final report

Project code: **FLOT.335**

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Date published: **September 2006**

ISBN: 9781741914627

PUBLISHED BY
Meat & Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

Improved measurement of heat load in the feedlot industry

Abstract

The aim of this project was to test and validate the new Heat Load Index (HLI), Accumulated Heat Load Units (AHLU) and Risk Assessment Program (RAP) software for the beef feedlot industry. Targeted data collection was undertaken at 4 feedlots during the summer of 2005/06. The data collection was undertaken to isolate certain key factors in determining heat tolerance, such as: genotype, presence of shade, days on feed and nutritional status. The results confirmed previous assumptions regarding the difference in heat tolerance between genotypes. The results also suggest that the new HLI and AHLU do adequately reflect the heat load status of feedlot cattle. As a result of this project, it was recommended that both the HLI and AHLU remain unchanged and are further released to the industry. Some changes to existing thresholds, and addition of some new thresholds within the RAP software are also recommended.

Executive Summary

The major goals of this project were to further test and validate the new HLI, AHLU and RAP software for use in the Australia beef feedlot industry. The specific objectives of this project were as follows.

1. Collect data sets of climatic and animal observations from 4 co-operator feedlots, located throughout eastern Australia, during the summer of 2005-06;
2. Utilise the collected datasets to test and validate the refined HLI, AHLU and the RAP software, using recognised statistical methods; and,
3. Make recommendations on changes that need to be incorporated into the RAP software package as a result of the project.

This project has resulted in the successful collection of datasets from 4 feedlots during the summer of 2005/06. The data collection was targeted at key factors in determining the heat tolerance of feedlot cattle such as: genotype, presence of shade, days on feed and nutritional status. Within each feedlot 6-8 pens of interest were selected to become part of the data collection. Once selected various features of the pen such as: animal genotype; presence, amount (m^2/hd) and type of shade; availability and access to water and nutritional status were defined.

The data collection was conducted from January – March 2006 with the aim of collecting the following data.

- Baseline data collection was to be conducted at the beginning of the trial during periods of low to moderate heat conditions (HLI generally <86). The aim was to conduct at least three days of baseline data collection.
- Data collection was also to occur during hot conditions (HLI generally >86). It was aimed to conduct at least ten days of data collection during hot conditions.

The ten days of hot data collection could occur at any time over the January-March data collection period.

Once collected, the datasets were subjected to recognised statistical tests. Once properly analysed, the following recommendations were made:

⇒ ***Recommendation 1: That no changes are made to the new HLI, and that its distribution to the industry continue.***

⇒ ***Recommendation 2: That no changes are made to the way the AHLU is calculated, and that the thresholds for the reference animal remain the same.***

⇒ ***Recommendation 3: That the recovery time of cattle exposed to high heat load (high HLI and AHLU) be further examined. This should be undertaken under controlled conditions.***

⇒ ***Recommendation 4: Divide the Bos indicus class into Brahman and Tropical Composites to better reflect the heat tolerance of breeds such as Santa Gertrudis and Droughmaster.***

⇒ ***Recommendation 5: Change the threshold for Brahman to +10, and the threshold for Tropical Composite to +8***

⇒ ***Recommendation 6: Change the threshold for Bos taurus x Bos indicus (50:50) to +7***

⇒ ***Recommendation 7: Add the Wagyu class with a threshold of +4 (shaded cattle)***

⇒ ***Recommendation 8: Further investigate the impact of the various types of shade structures currently being used within the industry. This study will need to be conducted in a research feedlot, not a commercial feedlot.***

The major industry to benefit from this work will be the beef feedlot industry. It will benefit immediately by being better able to predict the onset and manage the impact of heat stress events. The increased level of knowledge regarding the causes of heat stress in feedlot cattle and the most effective mitigation strategies will ensure that the beef feedlot industry as a whole will be better prepared to manage future heat stress events. Other intensive livestock industries such as the dairy and lamb feedlot industries may also be able to adapt some of the results of this project to their own industries.

Contents

1 Background

This project, FLOT.335 – Improved measurement of heat load in the feedlot industry, was conducted with funding support from Meat and Livestock Australia. The major research bodies involved in this project were E.A. Systems Pty Limited, an agricultural science and engineering firm and The University of Queensland. The project was conducted at commercial feedlots over the 2005/06 summer months.

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 brief summary of previous research projects conducted with the backing of Meat and Livestock Australia are shown below.

- 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.
- FLOT.330 – Validation of the new Heat Load Index for use in the feedlot industry

A major output from these projects was a new Heat Load Index (HLI) designed to better reflect the effect of the prevailing climatic conditions on feedlot cattle. The following climatic variables were identified as important, and as such, were included in the new HLI:

- Black Globe Temperature (BGT) (ºC);
- Wind Speed (WS) (m/s); and,
- Relative Humidity (RH) (%).

1.1.1 New Heat Load Index

During the formulation of the new HLI, it was recognised that cattle panting score (a major indicator of cattle heat stress) increased with BGT. There also appeared to be a threshold BGT above which the cattle response, as expressed through panting scores, seemed to change. This threshold occurred at 25ºC and as a result, it was decided to produce two HLI algorithms, one for BGT below 25 ºC and another for BGT above 25 ºC.

For Black Globe Temperatures less than 25°C:

- $HLI = 10.66 + 0.28 \times RH + 1.3 \times BGT - WS$

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)

Whilst the improved HLI gives an accurate reflection of the climatic conditions affecting feedlot cattle at any moment in time, it does not give an indication of the duration of exposure to those climatic conditions. It has been shown previously that duration of exposure to climatic conditions also has an impact on the heat load status of feedlot cattle at any particular point in time.

1.1.2 Accumulated Heat Load Units

In an attempt to capture this duration of exposure effect, the Accumulated Heat Load Units measure was developed. The AHLU is calculated based on two HLI threshold values, an upper and a lower threshold. If the HLI is above the upper threshold, then the animal is not able to adequately dissipate heat to the atmosphere and accumulates heat. If the HLI falls below the lower threshold, then the animal is dissipating heat to the atmosphere and is able to dispel accumulated heat. If the HLI is between the upper and lower thresholds, then the animal is neither accumulating nor dispelling heat and its heat status remains static.

There are a number of both site specific and individual animal factors that influence the two thresholds. For this reason, a reference animal was used during the formulation of the HLI and AHLU so that consistency could be achieved between datasets. This reference animal was a healthy steer with a black coat, was at least 100 days on feed with a condition score of 4-5 and kept in an unshaded pen. For this animal the upper HLI threshold was set at a HLI value of 86, whilst the lower threshold was set at 77.

Using these two thresholds as a guide, the HLI Balance can be calculated. At any particular moment in time, the difference between the HLI and the upper and lower HLI thresholds becomes the HLI Balance. For example, if a reference animal was experiencing a HLI of 92 at any particular moment in time, its HLI Balance would be +6. Similarly, if the same animal was experiencing a HLI of 72 at any particular moment in time, its HLI Balance would be -5. For HLI values between the two thresholds (e.g. 82) the HLI Balance for that moment in time is 0. The AHLU over a particular period of time is then calculated by accumulating the calculated HLI Balance over that period of time.

1.1.3 Risk Assessment Program

A computer based Risk Assessment Program (RAP) was also developed to assist feedlot managers in taking preventative action to ensure that the effects of heat stress are managed. The RAP 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.

2 Project Objectives

The objectives of the project were:

1. Collect data sets of climatic and animal observations from 4 co-operator feedlots, located throughout eastern Australia, during the summer of 2005-06;
2. Utilise the collected datasets to test and validate the refined HLI, AHLU and the RAP software, using recognised statistical methods; and,
3. Make recommendations on changes that need to be incorporated into the RAP software package as a result of the project.

There were a number of areas identified that required specific investigation throughout this project. They included:

- The impact of shade on both Bos Indicus and Bos Taurus feedlot cattle;
- The difference in heat tolerance between pure Bos Taurus and pure Bos Indicus;
- The heat tolerance of long-fed Wagyu feedlot cattle; and,
- The impact of the number of days on feed.

3 Methodology

The previous research project conducted in this area, FLOT.330, involved the collection of data from 13 different feedlot sites spread geographically across eastern Australia and allowed the feedlot staff to collect datasets on behalf of the research staff. During this project, the feedlots were asked to collect animal behaviour data from each selected pen three times a day. This approach yielded some good results from a wide variety of feedlot sites with a fairly even geographic distribution across eastern Australia.

It was felt for this project that a more intensive study was required, focusing on some specific issues that still required clarification. For this reason, fewer feedlots were studied and animal behaviour data was collected hourly from each pen selected. It would have been unfair to ask the participating feedlots to collect this more intensive data and as a result, all data collection was conducted by the research staff.

3.1 Participating Feedlots

The feedlots that participated in this project were:

- Aronui (Dalby, Qld);
- Kerwee (Jordaryan, Qld);
- Killara (Quirindi, NSW); and
- Rockdale (Yanco, NSW).

These feedlots were selected because they are reasonably well spread throughout eastern Australia and within one hour's drive from The University of Queensland's Gatton Campus and the major E.A. Systems offices (Toowoomba, Armidale and Wagga Wagga). They were also selected because, in the opinion of the research staff, they could offer the types of cattle that were to be targeted throughout this project.

The data collection period was scheduled to occur over January-March 2006. The basic outline for data collection was as follows.

- Baseline data collection was to be conducted at the beginning of the trial during periods of low to moderate heat conditions (HLI generally <86). The aim was to conduct at least three days of baseline data collection.
- Data collection was also to occur during hot conditions (HLI generally >86). It was aimed to conduct at least ten days of data collection during hot conditions.

The ten days of hot data collection could occur at any time over the January-March data collection period.

3.2 Pen Selection

The pen selection process was undertaken prior to the commencement of data collection. From each feedlot, 6-8 pens of interest were selected to be monitored over the duration of this trial. Pens were selected in an attempt to isolate some of the following factors, which were considered important prior to the commencement of this research project:

- presence of shade;
- genetic differences in heat tolerance, particularly the difference between Bos Indicus, Bos Taurus and wagyu cattle;
- age; and,
- days on feed.

It was also important that the animals within each pen were not going to be moved, or sent to slaughter during the trial. An outline of the pens that were selected for inclusion in this project is shown below in Table 1.

Table 1 The pens selected for monitoring at each feedlot.

Feedlot	Pen Number	Cattle Genotype	Shade
Aronui	P5	Wagyu	Y
	P6	Wagyu	Y
	Q6	Wagyu	Y
	Q4	Wagyu	Y
	J3	Brahman X	N
	J4	Shorthorn	N
	E3	Santa Gertrudis	N
	E1	Santa Gertrudis	N
Kerwee	C4	Brahman X	N
	C5	Brahman X	N
	F4	Bos Taurus	Y
	F5	Bos Taurus	Y
	F6	Bos Taurus	Y
	G4	Angus	Y
	G5	Angus	Y
	G6	Angus	Y
Killara	84	Bos indicus	Y
	87	Wagyu x Angus	Y
	99	Bos taurus	Y
	98	Bos indicus	Y
	24	Bos taurus	Y
	12	Angus	Y
	11	Bos taurus	Y
	10	Bos indicus X	Y
Rockdale	E73	Angus	N
	E76	Angus	Y
	J144	Mixed Bos taurus	Y
	J134	Mixed Bos taurus	N
	I128	Mixed (Bos Taurus and Bos indicus)	Y
	I129	Mixed (Bos Taurus and Bos indicus)	Y

3.3 Weather Data Collection

Each participating feedlot had a weather station on site. These weather stations were checked to ensure they were functioning properly, and that each station had all of the required sensors prior to the commencement of the trial. Each weather station was also checked to ensure that it would collect data at least hourly throughout the data collection period. As a minimum requirement, each feedlot weather station was required to have the following sensors:

- Black globe temperature (ºC);

- Ambient temperature (ºC);
- Solar radiation (W/m^2);
- Wind speed (m/s) or (km/hr);
- Rainfall (mm); and,
- Relative humidity (%).

3.4 Animal Behaviour Data Collection

Animal behaviour data collection was conducted only during sunlight hours. Generally speaking, data collection commenced at 0600 h and was completed by 1800 h. Visual assessments of each pen of interest were conducted hourly during each data collection day. The data collection sheets used are shown in Appendix 1. Visual assessments were conducted from the feedbunk, in an attempt to limit the disturbance to the animals in the pen.

The following parameters were estimated during each visual assessment:

- general location of animals within the pen (i.e. at water trough, feedbunk, under shade, etc.);
- estimate of the number of animals standing and the number of animals lying at each location within the pen;
- estimate of the number of animals at each panting score; and,
- general comments regarding animal behaviour, feedlot activity, and localised climatic effects.

The aim of this data collection was to quantify the level of heat load affecting the animals in the pens of interest. One of the most reliable and transferable methods for measuring heat load in cattle is the panting score measure. 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. A description of the indicators used at each panting score is shown in Table 2.

Table 2 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 also a series of reference photographs used during the data collection to assist the data collectors in making panting score assessments. These are shown in Appendix 2.

3.5 Statistical Analysis

One thousand nine hundred and fifty four observations were used in this study. Two hundred observations were not used in the analysis due to occasional failure of weather stations.

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). All 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 - 77.0; (3) Hot Conditions, when the HLI is 77.1 – 86.0; and, (4) Very Hot, when HLI is >86.0. When assessing threshold limits HLI was categorised as above except that categories of >86<90 and >90 were used in place of the >86 category. 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, AHLU, HLI categories and AHLU categories and the interaction of HLI and AHLU categories on MPS within and between genotypes. Feedlot was used as a covariant. Pen effects (shade or no shade) were considered where the same genotype was in shaded and un-shaded pens within or between feedlots. Statistical models for MPS included genotype x feedlot x pen type x HLI category; genotype x feedlot x pen type x AHLU category. Heat load index category x AHLU category interactions on MPS were also investigated. The effects of HLI, AHLU, HLI categories and AHLU categories and the interaction of HLI and AHLU categories on pen location of cattle (under shade, not under shade, feedbunk, water trough) and posture (standing or lying) was assessed for genotypes and feedlot. A 95% confidence interval was used for statistical significance.

3.6 Mean Panting Score

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

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

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

4 Results and Discussion

4.1 Mean Panting Scores

In a previous study it was apparent that Mean Panting Score (MPS) was both a function of the HLI and AHLU. An important factor influencing MPS (apart from genotype) is whether HLI and AHLU are increasing or decreasing. Furthermore the absolute magnitude of HLI and AHLU is important. For example it is possible to have a HLI less than 70, a level at which we would assume there would be no thermal stress on the animal, and at the same time have an AHLU>50, a level at which we would assume thermal stress. This scenario is often seen late in the afternoon or early evening when HLI is decreasing following a hot day during which AHLU exceeded 100. The decay of the AHLU is slower than changes in HLI. Therefore it is common at the end of a hot day to see a relatively low HLI and still have moderate (<10) to high (10 – 20) AHLU's. For example at one of the NSW feedlots on 3 January 2006, the HLI was 73 at 1800 h and the AHLU was 27.8. On the 6th January 2006, the HLI was 55 at 2100 h and AHLU 42.9 (it reached 0 at 2300 h). Similar examples can be found throughout the weather data collected for all four feedlots involved in the study. Some aspects of this will be discussed later.

Therefore both the absolute values of HLI and AHLU, and their direction (increasing or decreasing) need to be considered when assessing the thermal status of cattle[1]. It is not possible to set a critical level (i.e. a death point) for either HLI or AHLU as high values in one may be offset by low or decreasing values in the other. What is clear from the data however is that MPS is significantly elevated in *Bos Taurus* and predominantly *Bos Taurus* cross cattle exposed to a HLI > 86 coupled with AHLU's >50. The exception to this was for the Wagyu cattle which show a high degree of heat tolerance across a wide range of thermal conditions. It is not clear however if this heat tolerance is a genotypic response or an environmental response e.g. diet and access to shade.

This does not suggest that the above mentioned values can be used as an end point and none can be inferred from the data collected. Death of cattle during heat waves is a complex mix of many factors (animal, management and climatic) and the reason(s) for death can not be synthesized into a single value. Feedlot managers (all feedlot staff) need to be vigilant in regard to the cattle in their care, and the climatic conditions during the warmer months (November to March). Swift proactive and/or remedial action is the key to animal survival during heat waves. However even with the best management cattle may still die.

The statistical model showed that MPS was significantly ($P=0.0001$; $r^2=0.61$) affected by feedlot location, genotype and the interaction between HLI and AHLU. If MPS was assessed on the basis of HLI or AHLU on their own the model again showed significance ($P=0.0001$; $r^2=0.57$).

Pen type, that is shade or no shade, did not have a significant ($P=0.5156$) impact on MPS. Only two breeds Brahman and Angus were represented in shaded and non-shaded pens. The lack of differences is a function of the lack of overall representation, feedlot location and the climatic conditions to which the cattle were exposed. While it is not statistically significant the general trend was for the un-shaded cattle to have greater MPS than similar (but not identical) genotypes with access to shade, when exposed to similar climatic conditions.

[1] Other factors including: expected duration of the heat event, degree of adaptation, health status, body condition and nutrition need to be considered.

Under a range of climatic conditions Brahman cattle showed little response to high heat loads, easily handling HLI in excess of 95. However in some instances Brahman cattle without access to shade did show elevated panting (PS>1) when exposed to a HLI >88 and an AHLU >50. Most of these animals were at a Queensland feedlot. On a few occasions (two observation days) the MPS of the Brahmans at this feedlot exceeded a value of 1. At the same time Angus cattle at the same feedlot had MPS greater than 1.3, and MPS remained elevated in the Angus longer. The reasons for the higher than expected MPS of the Brahmans at the Queensland feedlot are not entirely clear. Factors such as time of eating and DOF may have influenced the result. At this stage there is no evidence to suggest that the HLI threshold of 96 (+10) should be changed for Brahman cattle (without shade).

Angus cattle (shaded – across all feedlots) showed a consistent response to HLI and AHLU. Panting scores increased (MPS>1) when the HLI was greater than 83 and had significantly greater numbers with MPS≥2 when HLI>86. In some cases increased panting (MPS<2 and >1) was observed when the HLI was 80 – 83. In some cases MPS above 0 but below 1 were observed when HLI and AHLU were below 86 and 1 respectively.

Differences in MPS of Brahman and Angus cattle at a Queensland feedlot over 9 hours on a single day are presented in Table 3. Four pens of Angus data are presented to demonstrate the consistency in response by these animals. The AHLU was zero from 2100 h (11 Feb) until 0900 h (12 Feb), and reached zero again at 2100 h (12 Feb). The cattle had 9 hours of 0 AHLU's. Based on previous studies 9 hours of 0 AHLU would be sufficient for cattle to somewhat recover from the previous day's heat event. However what is not evident is any "carry over" heat due to fermentation and digestion of feed. These animals were fed late morning/early afternoon but consumed most of their feed overnight.

Table 3 The differences in mean panting score for Brahman (B) steers (no-shade[A]) and four pens of Angus (A1 – A4) steers (shade) at hourly intervals (1045 to 1845 h[B]) on the 12 February 2006. The HLI and AHLU are provided as hourly means between 1045 and 1945 h.

	Mean Panting Scores						
Time	**B**	**A1**	**A2**	**A3**	**A4**	**HLI**	**AHLU**
1045	0.02	1.19	1.03	1.07	1.11	92.3	11.56
1145	0.00	1.21	1.01	1.02	1.15	96.4	21.92
1245	0.01	1.23	1.03	1.05	1.07	95.5	31.43
1345	0.04	1.27	1.07	1.04	1.12	93.3	38.72
1445	0.06	1.34	1.17	1.19	1.23	96.3	49.01
1545	0.01	1.38	1.23	1.22	1.28	90.4	53.4
1645	0.01	1.31	1.22	1.26	1.27	88.3	55.69
1745	0.00	1.29	1.17	1.24	1.23	81.7	55.69
1845	0.00	1.01	1.11	1.19	1.17	60.6	39.43
1945	-	-	-	-	-	57.2	19.57

[A.] Feedlot located in Queensland.
[B] It was too dark at 1945 to observe cattle.

The affect of prolonged heat exposure on Brahman, Angus and Angus x Hereford cattle is presented in Figure 1. The steers had entered the day with a carry over heat load of 128 AHLU. The cattle were exposed to heat wave conditions for over 3 days and high MPS were observed. Unfortunately the weather station ceased to function on the 4th February and two days of heat wave data were effectively lost. However, it is clearly evident that the Brahman cattle were under minimal heat load while the Angus x Hereford cattle were experiencing heat stress. The data also shows that the high AHLU (in excess of 200) is being offset on the day by a slight reduction in the HLI.

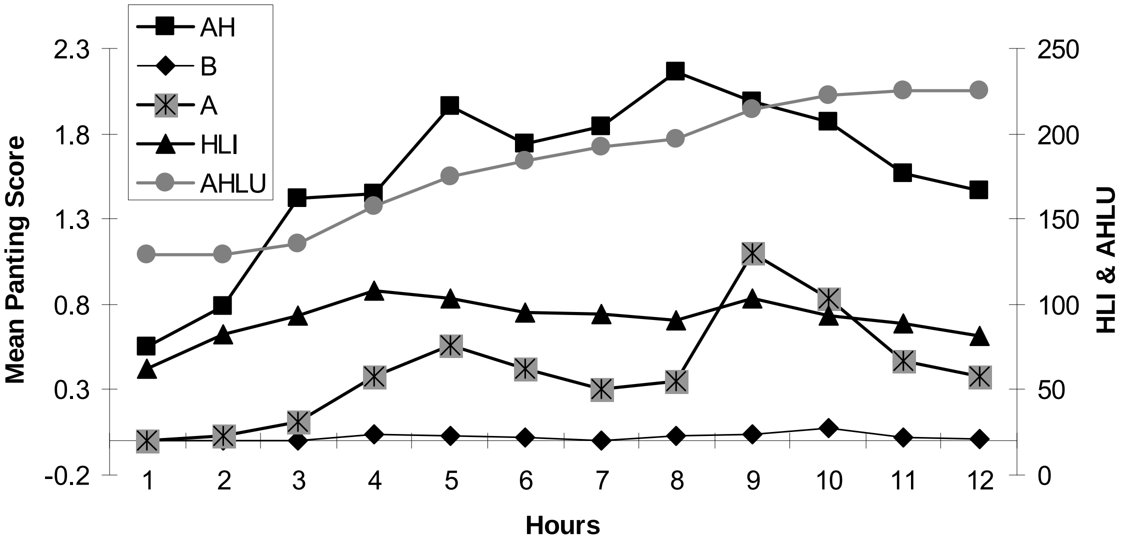

Figure 1 Comparison of the mean hourly panting scores for Angus x Hereford (AH) (n=181), Brahman (B) (n=279) and Angus steers (A) (n=133) all in shaded pens at a NSW feedlot. The hourly HLI and AHLU are also presented. Hours 1 – 12 represent 0600 – 1800 h on the 3rd February 2006.

There is evidence that the location of the pen in a feedlot may have an impact on the ability of cattle to dissipate heat. During the project an attempt was made to select pens that would not unduly influence the results. That is, to avoid having a “hot” pen and a “cool” pen. In feedlots were there were multiple pens of the same genotypes comparisons of pens was made to ensure consistency in the results. The data presented in Figure 2 shows the similarity in MPS between two pens of Angus at a NSW feedlot. The similarity between the two pens demonstrates the robustness of the data, and validates the assumptions made in regard to the response of cattle to the HLI and AHLU in this and previous studies.

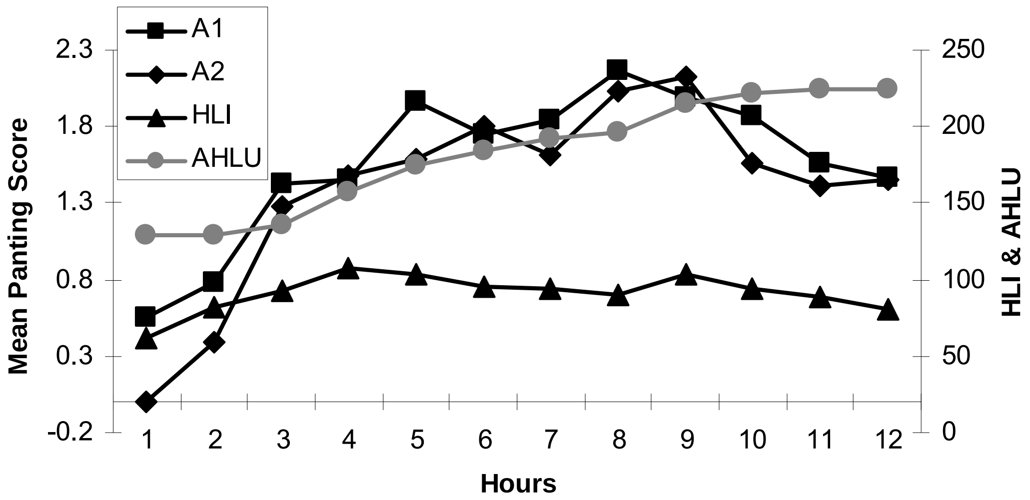

Figure 2 Comparison of two pens of shaded Angus steers (A1 and A2) at a NSW feedlot. The hourly HLI and AHLU are also presented. Hours 1 – 12 represent 0600 – 1800 h on the 3rd February 2006.

Mean panting score is a useful visual tool to assess the heat load status of feedlot cattle. As previously mentioned the interaction of HLI and AHLU should be considered when assessing thermal status. The relationship between MPS and the HLI x AHLU interaction for Angus cattle is presented in Figure 3.

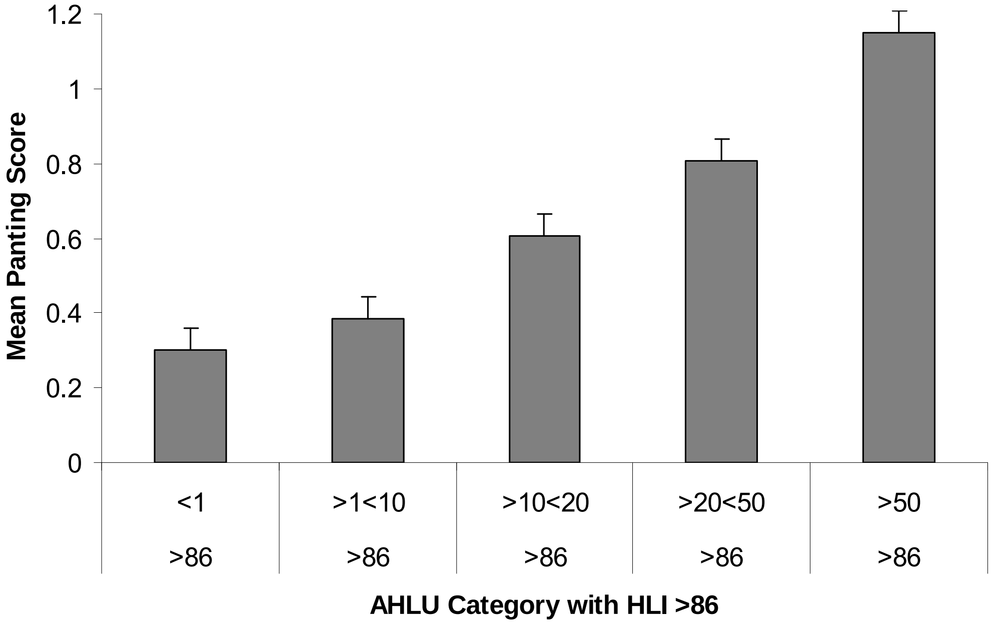

Figure 3 Mean panting scores of Angus steers (all feedlots combined) with access to shade for five categories of AHLU when HLI was greater than 86.

In some instances data needs to be interpreted by looking at the previous thermal conditions (Figure 4 and Figure 5). For example in Figure 4, the MPS of Angus cattle exposed to an AHLU greater than 50 and a HLI <70 are presented. This may look out of place since a positive (increasing) heat balance does not occur until the HLI≥86. However, what this does show is the situation where both HLI and AHLU are decreasing, a situation that has not been considered thus far. The HLI has decreased to less than 70 however there is a residual accumulated heat load.

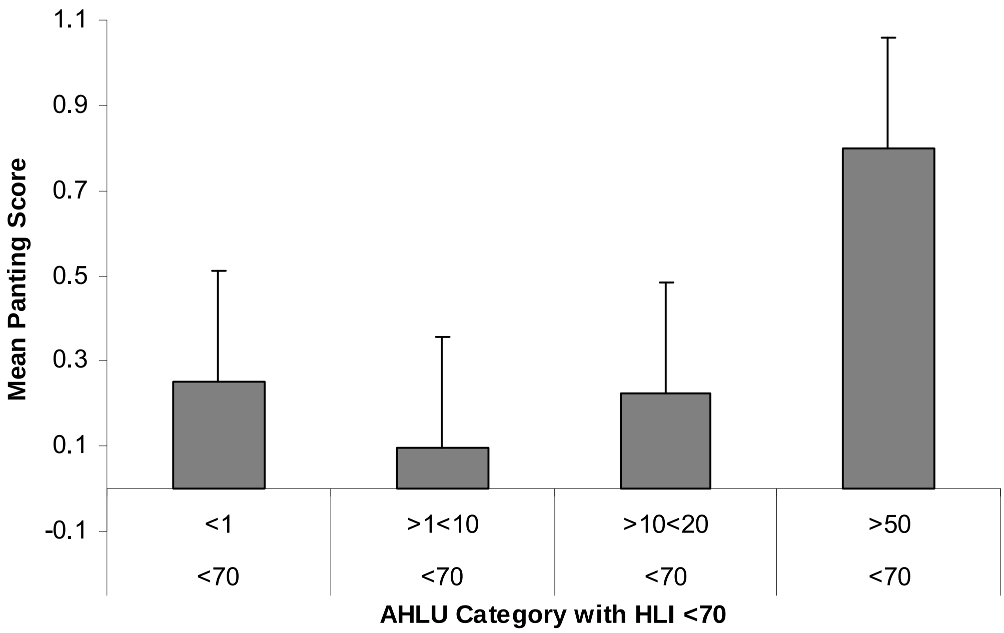

Figure 4 Mean panting scores of Angus steers (all feedlots combined) with access to shade for four categories of AHLU when HLI was less than 70.

The data presented in Figure 5 shows the MPS of Angus x Hereford cattle that were exposed to two heat waves one of two days and the second over 4 days. During each heat wave event there was minimal night time relief (0 to 4 hours). The high MPS when the AHLU is less than 1 demonstrates two things: (i) the fast respiratory response of cattle with prolonged exposure to hot conditions, and (ii) the carry over effects of prolonged heat exposure. These data suggest that the threshold maybe lower for cattle that have had prolonged exposure to adverse thermal loads.

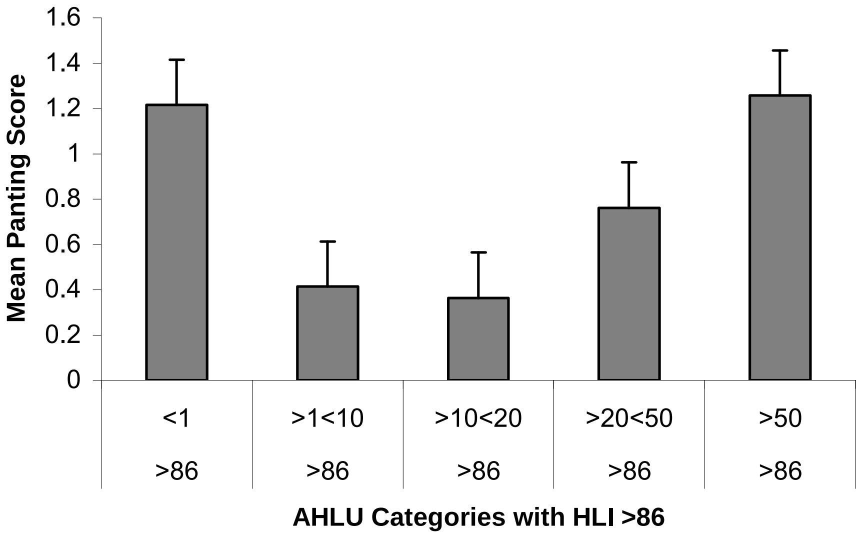

Figure 5 Mean panting scores of Angus x Hereford steers with access to shade for five categories of AHLU when HLI was greater than 86.

The MPS of Brahmans with access to shade rarely exceeded 0.1. Droughtmaster cross steers showed elevated MPS when exposed to a HLI>86 and an AHLU>20 (Figure 6). Further analysis of the data shows that the rise in MPS within the AHLU category of >20<50 is associated with a HLI ≥ 95.

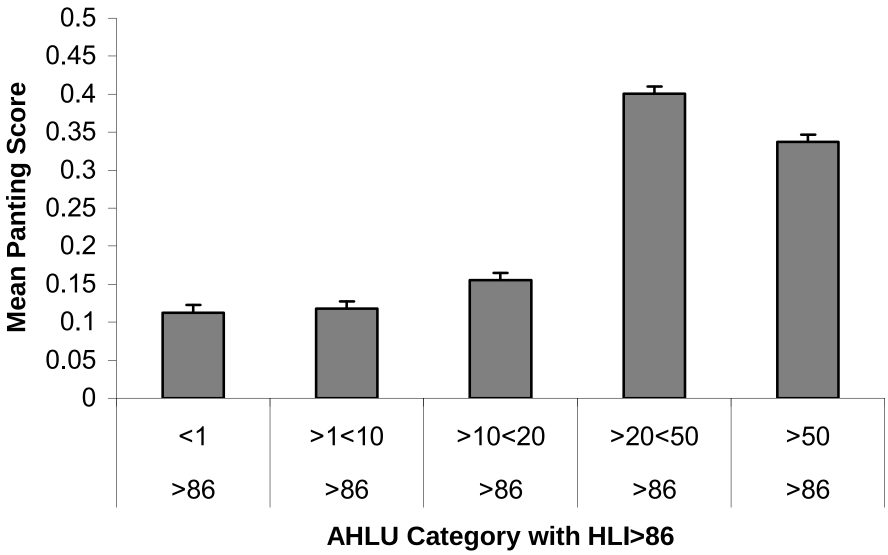

Figure 6 Mean panting scores of Droughtmaster cross steers (all feedlots combined) with access to shade for five categories of AHLU when HLI was greater than 86.

4.1.1 Validation of threshold limits.

The response of cattle (mean panting scores) was used to assess that validity of previously determined thresholds. Using five categories of HLI it was determined that the largest increase in MPS of shaded Angus occurred from a HLI>90 (Figure 7). This was a significant (P=0.0001) increase in MPS compared to the MPS when HLI was >86<90. In the unshaded Angus cattle MPS was 0.71 when HLI was >77<86. This was a significant (P=0.001) increase from when HLI was <77. These data suggest that the threshold of 86 is valid for un-shaded Angus. However, southern (unacclimated) cattle appear to be more susceptible to heat. A reduction in the threshold (-5) appears to be reasonable. Access to shade (shade type not defined) suggests an increase in the threshold of +4. When exposed to the same conditions, Brahman (no-shade) and Wagyu (shade) cattle had MPS of 0 or close to 0 for all categories. The 96 (+10) threshold holds for Brahman cattle. The threshold for Wagyu appears to be 90 (possibly slightly higher). Therefore a new category for ***shaded*** Wagyu (+4) should be considered.

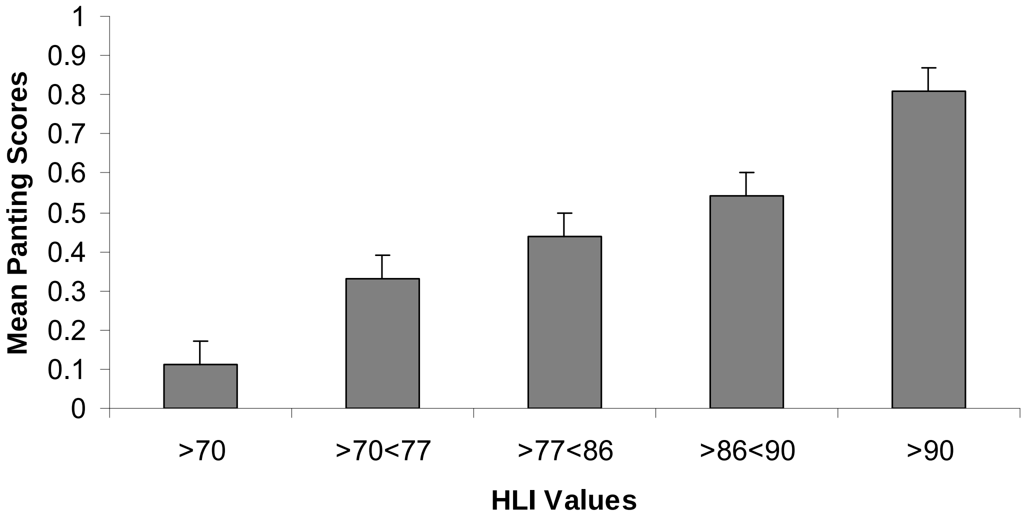

Figure 7 Mean panting scores of Angus (all feedlots combined – shade only) with access to shade for five categories of HLI.

4.2 Positional Behaviour

Animal location in pen and standing and lying behaviour were assessed. When cattle were exposed to a HLI>86 and an AHLU>50 (high thermal stress conditions) the percentages standing or lying (in brackets) under shade were: Angus 58.3% (32%), Angus x Hereford 57.4% (31.2%), Hereford x Charbray x Santa Gertrudis 51.4% (30.1%), Droughtmaster cross 44.3% (30.6%) and Brahman[2] 34.8% (40%). Under the same condition 1.7% Angus, 2.8% Hereford x Charbray x Santa Gertrudis, 10.6% Droughtmaster crosses and 9.9% Brahman were lying in the sun. On cool days (HLI<70; AHLU<1) 14.3% of Angus were lying in the sun and only 3.8% in shade. In contrast 51.9% of Brahmans were lying in the sun.

[2] For Brahmans with access to shade.

Under most of the climatic conditions encountered during the study ≥50% of Angus cattle were under shade (standing or lying). The general exception was when HLI<70 and AHLU<1 when only 16% used the shade. However when HLI<70 and AHLU >50 approximately 67.3% of Angus were standing under shade.

Across all feedlots more cattle were at the feedbunks (i.e. feedbunks with feed) when HLI<70 and AHLU<10. Very few animals (<3%) were observed at feedbunks when HLI>77 even when AHLU was <10. The HLI had a greater impact than AHLU on eating behaviour. However, when AHLU exceeded 50 all eating behaviour generally ceased even when HLI >70. For example the number of Angus cattle at feedbunks decreased from 23.3% to 10.1% when HLI <70 and AHLU>50. Overall there was not a lot of feeding behaviour observed.

Generally small numbers were observed at water troughs. Generally more of the un-shaded cattle could be found at the water troughs (Table 4). When HLI>86 and AHLU>50 more un-shaded Brahman (5.3%) were at the water trough compared to shaded Brahman (2.5%). Three percent of Angus and 5.4% of the Hereford x Charbray x Santa Gertrudis were at the water trough during extreme conditions.

On hot days shaded cattle tended to remain under shade. The exception was for Angus and Brahman when AHLU>50 (Table 4).

Table 4 The percentage of various genotypes at water during HLI >86 and AHLU categories of >10<20, >20<50 and >50.

AHLU[A]	DMX[B]	A	B	WA	SH[C]
>10<20	2.52	1.58	1.90	1.27	6.61
>20<50	1.92	1.39	1.72	1.14	3.15
>50	1.49	3.04	2.52	n.d.	6.14

[A] HLI was >86 for all AHLU categories.
[B] DMX = Droughtmaster cross; A = Angus, B = Brahman, WA = Wagyu, SH = Shorthorn.
[C] No access to shade.

5 Success in Achieving Objectives

The Objectives outlined at the beginning of the project were as follows:

1. Collect data sets of climatic and animal observations from 4 co-operator feedlots, located throughout eastern Australia, during the summer of 2005-06;
2. Utilise the collected datasets to test and validate the refined HLI, AHLU and the RAP software, using recognised statistical methods; and,
3. Make recommendations on changes that need to be incorporated into the RAP software package as a result of the project.

The success in achieving each of these objectives is outlined below:

1. There were datasets collected from 4 feedlots, with a large geographic spread between each during the summer of 2005-06. The feedlots and pens selected were done so to target certain specific factors in determining heat tolerance. Whilst it was a relatively mild summer, there were periods of extreme heat, of varying length and intensity observed at all of the co-operating feedlots.
2. The data collected was then used to test and validate the HLI, the AHLU and the various assumptions and thresholds used in the RAP software. The more interesting results of this process are shown in Section 4 above.
3. The recommendations made as a result of this project are presented in Section 7 below.

6 Impact on Meat and Livestock Industry – now & in five years time

The impact of this project on the meat and livestock industries, have been divided into the impact the project will have now (2006) and its likely impact in five years time (2011).

6.1 Impact on Meat and Livestock Industries – now (2006)

The impacts of this project will be largely felt through assisting the feedlot sector in better understanding and managing the impacts of heat stress on feedlot cattle. The major impacts this project will have on the feedlot sector will be:

- The ability to better predict the impact of extreme climatic conditions on feedlot cattle. The impact of a number of feedlot specific environmental, local topographical, climatic and management factors have now been well defined and researched.
- The ability to better predict the onset of the causative climatic variables and the most effective management strategies to deal with extreme climatic conditions.
- By better defining the impact of certain management strategies on reducing heat stress, effective heat management plans can be established for specific feedlots.

The impact of this project may not be limited to the feedlot industry. Other meat and livestock industries that are susceptible to the impacts of heat stress can also use these results to better predict and manage the impacts of heat stress on livestock. These industries would include any part of the red meat supply chain that confines animals for extended periods of time, and may include the following:

- Livestock transport industries;
- Live export industries; and,
- Livestock sale centres.

Whilst this research has focused on the specific impacts of heat stress on feedlot cattle, some of the general principles of heat stress management suggested can be extended to other intensive livestock industries, such as the sheep feedlot industry and the dairy industry.

6.2 Impact on Meat and Livestock Industries – in five years time (2011)

In five years time, the results of this project will ensure that the feedlot sector in particular will be better prepared to manage the impacts of heat stress on feedlot production. In particular, the feedlot sector will be better able to predict the onset of the adverse climatic conditions that cause heat stress in feedlot cattle. Feedlot managers will also have well defined management strategies, with quantifiable thresholds that will trigger specific management responses. New feedlots will also be better sited and better designed to ensure that they are constructed to properly mitigate against the impacts of heat stress. The feedlot sector as a whole will be better prepared to deal with the increased level of general public, media and regulatory scrutiny of animal welfare issues and remain proactive in its improvement of animal welfare across the entire Australian feedlot sector.

7 Conclusions and Recommendations

The conclusions and recommendations to be made following the results of this project can be divided into a number of important categories:

- The effect on the new HLI;
- The effect on the AHLU and its associated thresholds; and,
- The effect on the various thresholds for certain management strategies shown in the RAP software.

7.1 The new HLI

The new HLI, as outlined in Section 1.1.1, takes 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 results of this project certainly reinforce the assumption that the new HLI does adequately reflect the heat load affecting feedlot cattle at any particular moment in time

⇒ ***Recommendation 1: That no changes are made to the new HLI, and that its distribution to the industry continue.***

7.2 The new AHLU

The AHLU, outlined in Section 1.1.2 above, is a measure of both the intensity of the climatic conditions affecting feedlot cattle and the duration of that exposure. It uses the HLI and an upper and lower threshold to calculate the HLI Balance. For the reference animal[3], the lower threshold has been set at 77 and the upper threshold has been set 86. The HLI Balance is then used to calculate the AHLU over a certain period of time.

The results of this project indicate that the AHLU is a good measure of the heat load affecting feedlot cattle over a certain period of time. It does reflect both the intensity of exposure and the duration of that exposure. However, further work is needed to adequately model the recovery of cattle following exposure to high heat load events. It is not clear if the rate of recovery currently being used in the AHLU (i.e. subtracting the difference in HLI from the threshold from AHLU) is overestimating the rate of recovery or underestimating rate of recovery. The amount of time cattle are exposed to a 0 AHLU

[3] The reference animal, as outlined in Section 1.1.2, is a healthy black steer, of condition score 4-5, 100+ Days on Feed and in an unshaded pen.

or have no recovery are important. However we can not make firm recommendations on how much time cattle need to be at 0 or how much time spent at an elevated AHLU or what level of AHLU is critical for cattle. High AHLU (200) can be tolerated for a time and conversely cattle have died at relatively low levels (AHLU of 50). The key is probably recovery time, health status and management factors.

⇒ ***Recommendation 2: That no changes are made to the way the AHLU is calculated, and that the thresholds for the reference animal remain the same.***

⇒ ***Recommendation 3: That the recovery time of cattle exposed to high heat load (high HLI and AHLU) be further examined. This should be undertaken under controlled conditions.***

7.3 The RAP Software

The RAP software, as outlined in Section 1.1.3, contains a number of suggested changes to the HLI Balance thresholds used to customise the calculation of the AHLU for an individual feedlot, and for individual pens within that feedlot. Table 5 shows a list of some the changes to the upper HLI Balance threshold that are currently included in the RAP, along with any suggested changes to be made to these thresholds as a result of this project.

Table 5 Suggested changes to some of the HLI thresholds currently in the RAP software

Feedlot Management Factor	**Suggested relative effect on Upper HLI Threshold**	**Suggested Changes (shown in italics)**
Animal Genotype: Bos indicus (Brahman)	*+10*	*Change name to Brahman, Change to +10*
Tropical Composites	*+8*	*Split Bos indicus into Brahman and Tropical Composite (Santa Gertrudis, Droughmaster, etc.), Add Tropical Composite threshold of +8*
Bos Taurus x Bos indicus (50:50)	*+7*	*Change upper threshold to +7*
Europeans	+3	
Wagyu	*+4*	*Add Wagyu Class, Add threshold of +4 (shaded cattle)*
Bos taurus	0	
Unacclimated *Bos taurus*	- 3	
Shade: No Shade	0	*The impact of the various types of commonly used shade structures requires further investigation*
Shade (>1.5m^2/hd, <2m^2/hd)	+3	
Shade (>2m^2/hd, <3m^2/hd)	+5	
Shade (>3m^2/hd)	+7	

In summary, the following recommendations can be made as a result of this project.

- ⇒ ***Recommendation 4: Divide the Bos indicus class into Brahman and Tropical Composites to better reflect the heat tolerance of breeds such as Santa Gertrudis and Droughmaster.***
- ⇒ ***Recommendation 5: Change the threshold for Brahman to +10, and the threshold for Tropical Composite to +8***
- ⇒ ***Recommendation 6: Change the threshold for Bos taurus x Bos indicus (50:50) to +7***
- ⇒ ***Recommendation 7: Add the Wagyu class with a threshold of +4 (shaded cattle)***
- ⇒ ***Recommendation 8: Further investigate the impact of the various types of shade structures currently being used within the industry. This study will need to be conducted in a research feedlot, not a commercial feedlot.***

8 Appendices

8.1 Appendix 1 – Animal Behaviour Data Collection Sheets

DATA SHEETS - HEAT LOAD 2006

UNSHADED PEN		**Data Collector:**
Feedlot		**Date:**
Pen Number		**Time:**
Cattle Type	**Genotype**	**Dominant Breed (list below e.g. Angus)**
(circle one)	*Bos taurus* *Bos taurus x Bos taurus* *Bos taurus x Bos indicus*	
Number/Pen		**Mean Condition Score (1 - 5)**
Days on feed		

Behaviour	**Standing**	**Lying**
Feedbunk		
Water Trough		
Elsewhere		

Observations (e.g. bunching, milling about etc)

Number within each panting Score	
0	
1	
2	
2.5	
3	
3.5	
4	
4.5	

Pen Layout - show animal distribution & wind direction

Additional Comments & Feed bunk scores

DATA SHEETS - HEAT LOAD 2006

SHADED PEN		Data Collector:
Feedlot		Date:
Pen Number		Time:
Cattle Type	Genotype	Dominant Breed (list below e.g. Angus)
(circle one)	*Bos taurus* *Bos taurus x Bos taurus* *Bos taurus x Bos indicus*	
Number/Pen		Mean Condition Score (1 - 5)
Days on feed		

Behaviour	Standing	Lying
Shade		
No Shade		
Feedbunk		
Water Trough		
Elsewhere		

Observations (e.g. bunching, milling about etc)

Number within each panting Score

0	
1	
2	
2.5	
3	
3.5	
4	
4.5	

Pen Layout - show animal distribution & wind direction

Additional Comments & Feed Bunk Score

8.2 Appendix 2 – Panting Score Reference Sheets

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