On farm

Validation of the Heat Load Index for use in the feedlot industry

Project number: FLOT.330
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Feedlots

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ABSTRACT

In a previous MLA funded research project (FLOT.327) a new Heat Load Index (HLI) was developed for use in the feedlot industry to assist in the management of heat load in feedlot cattle. Along with the new HLI, a new indicator, called the Accumulated Heat Load Units (AHLU) was also developed. The AHLU measures both the severity and the duration of exposure to extreme heat conditions. Along with these indicators, a risk assessment program (RAP) was developed to quantify the risk of extreme heat events occurring at individual feedlots using a number of assumptions about the impact of key variables on heat load in feedlot cattle. Both of these new indicators, and the RAP software, require proper validation before they can be released with confidence to the industry. The purpose of this project was to collect appropriate data sets from Australian feedlots and then use those data sets to statistically test the new indicators. Although the datasets were collected during a relatively mild summer, the results, which show that the new indicators do adequately reflect the heat status of feedlot cattle, are encouraging.

EXECUTIVE SUMMARY

A number of new indicators for assessing the impacts of extreme heat events on feedlot cattle were developed in a previous MLA funded research project (FLOT.327). The new indicators were developed to assist feedlot operators to improve their heat load management plans and thereby reduce the impact of extreme heat load events. A new biologically based heat index for feedlot cattle (Heat Load Index; HLI) was developed by assessing the relationship between some key biological responses (respiration rate, panting score and body temperature) of a reference animal to key climatic variables that had been identified in previous research projects. The new HLI uses black globe temperature (°C), relative humidity (%) and wind speed (m/s) to calculate an index that reflects the impact of the surrounding climate on feedlot cattle. The reference animal is a black steer, body condition score 4+, 100 + days on feed, healthy and with no access to shade.

The index took the form:

For Black Globe Temperatures less than 25°C:

- HLI = 10.66 + 0.28 x RH + 1.3 x BGT - WS

For Black Globe Temperatures above 25°C:

- HLI = 8.62 + 0.38 x RH + 1.55 x BGT – 0.5 x WS + EXP(-WS +2.4)

The Accumulated Heat Load Units (AHLU) indicator was developed in an attempt to include both the intensity of exposure and the duration of that exposure to extreme heat. The AHLU is based on the THI-Hrs concept (Hahn and Mader 1997). The AHLU is a two dimensional function incorporating time and heat balance. The AHLU is calculated by determining the difference between the HLI at a given time and an upper and lower threshold HLI. The thresholds have been developed largely from climate room studies, but also from feedlot studies. When the HLI is above the upper threshold (≥86), cattle will not be able to effectively dissipate body heat, which means that there is likely to be an increase in core body temperature. When the HLI is below the lower threshold (≤79) then cattle are likely to dissipate body heat back to the environment. A transition zone exists when HLI is between 79.1 and 85.9. When the HLI is between the two thresholds it is not clear if cattle will be gaining or losing heat, therefore a zero value is recorded for heat balance which means that the animals are not gaining or losing body heat.

A new risk assessment program (RAP) was also developed in an attempt to assist feedlot operators in quantifying the risk of extreme heat events occurring at specific feedlots and specific feedlot pens. This new RAP software estimated the effect of certain key feedlot variables (presence of shade, dominant animal genotype, animal coat colour, etc.) on the upper HLI threshold mentioned above. By doing this, the probability of extreme heat load events occurring at specific feedlots and feedlot pens can be quantified. However, the assumptions used to quantify the risk of extreme heat load events occurring need to be validated using independent datasets.

The datasets required to independently validate the risk assessment tools produced in the FLOT.327 projects were collected from 13 Eastern Australian feedlots from 24 January 2005 to 11 March 2005. The majority of the data collection was undertaken by feedlot staff, with the animal observation data collected three times daily and the climatic data collected from the feedlot weather station. Once all of the data had been received, data collation and analysis was undertaken by the project team.

The data analysis undertaken suggests that the new HLI and AHLU adequately reflect the impact of the feedlot micro-climate on cattle. Further, some of the assumptions made in the RAP software were also tested. For example, it was shown that there is a genotypic difference in animal response to elevated heat load. As well, there were differences noted in the response of animals with varying coat colour, however, the actual impact of coat colour is difficult to separate from genotypic effects and needs further research.

1. INTRODUCTION

1.1. Industry Context

In the past, there have been a number of high heat load events at Australian feedlots that in extreme cases have resulted in the loss of feedlot cattle. The resultant losses in production and bad publicity have had an obvious negative impact on the feedlot industry as a whole. As a result, the industry has taken the proactive step of reducing the negative impact of future high heat load events on feedlot cattle by identifying the variables (micro-climate, animal and management) that cause heat load in feedlots.

A previous Meat and Livestock Australia (MLA) funded project (FLOT.327) was conducted in 2004/05 to identify variables that contribute to excessive heat load in feedlot cattle, and to produce a risk assessment program that could quantify the risk of high heat load events occurring at specific feedlots. One of the key outcomes from this project was the production of a new biologically based heat index for feedlot cattle (Heat Load Index; HLI). The HLI was developed to reflect the impact of the surrounding micro-climate on the heat status of feedlot cattle. Another key outcome from this project was the production of a Risk Assessment Program (RAP) which assessed the risk of high heat load events occurring at specific feedlot sites.

To fully test the accuracy and validity of both the HLI and RAP, they must be evaluated against datasets that were not used in their formulation. The purpose of this project was to collect the independent datasets required.

1.2. Project Background

The project FLOT.330 “Validation of the new Heat Load Index for use in the feedlot industry,” was funded by Meat and Livestock Australia (MLA) with research support from E.A. Systems Pty Limited and The University of Queensland. The project was formally contracted in April 2005 and was aimed for completion by the end of June 2005.

The objectives of this project were to collect and collate datasets from Australian feedlots for the purpose of testing and validating the HLI and RAP. The independent datasets collected by this project could then be used to statistically validate the HLI and RAP giving greater confidence to industry that the HLI and RAP are accurate.

The need for this research originally flowed from an ALFA Working Party appointed to review two reports that related to an incident in February 2000 where a number of cattle died due to extreme weather conditions. These two reports were:

‘A Report to the Director General, NSW Agriculture – Mortalities in Feedlot Cattle at Prime City Feedlot, Tabbita, NSW, February 2000’ K. Entwistle, M. Rose and B. McKiernan;

'Report to the Feedlot Industry Accreditation Committee on the Review of the Prime City Incident' K. Roberts, K. Sullivan, R. Burton and D. Rinehart.

The Working Party considered both reports and decided on certain target areas that needed further research. Following on from these decisions, a number of MLA funded projects were undertaken in an attempt to improve the understanding within the industry of the factors that cause extreme heat load events. The research projects that have been undertaken include:

- FLOT.307 – 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.

The work areas covered in these projects included:

- Identifying the climatic variables crucial to determining the heat load on feedlot cattle;
- Determining the differences in crucial climatic variables between in-pen conditions and conditions in the surrounding area; and,
- Development of the new HLI and RAP software to predict the risk of extreme heat load events occurring at individual feedlot sites.

These projects laid the foundation for the work undertaken in project FLOT.330.

1.3. The New HLI and RAP Software

The new HLI produced as a part of FLOT.327 uses the following climatic variables to reflect the heat load on feedlot cattle:

- Black Globe Temperature (°C);
- Relative Humidity (%); and,
- Wind Speed (m/s).

It was recognised during the formulation of the HLI that cattle panting score and respiration rate increased as black globe temperature increased. There appears to be a threshold (or break point) at the black globe temperature of 25^{o}C (23 - 26^{o}C). Below 25^{o}C the animal response to increasing black globe temperatures is linear and above 25°C the response is quadratic. Therefore two algorithms were developed, one for black globe temperatures of above 25°C and the second for black globe temperatures of below 25°C. The algorithms developed were:

For Black Globe Temperatures less than 25°C:

- HLI = 10.66 + 0.28 x RH + 1.3 x BGT - WS

For Black Globe Temperatures above 25°C:

- HLI = 8.62 + 0.38 x RH + 1.55 x BGT – 0.5 x WS + EXP(-WS +2.4)

The Accumulated Heat Load Units (AHLU) is calculated by measuring the period of time that the HLI is above an upper threshold. When this occurs, the animal is not dissipating sufficient body heat to the environment and therefore core body temperature increases. Alternatively, if the HLI falls below a lower threshold, then the animal is able to dissipate body heat to the environment, and core body temperature will fall. A transition zone exists when HLI is between the upper and lower thresholds. When HLI is between the two thresholds it is not clear if cattle will be gaining or losing heat, therefore a zero value is recorded for heat balance which means that the animals are neither gaining nor losing body heat.

The difference between a HLI value (i.e. measured real time at a feedlot) and the HLI threshold is called the HLI Balance, and is used to calculate the AHLU. There are a number of factors that influence the specific values for the upper threshold in particular. However, for the reference animal, which is a black steer of condition score 4-5, kept in an un-shaded pen with at least 100 days on feed, the upper threshold is 86 and the lower threshold is 79.

The Risk Assessment Program uses data from Bureau of Meteorology Automatic Weather Stations to quantify the climatic risk associated with the feedlot being located in specific regions. Once the regional climatic risk is quantified (based on the upper threshold for the reference animal), individual feedlot management strategies are then assessed, and the effect of these strategies on the feedlot's heat risk is quantified. Feedlot management strategies such as use of a properly designed shade structure will have a positive impact on the HLI threshold. That is, the upper threshold at which cattle will accumulate heat increases (e.g. moves from 86 to 91). Factors that increase the susceptibility to high heat load, such as cattle suffering from a disease challenge, particularly a respiratory disease, have a negative effect on the upper threshold. That is, the upper threshold falls (e.g. moves from 86 to 77). Using this method it is possible to quantify the effects of various heat load mitigation strategies on the upper and lower thresholds. Other factors include: genotype; manure management; and, feed management.

1.4. Project Objectives

The objectives of project FLOT.330 were to, by 15 June 2005;

1. Collect data sets of climatic, animal and feedlot site variables for 13 co-operator feedlots, located throughout eastern Australia during periods of high heat load; and,
2. Utilise the collected data sets to test and validate the refined HLI, the AHLU concept and the RAP software, using recognised statistical methods.

2. METHODOLOGIES

2.1. Training of Feedlot Staff

In an attempt to maximise the number of feedlots involved and their geographic spread, it was decided that the majority of the data collection should be undertaken by feedlot staff, rather than the research staff involved in this project. For this to be successful, a series of workshops were undertaken by the project team to train the staff from the feedlots involved. The workshops were conducted in early January at the following feedlots:

- Sandalwood Feedlot, Dalby, 12 January 2005;
- Rockdale Feedlot, Yanco, 13 January 2005; and,
- Killara Feedlot, Quirindi, 18 January 2005.

The purpose of these workshops was to ensure consistency in data collection methods across all the feedlots involved.

2.2. Feedlots involved

There were thirteen (13) feedlots involved in the data collection phase of this project. They were all situated in Eastern Australia with a geographic spread from Comet in Central Queensland to Charlton in Victoria. The feedlots involved, along with their respective locations are listed below:

- Goonoo (Comet, Central Queensland);
- Smithfield (Proston, Southern Queensland);
- Sandalwood (Dalby, Southern Queensland);
- Kerwee (Jondaryan, Southern Queensland);
- Teys Bros (Condamine, Southern Queensland);
- Beef City (Toowoomba, Southern Queensland);
- Aronui (Dalby, Southern Queensland);
- Myola (North Star, Northern New South Wales);
- Caroona (Quirindi, Northern New South Wales);
- Killara (Quirindi, Northern New South Wales);
- Prime City (Griffith, Southern New South Wales);
- Rockdale (Yanco, Southern New South Wales); and,
- Charlton (Charlton, Victoria).

2.3. Data Collection Methods

The data collection phase of this project was conducted from 24 January 2005 to 11 March 2005. The data that was required to be collected by the feedlots' staff included:

- Micro-climatic data (from the feedlot weather station);
- Pen description data; and,
- Animal behavior data.

2.3.1. Climatic Data Collection Methodologies

Prior to the commencement of the trial, the weather station at each of the participating feedlots was checked to ensure that it was operating correctly. At most of the participating feedlots, a member of the project team physically checked the weather station. Where it was not possible for a member of the project team to physically check the weather station, some recent data from the station was reviewed by the project team to ensure that the station was functioning properly.

At the same time, the data collection interval for each weather station was checked to ensure that the climatic data was being collected at a suitable interval. For the purposes of this project, the optimum data collection interval was between 10 minutes and one (1) hour. It was also desirable that the wind speed be expressed as an average over the data collection period, rather than a single spot measurement. Where necessary, the data collection interval was changed prior to the commencement of the trial. The climate data for the data collection phase (24 January – 11 March) from each feedlot weather station was then collected during and after the data collection period.

The weather parameters collected varied between feedlots, but the minimum weather parameters that were collected from all of the feedlot weather stations included:

- Black Globe Temperature (°C);
- Solar Radiation (w/m^2);
- Wind Speed (m/s) or (km/hr);
- Relative Humidity (%);
- Ambient Temperature (°C); and,
- Rainfall (mm).

2.3.2. Pen Description Data Collection Methodologies

The observation and collection of pen description data was undertaken by staff at each of the participating feedlots. Each feedlot was asked to select four separate pens to be observed over the entire data collection period. The pens at each feedlot were selected on the basis that the cattle within those pens were not going to be moved during the observation period. The pens were also selected in an attempt to maximise the variability between the pens observed at each feedlot.

Once the pens to be observed had been selected, a description was made of each pen. This description included: pen number; pen dimensions; number of cattle in pen; aspect; water trough space; water trough type; location of water trough; shade dimension; shade type; location of shade; and, some information on the components of the diet currently being fed to that pen. The data sheet used to collect the pen description data is shown in Appendix 2.

2.3.3. Animal Behavior Data Collection Methodologies

Once the pens to be observed had been selected and described, the animal observation data collection phase was undertaken. During the data collection period (24 January 2005 – 11 March 2005) the participating feedlots were asked to observe the animals in each of the selected pens three (3) times each day, at approximately 6:00 am, 12:30 pm and 4:00 pm.

The data collected during these animal observations was used to quantify the level of heat load affecting the animals in the selected pens. One of the most reliable and transferable methods for measuring heat load in cattle is the panting score measure. Panting scores were used to observe the cattle in the datasets that were used in the formulation of the HLI. Panting score was measured 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 1.

Table 1 Panting Score system used during data collection

Panting score	Breathing condition	Associated Respiration Rate (breaths/min)
0	No panting – normal. Difficult to see chest movement	< 40
1	Slight panting, mouth closed, no drool or foam. Easy to see chest movement	40 – 70
2	Fast panting, drool or foam present. No open mouth panting	70 – 120
2.5	As for 2 but with occasional open mouth, tongue not extended.	70 – 120
3	Open mouth + some drooling. Neck extended and head usually up.	120 – 160
3.5	As for 3 but with tongue out slightly & occasionally fully extended for short periods + excessive drooling.	120 – 160
4	Open mouth with tongue fully extended for prolonged periods + excessive drooling. Neck extended and head up.	> 160
4.5	As for 4 but head held down. Cattle “breath” from flank. Drooling may cease.	Variable ~ RR may decrease

There was a series of reference photographs and tables sent to each feedlot to assist them in assessing the panting score status of each pen, which is shown in Appendix 3. The staff undertaking the assessments were asked to make assessments of the number of cattle within each pen that were at each panting score. Other assessments they were asked to make at each observation included the position of the cattle within the pen (at feedbunk, water trough, etc.), the dominant genotype and sex within the pen, the condition of the pen surface, the feeding time and bunk scores and the time of observation. This data was used to gain a better understanding of the heat load levels within the observation pens. The data sheets used to record the animal behavior observations are shown in Appendix 2.

2.3.4. Average Panting Scores

When presenting data, in most cases the actual percentage of cattle with a particular panting score are presented. In a couple of places average panting score is used. Unless otherwise stated percentage panting score will be used.

The average panting score was calculated according to the following formula:

$$AvgPantingScore = \frac{(n_0 \times 0) + (n_1 \times 1)....... + (n_{4.5} \times 4.5)}{n}$$

Where: n_0 = the number of cattle observed at panting score 0
n_1 = the number of cattle observed at panting score 1
$n_{4.5}$ = the number of cattle observed at panting score 4.5
n = the total number of cattle being observed

So, the sum of the number of cattle observed at each panting score multiplied by the corresponding panting score level and divided by the total number of cattle being observed gives the average panting score.

2.3.5. CATTLE GENOTYPE

Seventeen (17) different genotypes were observed. The most common genotype was Angus (6 feedlots) followed by Santa Gertrudis (3 feedlots). There was some difficulty in identification of the component breeds in some of the crossbred cattle. For example in regard to the European cross at feedlot 8, neither breed was identified. It was determined that the cross was European based on conformation, but it was not determined if the cross was with *Bos indicus* or *Bos taurus.* The Wagyu cattle have been included with the purebreds. The genotype, coat colour, access to shade and the number of feedlots where genotypes were observed are as follows;

Pure Breed:

- Angus (A) (black) – shade: 6 feedlots.
- Brahman (B) (grey, red) – no shade: 2 feedlots
- Hereford (H) (red) – shade: 2 feedlots
- Hereford (HX) (red) – no shade: 2 feedlots[1]
- Santa Gertrudis (SA) (light red) – no shade: 2 feedlots
- Santa Gertrudis (SAS) (light red) – shade: 1 feedlot
- Wagyu (W) (black) – shade: 1 feedlot

Crossbred:

- Angus x Charolais (AC) (black) – no shade: 1 feedlot
- Angus x Hereford (AH) (black, white face) – shade: 2 feedlots

[1] The cattle classified as Hereford at one of the feedlots were *predominantly* Hereford. We classified these as Hereford on the basis of their colour and confirmation.

- Angus X (not with *Bos indicus*) (AX) (black) – shade:1 feedlot
- European X (not with *Bos indicus*) (EX) (white) – no shade: 1 feedlot
- European X (with *Bos indicus*) (EB) (white) – no shade: 1 feedlot
- European X (breed not determined) (EC) (red/white) – no shade: 1 feedlot
- Santa Gertrudis x Hereford (SAH) (red) – no shade: 1 feedlot
- Santa Gertrudis x Charolais (SAC) (light red) – no shade: 1 feedlot
- Santa Gertrudis X (with *Bos indicus*) (SAX) (red) – no shade: 1 feedlot
- Brahman X (breed not determined) (BX) (grey/brindle) – no shade: 1 feedlot
- Shorthorn x Hereford (SH) (dark red, white face) – no shade: 2 feedlots

2.3.6 Statistical Methods

Due to the uneven number of animals per pen within and across feedlots all observational data were converted from the actual observation number to the proportion of animals in the pen. For example if a pen contained 230 steers and 20 were observed with a panting score of 1 then the value 8.69 was used in the analysis ({20/230} x 100). Unless otherwise stated, all panting score data is presented as percentages. For statistical analysis the percentages of cattle recorded for each panting score (within a feedlot, and then within a genotype across and within feedlots) were transformed to a normalized distribution using squared root-arcsine transformation.

Heat Load Index (HLI) was divided into four categories: (1) Thermoneutral Conditions, when the HLI is <70.0; (2) Warm Conditions, when the HLI is 70.1 - 79.0; (3) Hot Conditions, when the HLI is 79.1 – 86.0; and, (4) Very Hot, when HLI is >86.0. Accumulated Heat Load Units (AHLU) was divided into 5 categories: (1) Thermoneutral Conditions, when the AHLU is <1; (2) Mild Conditions, when the AHLU is 1 - 10; (3) Warm Conditions, when the AHLU is 10.1 - 20; (4) Hot Conditions when the AHLU is 20.1 – 50; and, (5) Very Hot, when the AHLU is >50.

The data were analysed using Chi-Square analysis, PROC SORT, PROC MIXED and PROC GLM (SAS, 1996). The models used were the effects of HLI categories and AHLU categories on panting scores and DMI. Genotype effects on panting scores and DMI within HLI and AHLU categories was also investigated. Pen effects were considered where the same genotype was in shaded and un-shaded pens within a feedlot. Interactions between genotype, pen, HLI, AHLU, HLI categories, AHLU categories, and days on feed were analysed and the effect of those individual variables on dry matter intake (DMI) and panting scores were also statistically analysed. Statistical models for DMI and panting score included genotype x feedlot x pen x HLI category; genotype x feedlot x pen x AHLU category. Heat Load Index category x AHLU category interactions on panting score was also investigated. Interactions between pen surface condition, HLI and AHLU on panting score were assessed.

3. RESULTS AND DISCUSSION

3.1. Climatic Data

Whilst the climatic data collected was useful in validating the HLI and AHLU, there were only limited periods (1 – 3 days duration) of extreme climatic conditions (i.e. AHLU >100) observed during this trial. In most cases there was enough night time relief so that cattle did not have a carry over heat balance. Unfortunately during an extreme event at one feedlot the weather station failed, and no weather data was available. In another case no animal data was collected during an extreme event. The HLI and AHLU for a feedlot in NSW (Figure 1) where the maximum AHLU was 72, and another in Queensland (Figure 2) where the maximum AHLU was 300 are presented below. In both instances cattle in shaded and un-shaded pens were observed. Because the HLI is intended to reflect the impacts of heat of feedlot animals, it is important that the HLI be tested during periods of extreme heat. The limited duration of extreme heat events from this dataset should be noted when looking at the results.

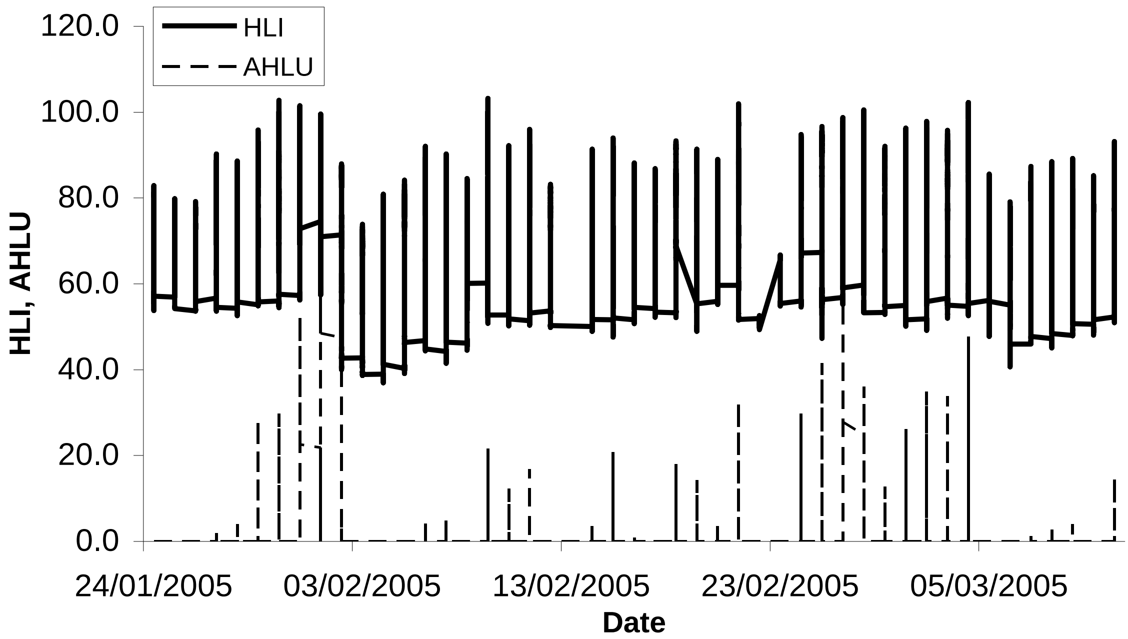

Figure 1 The heat load index and AHLU over the trial period for a feedlot located in NSW.

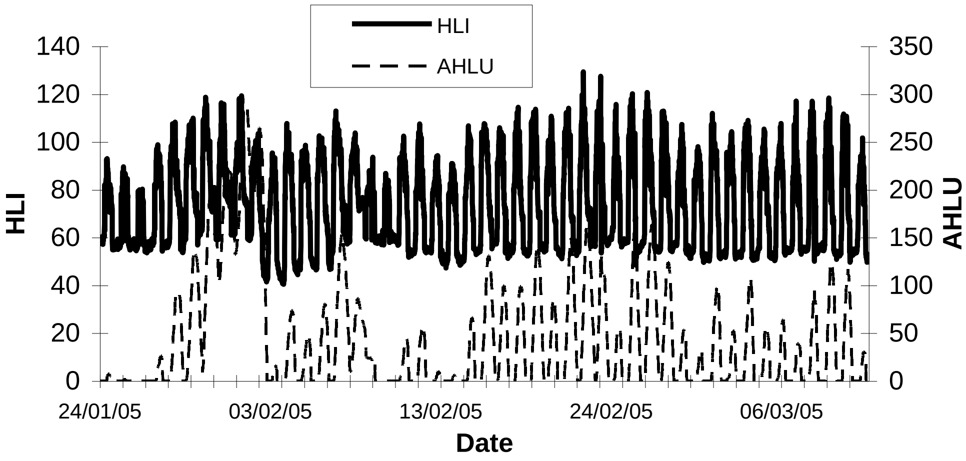

Figure 2 The heat load index and AHLU over the trial period for a feedlot located in QLD.

Figure 3 shows a climatic dataset that was collected from one of the participating feedlots during the data collection period. The variables shown are those used to calculate the HLI (black globe temperature, relative humidity and wind speed), along with the calculated HLI, the HLI Balance and the AHLU. This period was the longest period of "hot" weather that the feedlot was exposed to over the sampling period.

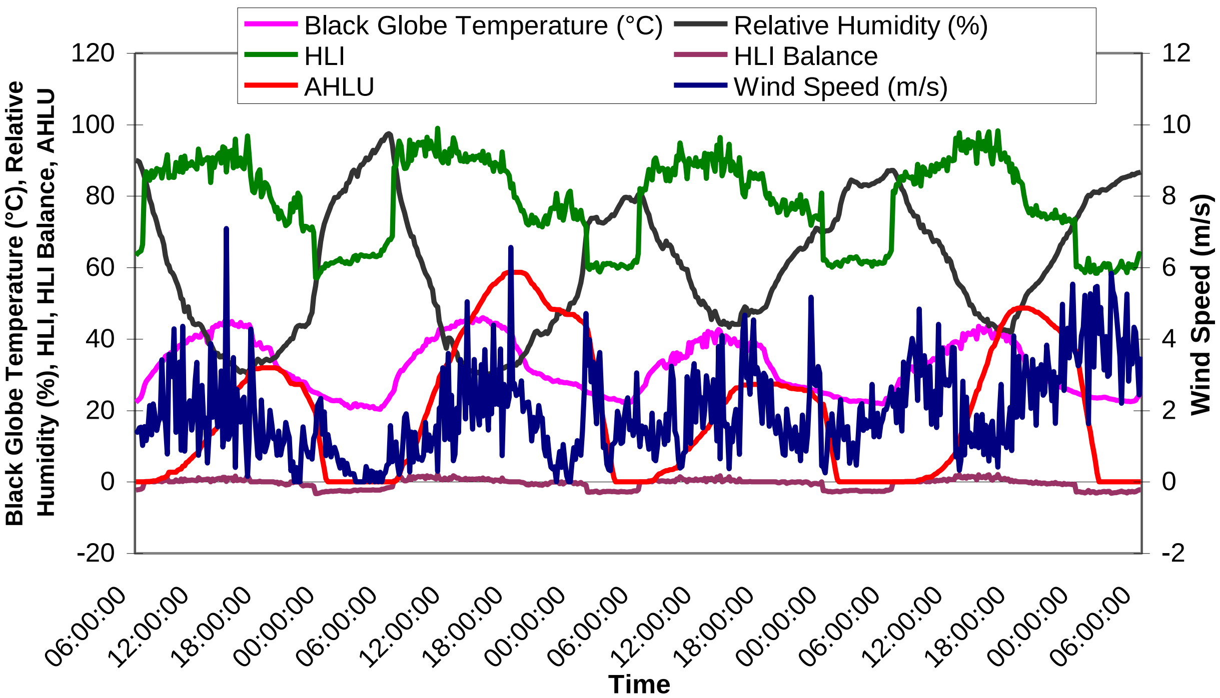

Figure 3 Climatic dataset from a Queensland feedlot over 96 h (data collected at 10 min intervals)

3.2. Animal Response

3.2.1. Relationship between Panting Score and HLI

The data presented in Table 2 and Table 3 is the percentage of cattle with a particular panting score within a HLI category. High numbers of cattle with a panting score of 0 is considered good, because these animals are not experiencing any significant heat load, whereas high numbers of cattle experiencing PS 1 or above are experiencing significant heat load.

Variations in animal responses to observed climatic conditions were investigated. The impact of factors such as genotype, coat colour and the presence of shade on DMI and panting score were investigated and are shown in the following tables. Panting scores for the pure bred genotypes (all feedlots combined) are presented in Table 2, and the crossbreds in Table 3.

As expected the British breeds (Angus and Hereford) had lower heat tolerance than Brahman and Wagyu (Table 2). The percentage of cattle with a panting score of 0 decreased as the HLI categories moved from thermoneutral to very hot, except for Brahman and Wagyu where the percentage did not decrease until very hot conditions were encountered.

The Santa Gertrudis did not respond as expected. This genotype (located on 3 of the feedlots studied) was not as heat tolerant as was expected especially under very hot conditions. At one feedlot the Santa Gertrudis steers were moved from un-shaded pens to shaded pens during the study. These animals are represented by the SAS nomenclature in Table 2. From the data presented it is clear that provision of shade had a marked affect on panting score for this genotype.

Table 2 Panting scores (%) for the purebred genotypes according to HLI category

		Panting Scores					
Genotype	**HLI**	**0**	**1**	**2**	**2.5**	**3**	**≥3.5[A]**
A	TNC	92.96[a]	6.65[a]	0.36	0.03	0	0
	Warm	83.31[c]	13.66[a]	2.89[a]	0.14	<0.01	0
	Hot	74.92[g]	23.41[a]	1.61[a]	0.06	0	0
	Very Hot	43.91[a]	37.77[a]	14.46[a]	3.12[a]	0.68	0.06
B	TNC	99.84[b]	0.16[b]	0	0	0	0
	Warm	99.60[d]	0.40[a]	0	0	0	0
	Hot	99.12[h,g]	0.88[b]	0	0	0	0
	Very Hot	79.69[b]	19.55[b]	0.64[b]	0.09[b]	0.03	0
H	TNC	88.55[a]	11.44[a]	0.01	0	0	0
	Warm	49.37[e]	44.22[b]	6.13[a]	0.28	0	0
	Hot	42.06[i]	43.31[c]	13.68[b]	0.82	0.14	0
	Very Hot	19.47[c]	54.31[c]	23.21[c]	2.69[a]	0.32	0
HX	TNC	93.13[a]	6.68[a]	0.19	0	0	0
	Warm	56.91[e]	38.84[c]	3.98[a]	0.20	0.07	0
	Hot	44.50[i]	38.58[c]	14.89[b]	2.28	0	0
	Very Hot	15.43[c]	43.57[c]	32.41[d]	8.17[c]	0.31	0.11
SA	TNC	93.57[a]	6.29[a]	0.14	0	0	0

	Warm	86.00[f]	13.64[d]	0.31[b]	0.05	0	0
	Hot	84.44[j,g]	14.33	1.21[a]	0.02	0	0
	Very Hot	35.83[c]	53.46[c]	8.81[e]	1.47[a]	0.36	0.07
SAS	TNC	99.60	0.40	0	0	0	0
	Warm	98.51	1.42	0.07	0	0	0
	Hot	98.13	1.08	0.79	0	0	0
	Very Hot	89.80	7.80	2.00	0.4	0	0
WA	TNC	98.90[b]	1.1[b]	0	0	0	0
	Warm	100.00[d]	0[a]	0	0	0	0
	Hot	97.87[g]	2.13[b]	0	0	0	0
	Very Hot	94.12[d]	5.88[d]	0	0	0	0

[A] Due to small numbers with panting scores greater than 3 the data for 3.5, 4 and 4.5 have been combined. [a,b,c,d,e,f] Means in a column (within HLI category, e.g. only hot compared to hot) with the same superscript are not significantly different (P>0.05).

One unexpected result was the difference between shaded and un-shaded Herefords. The shaded Herefords generally had lower panting scores than those without access to shade. There were some significant differences, however for the most part shaded and un-shaded steers had similar panting scores (Table 2). These animals were located on 2 feedlots (1 in Queensland and 1 in NSW) with shade structures and shade area per animal between the feedlots differing slightly. Shade cloth (90%) (2.66 m^2/head) was used at the NSW location, and steel (3.38 m^2/head) was used in Queensland. Under the same HLI categories fewer shaded cattle had a PS of 0 in NSW compared to Queensland. However, the same applied to un-shaded cattle at both locations. Therefore the effect appears to be more of a location (possibly adaptation) affect rather than a shade structure affect.

Table 3 Panting scores (%) for the crossbred genotypes according to HLI category

				Panting Scores			
Genotype	**HLI**	**0**	**1**	**2**	**2.5**	**3**	**≥3.5[A]**
AC	TNC	100.00[a]	0[a]	0	0	0	0
	Warm	100.00[a]	0[a]	0[a]	0	0	0
	Hot	87.86[a]	8.63[a]	2.88[a]	0.38	0.25	0
	Very Hot	21.74[a]	49.24[a]	20.36[a]	6.12[a]	2.24	0.3
AH	TNC	89.52[a]	10.37[b]	0.08	0.03	0	0
	Warm	78.52[a]	21.34[b]	0.14[a]	0	0	0
	Hot	60.03[b]	39.84[b]	0.13[a]	0	0	0
	Very Hot	35.30[b]	53.58[a]	8.68b	2.07[a]	0.34	0.03
AX	TNC	78.00[a]	22.00[c]	0	0	0	0
	Warm	23.83[b]	64.29[c]	11.88[b]	0	0	0
	Hot	5.00[c]	72.90[c]	22.10[b]	0	0	0
	Very Hot	2.56c	62.15[a]	28.92[a]	6.10[a]	0	0
EX	TNC	99.00[a]	1.00[a]	0	0	0	0
	Warm	84.89[a]	14.22[d]	0.89[a]	0	0	0
	Hot	56.91[b]	40.37[b]	2.33[a]	0.31	0.08	0
	Very Hot	34.52[b]	54.91[a]	9.04[b]	0.96[b]	0.52	0.05
EB	TNC	100.00[a]	0[a]	0	0	0	0
	Warm	97.50[a]	2.50[b]	0[a]	0	0	0
	Hot	94.58[a]	5.34[d]	0.08[c]	0	0	0

	Very Hot	77.73^{d}	19.66^{b}	2.41^{c}	0.17^{b}	0.03	0
EC	TNC	93.58^{a}	5.26^{b}	0.97	0.11	0.05	0.03
	Warm	97.50^{a}	2.50^{b}	0^{a}	0	0	0
	Hot	77.87^{a}	19.98^{e}	1.96^{a}	0.17	0.02	0
	Very Hot	55.67^{e}	37.16^{c}	5.31^{c,b}	1.10^{a,b}	0.53	0.23
SAH	TNC	100.00^{a}	0^{a}	0	0	0	0
	Warm	100.00^{a}	0^{a}	0^{a}	0	0	0
	Hot	98.93^{a}	1.17^{d}	0^{a}	0	0	0
	Very Hot	97.07^{f}	2.70^{d}	0.23^{d}	0^{a}	0	0
SAC	TNC	99.86^{a}	0.07^{a}	0.07	0	0	0
	Warm	100.00^{a}	0^{a}	0^{a}	0	0	0
	Hot	87.50^{a}	8.63^{d}	3.38^{a}	0.25	0.24	0
	Very Hot	30.24^{b}	54.92^{a}	11.32^{b}	2.08^{b}	1.24	0.2
SAX	TNC	100.00^{a}	0^{a}	0	0	0	0
	Warm	100.00^{a}	0^{a}	0^{a}	0	0	0
	Hot	99.51^{a}	0.49^{f}	0^{a}	0	0	0
	Very Hot	97.24^{f}	2.76^{d}	0^{d}	0^{a}	0	0
BX	TNC	100.00^{a}	0^{a}	0	0	0	0
	Warm	100.00^{a}	0^{a}	0a	0	0	0
	Hot	99.81^{a}	0.19^{f}	0a	0	0	0
	Very Hot	96.39^{f}	3.61^{d}	0^{d}	0^{a}	0	0
SH	TNC	94.02^{a}	5.48^{b}	0.34	0.12	0.04	0
	Warm	98.00^{a}	2.00^{b}	0^{a}	0	0	0
	Hot	78.74^{a}	19.48^{e}	1.47^{a}	0.27	0.04	0
	Very Hot	62.14^{e}	29.79^{c}	4.38^{c,b}	2.48^{b}	0.97	0.24

[A] Due to small numbers with panting scores greater than 3 the data for 3.5, 4 and 4.5 have been combined. [a,b,c,d,e,f] Means in a column (within HLI category, e.g. only hot compared to hot) with the same superscript are not significantly different (P>0.05).

The crossbred genotypes responded largely as expected (Table 3). The genotypes which contained a Brahman (or other non identified *Bos indicus*) base demonstrated greater heat tolerance than the *Bos taurus* cross cattle (those which did not include *Bos indicus*). The Angus x Hereford genotype had the lowest degree of heat tolerance. The Santa Gertrudis X Hereford cattle (SAH; un-shade; Queensland feedlot) had better heat tolerance than the pure bred genotypes observed in this study. The reasons for this are not clear.

Location affects are noticeable in that fewer of the NSW Herefords (shaded or un-shaded) had a panting score of 0 under the four HLI categories compared to the Queensland Herefords. This may indicate that the Queensland cattle have "adapted" to the summer conditions better than the NSW Herefords. However there is not enough data to support this. The un-shaded steers in NSW had fewer (P<0.05) steers with a panting score of 1 and 2 when HLI was classified as Hot or Very Hot (Table 4). Shade appeared to have a positive effect under these conditions, at least for the NSW cattle.

Table 4 Panting scores of shaded and un-shaded Herefords at a New South Wales and a Queensland feedlot.

		Panting Scores					
Genotype	**HLI**	**0**	**1**	**2**	**2.5**	**3**	**≥3.5[A]**
H (NSW)	TNC[B]	80.82	19.12	0	0	0	0
	Warm	20.93	68.17	10.34	0.48	0	0
	Hot	0	76.06	22.03	1.75	0	0
	Very Hot	3.13	63.55	27.18	3.37	0.3	0
HX (NSW)	TNC	81.10	18.21	0.54	0	0	0
	Warm	10.87	77.32	10.49	0.52	0.26	0
	Hot	5.55	47.52	36.83	10.40	0	0
	Very Hot	2.70	42.26	42.62	12.40	0.19	0
H (QLD)	TNC	96.16	3.62	<0.1	0	0	0
	Warm	94.00	5.57	0	<0.1	0	0
	Hot	57.36	27.12	14.66	0.84	0	0
	Very Hot	34.59	43.45	20.26	1.65	0	0
HX (QLD)	TNC	98.93	1.02	0	0	0	0
	Warm	78.84	19.63	1.03	<0.1	0	0
	Hot	50.35	37.60	11.13	0.46	0	0
	Very Hot	22.59	41.88	27.11	5.84	0	0

[A] Due to small numbers with panting scores greater than 3 the data for 3.5, 4 and 4.5 have been combined.
[B] TNC = thermonuetral conditions.

3.3. Relationship between Panting Score and AHLU

The AHLU is an indicator of the heat balance of cattle; a high AHLU indicates that cattle have been in a situation where they have not been able to radiate sufficient body heat to the environment. This results in a rise in body temperature, increased respiration rate and a higher panting score. Five AHLU categories are used.

The data presented in Tables 5 and 6 demonstrate the impact of AHLU on panting scores. These data show the impact of increased AHLU on the percentage of cattle with various panting scores. It is clear from this that when the AHLU is greater than 50 all genotypes will have elevated panting scores. The genotypes most affected were *Bos taurus* and *Bos taurus* cross animals, however, *Bos Indicus* cattle also have an elevated panting score when the AHLU is greater than 50.

Between TNC and very hot conditions the AHLU may be increasing, decreasing or be constant. Therefore there will be times when the number of cattle with a particular panting score within an AHLU category will not look logical. For example, in Table 5 there are more Angus with a panting score 0 under warm conditions than under mild conditions. This is largely due to lag effects and the timing of observations. Observations taken late in the afternoon will often occur at a time when the AHLU is decreasing. However cattle have not yet returned to ‘normal’ and therefore will have an elevated panting score. The observed panting score may not reflect the current conditions, but be a reflection of the climatic conditions 2 hours earlier.

This further highlights the importance of cattle observation during periods of elevated heat load. In addition these data suggest that there may be a need to consider the interaction of HLI and AHLU over time.

Table 5 Panting scores (%) for the purebred genotypes according to AHLU category

		Panting Scores					
Genotype	AHLU	0	1	2	2.5	3	<3.5[A]
A	TNC[B]	87.31^{a}	11.95^{a}	0.76^{a}	0.11	<0.01	0
	Mild	58.29^{d}	35.82^{e}	4.47^{d}	0.21	0.01	0
	Warm	74.98^{h}	20.57^{i}	4.21^{f}	0.19	0	0
	Hot	53.95^{j}	34.39^{k}	9.08^{g}	1.65	0.33	0.03
	Very Hot	36.55^{p}	41.47^{p}	17.74^{k}	4.51	1.08	0.10
B	TNC	98.12^{b}	1.57^{b}	0.01^{b}	0	0	0
	Mild	97.95^{e}	2.05^{f}	0	0	0	0
	Warm	78.63^{h}	26.12^{i}	0.06^{g}	0.03	0	0
	Hot	83.91^{k}	14.78^{l}	1.11^{h}	0.15	0.05	0
	Very Hot	84.54^{q}	14.50^{q}	0.57^{l}	0.07	0.04	0
H	TNC	72.91^{c}	24.48^{c}	2.37^{c}	0.07	0	0
	Mild	32.69^{f}	49.11^{g}	18.42^{e}	1.62	0	0
	Warm	50.05^{i}	39.89^{j}	9.74^{f}	0.26	0	0
	Hot	21.55^{l}	54.96^{m}	18.59^{i}	1.58	0.16	0
	Very Hot	11.72^{r}	49.11^{p}	33.32^{m}	4.60	0.92	0
HX	TNC	74.86^{c}	20.66^{c}	3.64^{c}	0.63	0	0
	Mild	34.61^{f}	$40.74^{e,g}$	21.73^{e}	3.11	0	0
	Warm	$50.79^{\ i}$	$29.39^{i,,j}$	18.43^{h}	1.29	0.07	0
	Hot	14.65^{l}	50.00^{m}	29.24^{j}	4.96	0.30	0.09
	Very Hot	16.74^{r}	37.26^{r}	30.00^{m}	13.41	0.50	0.66
SA	TNC	$89.82^{a,b}$	9.98^{a}	0.11^{a}	0	0	0
	Mild	84.87^{g}	12.20^{h}	2.38^{d}	0.07	0	0
	Warm	$62.88^{i,h}$	$29.39^{i,j}$	8.44^{f}	0.27	0	0
	Hot	37.63^{m}	52.87^{m}	8.96^{g}	2.31	0.60	0.15
	Very Hot	15.57	72.39^{s}	9.73^{n}	1.29	0.31	0.03
WA	TNC	99.50^{b}	0.50^{d}	0	0	0	0
	Mild	100.00^{e}	0	0	0	0	0
	Warm	75.00^{h}	25.00^{i}	0	0	0	0
	Hot	66.66^{n}	33.34^{n}	0	0	0	0
	Very Hot	-	-	-	-	-	-

[A] Due to small numbers with panting scores greater than 3 the data for 3.5, 4 and 4.5 have been combined.
[B] TNC = thermonuetral conditions.
[a,b,c,d,e,f,g,h,i,j,k,l,m,n,o,p,q] Means in a column (within AHLU category, e.g. only hot compared to hot) with the same superscript are not significantly different (P>0.05).

Table 6 Panting scores (%) for the crossbred genotypes according to AHLU category

		Panting Scores					
Genotype	AHLU	0	1	2	2.5	3	<3.5^{A}
AC	TNC^{B}	96.78^{a}	2.96^{a}	0.23^{a}	0.03	0	0
	Mild	62.38^{c}	30.63^{d}	5.25^{c}	0.88	0.86	0
	Warm	0	83.16^{f}	12.83^{g}	3.17	0.84	0
	Hot	17.94^{n}	43.91^{k}	25.67^{k}	9.92	2.34	0.67
	Very Hot	42.74^{v}	27.42^{s}	21.75^{n}	4.92	3.00	0.17
AH	TNC	81.95^{b}	17.89^{b}	0.15^{a}	0.01	0	0
	Mild	49.23^{d}	50.66^{e}	0.11^{d}	0	0	0
	Warm	50.82^{h}	48.03^{g}	0.99^{h}	0.16	0	0
	Hot	45.87^{q}	47.64^{k}	4.82^{l}	1.38	0.29	0
	Very Hot	20.51^{w}	53.18^{t}	20.99^{n}	4.59	0.65	0.08
AX	TNC	62.40^{c}	34.16^{c}	3.44^{b}	0	0	0
	Mild	0	62.33^{f}	34.20^{e}	3.47	0	0
	Warm	12.50^{i}	47.00^{g}	39.25^{i}	1.25	0	0
	Hot	0	74.95^{l}	19.05^{k}	6.00	0	0
	Very Hot	6.67^{x}	66.20^{u}	23.00^{n}	4.13	0	0
EX	TNC	81.70^{b}	16.51^{b}	1.47^{b}	0.18	0.13	0.01
	Mild	52.69^{d}	38.49^{d}	7.50^{c}	1.13	0.19	0
	Warm	33.00^{j}	60.75^{h}	5.75^{j}	0.50	0	0
	Hot	0.50^{p}	86.25^{m}	13.00^{m}	0	0.25	0
	Very Hot	-	-	-	-	-	-
EB	TNC	93.90^{a}	6.00^{a}	0.10^{a}	0	0	0
	Mild	93.90^{e}	5.50^{g}	0.55^{d}	0.05	0	0
	Warm	93.83^{k}	6.17^{i}	0	0	0	0
	Hot	81.66^{r}	17.17^{n}	1.17^{l}	0	0	0
	Very Hot	79.05^{y}	17.71^{v}	3.00^{p}	0.24	0	0
EC	TNC	87.54^{a,b}	10.91^{a,b}	1.42^{b}	0.11	0.01	0.01
	Mild	77.02^{f}	18.68^{h}	1.45^{f}	0.11	0.02	0.02
	Warm	51.38^{l}	41.72^{g}	5.56^{j}	1.11	0.11	0.12
	Hot	52.15^{s}	39.21^{p}	6.79^{l}	1.42	0.21	0.22
	Very Hot	62.98^{z}	32.83^{w}	2.17^{p}	1.34	0.34	0.34
SAH	TNC	98.48^{a}	1.52^{a}	0	0	0	0
	Mild	98.86^{e}	1.07^{g}	0.07^{d}	0	0	0
	Warm	99.71^{k}	0.29^{j}	0	0	0	0
	Hot	99.83^{t}	0.17^{q}	0	0	0	0
	Very Hot	97.25^{a}	3.00^{x}	0.29^{q}	0	0	0
SAC	TNC	97.03^{a}	2.88^{a}	0.09^{a}	0	0	0
	Mild	61.72^{g}	29.57^{d}	7.42^{c}	1.29	0	0
	Warm	25.14^{m}	64.71^{h}	8.86^{j}	1.29	0	0
	Hot	24.20^{u}	56.20^{r}	16.50^{m}	3.10	0	0
	Very Hot	56.55^{z}	31.20^{w}	11.00^{r}	1.25	0	0

[A] Due to small numbers with panting scores greater than 3 the data for 3.5, 4 and 4.5 have been combined.

[B] TNC = thermonuetral conditions.

[a,b,c,d,e,f,g,h,i,j,k,l,m,n,o,p,q,r,s,t,u,v,w,x,y,z] Means in a column (within HLI category, e.g. only hot compared to hot) with the same superscript are not significantly different (P>0.05).

3.4. Relationships between HLI x AHLU and Panting Score

Figure 4 shows a weather dataset, collected from a different feedlot from that shown in Figure 1. Figure 4 shows the HLI and the AHLU, along with the average panting score across all four pens that were observed during the data collection period. This gives an indication of the overall heat load status of the pens being observed. As can be seen in this figure, the panting score increases with increases in both the HLI and AHLU. As the duration of exposure to high heat load increases, i.e. over a 2 or 3 day event, even where AHLU falls to 0 again, cattle may have some difficulty in returning to a normal physiological status. Therefore it is not unusual to see elevated panting scores on the day following a heat event, even if that day is considerably cooler. The reasons for this although somewhat complex can be explained by the inability of the animal to completely shed heat from the previous day (i.e. there is a lag period). In addition, cattle that have been exposed to hot conditions for a couple of days will anticipate another hot day and will increase respiration rate in response to a perceived increase in ambient temperature. Other factors as yet not identified may also play a role.

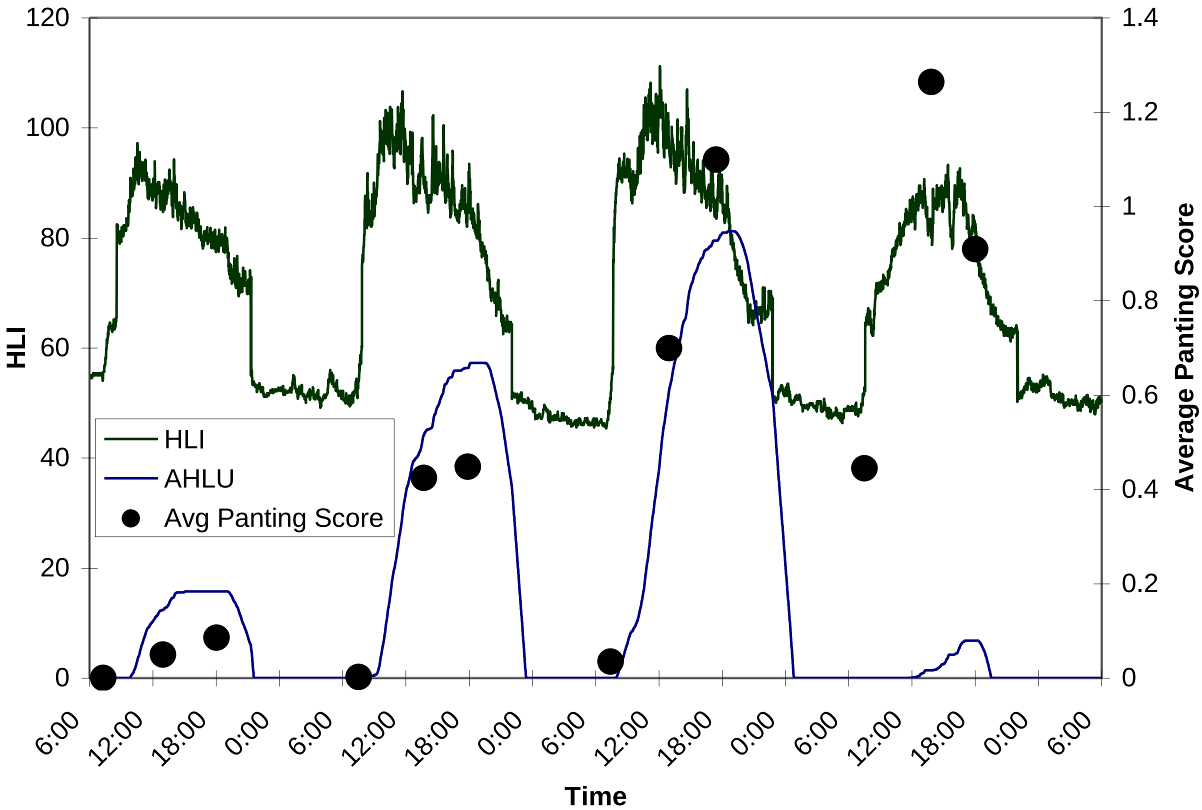

Figure 4 HLI and AHLU along with average panting scores from Feedlot 9 over a 96 hour period (climatic data collected every 60 s)

There are interactions between HLI and AHLU. On a daily basis cattle may be subjected to a HLI greater than 86 and yet have an AHLU less then 1. In addition cattle may be exposed to a HLI less than 70 but have an AHLU greater than 50. In both cases respiration rate (or panting score) will be elevated for *Bos taurus* cattle (Figure 5). Brahman cattle are affected to a lesser extent even under extreme conditions (HLI>86, AHLU>50) (Figure 6). The data presented in Figure 5 represents the mean panting scores for shaded Angus cattle (all feedlots) when the interactions between HLI and AHLU are considered. In some cases the data sets are not complete, for example where AHLU are >1 and <10, there were no periods during cattle panting score data collection events where the HLI was <70. This does not mean that a HLI of <70 did not occur.

It is clear from the data that shaded Angus cattle exposed to a HLI > 86 and an AHLU > 50 will be under a degree of heat stress, based on the low percentage with a normal panting score. These data highlight the importance of not just looking at single points in time or either HLI and AHLU on their own.

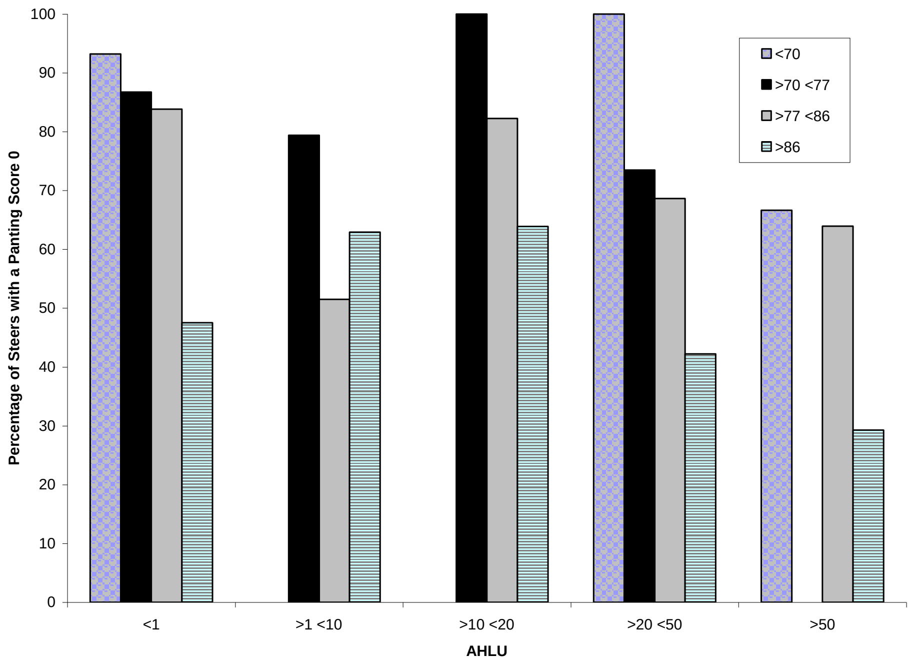

Figure 5 The effect of HLI category within an AHLU category on the percentage of Angus steers with panting score of 0

As expected Brahman cattle were not greatly affected by the HLI and AHLU encountered (Figure 6), nevertheless they were affected by extreme conditions. Increased respiration rates (and panting scores) were observed when AHLU exceeded 10 and HLI was greater than 86. However, the percentage of cattle with a panting score of 0, was significantly higher (P<0.05) when compared to Angus exposed to similar climatic conditions.

Bos indicus cross cattle tended to have a similar response to Brahman, and crossbred *Bos taurus* cattle (no *Bos indicus* in cross) were similar to Angus. Santa Gertrudis showed similar results to *Bos taurus* cattle which was unexpected, and Wagyu were more like Brahman.

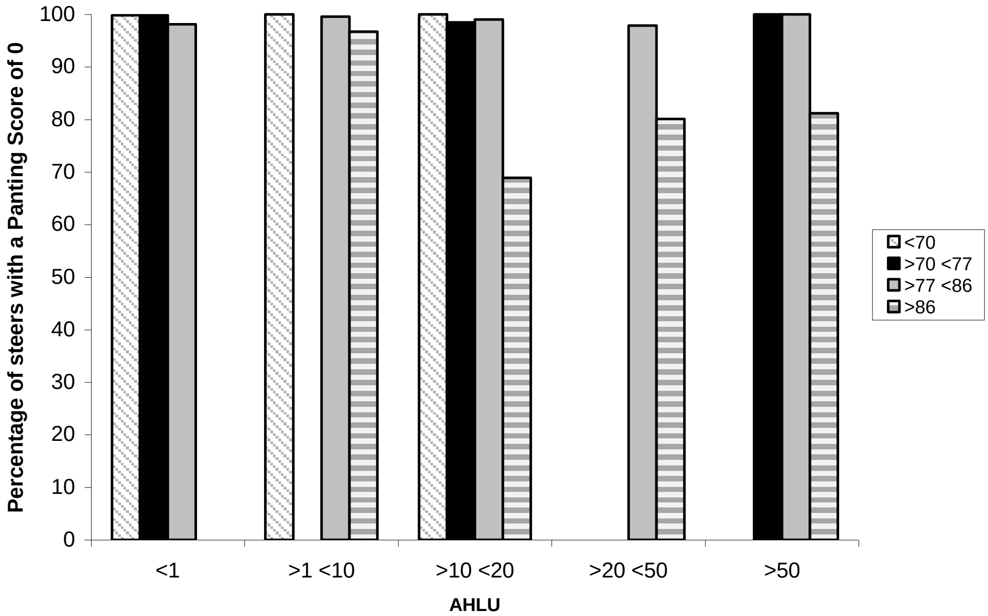

Figure 6 The effect of HLI category within an AHLU category on the percentage of Brahman steers with panting score of 0

3.5. Dry Matter Intake

Dry matter intake (DMI) was largely influenced by days on feed and climatic conditions. There were also genotype and environment effects on dry matter intake. Days on feed at the commencement of the study ranged from 6 to 125 days. The majority were between 50 and 80 days at the start of the study.

The DMI of Angus x Charolais (AC), Brahman (B) (2 pens) and Santa Gertrudis x Charolais steers for a Queensland feedlot are presented in Table 7. There were differences between the three genotypes (P<0.05). The differences were due to days on feed (DOF) and genotype. The lowest intake (P<0.05) was for the AC steers (12 DOF) followed by a pen of B (26 DOF). The SAC and the remaining B pen of steers had the highest DMI (P<0.05) and were also longest on feed. Genotype differences were evident in that the SAC steers had lower (P<0.05) DMI than the B steers even though they were on feed for similar times (53 and 55 DOF respectively).

Table 7 Dry matter intake (DMI) (kg/head/day) for Angus x Charolais (AC), Brahman (B) (2 pens) and Santa x Charolais (SAC) over the duration of the study (Queensland feedlot)

Genotype	DOF	DMI
AC	12	$11.00^{a} \pm 0.14$
B	26	$12.95^{b} \pm 0.12$
B	53	$14.29^{c} \pm 0.12$
SAC	55	$13.95^{d} \pm 0.13$

[abcd] Means in a column with the same superscript are not significantly different (P>0.05)

The data presented in Table 8 is for another Queensland feedlot, different from the one presented in Table 7. The cattle observed ranged from 6 DOF to 54 DOF at the commencement of the study. Within genotype variation can be seen for the Angus (A) steers. The difference in

DMI between the two Angus (A) pens is difficult to explain. The cattle for both pens were sourced from southern Australia, and were similar in terms of confirmation and BCS. Both pens were shaded. It is possible that the differences are due to within genotype variation, between pen differences, health status or background prior to arrival at the feedlot.

Table 8 Dry matter intake (DMI) (kg/head/day) for Angus x Hereford (AH), Santa Gertrudis (SA) and Angus steers (A) (2 pens) over the duration of the study (Queensland feedlot)

Genotype	DOF	DMI
AH	6	$10.80^{a} \pm 0.19$
SA	14	$11.51^{b} \pm 0.19$
A	44	$12.12^{c} \pm 0.20$
A	54	$10.00^{d} \pm 0.19$

^{abc} Means in a column with the same superscript are not significantly different (P>0.05)

Similar results were seen for cattle at NSW feedlots. Over the duration of the study Angus (A) steers and shaded Hereford (HX) steers consumed more (P<0.05) feed than un-shaded Herefords (H) and Angus cross (AX) steers (Table 9). This is a function of differences in days on feed between the genotypes and is not a reflection of genotype differences, or pen differences (i.e. shaded vs un-shaded).

Table 9 Mean dry matter intake (DMI) (kg/head/day) for Angus (A), Hereford (H), Hereford cross (HX) and Angus cross (XA) steers for the duration of the study (NSW feedlot)

Genotype	DOF	DMI
AX	16	$11.87^{a} \pm 0.09$
H	30	$14.10^{b} \pm 0.09$
HX	56	$17.01^{c} \pm 0.09$
A	58	$17.24^{c} \pm 0.11$

^{abc} Means in a column with the same superscript are not significantly different (P>0.05)

3.6. Affect of HLI and AHLU on DMI

In general DMI fell when the cattle were exposed to either, or a combination of, high HLI (>86) and an AHLU of greater than 20 (Figure 7). The climatic conditions during the event shown in Figure 7 were of high HLI (>86) and AHLU (>20) during the days preceding the event (28/1 – 2/2). Anecdotal evidence from the feedlot operators suggest that on the day where there was a dramatic fall in DMI (2/2), cattle were crowding around the water troughs and almost completely avoided their afternoon feed. Whilst there were general falls in DMI when cattle were exposed to hot conditions, there was considerable variation between genotypes and between shaded and unshaded cattle.

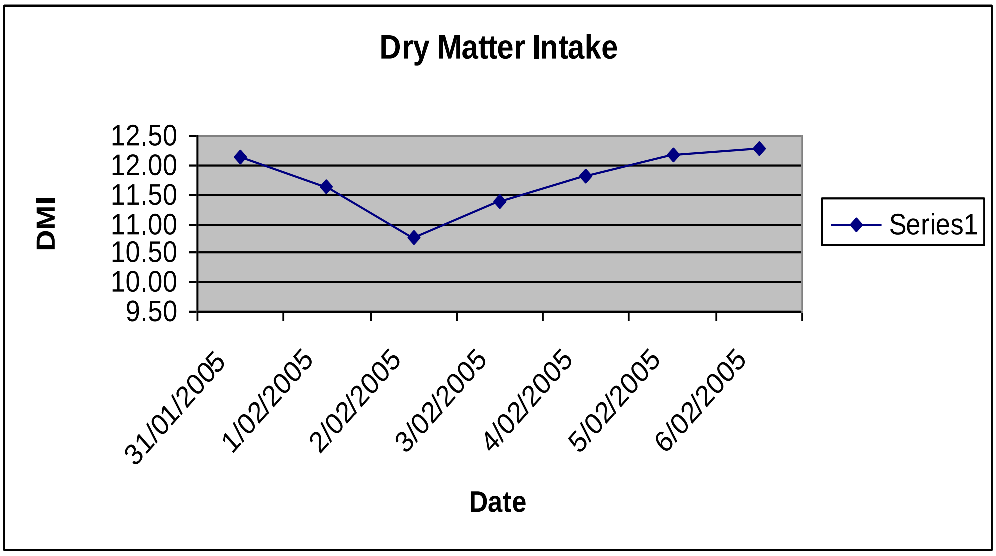

Figure 7 The dry matter intake (DMI) of *Bos taurus* steers prior to, during and following a heat event in Queensland

Dry matter intake was reduced when the AHLU was high. Generally as the AHLU rose above 20, DMI fell. The AHLU for a 5 day period at a Queensland feedlot are presented in Figure 8. During this time the DMI of un-shaded cattle (SA) fell by 60.5% (11.9 – 4.7 kg/d). Following the cessation of the heat event it took a further 6 days before intakes increased. The largest reductions occurred on day 3 of the heat wave, following a night of no relief. Another un-shaded group (EX) at the same feedlot had reductions of less than 5%.

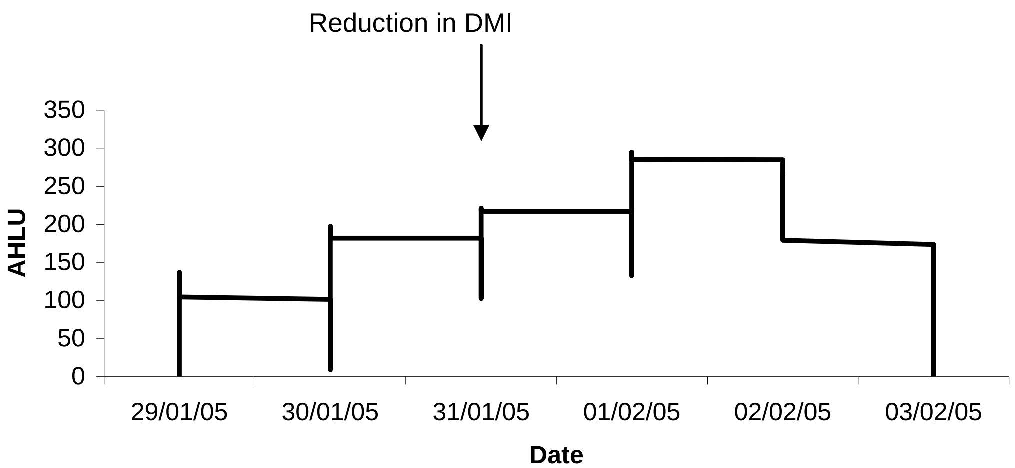

Figure 8 The AHLU over a five day heat event in Queensland.

High heat load conditions also leads to fluctuations in DMI. The data presented in Figure 9 is from one feedlot. Of interest is the lag observed between the peak in HLI on day 7 and the corresponding fall in DMI. This may indicate that other factors have resulted in the DMI reductions.

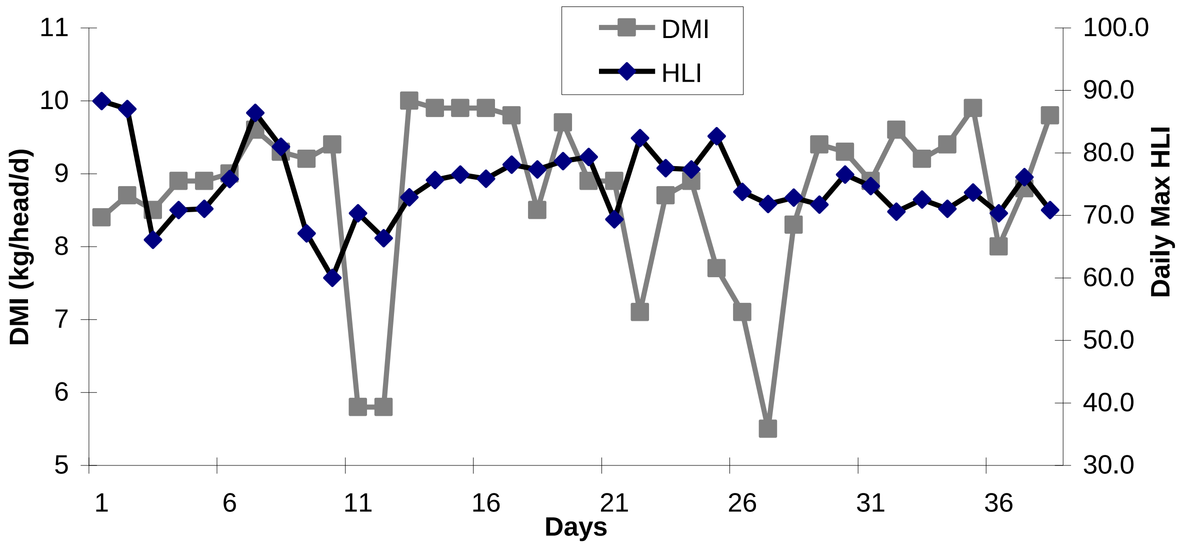

Figure 8 Changes in DMI over 39 days in Summer

3.7. Affect of Shade on DMI

Shade appeared to have a positive response in regard to DMI during periods of extreme conditions (HLI>86; AHLU >50). For example shaded Herefords at a NSW feedlot reduced DMI by 8.5% (14 kg/d to 12.8 kg/d). In contrast the un-shaded Herefords reduced intake by 16% (18.1 kg/d to 15.2 kg/d).

3.8. Pen Surface Condition

There were no observed interactions between pen surface conditions and panting scores.

4. CONCLUSIONS

There was considerable variation in the responses of cattle of similar genotypes to conditions of similar HLI and AHLU in the different feedlots. Variations in the responses of cattle of similar genotype in different pens within an individual feedlot were also evident.

The thresholds used in the data analysis were determined by looking at the data sets and establishing the approximate values at which panting scores of 1, 2 or greater occurred. These thresholds were then tested statistically. Both the HLI and AHLU thresholds appear to be reliable indicators of heat load in feedlot cattle. When panting score was assessed by HLI category the largest shift from PS0 to PS1 for *Bos taurus* cattle occurred in the >86 category. The largest shift in panting score of *Bos taurus* cattle occurred when the AHLU was greater than 20, with significant changes seen when AHLU was greater than 50. In comparison the thresholds for *Bos indicus* cattle appear somewhat higher. There appears to be a need to adjust the thresholds set out in the RAP for Brahman cattle and some variations required within the crossbred cattle to account for various percentages of *Bos indicus* and *Bos taurus* combinations.

Because the panting score data sets are not continuous i.e. only three data points per day, it is not possible to statistically determine the affect on panting score when HLI or AHLU are increasing or decreasing. The AHLU is generally more robust because it incorporates a time factor, and therefore gives a better indicator of the total heat load. It is important that both HLI and AHLU are considered. The use of AHLU categories rather than spot values appears to be a more reliable indicator of heat load status.

Where there were more than 2 or 3 days of high heat load it appears that the thresholds are lower. That is, cattle “suffer” from heat stress at a lower HLI and AHLU following previous exposure. Although not statistically analysed it would appear that a 3 day heat wave (with little or no respite) lowers the HLI threshold by 3 – 5 units (for *Bos taurus* steers). As expected Brahman cattle had high heat tolerance and serve as a useful control. The inability to determine the percentage of *Bos indicus* in the crossbred cattle used in the trial work make any assumptions about the heat tolerance of *Bos taurus x Bos indicus* steers difficult. Steers with 50% *Bos indicus* content were for the most part similar to Brahman in terms of panting scores. Santa Gertrudis steers did not appear to have high heat tolerance. The reasons for this are not clear and need further investigation.

Genotype (% *Bos taurus*) was more important in determining lack of heat tolerance than coat colour *per se*, however, there was a general trend to a lower threshold for black cattle as expected (about where it is currently set in the RAP). One of the difficulties with white cattle is that it is likely that we are measuring a genotype effect (Charolais) rather than a white coat effect. In addition some pens contained cattle of various colours and there was no way of checking on this in the data sets. At this stage there is no evidence to suggest that the adjustment factor for black cattle should be changed.

Setting high risk at an AHLU of 25 units or more is prudent. However, as always it is the duration x intensity that is important. So, 35 units in 1 day, while stressful, may not be as bad as 3 days of 20 units. This is the most difficult factor to include in the model, hence the need to keep emphasising the need to monitor cattle, and also daily and weekly climatic trends.

Geographic location did not appear to have a major role in regard to heat tolerance. There were differences between feedlots in terms of cattle responses to similar HLI and AHLU. However to state that the differences are due to location *per se* is not prudent. Obviously climatic conditions are the major determining factor. Cattle in southern feedlots do appear to be more susceptible to high heat loads and it may be necessary to have a lower threshold for these cattle especially at the start of summer (refer to Table 4). However, the background of the cattle needs to be known before any firm recommendation can be made. As it stands the current threshold is valid for black *Bos taurus* cattle at the locations investigated. Feedlot managers should be encouraged to make adjustments based on their cattle. A provision in the RAP for southern or northern cattle is not necessary at this stage. The current adjustment for adapted verses not adapted cattle is sufficient.

Based on the data sets used it is not possible to make any recommendations on the ideal shade structure, area of shade or changes to the values in the RAP. Shade area varied from 1.07 m^2/head to 3.77 m^2/head. Materials used included shade cloth (90%) and galvanised iron (various combinations of open spacing between solid and open areas). No real differences were detected for the various shade type used. At this stage no changes should be made to the RAP. The values used appear valid. More work is needed in this area to scientifically quantify the effect of shade on cattle heat load status.

Other management factors such as manure management did not appear to have any impact on the measured parameters. However this may be due to the overall lack of extreme weather conditions during the study period. The events that did occur were of relatively short duration. Factors such as the benefit of additional water troughs are hard to quantify without a controlled study.

5. RECOMMENDATIONS

5.1. Implementation of the HLI and AHLU

Whilst the climatic conditions experienced during this trial were less than ideal for the testing of the HLI and AHLU concepts, the statistical procedures conducted were useful. It was found that the HLI does adequately reflect the impact of the surrounding climate on feedlot cattle. The animal response, reflected in the corresponding increases in panting scores to an increasing HLI, was as expected. However, continual upgrading of the HLI should be undertaken as more data become available.

The analyses found that the AHLU concept reflects the impacts of the surrounding climate on feedlot cattle, perhaps more effectively than just the HLI measurement. This is because the AHLU includes a time factor which measures the cattle's length of exposure to extreme climatic conditions. Using both the HLI and AHLU as indicators of the climatic conditions feedlot cattle are exposed to is an effective method of monitoring cattle heat load and preventing extreme heat events.

However, as the HLI and AHLU are only measures of the climatic conditions that feedlot cattle are exposed to, they should not be the only indicators of heat load utilised by Australian feedlot operators. There is no replacement for increased monitoring and implementation of appropriate heat load action plans. The HLI and AHLU should not be relied on as the only means of preventing extreme heat events in feedlots cattle.

With that in mind, it is recommended that once the AHLU reaches a level of 25 units, increased monitoring of the cattle response should be enacted, with particular focus on indicators of heat load such as panting score and respiration rate. That monitoring should continue for as long as the AHLU is above the threshold of 25, even if the HLI has fallen below the threshold. If that monitoring shows that the cattle are suffering from elevated heat loads, then an appropriate heat load action plan should be enacted.

Recommendation 1: The new HLI and AHLU be released (with confidence) to the industry.

5.2. Changes to Genotype Values in the RAP

Data collected during the project supports the current threshold level for the standard reference animal. It also suggests that *Bos indicus x Bos taurus* cross (50:50) have better heat tolerance than accounted for in the RAP and that the value (+9) for Brahman is too low. The use of the term *Bos indicus* needs to be clarified. The original RAP values for *Bos indicus* were developed using Brahman cattle. The lower heat tolerance than expected for the Santa Gertrudis may be an anomaly. However consideration should be given to a new genotype category: Tropical composites.

In some cases the breed composition of the genotypes used in the study were not known or doubtful.

Recommendation 2: That the relative effect on the upper threshold for Bos indicus x Bos taurus cross (50:50) be changed from +5 to +7.

Recommendation 3: That the term Bos indicus (in current RAP) be changed to Brahman with a new value of +10, and that Tropical Composites be added with a value of +8.

Recommendation 4: That a study be undertaken to further understand the differences between genotypes. This should be undertaken on commercial feedlots over summer 2005/2006.

5.3. Changes to Shade Values in the RAP

There is a clear lack of data on the benefits of shade to the feedlot industry. The currents study showed that the shade area utilized was highly variable. Because of this it is not possible to recommend any changes to the RAP.

Recommendation 5: That a shade study be undertaken to fully explore the impact of various shade areas on cattle response (e.g. panting score) to elevated HLI and AHLU.

This would strengthen the RAP and benefit the industry as a whole.

5.4. Changes to Animal Health Values in the RAP

No adjustments can be made at this stage due to a lack of data.

Recommendation 6: That a study be undertaken to access the impact of current and previous health on heat tolerance. This could be part of the study suggested above (Recommendation 4).

REFERENCES

Hahn GL and Mader TL 1997. Heat waves in relation to thermoregulation, feeding behaviour and mortality of feedlot cattle. In. Livestock Environment V - Proceedings of the Fifth International Symposium, Bloomington, MN, USA. pp. 563 – 571.

APPENDICES

Appendix 1 MLA Milestone Reports

MEAT & LIVESTOCK AUSTRALIA

Milestone Report

MLA project code: FLOT 330

MLA project title: Validation of the Heat Load Index for use in the feedlot industry

Project leader: EA. Systems Pty Limited

MLA project manager/coordinator: **Des Rinehart**

Milestone number: 2

Milestone:

2 Data collection completed by feedlots and Milestone Report detailing summary of the data sets collected provided to MLA.

Abstract

In a previous MLA funded project, a new Heat Load Index (HLI) was produced for use in the feedlot industry. For this HLI to be statistically valid, it must be validated using datasets collected independently from the datasets used in the formulation of the Index. The purpose of this project was to collect the required datasets from Australian feedlots and to use those datasets to validate the new HLI. A summary of the datasets that have been collected are provided below.

Project objectives

The objectives of this project are by June 15 2005 to complete the following:

1. Collect datasets of climatic, animal and feedlot site variables from 13 co-operator feedlots located throughout eastern Australia during periods of high heat load; and
2. Utilise the collected datasets to test and validate the refined HLI, the AHLU concept and the RAP software, using recognised statistical methods.

Success in achieving milestone

Data collection

Data collection was undertaken at 13 participating feedlots from 24 January 2005 to 11 March 2005. The 13 participating feedlots are shown below:

1. Goonoo;
2. Smithfield;
3. Aronui;
4. Sandalwood;
5. Kerwee;
6. Beef City;
7. Teys Bros Feedlot (Condamine);
8. Myola;
9. Killara;
10. Caroona;
11. Rockdale;
12. Charlton; and
13. Prime City.

Prior to the commencement of the data collection, training workshops were conducted to inform staff at the participating feedlots of the data collection requirements and protocols. Three workshops were conducted, at Sandalwood, Killara and Rockdale feedlots. The feedlots that were not able to attend those workshops (Goonoo and Myola) were stepped through the data collection protocols over the phone.

Checks on each individual feedlot's weather station were also conducted prior to the commencement of the trial. These checks showed that there were no apparent problems with the majority of the weather stations involved, except for Teys Bros (Condamine) whose weather station was being serviced by E.A. Systems at the commencement of the trial.

The participating feedlots were asked to select four (4) pens of cattle that would be present at the feedlot over the entire data collection period. They were then asked to monitor those pens three times daily over the trial period. Examples of the data collection sheets used by the participating feedlots are included in Appendix 1.

Datasets collected

A brief summary of some of the crucial animal variables measured during the trial period are shown below:

- Breed: The breeds observed during this trial included straight Bos Taurus, Bos Taurus X Bos Indicus cross animals, straight Bos Indicus animals and Wagyus (not an exclusive list);
- Presence of shade: There were a number of both shaded and non-shaded pens observed during this trial;

- Dry Matter Intake: Dry Matter Intake was measured and generally recorded on a daily basis (the interval of measurement varied between feedlots);
- Manure management: an assessment of the manure pad within each pen was conducted daily.
- Water: the dimensions of the water troughs in each pen was also provided, along with the trough type; and
- Stocking rate: the pen stocking rate for the duration of the trial was also provided.

The weather data recorded from each feedlot's weather station included, as a minimum:

- Black Globe Temperature (if present);
- Ambient Temperature and Incoming Solar Radiation (if Black Globe sensor not present);
- Relative Humidity; and
- Wind Speed.

The collection interval varied from twice daily in some instances to every minute. Generally, the data collection interval was every 10 minutes. There were some holes in the weather data, probably due to regular station servicing conducted during the trial period.

Overall progress of the project

All of the data has now been collected from each feedlot. Currently, the data is being put into a format that will allow the statistical package SAS to analyse the data accordingly. This process is almost complete and data analysis will begin shortly.

Recommendations

There are no recommendations at this stage.

Appendices

Appendix 1: Animal observation data collection sheets

DATA SHEETS - HEAT LOAD 2005

Pen Description

	Data Collector		
Feedlot		Date	
Pen Number		Pen Dimensions	
Aspect		Number in Pen	
Water trough space (m^2/hd)		Shade Dimensions	
Trough type (e.g. concrete, fibreglass,etc.)		Shade Type	
Location of water trough (e.g. in fenceline, distance from feedbunk)		Location of shade (distance from feedbunk)	

	Nutritional Information (please include units)
Energy	
Protein	
Fibre	

DATA SHEETS - HEAT LOAD 2005

SHADED		Data Collector:	
Feedlot		Date:	
Pen Number		Pen DMI:	
Cattle Type	Genotype	Dominant Breed (list below e.g. Angus)	
place a line through your genotype	*Bos taurus* | *Bos indicus* *Bos taurus x Bos taurus* *Bos taurus x Bos indicus*		
Number in Pen		Sex (circle)	Steers Heifers Mixed

Behaviour	ST - AM	LY - AM	ST - MD	LY - MD	ST - PM	LY - PM
Shade						
Feedbunk						
Water Trough						
Elsewhere						

Pen Surface (tick one)

	AM	MD	PM
dry dusty			
smooth			
compact			
plugged			
slurry			

Data Collection

Actual	Time
(eg 6 AM, 1230, 4 PM)	
AM	
MD	
PM	

Number for each Panting Score

	AM	MD	PM
0			
1			
2			
2.5			
3			
3.5			
4			
4.5			

SEE PHOTO GUIDE FOR PANTING SCORES

Manure Depth (mm)	
Feeding Times	Bunk Scores
Number of Pulls	

Additional Comments & Observations (include mortalities, pulls, genotype differences etc)

DATA SHEETS - HEAT LOAD 2005

UNSHADED		Data Collector:				
Feedlot				Date:		
Pen Number				DMI:		
Cattle Type	Genotype		Dominant Breed (list below e.g. Angus)			
place a line	*Bos taurus*	*Bos indicus*				
through your	*Bos taurus x Bos taurus*					
genotype	*Bos taurus x Bos indicus*					
Number in Pen			Sex (circle)	Steers	Heifers	Mixed
Behaviour	ST - AM	LY - AM	ST - MD	LY - MD	ST - PM	LY - PM
Feedbunk						
Water Trough						
Elsewhere						

Pen Surface (tick one)

	AM	MD	PM
Dry dusty			
smooth			
compact			
plugged			
slurry			

Actual	Time
(eg 6 AM, 1230, 4 PM)	
AM	
MD	
PM	

Number for each Panting Score

	AM	MD	PM
0			
1			
2			
2.5			
3			
3.5			
4			
4.5			

Manure Depth (mm)	
Feeding Times	Bunk Scores
Number of Pulls	

SEE PHOTO GUIDE FOR PANTING SCORES

Additional Comments & Observations (include mortalities, pulls, genotype differences etc)

Appendix 2 Data Sheets used during the data collection phase

DATA SHEETS - HEAT LOAD 2005

Pen Description

	Data Collector		
Feedlot		Date	
Pen Number		Pen Dimensions	
Aspect		Number in Pen	
Water trough space (m^2/hd)		Shade Dimensions	
Trough type (e.g. concrete, fibreglass,etc.)		Shade Type	
Location of water trough (e.g. in fenceline, distance from feedbunk)		Location of shade (distance from feedbunk)	

Nutritional Information (please include units)

Energy	
Protein	
Fibre	

DATA SHEETS - HEAT LOAD 2005

SHADED

		Data Collector:				
Feedlot				Date:		
Pen Number				Pen DMI:		
Cattle Type	Genotype		Dominant Breed (list below e.g. Angus)			
place a line through your genotype	*Bos taurus*	*Bos indicus*				
	Bos taurus x Bos taurus					
	Bos taurus x Bos indicus					
Number in Pen			Sex (circle)	Steers	Heifers	Mixed
Behaviour	ST - AM	LY - AM	ST - MD	LY - MD	ST - PM	LY - PM
Shade						
Feedbunk						
Water Trough						
Elsewhere						

Pen Surface (tick one)

	AM	MD	PM
dry dusty			
smooth			
compact			
plugged			
slurry			

Data Collection

Actual	Time
(eg 6 AM, 1230, 4 PM)	
AM	
MD	
PM	

Number for each Panting Score

	AM	MD	PM
0			
1			
2			
2.5			
3			
3.5			
4			
4.5			

SEE PHOTO GUIDE FOR PANTING SCORES

Manure Depth (mm)	
Feeding Times	Bunk Scores
Number of Pulls	

Additional Comments & Observations (include mortalities, pulls, genotype differences etc)

DATA SHEETS - HEAT LOAD 2005

UNSHADED	Data Collector:					
Feedlot			Date:			
Pen Number			DMI:			
Cattle Type	Genotype		Dominant Breed (list below e.g. Angus)			
place a line through your genotype	*Bos taurus*	*Bos indicus*				
	Bos taurus x Bos taurus					
	Bos taurus x Bos indicus					
Number in Pen			Sex (circle)	Steers	Heifers	Mixed
Behaviour	ST - AM	LY - AM	ST - MD	LY - MD	ST - PM	LY - PM
Feedbunk						
Water Trough						
Elsewhere						

Pen Surface (tick one)

	AM	MD	PM
Dry dusty			
smooth			
compact			
plugged			
slurry			

Actual	Time
(eg 6 AM, 1230, 4 PM)	
AM	
MD	
PM	

Number for each Panting Score

	AM	MD	PM
0			
1			
2			
2.5			
3			
3.5			
4			
4.5			

Manure Depth (mm)	
Feeding Times	Bunk Scores
Number of Pulls	

SEE PHOTO GUIDE FOR PANTING SCORES

Additional Comments & Observations (include mortalities, pulls, genotype differences etc)

Appendix 3 Panting Score Reference Sheets distributed to participating feedlots

Panting Score 1

Panting Score 2

Panting Score 2.5

Panting Score 3

Panting Score 3.5

Panting Score 4

Panting Score 4.5

Breathing condition	Panting score (PS)	Associated Respiration Rates (breaths/min)
No panting – normal. 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 with occasional open mouth, tongue not extended.	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 head held down. Cattle "breath" from flank. Drooling may cease.	4.5	Variable ~ RR may decrease