Excessive Heat Load Index for Feedlot Cattle

FLOT.316
Final Report prepared for MLA by:

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ABSTRACT

In Australia periods of high heat load have and will impact on the performance and welfare of feedlot cattle. Past incidences have tarnished the good image of the Australian feedlot industry which now proactively is researching the impact of high heat load to minimize production losses and to ensure high standards of animal welfare are maintained.

This study was conducted on four Australian commercial feedlots during the summer of 2000/2002, and in accordance with its objectives developed and refined:

- A cattle panting score photo guide, enabling feedlot personnel to determine the thermal status of their cattle by visual assessment.

- Meaningful climate (temperature, humidity, solar radiation and wind speed) based indices namely;
  - A heat load index, and
  - An accumulative heat load index

The indices will be able to evaluate the thermal status of feedlot cattle and thereby assist feedlot management ameliorate the impact of high heat load via proactive management during periods of hot weather.
EXECUTIVE SUMMARY

In Australia occasional periods of high heat load have and will impact on the performance and welfare of feedlot cattle. In most past cases mortality has been relatively rare, but loss of production may have incurred a high monetary cost. Additionally, incidences have tarnished the image of the Australian feedlot industry. The industry is proactively researching the impact of high heat load on feedlot cattle to minimize production losses and ensure that the high standards of animal welfare are maintained.

The assessment of the heat load status of cattle is difficult. For a number of years a temperature-humidity index (THI) has been used as an indicator of thermal discomfort in the dairy industry and to a lesser extent in the feedlot industry. However, the THI was developed as an index for humans with no exposure to the sun or wind and does not take into account the impact of solar radiation on the thermal status of feedlot cattle. Furthermore the THI is only a spot measure and is unable to provide for the accumulative effect of ongoing high heat load exposure, and/or possible cooling such as at night. When exposed to hot conditions cattle may accumulate heat during the day, that is, their body temperature rises, and lose heat during a cool night. If there is insufficient night cooling they may enter the following day with an accumulated heat load, which the THI is unable to reflect. Suitably informed commercial feedlot management need to know the carry over “accumulated heat load” their cattle have from a previous day to effectively assess the possible impact of a new hot day.

Project FLOT.316 has been commissioned by Meat and Livestock Australia Ltd. following recommendations arising from FLOT.307, 308 and 309 (Heat Load in Feedlot Cattle 2001) which highlighted the need for further research and suggested that the THI needs to be further developed, as an aid to industry in managing high heat load situations.

(i) Objectives

The objectives of FLOT.316 were to develop the following.

- A cattle panting score photo guide, enabling feedlot personnel to determine the thermal status of their cattle by visual assessment.

- Meaningful climate (temperature, humidity, solar radiation and wind speed) based on:
  - A heat load index, and
  - An accumulative heat load index

  The indices will be able to evaluate the thermal status of feedlot cattle and thereby assist feedlot management ameliorate the impact of high heat load via proactive management during periods of hot weather.

(ii) Brief Methodology

The project studied high heat load situations in four commercial Australian feedlots. Two were in Queensland, namely:

- Feedlot A – located 16 km north east of Dalby (151°15’ E, 27°10’ S). The feedlot has a capacity of 18,000 head with a pen size approximately 3200 m². The average stocking density of the study pens was 22 m²/head.
Feedlot B – located approximately 14 km west of Oakey (151°43’ E, 27°26’ S). The feedlot has a capacity of 7,100 head, with a pen size of approximately 3000 m². The average stocking density of the study pens was 19 m²/head.

Two feedlots were used in NSW, namely:

- Feedlot C – located 65 km south west of Tamworth (150°56’ E, 31°05’ S) and 50 km south of Gunnedah (150°15’ E, 30°54’ S). The feedlot has a capacity of 25,000 head, with an average pen size of 4,680 and 4,950 m². The average stocking density was 14 to 15 m²/head.
- Feedlot D – located 10 km east of Yanco (146°24’ E, 34°36’ S). The feedlot has a capacity of 53,000 head, with an average pen size of approximately 6400 m². The average stocking density was 15 m²/head.

The pens chosen at each feedlot attempted to be consistent in terms of cattle genotype (Angus), days on feed (100 +), body condition (4 – 5), sex (steers) and cattle size.

In the nature of commercial feedlots, there were minor differences between feedlots. The pen size, stocking rates, bunk space, water trough space, shade design and area under shade were unable to be standardized between the feedlots, and there were differences in the type of ration fed (e.g. feedlot B used a summer ration), the ingredients used and feeding times. Commercial in confidence prevents detailed description of diets used, in general DM = 85 % and ME = 11 MJ/kg, DM.

The project during the period 1st January to 30th March 2002, observed:

- Feedlot A – 4 pens (2 shaded ~ 180 and 133 head/pen) (2 unshaded ~ 117 and 155 head/pen)
- Feedlot B – 2 pens (1 shaded ~ 144 head/pen (59 days only)) (1 unshaded ~ 149 head/pen)
- Feedlot C – 2 pens (1 shaded ~ 374 head/pen) (1 unshaded ~ 375 head/pen)
- Feedlot D – 2 pens (1 shaded ~ 434 head/pen) (1 unshaded ~ 429 head/pen)

The climatic data relevant to pen conditions was automatically recorded at each feedlot, and three times daily observations were made as to animal behaviour patterns, animal distribution within the pen, animal panting scores and response to heat, and eating behaviour.

Six climatic spot indices were assessed as to their relevance in indicating the thermal status of feedlot cattle. The THI was determined to be a suitable spot index for shaded cattle, and the BGHI a suitable index for unshaded cattle, following an adjustment for wind.

A new heat load index (HLI) is proposed and defined for when BGHI exceeds 79, and when BGHI is less then 79. Additionally the study illustrated by example the need to incorporate the accumulated heat load (AHL) assessment in a meaningful indicator of the thermal status of feedlot cattle.
It is concluded that high heat load in feedlot cattle is a result of local climatic conditions (i.e. in the pen) and animal factors lead to an increase in body heat beyond the animals’ normal physiological range and its ability to cope. By using a combination of observed local climatic conditions and animal responses to the climate (e.g. panting scores) feedlot management will be well placed to implement strategies to reduce the impact of severe hot weather conditions on their cattle.

The major conclusions from this study are:

- The modified Panting Score Guide is a useful management tool for assessing the thermal status of cattle.
- In vulnerable cattle the panting score moves from 0 to 1 at approximately 26 °C, and from 1 to 2 at approximately 33 °C.
- The THI index is a suitable spot index for shaded cattle but not unshaded cattle.
- Black globe temperature should be used instead of ambient temperature.
- Using the accumulative heat load (HLI-hours) for an index provides a better guide to thermal status of cattle than the spot environmental conditions at a specific point in time.

The major recommendations from this study are that feedlot management monitor the thermal status of cattle by way of:

- Determining the existing THI and THI-hours for shaded cattle.
- Apply the new spot heat load index (HLI) in lieu of the current THI for unshaded cattle.
- Develop further the use of the new accumulative heat load index hours (HLI-hours).
- Use the Panting Score Guide in conjunction with the HLI to assess cattle heat load status.
1. INTRODUCTION

1.1 Project Background

In Australia occasional periods of high heat load have and will impact on the performance and welfare of feedlot cattle. In most past cases mortality has been relatively rare, but loss of production may have incurred a high monetary cost. Additionally, incidences have tarnished the image of the Australian feedlot industry. The industry is proactively researching the impact of high heat load on feedlot cattle to minimize production losses and ensure that the high standards of animal welfare are maintained.

The assessment of the heat load status of cattle is difficult. For a number of years a temperature-humidity index (THI) has been used as an indicator of thermal discomfort in the dairy industry and to a lesser extent in the feedlot industry. However, the THI was developed as an index for humans with no exposure to the sun or wind and does not take into account the impact of solar radiation on the thermal status of feedlot cattle. Furthermore the THI is only a spot measure and is unable to provide for the accumulative effect of ongoing high heat load exposure, and/or possible cooling such as at night. When exposed to hot conditions cattle may accumulate heat during the day, that is, their body temperature rises, and lose heat during a cool night. If there is insufficient night cooling they may enter the following day with an accumulated heat load, which the THI is unable to reflect. Suitably informed commercial feedlot management need to know the carry over “accumulated heat load” their cattle have from a previous day to effectively assess the possible impact of a new hot day.

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1.2 Project Objectives

The objectives of FLOT.316 were to develop the following.

- A cattle panting score photo guide, enabling feedlot personnel to determine the thermal status of their cattle by visual assessment.

- Meaningful climate (temperature, humidity, solar radiation and wind speed) based indices, namely:
  - A heat load index, and
  - An accumulative heat load index

In combination these will be able to evaluate the thermal status of feedlot cattle and so assist feedlot management ameliorate the impact of high heat load via proactive management during periods of hot weather.
2. METHODOLOGY

2.1 Study Feedlots

The project studied high heat load situations in four commercial Australian feedlots (refer Appendix2 for fuel details). Two were in Queensland, namely:

- **Feedlot A** – located 16 km north east of Dalby (151°15' E, 27°10' S). The feedlot has a capacity of 18,000 head with a pen size approximately 3200 m². The average stocking density of the study pens was 22 m²/head.

- **Feedlot B** – located approximately 14 km west of Oakey (151°43’ E, 27°26’ S). The feedlot has a capacity of 7,100 head, with a pen size of approximately 3000 m². The average stocking density of the study pens was 19 m²/head.

Two feedlots were used in NSW, namely:

- **Feedlot C** – located 65 km south west of Tamworth (150°56’ E, 31°05’ S) and 50 km south of Gunnedah (150°15’ E, 30°54’ S). The feedlot has a capacity of 25,000 head, with an average pen size of 4,680 and 4,950 m². The average stocking density was 14 to 15 m²/head.

- **Feedlot D** – located 10 km east of Yanco (146°24’ E, 34°36’ S). The feedlot has a capacity of 53,000 head, with an average pen size of approximately 6400 m². The average stocking density was 15 m²/head.

The pens at each feedlot attempted to be consistent in terms of cattle genotype (Angus), days on feed (100 +), body condition (4 – 5), sex (steers) and cattle size.

In the nature of commercial feedlots, there were minor differences between feedlots. Pen size, stocking rates, bunk space, water trough space, shade design and area under shade were unable to be standardized between the feedlots, and there were differences in the type of ration fed (e.g. feedlot B used a summer ration), the ingredients used and feeding times. Commercial in confidence prevents detailed description of diets used, in general DM = 85 % and ME = 11 MJ/kg, DM.

- **Feedlot A** – 4 pens
  - 2 shaded ~ 180 and 133 head/pen
  - 2 unshaded ~ 117 and 155 head/pen

- **Feedlot B** – 2 pens
  - 1 shaded ~ 144 head/pen (59 days only)
  - 1 unshaded ~ 149 head/pen

- **Feedlot C** – 2 pens
  - 1 shaded ~ 374 head/pen
  - 1 unshaded ~ 375 head/pen

- **Feedlot D** – 2 pens
  - 1 shaded ~ 434 head/pen
  - 1 unshaded ~ 429 head/pen
2.1.1 Areas and Shade Structures

There were between feedlot differences in the stocking rates and shade areas, largely summarized in Table 2.1.

<table>
<thead>
<tr>
<th></th>
<th>Head/pen</th>
<th>Pen Area</th>
<th>Stocking Rate</th>
<th>Shade Area</th>
<th>Shade/head</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A Shaded</td>
<td>180</td>
<td>3200</td>
<td>17.8</td>
<td>702</td>
</tr>
<tr>
<td></td>
<td></td>
<td>133</td>
<td>3200</td>
<td>24.0</td>
<td>702</td>
</tr>
<tr>
<td>A Unshaded</td>
<td>117</td>
<td>3200</td>
<td>27.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>155</td>
<td>3200</td>
<td>20.6</td>
<td>-</td>
</tr>
<tr>
<td>B</td>
<td>B Shaded</td>
<td>144</td>
<td>3000</td>
<td>20.8</td>
<td>370</td>
</tr>
<tr>
<td></td>
<td>B Unshaded</td>
<td>149</td>
<td>3000</td>
<td>20.1</td>
<td>-</td>
</tr>
<tr>
<td>C</td>
<td>C Shaded</td>
<td>374</td>
<td>4680</td>
<td>12.5</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>C Unshaded</td>
<td>375</td>
<td>4950</td>
<td>13.2</td>
<td>-</td>
</tr>
<tr>
<td>D</td>
<td>D Shaded</td>
<td>434</td>
<td>6400</td>
<td>14.8</td>
<td>1200</td>
</tr>
<tr>
<td></td>
<td>D Unshaded</td>
<td>429</td>
<td>6400</td>
<td>14.9</td>
<td>-</td>
</tr>
</tbody>
</table>

The type of shade structures used at each feedlot was as follows (refer Appendix 2).

- Feedlot A – Permanent 13 m wide x 4.5 m tall shade structures composed of galvanized iron sheets. The sheets were placed to give approximately 5.4 m² of shade interspaced by a 0.5 m gap. The shade structure ran the length of the pen. All cattle could access the shade at one time (see Plate 1).

- Feedlot B – Permanent galvanized shade structure 15 m wide with a maximum height of 5.4 m. The shade was angled at approximately 5° with the low side (4.8 m) to the west (see Plate 1).

- Feedlot C – No climatic data from shaded pen. Therefore shade data not used.

- Feedlot D – A 15 m wide strip of 80% shade cloth to be attached to 4 m posts so cloth can be removed in winter. The shade structure ran the length of the pen and all cattle could access the shade at one time (see Plate 2).
Plate 1. Shade Structures at Feedlot A (left) and Feedlot B (right).

Plate 2. Shade cloth structures at Feedlot D.
2.2 Project Duration

The overall field study ran from the 1st January to 30th March 2002. Due to delays receiving some equipment the NSW feedlot observations started a week later than those in Queensland.

Data collection was carried out at

- Feedlot A – 0600, 1200 and 1700 hours (Eastern Standard Time) each day from 2nd Jan until 19th March 2002 (76 days).
- Feedlot B – 0600, 1200 and 1700 hours (Eastern Standard Time) each day from 2nd Jan 2002 until 27th March 2002 (84 days).
- Feedlot C – 0700, 1200 and 1600 hours (Daylight Savings Time) each day from 9th Jan 2002 until 27th March 2002 (77 days).
- Feedlot D – 0600, 1200 and 1700 hours (Daylight Savings Time) each day from 7th Jan 2002 until 27th March 2002 (79 days).

In addition at both Feedlot A and B data was also collected hourly from 0800 hours to 1600 hours on 12 days. The collection days corresponded to days when excessive heat load (EHL) was anticipated, i.e. when maximum ambient temperature was expected to be above 36 °C, as determined from weather forecasts the night preceding and on the morning of data collection.

2.3 Animal Data Collected

The genotype, coat colour, expected days on feed, body condition score and/or live weight (at the start of the study) were recorded at the start of the study, and the number per pen (done daily to keep track of pulls) were recorded throughout the study.

Each day at the times outlined in Section 2.2 the number of cattle at the feedbunk, at the water trough, standing or lying under shade (shaded pens) or standing or lying in sun were recorded. Cattle were determined to be at the water trough even if they were not drinking. Cattle were determined to be at the feedbunk only if they were eating. Daily feed intake was also recorded (refer Appendix 3 for data collection sheet), and average dry matter intake determined.

Specific abnormal behaviour patterns (e.g. milling around, water splashing) were noted.

In addition panting scores (PS) were recorded. The PS’s were determined with reference to the basis the photo guide developed and provided at each feedlot (refer Appendix 4). The number of animals in a pen with panting scores of 0 to 4 were determined by counting cattle at the three times outlined above for each feedlot (Table 2.2).

A total of 2187 observations were made, namely 813 at Feedlot A, 474 at Feedlot B, 474 at Feedlot C and 426 at Feedlot D.

Additional data collected at feedlots A and B involved the mapping of the distribution of cattle within a pen, their respiration rates measured and pen ambient temperature, relative humidity, black globe temperature, wind speed and pen surface temperature together with cloud cover.
Table 2.2. The panting scores for observed breathing condition and respiration rate.

<table>
<thead>
<tr>
<th>Breathing Condition</th>
<th>Respiration Rate (bpm)</th>
<th>Panting Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>No panting</td>
<td>Less than 40</td>
<td>0</td>
</tr>
<tr>
<td>Slight panting, mouth closed</td>
<td>40 – 70</td>
<td>1</td>
</tr>
<tr>
<td>Fast panting, occasional open mouth</td>
<td>70 – 120</td>
<td>2</td>
</tr>
<tr>
<td>Open mouth + some drooling</td>
<td>120 – 160</td>
<td>3</td>
</tr>
<tr>
<td>Open mouth tongue out + drooling</td>
<td>&lt; 160</td>
<td>4</td>
</tr>
</tbody>
</table>

A Count respiration rate by watching flank movements – record time for 10 movements.
C Refer to Section 3.2 for progressive modification

B At this stage, respiration rate may decrease due to change to deep phase breathing.

2.4 Weather Data

Automatic weather stations recorded air temperature, solar radiation, wind speed, relative humidity and black globe temperature at 10-minute intervals for the duration of the study. Rainfall events were also recorded. The weather data was downloaded daily via mobile phone and modem. Approximately 12400 points of weather data were collected at Feedlots A, C and D, and 8400 points at Feedlot B.

The weather stations were located in each pen at Feedlots B and D, and between the two shade pens and two unshaded pens at Feedlot A. In the shaded pens the weather station was located under the shade, except at feedlot C. The weather stations were protected from cattle by portable yard panels at all locations.

2.5 Climatic Indices Evaluated

The following climatic indices were determined for comparative assessment throughout the study.

Index 1. Temperature-humidity index (THI) \( \sim 0.8 \times T_a + (RH/100 \times (T_a -14.4)) + 46.4 \)

Index 2. Quadratic temperature index \( \sim 31.6 + (0.28 \times T_a + (0.061 \times T_a^2)) \)

Index 3. Energy balance 1 \( \sim (0.89 \times T_a) - (0.39 \times Ws) - 34.65 \)

Index 4. Energy balance 2 \( \sim (1.33 \times T_a) - (0.99 \times Ws) - 50.69 \)

Index 5. Environmental stress index (ESI) \( \sim (0.63 \times T_a) - (0.03 \times RH) + (0.002 \times SR) + (0.0054 \times (T_a \times RH)) - (0.073/(0.1 \times Ws)) \)

Index 6. Black globe humidity index (BGHI) \( \sim ((1.8 \times BG) + 32) - ((0.55 - (0.55 \times RH/100)) \times ((1.8 \times BG) - 26)) \)

Where;
- \( T_a \) = ambient temperature (°C)
- \( RH \) = relative humidity (%)
- \( Ws \) = wind speed (m/s)
- \( SR \) = solar radiation (W/m²)
- \( BG \) = black globe temperature (°C)
2.6 THI-hours and BGHI-hours (Accumulative Heat Load)

The accumulative time of exposure to thermal load is crucial to determining the thermal status and well-being of cattle. Hence the accumulative heat load (AHL) for the indices THI and BGHI were determined and are expressed as THI-hours and BGHI-hours. These record the accumulative heat load as an adaptation of the THI and BGHI indices with a time dimension added, by assessing the amount of time in hours that the THI or BGHI exceeds a threshold value (Hahn et al., 1999).

The threshold value is selected on the basis of the animals suspected vulnerability to high heat load. For the THI the threshold value was set at 74, on the basis that a THI of 73 is generally considered to be the value above which cattle start to respond to heat load (Sparke et al., 2001, p. 39). For the BGHI the threshold was set at 79, on the basis that this is the value at which cattle commence to visibly show the effects of heat load (i.e. increased respiration rate) based on observations of cattle in commercial feedlots in Australia and USA. It is assumed that when BGHI > 79 cattle accumulate heat and, when BGHI < 79 cattle can dissipate accumulated heat.

2.7 Calculating the Accumulative Heat Load

The calculation of accumulated heat load as BGHI-hours is basically the same as for THI-hours (refer Sparke et al. 2001, pp 40 – 42), and is illustrated below in Table 2.3.

<table>
<thead>
<tr>
<th>BGHI</th>
<th>Heat Balance (based on a BGHI threshold of 79)</th>
<th>Accumulative Heat Load (BGHI-hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>76.27</td>
<td>- 0.455 (76.27 – 79 = - 2.73): - 2.73/6 = - 0.455</td>
<td>0[^a]</td>
</tr>
<tr>
<td>81.48</td>
<td>0.413 (81.48 – 79 = 2.48): 2.48/6 = 0.413</td>
<td>0.413 (0 + 0.413 = 0.413)</td>
</tr>
<tr>
<td>81.64</td>
<td>0.44 (81.64 – 79 = 2.64): 2.64/6 = 0.44</td>
<td>0.853 (0.413 + 0.44 = 0.853)</td>
</tr>
<tr>
<td>85.6</td>
<td>1.1</td>
<td>1.953</td>
</tr>
<tr>
<td>86.93</td>
<td>1.321</td>
<td>3.274</td>
</tr>
<tr>
<td>83.44</td>
<td>0.74</td>
<td>4.014</td>
</tr>
<tr>
<td>91.5</td>
<td>2.08</td>
<td>6.094</td>
</tr>
<tr>
<td>86.5</td>
<td>1.25</td>
<td>7.344</td>
</tr>
<tr>
<td>77.1</td>
<td>- 0.32</td>
<td>7.024 (7.344 – 0.32) = 7.024</td>
</tr>
<tr>
<td>73.5</td>
<td>- 0.9</td>
<td>6.124</td>
</tr>
</tbody>
</table>

\[^a\] In this example the heat balance is divided by 6 because weather data is being collected at 10-minute intervals. If weather data were collected at 15-minute intervals than the division would be by 4, and if 20-minute collections then by 3.

\[^b\] The heat balance is negative, and there is no accumulated heat load so the animal does not need to lose heat. Therefore the accumulation = 0.
3. RESULTS

3.1 Climatic Data

The climatic data over the study period, 2nd January – 27th March 2002, summarised in Table 3.1, were similar for all feedlots. The Queensland feedlots however experienced more days with BGHI > 80.

Table 3.1. The climatic ranges and averages (± s.d) for unshaded pens during the study period

<table>
<thead>
<tr>
<th>Variable</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days</td>
<td>76</td>
<td>84</td>
<td>77</td>
<td>79</td>
</tr>
<tr>
<td>T_a (°C)</td>
<td>11.9 – 40.0</td>
<td>12.8 – 36.3</td>
<td>9.0 – 37.2</td>
<td>8.9 – 38.7</td>
</tr>
<tr>
<td></td>
<td>(24.0 ± 4.9)</td>
<td>(23.4 ± 4.7)</td>
<td>(22.6 ± 5.3)</td>
<td>(22.1 ± 5.8)</td>
</tr>
<tr>
<td>BG (°C)</td>
<td>11.5 – 51.2</td>
<td>12.7 – 47.9</td>
<td>7.9 – 50.8</td>
<td>7.9 – 52.0</td>
</tr>
<tr>
<td></td>
<td>(27.3 ± 8.1)</td>
<td>(25.5 ± 6.8)</td>
<td>(25.8 ± 8.8)</td>
<td>(24.9 ± 8.7)</td>
</tr>
<tr>
<td>SR (W/m²)</td>
<td>0 – 1557.1</td>
<td>0 – 1231.7</td>
<td>0 – 1532.2</td>
<td>0 – 1521.7</td>
</tr>
<tr>
<td>WS (ms⁻¹)</td>
<td>0 – 11.5</td>
<td>0 – 11.4</td>
<td>0 – 12.4</td>
<td>0.0 – 14.8</td>
</tr>
<tr>
<td></td>
<td>(2.2 ± 1.5)</td>
<td>(1.9 ± 1.3)</td>
<td>(2.4 ± 1.7)</td>
<td>(2.2 ± 1.5)</td>
</tr>
<tr>
<td>RH (%)</td>
<td>17.3 – 98.1</td>
<td>24.9 – 94.6</td>
<td>21.8 – 98.5</td>
<td>16.0 – 96.1</td>
</tr>
<tr>
<td></td>
<td>(62.5 ±17.9)</td>
<td>(63.4 ± 16.6)</td>
<td>(59.7 ± 17.8)</td>
<td>(51.9 ± 18.5)</td>
</tr>
<tr>
<td>THI</td>
<td>53.8 – 84.6</td>
<td>55.1 – 82.3</td>
<td>49.6 – 83.4</td>
<td>49.2 – 82.7</td>
</tr>
<tr>
<td></td>
<td>(70.9 ±5.5)</td>
<td>(70.2 ± 5.4)</td>
<td>(68.8 ± 6.2)</td>
<td>(67.3 ± 6.6)</td>
</tr>
<tr>
<td>BGHI</td>
<td>53.2 – 103.1</td>
<td>55.0 – 96.0</td>
<td>48.1 – 101.4</td>
<td>47.7 – 101.9</td>
</tr>
<tr>
<td></td>
<td>(75.3 ± 9.7)</td>
<td>(72.9 ± 8.2)</td>
<td>(72.9 ± 10.7)</td>
<td>(70.9 ±10.3)</td>
</tr>
<tr>
<td>Days BGHI &gt; 80</td>
<td>73</td>
<td>67</td>
<td>56</td>
<td>43</td>
</tr>
<tr>
<td>Days BGHI &gt; 85</td>
<td>60</td>
<td>56</td>
<td>43</td>
<td>34</td>
</tr>
<tr>
<td>Days BGHI &gt; 90</td>
<td>29</td>
<td>27</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>Days BGHI &gt; 95</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

^ BGHI had to exceed these values for at least 1 hr during the day to be included.
3.2 High Heat Load Days

High heat load days are defined as those days when some cattle exhibit a panting score (PS) greater than zero (Table 3.2). Generally this occurred when BGHI exceeded 80. While at all the study feedlots the number of animals with a PS greater than 1 was low, more cattle exhibited a PS greater than 1 in unshaded pens than in the shaded pens.

The criteria for PS2 has been modified after further analysis of data collected at Feedlots A and B. In the future the conditions for PS 2 (refer Table 3.2) should in future specify "occasional open mouth panting or some saliva (drool or foam) present". A point system is also introduced, enabling a PS of 2.5 or 3.5. The modified guide better describes the animals status and is detailed in Appendix 4.

- Feedlot A – Shaded cattle – On 55 days PS’s greater than 0 were observed. On 49 of these days at least some cattle with a PS1 were observed, on 4 days PS2’s were observed, and on one day each a PS3 and PS4 were observed.

- Unshaded cattle – On 60 days PS’s greater than 0 were observed. On 24 of these days at least some cattle with a PS1 were observed, on 22 days PS2’s were observed and on 13 days PS3’s were observed. PS4’s were observed on one day.

- Feedlot B – Shaded cattle (59 days of study only) – On 38 days PS’s greater than 0 were observed. On 37 of these days cattle with PS1’s were observed and for one day only PS2’s were observed. No PS3 or PS4 were observed.

- Unshaded cattle – On 76 days PS’s greater than 0 were observed. On 46 of these days cattle with a PS1 were observed, on 26 days PS2’s were observed and on 4 days PS3’s were observed. No PS4’s were observed.

- Feedlot C – Shaded cattle – On 74 days PS’s greater than 0 were observed. On 47 of these days cattle with PS1 were observed, on 26 days PS2’s were observed and on one day PS3’s were observed.

- Unshaded cattle – On 73 days PS’s greater than 0 were observed. On 21 of these days cattle with PS1 were observed, on 36 days PS2’s were observed and on 16 days PS3’s were observed. No PS4’s were recorded.

- Feedlot D – Shaded cattle – On 21 days PS’s greater than 0 were observed. On 14 of these days cattle with PS1 were observed, and on 7 days PS2’s were observed. No PS3’s or PS4’s were observed.

- Unshaded cattle – On 26 days PS’s greater than 0 were observed. On 12 of these days PS1’s were observed, on 12 days PS2’s were observed and on 2 days PS3’s were observed. No PS4’s were observed.
Table 3.2. The number of cattle and their cumulative total (%) with panting scores of either 0, 1, 2, 3 or 4 for each feedlot over the study period.

<table>
<thead>
<tr>
<th></th>
<th>PS0</th>
<th>PS1</th>
<th>PS2</th>
<th>PS3</th>
<th>PS4</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Shaded</td>
<td>45208 (69.8%)</td>
<td>19140 (29.6%)</td>
<td>396 (0.6%)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>A Unshaded</td>
<td>32105 (58.1%)</td>
<td>19624 (35.5%)</td>
<td>3388 (6.1%)</td>
<td>92 (0.2%)</td>
<td>8 (0.1%)</td>
</tr>
<tr>
<td>B Shaded</td>
<td>23426 (93.5%)</td>
<td>1594 (6.4%)</td>
<td>36 (0.1%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B Unshaded</td>
<td>31541 (70.7%)</td>
<td>11296 (25.3%)</td>
<td>1678 (3.8%)</td>
<td>102 (0.2%)</td>
<td>0</td>
</tr>
<tr>
<td>C Shaded</td>
<td>72413 (82.4%)</td>
<td>14293 (16.3%)</td>
<td>1189 (1.3%)</td>
<td>11 (0.01%)</td>
<td>0</td>
</tr>
<tr>
<td>C Unshaded</td>
<td>50765 (67.5%)</td>
<td>18875 (25.1%)</td>
<td>4751 (6.3%)</td>
<td>822 (1.1%)</td>
<td>0</td>
</tr>
<tr>
<td>D Shaded</td>
<td>86642 (94.6%)</td>
<td>4372 (4.8%)</td>
<td>590 (0.6%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D Unshaded</td>
<td>81467 (91.5%)</td>
<td>6250 (7.0%)</td>
<td>1292 (1.5%)</td>
<td>53 (0.06%)</td>
<td>0</td>
</tr>
</tbody>
</table>
3.3 Cattle Behaviour

The location of cattle within a pen was evaluated three times daily during the study period (Table 3.3). Generally cattle spent more time standing than lying. At Feedlots A and B, it was usual to see 100% of cattle standing when BGHI exceeded 80 units.

3.3.1 Activity at water troughs

The number of grouped cattle around water troughs was generally not temperature related. There were similar numbers around the troughs at all feedlots when BGHI was greater than 85 as when BGHI was less than 78. Some crowding of the water trough was noted when BGHI exceeded 89 however. There was a tendency for more cattle to be drinking at the 0600 hours or 0700 hours observations.

- Feedlot A – There were more cattle around the water troughs in the unshaded pens (7 – 14%) then in the shaded pens (0 – 7%).
- Feedlot B – There were no significant differences between the unshaded (0 – 19%) and shaded pens (0 – 16%) in terms of number of cattle around the water troughs.
- Feedlot C – There were significantly more cattle around the water troughs in the unshaded pens (6 – 25%) then in the shaded pens (5 – 12%).
- Feedlot D – There were more cattle about the water troughs in the unshaded pens (1 – 8%) then in the shaded pens (0 – 4%).

3.3.2 Eating Behaviour and Feed Intake

Most cattle at feedlots A, B and C were observed eating at 1700 hours. At Feedlot D most cattle were observed eating at 0700 hours.

The eating times reflect the feeding programs employed by the respective feedlots. The average daily feed intake was affected by ambient temperature. When BGHI > 85 average daily declines of 8% or greater were observed. The impact was more severe when the maximums BGHI > 85 for four or more hours on two or more consecutive days. This is illustrated for unshaded cattle in Figure 3.1.

In Figure 3.1 the arrow indicates a 22.6% reduction in feed intake (14.6 to 11.3 kg) over a 3 day period. During this period the BGHI > 80 by 0700 hours on each day. On the first day the cattle were exposed to a BGHI > 80 for 4 hours, and > than 85 for 5 hours. The maximum BGHI on this day was 90.2. The maximum accumulated heat load on the first day was 70 hours, and did not return to 0 until 0200 h the following day. The cattle had a 0 heat load from 0200 hours until 0730 hours (~ 5 hours recovery) when BGHI was 81. On the second day the cattle spent 4 hours with a BGHI > 80, 4 hours with BGHI > 85 and 2 hours with BGHI > 90. Maximum BGHI on this day was 95.9 (1400 h). The maximum accumulated heat load on day 2 was 85 hours. The cattle returned to 0 heat load at 0400 hours on the third day. On the third day BGHI was again > 80 by 0730 hours. Therefore the cattle only had 3.5 hours of recovery. The third day was mild, with BGHI < 80 and this is reflected in the jump in feed intake.
In comparison over the same period the daily feed intake in the shaded pens fell by 9.9% (14.1 to 12.7 kg/head).

**Figure 3.1** Average daily feed intake (kg/head) for unshaded cattle over a 100 day period. (The thin line is the moving average).
Table 3.3. The number and percentage\(^{A}\) of cattle either standing or lying in the sun, standing or lying in the shade, at the water trough or at the feed bunk for observations three times daily.

<table>
<thead>
<tr>
<th>Feedlot</th>
<th>Stand/Sun</th>
<th>Stand/Shade</th>
<th>Ly/Sun</th>
<th>Ly/Shade</th>
<th>Water</th>
<th>Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Shaded</td>
<td>62 (39.5%)</td>
<td>29 (18.5%)</td>
<td>24 (15.3%)</td>
<td>13 (8.3%)</td>
<td>4 (&lt;0.1%)</td>
<td>25 (15.9%)</td>
</tr>
<tr>
<td>A Unshaded</td>
<td>86 (63.7%)</td>
<td>-</td>
<td>31 (22.9%)</td>
<td>-</td>
<td>5 (3.7%)</td>
<td>13 (9.6%)</td>
</tr>
<tr>
<td>B Shaded</td>
<td>38 (26.4%)</td>
<td>38 (26.4%)</td>
<td>39 (27.1%)</td>
<td>11 (7.6%)</td>
<td>4 (2.8%)</td>
<td>14 (9.7%)</td>
</tr>
<tr>
<td>B Unshaded</td>
<td>71 (47.9%)</td>
<td>-</td>
<td>53 (35.8%)</td>
<td>-</td>
<td>10 (6.8%)</td>
<td>14 (9.5%)</td>
</tr>
<tr>
<td>C Shaded</td>
<td>78 (20.9%)</td>
<td>113 (30.2%)</td>
<td>87 (23.3%)</td>
<td>58 (15.5%)</td>
<td>10 (2.7%)</td>
<td>28 (7.5%)</td>
</tr>
<tr>
<td>C Unshaded</td>
<td>147 (46.7%)</td>
<td>-</td>
<td>106 (33.7%)</td>
<td>-</td>
<td>28 (8.8%)</td>
<td>34 (10.8%)</td>
</tr>
<tr>
<td>D Shaded</td>
<td>135 (31.4%)</td>
<td>161 (37.4%)</td>
<td>75 (17.4%)</td>
<td>13 (3.0%)</td>
<td>8 (1.8%)</td>
<td>38 (8.8%)</td>
</tr>
<tr>
<td>D Unshaded</td>
<td>268 (64.1%)</td>
<td>-</td>
<td>98 (23.4%)</td>
<td>-</td>
<td>11 (2.6%)</td>
<td>41 (9.8%)</td>
</tr>
</tbody>
</table>

\(^{A}\) The percentages are based on the average number of animals per pen.

4. DISCUSSION

4.1 Assessment of Current Heat Load Indices

Six climatic spot indices were assessed as to their relevance in indicating the thermal status of feedlot cattle (refer 2.5). Of the six indices tested three, Index 2, 3 and 4 were rejected as being unsuitable as they did not adequately reflect cattle response to the given climatic conditions. Index 5 (ESI), originally developed for use with humans, had value but the numerical spread was too narrow to be of practical use with feedlot cattle, and it was also rejected.

The THI (Index 1) was determined to be a suitable spot index for shaded cattle and the BGHI (Index 6) a suitable spot index for unshaded cattle, following an adjustment for wind.

4.2 Development of New Heat Load Index (HLI)

The development of a new heat load index (HLI), necessitates, firstly determining the relative significance of the climatic variables which might be included, and secondly the ease with which the index output can be interpreted.

Addressing the second issue first, the traditional THI or BGHI output units are found to be easily understood and suitable, and present a satisfactory form for a new heat load index output.

With respect to the first issue, the overall importance of the three climatic variables, relative humidity, wind speed and black globe temperature stood out throughout the study.

Relative humidity (RH) had a major influence on panting scores when \(T_a\) exceeded 30 °C, and little impact when \(T_a\) was below 30 °C. RH is incorporated into the new heat load index.
Wind speed (Ws) in particular had an effect on panting scores, and an ameliorating effect on the thermal status of the cattle. Panting scores were reduced with increasing wind, even when the cattle were exposed to hot conditions. Ws is incorporated in the new index.

The tested models indicated that black globe temperature (BGT) had a stronger impact on panting scores than did solar radiation, and that there was a low correlation (0.55) between solar radiation and BGT. BGT is incorporated in the new index.

Inclusion of ambient temperature (T_a) in the model did not strengthen its effectiveness. T_a is excluded from the new index.

The heat load index \textbf{HLI} for \textbf{unshaded cattle} builds on the strength of the BGHI, and is expressed as:

\textbf{For when HLI >79} (unshaded cattle); For when HLI > 82 (unshaded cattle).

\[\text{Heat Load Index} = 33.2 + 0.24 \times RH + 1.2 \times BGT - 0.62 \times Ws \quad \text{Eqn.1}\]

\textbf{For when HLI <79} (unshaded and shaded cattle).

\[\text{Heat Load Index} \sim \text{BGHI} < 79 = 32.5 + 0.09 \times RH + 1.4 \times BGT - 0.57 \times Ws \quad \text{Eqn. 2}\]

Where;

- \(RH\) = relative humidity (%)
- \(Ws\) = wind speed (km/h)
- \(BGT\) = black globe temperature (°C)

Comparisons of the HLI\(^2\times3\) and BGHI under two climatic ranges are shown in Figures 4.1 and 4.2.

![Figure 4.1](image-url)  
Figure 4.1 Comparison of the BGHI and HLI at various wind speeds where BGT = 36 °C and RH =10%
Note 1: If BGT is not available, Ta could be used. However, as the correlation between BGT and Ta was only 0.88%, its use weakens the model.

Note 2: The HLI development is the result of observing pen climatic conditions and the cattle responses to these conditions, specifically panting scores. It is not however itself a panting score. The panting score should be used in conjunction with the index for maximum benefit.

Note 3: The following conditions are assumed to generally apply.

- Cattle are healthy with a black coat and a body condition score of 4+.
- Cattle are on feed for 100+ days.
- Air movement in pens is not restricted by outside structures.
- Cattle have access to high-energy (11+ MJ/kg DM) grain-based diets.

Figure 4.2 A comparison of the BGHI and HLI at various wind speeds where BGT = 40 °C and RH = 60%.

4.3 Accumulative Heat Load

The study again illustrated that the inclusion of an accumulated heat load (AHL) assessment provides a more meaningful indicator of the thermal status of cattle than a spot measure.

The measurement of AHL provides a meaningful indicator as to whether cattle have had sufficient night cooling to adequately recover from the previous days heat load. When the cattle have insufficient recovery (i.e. when accumulated heat load ≠ 0 for at least 4 hours) they tended to have higher panting scores and lower feed intake the following day even where the following day was slightly cooler.

The accumulated heat load index-hours (HLI-hours using the new index) will be able to progressively record the accumulative heat load for consecutive days.

This progressive HLI-hours tally, in conjunction with appropriate weather forecasts and ongoing observations as to the thermal status of cattle should alert feedlot management to possible approaching EHL problems in particular among vulnerable cattle.
The accumulative heat load is the key to an adequate assessment of the thermal status of feedlot cattle. The new heat load index (HLI) can satisfactorily form the basis of the accumulated heat load assessment (HLI-hours). A threshold level of 79 units is appropriate, above which cattle have a net gain of heat and below which they have a net loss of heat.

### 4.4 Heat Load Index (HLI) Thresholds

HLI thresholds have been estimated for various classes of feedlot cattle based on field and laboratory observations in Australia and in the USA (Table 4.1).

Above the HLI threshold values cattle will have a net gain of body heat, and, below the HLI threshold values they will have a net loss of heat.

The thresholds are difficult to predict due to a large number of interacting factors influencing the animals response to a given climatic condition. It is therefore important that feedlot management use cattle observations (i.e. panting scores) in conjunction with the estimates shown below.

Table 4.1 Estimated HLI thresholds for various classes of feedlot cattle with or without access to shade.

<table>
<thead>
<tr>
<th>Threshold Values</th>
<th>Unshaded</th>
<th>Shaded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newly arrived &lt; 2 weeks</td>
<td>74</td>
<td>74</td>
</tr>
<tr>
<td>Sick or recovering</td>
<td>73</td>
<td>73</td>
</tr>
<tr>
<td>Dark coated (black/dark red)</td>
<td>79</td>
<td>82</td>
</tr>
<tr>
<td>Light coated (white/grey)</td>
<td>82</td>
<td>84</td>
</tr>
<tr>
<td>Body condition score 3 – dark coat</td>
<td>79</td>
<td>82</td>
</tr>
<tr>
<td>Body condition score 3 – light coat</td>
<td>82</td>
<td>84</td>
</tr>
<tr>
<td>Body condition score 4 – dark coat</td>
<td>77</td>
<td>80</td>
</tr>
<tr>
<td>Body condition score 4 – light coat</td>
<td>80</td>
<td>82</td>
</tr>
<tr>
<td>No adaption</td>
<td>74</td>
<td>78</td>
</tr>
<tr>
<td>Adaption</td>
<td>82</td>
<td>84</td>
</tr>
</tbody>
</table>

*Lower thresholds may be appropriate for heifers (not spayed). HGP usage, type of shade structures and ration type will also influence the threshold.

### 4.5. Success in Meeting Project Objectives

The panting score photo guide has been developed and satisfactorily field tested and further refined with several minor modifications. It is now suitable for commercial feedlot application.

A new climate based heat load index (HLI) has been developed and will allow meaningful evaluation of the heat load status of feedlot cattle on a spot basis. This has been further developed to incorporate the accumulative heat load of cattle (HLI-hours).

There is a need for further software development to enable HLI-hours to be readily available to feedlot management as an on site aid in ameliorating the high heat load effects on the performance and welfare of feedlot cattle.
4.6. Impact on Meat and Livestock Industry

The adoption of the HLI-hours model by the Australian feedlot industry can improve summertime management of cattle. It provides the means of determining the thermal status of cattle at say 0600 hours (or at anytime of the day) and in conjunction with daily forecast weather determine the probability of future EHL situations and the need for corrective action.

This will enable management to minimize the adverse effects of high heat load on animal production and avoid adverse animal welfare situations which might otherwise be unfavourable for the Australian feedlot industry.

Its implementation could be encouraged by being a component in feedlot QA systems.

It needs to be pointed out that even with the adoption of this development cattle may still die from EHL in extreme hot summer conditions.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Results

High heat load in feedlot cattle is a result of local climatic conditions (i.e. in the pen) and animal factors which lead to an increase in body heat content beyond the animals’ normal physiological range and its ability to cope. By using a combination of observed local climatic conditions and animal responses to the climate (e.g. panting scores) feedlot management will be well placed to implement strategies to reduce the impact of severe hot weather conditions on their cattle.

The major conclusions from this study are:

- The modified Panting Score Guide is a useful management tool for assessing the thermal status of cattle.
- In vulnerable cattle the panting score moves from 0 to 1 at approximately 26 °C, and from 1 to 2 at approximately 33 °C.
- The THI index is a suitable spot index for shaded cattle but not unshaded cattle.
- Black globe temperature should be used instead of ambient temperature.
- Using the accumulative heat load (HLI-hours) for an index provides a better guide to the thermal status of cattle than the spot environmental conditions at a specific point in time.
The major recommendations from this study are that feedlot management monitor the thermal status of cattle by way of:

- Determining the existing THI and THI-hours for shaded cattle.
- Apply the new spot heat load index (HLI) in lieu of the current THI for unshaded cattle.
- Use the Panting Score Guide in conjunction with the HLI.
- Develop further the use of the new accumulative heat load index hours (HLI-hours) for general use.

5.2 Future Research

The new HLI and HLI-hours indices require ongoing assessment, refinement, and incorporation into a practical software package capable of recording the HLI-hours, for ready use by commercial industry.

It is recommended the following be completed.

- Refine the HLI through incorporation of provision for genotype, coat colour, body condition score, hair length, days on feed and ration type.
- Further refine the HLI-hours concept, in particular to recovery time under commercial feedlot conditions. This should proceed during summer 2002/2003.
- Further test the HLI and HLI-hours indices during summer 2002/2003 under commercial feedlot conditions and refine a suitable software package.

Also with respect panting scores:

- Clarify at what percentage of cattle in a pen with a PS of 2 or more constitutes a heat load problem.

6. BIBLIOGRAPHY


Sparke et al. 2001. Heat Load in Feedlot Cattle. MLA, North Sydney NSW.
Development of an excessive heat load index for use in the Australian feedlot industry.

**Progress Report FLOT.316 – Number 1.**

**General.**

During the period 22 November 2001 to 2 January 2002, data collection occurred at Sandalwood feedlot (4 days) and Kerwee feedlot (3 days). Data collected (hourly or two hourly) included the following: Panting scores, position in pen, feeding activity, and weather data (air temperature, black globe temperature, relative humidity, wind speed, cloud cover, and infrared ground temperature). These data have been used to help formulate or confirm the “stress” equations discussed in item 2 below.

**Item 1: Panting Score Photo Guide.**

The photo guide has been completed and has been distributed to E.A. Systems, and co-operator feedlots. The guide consists of 7 laminated pages. A panting score table, and seven photos of feedlot cattle with panting scores of 0 – 4 are included. The photo guide will be updated and modified through the duration of the project. A copy of the guide will be available if requested.

**Item 2: THI weightings.**

Eight equations are being evaluated. The equations are mostly based on existing data, including conventional THI equation. Additional data collected during November, December and January have been used to develop equations SI6 and SI7. The seven equations are been evaluated in conjunction with weather data, and cattle panting scores and behavioural data collected at feedlots.
Excessive Heat Load Index FLOT.316

SI1 0.8 x Ta + RH x (Ta - 14.4) + 46.4
SI2 31.6 + (0.28 x Ta) + (0.061 x Ta x Ta)
SI3 ((1.8 x Ta) + 32) - ((0.55 - (0.55 x RH/100)) x ((1.8 x Ta) - 26)
SI4 6.67 + 3.20 x Ta
SI5 (3.34 x THI) - 155.80
SI6 (0.89 x Ta) - (0.39 x WS) - 34.65
SI7 (1.33 x Ta) - (0.99 x WS) - 50.69

Ta = dry bulb temperature (°C)
RH = relative humidity in numeric form e.g. 0.55 NOT 55% for SI1, & as % in SI3
THI = equation SI1
WS = wind speed (m/s)

**Item 3: THI-hours**

The THI-hour concept was explained in “Heat Load in Feedlot Cattle” (FLOT 307, 308, 309), pages 39 – 40.

Our preliminary field data suggests that the THI-hours concept as outlined previously holds, with some modification.

In the heat load publication a THI of 73 was used as a lower threshold. Above this threshold it was assumed that cattle would be under a low level of stress. It would appear that this is too low for the cattle we have observed at both Sandalwood and Kerwee. Based on discussions with our US co-workers, and from previous data sets we will use a THI of 78 as the threshold THI for un-shaded cattle. Unshaded cattle can cope with THI between 78 and 83 by changing eating behaviour (either natural or management induced), and providing there is adequate air movement, access to water. Unshaded cattle exposed to a combined THI-hours of more than 15 hours per day above a THI of 84 are likely to be at risk, if they are exposed to this for 2 or more days – this is influenced by a number of factors (see following discussion).

Although the data is preliminary it would appear that for cattle with access to shade that the THI threshold maybe somewhat higher than for un-shaded cattle. Shaded cattle exposed to showed little signs of discomfort when THI was 81 (98% panting score = 0) compared to unshaded cattle exposed to THI of 79 (58% panting score 2 & 25% panting score 3).

A note of caution: Wind has a major influence and can substantially change the effect of hot conditions on cattle. Preliminary data (very small data set) suggests that the THI threshold for un-shaded cattle can be increased to a THI of 80 if wind speed is greater than 2 m/s. This concept will be further developed as the study progresses.

The degree of adequate night time cooling to negate day time heat load build up will be determined through the duration of the study.

The THI-hours concept will need further modification once we have sufficient 24-hour weather data, and panting score information from the feedlots (accumulation of these data commenced on 01/01/02).

John Gaughan
Appendix 2 - Second Progress Report

Feedlot Site Descriptions (Section 2.1.1 of the MLA.317 Draft Report)

Four feedlot sites were selected for the measurement of microclimatic conditions over the 2001/2002 summer period. Two of the sites were feedlot sites involved in project FLOT.310. Two additional sites, one each in Queensland and New South Wales, were added to these for data collection in FLOT.317. Site selection aimed at ensuring that the feedlots were representative of operations in eastern Australia. The four feedlots that were selected for the study are described below.

Feedlot A is located in southern Queensland on the Darling Downs some 16 km north east of Dalby (151°15' E, 27°10' S).

Feedlot A has a capacity of 18,000 head. Four individual pens were used for the cattle measurements. Each of these pens had an area of approximately 3200 m² and were stocked at an average density of 22 m²/head over the study. Two of the selected pens contain permanent 15 metre wide shade structures composed of galvanised iron sheets (see Plate 1). The pens are on a slope of about 2.5% with a westerly aspect.

Feedlot B is also located in southern Queensland on the Darling Downs. This feedlot is situated approximately 45 km to the south east of Feedlot A, and 14 km west of Oakey (151°43' E, 27°26' S).

The capacity of Feedlot B is 7,100 head. The area of the feedlot pens within which the automatic weather stations were installed were 3000 m². During the study period the stocking density of these pens averaged 19 m²/head. During early January, shade structures were constructed in newly developed pen areas and as such one of these shaded pens was utilised later in the study period. The shade structures consist of galvanised sheets with a minimum height of 4.8 metres, angled at approximately 5° with the low side to the west (see Plate 1).

Feedlot C is situated on the north west slopes and plains of NSW. The feedlot is located 65 km south west of Tamworth (150°56’ E, 31°05’ S) and 50 km south of Gunnedah (150°15’ E, 30°54’ S). The nearest BOM stations that record climatic data additional to rainfall are Tamworth Airport (station no. 55054), Gunnedah Airport (station no. 55202) and Barraba Post Office (station no. 54003).

This feedlot has an operating capacity of 25,000 head. The pens used for the cattle measurements had areas of 4,680 and 4,950 m² and were stocked at an average density of 14 to 15 m²/head. The pens had a slope of 3 to 4% with pens located on a ridge above a valley floor.

Feedlot D is located in the Murrumbidgee Irrigation Area (MIA) of southern NSW. The feedlot is situated 10 km south east of Yanco (146°24’ E, 34°36’ S). The closest BOM stations to this site are Narrandera Airport (station no. 074148), Narrandera Council Depot (station no. 074221), and Narrandera Post Office (station no. 074082).

Feedlot D has a capacity of 53,333 head. The pens at this site are larger than those at the other three feedlot sites and as such only two of the 6400 m² pens were used for the cattle and pen surface measurements. Over the project duration the stocking density of these pens averaged 15 m²/head. Both pens contained fixed pole structures that enabled a 15 metre wide strip of shade
cloth to be fastened across the length of the pen (see Plate 2). Management of the feedlot operation sees that the pens are shaded over the warmer months of December to March. For the purpose of the project the shade cloth was removed from one of these pens for the duration of the study. The pens at Feedlot D are on a slope of about 2 to 3% with a westerly aspect.
Cattle Comfort Measurements for Shaded Pens  
(Please Print Clearly)

Pen No:______________ Pulls: ___________ Mortalities:______________ Food intake:____________
Date:______________ Name of Recorder:_____________________ Sick Returns:__________ Average Weight:__________

6AM EST
N°. Head in pen__________
Pen Surface Condition: Dry Dusty / Smooth / Compact / Pugged / Saturated (Slurry)

<table>
<thead>
<tr>
<th>N°. outside shade</th>
<th>N°. using shade</th>
<th>Observations/Comments:</th>
</tr>
</thead>
<tbody>
<tr>
<td>N°. around water trough</td>
<td>N°. at feed:</td>
<td>N°. with each panting score</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

12Noon EST
N°. Head in pen__________
Pen Surface Condition: Dry Dusty / Smooth / Compact / Pugged / Saturated (Slurry)

<table>
<thead>
<tr>
<th>N°. outside shade</th>
<th>N°. using shade</th>
<th>Observations/Comments:</th>
</tr>
</thead>
<tbody>
<tr>
<td>N°. around water trough</td>
<td>N°. at feed:</td>
<td>N°. with each panting score</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

5PM EST
N°. Head in pen__________
Pen Surface Condition: Dry Dusty / Smooth / Compact / Pugged / Saturated (Slurry)

<table>
<thead>
<tr>
<th>N°. outside shade</th>
<th>N°. using shade</th>
<th>Observations/Comments:</th>
</tr>
</thead>
<tbody>
<tr>
<td>N°. around water trough</td>
<td>N°. at feed:</td>
<td>N°. with each panting score</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Definitions:
Pulls  Number of individuals removed from pens
N° around water trough  Standing close to water trough including those not drinking
N° at feed  In the process of ingesting feed at feed trough
Panting Score  See Table 1

Table 1. Breathing Condition, Respiration Rate and Panting Score.

<table>
<thead>
<tr>
<th>Breathing Condition</th>
<th>Respiration Rate (bpm)</th>
<th>Panting Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>No panting</td>
<td>Less than 40</td>
<td>0</td>
</tr>
<tr>
<td>Slight panting, mouth closed</td>
<td>40 – 70</td>
<td>1</td>
</tr>
<tr>
<td>Fast panting, occasional open mouth</td>
<td>70 – 120</td>
<td>2</td>
</tr>
<tr>
<td>Open mouth + some drooling</td>
<td>120 – 160</td>
<td>3</td>
</tr>
<tr>
<td>Open mouth, tongue out + drooling</td>
<td>&lt; 160°</td>
<td>4</td>
</tr>
</tbody>
</table>

SEE PHOTO SHEET FOR PANTING SCORES

\(^\text{A} \) Count respiration rate for at least 2 minutes
\(^\text{B} \) At this stage, RR may decrease due to change to deep phase breathing

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### Cattle Comfort Measurements for Unshaded Pens

(Please Print Clearly)

Pen No:__________________
Pulls: ____________ Mortalities:____________ Food intake:____________
Date:________________________ Name of Recorder:________________________ Sick Returns:__________ Average Weight:__________

**6AM EST**

N°. Head in pen

<table>
<thead>
<tr>
<th>N°. around water trough</th>
<th>N°. at feed:</th>
<th>N°. with each panting score</th>
<th>N°. Lying:</th>
<th>N°. Standing:</th>
<th>Observations/Comments:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

**Pen Surface Condition:** Dry Dusty / Smooth / Compact / Pugged / Saturated (Slurry)

**12 Noon EST**

N°. Head in pen

<table>
<thead>
<tr>
<th>N°. around water trough</th>
<th>N°. at feed:</th>
<th>N°. with each panting score</th>
<th>N°. Lying:</th>
<th>N°. Standing:</th>
<th>Observations/Comments:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

**Pen Surface Condition:** Dry Dusty / Smooth / Compact / Pugged / Saturated (Slurry)

**5PM EST**

N°. Head in pen

<table>
<thead>
<tr>
<th>N°. around water trough</th>
<th>N°. at feed:</th>
<th>N°. with each panting score</th>
<th>N°. Lying:</th>
<th>N°. Standing:</th>
<th>Observations/Comments:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

**Pen Surface Condition:** Dry Dusty / Smooth / Compact / Pugged / Saturated (Slurry)

### Definitions:

- **Pulls:** Number of individuals removed from pens
- **N° around water trough:** Standing close to water trough including those not drinking
- **N° at feed:** In the process of ingesting feed at feed trough
- **Panting Score:** See Table 1

### Table 1. Breathing Condition, Respiration Rate and Panting Score.

<table>
<thead>
<tr>
<th>Breathing Condition</th>
<th>Respiration Rate (^a) (bpm)</th>
<th>Panting Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>No panting</td>
<td>Less than 40</td>
<td>0</td>
</tr>
<tr>
<td>Slight panting, mouth closed</td>
<td>40 – 70</td>
<td>1</td>
</tr>
<tr>
<td>Fast panting, occasional open mouth</td>
<td>70 – 120</td>
<td>2</td>
</tr>
<tr>
<td>Open mouth + some drooling</td>
<td>120 – 160</td>
<td>3</td>
</tr>
<tr>
<td>Open mouth, tongue out + drooling</td>
<td>&lt; 160*</td>
<td>4</td>
</tr>
</tbody>
</table>

\(^a\) Count respiration rate for at least 2 minutes

\(^*\) At this stage, RR may decrease due to change to deep phase breathing

SEE PHOTO SHEET FOR PANTING SCORES

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Appendix 3 - Modified Panting Score Chart

<table>
<thead>
<tr>
<th>Breathing Condition</th>
<th>Panting Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>No panting – normal.</td>
<td>0</td>
</tr>
<tr>
<td>Slight panting, mouth closed, no drool or foam.</td>
<td>1</td>
</tr>
<tr>
<td>Fast panting, drool or foam present.</td>
<td>2</td>
</tr>
<tr>
<td>As for 2 but with occasional open mouth.</td>
<td>2.5</td>
</tr>
<tr>
<td>Open mouth + some drooling. Neck extended and head usually up.</td>
<td>3</td>
</tr>
<tr>
<td>As for 3 but with tongue out slightly.</td>
<td>3.5</td>
</tr>
<tr>
<td>Open mouth tongue out + drooling. Neck extended and head up.</td>
<td>4</td>
</tr>
<tr>
<td>As for 4 but head held down.</td>
<td>4.5</td>
</tr>
</tbody>
</table>

PS 0

PS 1

PS 2

PS 2.5
Excessive Heat Load Index FLOT.316

PS 3                                   PS 3.5

PS 4                                                     PS4.5
Appendix 4 - Testing validity of the HLI.

In testing the validity of the index we developed equations for each feedlot. The developed equations were similar between feedlots. The “heat load” index equations for Feedlots A, C and D are listed below. The similarity between the feedlots lends validity to the equation. We were unable to develop equations for Feedlot B due to problems with the weather stations.

Equation A1. \( HL = 29.96 + 0.12 \times RH - 0.44 \times Ws + 1.36 \times BG \) (all data).

Equation A2. \( HL = 30.08 + 0.11 \times RH - 0.52 \times Ws + 1.43 \times BG \) (for \( T_a \) below 30 °C).

Equation A3. \( HL = 31.81 + 0.24 \times RH - 0.62 \times Ws + 1.18 \times BG \) (for \( T_a \) above 30 °C).