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The effect of mud on cattle motivation for feedlot or pasture environments

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Executive summary

An animal's environment provides it with resources such as food to chew and swallow, shelter, surfaces to lie on and rub against, and social interactions. Individual resources and the environment that provides them can be beneficial, neutral or unpleasant to the animal. The animal engages with these resources through enacting behaviours to access or avoid the resources in order to fulfil its life history. The daily repertoire of behaviours, the animal's ethogram, is generally aligned with the circadian cycle, and includes periods of activity and rest. There is some elasticity in the way the daily time budget is expended. In periods of feed shortage cattle will spend more time grazing. In periods of extreme heat cattle will spend more time in shade during the heat of the day and more time grazing at night. During water shortage cattle will walk longer distances to drink.

When studying the effect of an animal's environment on its behaviour, the usual starting point is to establish its ethogram. However elasticity within the time budget makes it difficult to interpret from data in time budgets alone whether the animal is challenged by or coping with its environment. Some insight to this question is provided by testing the animal's preference for accessing the resources in one environment over another, for instance using a Y maze to let the trained animal choose between 2 environments such as pasture or feedlot. Further insight into the importance the animal places on access to resources is gained by imposing a cost to the choice, whereby when the animal chooses environment 1 it is denied access to environment 2 for a period of time relevant to the circadian behavioural pattern of the animal.

In B.FLT.0349 we established the daily lying pattern when cattle were given free choice to either a feedlot or pasture environment. In B.FLT.0149 we developed a Y-maze to test preference for pasture vs feedlot and examined the impact of a cost on the animals' choice. Interpreting behavioural data is not easy and usually no single test paradigm (e.g. ethogram, preference, cost etc.) unequivocally answers how important to the animal a resource is and how significant the impact on the animal of access to or lack of the ability to avoid a particular environment is. Does say a 10% reduction in time spent lying matter? Results from a single study need to be interpreted in light of other studies on cattle behaviour.

In this project we examine the impact of *ad libitum* feed availability (Experiment 1) and differing degrees of mud (Experiment 2) in the feedlot on preference for feedlot versus pasture. This project focuses on preference and lying time as the previous studies reported that cattle preferred the feedlot during the day where they met their daily nutritive requirements and the pasture at night where they lay down for 90% of the time.

In experiment 1, cohort 1 cattle showed a preference for the feedlot on days 2 to 8 of testing and cohort 2 showed a preference for the pasture on all 10 days of testing. Cattle spent more time lying in the paddock than in the feedlot and they tended to prefer the feedlot during the day and the paddock at night. Cattle also showed individual differences in their preferences for the feedlot or pasture environments, with some animals consistently preferring one or other of the environments. This may have contributed to the significant cohort effects which made it difficult determine the feedlot preferences under ad libitum feeding conditions. Nonetheless, it was evident that cattle did not find the feedlot environment aversive.

In Experiment 2, cattle showed no difference in their preference for the feedlot or pasture under differing feedlot pad scores. Cattle more frequently chose the pasture during the afternoon and had higher numbers of lying bouts of between 1 and 2% (transitions from lying to standing) with increasing feedlot mud levels. Cattle spent 5% more time lying at pasture and performed a greater number of steps. This research indicates that under the conditions of this experiment, cattle did not perceive the feedlot environment negatively even when it was muddy. Even at the higher levels of mud, cattle still chose to enter the feedlot and showed an equal preference for the feedlot or pasture.

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1 Background

Two previous projects have examined the motivation of cattle to access a feedlot or pasture environment. The initial study (B.FLT.0349) employed the accepted practice of ‘free choice testing’, and showed that the two strong preferences of cattle were to access the feedlot during the day where they consumed the majority of their daily nutritive requirements, and to access the pasture at night where they mainly lay down to rest.

The second study (B.FLT.0149) utilised the Y-maze methodology, which enabled the imposition of a “cost” on the animal’s decision, and assessed motivation to enter either the feedlot or pasture environment. This work demonstrated that cattle showed a preference for the feedlot when there was a cue associated with feeding and that they were willing to pay the cost of their choice by then being unable to access the pasture. However, further work is needed to assess cattle choice under ad libitum feeding conditions which are more reflective of a commercial feedlot. This will be examined in the first experiment contained in this report.

Both previous studies showed that cattle had a tendency to access the feedlot less during periods of rain. In the B.FLT.0349 project, cattle in the commercial feedlot environment at Tullimba were found to spend less time in the feedlot with increasing rain events. In the B.FLT.0149 project, there was also a trend for cattle to spend less time in the feedlot with increasing rain events. However, as there were very few rain events during the study, examination of the relationship between feedlot preference and feedlot pad score was limited. There is a need to objectively assess feedlot preferences independent of the influence of rain by artificial wetting of the surface.

Wet and muddy pen conditions add to the negative public perception of feedlots, and there is a lack of scientifically defensible evidence to either support or counter such claims. Given the Y-maze testing model is now developed, the next stage is to test the hypothesis that ‘cattle preference for the feedlot declines as muddy conditions increase’, and provide industry with objective data on cattle perception of muddy conditions. Experiment 2 of this project will assess cattle motivation for a feedlot or pasture environment under differing feedlot pad conditions and will provide industry with objective, science-based information on the influence of mud on motivation of cattle for feedlot or pasture environments.

2 Experiment 1: feedlot preference of cattle provided with an ad libitum diet

Abstract

Experiment 1 was conducted to assess cattle motivation to access a feedlot or pasture environment when cattle received *ad libitum* feeding. Following habituation to the pasture for 10 days and feedlot for 10 days, cattle were trained to learn the location in a Y-maze of a feedlot and pasture environment. Twenty Angus steers were tested twice daily in a Y-maze (08:30h and 16:00h) for 10 days and then four times daily for 9 days to determine their choice to enter a feedlot or pasture environment. Cattle were fed a feedlot starter diet ad libitum whilst in the feedlot. For the twice daily testing, there was a significant effect of cohort on the choice for pasture or feedlot ($P<0.001$). Cohort 1 cattle showed a preference for the feedlot on days 2 to 8 of testing and cohort 2 showed a preference for the pasture on all 10

days of testing (P<0.01). There were no significant effects of the three weather variables (rainfall, min. and max. temperature) or day on the choice of paddock vs feedlot (all *P*>0.80). There were no significant effects of pad score (P=0.505) and side of testing (P=0.435) and cattle showed a tendency to choose the pasture for the 16:00 h testing (P=0.06). For the four times a day testing, cohort 1 cattle showed a preference for the pasture on day 1 and then no preference for either the feedlot or pasture environment on the next 8 days and cohort 2 showed a preference for the pasture on all 10 days of testing (P<0.01). There was a tendency for time of day to affect choice (P=0.098). For the twice daily testing, behavioural recordings indicate that cattle spent on average 42 minutes more time lying in the paddock than in the feedlot per day (9h 6 min vs 8h 24 min respectively; P=0.0004) and cattle tended to prefer the feedlot during the day and the paddock at night (P=0.06). Increasing pad scores (mud levels) were significantly related to reduced lying in the feedlot with an 8% reduction from pad score 1 to pad score 3 and reduced number of lying bouts (both P<0.0001). Cattle also showed individual differences in their preferences for the feedlot or pasture environments, with some animals consistently preferring one or other of the environments. This may have contributed to the significant cohort effects which made it difficult determine the feedlot preferences under ad libitum feeding conditions. Nonetheless, it was evident that cattle did not find the feedlot environment aversive as they chose to enter the feedlot and did not show a strong preference for the pasture.

2.1 Objectives

Provide objective, science-based information on the motivation of cattle to access feedlot or pasture environments under ad libitum feedlot feeding conditions.

2.2 Materials and Methods

2.2.1 Ethical approval of animal experimentation

The protocol and conduct of the study were approved by the McMaster Laboratory Animal Ethics Committee, under the New South Wales Animal Research Act 1985.

2.2.2 Animals and facilities

The experiment was conducted at Armidale NSW, Australia from October till December 2014. The average daily minimum temperature was 10.6 ºC and the average daily maximum was 24.1 ºC. A Y-maze testing facility (maze approximately 12 m long, 1.8 m high) was constructed consisting of two Y-mazes leading to an option of a feedlot or 9 acres of pasture (See ***Figure 1***). The feedlot was 162 m^2 in size (15 x 10.8 m) which was sufficient to contain the animals at the recommended feedlot density of at least 9 m^2 per animal (Model code of practice for the welfare of animals Cattle, PISC, 2004). The feed was placed in two troughs (0.65 m wide x 0.55 m high x 2.9 m long). A shelter covered the feed bunker to prevent feed spoilage by rain. The shelter was orientated to ensure that no shade was provided to cattle in the feedlot. The feedlot pad was prepared by laying a gravel base that was covered with a feedlot compost (250 mm thick) which was rolled to form a pad that was well drained and sloped. As it is not commercial practice in Australia to use bedding, no bedding was added to the feedlot pad. The feedlot and pasture environments contained identical water troughs and water from the same source. No shelter, trees or shade were offered in either environment. The pasture was of a quality and type typical for extensively farmed cattle. The

Y-maze walls were opaque to ensure cattle could not see through using split belt (Andromeda Engineering, Moonbi, Australia).

A total of 22 Angus steers were used for the study. All cattle were tested in a Y-maze to determine their natural side preference. Side preferences vary between individuals with some behaviours preferentially performed by one side of the body and are the effect of brain lateralization on the way information is processed by animals. Cattle were weighed and flight speed tested to allocate to 2 cohorts of 10 animals by balancing for weight, side preference and flight speed. Cohort 1 were 410 ± 4.7 kg and cohort 2 were 460 ± 7.5 kg (body weight, mean ± SEM) at the start of the experiment. Two steers were kept as spare animals and were used as companions when required.

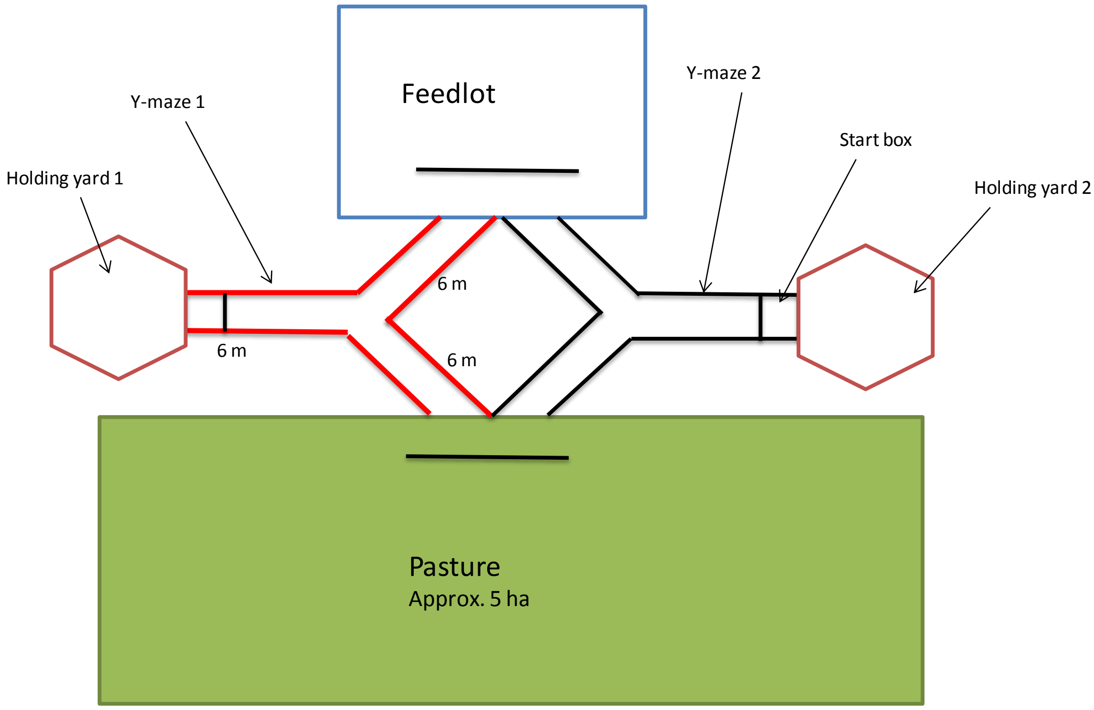

Figure 1. The design of the testing facilities

2.2.3 Feedlot Diet

The feedlot feed was a starter feedlot diet provided by Tullimba feedlot, The University of New England. The diet was prepared every 2 to 3 days and stored in sealed containers at the site of the feedlot. The diet nutritional analysis for the cohorts is shown in Table 1. The feedlot diet was available ad libitum whilst animals were in the feedlot and was refreshed several times throughout the day.

Table 1. Diet nutritive analysis (% of dry matter)

Component	Cohort 1	Cohort 2
Crude protein (%)	14	14
Neutral detergent fibre (%)	29	29
Acid detergent fibre (%)	15	15
Fat (%)	3.6	4
Metabolisable energy (MJ/kg DM)	11.9	12

2.2.4 Habituation and training

Cohort 1 were first habituated to the pasture (10 days) and feedlot (10 days). During habituation cattle in the feedlot were fed an ad libitum starter diet (to mimic the normal feedlot experience). Next, they were trained in the Y-maze to learn the direction of the feedlot and pasture environments. Each animal performed 12 forced trials per day (alternating between feedlot and pasture) for 3 consecutive days (total of 36 trials each). There were 6 trials per maze per day. A visual cue (A4 size black X on laminated paper) was placed at the feedlot side on the Y-maze at cattle head height to facilitate animals learning the side of the feedlot and pasture. Following training, icetags (IceRobotics, Scotland) were placed on the cattle to monitor standing and lying behaviours and cattle were placed in the feedlot overnight.

2.2.5 Y-maze testing twice daily

Next, cattle were tested from alternate Y-mazes on each day. At approximately 08:00h on the morning of testing, individual cattle were brought into the holding pen and introduced into the start box where they were given a choice of accessing pasture or the feedlot. Animals were confined to the feedlot or pasture environment once they made a choice in the Y-maze. The two spare cattle were used as companion animals where needed (e.g. if only one animal chooses the pasture or feedlot). At approximately 16:00h, cattle from each environment were moved back into the holding pen for Y-maze testing. This was repeated for 10 consecutive days. Testing in the morning and in the evening enables the effect of time of day to be assessed. This process was repeated for cohort 2. Testing commenced in the alternate holding pens to balance the design and account for side biases.

2.2.6 Y-maze testing 4 times per day

Following the twice daily testing, we examined feedlot choice 4 times per day (07:00h, 11:00h, 15:00h and 19:00h). This testing regime reduces the cost of their choice by enabling them to make a decision more often throughout the day. Cattle were tested for 9 consecutive days. Cohort 2 were tested following completion of cohort 1. Behaviour monitoring devices (Icetags) were placed on the animals prior to testing and removed at completion of testing.

2.2.7 Pasture

Pasture samples were collected from the paddock using a quadrant during habituation to pasture and at the start of testing each cohort. This involved collecting 10 samples from the paddock. Samples were oven dried at 65°C for 4 days for calculation of dry weight. Pasture nutritive values are shown in ***Table 2***. Following this, samples will be analysed for nutritive value by the Department of Primary Industries, Wagga Wagga, NSW, Australia.

Table 2. Pasture nutritive analysis (% of dry matter).

Pasture measure	Cohort 1	Cohort 2
Neutral detergent fibre (%)	61.5	66
Acid detergent fibre (%)	36	40
Crude protein (%)	6.8	8.0
Dry matter digestibility (%)	54.5	52
Dry organic matter digestibility (%)	56.5	54
Organic matter (%)	92.5	93
Metabolisable energy (MJ/kg DM)	8.1	8
Herbage mass (kg DM/ha)	2007	1930

2.2.8 Climate

Daily temperature and rainfall were recorded daily from a portable weather station and are shown in Table 3. Feedlot pad conditions were scored as values between 1 and 5 as illustrated in the Appendix.

Table 3. Daily average climatic conditions and feedlot pad score for the twice and four times daily testing.

Average	**Cohort 1**	**Cohort 2**
Twice daily testing		
Total rainfall (mm/day)	113	26
Minimum temperature (ºC)	12.4	6.8
Maximum temperature (ºC)	26.0	18.6
Feedlot pad score (1-5)	1.8	1.1
Four times daily testing		
Total rainfall (mm/day)	2	12
Minimum temperature (ºC)	11.9	11.6
Maximum temperature (ºC)	26.8	25.3
Feedlot pad score (1-5)	1	1.1

2.2.9 Statistical analysis

To analyse the preference data (paddock vs feedlot), a logistic generalised linear mixed model was used to model the probability of the animal selecting a paddock (1) vs a feedlot (0). The form of the model was as follows:

$$\log_e\left(\frac{\pi}{1-\pi}\right) = \text{constant} + \text{PadScore} + \text{Day} + \text{Time} + \beta_1\text{Rainfall} + \beta_2\text{MinTemp} + \beta_3\text{MaxTemp} + \text{Cohort} + \text{Animal}$$

where π = P(Y = 1), i.e. probability that the animal chooses a paddock; Pad score, Day, Time and Side were fixed effects (factors); Cohort, Rainfall, MinTemp, and MaxTemp were fixed effects (covariates); and Animal was a random effect. The model was fitted using ASReml-R (Butler et al., 2009). Preference for choosing the feedlot was tested by comparing the observed choice to random chance (50%). The hypothesis was that if animals have no preference for the feedlot or pasture they would choose the feedlot and pasture environments an equal amount of time. Data were analysed using ASReml in a linear model to calculate the mean preference. In the model, the dependent variable was Preference (0 for pasture, 100 for feedlot) and fixed effects were fitted for day (20 days in total; 1 to 10 for cohort 1 and 11 to 20 for cohort 2) and time of day (AM vs. PM). 95% confidence intervals were calculated as the mean +/- 1.96 SEM. In addition, the effect of weather conditions were tested looking at rainfall, minimum and maximum temperature and feed pad score which were fitted separately as covariates to the base model.

To analyse the standing and lying behaviour, the data were considered as a binary outcome, i.e. whether or not the animal stands for any amount of time of the 15-min interval.

$$\text{Stand} = \begin{cases} 1 & \text{Standing time} > 0 \\ 0 & \text{Standing time} = 0 \end{cases}$$

A logistic generalised linear mixed model (GLMM) was used to analyse these binary data. However, the standing / lying status of an animal at one point of time (t) was very dependent on what it was doing at the last point of time (t – 1), so this serial dependence was taken into account in the model. In addition, since the data were collected over 24-hour periods, the analysis included a 24-hr period effect, and this was incorporated by the use of sine-cosine

$$\log_e\left(\frac{\pi_i^{(\text{Stand})}}{1-\pi_i^{(\text{Stand})}}\right) = \text{constant} + \text{PadScore} + \text{Location} + \text{Stand}_{t-1} + \text{Day} + \beta_S S + \beta_C C + s(S) + s(C) + \text{AnimalID}$$

where

$\pi_i^{(\text{Stand})}$ = probability of animal standing at time t, i.e. $P(\text{Stand}_t = 1)$

and

Pad score = effect pad score 1, 3, or 5;
Location = effect of feedlot, or paddock;
Stand_{t-1} = effect of Stand status in the previous 15-min interval; and
Day = effect of day 1, 2, …, 10

are fixed factor effects; and

$S = \sin(2\pi h/24)$ and $C = \cos(2\pi h/24)$ with h being the time (hr) of the data ($0 \le h < 24$)

are fixed covariate effects; and

$s(S)$ and $s(C)$ are smooth spline functions of S and C; and
AnimalID = random effect of the animal.

Note that the fixed effects of S and C provide a sinusoidal 24-hr cycle, while the smooth spline functions allow a smooth deviation from a strict sine function form, but still imposes a 24-hr cycle. The model was fitted using ASReml-R (Butler 2009). Note that for the formulation of splines in ASReml-R, they are specified as part of the random effects model. Significance testing of fixed effects was conducted using Wald F-tests.

Data for the number of steps an animal is recorded in consecutive 15-min periods. However, there are many intervals where no steps are taken, resulting in a “spike” at zero steps. Consequently, a two stage modelling approach was adopted: 1) model for the probability that steps were taken (vs standing still), and 2) a model for the number of steps (# Steps) taken, conditional on at least one step being taken, i.e. excluding data where no steps were taken.

This analysis was conducted as follows. Initially, we define

$$\text{Step} = \begin{cases} 1 & \#\text{ Steps} > 0 \\ 0 & \#\text{ Steps} = 0 \end{cases}$$

The model for $P(\text{Step}_t = 1) = \pi_i^{(\text{Step})}$ proceeds as in the above model for $P(\text{Stand}_t = 1) = \pi_i^{(\text{Stand})}$ with the prior dependence term Stept–1 replacing Standt–1. The model for # Steps, conditional on the animals moving, is the following linear mixed model:

$$\log_e\left(\#\text{ Steps}_i\right) = \text{constant} + \text{PadScore} + \text{Location} + \text{Step}_{t-1} + \text{Day} + \beta_S S + \beta_C C + s(S) + s(C) + \text{AnimalID} + \varepsilon$$

where all the terms are the same as in the Stand model, and where ε is a random error.

Note that the counts (# Steps_i) were sufficiently large to warrant the use of a linear mixed model (on log-transformed data) as opposed to a Poisson GLMM. ASReml-R was again used for fitting both models.

Finally, overall model-based mean counts were estimated as $\hat{\pi}_i^{(\text{Step})} \times \hat{\mu}_i^{(\text{Step})}$ where $\hat{\pi}_i^{(\text{Step})}$ is the estimated probability of an animal stepping, and $\hat{\mu}_i^{(\text{Step})}$ is the estimate means number of steps, given an animal makes at least one step (calculated as the back-transformed mean, given the model was fitted on a logarithmic scale). The standard error of these overall means are calculated as $\left\{\text{se}[\hat{\pi}_i^{(\text{Step})}]^2 \times \text{se}[\hat{\mu}_i^{(\text{Step})}]^2 + \text{se}[\hat{\pi}_i^{(\text{Step})}]^2 \times [\hat{\mu}_i^{(\text{Step})}]^2 + [\hat{\pi}_i^{(\text{Step})}]^2 \times \text{se}[\hat{\mu}_i^{(\text{Step})}]^2\right\}^{1/2}$, where $\text{se}[\hat{\pi}_i^{(\text{Step})}]^2$ and $\text{se}[\hat{\mu}_i^{(\text{Step})}]^2$ are the squared standard errors for the estimates of $\hat{\pi}_i^{(\text{Step})}$ and $\hat{\mu}_i^{(\text{Step})}$, respectively.

The number of lying bouts has been modelled using a Poisson GLMM. The following model was fitted to the data:

$$\log_e \lambda_i = \text{constant} + \text{PadScore} + \text{Location} + \text{Stand}_{t-1} + \text{Day} + \beta_S S + \beta_C C + s(S) + s(C) + \text{AnimalID}$$

where λi = mean number of lying bouts, and the remainder of the terms in the model are as defined above.

2.3 Results

2.3.1 Preferences for the feedlot or pasture environment

2.3.1.1 Y-maze testing twice daily

Daily preference for the feedlot is shown in Figure 2. There was a significant cohort x day interaction with cohort 1 cattle showing a preference for the feedlot on days 2 to 8 of testing and cohort 2 showing a preference for the pasture on all 10 days of testing (P<0.01). There was a significant effect of cohort on the choice for pasture or feedlot (P<0.001; Figure 3). Cattle showed a tendency to choose the pasture for the PM testing (P=0.06; Figure 4). There were no significant effects of the three weather variables (rainfall; Figure 5, min. and max. temperature) or day (Figure 6) on the choice of paddock vs feedlot (all P>0.80). There were no significant effects of pad score (P=0.505; Figure 7) and side of testing (P=0.435; Figure 8).

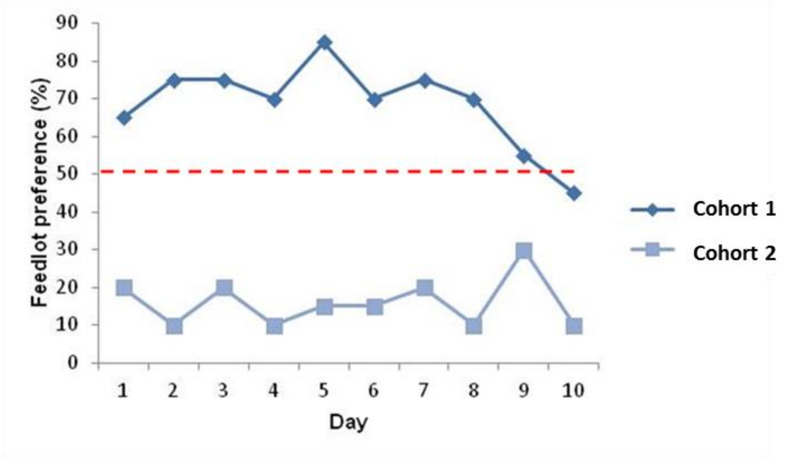

Figure 2. Mean preference for the feedlot for Cohort 1 and Cohort 2 when tested twice daily (08:00 h and 16:00h). The red line indicates the 50% chance level. SEM = 9.34.

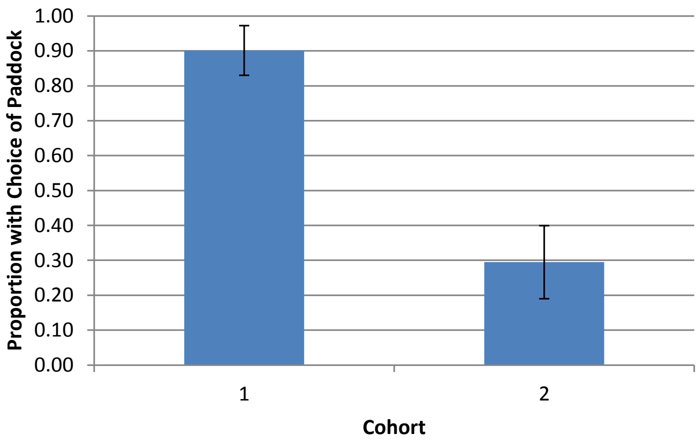

Figure 3. Estimated model-based proportions of cohort effects on choice for the paddock. Cohort 2 chose the paddock significantly more than cohort 1.

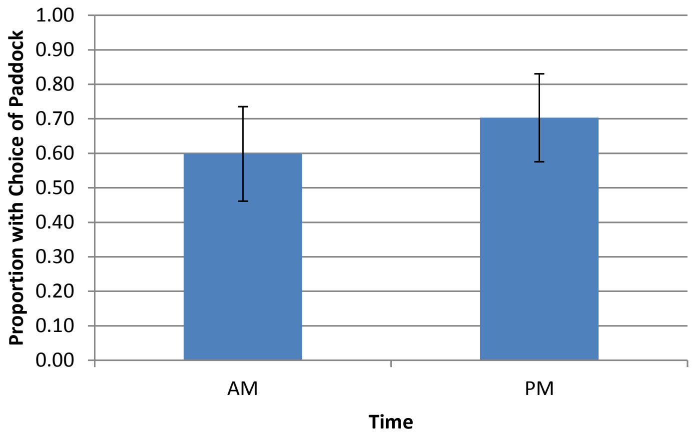

Figure 4. . Estimated model-based proportions of cattle choosing the pasture when tested at 08:00h and 16:00h. There was a tendency for cattle to choose the paddock at the 16:00 h testing.

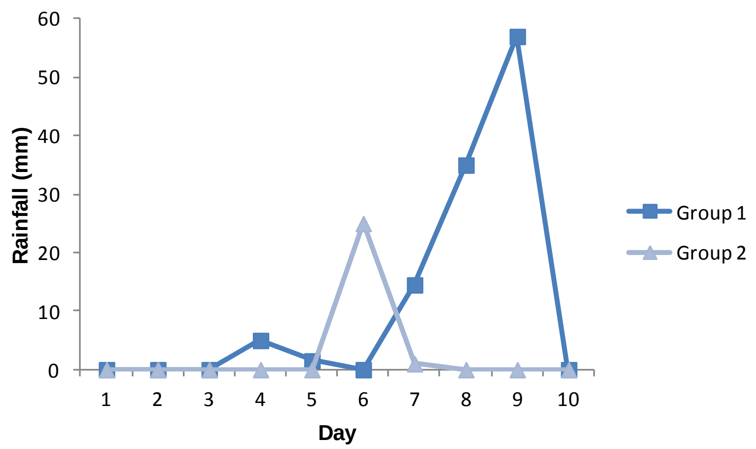

Figure 5. Daily rainfall for cohort 1 and 2 for the twice daily testing.

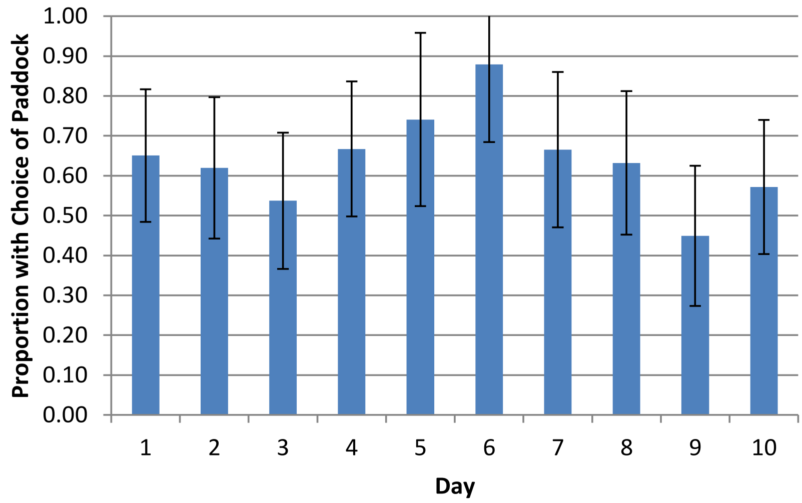

Figure 6. . Estimated model-based proportions of cattle choosing the pasture when tested twice daily over 10 days of testing. There was no significant effect of day.

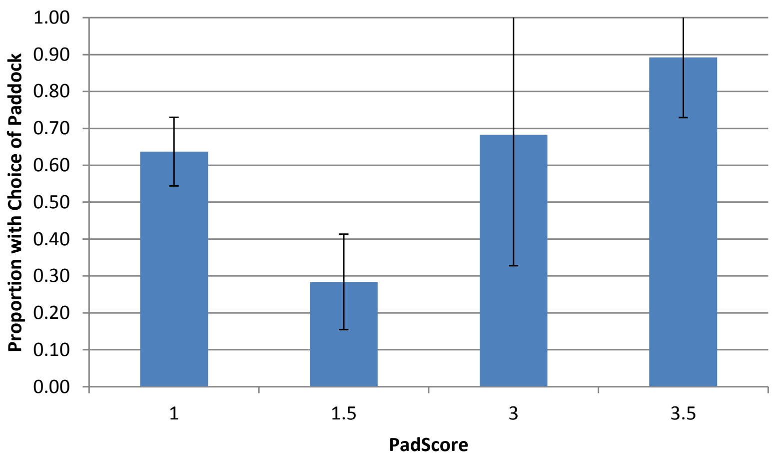

Figure 7. Estimated model-based proportions of cattle choosing the pasture when tested twice daily at pad scores measured during the experimental period (means +/- sem). Pad score did not significantly affect choice.

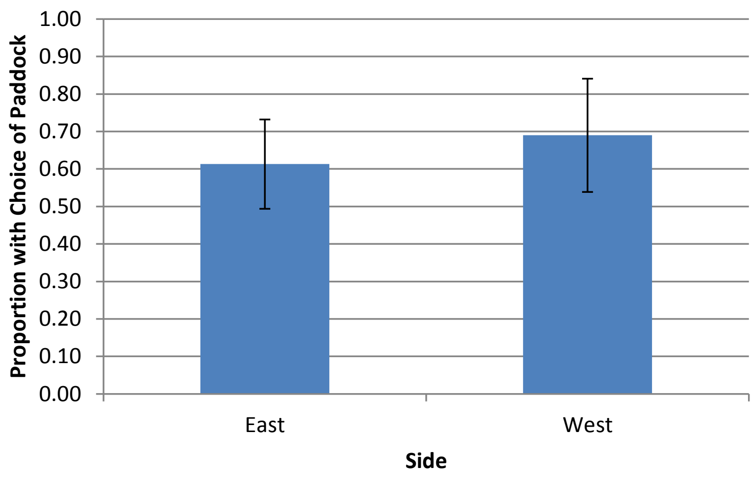

Figure 8. . Estimated model-based proportions of cattle choosing pasture when tested twice daily from the 2 different mazes (oriented to the east and west). Side tested on did not significantly affect choice.

2.3.1.2 Y-maze testing 4 times per day

There was a significant cohort x day interaction with cohort 1 cattle showing a preference for the pasture on day 1 and then no preference for either the feedlot or pasture environment on the next 8 days of testing and cohort 2 showing a preference for the pasture on all 10 days of testing (P<0.01; see Figure 9). There were no significant effects of rainfall (P=0.101), minimum temperature (P=0.813) and maximum temperature (P=0.809) on choice for the paddock vs. feedlot. Cohorts differed significantly in their choice for the paddock vs. feedlot (P<0.001). There were tendencies for pad score (P=0.085; Figure 10) and time of testing to affect choice (P=0.095; Figure 11). The maze side that the cattle were tested on significantly affected choice for the feedlot or pasture (P=0.028; Figure 12).

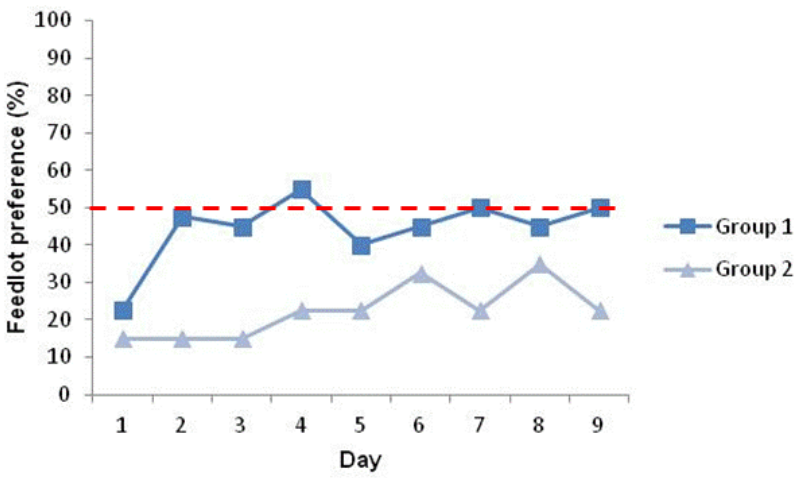

Figure 9. Mean preference for the feedlot for Cohort 1 and Cohort 2 when tested four times daily (07:00 h. 11:00 h, 15:00 h and 19:00h). The red line indicates the 50% chance level. SEM = 7.22.

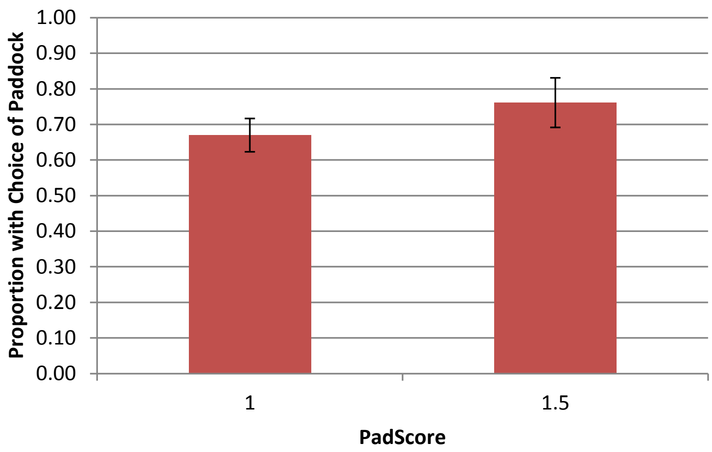

Figure 10. Estimated model-based proportions of cattle choosing the paddock at the pad scores experienced during the experimental period when tested four times per day.

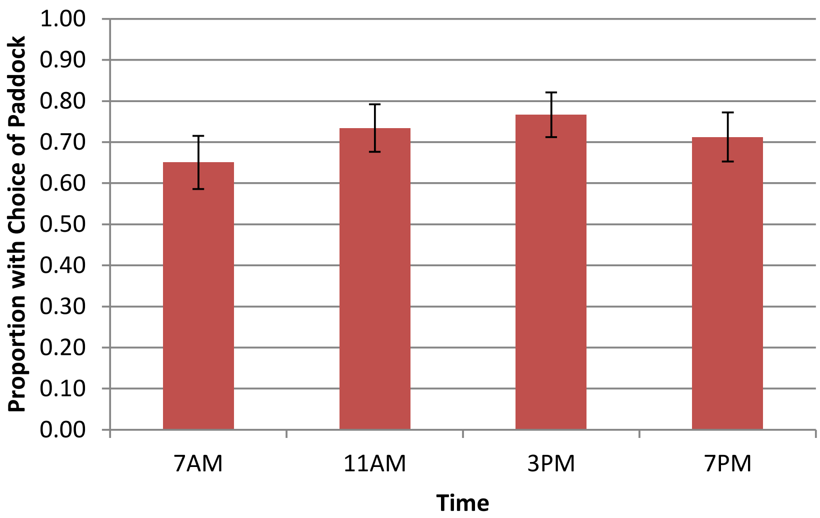

Figure 11. Estimated model-based proportions of cattle choosing the pasture when tested at four times of the day.

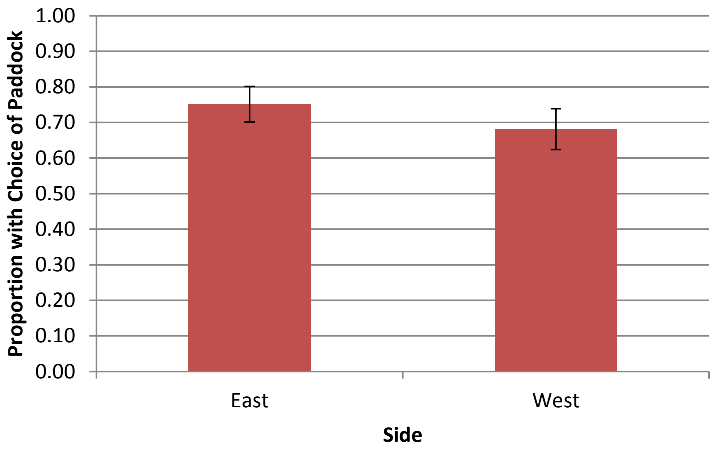

Figure 12 . Estimated model-based proportions of cattle choosing the pasture when tested from the 2 mazes (east and west) four times daily.

2.3.2 Individual differences in feedlot preferences

There is evidence of significant between animal variation (individual differences), with an estimated variance component of 1.87 ± 0.83 (for Two times testing) and 0.67 ± 0.28 (for Four times testing). The estimated animal effects (on the logit scale) for each animal when assessed 'Two times; vs 'Four times' is shown in Figure 13. There is clearly much consistency (correlation: r = 0.732), suggesting the estimate effects are indeed indicative of individual animal preferences. Averaging across the two estimates, these range from -1.42 (Animal 87) i.e. least likely to choose the paddock, to +1.77 (Animal 2) that is most likely to choose the paddock.

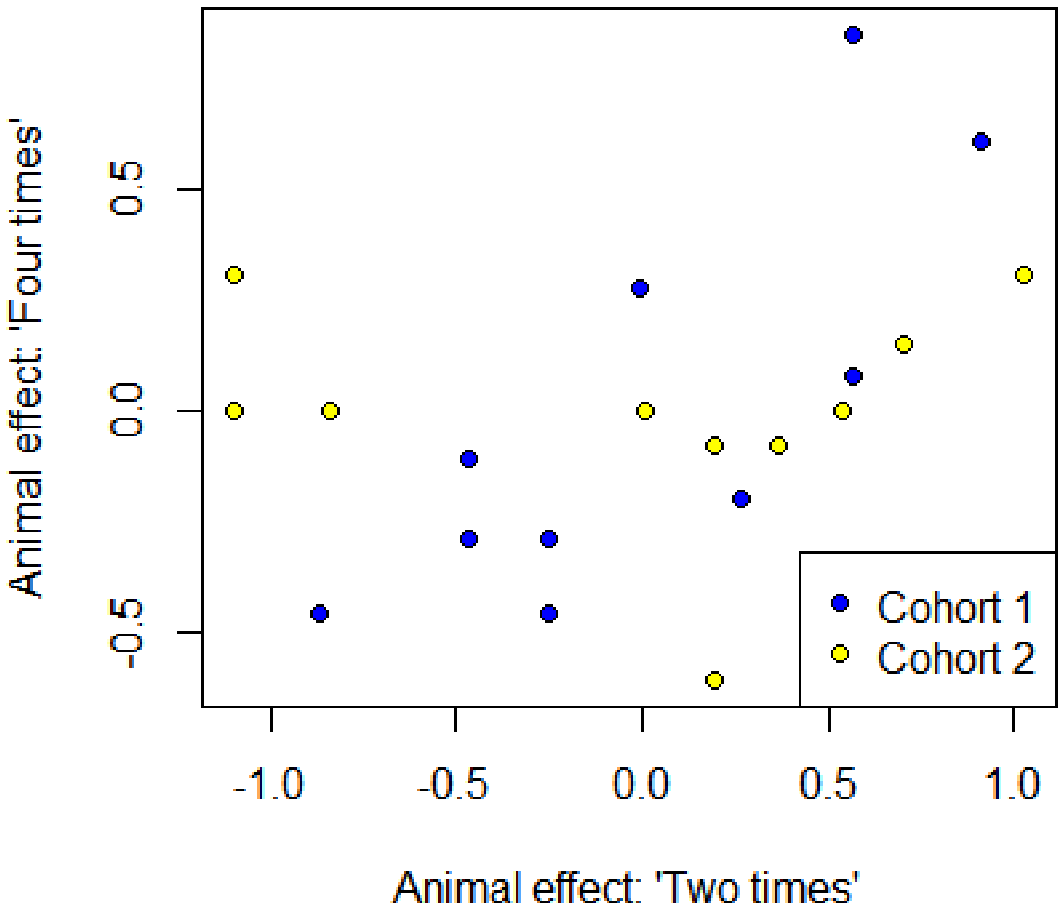

Figure 13. Estimated animal effects on the logit scale for each animal when tested at the different times.

2.3.3 Behaviours in the feedlot and pasture environments (twice daily testing)

2.3.3.1 Standing/Lying

Behaviours are only presented for the twice daily testing of cattle. Results are presented as proportion of time spend standing which also indicates the time spent lying because if cattle are not standing then they are lying (i.e. these behaviours add to 100% and are mutually exclusive). For standing behaviours, there were significant effects of location ($P=0.0004$; Figure 14), when animals were in the paddock, they were least likely to be standing (most likely to be lying). Cattle spent on average 42 minutes more time lying in the paddock than in the feedlot per day (9h 6 min vs 8h 24 min respectively). Pad score was a significant effect with standing increasing significantly as the pad score increased, i.e. reduced lying with increasing pad score (lying times of 9h 38 min for pad score 1 vs. 7h 43 min for pad score 3.5; $P<0.0001$; Figure 15). There were no statistically significant differences across the ten sampling days, and no discernible trend was apparent ($P = 0.119$; Figure 16).

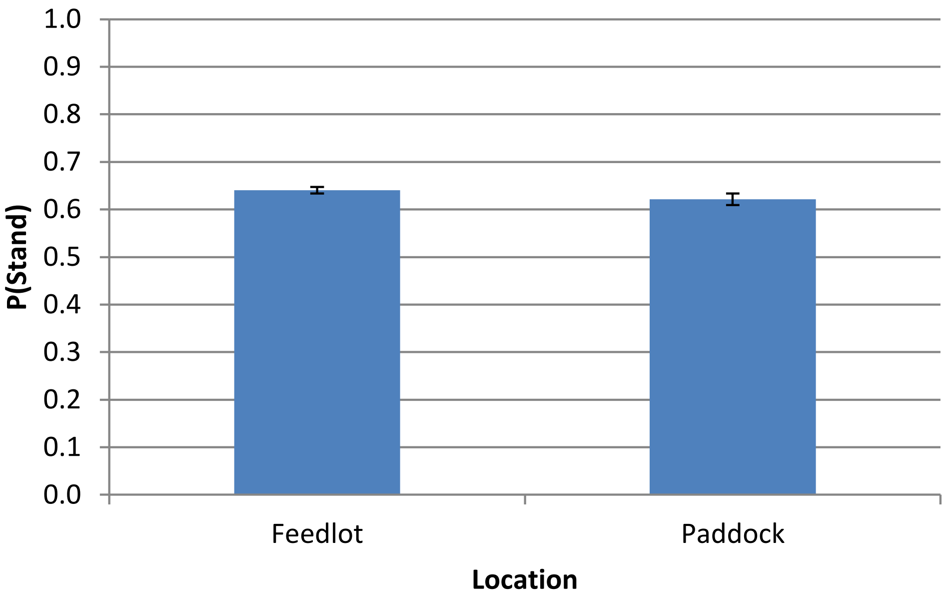

Figure 14. Estimated model-based proportions of time spent standing when cattle are located in the feedlot or paddock. There was a significant difference with cattle standing more when in the feedlot than in the paddock.

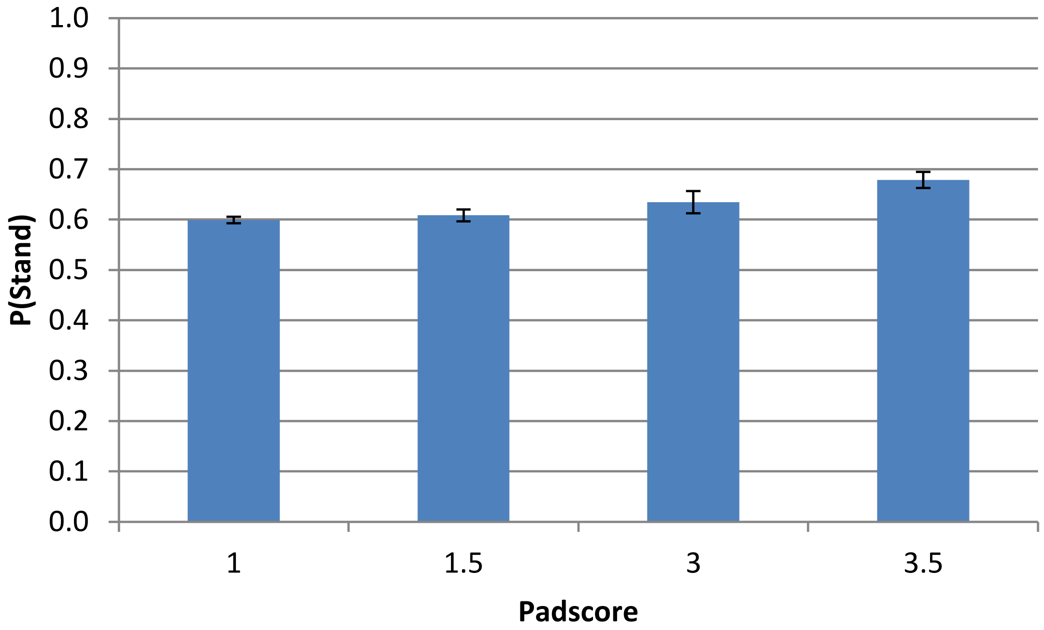

Figure 15. Estimated model-based proportions of time spent standing at differing Pad Scores. Pad score significantly affected time spent standing with increased standing at higher pad scores.

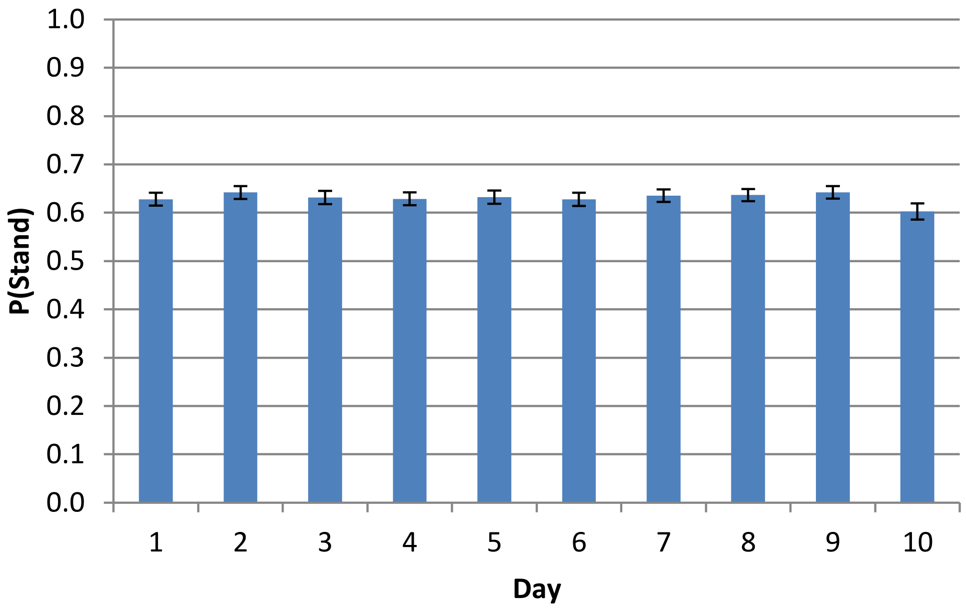

Figure 16. Estimated model-based proportions of time spend standing over the 10 days of testing. There was no significant effect of day on standing behaviours.

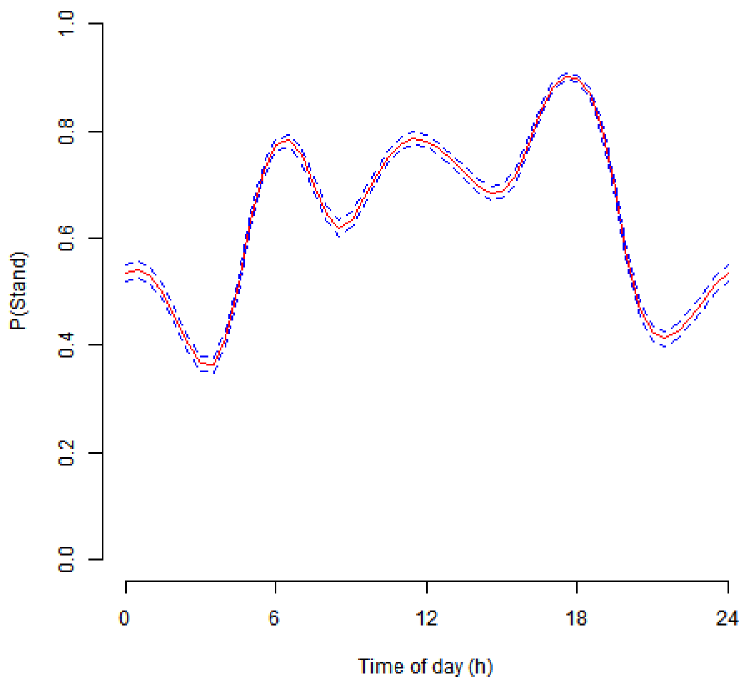

Figure 17. Model-based proportions of an animal standing in a 15-min period over the 24 hr cycle. The red line represents the model-based probability, and the dashed blue line represents ± one standard error of the estimate.

There was very strong evidence of a diurnal pattern in the change of the behaviour, as indicated by the significance of the sine and cosine terms (P< 0.0001). The changes in the model-based probabilities of standing are shown in Figure 17. Animals spent least time standing (most time lying) around 03:30 and 21:30, and most time standing (least time lying) around 17:30. Note that the significance of the variance components associated with the spline terms cannot be tested, but is apparent from the departure from a standard sine curve.

2.3.3.2 Lying bouts

All terms in the model with the exception of Location (P = 0.51; ***Figure 18***) were significantly associated with the number of lying bouts. There was a decrease in the number of lying bouts as the pad score increased (Average number per day of 12.2 at pad score 1 vs. 7.3 at padscore 3.5; P<0.0001; ***Figure 19***). Again, no discernible trend over the 10-day period was discernible, despite the significance (P=0.0063; ***Figure 20***). ***Figure 21*** shows the changes over a 24-hr periods, with reduced number of lying bouts around 06:00 and 18:00.

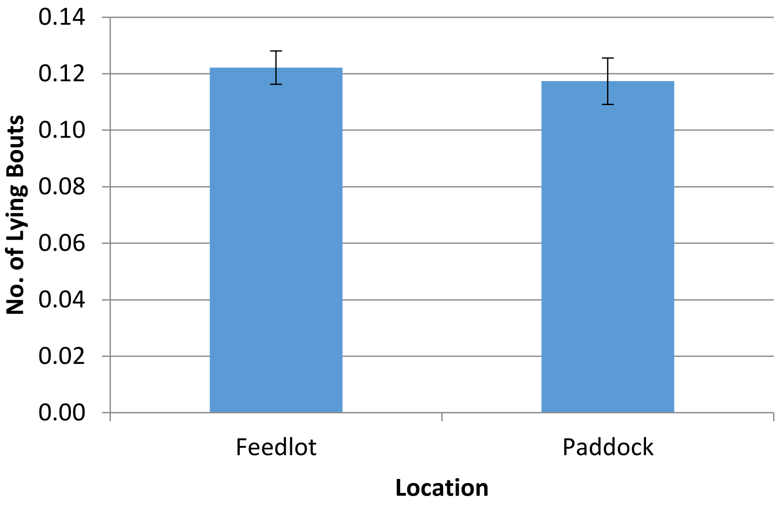

Figure 18. Estimated model-based proportions of average number of lying bouts in a 15 min period in the feedlot or paddock locations. Location did not significantly affect lying bouts.

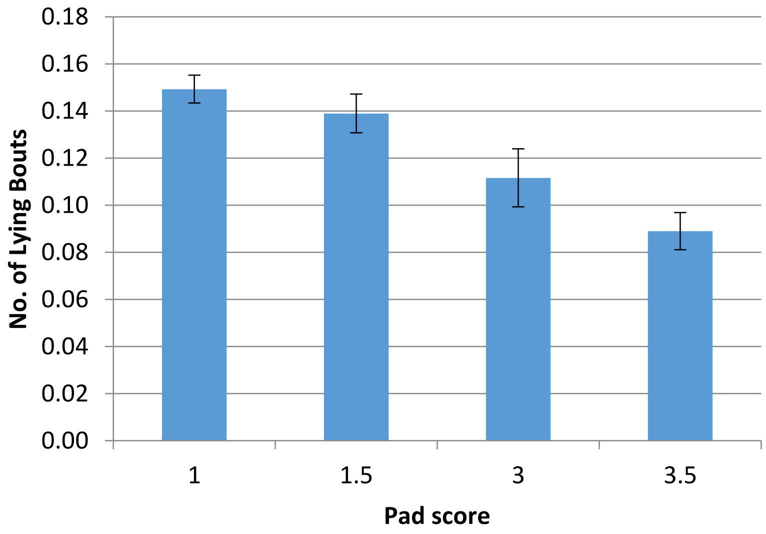

Figure 19. Estimated model-based proportions of average number of lying bouts in a 15 min period at the pad scores measured during the experiment. Increasing pad score significantly reduced lying bouts.

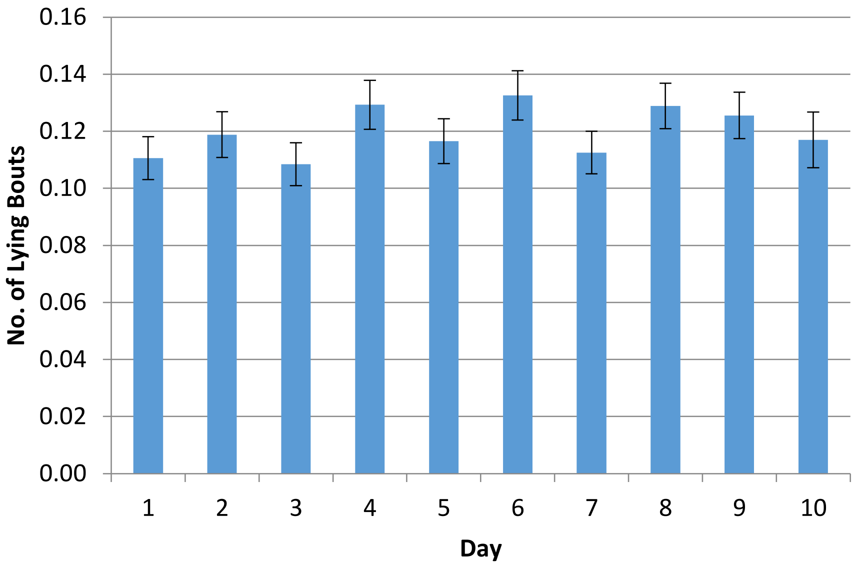

Figure 20. Estimated model-based proportions of number of lying bouts in a 15 min period over the 10 days of testing. Day of testing significantly affected lying bouts.

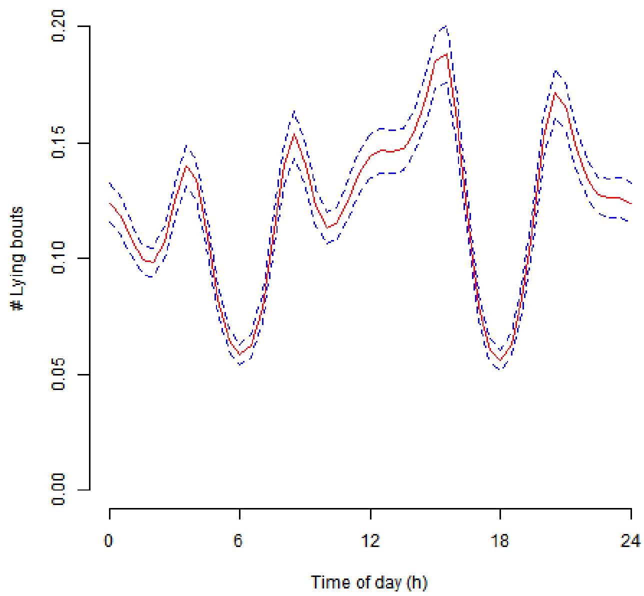

Figure 21. Model-based mean number of lying bouts of an animal in a 15-min period over the 24 hr cycle. The red line represents the model-based mean, and the dashed blue line represents ± one standard error of the estimate.

2.3.3.3 Number of steps

There was a significant effect of the location (paddock or feedlot) on the number of steps (P=0.0013) with overall animals taking ~ 2.3 times more steps when in the paddock, compared to when they were in the feedlot (Figure 22). Pad Score was highly significant with the intermediate score (3) being associated with slightly more steps (P < 0.0001; Figure 23). Day was not significant for the number of steps (P = 0.129; Figure 24).

The 24-hr cycle sine and cosine terms were highly significant (P < 0.0001). As shown in Figure 25, there was a very strong 24-hr diurnal pattern, with a peak in steps around 18:00, with smaller peaks around 0:00, 6:00 and 12:00. These also correspond to the peaks in the probability of standing (Figure 17).

There is strong evidence of between-animal variation for stepping, as given by the estimated variance components: for stepping vs stationary: 0.0187 ± 0.0077 (z = 2.43) on the logit scale; for number of steps, given they were not stationary: 0.0154 ± 0.0054 (z = 2.86) on the logarithmic scale (see Figure 26).

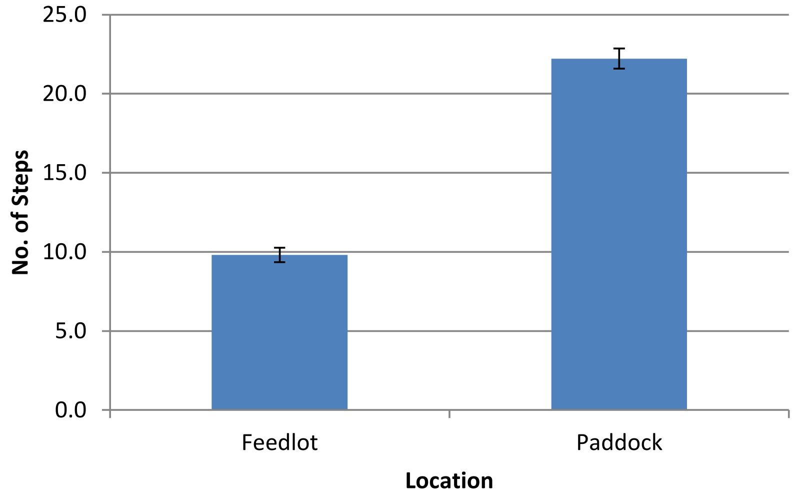

Figure 22. Estimated model-based proportions of number of steps performed in the feedlot or paddock environment. Cattle performed significantly more steps in the paddock.

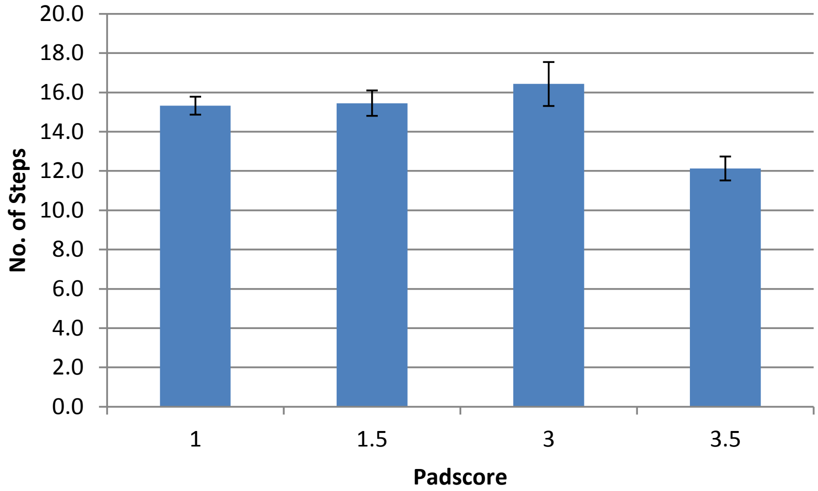

Figure 23. Estimated model-based proportions of number of steps performed at differing pad scores.

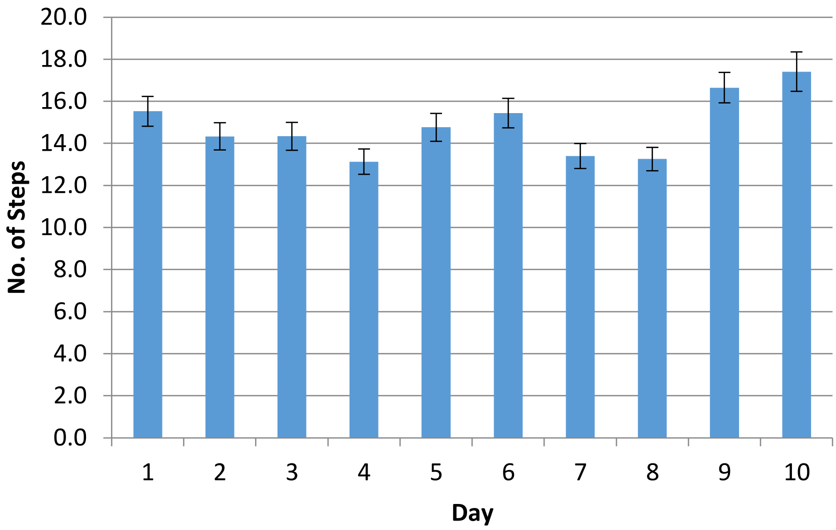

Figure 24. Estimated model-based proportions of steps performed over the 10 days of testing. There was no significant effect of day.

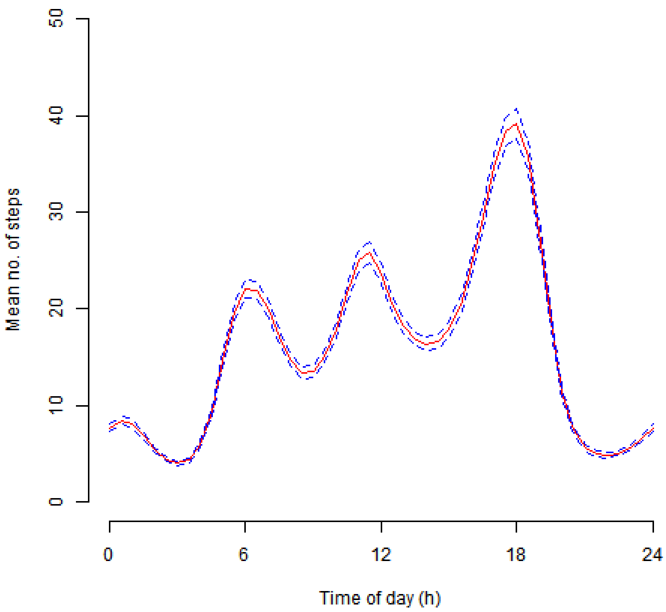

Figure 25. Model-based mean number of steps of an animal in a 15-min period over the 24 hr cycle. The red line represents the model-based mean, and the dashed blue line represents ± one standard error of the estimate.

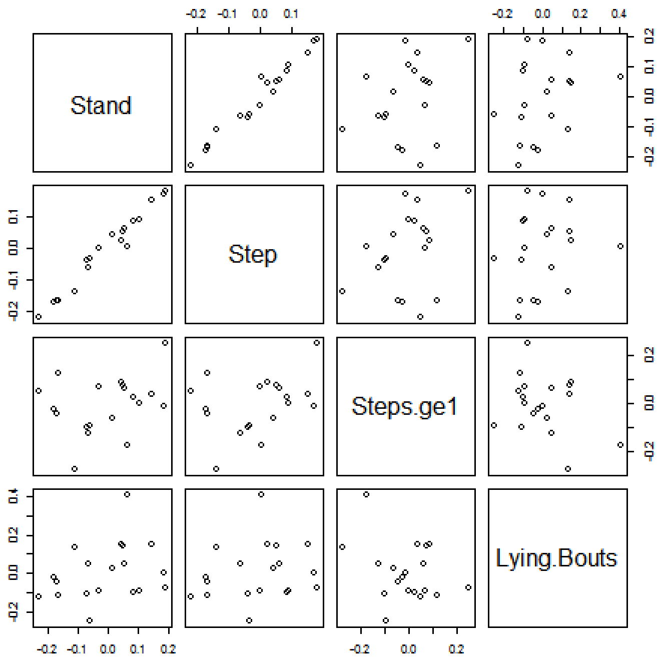

Figure 26. Scatter plot matrix of the estimated individual random animal effects for the probability of an animal standing (Stand), expressed on the logit scale; probability of stepping (Step) also expressed on the logit scale, the number of steps, given that it was not stationary (Steps.ge1), on the logarithmic scale, and the number of lying bouts (Lying.Bouts), on the logarithmic scale.

2.4 Discussion

The study showed that cattle spend slightly more time (2.1% lying in the paddock than in the feedlot and that they preferred the feedlot during the day and the paddock at night when there is a cost imposed on their choice. Interestingly, these findings align with the previous free choice study (B.FLT. 0349) that showed cattle prefer the feedlot during the day and the pasture at night (Lee *et al.* 2013). Increasing pad score or mud levels was significantly related to reduced lying in the feedlot with cattle lying 8% less at pad score 3.5 vs. a dry feedlot. The design of the current study, where cattle were able to choose different environments twice daily, make it difficult to determine what factors are influencing behaviour as it may be that cattle were compensating based on the previous environment they chose, e.g. If cattle chose the pasture, they may have prioritised grazing over resting in order to meet their dietary requirements. For diurnal profiles, cattle displayed a similar pattern in lying and standing behaviours as reported in the free choice study with peaks in lying at 03:30 and 21:30 h (Lee *et al.* 2013).

The differences shown between cohorts in their preference for the feedlot was large and opposite with cohort 1 preferring the feedlot and cohort 2 preferring the pasture. These findings were unexpected as previous studies did not find any differences between cohorts (B.FLT.0149). Pasture availability was towards the low side (<2000 kg DM/ha) but there were little differences between the cohorts, therefore this was unlikely to have been responsible for these differences. Likewise, pasture and feedlot diet nutritive values were similar between the cohorts. Nonetheless, from our findings, it appears that there are individual differences in cattle preference for a feedlot or pasture environment with some animals consistently choosing one environment or the other.

The four times per day testing was an additional component that was conducted to provide guidance on the optimal times of day to test cattle for use in future studies. However, the cattle had already undergone 10 days of testing and this may have influenced their subsequent choices in this phase of testing. The frequent testing provided more of an opportunity for the cattle to choose the feedlot by reducing the cost of their choice. In addition, cattle had 4 hours to consume the diet at each testing session during the day and 12 hours overnight. This would have enabled consumption of the majority of their daily nutritional requirements so they would not have a strong need to enter the feedlot more than once a day. This data aligns with the Lee *et al.* (2013) study where cattle were given free choice and spent 25% of their time in the feedlot where they ate for 1.3h per day and consumed sufficient diet to meet their nutritional requirements. The finding that cattle chose to enter the feedlot at least once per day suggests that they did not perceive the environment negatively.

The current study design which has been developed from the previous project (B.FLT.0149; Lee (2014) accounts for side biases by altering the maze side that cattle are tested in on a daily basis. Maze side of testing was a significant effect in the model, however as the design was balanced, we are confident that the results are valid. This means for example, that on day 1, cattle were tested in maze east where the feedlot was on the left arm of the maze and on day 2, they were tested in maze west where the feedlot was on the right side. From the results for preferences, we can see that cattle had learnt the location of the feedlot and pasture as on most days, cattle showed a significant preference for one of these locations. If cattle had not learnt the locations, then we would have expected them to show no preference (i.e. no difference to 50% chance level).

The current feedlot design enables only one cohort to be tested at a time and takes up to 6 weeks to complete testing per cohort. This brings in additional sources of variation due to changes in weather, pasture and other variables. While we cannot be sure what factors were responsible for the differences found between the cohorts in this study, we can attempt to reduce some of the variation caused by testing the cohorts at different times. Altering the feedlot design to include 2 feedlot and pasture environments will enable 2 cohorts to be tested at the same time. This alteration was utilised in experiment 2 of the project to investigate the effect of mud on feedlot preferences. This will reduce variation due to differences in climate and pasture as well as other factors which differ when cohorts are tested at different times of the year.

3 Experiment 2: The effect of mud on cattle preference for feedlot or pasture environments

Abstract

Experiment 2 was conducted to determine the effect of increasing levels of feedlot mud on cattle preferences for a feedlot or pasture environment. Preferences for the feedlot or pasture were tested under three feedlot pad scores: 1 (dry), 3 (medium mud) and 5 (high mud), relating to the depth of manure permitted on feedlot surfaces under the Queensland class system for feedlots. A total of 60 cattle (2 cohorts per pad score; 10 cattle per cohort) were habituated to the feedlot and pasture environments. Next they were trained in the Y-maze to learn the direction of the feedlot and pasture and then they were tested twice daily at 08:00 h and 18:00 h over 10 days to assess their choice to either enter a feedlot or pasture. Once the cattle made a choice, they were confined to the chosen environment until the next testing session. Cattle showed no difference in their preference for the feedlot or pasture under differing feedlot pad scores. There was a preference shown for the pasture environment when the feedlot was least muddy (pad score 1) and no preferences shown for either the feedlot or pasture at the other pad scores tested. Behaviours (time standing, lying and number of steps) were recorded with IceTag devices. Level of mud did not affect cattle preference for the feedlot or pasture environments. Day of testing ($P<0.001$), side tested ($P=0.022$) and time of day ($P=0.043$) were found to affect cattle preference, with cattle more frequently choosing pasture during the afternoon. Cattle showed an increase of between 1 and 2 % in numbers of lying bouts (transitions from lying to standing) with increasing feedlot mud levels ($P<0.0001$) which may indicate that they found the muddy feedlot less comfortable for resting than a dry feedlot. Cattle spent more time lying at pasture ($P<0.001$) and performed a greater number of steps ($P<0.001$). This research indicates that cattle do not perceive the feedlot environment negatively even when it is muddy. Despite high levels of mud, cattle still chose to enter the feedlot and did not show a strong preference for pasture. However, it is important to note that this study was conducted during in the warmer months of the year (spring, summer and autumn) when the muddy feedlot would not have provided a thermoregulatory challenge to the animals. Further research is needed to determine cattle preference for a muddy feedlot vs pasture under colder conditions such as in winter when the thermoregulatory challenge on the animal would be greater.

3.1 Project Objectives

Provide objective, science-based information on the influence of feedlot pad surface conditions on motivation of cattle for feedlot or pasture environments.

3.2 Methodology

3.2.1 Test facilities

The protocol and conduct of the study were approved by the McMaster Laboratory Animal Ethics Committee, under the New South Wales Animal Research Act 1985.

The experiment was undertaken at CSIRO, FD McMaster Laboratories, Armidale from February to December 2015. During study periods, the average daily minimum temperature ranged from 4.5°C to 15.5°C and the average daily maximum temperature was from 16.3°C to 32.1°C. A previously constructed Y-maze testing facility (B.FLT.0149) consisting of two opposing Y mazes leading to either a feedlot or pasture environment was modified to contain 2 pasture and 2 feedlot environments (***Figure 27***). This enables 2 cohorts to be tested during the same period to reduce sources of variation related to pasture and climate. The paddocks were approximately 5 acres in size. The walls of the Y-maze were lined with opaque rubber belting (Andromeda Engineering, Moonbi, Australia) to prevent cattle from seeing one another during testing. This ensured that each animal was making an independent choice to enter either the feedlot or pasture. Each feedlot was 114 m^2 in size (11.1 x 10.3 m) which was sufficient to contain the animals at the recommended feedlot density of at least 9 m^2 per animal (Model Code of Practice for the Welfare of Animals- Cattle, PISC, 2004). Shelters (2.3m wide x 2.5 m high x 7.8 m long) with a flat roof and open sides were erected over the troughs to provide protection from rain and to prevent feed spoilage (***Figure 28***). Each feedlot contained a concrete feed bunk (6 m long x 0.6 m wide x 0.56 m high). The shelters were oriented in such a way as to ensure that no shade was provided to cattle while in the feedlot. The feedlot pad was prepared by laying a gravel base that was covered with a feedlot compost (250 mm thick) which was rolled to form a pad that was well drained and sloped. As it is not commercial practice in Australia to use bedding, no bedding was added to the feedlot pad. The feedlot and pasture environments contained identical water troughs and water from the same source. No additional trees or shade was available in either environment. Pasture across the 3 phases was of a type and quality similar to that of extensively farmed cattle.

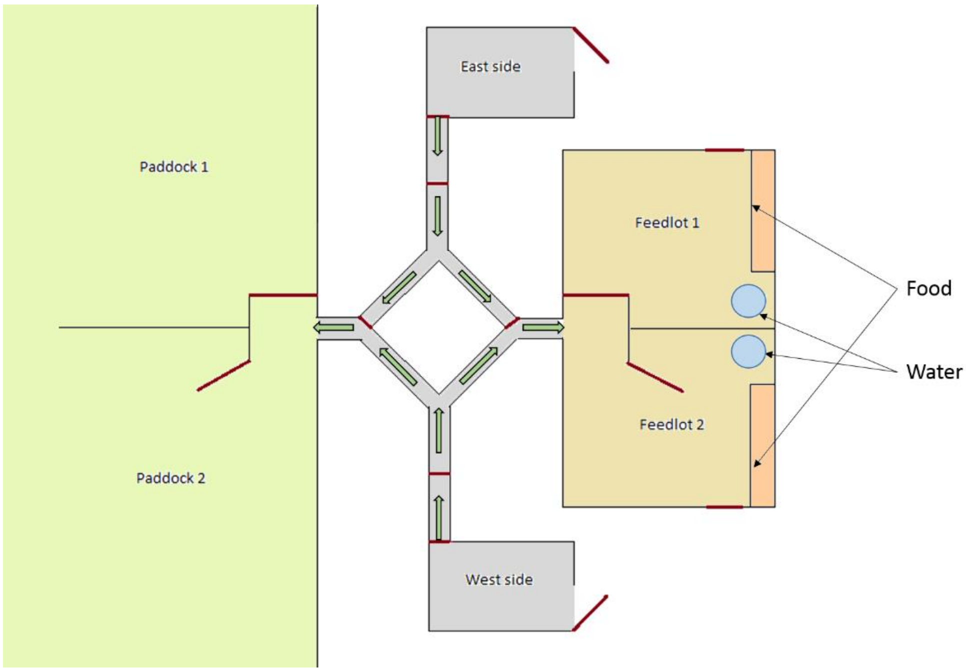

Figure 27. The design of the testing facilities. Red lines indicate gates and green arrows indicate the pathway that cattle can choose within the Y-mazes.

Figure 28. Photo showing cattle at the feed bunks with the shelters overhead to protect the feed from spoiling.

3.2.2 Animals

A total of 62 Angus steers were used in the study. Cattle were sourced from the CSIRO Angus Performance Recorded herd. All cattle were tested in a Y-maze to determine their natural side preference. Side preferences vary between individuals with some behaviours preferentially performed by one side of the body and are the effect of brain lateralization on the way information is processed by animals. Cattle were weighed and flight speed tested to allocate to six cohorts of 10 animals each which were balanced for weight, side preference and flight speed. Two steers were kept as spare animals and were used as companions as needed. The six cohorts were tested for choice in the Y-maze at 3 different pad scores which occurred in the same period (2 cohorts per pad score). Body weights (mean; SE) at the start of testing were as follows: Cohort 1 (532.7±14 kg), Cohort 2 (549.3±12 kg), Cohort 3 (377.5 ±14 kg), Cohort 4 (380.4±14 kg), Cohort 5 (444.4 ±14 kg) and Cohort 6 (443.0 ±11 kg). The pad scores were tested in three periods in 2015 (Figure 34) occurring in autumn (February till March; pad score 1; cohort 1 and 2), spring (October till November; pad score 3; cohorts 3 and 4) and early summer (December; pad score 5; cohorts 5 and 6).

3.2.3 Pad scores

Three pad scores were artificially created in the experiment; 1, 3 and 5 relating to the depth of manure permitted on feedlot surfaces under the Queensland class system for feedlots. This translated as feedlot pad score 1 (Queensland class system Class 1), feedlot pad score 3 (Class 2 and 3) and feedlot pad score 5 (Class 4). Feedlot pad score 1 utilised no mud or artificial wetting of the pad. There were minimal rain events during this period, so the feedlot was maintained at a pad score 1 throughout the testing period. Feedlot pad score 3 was created by artificially wetting the pad to create mud, the level of which was maintained by daily wetting with a hose throughout this phase of the experiment. Feedlot pad score 5 was created by both artificially wetting the pad and placing additional cattle (other than test cattle) on the pad for 7 days prior to experimental studies. The level of mud was maintained to be consistent throughout this phase through daily wetting with a hose. The mud depth was measured by observing the cattle and determining that the pad score levels were achieved from this. The photos below show the different pad scores in the feedlot (Figure 29, Figure 30 and Figure 31).

Figure 29. Photograph showing Feedlot pad score 1.

Figure 30. Feedlot pad score 3

Figure 31. Feedlot pad score 5.

3.2.4 Feedlot diet

The feedlot diet was sourced from Tullimba Feedlot, the University of New England (see Figure 32). Feed was collected every 3-4 days depending upon rate of consumption, and stored on site at the feedlot. A nutritional analysis of the feedlot diet for all pad scores is shown in

Table 4. Feed was replenished in feed bunks after each testing session.

Table 4. Nutritional analysis of diet samples for all pad scores. Data are presented on a DM basis.

Component (%)	Pad score 1	Pad score 3	Pad score 5
Dry matter	91.5	90.6	90.4
Crude Protein	13.6	12.3	13.0
Neutral detergent fibre	39	34	34
Acid detergent fibre	23	17	17
Ash	7	6	7
Organic matter	93	94	93
Dry organic matter digestibility	59	71	73
Dry matter digestibility	59	72	74
Fat	4.8	3.6	3.3
Metabolisable energy (MJ/kg DM)	10.3	11.7	11.8

Figure 32. The feedlot diet was collected from the Tullimba feedlot into a tip truck and transported to CSIRO Chiswick.

3.2.5 Pasture

Pasture was sampled from each of the two paddocks using quadrats. A total of 10 samples were taken from each paddock and weighed for wet weight. The samples were then oven dried at 65°C for approximately 48 h and reweighed to obtain dry weight. Nutritional component analysis was conducted by the Department of Primary Industries (Wagga Wagga, NSW, Australia). The pasture was semi-improved and consisted of a mix of natives and some improved species. Pasture identified included Tall Fescue, Ryegrass, Shepherds Purse, Tussock Poa, Flatweed, Native Plantain and Phalaris (Figure 33). While the herbage mass was on the low side, it was still sufficient to meet the dietary requirements of the cattle as it was above the critical mass recommendations of 900-2700 kg DM/ha (Bell 2006) for all cohorts tested (Table 5).

Table 5. Nutritional analysis of pasture for all cohorts (% dry matter).

Component (% of dry matter)	Cohort 1	Cohort 2	Cohort 3	Cohort 4	Cohort 5	Cohort 6
Dry matter (%)	92.3	92.4	91.1	91.5	91.5	91.9
Crude Protein (%)	7.2	7.3	14.4	10.1	8.5	8.1
Neutral detergent fibre (%)	67	65	54	63	64	66
Acid detergent fibre (%)	37	38	31	38	40	39
Organic matter (%)	93	92	92	92	89	91
Dry organic matter digestibility(%)	55	54	62	52	50	52
Dry matter digestibility (%)	53	53	65	53	51	54
Metabolisable energy (MJ/kg DM)	7.8	7.7	9.5	7.5	7.1	7.6
Herbage mass (kg DM/ha)	2534	2085	1954	1265	2267	1301

Figure 33. Angus steers in the two pasture environments.

3.2.6 Habituation and training

The timelines for the experiment are shown in (Figure 34). For each pad score tested, all cattle were habituated to the feedlot in their cohort of 10 animals plus a spare companion for 10 days and then their pasture environment for 10 days to enable them to experience and learn about each environment. Whilst in the feedlot, cattle were provided ad libitum a starter feed diet in order to mimic the commercial feedlot environment. This diet contained buffer to minimise risk of acidosis. Next, cattle were trained in the Y-maze to learn the direction of the feedlot and pasture environments. Each animal performed 12 forced trials per day (6 trials per East and West maze; alternating between feedlot and pasture) for 3 consecutive days (total of 36 trials each). A visual cue (A4 size black X on laminated paper) was placed at the feedlot side on the Y-maze at cattle head height to facilitate animals learning the side of the feedlot and pasture.

Following the completion of training, steers were fitted with Iceqube accelerometers (IceRobotics, Scotland) on the front leg. Steers were kept in the feedlot overnight before the commencement of testing.

3.2.7 Y-maze testing

Testing occurred over 10 consecutive days for each pad score twice daily at approximately 08:00 h and 18:00h. Testing in both morning and evening allowed for the effect of time of day to be included in the analysis. Each cohort was separately mustered into the holding pens (East and West) before testing commencing on the Eastern side. Cattle were moved into a start box where they were released into the Y-maze and could make a choice to enter either the feedlot or pasture. Animals in the pen were not able to see what other animals had chosen as the start box was opaque. This prevented the cattle from being influenced by other animals in making their choice. Cattle were confined in their chosen environment until the next testing session to impose a cost on their choice. The maze side (east or west) the cohorts were tested from alternated daily. Each cohort remained in the same paddock and feedlot throughout the testing period. The choice of each animal was recorded at the time of testing. Cattle were also monitored during this period for any signs of acidosis or compromised foot health. At completion of each test, the spare steers were directed to the environment with the least number of animals. Feed was available ad libitum to cattle whilst in the feedlot. Fresh feed was delivered into the bunks while the animals were in the holding pens prior to testing. If the feed was spoiled or wet, it was removed and fresh feed was added. Once animal were tested and had made their choice, additional feed was added depending on the numbers of animals in the feedlot.

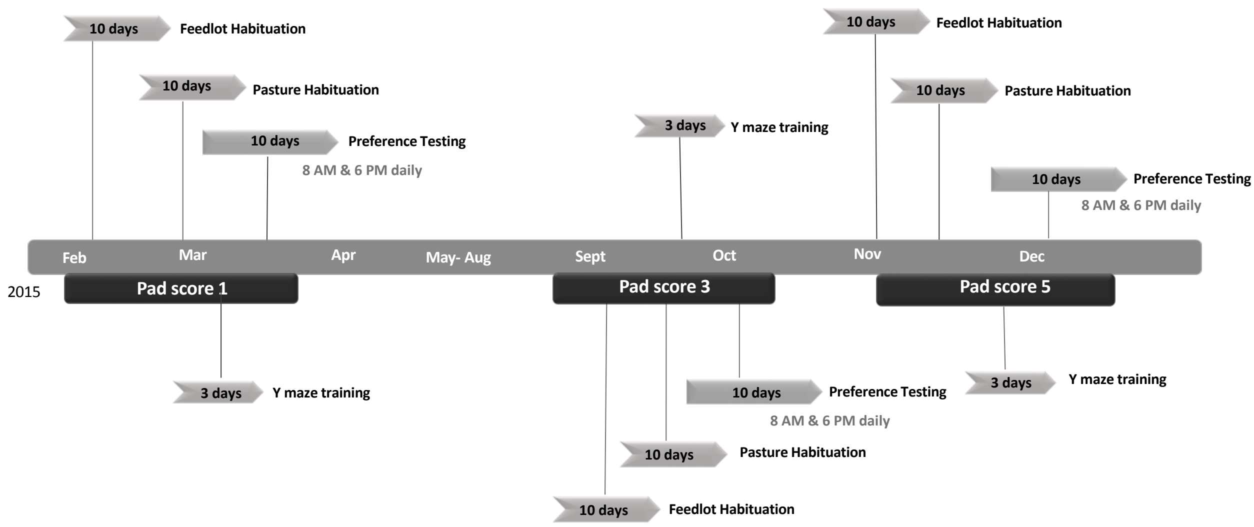

Figure 34. Timelines of the mud experiment showing the different habituation, training and testing phases for each pad score.

3.2.8 Climate

Data was recorded from a portable weather station located within 500 m of the testing facility. The climate data is presented in ***Table 6***.

Table 6. Summary of rainfall, maximum and minimum temperatures for all pad scores.

Climate measure	Pad score 1	Pad score 3	Pad score 5
Average Rainfall (mm)	0.7	3.1	1.8
Total Rainfall (mm)	7	31	18
Average maximum temperature (°C)	24.7	23	24.2
Average minimum temperature (°C)	12	8.2	12.4

3.3 Statistical Analysis

To analyse the preference data (pasture vs feedlot), a logistic generalised linear mixed model was used to model the probability of the steer selecting a pasture (1) vs a feedlot (0). The form of the model is as follows:

$$\log_e\left(\frac{\pi}{1-\pi}\right) = \text{constant} + \text{PadScore} + \text{Day} + \text{Time} + \text{Side} + \beta_1\text{Rainfall} + \beta_2\text{MinTemp} + \beta_3\text{MaxTemp} + \\ +\text{Animal}$$

where π = P(Y = 1), i.e. probability that the animal chooses a paddock; Pad Score, Day and Time (morning or evening) are fixed effects (factors); Rainfall, MinTemp, and MaxTemp are fixed effects (covariates); and Cohort and Animal are random effects. This analysis excludes a term for Cohort as a random effect. The argument would need to be made that there are no expected cohort differences because animal choices were made in isolation from other animals. The model was fitted using ASReml-R (Butler, 2009). Preference for choosing the feedlot was tested by comparing the observed choice to random chance (50%). The hypothesis was that if animals have no preference for the feedlot or pasture they would choose the feedlot and pasture environments an equal amount of time. 95% confidence intervals were calculated as the mean +/- 1.96 SEM.

To analyse the standing and lying behaviour, the data are considered as a binary outcome, i.e. whether or not the animal stands for any amount of time of the 15-min interval.

$$\text{Stand} = \begin{cases} 1 & \text{Standing time} > 0 \\ 0 & \text{Standing time} = 0 \end{cases}$$

A logistic generalised linear mixed model (GLMM) was used to analyse these binary data. However, the standing / lying status of an animal a one point of time (t) is very dependent on what it was doing at the last point of time (t – 1), so this serial dependence needs to be taken into account in the model. In addition, since the data were collected over 24-hour periods, the analysis needs to include a 24-hr period effect, and this is incorporated by the use of sine-cosine functions with a 24-hr cycle. The following model was fitted to the data:

$$\log_e\left(\frac{\pi_i^{(\text{Stand})}}{1-\pi_i^{(\text{Stand})}}\right) = \text{constant} + \text{PadScore} + \text{Location} + \text{Stand}_{t-1} + \text{Day} + \beta_S S + \beta_C C + s(S) + s(C) + \text{AnimalID}$$

where

$\pi_i^{(\text{Stand})}$ = probability of animal standing at time t, i.e. $P(\text{Stand}_t = 1)$

and

Pad score = effect pad score 1, 3, or 5;
Location = effect of feedlot, or paddock;
Stand_{t-1} = effect of Stand status in the previous 15-min interval; and
Day = effect of day 1, 2, …, 10

are fixed factor effects; and

$S = \sin(2\pi h/24)$ and $C = \cos(2\pi h/24)$ with h being the time (hr) of the data ($0 \le h < 24$)

are fixed covariate effects; and

$s(S)$ and $s(C)$ are smooth spline functions of S and C; and
AnimalID = random effect of the animal.

Note that the fixed effects of S and C provide a sinusoidal 24-hr cycle, while the smooth spline functions allow a smooth deviation from a strict sine function form, but still imposes a 24-hr cycle. The model was fitted using ASReml-R (Butler et al., 2009). Note that for the formulation of splines in ASReml-R, they are specified as part of the random effects model. Significance testing of fixed effects was conducted using Wald F-tests.

Data for the number of steps an animal is recorded in consecutive 15-min periods. However, there are many intervals where no steps are taken, resulting in a “spike” at zero steps. Consequently, a two stage modelling approach was adopted: 1) model for the probability that steps were taken (vs standing still), and 2) a model for the number of steps (# Steps) taken, conditional on at least one step being taken, i.e. excluding data where no steps were taken.

This analysis was conducted as follows. Initially, we define

$$\text{Step} = \begin{cases} 1 & \#\ \text{Steps} > 0 \\ 0 & \#\ \text{Steps} = 0 \end{cases}$$

The model for $P(\text{Step}_t = 1) = \pi_i^{(\text{Step})}$ proceeds as in the above model for $P(\text{Stand}_t = 1) = \pi_i^{(\text{Stand})}$ with the prior dependence term Stept–1 replacing Standt–1. The model for # Steps, conditional on the animals moving, is the following linear mixed model:

$$\log_e\left(\#\ \text{Steps}_i\right) = \text{constant} + \text{PadScore} + \text{Location} + \text{Step}_{t-1} + \text{Day} + \beta_S S + \beta_C C + s(S) + s(C) + \text{AnimalID} + \varepsilon$$

where all the terms are the same as in the Stand model, and where ε is a random error. Note that the counts (# Steps_i) were sufficiently large to warrant the use of a linear mixed model (on log-transformed data) as opposed to a Poisson GLMM. ASReml-R was again used for fitting both models.

Finally, overall model-based mean counts were estimated as $\hat{\pi}_i^{(\text{Step})} \times \hat{\mu}_i^{(\text{Step})}$ where $\hat{\pi}_i^{(\text{Step})}$ is the estimated probability of an animal stepping, and $\hat{\mu}_i^{(\text{Step})}$ is the estimate means number of steps, given an animal makes at least one step (calculated as the back-transformed mean, given the model was fitted on a logarithmic scale). The standard error of these overall means are calculated as $\left\{\text{se}[\hat{\pi}_i^{(\text{Step})}]^2 \times \text{se}[\hat{\mu}_i^{(\text{Step})}]^2 + \text{se}[\hat{\pi}_i^{(\text{Step})}]^2 \times [\hat{\mu}_i^{(\text{Step})}]^2 + [\hat{\pi}_i^{(\text{Step})}]^2 \times \text{se}[\hat{\mu}_i^{(\text{Step})}]^2\right\}^{1/2}$, where $\text{se}[\hat{\pi}_i^{(\text{Step})}]^2$ and $\text{se}[\hat{\mu}_i^{(\text{Step})}]^2$ are the squared standard errors for the estimates of $\hat{\pi}_i^{(\text{Step})}$ and $\hat{\mu}_i^{(\text{Step})}$, respectively.

The number of lying bouts has been modelled using a Poisson GLMM. The following model was fitted to the data:

$$\log_e \lambda_i = \text{constant} + \text{PadScore} + \text{Location} + \text{Stand}_{t-1} + \text{Day} + \beta_S S + \beta_C C + s(S) + s(C) + \text{AnimalID}$$

where λi = mean number of lying bouts, and the remainder of the terms in the model are as defined above.

4 Results

4.1 Choice for pasture or feedlot

There was no significant effect of pad score on the choice for the pasture or feedlot (P = 0.449; Figure 35). While there was a slight trend for a decline in choice preference for pasture with increasing pad score, this was not significant. Pad score 1 cattle showed a 67% preference for the pasture environment which was significantly different from 50% chance (P<0.05). Pad score 3 and 5 cattle did not show a preference for either the feedlot or pasture and their choice did not differ from 50% chance.

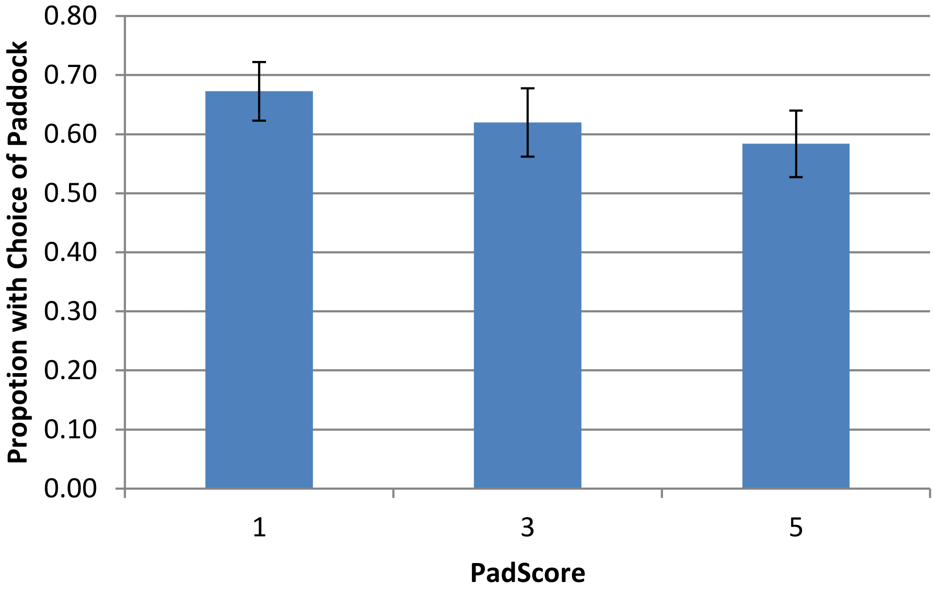

Figure 35. Estimated model-based proportions of time cattle choose the pasture for each of the pad score treatments (means +/- sem).

There was a highly significant effect of day (P<0.001; ***Figure 36***) but no discernible trend. Time of day significantly affect choice for paddock or feedlot (P = 0.043; ***Figure 37***) with a greater preference for the pasture in the afternoon, compared with the morning. The interaction between Day × Time was not significant ($\chi 2$ = 10.67, df = 9, P = 0.30). There were no significant effects of the three weather variables on the choice of pasture vs feedlot (all P > 0.10).

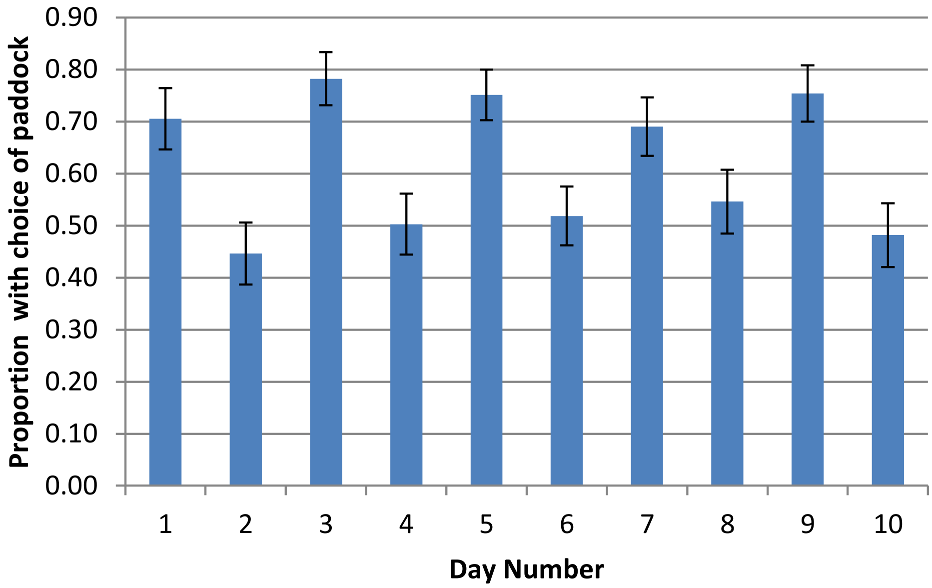

Figure 36 Estimated model-based proportions of time cattle choose the pasture over the 10 days of testing (means +/- sem).

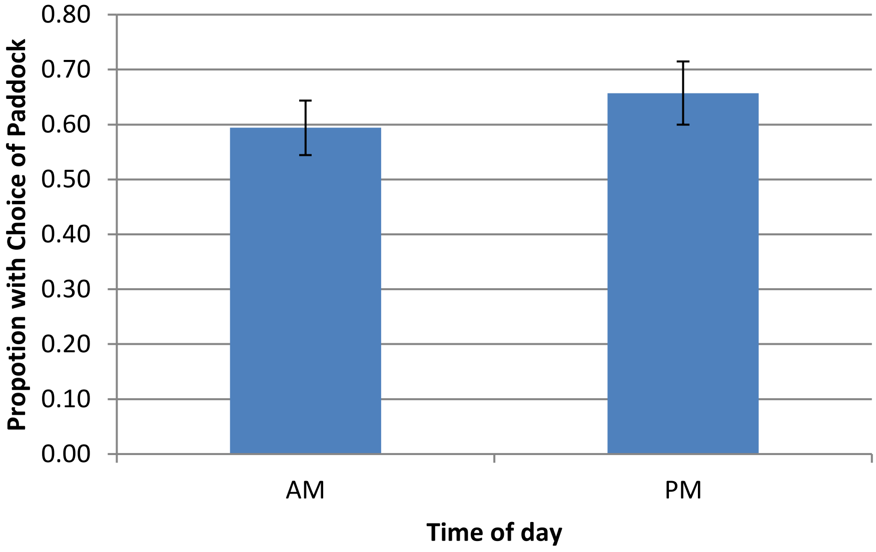

Figure 37. Estimated model-based proportions of time cattle choose the pasture when tested at 08:00h and 18:00 h daily (means +/- sem).

4.1.1 Individual differences in choice

The variance component estimate for Cohort was 0.16 ± 0.20, indicating no detectable between-cohort variation. However, there is evidence of significant between animal variation, with an estimated variance component of 0.50 ± 0.15. Figure 38 shows the estimated animal effects (on the logit scale) in sorted order. These range from -1.44 (Animal 445) that is least likely to choose the pasture, to +1.43 (Animal 407) that is most likely to choose the pasture.

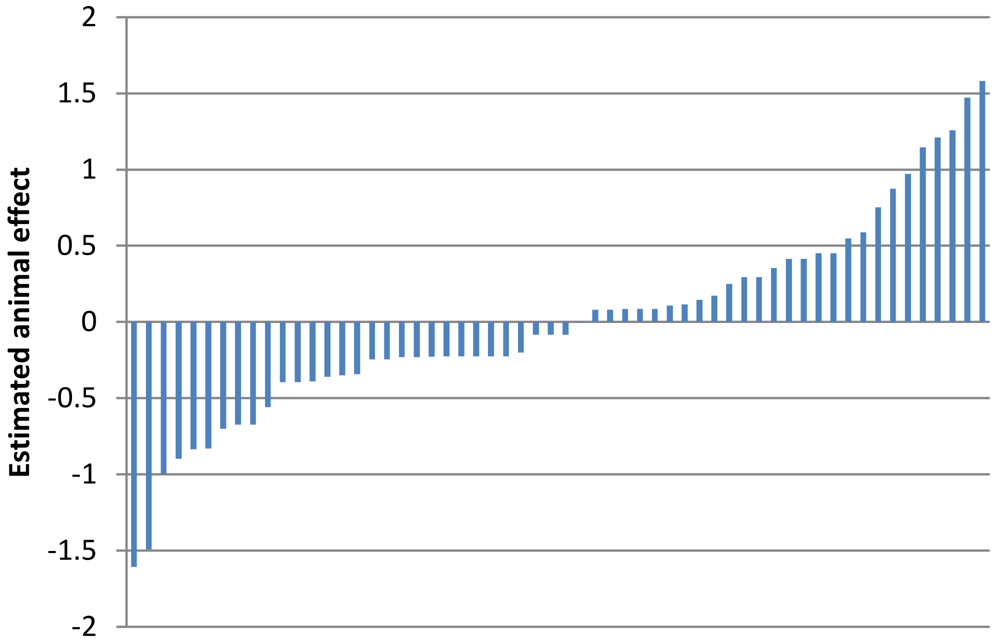

Figure 38. Estimated animal effects (on the logit scale) showing variation in the choice for feedlot or pasture.

4.2 Behaviours

4.2.1 Standing vs. lying

Please note that standing and lying events are mutually exclusive, i.e., if one is occurring the other can't be as well (standing behaviour will be the converse of lying behaviour). While the probability of standing decreases with increasing mud level (Figure 39), the decrease was not significant (P=0.351). Standing and lying were affected by the location of the animal (Figure 40), when animals were in the paddock, they were 5% more likely to be lying (P<0.0001) than when they were in the feedlot. While there are statistically significant differences across the ten sampling days (P<0.0001), no discernible trend was apparent (Figure 41).

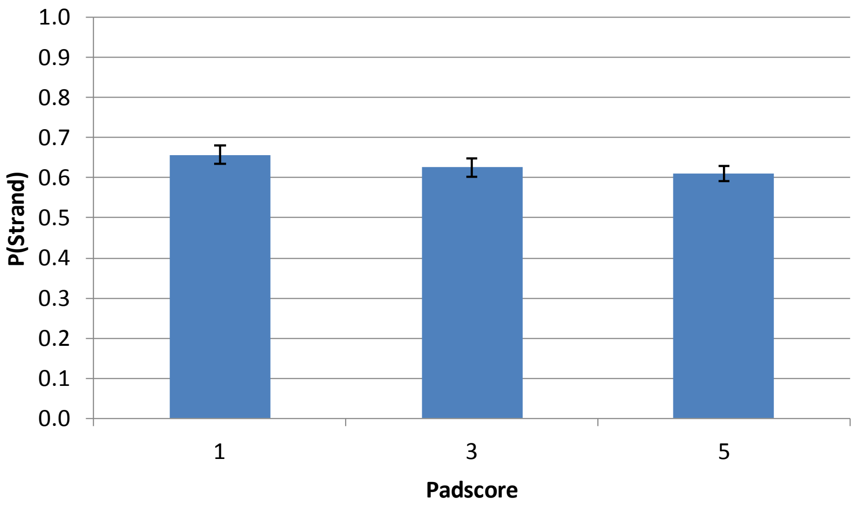

Figure 39. Estimated model-based proportions of an animal standing due at the 3 pad scores tested.

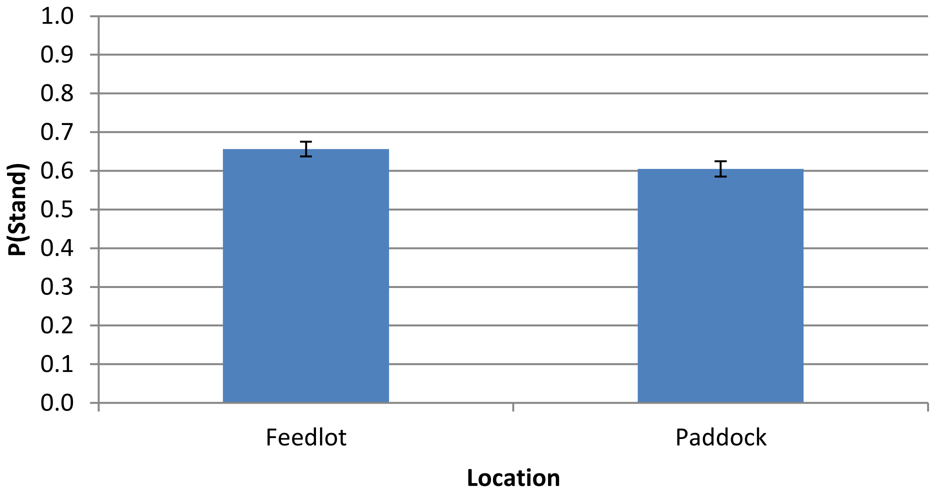

Figure 40. Estimated model-based proportions of an animal standing in the feedlot and pasture environments.

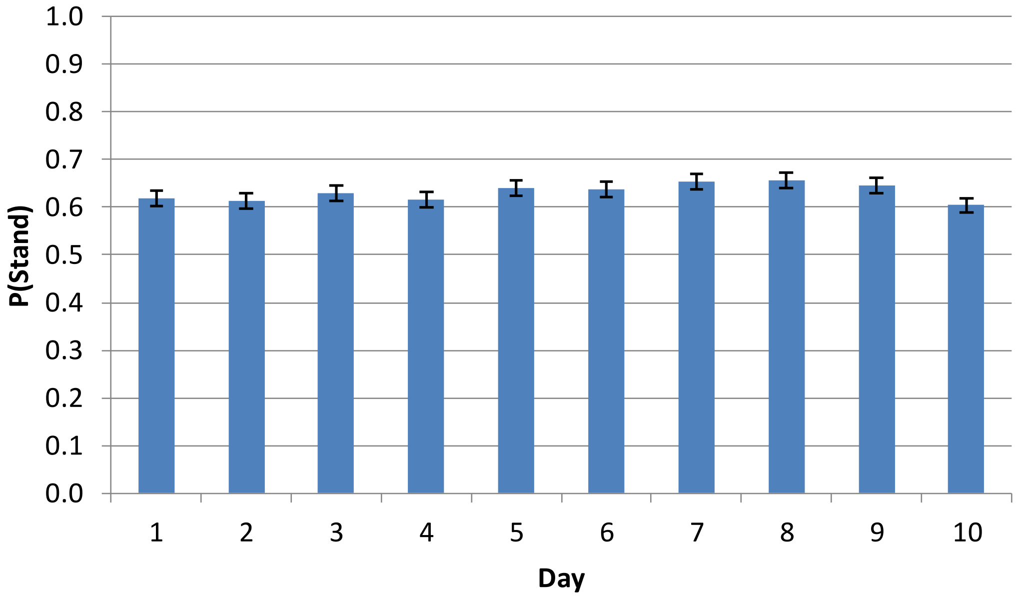

Figure 41. Estimated model-based proportions of an animal standing over the 10 test days.

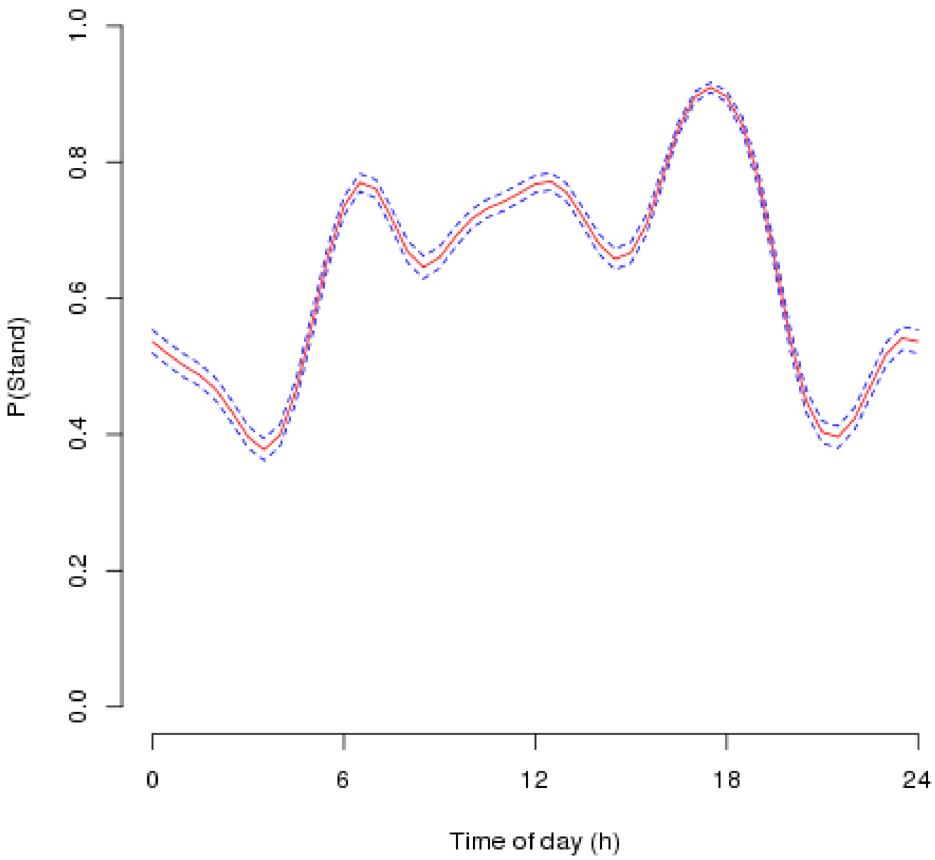

Figure 42. Model-based proportions of an animal standing in a 15-min period over the 24 hr cycle. The red line represents the model-based probability, and the dashed blue line represents ± one standard error of the estimate.

There was very strong evidence of a diurnal pattern in the change of standing behaviour (***Figure 42***), as indicated by the significance of the sine and cosine terms (P<0.001). Animals spent least time standing (most time lying) around 03:30 and 21:30, and most time standing (least time lying) around 17:30.

4.2.2 Number of steps

There was a suggestive association between pad score and the number of steps (P = 0.064; ***Figure 43***). This shows a slight effect of pad score, with the intermediate score (pad score 3) being associated with slightly more steps. Location significantly affected the number of steps (P<0.0001), with overall, animals taking ~ 2.6 times more steps when in the paddock, compared to when they were in the feedlot (***Figure 44***). Despite being significant (P<0.0001), no obvious pattern in the number of steps is evident across the 10 days of training (***Figure 45***).

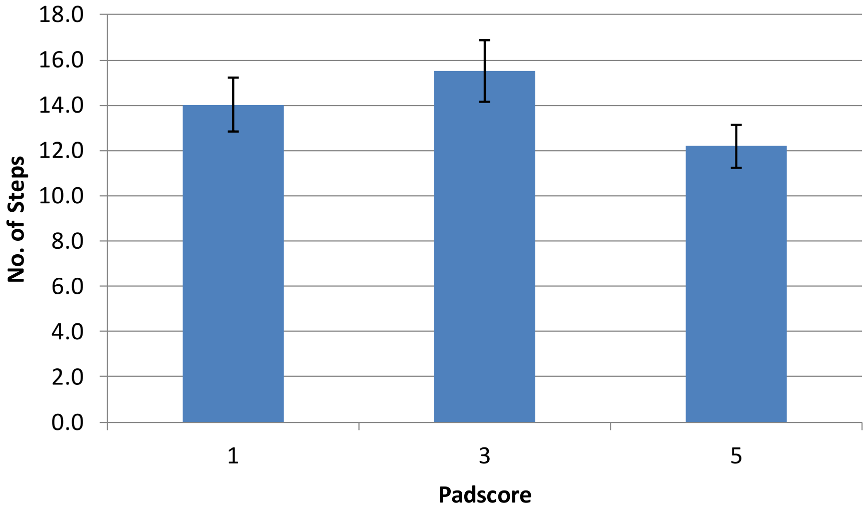

Figure 43. Estimated model-based proportions of the number of steps taken at the 3 feedlot pad scores.

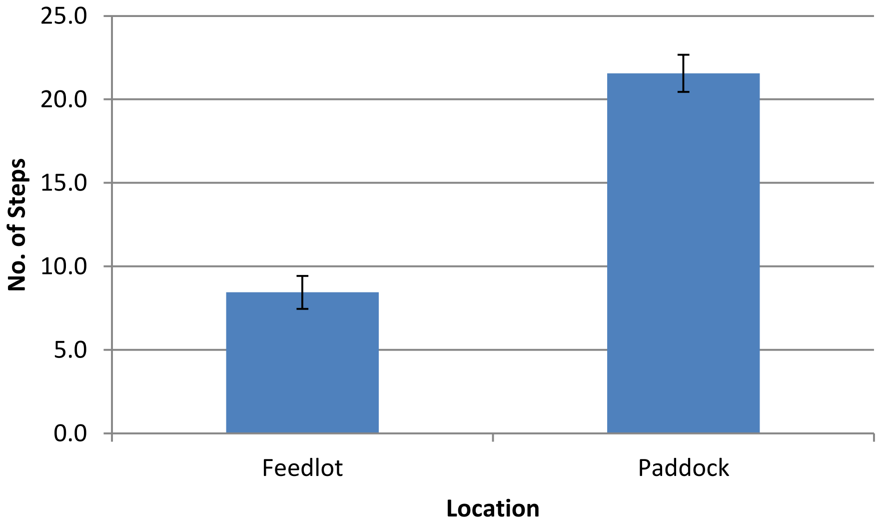

Figure 44. Estimated model-based proportions of the number of steps taken in the feedlot and paddock locations.

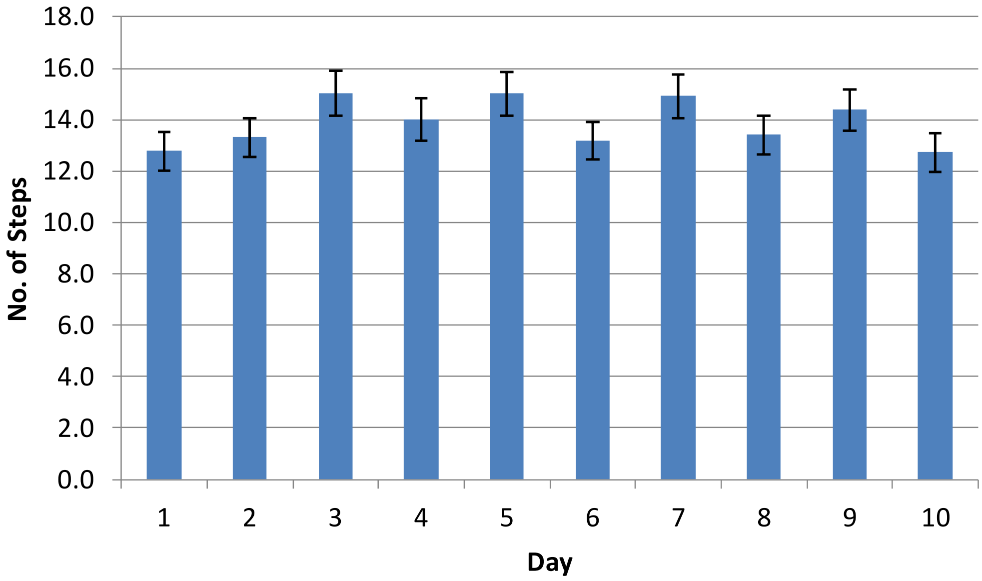

Figure 45. Estimated model-based proportions of the number of steps taken over the 10 days of testing.

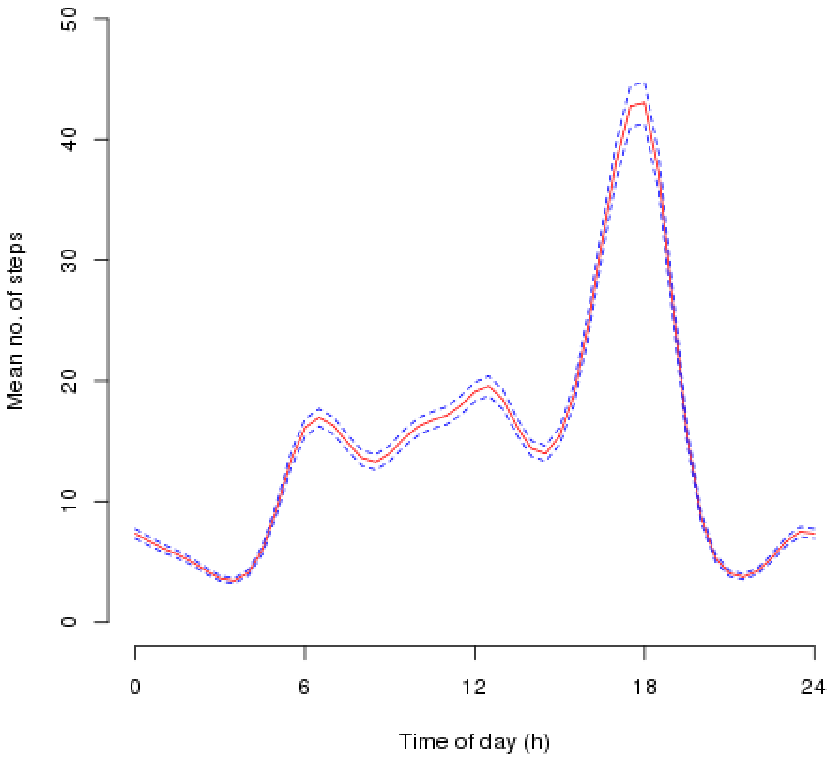

Figure 46. Model-based mean number of steps of an animal in a 15-min period over the 24 hr cycle. The red line represents the model-based mean, and the dashed blue line represents ± one standard error of the estimate.

As shown in Figure 46, there was a very strong 24-hr diurnal pattern, with a peak in steps around 18:00, with smaller peaks around 0:00, 6:00 and 12:00. These also correspond to the peaks in the probability of standing.

4.2.3 Lying bouts

All terms in the model with the exception of location (P = 0.376; Figure 47) were significantly associated with the number of lying bouts. There was an increase in the number of lying bouts as the pad score increased but these differences were small (1.1% difference for pad score 5 and 1.8% for pad score 3 compared to pad score 1; P<0.0001; Figure 48). No discernible trend over the 10-day period was evident, despite the significance (P=0.0063; Figure 49). Figure 50 shows the changes over a 24-hr period, with reduced number of lying bouts around 06:00 and 18:00.

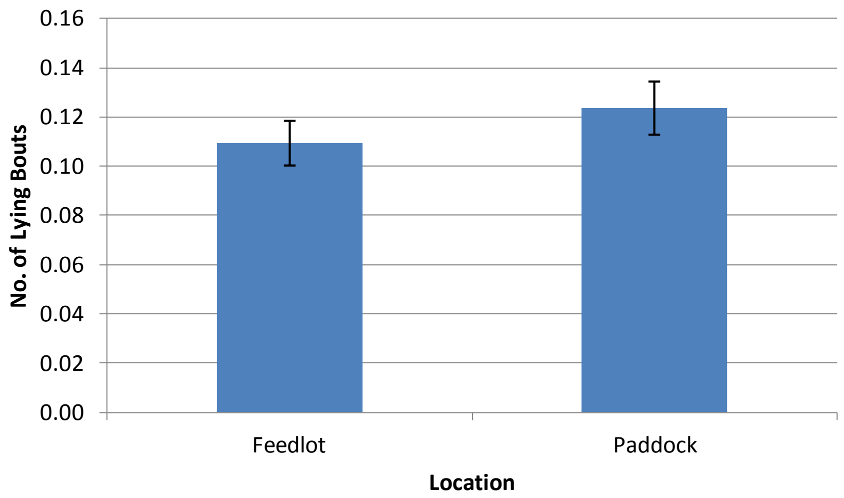

Figure 47. Estimated model-based proportions of the number of lying bouts in a 15 min period the feedlot and paddock environments.

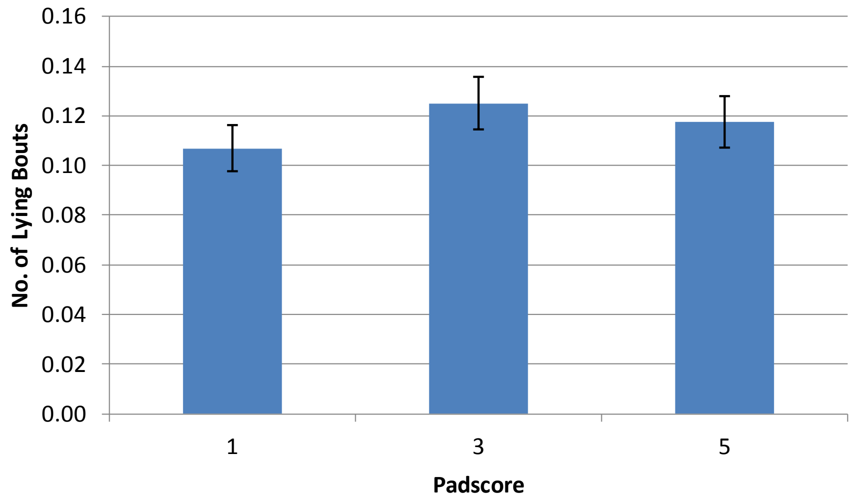

Figure 48. Estimated model-based proportions of number of lying bouts in a 15 min period at the different pad scores.

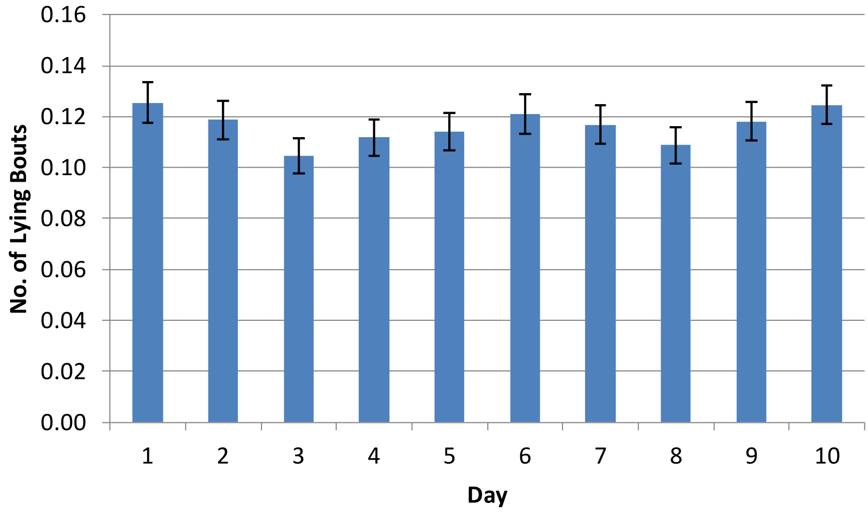

Figure 49. Estimated model-based proportions of the number of lying bouts in a 15 min period over the 10 days of testing.

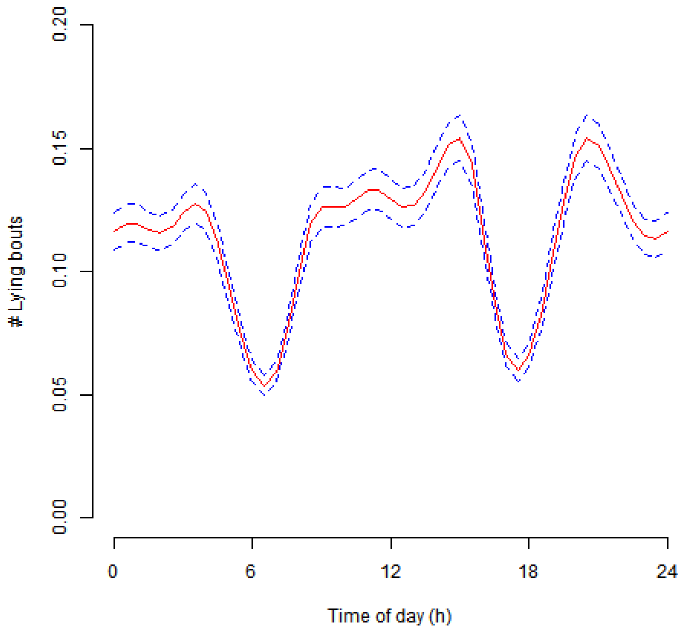

Figure 50. Model-based mean number of lying bouts of an animal in a 15-min period over the 24 hr cycle. The red line represents the model-based mean, and the dashed blue line represents ± one standard error of the estimate.

4.2.4 Individual animal variation in time spent standing and lying, number of steps and lying bouts

The variation between animals is represented in Figure 51. The estimated variance component for individual animal (0.170 ± 0.040, z = 4.23) indicates significant between-animal variation in the overall lying vs standing behaviours. This presents the effects on the logit scale, where the negative effects represent animals with least preference for standing, and the positive ones with the greatest preference for standing. There is also strong evidence of between-animal variation for stepping, as given by the estimated variance components: for stepping vs stationary: 0.116 ± 0.028 (z = 4.08) on the logit scale; for number of steps, given they were not stationary: 0 .061 ± 0.013 (z = 4.86) on the logarithmic scale.

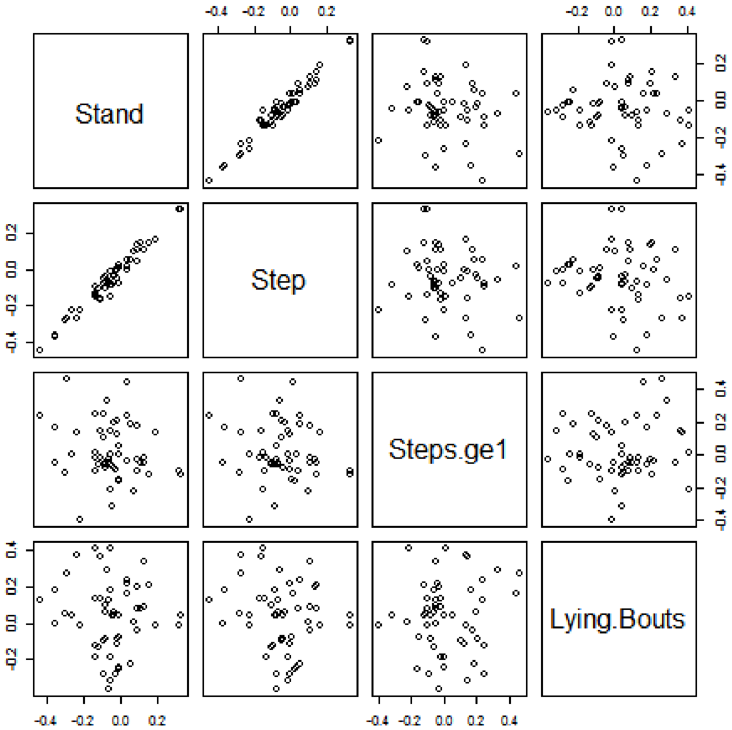

Figure 51. Scatter plot matrix of the estimated individual random animal effects for the probability of an animal standing (Stand), expressed on the logit scale; probability of stepping (Step) also expressed on the logit scale, and the number of steps, given that it was not stationary (Steps.ge1), on the logarithmic scale. Note that one effect is off the scale (Stand: +2.59; Step: +2.64), indicating an animal extremely likely to stand and step in all situations.

4.3 Discussion

Mud is a welfare and production issue in feedlots as it can impact on animal comfort and in winter can provide a thermoregulatory challenge to the animal which can significantly reduce performance, as reported in US feedlots (Morrison 1970; Mader 2011). We predicted that increasing the level of mud in the feedlot would reduce cattle preference for the feedlot and increase the preference for pasture. Our study did not confirm this prediction, with increasing feed pad score not affecting cattle preference for the feedlot in temperatures ranging from 8 to 24.7°C. One of the few other studies examining the effects of mud on feedlot cattle in

Australia was also conducted in similar climatic conditions and reported no differences in welfare of beef cattle (Wilson *et al.* 2002), and no effect on lying or feeding behaviour (Wilson 2005) when comparing dry and muddy feedlots. While the number of lying bouts (change of behaviour between lying and standing) increased with increasing pad score, this finding is opposite to the trend in experiment one, is a small effect and does not demonstrate a linear relationship between increasing pad score and lying bouts, therefore, this finding should be interpreted with caution.

The diurnal patterns of lying/standing observed in the current study were similar to that reported when cattle have free choice to enter a feedlot or pasture with peaks of lying at night and peaks of standing between 07:00h and 09:00h and again between 18:00h and 20:00h (Lee *et al.* 2013). Cattle had a preference for the pasture in the afternoon and cattle spent more time lying when at pasture which is consistent with the free choice testing study where cattle preferred the feedlot during the day (61% preference) and the pasture at night (90% preference) where there were lying down 80% of the time (Lee *et al.* 2013). This pattern may also reflect the need to compensate for the time spent in the muddy feedlot where lying may have been less comfortable. Several studies have reported a preference for pasture during the night in dairy cows (Legrand *et al.* 2009; Charlton *et al.* 2011; Charlton *et al.* 2013) and this suggests that cattle perceive pasture as a more attractive place for resting. We did not find any difference in feedlot preference when testing in the morning or afternoon in the Y-maze study using the pelleted diet (B.FLT.0149) which further supports the interpretation that cattle found the pelleted diet highly rewarding or they were responding to the auditory cue associated with feeding. This resulted in a strong motivation to access the pelleted diet in the feedlot which may have been stronger than the preference for lying down at pasture at night. In comparison, the feedlot diet in the current study may have been less attractive to the cattle and hence the diurnal preferences for behaviour were expressed and not masked by the high motivation to access the feed. It should be noted that the diet provided in the current study was a starter diet which is higher in roughage and may be less attractive than a grower or finisher diet. However, due to the risk of acidosis, we could not use a diet with a higher grain percentage for the current study. Testing with a grower or finisher feedlot diet may have increased preference for the feedlot.

Our previous studies have found some reduction in preference for the feedlot with increasing rainfall events (B.FLT.0349). In B.FLT.0349 cattle tested in the Tullimba feedlot spent less time in the feedlot with increasing rain events. However this was with higher pasture herbage mass availabilities (between 3000 and 4000 kg DM/ha) than the current study. While differing pasture availabilities did not alter cattle choice for the feedlot or pasture when tested under free choice conditions (Lee *et al.* 2013), the extent that feed availability affects feedlot choice in the Y-maze preference test is not known. We have found mixed results relating to feedlot preferences using the Y-maze model under different pasture availabilities. There was a strong preference for the feedlot in a previous Y-maze study with higher pasture availabilities of 4000 kg DM/ha (B.FLT.0149). In the current study herbage mass availabilities were lower (between 1200 and 2500 kg DM/ha) but still within the critical herbage mass recommendations of 700-2900 kg DM/ha for cattle (Bell 2006) and cattle did not show a strong preference for either environment. It is likely that numerous factors influence the choice of cattle for the feedlot or pasture, including the feed type and cues given during testing. In the current study, pad condition was not one of these factors.

There were little nutritive differences between the feedlot diets with the pelleted feed (B.FLT.0149) being similar in energy and protein (9.5 MJ/kg DM, 12% protein) to the Tullimba sourced diet (10.3 MJ/kg DM, 12% protein) which was used in the current study. However, the pelleted diet may have been more palatable and attractive as they ate their full diet within 30 min and this may have affected their choice to enter the feedlot, while the Tullimba diet was available ad libitum. In addition, cattle may have learned that availability of the reward in B.FLT.0149 was limited and have been more motivated to access the reward. In the current study, where cattle were provided with an ad libitum commercial feedlot starter diet whilst in the feedlot, no preference for the feedlot was shown and a preference for the pasture was shown only at pad score 1. In contrast, cattle provided with a pelleted feedlot starter diet twice daily showed a strong preference for the feedlot (B.FLT.0149). The preference for the feedlot in this second study could not be explained by pasture availability as it was higher than the current study (previously discussed above) but it was evident that coupling the testing with an audio cue of the diet being dispensed into the feed troughs did increase cattle choosing the feedlot. This is not surprising as cattle have been shown to respond to audio cues to enter a milking parlour where they received a feed reward (Wredle *et al.* 2006). As well, cattle would have been anticipating the forthcoming feed reward which would have provided motivation to enter the feedlot environment.

The choice of the cattle differed significantly over the 10 days of testing. An alternating pattern was evident which may be a consequence of hunger after being locked out from the feedlot so that cattle compensate by entering the feedlot the next day. This is the first time we have seen this type of response as the previous studies did not show this seesaw pattern.

Compared to extensive beef cattle grazing systems, feedlots confine cattle to a pen where they are not able to move freely over large distances. Not surprisingly, cattle took fewer steps when confined to a feedlot, than when they chose the pasture environment, which may relate to the need to graze to meet their energy requirements. However, whether restriction in movement associated with confinement in a feedlot is an issue to the animal or has welfare implications is not clear. It does appear that cattle were willing to “trade off” the access to grazing and free movement to access the feedlot diet even in muddy conditions. It may also be that the reward value of the feedlot diet outweighed the experience of being confined in a muddy feedlot.

Future research

Lying behaviours (time spent lying and lying bouts) have been reported to indicate how cattle perceive different surfaces for lying (Haley *et al.* 2000) and several studies in dairy cows report reduced lying time on muddy surfaces (Tucker 2010). The reduced lying time of dairy cows housed on muddy surfaces is more evident at colder temperatures (Fisher *et al.* 2003) and during winter (Muller *et al.* 1996). The effects of reduced lying time can induce chronic stress as demonstrated through alterations in pituitary-adrenal axis function in dairy cows (Fisher *et al.* 2002). Thermal comfort has been reported to be reduced in cows when exposed to a combination of wet, windy, cold conditions (Holmes *et al.* 1978). The current study was conducted at temperatures between 8 to 26° when the muddy surface was less likely to induce a thermoregulatory challenge and the mud would be less aversive to cattle than in winter. Further research is needed to determine cattle preference for a muddy feedlot vs pasture under colder conditions which may impose a greater thermoregulatory challenge to cattle. However, pasture quality and availability would be low in winter so some form of sown winter fodder would be necessary to compare the choice between pasture and feedlot.

The project objectives were to "Provide objective, science-based information on the influence of feedlot pad surface conditions on motivation of cattle for feedlot or pasture environments". This objective was met through assessing the preference and behaviours of cattle under different feedlot pad scores using a Y-maze model.

4.4 Conclusions/Recommendations

In conclusion, increasing levels of mud did not influence cattle preference for the feedlot or pasture environment when tested under relatively warm weather conditions. Even with high mud levels, cattle chose to enter the feedlot and therefore, it appears that they do not find the feedlot environment aversive. We would recommend testing the influence of mud under colder conditions in winter and using an established winter pasture or fodder crop set up to overcome pasture availability issues that would occur in winter in the New England.

4.5 Acknowledgements

We thank the team of technicians who worked on the studies: Dom Niemeyer, Tim Dyall, Sue Belson and Troy Kalinowski. And thank you to Kelsey Pool from the University of Sydney and Helene Pecourt from AgroParisTech, France for their contributions to the project. Thank you to the CSIRO workshop team, Barry Lockwood and Lindsay Wittig for building the shelters for the feedlot bunks. We also thank Colin Crampton from the Tullimba feedlot for supplying the feedlot ration for the studies. We also acknowledge and thank Peter Thomson from Sydney University for conducting the statistical analyses.

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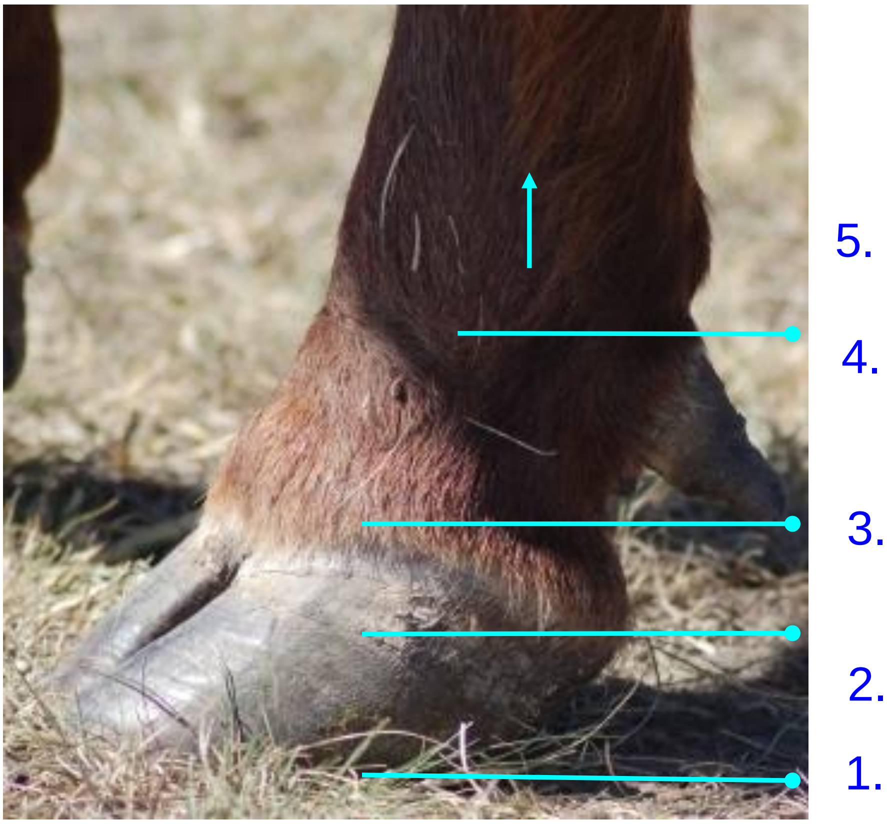
6 Appendix

Feedlot Pad scoring system



1. Dry feedlot pad.
2. Pad surface up to the heel bulb.
3. Pad surface up to the coronary band.
4. Pad surface up to fetlock height.
5. Pad surface past fetlock height.