final**report**

FEEDLOTS

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Assessment of varying allocations of shade area for feedlot cattle – Part 2 (182 days on feed)

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Abstract

While there is general agreement that provision of shade improves the welfare of *Bos taurus* feedlot cattle when they are exposed to hot weather there is little scientific evidence showing a production response. Furthermore that optimal area of shade (m^2/animal) has not been determined. The purpose of this study was to investigate these issues.

A 182 d finisher feedlot study using 126 Angus steers (BW = 335 ± 24 kg) was undertaken to determine the optimal shade area to alleviate heat stress. The cattle entered the feedlot on the 13th September 2007 and exited on the 13th March 2008. Four shade treatments (70% solar block) were used: no shade, 2.0, 3.3 and 4.7 m^2/animal. The shade was 4 m high with a north-south orientation. Each shade structure was replicated four times. Cattle were randomly allocated to a pen (9/pen; 19.2 m^2/animal). Animal and climatic data were collected over 134 days from 1st November 2007 – 13th March 2008. Climatic conditions (ambient temperature, relative humidity (RH), black globe temperature (BG), wind speed (WS) were recorded every 10 min. From these data the heat load index and accumulated heat load units (AHLU) were determined.

Individual panting score were obtained every 2 h from 0600 to 1800 h when HLI>86. Treatment mean panting scores (MPS) were then determined. A MPS of 0 to 0.4 indicates little or no stress; 0.4 to 0.8 low stress; 0.8 to 1.2 high stress, and >1.2 extreme stress. Treatment differences were examined using repeated measures analysis. The MPS within treatment increased ($P < 0.01$) when heat load shifted from mild to hot, however there were no between treatment differences. There were small changes in MPS when heat load changed from hot and very hot, and larger increases ($P < 0.01$) when heat load changed from very hot and extreme. The MPS was greatest (MPS = 1.56; $P < 0.001$) in the un-shaded cattle under extreme conditions. There were differences ($P < 0.001$) between the shade treatments when climatic stress was extreme. The cattle with access to 4.7 m^2 of shade had the lowest MPS (1.27) followed by the 3.3 m^2 (1.32) and the 2.0 m^2 (1.38). The provision of shade reduced the effects of extreme climatic stress conditions, but did not eliminate it. When the HLI and AHLU were combined the un-shaded cattle the highest ($P<0.001$) MPS of 2.3 when conditions were extreme (HLI>95; AHLU>100). Under extreme conditions the MPS was elevated in all groups. The values were lowest ($P<0.001$) in the 4.7 m^2 treatment (1.62) cv. 1.97 and 1.86 for the cattle in the 2.0 and 3.3 m^2 treatments. Shade improved the welfare of the cattle by reducing heat load. However shade did not completely eliminate heat stress.

The area of shade an affect on feed efficiency. The un-shaded cattle had an overall feed efficiency of 8.4:1 compared to 6.1:1 for the 4.7 m^2 treatment. This resulted in a margin over feed cost advantage of $171.43/animal advantage for the 4.7 m^2 cattle *cv.* the un-shaded cattle.

Eight recommendations have been made.

Executive summary

The objectives of this project were to:

- Provide a scientific basis for shade usage for feedlot cattle by: (i) studying the impact of the provision of various shade area (m^2/animal) on production and welfare of feedlot cattle, and (ii) developing firm recommendations on the amount of shade needed to achieve the desired animal welfare outcomes, and production benefits, if they exist in a cost-effective manner, and
- Make recommendations, based on the study outcomes, on changes required to the thresholds for the various shade areas used in the Risk Analysis Program (RAP).

The study was conducted between the 13th September 2007 and the 13th March 2008 using 126 Angus steers (335 ± 24 kg at induction on 17th September 2007). The steers were on fed for 182 days. Four shade areas were used: 0.0, 2.0, 3.3 and 4.7 m^2/animal (the shade area represents the amount of shade available at 1200 h (EST). The data collection period was from 1st November 2007 to the 13th March 2008 (134 days; NB: feed and water data were collected from day 1). The following data were collected:

Climatic data:

- Ambient temperature (°C)
- Relative humidity (RH; %)
- Wind speed (WS; m/s)
- Wind direction
- Solar radiation (w/m^2)
- Black globe temperature in the sun (BG; °C)
- Black globe temperature under shade in pen 6 (BG; °C)
- Rainfall (mm)

From these data the heat load index (HLI)[1] and the accumulated heat load units (AHLU)[2] were calculated. The relationships between the animal data (see below) and the HLI and AHLU were determined by categorizing the HLI and AHLU as follows. **HLI:** (1) Mild (HLI < 70), (2) Moderate (HLI 70.1 – 77), (3) Hot (HLI 77.1 – 86), (4) Very Hot (HLI 86.1 – 95) and (5) Extreme (HLI > 95). **AHLU:** (1) Mild (AHLU < 10), (2) Moderate (AHLU 10.1 – 25), (3) Hot (25.1 – 50), (4) Very Hot (50.1 – 100), and (5) Extreme (AHLU > 100).

The HLI and AHLU were then combined to produce 5 HLI × AHLU risk categories. **HLI × AHLU:** Mild: HLI<70; AHLU<10, Moderate: HLI 70.1 – 77; AHLU 10 – 20, Hot: HLI 77.1 – 86; AHLU 25 – 50, Very Hot: HLI 86.1 – 95; AHLU 50 – 100, and Extreme: HLI>95; AHLU>100.

[1] The HLI consists of 2 parts based on a BG threshold of 25 °C: $HLI_{BG>25} = 8.62 + (0.38 \times RH) + (1.55 \times BG) - (0.5 \times WS) + [e^{(2.4 - WS)}]$, and $HLI_{BG<25} = 10.66 + (0.28 \times RH) + (1.3 \times BG) - WS$. Where e = the base of the natural logarithm (approximate value of e = 2.71828).

[2] See Appendix 2

Animal data:

- Individual panting score ~ collected at 0600, 1200 and 1800 h on low heat load days (max HLI predicted to be below 86 ~ from (www.katestone.com/MLA), and every 2 h between 0600 and 1800 h on high heat load days (max HLI predicted to exceed 86 or conditions at 0800 h suggested that the HLI would exceed 86).
- Location and posture in yard (standing or lying – in shade or sun, eating or drinking) ~ collected at 0600, 1200 and 1800 h on low heat load days, and every 2 h between 0600 and 1800 h high heat load days)
- Liveweight (start, 5 occasions during the study, end of study)
- Blood samples (5 occasions during study corresponding with weighing)
- Feed intake (weekly) ~ pen basis
- Feed to gain ratio ~ calculated from liveweight and feed intake (treatment basis)
- Carcass weight
- P8 fat depth
- Butt shape
- Bruising score

Climatic summary

Five major heat load events occurred during the data collection period of the study (1st November 2007 – 13th March 2008), mainly as a result of high humidity. During this period rain was recorded on 64 days. The majority of the rain fell during February (237.1 mm; 16 days of rain) and was characterized by occasional localized storms and general widespread rain. The February rainfall was 105 mm above the long term averages. Rainfall during the remainder of the months were close to the long term averages. During the study period mean monthly maximum temperatures reported by the Bureau of Meteorology were slightly below the long term averages for the Gatton area. Based on long term (1913 – 2007) climate averages for Gatton the mean number of days exceeding 30°C for the period 1st November to 13th March is 79 days. For the period 1st November 2007 – 13th March 2008, a maximum of 30°C was recorded on 43 days, and exceeded 35°C on four days. The highest ambient temperature recorded were: November (37.4°C), December (33.1°C), January (32.6°C), February (38.4°C) and March (29.1°C; 13 days only). Over all the maximum mean temperature for November was -1.7°C below average, December -2.2°C below average, January -3.1°C below average, February -1.7°C below average, and March -1.4°C below average (13 days only). Based on ambient temperature alone the summer period was mild with a few intermittent hot days.

HLI: The maximum HLI < 86 on 16 of the 134 days data was collected, and HLI>86 for 86 days. Of the 86 days, maximum HLI>90 for 82 days, >96 for 45 days, >100 for 32 days, and >110 for 3 days. (Figure 4). The minimum HLI was below 60 units 34/134 days.

AHLU: Shaded cattle ~ The AHLU for the shaded cattle was greater than 0 and less than 10 on 34 days; was between 10 and 25 on 9 days; between 25 and 50 on 14 days; between 50 and 100 on 9 days; and exceeded 100 on 3 days. The highest AHLU recorded for the shaded pens was 127.6. There were 3 carry over heat events during the study. ***AHLU: Un-shaded cattle*** ~ The AHLU for the un-shaded cattle was greater than 0 and less than 10 on 29 days; was between 10 and less than 25 on 16 days; was between 25 and 50 on 20 days; was between 50 and 100 on 16 days; and was greater than 100 on 16 days. The highest AHLU recorded for the un-shade pens was 294.1. There were 5 carry over heat events during the study ranging from 2 – 6 days duration.

Panting Score

Panting score (PS) was used as an indicator of the stress imposed on the animal by the climatic as measured by HLI. Panting scores were similar between treatments under cool, moderate and hot conditions. When conditions were classified as very hot (HLI 86 – 95) or extreme (HLI >95) differences were seen. Under very hot conditions the mean panting score was greatest ($P < 0.001$) in the un-shaded cattle. A mean PS (MPS) greater than 1.2 is indicative of excessive heat load and high levels of stress (Gaughan et al. 2008). The MPS of the cattle in the un-shade pens was 2.14 when HLI × AHLU was classified as extreme. Under the same classification the MPS of the shaded cattle were lower ($P < 0.001$) at 1.97, 1.92 and 1.82 respectively for 2.0, 3.3 and 4.7 m^2.

Blood Parameters

The concentration of creatine kinase may be a useful indicator of welfare status. Exposure to stress (physical or disease) often leads to tissue damage in animals. When this happens there are changes in serum enzyme activity. Creatine kinase (CK) levels in the blood are associated with muscle damage. In the current study the CK levels were highest ($P<0.01$) in the un-shaded cattle (365.3 U/L). The values in the shaded cattle were similar across the treatments (134.7 – 154.7 U/L).

Recommendations

Eight recommendations arising from this study have been made, and these are:

Recommendation 1: Shade should be considered as a priority for black *Bos taurus* cattle in areas were high heat load is expected. Shade will improve animal welfare.

Recommendation 2: Based on the results a shade area of 3.3 – 4.7m^2/animal should be recommended for black *Bos taurus* cattle 100 – 180 days on feed. This should provide adequate shade for stocking densities from 14 – 19.2 m^2/animal. A shade area of ≤ 2.0 m^2 should not be recommended due to the negligible production response. Firmer recommendations could be made following the completion of Recommendation 3.

Recommendation 3: The optimal shade area be determined based on a economic assessment of the cost: benefit of erecting shade. This should include performance factors such as feed efficiency, and costs associated with pen maintenance. This could be done in part in conjunction with Recommendations 6 and 7, or as a stand alone project.

Recommendation 4: A 70% solar block appears to be adequate, however any additional benefits or costs associated with increasing the solar block more e.g. 80 – 100% solar block should be examined.

Recommendation 5: Maintain the shade thresholds in the Risk Analysis Program, but add that these values are adequate for Angus cattle only.

Recommendation 6: The adjustments to the shade thresholds in the Risk Analysis Program for genotypes other than Angus should be determined. It is possible that this can be done using existing data from previous MLA funded projects, and in conjunction with Recommendation 7.

Recommendation 7: Feed intake, feed efficiency and cattle performance data should be collected from a number of commercial feedlots (with and without shade; and with different genotypes) over summer to further refine the shade component of the Risk Analysis Program. This should be done in conjunction with Recommendation 6.

Recommendation 8: The recovery time need by cattle exposed to high heat load be further refined.

Contents

1 Background

This project – B.FLT.0344 – "*Assessment of varying allocations of shade area for feedlot cattle – Part 2 182 days on feed*" – was conducted with funding from Meat and Livestock Australia Ltd. The study was undertaken at The University of Queensland Gatton between September 2007 and March 2008, and follows B.FLT.0337 – "*Assessment of varying allocations of shade area for feedlot cattle – Part 1 120 days on feed*" which was conducted over summer 2006/07.

Predictions from climate change models suggest that there will be more extreme thermal events and that the duration of these events will be longer. Severe heat episodes resulting in significant cattle losses (estimates in brackets) have occurred in Australia. For example, January/February 2000 – Queensland and New South Wales (24 human, 1,600 cattle); December 2002 – South Australia; September 2003 – northern New South Wales; February 2004 – New South Wales and Queensland (900 cattle); December 2004 – South Australia; February 2006 – Queensland; October 2006 – central New South Wales.

The cost of cattle mortality is easy to determine. However, production losses are not easy to determine especially on a national basis. It has been estimated that Australian feedlots lose $16.5 million (due to reductions in animal performance) over summer (Sackett et al. 2006). The 1995 US heat wave resulted in production losses of over $20 million. There is little understanding of the effects on feedlot cattle during and following prolonged exposure to high heat load. Despite its importance there are few effective strategies for combating heat stress in feedlot cattle. Recent and on-going research suggests that the effects of heat stress in cattle can be reduced by nutritional management (timing of feeding and ingredient selection), selection of heat tolerant genotypes, using fans, water application via sprinklers, and the provision of shade. Under Australian beef feedlot conditions shade appears to be the most effective method for reducing heat load.

1.1 Previous research

There has been a number of research projects conducted in the area of heat load management in the Australian feedlot industry. A list of previous research projects funded by Meat and Livestock Australia Ltd. is shown below.

- FLOT.307, 308 & 309 – Recommendations for reducing the impact of elements of the physical environment on heat load in feedlot cattle.
- FLOT.310 – Measuring microclimate variations in two Australian feedlots.
- FLOT.312 – Heat stress software development.
- FLOT.313 – Forecasting feedlot thermal comfort.
- FLOT.315 – Applied scientific evaluation of feedlot shade design.
- FLOT.316 – Development of an excessive heat load index for use in the Australian feedlot industry.
- FLOT.317 – Measuring the microclimate of eastern Australian feedlots.
- FLOT.327 – Reducing the risk of heat load for the Australian feedlot industry.
- FLOT.330 – Validation of the new Heat Load Index for use in the feedlot industry
- FLOT.335 – Improved measurement of heat load in the feedlot industry.

- B.FLT.337 – Assessment of varying allocations of shade area for feedlot cattle – Part 1 120 days on feed

Major outputs from these projects include the development a new Heat Load Index (HLI), the Accumulated Heat Load Units (AHLU) and the Risk Analysis Program (RAP).

2 Project objectives

The objectives of Project B.FLT.0344 were to;

1. Provide a scientific basis for shade usage for feedlot cattle by: (i) studying the impact of the provision of various shade area (m^2/animal) on production and welfare of feedlot cattle, and (ii) develop firm recommendations on the amount of shade needed to achieve the desired animal welfare outcomes, and production benefits, if they exist in a cost-effective manner, and
2. Make recommendations, based on both a review of the scientific literature and the study outcomes, on changes required to the thresholds for the various shade areas used in the Risk Analysis Program (RAP).

3 Methodology

3.1 Feedlot

The study was undertaken at The University of Queensland, Gatton between 13th September 2007 (entry to feedlot) and the 13th March 2008 (exit feedlot). Cattle arrived on the 13th September and immediately entered the feedlot. The data collection period was from 1st November (Day 45) to 13th March 2008 (Day 177). Sixteen pens (7.5 x 23 m) were used at the UQ Feedlot (Accreditation No#. NFAS 977). A 2 tonne self feeder (Warwick Cattle Crush Company, Forest Hill, Queensland) was shared between two pens (same treatment) ~ approximately 32.5 cm feeder space/animal. Each pen had a 1200 L water trough (Rapid Plas 1200 L Pro Tub) ~ approximately 31.1 cm trough space/animal. Shade cloth was erected over 12 of the pens (1 – 12). There was no shade over pens 13 – 16. Cattle yards and a crush are located opposite pens 11 and 12. Two automated weather stations were located on site. One was located between pens 6 and 11. The second was located on the northern side of pen 9. See Appendix 1 for a layout of the facility.

3.2 Animals

One hundred and twenty six Black Angus (335 ± 24 kg; 17th September 2008 – induction) yearling steers were used. The cattle were sourced from the Tamworth district NSW, and were therefore un-adapted to Queensland climatic conditions. The cattle arrived at Gatton on 13th September 2007 and immediately entered the feedlot. The cattle were randomly allocated to pens 9/pen and allowed a 3 day rest period. On the 17th September 2007 the cattle were weighed and allocated to treatment groups on the basis of liveweight (similar liveweight per pen). At the initial weighing the cattle were ear tagged (management tag), treated against internal and external parasites (Cydectin; Fort Dodge

Australia P/L, Baulkham Hills, NSW), vaccinated against clostridial disease (7 in 1; Pfizer Animal Health, West Ryde, NSW), bovine ephemeral fever (Fort Dodge Australia P/L, Baulkham Hills, NSW), and tick fever (trivalent) (Tick Fever Centre, Wacol, Qld).

3.3 Treatments

Cattle were randomly allocated (9/pen:19.17 m^2/animal) to one of four treatments:

(i) no shade,
(ii) 2.0 m^2
(iii) 3.3 m^2, and
(iv) 4.7 m^2.

The area of shade is *the shade provided at mid day (1200 h Eastern Standard Time)*. Shade was provided by 70% solar block shade cloth attached to a 4 m high frame (Rural pacific marketing P/L., Gatton) located in the middle of each shaded pen with a north-south orientation. The shade orientation allowed the shade to move across the pens (west to east) during the day. The area of shade within a pen was achieved by altering the width of the shade cloth. The 2.0 m^2 shade cloth dimensions were 7.5 × 2.40 m, the 3.3 m^2 were 7.5 × 3.96 m, and the 4.7 m^2 were 7.5 × 5.64 m.

The no shade treatment was replicated twice, and all of the shade treatments were replicated four times. The no shade treatment was replicated twice due to animal welfare factors. The approving Animal Ethics Committee was concerned that un-shaded cattle suffer given normal summer conditions, and that there was a risk of death. Therefore they would only approve the project if un-shaded cattle numbers were reduced.

3.4 Nutrition

3.4.1 Feed

From the 13th September to the 26th September the cattle were fed a starter 1 ration (Table 1). Low quality barley hay was available *ad libitum* from day 1 to day 7. From day 7 the amount of hay offered was reduced so that by day 12 the cattle only had access to starter 1. From the 27th September to the 15th November the cattle were fed starter 2, and from the 15th November to the 14th February 2008 the cattle had access to a finisher diet. During the period 15th February to 13th March 2008 the cattle were switched back to a starter 2. This was done because the cattle were finishing too quickly and would have become over fat.

Both the starter and finisher rations were obtained from a commercial feed mill (Ridley Agriproducts). The grain used in the study had been purchased prior to commencement of the study. Feed intake was recorded on a pen × treatment basis.

3.4.2 Dry matter intake

Due to the feeding method used (self feeders) dry matter intake could not be measured on a daily basis. Instead a weekly measure was made. Dry matter intake was calculated from the weekly weight of feed added to each feed bin. At the end of the study all residue feeds were removed from the bins and weighed. This amount was then subtracted from the overall feed usage. On occasions when contaminated feed (due to rainfall or faeces) was removed, the feed was weighed and DM determined. See 2.4 for the sampling procedure.

Table 1 Ingredients used in the starter and finisher diets (As-fed basis)

Ingredient	Starter 1, kg	Starter 2, kg	Finisher, kg
Wheat – cracked	150.0	225.0	300.0
Sorghum - cracked	330.0	450.2	430.7
Barley - cracked	343.7	180.5	225.0
Canola Meal	75.0	150.0	150.0
Millrun	150.0	150.0	150.0
Legume hulls	150.0	225.0	150.0
Molasses	30.0	30.0	30.0
Soybean hulls	180.0	--	--
Limestone	18.0	18.0	22.0
Urea	2.0	--	--
Salt	7.5	7.5	7.5
Potassium Chloride	2.0	2.0	3.0
Bentonite	60.0	60.0	30.0
ANP Beef/Sheep Pre-mix	1.5	1.5	1.5
Rumensin 100	0.3	0.3	0.3

3.4.3 Approximate analysis

A 500 g sample of feed was taken from each delivery. A sub-sample (approx. 100 g) was removed and the percentage dry matter. The remaining 400 g was frozen at -20 ^{o}C. The frozen samples were thawed at the end of the study and then thoroughly mixed within feed type i.e. starter samples were mixed together and finisher samples mixed. Sub-samples of these were removed and nutrient composition determined by proximate analysis (Table 2).

Table 2 Nutrient composition ^{A} (as a % of dry matter) of diets used during the study

	Starter 1	Starter 2	Finisher
DM,%	89.8	90.2	90.1
ME, MJ/kg	10.43	10.35	10.67
Crude fat, %	2.18	2.07	2.14
Crude protein, %	11.94	12.93	13.34
NDF, %	27.74	26.66	23.09
Na, %	0.22	0.22	0.22
K, %	0.69	0.71	0.73
P, %	0.37	0.44	0.37
Cl, %	0.18	0.19	0.18
S, %	0.18	0.21	0.22
Ca, %	0.60	0.59	0.69
Monensin, mg/kg	20.0	20.0	20.0

^{A} Determined by proximate analysis

3.4.4 Water usage

Water usage was recorded using water meters on a pen basis. Water usage rather than intake is used due to evaporative water loss and losses due to splashing. Changes in the volume of water in the water troughs following rain events was taken into consideration i.e. additional water added to the total. Water troughs were cleaned at least every 3 days.

3.5 Climatic data

Climatic data were obtained from two automated weather stations. Data was collected at 10 min intervals from one station (Esidata MK-3; Environdata Australia P/L, Warwick, Qld. Australia) and at 30 min intervals from the second (Vantage Pro 2; Davis Instruments, Hayward, California, USA) from the 1st November 2007 until 13th March 2008. The two weather stations were used to ensure no data was lost in case of malfunction of one of the weather stations. The Davis weather station transmitted weather data to a monitor which allowed continuous observations of climatic conditions. In addition an official Bureau of Meteorology (BOM) site was located 1.5 km north of the feedlot. The BOM site recorded weather data at 1 hour intervals.

The weather variables recorded on site were:

- Ambient temperature (°C)
- Relative humidity (RH; %)
- Wind speed (WS; m/s)
- Wind direction
- Solar radiation (w/m^2)
- Black globe temperature in the sun (BG; ^{o}C) (Esidata MK-3 only)
- Black globe temperature under shade in pen 6 (BG; ^{o}C) (Esidata MK-3 only)
- Rainfall (mm) (Vantage Pro 2 only)

The ambient temperature and relative humidity sensors of the Esidata MK-3 were located 1.5 m above the ground. The black globe located in the sun was 2 m above the ground and the shaded black globe in pen 6 was 2 m above the ground and located so that it could not be licked by the cattle. The anemometer and the solar radiation sensor of the Esidata MK-3 were located 2 m above the ground. The ambient temperature and relative humidity sensors of the Vantage Pro 2 were located 2 m above the ground. The anemometer, solar radiation sensor and the rain gauge were located 2.5 m above the ground. The sensors of both weather stations were cleaned at least weekly, and more often if conditions were dusty. The sensors were calibrated at the start, on day 100 and at the end of the study.

The weather data was downloaded daily from each weather station at approximately 0800 h. At this time the heat load index (HLI)[3] and the accumulated heat load unit (AHLU)[4] for the previous 24

[3] The HLI consists of 2 parts based on a BG threshold of 25 ^{o}C: $HLI_{BG>25} = 8.62 + (0.38 \times RH) + (1.55 \times BG) - (0.5 \times WS) + [e^{(2.4 - WS)}]$, and $HLI_{BG<25} = 10.66 + (0.28 \times RH) + (1.3 \times BG) - WS$. Where e = the base of the natural logarithm (approximate value of e = 2.71828).

[4] See Appendix 2

hours were calculated (Gaughan et al. 2008). The Katestone website (www.katestone.com/MLA) was then accessed and the predictions for the current day and next 3 days were observed. The basis for whether 3 times a day or 2 hourly data collection would be undertaken was the predicted HLI and AHLU from the Katestone site, the HLI and the AHLU at the feedlot as at 0800 h, and animal observations.

The cattle were observed and their location in the pen (in shade, in sun, at water or at feed), their posture (standing or lying) and their panting score (0 – 4.5) were recorded 3 times each day (0600 h, 1200 h and 1800 h) on days when the maximum predicted HLI < 86, and 7 times a day (0600 h, 0800 h, 1000 h, 1200 h, 1400 h, 1600 h and 1800 h) when the daily maximum HLI was predicted to be > 86; or when 10% of cattle within or between treatments had panting score > 1 at 0800 h). In addition two hourly data collection would be undertaken if it were clear that the maximum predicted HLI would exceed 86.

Pen surface temperatures were measured using an infrared temperature sensor (Raynger MX, Raytek, Santa Cruz, California) on 19 occasions (1st November, 16th November, 29th November, 8th – 13th December (heat wave), 16th December, 22nd December, 3rd January, 20th January, 5th February, 7th February, 14th February, 22nd February, 8th March and 12thMarch. These occasions were determined on the basis of the day e.g. cool, hot, heat wave conditions (max daily HLI>96) or following a rain event. Pen surface temperature was measured on dry, wet, shaded and un-shaded surfaces within the shaded pens, and dry, wet and un-shaded surfaces within the un-shaded pens. Surface temperature was measured by holding the infrared senor 1 m above and facing the ground. On each occasion measurements were made between 1000 h and 1600 h. Pen surface temperature was measured in each pen on each occasion and the mean of readings relating to each surface type (e.g. dry) were calculated.

3.5.1 HLI thresholds

The HLI thresholds used were determined on the basis of the previously developed thresholds (Gaughan et al. 2008). The base threshold of 86 was adjusted by +2 (HLI threshold = 88) for both the shaded and un-shaded cattle for the first 80 days on feed 13th September 2007 – 1st December 2007. In addition the threshold was further adjusted (+5) for the shaded pens giving a threshold of 93 (88 + 5). From the 1st December 2007 the HLI used was 86 for the un-shaded pens and 91 for the shaded pens. The +5 used for the shaded pens was the average adjustment for the shaded pens. Based on the previously developed thresholds the 4.7 m^2 pen would have an adjustment of +7, the 3.3 m^2 +2 and the 2.0 m^2 + 3.

3.6 Cattle

3.6.1 Liveweight

Cattle were weighed at the start of the study (17th September 2007; induction into feedlot), five times during the study (1st November 2007 – Day 49, 29th November 2007 – Day 77, 20th December 2007 – Day 98, 17th January 2008 – Day 125, 14th February 2008 – Day 153) and the day before exiting the feedlot (12th March 2008 – Day 182). All weighing commenced at approximately 0800 h. There were no water or feed curfews prior to any of the weighing.

3.6.2 Blood samples

Blood samples (2 x 10 ml samples/animal) were initially collected from 4 randomly selected animals from each pen (16 per treatment) on Day 49 (1^{st} November 2007). Samples were also collected on days 77, 98, 125, 153 and 182 all of which corresponded with the weighing of cattle. The same 4 animals were bled on each occasion giving a total of 6 samples per animal. Blood was collected from the caudal vein by vacutainer® (Beckton Division, New Jersey USA). Serum (tubes with lithium heparin used for biochemical analysis) and plasma (tubes with EDTA anti coagulant for haematological assay) were then separated following centrifugation for 15 min at 3000 rpm. Centrifugation took place within 20 min of collection. The serum and plasma were removed immediately and stored at -20°C until analysed for the concentration of glucose, insulin, sodium, potassium, chloride, lactate dehydrogenase (LDH), creatine kinase (serum) (CELL-DYN 3700, Abbott Diagnostics Division, Nth Ryde, NSW) and insulin (serum) (IMMULITE, Bio-Mediq DPC, USA).

3.6.3 Panting score

Panting scores were visually assessed using the 0 – 4.5 scale, with panting score 0 being an animal under no heat load, and 4.5 being a severely heat stressed animal. The indicators for each panting score are shown in Table 3.

Table 3 Panting Score system used during data collection

Panting Score	Breathing Condition
0	No panting – normal. Difficult to see chest movement
1.0	Slight panting, mouth closed, no drool or foam. Easy to see chest movement
2.0	Fast panting, drool or foam present. No open mouth panting
2.5	As for 2 but with occasional open mouth panting, tongue not extended
3.0	Open mouth + drooling. Tongue not extended. Neck extended and head usually up
3.5	As for 3 but with tongue out slightly & occasionally fully extended for short periods + excessive drooling
4.0	Open mouth with tongue fully extended for prolonged periods + excessive drooling. Neck and head up.
4.5	As for 4.0 but head down. Cattle “breath” from flank. Drooling may cease.

(Modified from Mader et al. 2006).

Panting score was the key physiological and behavioural factor used in development of the HLI, and in establishing the heat load thresholds. Mean panting score was calculated according to the following formula;

$$\text{Panting Score} = \frac{\sum_{i=0}^{4.5} N_i \times i}{\sum_{i=0}^{4.5} N_i} \qquad \text{Eq. 1}$$

where

N_i = the number of cattle observed at panting score i

The effect of mean panting score (MPS) on cattle was assessed as follows: 0 to 0.4 minimal heat load – no stress; 0.4 to 0.8 moderate heat load – slight stress; 0.8 to 1.2 high heat load – moderate heat load; >1.2 extreme heat load cattle highly stressed (Gaughan et al. 2008).

3.6.4 Location and posture

In addition to panting score cattle location (and number of cattle) within a pen (at feeder, at water trough, in sun, under shade (if applicable) and posture (standing or lying) were recorded.

3.7 Animal ethics approval

The use of animals in this study was approved (SAS/524/07/MLA) by The University of Queensland Production and Companion Animal Ethics Committee in accordance with the Queensland Animal Care and Protection Act and the Australian Code of Practice for the Care and Use of Animals for Scientific Purposes.

3.8 Statistical analysis

The **HLI** was divided into 5 categories: (1) Mild, when HLI is < 70.0; (2) Moderate, when the HLI is 70.1 – 77.0; (3) Hot, when the HLI is 77.1 – 86; and (4) Very Hot when the HLI is 86.1 – 95, and Extreme when the HLI >95. The **AHLU** was divided into 5 heat load categories (modified from Gaughan et al 2008): (1) Mild, when the AHLU is < 10; (2) Moderate, when the AHLU is 10.1 to 25; (3) Hot, when AHLU is 25.1 to 50; and (4) Very Hot, when the AHLU 50.1 – 100, and Extreme when AHLU > 100.

In addition the HLI and the AHLU were combined to produce 5 risk categories which were used to gain a better understanding of the relationship between climatic conditions, body heat content and mean panting scores. The following categories were used: Mild (mild: HLI < 70; AHLU < 10), Moderate (mod: HLI 70.1 – 77; AHLU 10.1 - 25), Hot (hot: HLI 77.1 – 86; AHLU 25 – 50), Very Hot (vhot: HLI 86.1 – 95; AHLU 50.1 – 100), and Extreme (ext: HLI > 95; AHLU > 100).

Mean panting score data were analysed using a repeated measure model (PROC Mixed, SAS Inst. Inc., Cary, NC) which included HLI, AHLU, day, time of day (0600, 0800, 1000, 1200, 1400, 1600, 1800 h), pen, treatment, pen × treatment, HLI category, AHLU category and HLI × AHLU as fixed effects and animal as a random effect. The specific term for repeated statement was day. The location of cattle within a pen, and posture (standing or lying) were also analysed using repeated measures. The model included HLI, AHLU, day, time of day, pen, treatment, pen × treatment, HLI category, AHLU category and HLI × AHLU as fixed effects and animal as a random effect.

Blood data were analysed using PROC Mixed (SAS). The effects of treatment and treatment × collection period (i.e. 1^{st} – 5^{th} collection) were determined. Carcass data were analysed using PROC GLM (SAS). The statistical model included animal, treatment, and animal × treatment. Initial live weights were used as a co-variant in the carcass analysis. Differences between treatments were separated using PDIFF procedure of SAS. Treatment differences are termed significant when P values ≤ 0.05.

4 Results and discussion

4.1 Climatic conditions

Rainfall during the period of data collection is presented in Appendix 3. The daily black globe temperature, relative humidity and wind speed are presented in Figure 1, 2 and 3.

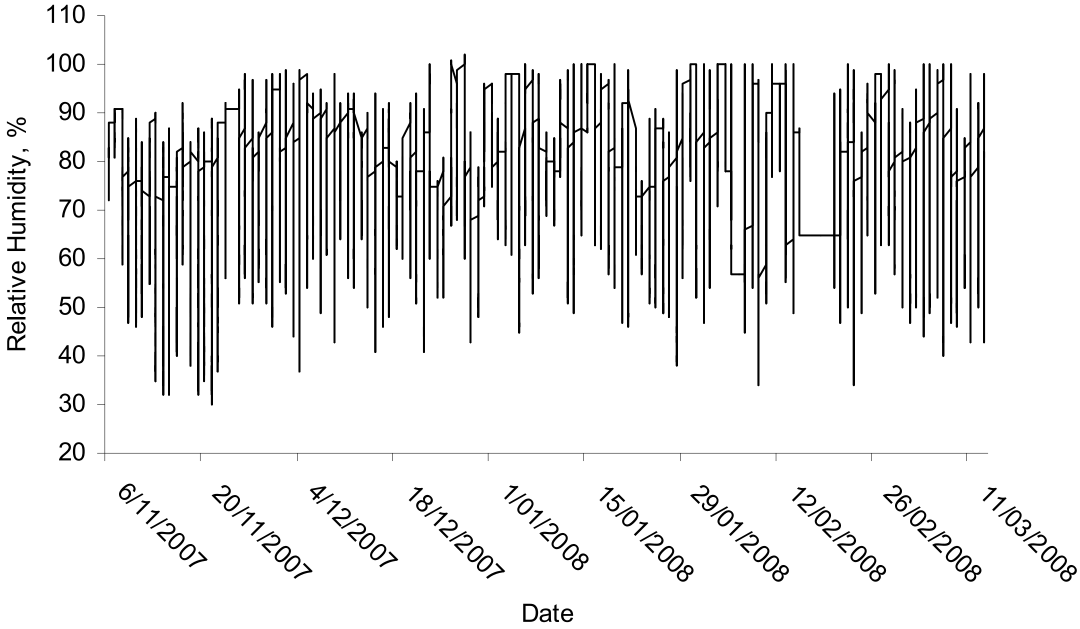

Figure 1 Daily maximum and minimum relative humidity from the 1st November 2007 to the 13th March 2008

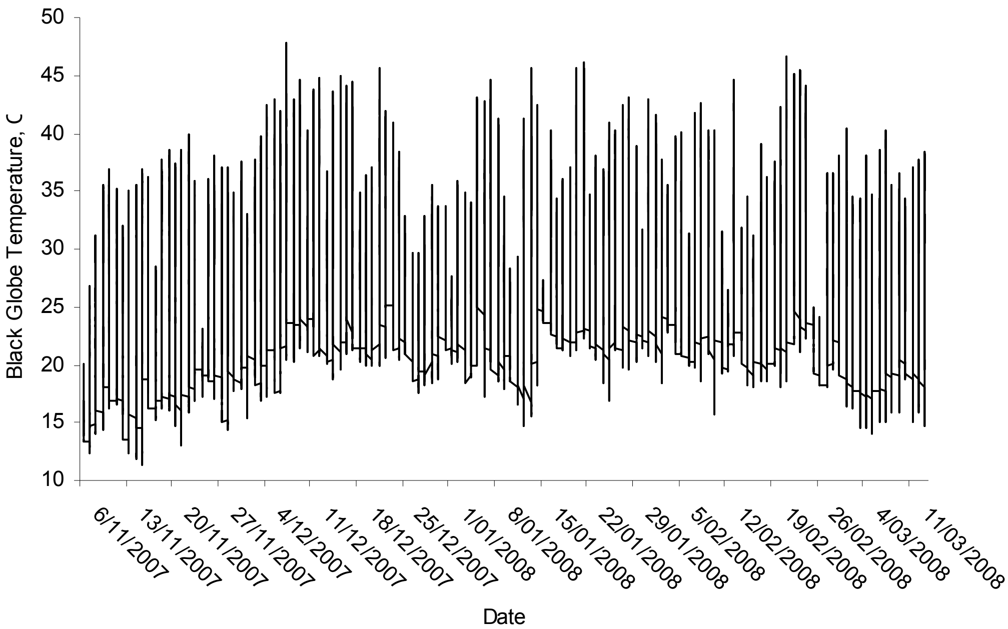

Figure 2 Daily maximum and minimum black globe temperature (^oC) from the 1st November 2007 to the 13th March 2008

4.2 Heat Load Index

The maximum HLI was less than 86 on 16 of the 134 days of data collection (Figure 4). The maximum HLI exceeded 86 on 118 days (72.9%), 82 of which the HLI>90. Within these 82 days, the maximum HLI exceeded 96 on 45 days (24.7%), exceeded 100 on 32 days (23.8%), and exceeded 110 on 3 days (2.2%). The minimum HLI was greater than 60 units on 36 nights.

4.3 Accumulated Heat Load Units

4.3.1 Shaded cattle

The AHLU for the shaded cattle was greater than 0 and less than 10 on 34 occasions (Figure 5). It was between 10 and 25 on 9 occasions, and between 25 and 50 on 14 occasions. The AHLU of the unshaded cattle was between 50 and 100 on nine occasions and exceeded 100 three times on the 8th February (111.1), the 22nd February (127.6) and on the 23rd February (122.2). The AHLU did not return to zero on the 7th and 8th of January (2 nights), the 8th and 9th of February (2 nights), and between the 22nd and 24th February (3 nights). In contrast the maximum AHLU of shaded cattle during study 1 (B.FLT.0334) was 36.2, and there were no carry over heat loads.

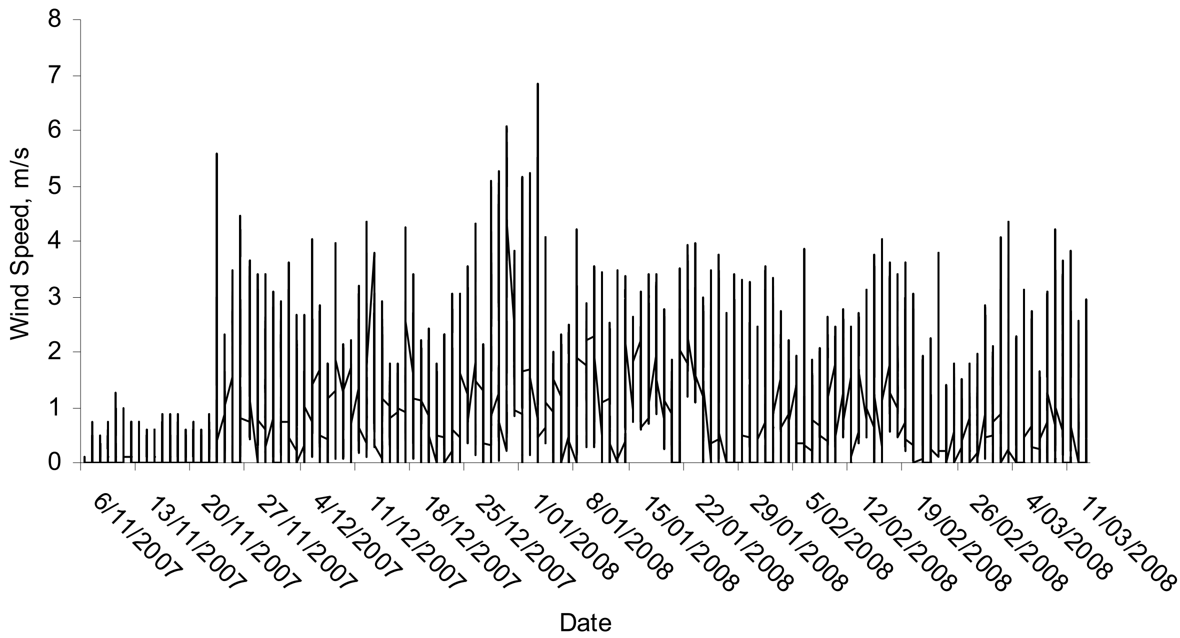

Figure 3 Daily maximum and minimum wind speed (m/s) from the 1st November 2007 to the 13th March 2008

4.3.2 Un-shaded cattle

The AHLU for the un-shaded cattle was greater than 0 but less than 10 on 29 days. It was greater than 10 and less than 25 on 16 days and was greater than 25 and less than 50 on 20 days. The AHLU was between 50 and 100 on 16 occasions and exceeded 100 on 16 occasions (Figure 6).

There were five periods when the AHLU did not fall back to zero. These were; the 8th – 13th December (6 nights), the 16th – 17th December (2 nights), the 5th – 8th February (3 nights), the 8th – 10th February (3 nights) and the 22nd – 25th February (4 nights). In all of these events the maximum AHLU exceeded 150. A major heat wave commenced on the 21st February and continued until the 25th February. During this time the maximum AHLU was 294.1 (24/02/08), maximums of 253.9, 282.4 and 272.2 (at midnight ~ AHLU was falling) were obtained on the 22nd, 23rd, and 25th February respectively. The cattle had a positive heat load from 0900 h on the 21st February until 0900 h on the 26th February. Although a cool south westerly front moved trough at 1830 h on the 24th February the cattle were not able to completely dissipate their heat load until 0900 h on the 26th February when the AHLU returned to 0.

4.3.3 Heat waves

The first heat event occurred from 5th December until the 13 December. During this period the cattle were under heat load from the 7th December (0700 h) until 13 December (2300 h). This heat event was largely driven by high relative humidity. Between the 5th and 7th December 61.2 mm of rain was recorded at the feedlot. The pens which were already wet due to rainfall in late November (77 mm of rain was recorded between 23rd and 25th November) became very boggy. This contributed to the high humidity. During this period the relative humidity ranged between 56 and 91%. The maximum AHLU was recorded on the 12th December (141.2).

The second heat event occurred between 0730 h (15/12/07) until 0400 h (18/12/07). This event was due to high solar load on the 16th and 17th. On these days the black globe temperature ranged from 37 – 44°C between 0830 h and 1630 h. Relative humidity was also high ranging from 50 – 80% over the same time period.

The third heat event occurred between 0800 h (05/01/08) until 0400 h (09/01/08). During this period the maximum AHLU was 156.7. Like the first event this was largely driven by high relative humidity (50 – 90%). Between the 5th and 8th January 80.0 mm of localized storm rain fell on the feedlot (the official BOM site located 1.5 km to the north recorded 60.4 mm).

The fourth heat wave ran from the 7th – 11th February. The cattle had a positive heat load from 0930 h (07/02/08) until 0500 h (08/02/08). Following 3 hours of respite the cattle again had a positive heat load from 0800 h (08/02/02) until 0430 h (11/02/08). The maximum heat load was 165.6 (1700 h; 09/02/08). This event was due to high black globe temperatures (38 – 40 °C, high humidity (80 – 95%) and low wind speed (less than 1.0 m/s) between 0900 h and 1630 h on the 7th to the10th February.

High ambient and black globe temperatures, high humidity and low wind speed combined to produce extreme conditions on the 22nd and 23rd February (5th heat event). On the 22nd the black globe temperature was between 40.0°C and 47°C from 1000 h until 1600 h, relative humidity was 50 – 70%, and wind speed less than 1.0 m/s. The following day the black globe temperature reached 40°C by 0900 h and reached a maximum of 45.0°C at 1400 h before falling below 40°C at 1730 h. Over the same time period the relative humidity ranged from 66% to 36%, while wind speed remained below 1.0 m/s. The un-shaded cattle were under considerable stress (high respiration rate; maximum 190 breaths per minute, and high mean panting score; 3.4) during this period. As part of the heat load management plan the cattle were observed every 30 minutes during daylight hours over this period. If conditions had not abated on the 24th shade would have been provided for the cattle. Conditions cooled considerably by the 25th where the maximum ambient and black globe temperature were each 24°C.

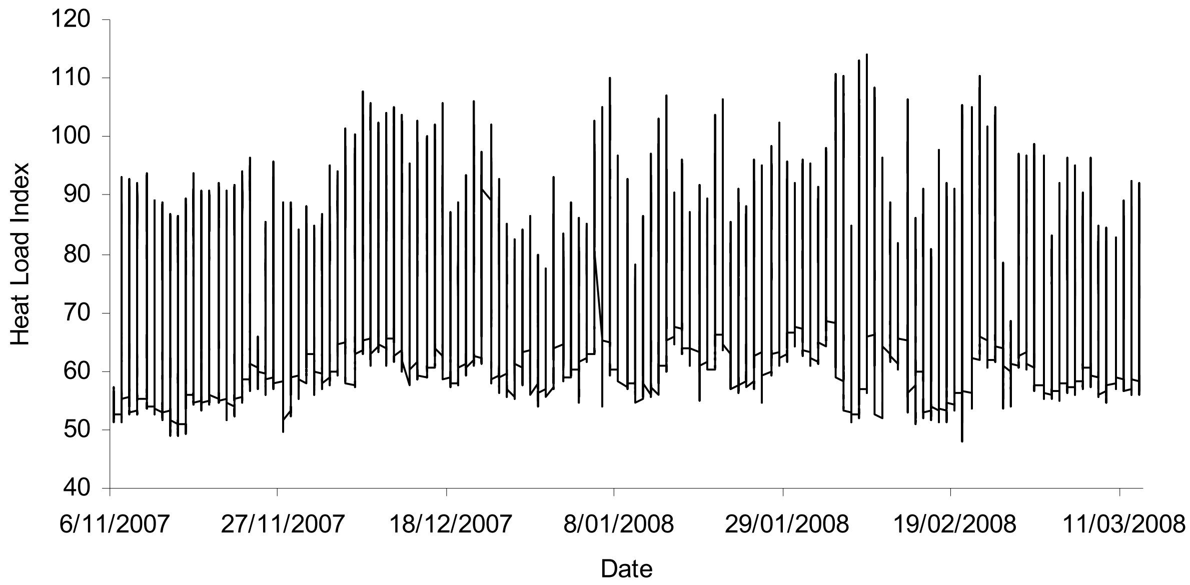

Figure 4 The maximum and minimum daily heat load index recorded at the UQ feedlot from 1st November 2007 to the 13th March 2008

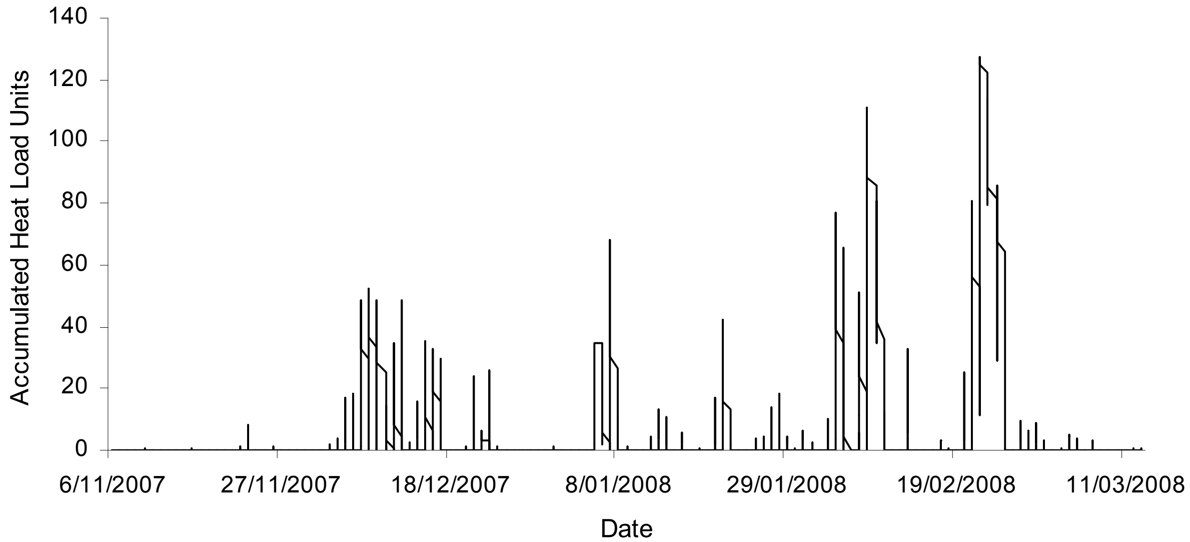

Figure 5 The accumulated heat load units for shaded cattle (heat load index threshold = 93 from 01/11/07– 20/01/08; threshold = 91 after 20/01/08) from the 1st November 2007 to the 13th March 2008

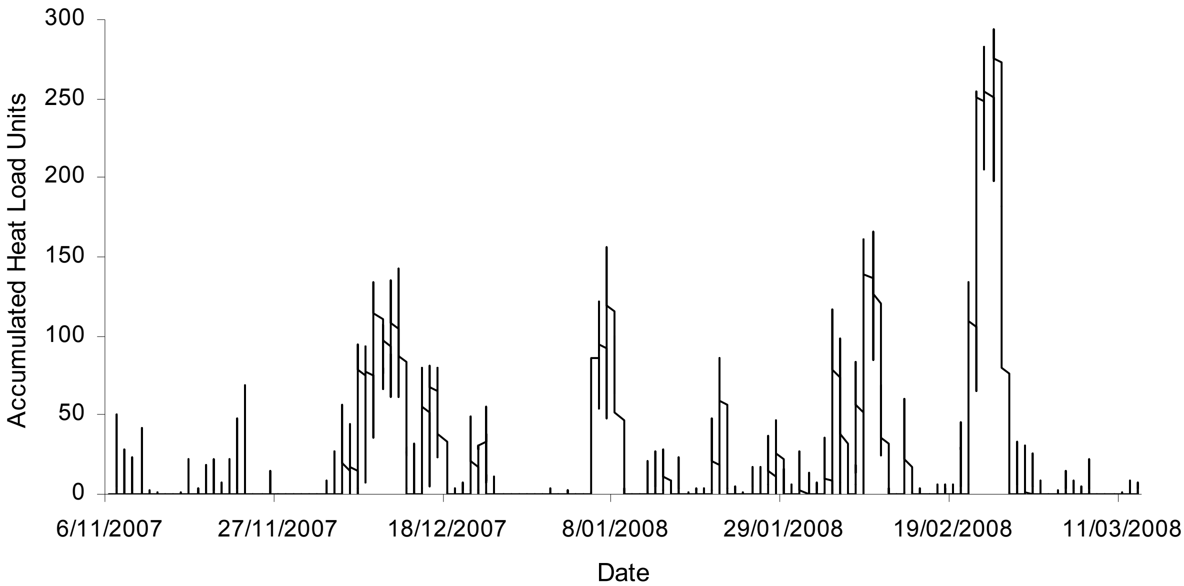

Figure 6 The accumulated heat load units for un-shaded cattle (heat load index threshold = 88 from 01/11/07 – 20/01/08; threshold = 86 after 20/01/08) from the 1st November 2007 to the 13th March 2008

4.4 Pen surfaces

4.4.1 Pen surface temperatures

Direct sunlight penetration under the shade was 72% lower than un-shaded areas. The mean un-shaded pen surface temperature was 44.6°C (range 36.8 – 53.4°C). In the shaded pens the mean pen surface temperature in the sun was 44.7°C (range 33.3 – 54.8°C). The pen surface temperature under the shade was 10 – 15°C lower than in the sun. The mean surface temperature under shade was 38.4°C (ranged from 32 – 39°C). Wet areas under shade were on average 6°C lower than the dry surfaces under the shade. A similar result was obtained in B.FLT.0337. When the HLI < 70 the fully exposed surface temperatures did not exceeded 28°C. On sunny days immediately following a rain event (n = 12) the average pen surface temperature was 29.6°C (range 24.2 – 32.1°C), even when the HLI>86.

Overall the values reported here for pen surface temperatures are lower than the values presented for the previous study (B.FLT.0337), most likely due to the wet pen surfaces encountered in the current study.

4.4.2 Pen surfaces – General

It was planned that the pens would be cleaned approximately every 28 days. However due to wet conditions the mean cleaning interval was 38 days. In addition to under the fence lines, the area around the water troughs and feed bins were cleaned weekly. Holes in the pen surfaces were repaired as necessary, which due to the wet conditions was about every 4 weeks. However the area around the water trough in the unshaded pens needed a high level of maintenance. Repairs were undertaken at 10 – 14 day interval. Holes developed in the ground under all of the shade structures and these required additional work towards the end of the study. Generally the ground under the shade remained wetter for longer following a rain event compared to the un-shaded pens. The ground under the 4.7 m^2 shade remained wetter for longer *cv.* the 2.0 and 3.3 m^2 pens. And although there was more room under the shade these pens needed more maintenance that the 2.0 and the 3.3 m^2 treatments. The un-shaded cattle had a tendency to make wallows especially during periods of high heat load.

4.5 Panting score

4.5.1 Heat Load Index

Mean panting score (MPS) increased in all treatments when the HLI category shifted from mild to moderate (Figure 7). There were inconsistent but small changes in mean panting score when conditions moved from moderate to hot and larger increases when conditions changed from hot to very hot. The largest increase was seen in the un-shaded cattle. Panting scores were similar ($P > 0.05$) between treatments under mild, moderate and hot conditions. It was only when conditions were classified as very hot or extreme (HLI >95) that differences were seen. Under very hot conditions the mean panting score was greatest ($P < 0.01$) in the un-shaded cattle (MPS = 1.09). The 2.0 m^2 shaded cattle had a higher ($P<0.05$) mean panting score (MPS = 0.99) than the 3.3 m^2 group (MPS = 0.89) and the 4.7 m^2 group (MPS = 0.85). When conditions were categorized as extreme the un-shaded cattle had the highest ($P<0.01$) mean panting score (MPS = 1.57). The 2.0 m^2 shaded cattle had a higher ($P<0.05$) mean panting score (MPS = 1.38) compared to the 4.7 m^2 group (MPS = 1.27). There were no differences ($P>0.05$) between the 3.3 m^2 group (MPS = 1.32) and the 4.7 m^2 group.

4.5.2 HLI × AHLU risk categories

During the study period, humidity and low air speed were the main influencing factors when conditions were classified as very hot or extreme. The differences in mean panting score between the shaded and un-shade animals is largely due to the impact of solar load. A mean panting score of 0.8 – 1.2 indicates moderate stress whereas a mean panting score greater than 1.2 is indicative of excessive heat load and high levels of stress (Gaughan et al. 2008). The mean panting score of the un-shade cattle exceeded 1.2 when conditions were very hot (MPS = 1.49) and extreme (MPS = 2.34) (Figure 8). A large number of un-shaded cattle had individual PS ≥3 under extreme conditions (HLI>95, AHLU>100). Cattle with a PS of 4 were observed within this group on five occasions. Under the extreme category the mean panting score of the shaded cattle also exceeded 1.2. The 2.0 m^2 group hade the highest ($P<0.01$) of the shaded cattle, followed by the 3.3 m^2 group and the 4.7 m^2 group with mean panting scores of 1.97,1.86 and 1.62 respectively.

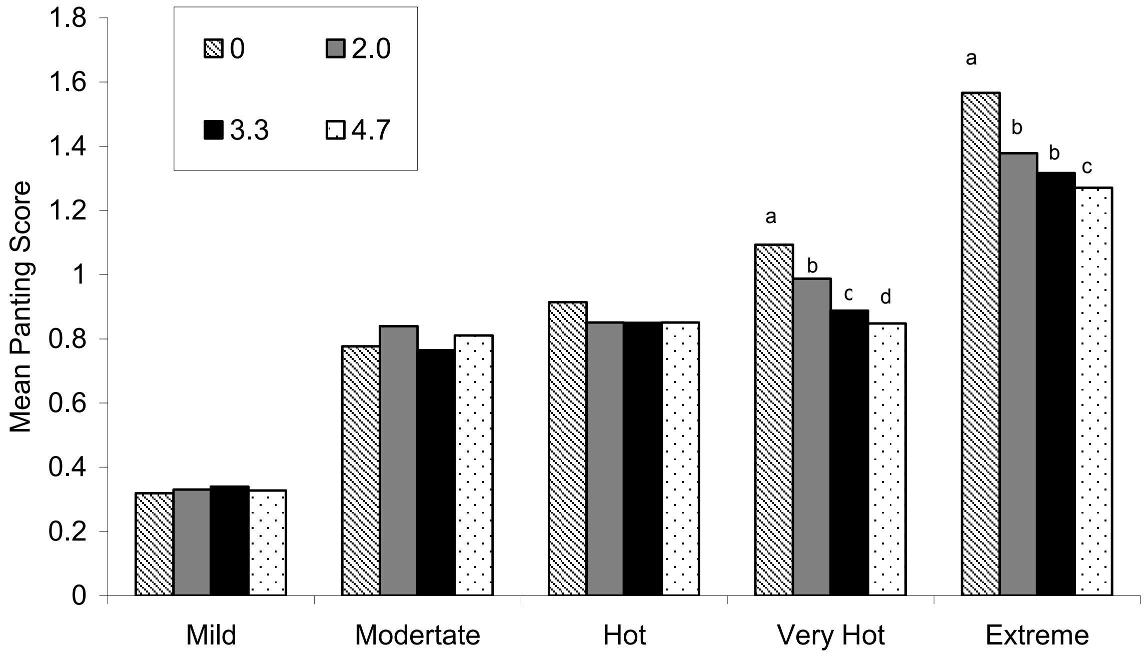

Figure 7 Mean panting score for cattle with no access to shade (0), access to 2.0 m^2 of shade per animal (2), access to 3.3 m^2 of shade per animal, and access to 4.7 m^2 of shade per animal, when HLI were classified as mild (HLI < 70.0), moderate (HLI 70.1 – 77.0), hot (HLI 77.1 – 86.0), very hot (HLI 86.1 – 96.0), and extreme (HLI>96). [abcd] Bars with different superscripts are significantly different (P<0.001)

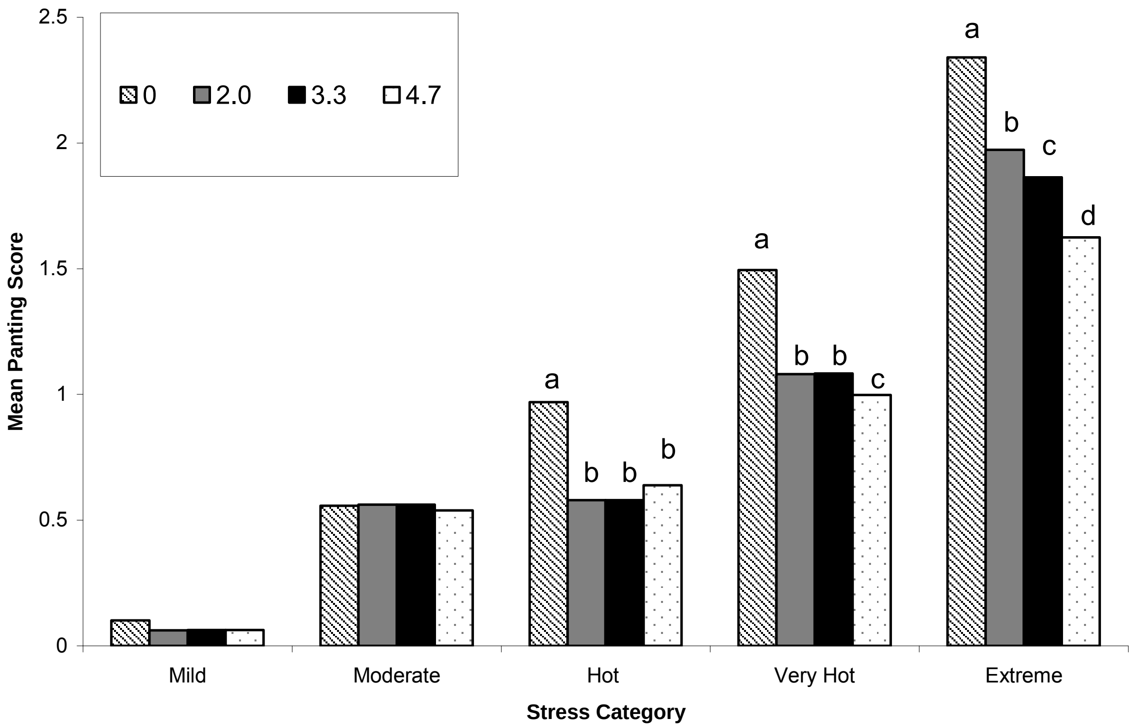

Figure 8 Mean panting score for cattle with no access to shade (0), access to 2.0 m^2 of shade per animal (2), access to 3.3 m^2 of shade per animal, and access to 4.7 m^2 of shade per animal, when AHLU were classified as mild (HLI < 70.0; AHLU < 10), moderate (HLI 70.1 – 77.0; AHLU 10 – 25), hot (HLI 77.1 – 86.0; AHLU 25 – 50 , very hot (HLI 86.1 – 96.0; AHLU 50 – 100), and extreme (HLI>96; AHLU > 100). [abcd] Bars with different superscripts are significantly different (P<0.001)

4.6 Dry matter intake, feed efficiency, water usage, growth performance and carcass data

4.6.1 Dry matter intake

As it is not valid to statistically analysis mean daily intakes from whole pen intakes all DMI data are presented with no statistical analysis. The DMI (weekly mean treatment intakes converted to a per head per day basis) between the 0 and 2.0 m^2 shade treatments were numerically similar (Table 4). The DMI was lowest in the 4.7 m^2 cattle (9.8 kg/animal/day). Daily DMI was affected by the daily maximum HLI. In the un-shaded group DMI – on a pen basis – fell from approximately 10.2 kg/animal/d to 5.5 kg/animal/d in weeks that included days that were classified as extreme (HLI>95). Over the first 90 d in the feedlot the DMI of the un-shaded pens was lower (P<0.05) than the shaded groups. In a similar response to part one of the study (B.FLT.0337) the DMI of the un-shaded group increased markedly over the last 30 days of the study when the climatic conditions were less stressful. The DMI also increased over the last 30 days on the 2.0 m^2 group – this was not seen in the first study. There was little change within the 3.3 and 4.7 m^2 groups over the last 30 days of the study compared to the first 150 days. The DMI of the 0, 2.0 and 3.3 m^2 groups were slightly more than expected (10.0 kg/animal/day) while intakes in the 4.7 m^2 group were slightly lower than expected.

Table 4 The mean daily DMI (kg/steer/d), cost of feed per day[A] ($/d), total cost of feed ($/steer) over 177 days on feed, and the difference in feed costs over 177 days ($/steers) for each treatment

Treatment	DMI, kg/steer/d	Cost of feed, $/steer/d (DM basis)	Total cost of feed, $/steer (DM basis)	$ difference
0.0	12.2	$4.76	$ 842.17	--
2.0	12.1	$4.72	$ 835.26	$ 6.90
3.3	11.5	$4.49	$ 793.85	$ 41.42
4.7	9.8	$3.82	$ 676.49	$ 117.35

[A] Feed cost = $390/t DM basis.

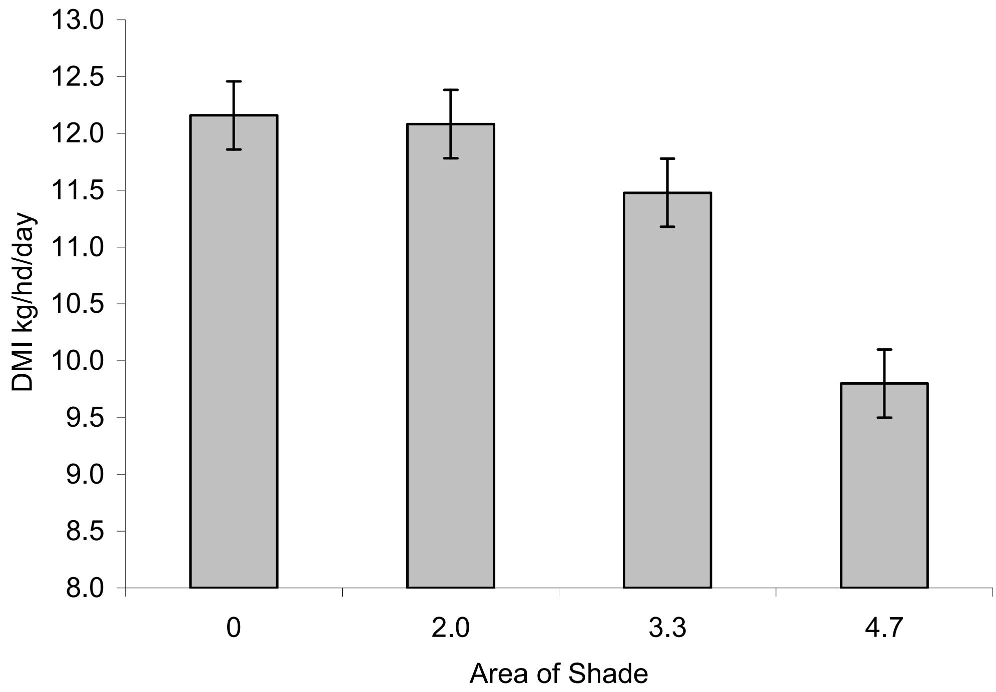

Figure 9 Mean feed intake (as fed) (kg/animal/day) over 177 days in the feedlot

4.6.2 Feed efficiency

Feed efficiency (feed to gain) has a major influence on feedlot profit. Based on the age and breed of cattle used in the study, and the feeding methods used a feed to gain ratio of 7:1 was expected. The 4.7 m^2 group had the best feed efficiency (6.0:1), followed by the 3.3 m^2 cattle (7.4:1), the 2.0 m^2 group (7.7:1) and the un-shaded cattle (7.9:1) (Figure 10).

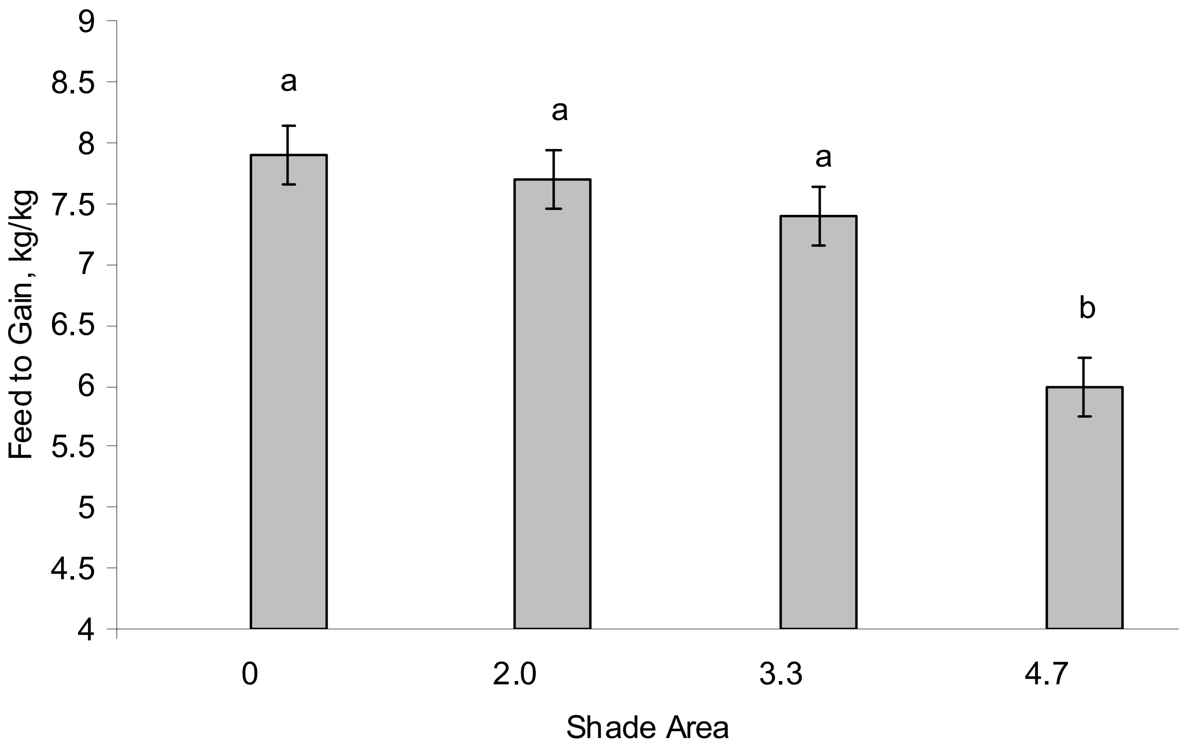

Figure 10 Mean feed to gain (kg/kg) over 177 days in the feedlot

4.6.3 Water usage

Rainfall contributed to the volume of water in the troughs so this was added to the total amount of water used. Water meters were read each day. Water splashing was evident in all treatments but more so in the un-shaded pens when day was categorized as very hot. There were no differences between shaded pens and water usage during the study.

On days when maximum HLI<80 there were no differences (P>0.05) between shaded and un-shaded cattle in water usage at (24.6 L/animal/day). Similar intakes were reported by Yousef et al. (1968). There were no differences in water intakes of cattle in shaded pens, under any of the climatic conditions to which they were exposed. Under moderate and hot conditions water usage was higher (P<0.05) for cattle in the un-shaded pens at 68 L/animal/day compared to 47 L/animal/day for cattle in the shaded pens. When days were categorized as extreme (HLI>96), water usage increase markedly to approximately 74 L/animal/day for cattle in the un-shaded pens and 62 L/animal/day for cattle in the shaded pens. These values were lower than the 70 L per animal (*Bos taurus* cattle) when night time ambient temperature was 30 ^{o}C (Yousef et al 1968). The same authors reported intakes of 120 L per animal when ambient temperature was 30 ^{o}C during the day. Throughout the study relative humidity was high. When exposed to high relative humidity water consumption tends to drop (Yousef et al., 1968). Daily water usage were similar to B.FLT.0334.

4.6.4 Growth performance and carcass traits

There were no between treatment differences (P<0.05) for liveweight at the commencement of the study (Table 5). By the completion of the study the cattle with access 4.7 m^2 where the heaviest (P<0.05) at 622.3 kg (Table 5).The cattle with access to 4.7 m^2 shade had the best (P<0.01) ADG (1.62 kg/d). There were no differences (P>0.05) between the 0, 2.0 and 3.3 m^2 treatment groups.

There were no treatment differences for marbling score, hot standard carcass weight, P8 fat depth, fat colour or meat colour (Table 6). However, the cattle with access to 4.7m^2 of shade had a lower (P<0.05) dressing percentage compared to the other 3 treatments. The reason for the differences in dressing percentage are not known. There was no differences in carcass value between treatments.

Table 5 Means ± SE for initial live weight (LW, kg), final liveweight (177 days), and average daily gain over 177 days for un-shaded cattle (0), and cattle with access to shade at 2.0, 3.3 or 4.7 m^2/animal

Shade Area, m^2	Initial Weight kg	Final weight kg	ADG^2 kg/d
0	338.7^a	605.9^a	1.54^a
2.0	337.2^a	608.9^a	1.56^a
3.3	335.3^a	605.8^a	1.56^a
4.7	333.4^a	622.3^b	1.62^b
SE	4.1	4.9	0.02

Means in a column with different superscripts are significantly different (P<0.05).

Table 6 Means ± SE for dressing percentage, hot standard carcass weight (HSCW, kg), P8 fat depth (mm), marbling score, fat colour, meat colour, carcass value ($) and carcass return per kg ($/kg) for un-shaded cattle (0), and cattle with access to shade at 2.0, 3.3 or 4.7 m^2/animal

	0.0	2.0	3.3	4.7	SE
Dressing %	56.6^a	56.7^a	56.6^a	55.8^b	0.2
HSCW, kg	342.9	345.5	343.1	347.2	3.5
P8, mm	17.8	17.5	18.9	18.3	0.9
Marbling Score	2.1	2.3	2.1	2.0	0.2
Fat colour	0	0	0	0	--
Meat colour	1b	1b	1b	1b	--
Carcass value	$ 1324.75	$ 1325.45	$ 1324.81	$ 1325.10	2.3
Carcass, $/kg	$ 3.92	$ 3.84	$ 3.86	$ 3.82	--

Means in a row with different superscripts are significantly different (P<0.05).

4.6.5 Carcass value less feed costs and cost of gain

When the cost of feed used was subtracted from the value of the carcass the cattle with access to 4.7m^2 of shade had a margin of $648.61 compared to $482.58 for the un-shaded cattle (Table 7). Overall there was a $166.03 advantage for the 4.7 m^2 cattle compared to the un-shaded cattle.

Table 7 Value of animal carcass price less the cost of feed

Treatment	MOFC[A]	Difference in MOFC between treatments	
0.0	$ 482.58	-	
2.0	$ 490.19	$ 7.61	-
3.3	$ 530.96	$ 48.38	$ 40.77
4.7	$ 648.61	$ 166.03	$ 117.65

[A] MOFC = margin over feed costs.

Based on the feed efficiency and the cost of feed on a dry matter basis the cost of gain on live weight was calculated. The cost of gain was lowest for the cattle with access to 4.7m^2 shade ($2.34/kg LW gain) followed by the 3.3 m^2 cattle ($2.89/kg LW gain), the 2.0 m^2 cattle ($3.00/kg LW gain) and the un-shaded cattle ($3.08/kg LW gain).

4.7 Animal posture/shade usage in relation to HLI x AHLU

The use of shade by cattle is influence by climatic conditions. The major climatic factors are to a combination of ambient temperature and solar radiation (basically black globe temperature), and relative humidity. However cattle responses to environmental conditions are complex, being further influenced by a variety of factors such as, nutrition, health status, and previous exposure to stressful climatic conditions.

Shade usage was assessed on the basis of the previously mentioned categories of HLI, AHLU and the HLI x AHLU combination. When the HLI was categorized as mild or moderate approximately 24% of the cattle where under the shade (Figure 11). This increased to 44.6% when HLI was hot, and almost 80% when HLI was extreme. The movement of another 20% cattle to shade when HLI 77 – 86 followed by a further 40% when HLI>96. These data suggests that there is no need to revise the current threshold of 86 for the reference animal.

The data presented in Figure 12 are the results mild stress and extreme stress categories of the HLI x AHLU. In this figure the average number of cattle per treatment pen that are standing or lying under shade, in the sun, at a feedbunk or at a water trough are shown. For example, in Figure 12(a) there are on average 6 steers standing within each of the 4 pens with 2.0 m^2 of shade when conditions are extreme. More ($P<0.05$) of the cattle with access to shade were standing in the shade when conditions were extreme, than when conditions were mild. The only between shade difference was that more of the cattle with access to 3.3 m^2 of shade were lying under shade (LSH) when conditions were extreme. More ($P<0.05$) of the unshaded cattle were observed standing at the water trough (SWT) when conditions were extreme. The cattle were observed with heads over the water, occasionally dunking their heads into the water but rarely drinking at these times. Most drinking behaviour occurred late in the afternoon (after 1700 h) and early in the morning (0600 – 0700 h). The un-shaded cattle at the feedbunk (SFB) were not eating but were seeking shade. The orientation of the feed bin in pen 13 was such that a small area of shade (approximately 1 m × 2 m) was present in the afternoon. Often a single animal would be observed standing so that its head was within the shade.

There are clear response differences (P < 0.001) between un-shaded and shaded cattle in terms of numbers standing in the sun under all HLI categories. However the biggest differences were seen when HLI was categorized as very hot (HLI > 86.1 – 95). These data show that Angus cattle used the available shade especially when HLI > 86. Similarly as AHLU increased cattle spent more time under the shade. The posture (standing or lying) of the un-shaded cattle was not affected (P>0.05) by HLI category. Within the shade treatments fewer (P < 0.01) of the 2.0 m^2 group were lying in the shade compared to the 3.3 and 4.7 m^2 groups. This was due to a lack of space under the shade. It was not possible for all 9 animals to lie down and be under the 2.0 m^2 shade during the middle of the day (1100 – 1500 h). All cattle in the 3.3 and 4.7 m^2 treatments could lie under the shade at the same time. As reported in B.FLT.0337 this did not appear to be a problem in terms of welfare (panting score) but may have impacted on performance. Another confounding factor in regards to animals under the shade was with shade movement due to positional change of the sun. Cattle would be observed lying in the shade at one observation, but would be in the sun at the next observation. There were no differences between shade treatments for animals standing in the sun. The un-shaded cattle also exhibited shade seeking behaviour. These animals tended to find shade where ever they could. For example the feed bin, fence posts and other from animals. These animals also tended to crowd the water trough and bunch together during periods of high heat load.

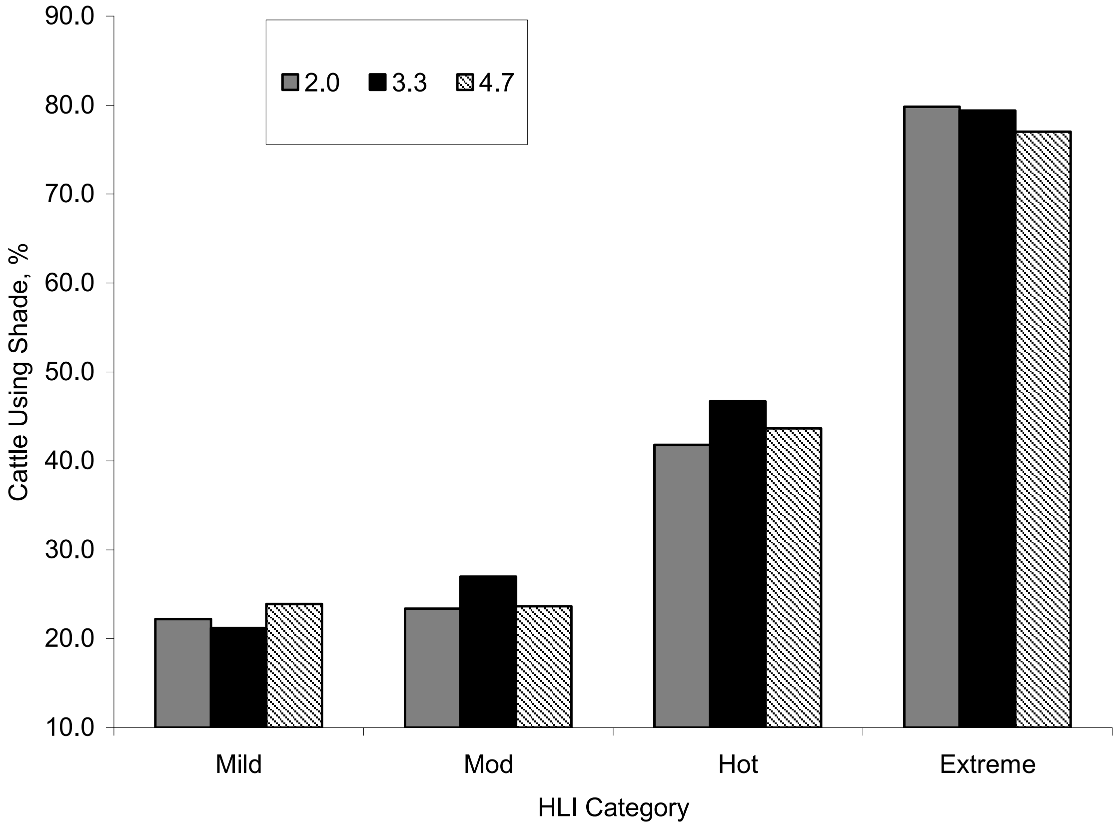

Figure 11 The percentage of cattle under shade when the HLI category is mild, moderate (Mod), hot or extreme

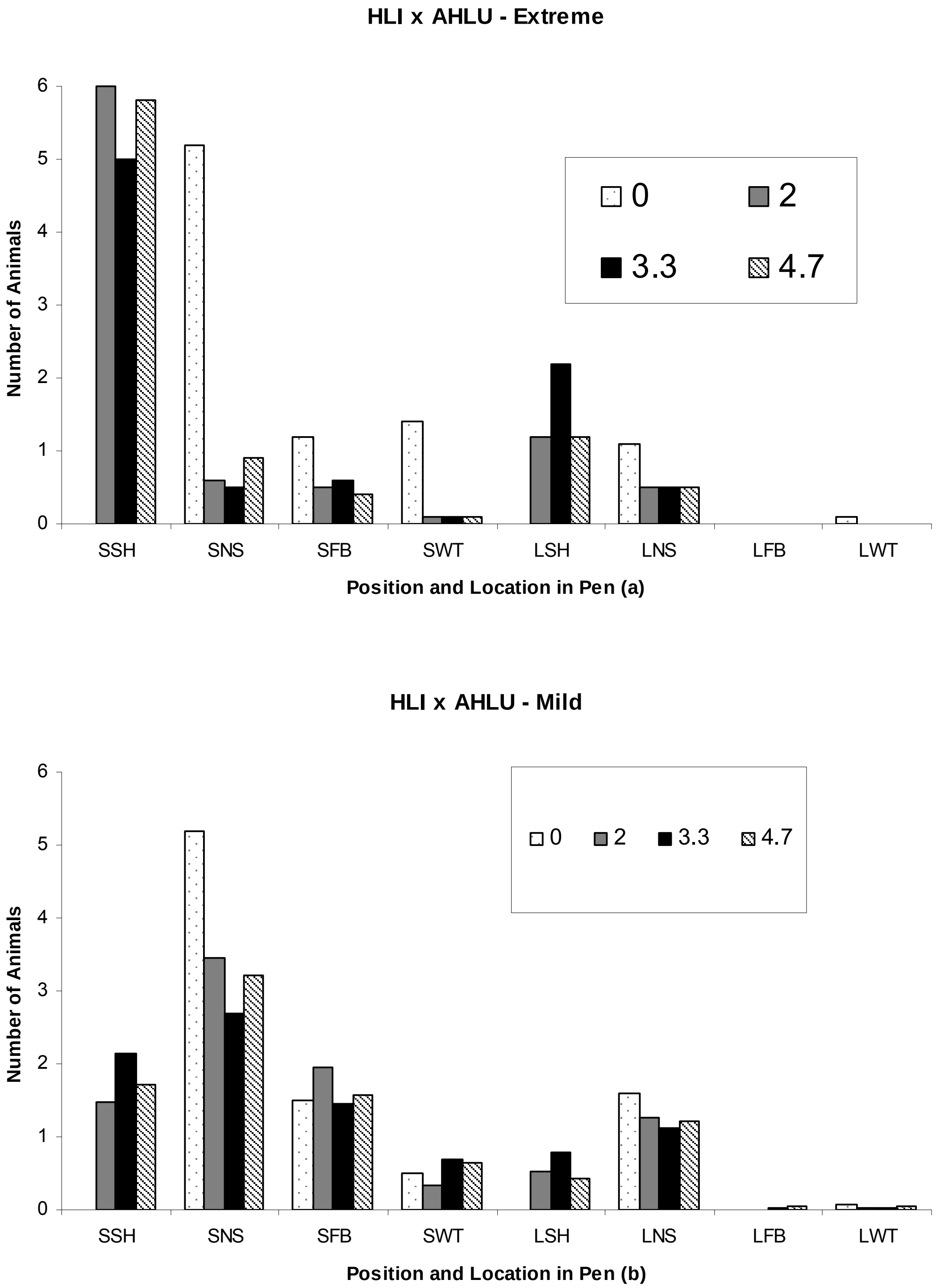

Figure 12 Position (standing (S) or lying (L)) and location in pen (in shade (SH), in sun (NS), at feed (FB) or at water (WT). {SSH = standing in shade; SNS = standing no shade; etc}

4.8 Blood parameters

The mean (pooled for all bleeds) serum concentrations of creatine kinase, glucose, insulin, lactate dehydrogenase, sodium, potassium and chloride are presented in Table 8. The concentration of the measured metabolites was influenced ($P<0.05$) by the day blood was collected. This may be a function of climatic conditions or changes in body composition of the cattle. There were no day x treatment effects, therefore only pooled data is presented.

4.8.1 Creatine kinase

The concentration of creatine kinase may be a useful indicator of welfare status. Exposure to stress (physical or disease) often leads to tissue damage in animals. When this happens there are changes in serum enzyme activity (Barrow and Clarke, 1998). Creatine kinase (CK) is one of many enzymes that will increase in the blood when an animal is exposed stress including high heat load. Based on the published data the normal range of CK in cattle is highly variable.

Reference values for non-stressed cattle range from 2 – 280 U/L (Wright et al. 1981; Fraser et al. 1991; Kaneko et al. 1997; Ruhland et al. 1999; Radostitis et al. 2000; Kanelov et al. 2008). However, most suggest that for non-stressed cattle the maximum level is below 100 U/L. Only a few studies have reported the effect of major stressors on CK levels in cattle. Wright et al. (1981) reported that cattle infected with *B. bovis* had pre-exposure levels of 10.5 U/L. Ten days post exposure the level had increased to 5250 U/L. However physical activity (e.g. walking, standing for long periods) will also lead to an increase in CK concentration in animals (Terblanche and Nel, 1998; Kaneko et al. 1997; Nazifi et al. 1999). The amount CK released is related to muscle mass (Doornenbal et al. 1988) therefore it may be necessary to adjust CK concentrations to account for this.

In the present study CK values ranged from 32 – 1697 U/L, which were much higher than the values reported in (B.FLT.0337). The treatment ranges were 55 – 1697 U/L, 32 – 1011 U/L, 50 – 1155 U/L and 49 – 872 U/L for the 0, 2.0 3.3 and 4.7 m^2 groups respectively. Variation within animals could be high, e.g. over the 5 bleeds CK values for steer 106 were 67 – 1027 U/L, and for steer 64 105 – 550 U/L. This is in agreement with Kanelov et al. (2008) who reported substantial variation between cows. Conversely for others there was little variation in CK concentration e.g. steer 112 CK ranged from 72 – 92 and for steer 53 the range was 67 – 81 U/L.

The CK levels were higher ($P < 0.05$) for the un-shaded cattle suggest that these animals have been exposed to a higher level of stress compared to the cattle with access to shade. On average the CK levels of cattle in the present study suggest that all cattle were stressed to some degree (64% recorded a CK level >100 U/L at some stage). This is supported to some extent by the panting score data. However, the high variation within and between animals, and within and between treatments suggests that CK on its own may not be a good welfare indicator for a group, but has potential as an indicator for individuals. However, as with any blood based indicators it has limited application under field conditions.

4.8.2 Metabolites

The serum concentrations of glucose, chloride, sodium, and potassium are within the normal range for cattle (Fraser et al. 1991; Doornenbal et al. 1988; Yokus and Cakir 2006).

4.8.3 Lactate dehydrogenase

Lactate dehydrogenase is the last enzyme of the glycolytic pathway and catalyzes the conversion of pyruvate to lactate (when O_2 is not available in muscle cells) or lactate to pyruvate (when O_2 is available) (Doornenbal et al. 1988; Looper et al. 2008). Therefore the level of LDH may give an indirect measure of the energy status of the animal. The concentration of lactate dehydrogenase is above the normal range presented by Fraser et l. (1991) at 309 – 938 U/L and by Yokus and Cakir (2006) at 374 – 518 U/L for unmated cows, but is in agreement with Doornenbal et al. 1988 for 12.5 month old beef steers (1238.6 U/L). The LDH concentration for non stressed dairy cows in a cool climate ranged from 1280 – 1678 U/L (Ruthland et al. 1999). Abeni et al. (2005) reported higher mean LDH concentrations of 2085 U/L for lactating dairy cows. The concentration of LDH can be elevated by exercise (e.g. walking, elevated respiration rate), is positively correlated with lean content, and negatively correlated with fat content (Renand et al. 1995). The serum concentrations of LDH may be affected by growth rate in young cattle (Doornenbal et al. 1988), but is stable in mature cows (Looper et al. 2008).

4.8.4 Insulin

The serum insulin values obtained from the cattle in the present study were lower than values reported by Borger et al. (1973) for feedlot steers. Using diets containing either 11% CP or 12.5% CP Borger et al. (1973) reported mean insulin levels of 49.6 and 63.9 µU/ml respectively. However, Gregory et al. (1982) reported a range of 12.3 – 12.9 µU/ml for growing cattle, and Jenny et al (1974) reported a range of 13 – 31 µU/ml for grain fed dairy cows.

Table 8 Mean serum levels for creatine kinase (CK), glucose (GLU), insulin (INS), lactate dehydrogenase (LDH), sodium (Na), potassium (K) and chloride (CL) for un-shaded cattle (0), cattle with access to shade at 2.0, 3.3 or 4.7 m^2/animal

	0	2.0	3.3	4.7	SE
CK, U/L	365.3^a	134.7^b	141.6^b	154.7^b	49.9
GLU, mmol/L	4.2	4.6	4.2	3.9	0.2
INS, µU/ml	35.8^a	17.3^b	16.4^b	24.9^b	3.8
LDH,U/L	1390.6	1415.1	1424.5	1351.3	24.7
Na, mmol/L	141.0	141.3	142.3	145.6	1.6
K, mmol/L	4.7	4.6	4.8	4.8	0.1
Cl, mmol/L	102.2	102.6	102.9	103.2	0.3

5 Success in achieving objectives

The climatic conditions which prevailed over the data collection period were sufficient to induce heat stress in the cattle. Clear welfare and performance differences were seen between shaded and un-shaded cattle. In addition welfare and performance differences were seen between shade treatments. Therefore the project has been able to achieve the objectives as set out in section 2 of this report.

6 Impact on meat and livestock industry – now & in five years time

The findings from this study and B.FLT.0334 provide for the first time a scientific basis to the use of shade in Australian feedlots. These studies have shown that there are positive, measurable welfare outcomes when shade is used for Angus cattle over the summer months. In addition provision of shade has demonstrated a production outcome in terms of feed efficiency.

The use of shade will not only improve animal welfare, and will improve the publics perception of the welfare of feedlot cattle. This will have both short and longer term benefits for the feedlot industry.

The demonstrated production benefits will also have an immediate and long term impact on financial returns over the summer months.

7 Conclusions and recommendations

7.1 Conclusions

Based on the production and welfare findings from this study, the type of cattle, stocking density, diets and shade structure used in the current study the following conclusions are made.

- Shade reduces the impact of extreme conditions but does not eliminate heat stress.
- Angus cattle increased shade usage when the HLI>86. This suggests that the Risk Analysis Program thresholds are correct for the reference animal.
- All shade was beneficial in terms of production responses. The positive production responses increased as area of shade increased. However, the response from the 2.0 m^2 group was very small suggesting that the area of shade is insufficient, and therefore should not be recommended. Before firm recommendations can be made the cost benefit of increasing shade area from 3.3 – 4.7 m^2 needs to be examined.
- Not having access to shade had a negative welfare (based on panting scores and serum CK concentration) and production (feed efficiency) impact on cattle.
- There were differences in terms of welfare for shade areas used (2.0, 3.3 and 4.7 m^2) in the current study (stocking density of 19.17m^2). Under extreme conditions welfare improved as area of shade increased.
- The area under the shade structure tended to stay wetter longer following rain.
- More pen maintenance is required under shade structures.
- The height and orientation of the shade appears to be adequate.

7.2 Recommendations

Based on the production and welfare findings from this study, the type of cattle, stocking density, diets and shade structure used in the current study the following recommendations are made.

Recommendation 1: Shade should be considered as a priority for black *Bos taurus* cattle in areas were high heat load is expected. Shade will improve animal welfare.

Recommendation 2: Based on the results a shade area of 3.3 – 4.7m^2/animal should be recommended for black *Bos taurus* cattle 100 – 180 days on feed. This should provide adequate shade for stocking densities from 14 – 19.2 m^2/animal. A shade area of ≤ 2.0 m^2 should not be recommended due to the negligible production response. Firmer recommendations could be made following the completion of Recommendation 3.

Recommendation 3: The optimal shade area be determined based on a economic assessment of the cost: benefit of erecting shade. This should include performance factors such as feed efficiency, and costs associated with pen maintenance. This could be done in part in conjunction with Recommendations 6 and 7, or as a stand alone project.

Recommendation 4: A 70% solar block appears to be adequate, however any additional benefits or costs associated with increasing the solar block more e.g. 80 – 100% solar block should be examined.

Recommendation 5: Maintain the shade thresholds in the Risk Analysis Program, but add that these values are adequate for Angus cattle only.

Recommendation 6: The adjustments to the shade thresholds in the Risk Assessment Program for genotypes other than Angus should be determined. It is possible that this can be done using existing data from previous MLA funded projects, and in conjunction with Recommendation 7.

Recommendation 7: Feed intake, feed efficiency and cattle performance data should be collected from a number of commercial feedlots (with and without shade; and with different genotypes) over summer to further refine the shade component of the Risk Assessment Program. This should be done in conjunction with Recommendation 6.

Recommendation 8: The recovery time need by cattle exposed to high heat load be further refined.

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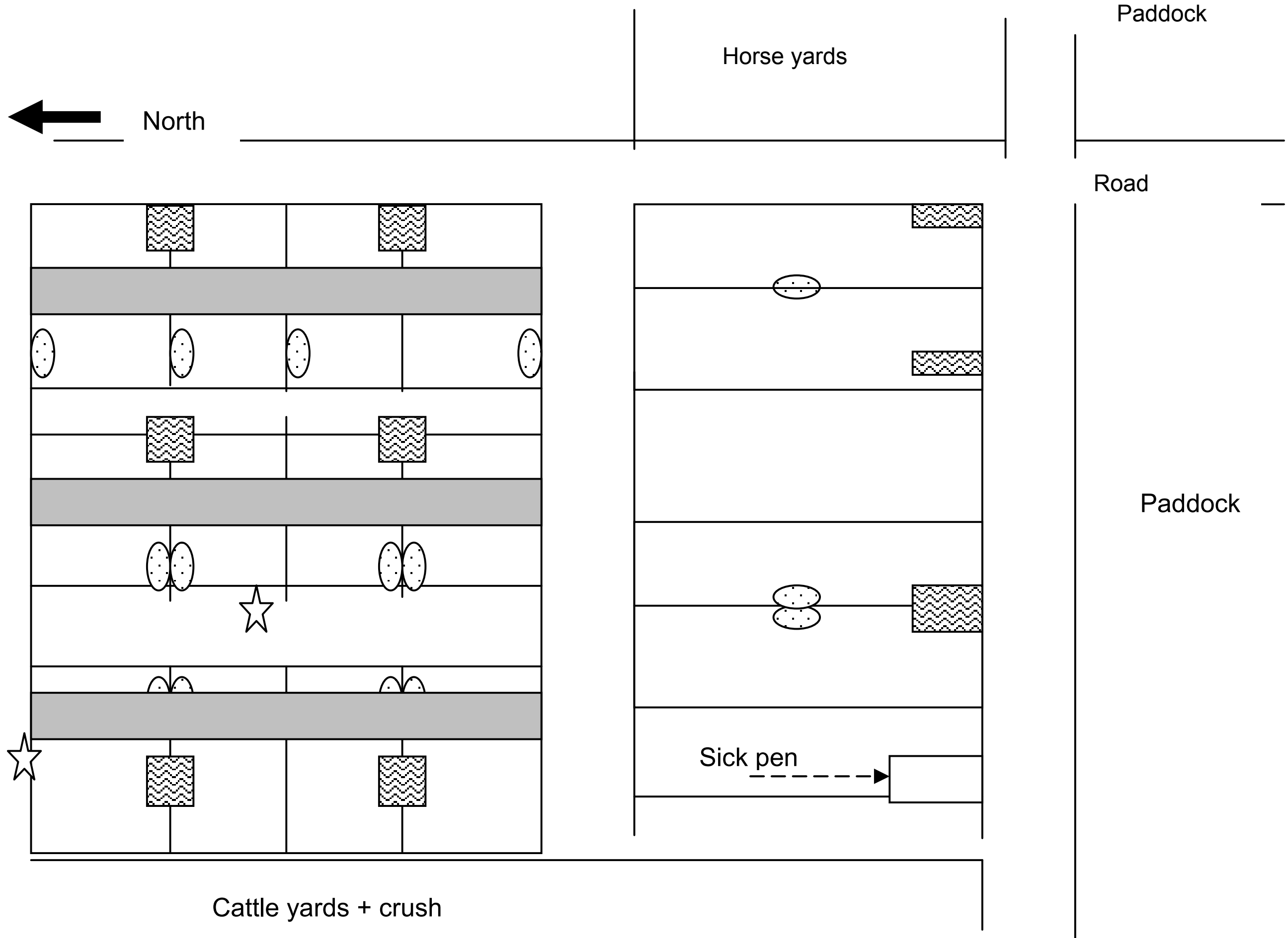
9 Appendices

9.1 Appendix 1



Notes:

Water trough

Self-feeder

Shade structure (70% solar block out shade cloth) (Shade runs north – south)

Weather station

Yards and Dimensions:
Total number of yards = 16
Pen dimensions = 7.5 m x 23 m (172.5 m^2)
Stocking density and Standard Cattle Units:
Animals per pen (max) = 9 (stocking density = 19.2 m^2)
Max SCU on site = 131 max turnoff weight 600 kg.

9.2 Appendix 2

The following equation was used to calculate the AHL (in Excel);

$$IF\ (HLI_{ACC} < HLI_{Lower\ Threshold},\ (HLI_{ACC} - HLI_{Lower\ Threshold})/(Mx2),\ IF\ (HLI_{ACC} > HLI_{Upper\ Threshold},\ (HLI_{ACC} - HLI_{Upper\ Threshold})/M,\ 0))$$

Where HLI_{ACC} = the actual HLI value at a point in time; $HLI_{Lower\ Threshold}$ = the HLI threshold below which cattle in a particular class will dissipate heat e.g. 77 for the reference animal;

$HLI_{Upper\ Threshold}$ = the HLI threshold above which cattle in a particular class will gain heat e.g. 86 for the reference animal; and M = measures per h i.e. how often HLI data is collected per h. If every 10 min then M = 6.

Because cattle do not dissipate heat at the same rate that they gain heat the M value in first part of the equation is multiplied by 2 – this slows the rate of heat loss in the equation.

9.3 Appendix 3

Rainfall (mm) from the 1st November 2007 to 13th March 2008 for the UQ Feedlot

	November	December	January	February	March
1	0.2	7.4	12.8	0	0.2
2	0.2	0.1	1.6	0	0
3	0.2	0	1.6	0	0
4	0	0	6.6	41.2	0
5	0	4.7	44.3	74.8	0
6	5.7	31.8	15.3	8.1	0
7	8.1	0	20.4	12.4	0
8	14.8	15.4	0	1.0	0
9	0	0.5	0	0	0
10	0.1	1.5	0	0	0
11	0	1.1	0.8	0	0
12	0	9.6	0.4	5.6	0
13	0	6.6	0	7.4	1.2
14	0	0.8	0	32.6	-
15	0	0	22.6	0	-
16	0	0	3.1	0.4	-
17	0	0	0	1.4	-
18	1.0	7.8	0	0	-
19	0	0.1	0	0.2	-
20	0	0	0	0	-
21	0	0	0	0	-
22	0	0.2	7.9	26.0	-
23	9.8	1.9	0.3	0	-
24	62.4	3.0	0	0	-
25	5.2	0	0	0.2	-
26	0	0	0.2	12.8	-
27	0	1.2	0	12.8	-
28	0.2	2.4	0	0.2	-
29	0	3.3	0	-	-
30	0	0	0.6	-	-
31	-	0	6.0	-	-