the hormonal status of pregnant and non-pregnant cattle prior to or during shipment include:

- prolonged access by to *ad libitum* pelleted feed with insufficient chaff in pre-export facilities combined with long-haul voyages
- presence of zearalenone (potential source of oestrogen) and/or other mycotoxins either incorporated into cereal-based pellets at manufacture (not supported by (Mansell et al., 2015) and/or through fungal spoilage of shipboard feed during voyages (ship silos are not emptied after every voyage)
- co-mingling/transport/other stresses
- constant lighting which could affect prolactin and IGF secretion (Mansell et al., 2012).

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

Onboard data loggers are essential to collect good quality data including WBT, DBT and RH on the proviso that they are placed in appropriate locations and that daily strategic recordings are obtained and analysed which reflect a true indication of the conditions being endured by all cattle on the voyage.

The capacity to collect automatically logged environmental data such as WBT, DBT and RH for entire voyages was demonstrated nearly 2 decades ago (Figure 12.1). A recommendation to monitor environmental conditions during export of livestock by sea was made then (Maunsell-Australia, 2004; McCarthy, 2005). See response to Recommendation 8.

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.

Training and legislation *may* ensure the use of and reporting of cattle panting scores are consistent. The recommendation to record panting scores in cattle and sheep to monitor animal performance during export from Australia by sea appeared in a pilot study nearly 2 decades ago (McCarthy, 2005). The DAWE Daily Voyage Report for *sheep* that AAVs/accredited stockpersons forward to the Department on a daily basis now includes panting scores (DAWR, 2018a).

Monitoring of panting scores in cattle must be implemented as soon as practicable, as per Table 4.3 in www.veterinaryhandbook.com.au (Table 13.1; (LiveCorp and MLA, 2019)).

Section 4.4.1 of the Draft Report indicated the variable quality and quantity of data in voyage reports (DAWE, 2021b). The RSPCA faced similar challenges using the publicly available data, including the use of and reporting of panting scores. For example, MIR 73 states: "*AAV reported there was a spike in temperature passing through the Equator which affected all decks, particularly the enclosed decks (4, 4A, 5). During this time, the majority of cattle on decks 1-5A had a pant score of 2 (mild panting) with 1% of cattle reaching a pant score of 4 (open mouth panting with tongue out).*" The normal respiratory rate for cattle is 10-30 breaths/minute under average land conditions (Radostits et al., 2007). A panting score of 1, with a respiratory rate of 40-70 breaths/minute would be classified as slight or mild panting (Table 13.1).

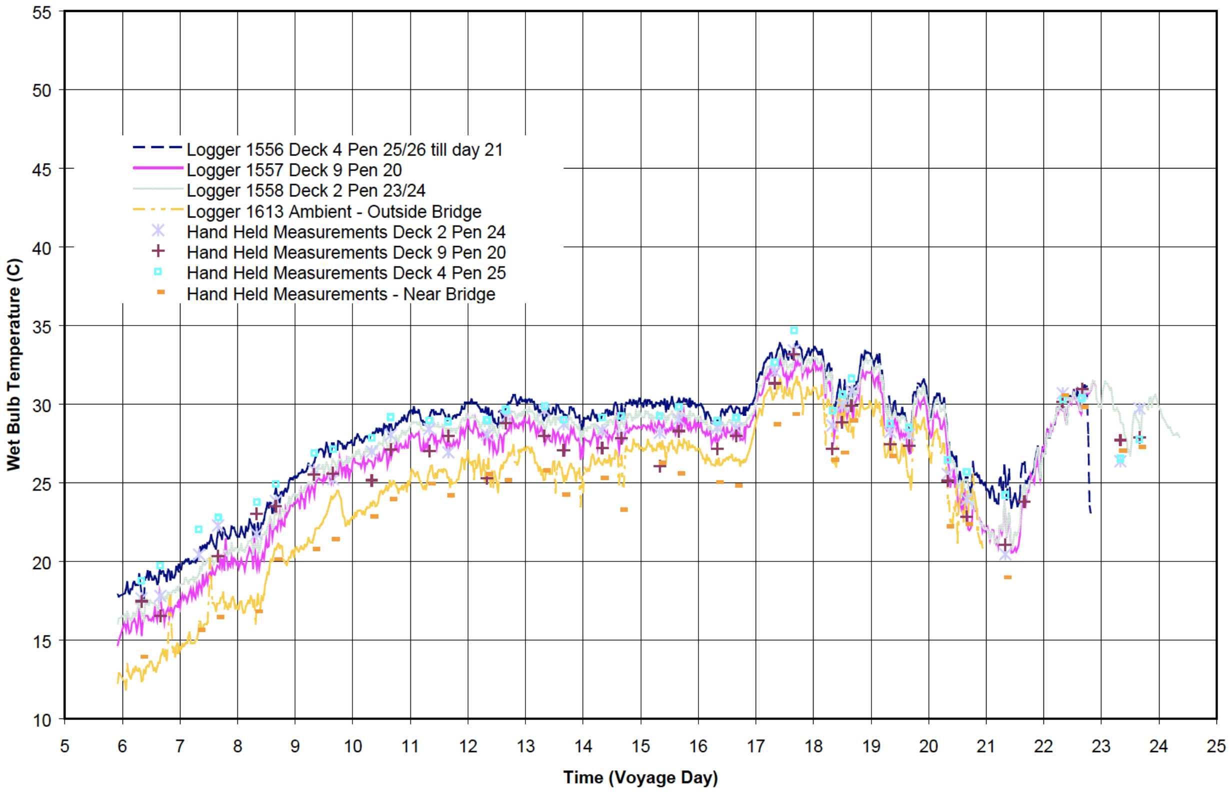


Figure 12.1. Wet bulb temperatures calculated from automatically logged data collected on a voyage to the Middle East in June/July 2002. (Maunsell-Australia, 2004). Interestingly, the report noted that "*although the dry bulb temperatures and relative humidity may oscillate considerably, the wet bulb temperature changes more slowly with time*" and "*there may be no overnight respite*". Lack of ability to shed heat load from south of the Equator for many days in a row leaves livestock in a precarious position on ships.

Table 13.1. Panting score used in the assessment of heat stress in cattle [appears as Table 4.3 in the Veterinary Handbook (LiveCorp and MLA, 2019) based on Table 2 in (McCarthy, 2005)].

Breathing Pattern	Panting score (PS)	Respiratory rate (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 without occasional open mouth. 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 & 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 with head held down. Cattle 'breath' from flank, drooling may cease	4.5	Variable - RR may decrease

Section 4.4.1 of the Draft Report indicated the variable quality and quantity of data in voyage reports (DAWE, 2021b). The RSPCA faced similar challenges using the publicly available data, including the use of and reporting of panting scores. For example, MIR 73 states: "*AAV reported there was a spike in temperature passing through the Equator which affected all decks, particularly the enclosed decks (4, 4A, 5). During this time, the majority of cattle on decks 1-5A had a pant score of 2 (mild panting) with 1% of cattle reaching a pant score of 4 (open mouth panting with tongue out).*" The normal respiratory rate for cattle is 10-30 breaths/minute under average land conditions (Radostits et al., 2007). A panting score of 1, with a respiratory rate of 40-70 breaths/minute would be classified as slight or mild panting (Table 13.1).

In this same voyage, cattle were exposed to WBTs that approached their HSTs on Days 3-5 of the voyage, surpassed HSTs on Days 6-13, and yet panting scores remained at an average of 0.5 in all cattle across all decks on Days 1-7 and reached an average of panting score 2 on Day 8 of the voyage (Figure 13.2). One would have anticipated a stepwise progression of panting scores as WBT approached HST (Figure 13.3).

The livestock export industry recently commissioned another pilot study on animal welfare indicators during voyages to better understand shipboard life from the point of view of livestock. The study recommends collection of data once or twice daily on elected days on welfare indicators including posture, resting, ruminating, roughage availability, ocular and nasal discharge, coat faecal contamination, and faecal pad moisture and depth to better understand heat stress in livestock including feeder and slaughter cattle (Collins et al., 2021).

The requirement for more data collection during voyages must be implemented as soon as practicable and data interpreted at the completion of every voyage to update ASEL in a timely manner and on an ongoing basis to optimise animal welfare.

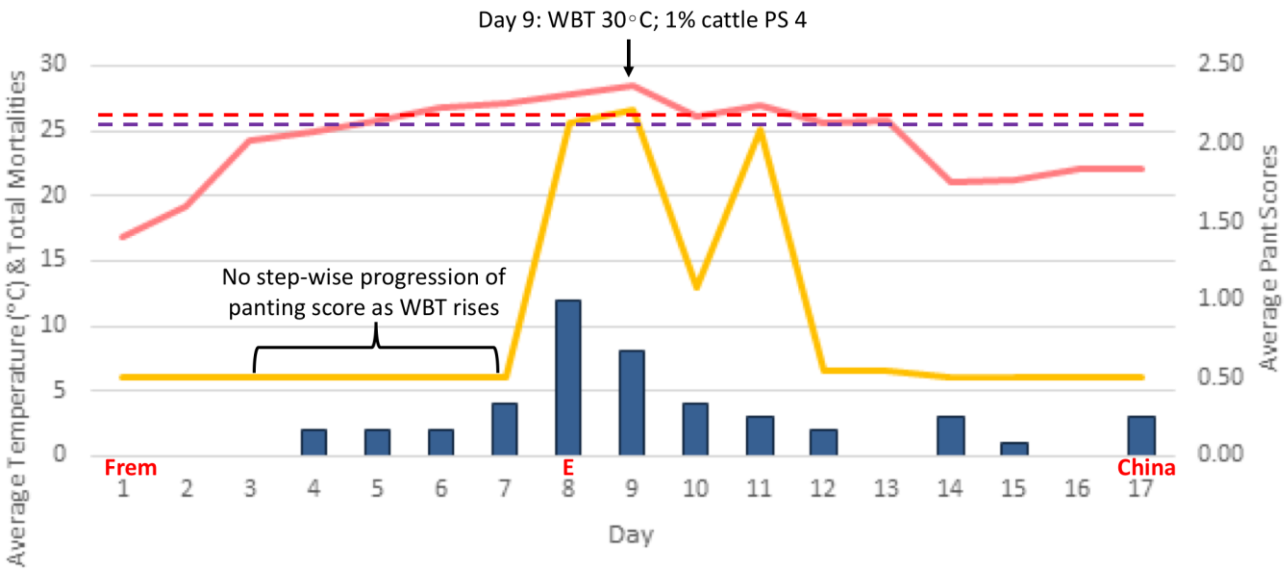


Figure 13.2. Daily mortality (blue bars), average wet bulb temperature (solid pink line) and pant score (solid yellow line) across all decks, for a 17-day voyage from Fremantle (Frem) to China, in May 2018 that crossed the Equator (E) on Day 8, carrying 3180 slaughter cattle where 46 died (1.45% mortality rate; MIR 73). Heat stress thresholds for cattle weighing 588 kg (26.34°C WBT; dotted red line) and 704 kg (25.50°C WBT; dotted purple line) are shown. Assumptions for HST calculations are shown in Table 1.1. An independent observer was not on board the ship.

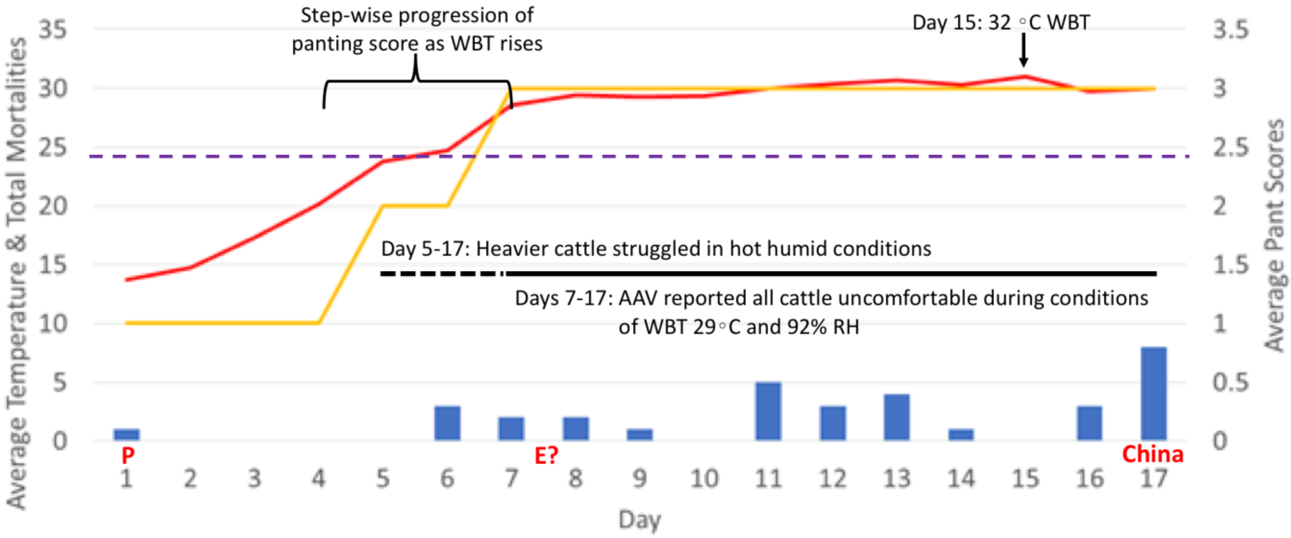


Figure 13.3. Daily mortality (blue bars), average wet bulb temperature (red solid line) and pant score (solid yellow line) across all decks, for a 17-day voyage from Portland (P) to China, in July 2018 that crossed the Equator (E) on an unstated day, carrying 2192 slaughter cattle from NSW and SA where 33 died (1.51% mortality rate; MIR74). Heat stress threshold for cattle weighing 597 kg (24.25°C WBT; dotted purple line) is shown (assumptions in Table 1.1). Heat stress was found to be the main cause of mortalities. An independent observer was on board the ship.

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.

The RSPCA concurs with the sentiments in all the cold stress recommendations 14-18 in the Draft Report and notes the lack of data on the public record on this topic, in spite of cattle export by sea to cold climate destinations, such as Russia and China, for many years.

In a recent review of cattle exports to China between July 2018 and December 2019 through examination of IORSs, a DBT ≤ 2°C was recorded on 5/27 (14%) voyages with unspecified cold temperatures recorded in other IORSs (Hing et al., 2021).

Further research into cold stress is essential and should include examination of temperature range as well as absolute temperatures for the voyage duration.

Until further research can be undertaken into cold stress in cattle, the precautionary principle should prevail by implementing the following recommendations between December and February to cold climate destinations:

- **Only *B. taurus* feeder, breeder and slaughter cattle > 250 kg with body condition score ≥ 3 (out of 5) should be exported to cold climate destinations between December and February (inclusive) to ensure adequate body size, subcutaneous fat reserves that will insulate against the cold and support an increased metabolic rate. Summer-acclimatised cattle lack homeorhetic winter adaptations including insulation from a heavy winter coat and adequate level of feed intake.**
- **Minimum loaded rations to be increased by 5% to allow for 10% increased energy requirements in second half of any voyage to a cold destination port.**
- **Second feed of the day as late as possible to coincide with feed-related increases in metabolic heat production with colder night conditions.**
- **Provision of wind-chill prevention by:**
    - **consideration of timing and method of deck wash-downs so cattle are not wetted in the last 5 days of voyages between December and February**
    - **destocking open decks susceptible to inundation in wet weather/rough seas between December and February.**
- **Provision of twice the volume of bedding in ASEL 3.2 to provide adequate bedding across Equator and in the last 5 days of the voyage.**

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Table A.1. 2016-2020 long-haul voyages (10-30 days) from southern ports to China, the Middle East and Mexico where cattle mortality > 0.40% (sourced from: www.awe.gov.au/biosecurity-trade/export/controlled-goods/live-animals/live-animal-export-statistics/reports-to-parliament).

									Cattle			Sheep		
Load Date	**MIR ***	**IO ^**	**Exporter Licence Holder(s)**	**Load Port(s)**	**Destination Port(s)**	**Region/ country**	**Discharge Date**	**Duration (days)**	**Load**	**Loss**	**%**	**Load**	**Loss**	**%**
Feb 2016			LSS	Fremantle	Aqaba/Eilat	Red Sea	Mar 2016	27	**10768**	**47**	**0.44%**	41778	269	0.64%
Apr 2016			Elders	Portland	Tianjin	China	Apr 2016	19	**3119**	**20**	**0.64%**			
Apr 2016	62		Landmark	Portland	Mazatlan	Mexico	May 2016	26	**6677**	**153**	**2.29%**			
Apr 2016			LSS	Adelaide/ Fremantle	Aqaba/Eilat	Red Sea	May 2016	29	**10215**	**48**	**0.47%**	60973	372	0.61%
Jun 2016			Landmark/LSS	Adelaide/ Fremantle	Aqaba/Eilat	Red Sea	Jul 2016	23	**8531**	**56**	**0.66%**	40709	488	1.20%
Jul 2017			Emanuel	Fremantle	Hamad/Jebel Ali/Kuwait	Persian Gulf	Jul 2017	23	**200**	**2**	**1.00%**	63056	527	0.84%
Dec 2017			Atlas/Emanuel/ EMS Rural/ILE	Fremantle/ Portland	Hamad/Karachi/ Kuwait/Muscat	Persian Gulf	Jan 2018	31	**2607**	**13**	**0.50%**	77130	521	0.68%
Mar 2018			Frontier	Fremantle	Weifang	China	Apr 2018	16	**1559**	**13**	**0.83%**			
Apr 2018		x	Landmark	Portland	Dalian	China	May 2018	21	**2269**	**11**	**0.48%**			
May 2018		x	NACC	Fremantle	Huanghua	China	May 2018	15	**1799**	**10**	**0.56%**			
May 2018	73	x	Phoenix Exports	Fremantle	Lianyungang	China	Jun 2018	17	**3180**	**46**	**1.45%**			
Jun 2018		x	Phoenix Exports	Portland	Qing Dao	China	Jun 2018	17	**2540**	**17**	**0.67%**			
Jun 2018		x	NACC	Portland	Huanghua	China	Jul 2018	20	**1949**	**13**	**0.67%**			
Jun 2018		x	Australian Rural	Portland	Jingtang-Tangshan	China	Jul 2018	21	**3232**	**15**	**0.46%**			
Jul 2018	74	12	Phoenix Exports	Portland	Ningbo	China	Jul 2018	19	**2192**	**33**	**1.51%**			
Nov 2018		40	Landmark	Portland	Tianjin	China	Dec 2018	21	**5606**	**47**	**0.84%**			
May 2019	79	136	SACC	Fremantle	Huanghua	China	Jun 2019	15	**1832**	**25**	**1.36%**			
May 2019		133	RETWA	Fremantle	Jebel Ali/Kuwait	Persian Gulf	Jun 2019	16	**135**	**1**	**0.74%**	56915	65	0.11%
May 2019		127	LSS	Fremantle	Aqaba/Eilat	Red Sea	Jun 2019	25	**8152**	**43**	**0.53%**	48610	118	0.24%
Aug 2019		173	SACC	Fremantle	Ningbo	China	Aug 2019	12	**1812**	**14**	**0.77%**			
Dec 2019		207	LSS	Fremantle	Eilat/Aqaba	Red Sea	Jan 2020	25	**11318**	**90**	**0.80%**	42744	119	0.28%
May 2020			SEALS	Fremantle	Weifang	China	May 2020	14	**1863**	**10**	**0.54%**			
Jun 2020			SACC	Fremantle	Port of Macun	China	Jul 2020	11	**1785**	**12**	**0.67%**			

*Mortality Investigation Reports available from: www.awe.gov.au/biosecurity-trade/export/controlled-goods/live-animals/livestock/regulatory-framework/compliance-investigations/investigations-mortalities
^Independent Observer Report Summaries available from: www.awe.gov.au/biosecurity-trade/export/controlled-goods/live-animals/livestock/regulatory-framework/compliance-investigations/independent-observations-livestock-export-sea#2019. "x" indicates no IO on vessel.

Table A.2. Excerpts from independent observer report summaries (IORS) between 2018-2020 from long-haul voyages (10-30 days) from southern ports to China and the Middle East where cattle mortality exceeded 0.40% (excluding IORS 133 as only 135 cattle on voyage and no mention made of them in report). Source www.awe.gov.au/biosecurity-trade/export/controlled-goods/live-animals/livestock/regulatory-framework/compliance-investigations/independent-observations-livestock-export-sea.

IORS number	Date set sail	Vessel	AAV	Australian port	Destination port/s	Voyage length (days)	Type of cattle	No. of cattle*	Deaths	% mortality
12 (MIR 74)	8/07/2018	MV Yangtze Fortune	yes	Portland	Ningbo, China	20	Slaughter Angus cattle	2192	33	1.51%
WBT reached 28C (30C DBT & RH 92%) on Day 7 with no relief for the remainder of the voyage. "*Cattle on decks 4-8 generally showed elevated panting with a closed mouth, and it was usual to find 2-3 cattle per deck showing open mouth panting. Cattle on decks 1-3 generally did not progress beyond panting with a closed mouth…Mortalities attributed to heat stress occurred in line with the increase and subsequent maintenance of temperature and humidity. The first occurred on Day 6, continuing through to discharge with between 1-4 heat stress mortalities reported on all days except one (Day 9)*" Pad condition varied from "*firm to sloppy*", but roof leaks, water hose/trough faults contributed to deterioration of pads.										
40	23/11/18	MV Ocean Ute	no	Portland	Tianjin, China	22	Breeder Angus cattle	5606	47	0.84%
"*Bedding was loaded on the vessel in accordance with the ASEL requirements. Some bedding was spread on the ramps and alleys, however was not spread in pens at loading. The bedding was used following the last wash down closer to unloading.*" "*Over the course of voyage (sic), the pad condition ranged from soft to very sloppy. Early in the voyage, the pad condition appeared to be comfortable but particularly the lower decks became wet and very sloppy from day 8 as the temperature and humidity increased.*" WBT was > 28C on Day 6 (DBT 32C & RH 86%) and "*temperatures and humidity remained similar (without any relied at night) until day 15 of the voyage*". "*By day 17, the temperature on the deck was around zero. The heat/humidity and subsequent cold temperatures appeared to adversely affect the health of some of the cattle, particularly those in poorer condition.*" "*The main causes of the mortalities were mainly lame cattle that were unable to rise and BRD*" No vet on board … who makes the diagnosis? "*Overall the environment and vessel factors appeared to result in some lameness and subsequent mortalities, poor condition of the pad … and some loss of condition of shy feeders and lame cattle.*"										

IORS number	Date set sail	Vessel	AAV	Australian port	Destination port/s	Voyage length (days)	Type of cattle	No. of cattle*	Deaths	% mortality
127	19/5/19	MV Maysora	yes	Fremantle	Eilat, Israel & Aqaba, Jordan	29	Mixed breed B. taurus beef cattle, possibly feeders based on photos	8152	43	0.53%
"*The most common cause of mortality in cattle was pulmonary disease.*" "*The nature of the open decks (Decks 7-11) meant that individual areas of the open decks were subjected to varying air flow so 'hotspots' tended to be unpredictable … The ship made regular minor course changes as required to improve airflow across the open decks*" because there is no forced ventilation on open decks. "*In the enclosed decks temperature and humidity readings were less variable. During periods of increased humidity, open mouth panting was rarely observed (<1% of animals observed). The observer noted that whilst watching animals with open mouth breathing, most reverted to closed mouth breathing once the observer was seen by the flock.*" "*Extra fans were placed in the lower decks near bulkheads to improve air flow in these slightly restricted spaces.*" "*Cattle pads in some pens was (sic) soft to wet following wash down … Sawdust was applied to pens that had wet areas to firm up pad condition. This did not always absorb sufficient moisture to improve the pad condition, however, no adverse animal welfare issues were noted.*" Why were pads soft after washdown? They should have been clean. "*The extreme conditions were observed from Day 24 until completion of discharge with temperatures reaching 25.8C WBT (37.2C DBT & RH 40%). During this period … For cattle there was a longer period at panting score zero during each 24 hour period with only occasional brief periods at panting score one. Open mouth panting was rarely (<1%) observed in either sheep or cattle even on the days with the highest wet bulb temperatures (32°C).*"										
136 (MIR 79)	29/5/19	MV Ganado Express	yes	Fremantle	Huanghua, China	19	Mixed breed *B. taurus* & *B. indicus* beef cattle, likely for slaughter based on photos	1832	25	1.36%
"*cattle had a suppressed appetite for the first 10 days of the voyage, however this improved on day 12 as the temperatures declined*" "*At various times during the voyage, hold 3 on Decks 4 and 5 appeared to have a slightly smoky haze and the observer noted a residue on the walls of these holds on day 12. However, it was only on day 6 (day of crossing the equator) that three cattle had the highest panting scores of 2.5 in these areas. The observer noted that these panting scores were not representative of all animals on the voyage.*" "*Pads remained acceptably dry for the most part of the voyage.*" "*Twenty-three mortalities were observed from day 5-11. Temperatures on the daily reports for days 5-10 listed WBT 26-27C (DBT 30-31C & RH 73%). Most afternoons and evening temperatures were cooler because of cloud cover, and it was noted the livestock did receive respite during these periods. Temperatures after day 12 reduced substantially and mortalities seized (sic). The observer noted that 17 mortalities were located on Deck 4 and 5 in hold 3.*"										

<table>
<tr><th>IORS number</th><th>Date set sail</th><th>Vessel</th><th>AAV</th><th>Australian port/s</th><th>Destination port/s</th><th>Length of voyage (days)</th><th>Type of cattle</th><th>No. of cattle</th><th>Deaths</th><th>% mortality</th></tr>
<tr><td>173</td><td>17/8/19</td><td>MV Galloway Express</td><td>yes</td><td>Fremantle</td><td>Ningbo, China</td><td>14</td><td>Angus & other B. taurus. Likely for slaughter based on photos</td><td>1812</td><td>14</td><td>0.77%</td></tr>
<tr><td colspan="11">"high equatorial temperatures were experienced for much of the day and night, providing little or no period of respite for the cattle. Temperatures were recorded at around 9:30am daily on each deck using a whirling hygrometer. The observer noted that the temperatures recorded at 9:30am were not the hottest part of the day. The daily deck temperatures recorded in the daily report around the equatorial region when the signs of heat stress were observed were 27-28°C WBT (30-33°C DBT & RH 72 – 78%)"
"For the most part of the voyage, pads remained dry and appeared acceptable"
"On day 6, the vessel stopped for engine repairs between 11:30am and 5:48pm. Livestock services including the ventilation system were maintained. However, the walls and sundeck were being heated by direct sunlight as there was an absence of any cloud cover in the equatorial region with no cooling effect from normal travel movement. The AAV noted that heat from the engine room contributed to the hot areas on the vessel."
"There were five mortalities cause by heat stress between days 6 and 8. High temperatures negatively impacted the health and welfare of other animals on the vessel. The observer noted 25% of livestock were affected by heat stress on Deck 4, hold 3 on days 6-8. The signs of heat stress included increased respiratory rate, necks extended, open mouth breathing, tongues protruding, cattle congregating usually under the best ventilated area, lethargic demeanour and suppressed appetite."
"Strategies were implemented to reduce the number of livestock affected by the heat including reducing the stocking densities of pens in hot spots of Deck 4, hold 3, ensuring ad lib access to clean cool water, washing the decks, spraying the vessel structure to reduce heat and minimise the disturbance of livestock."</td></tr>
<tr><td>207</td><td>10/12/19</td><td>MV Maysora</td><td>yes</td><td>Fremantle</td><td>Eilat, Israel & Aqaba, Jordan</td><td>26</td><td>Mixed breed B. taurus & B. indicus beef cattle, likely for slaughter based on photos</td><td>11,318</td><td>90</td><td>0.80%</td></tr>
<tr><td colspan="11">"Ventilation was effective throughout the voyage. Additional fans were utilised in order to manage identified hot spots. Zig zagging of the vessel was implemented on 2 days of the voyage. On one of these days the observer noted a reduction in wet bulb temperature from 28.7°C to 27.1°C and the dry bulb from 32.5°C to 31.5°C in 10 minutes."
"Cattle pads were soft to muddy with depths ranging from heel to hock."
"Signs of significant respiratory issues in a group of cattle arose on day 2 of the voyage. A BRD management program was implemented. As part of this program measures such as aerial disinfection, reduced stocking densities and medical treatment in cattle exhibiting treatment were implemented."
90 cattle died, but no mention of cause in IORS. Infer BRD + heat-stress?</td></tr>
</table>

*Number of *B. taurus* v *B. indicus* not stated.