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Feeling the heat: a retrospective investigation of thermal load impacts on calf loss

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Abstract

Northern Australia's beef industry annually experiences high heat loads and variable pasture conditions, yet their impact on reproductive wastage remains relatively unquantified. This study analysed retrospective herd data (26,903 cow-production years; 17 herds) to identify predictors of foetal and calf loss (FCL) in northern Australia, integrating climatic, pasture, and animal-level variables. Multilevel logistic regression revealed animal class, lactation status, relative pasture utilisation rate, body condition score and calving period as major factors. Counterintuitively, monthly heat stress indices (CCI) showed no direct association ($p=0.59$), potentially masked by monthly averaging or its effect moderated by other factors contained in the model. These results further underscore the importance of grazing and nutritional management in mitigating reproductive losses in northern beef cattle herds.

Introduction

Approximately 60% of Australia's national cattle herd is in northern Australia, encompassing Queensland, the Northern Territory and the northern regions of Western Australia (Bray et al., 2016). Beef production in a major industry in the region, characterised by extensive grazing on native pastures with limited augmentation with legumes. The breed composition is predominantly Bos indicus, due to its adaptability to the tropical and subtropical climate.

Northern Australia experiences extreme heat and humidity during summer, with temperatures frequently exceeding 35°C and relative humidity levels above 70%(Gaughan et al., 2010). Such conditions pose significant risks of heat stress in livestock, a metabolic state arising when heat accumulation surpasses an animal's capacity for thermoregulation (Brown-Brandl, 2018). Heat stress manifests in reduced feed intake, impaired growth and diminished milk production. The adverse effects of heat stress on reproductive performance (including reduced fertility rates, prolonged calving intervals, and elevated embryonic loss) are well-documented, though research has predominantly focused on dairy production systems (Takahashi, n.d.).

The repercussions of heat stress extend to neonatal health and immunity. Late-gestation heat stress in cows has been linked to reduced circulating immunoglobulin levels and suppressed milk yield (Monteiro et al., 2016). For calves, colostrum intake within the first hours of life is critical for establishing passive immunity, a key determinant of morbidity and mortality reduction in beef herds. Heat stress exacerbates dehydration risk in neonates due to suppressed milk supply, impaired thermoregulatory capacity and reduced suckling behaviour. Compounding this, heat-stressed calves exhibit suppressed immune function, increasing disease susceptibility(Tao et al., 2018).

This work formed part of the broader *Sweet Spot* project, which developed a retrospective dataset to investigate the relationship between pasture utilisation and reproductive performance of beef breeding females in northern Australia. This paper reports the results of an explanatory analysis determining the impacts of pasture and environmental conditions during the month of calving influenced the risk of calf loss. Additionally, parameters associated with beef breeding females and pasture conditions were investigated to assess their impact on losses between confirmed pregnancy and weaning.

Methods

A retrospective animal performance dataset was constructed by collating herd records from participating properties using a standardised data template. This template captured individual animal identifiers (e.g., electronic and visual ID, breed, location), management group details (e.g., age class, paddock), and muster-event variables such as body condition score (BCS), lactation status, pregnancy status, foetal age, live weight, and dates. To ensure consistency, farm-reported BCS scales were standardised to a 1–5 system, and heterogeneous Excel datasets were merged into a unified format. This enabled longitudinal tracking of individual females across annual production cycles, defined as the interval between consecutive pregnancy-testing musters.

Losses between pregnancy and weaning were assessed using annual pregnancy status (binary: 1 = pregnant, 0 = not) and lactation status. Using an assumed gestation length of 285 days, the month of conception and expected calving month were estimated based on foetal age and the date of pregnancy testing, pregnancies were assigned to an annual production year, with a September 1 cutoff for conception. Advanced pregnancies detected post-September were attributed to the subsequent cycle. Lactation status classified females as lactating or non-lactating. Calf loss occurred when a female confirmed pregnant in year t was non-lactating post-calving in year $t+1$, with successful rearing requiring lactation confirmation.

Climatic conditions during the month of expected calving were characterised using historical data sourced from SILO (https://www.longpaddock.qld.gov.au/silo/). To quantify heat stress risk, the Temperature Humidity Index (THI) and Comprehensive Climate Index (CCI) were calculated for each site. For each site, maximum daily index values were then summarised by mean and median and the proportion of days exceeding established heat stress thresholds.

Pasture dynamics were modelled for the annual growth cycle (1 October – 30 September) across 60 paddocks in northern Australia as part of the *Sweet Spot* project. The GRASP model (Rickert et al. 2000) was applied to simulate pasture growth and utilisation, integrating gridded historical climate data from SILO (https://www.longpaddock.qld.gov.au/silo/) supplemented with site-specific rainfall records where available. Modelled pasture growth was calibrated against ground-truthed measurements, including satellite-derived green ground cover and paddock-level Total Standing Dry Matter (TSDM). To assess pasture conditions during critical reproductive phases, modelled outputs were averaged across three temporal windows: (1) the month of expected calving, (2) the two preceding months and (3) the three-month post-calving period.

Statistical analyses were conducted using R (R Core Team 2024) to evaluate the relationship between pasture and animal parameters and foetal and calf loss. Mixed logistic regression analyses were performed with animal as the unit of analysis with animal within station and year specified as random effects. A forward stepwise modelling approach was applied. Continuous variables were assessed for linear or non-linear trends, and interactions were explored and only biologically plausible interactions retained. Results are reported as adjusted means with standard errors, reflecting adjustments for all model terms.

Results

The starting dataset contained 26,903 rows of data representing a production year for an individual cow. On average, each individual cow contributed 1.76 (95% CI, 1.74-1.77) animal-production years of data for which a valid foetal or calf loss was ascribed. Seventeen herds contributed information to the analytical dataset with a median of 1085 (interquartile range, 500 - 2387) FCL outcomes relating to an individual herd.

The final multilevel model, accounting for hierarchical data structures, which explained the greatest variation in foetal and calf loss contained the fixed effects: animal class (*Heifer, 1st Lactation cow, Mature cow, Aged Cow;* F=8.78, p<0.001), a quadratic polynomial of body condition score (F=3.23, p=0.04), Estimated period of calving (*Jul-Aug, Sep-Oct, Nov-Dec, Jan-Feb, Mar-Apr, May-Jun;* F=1.93, p=0.09), annualised lactation status (*Lactated, Didn't lactate*; F=45.18, *p*<0.001), Pasture utilisation rate relative to recommended safe carrying capacity (continuous; F=24.90, *p*<0.001), average maximum comprehensive climate index for the expected month of calving (continuous; p=0.59) and region category (*NE Qld, South NT, Central NT, North NT;* F=0.93, p=0.48), with a significant interaction between calving period and region (F=4.04, *p*<0.001).

The occurrence of foetal and calf loss was predicted for each factor using the final multilevel model, with predicted probabilities and approximate 95% confidence limits of the mean presented in Figure 1.

Discussion

This paper is one of the few that describes the influence of pasture utilisation and heat load indices in relation to the reproductive performance of free-grazing beef females in northern Australia, specifically foetal and calf loss. However, it is important to acknowledge that the analyses were conducted using a retrospective dataset comprising both research and commercial herd performance data. Consequently, the individual datasets exhibit inherent idiosyncrasies and management practices may have been influenced by trial design and an appropriate level of caution is advised in interpreting the findings presented in this paper.

The final model highlighted the importance of management practices that support the nutritional requirements of pregnant females to maximise reproductive performance. These effects were nuanced by the expected calving period, highlighting the need for tailored nutritional strategies. Notably, pasture utilization rate relative to safe carrying capacity had a strong influence on calf loss, with overstocking leading to increased losses. This finding reinforces the critical role of nutrition in maternal support, particularly through milk and colostrum production. Animal class was a critical determinant. Consistent with previous research findings, heifers were found to exhibit greater calf loss compared to 1st Lactation and mature cows (Fordyce et al., 2022). Heifers generally have higher energy requirements due to the simultaneous demands of growth and lactation, leading to increased competition for nutrients. This heightened demand can result in a negative energy balance, which may negatively impact their reproductive performance. Overall, cows that lactated in the previous reproductive cycle (contributed a weaner) had 3.8 percentage points lower occurrence of calf loss. These findings align with previous research demonstrating that cows with a history of producing calves tend to have improved reproductive efficiency (Fordyce et al., 2022).

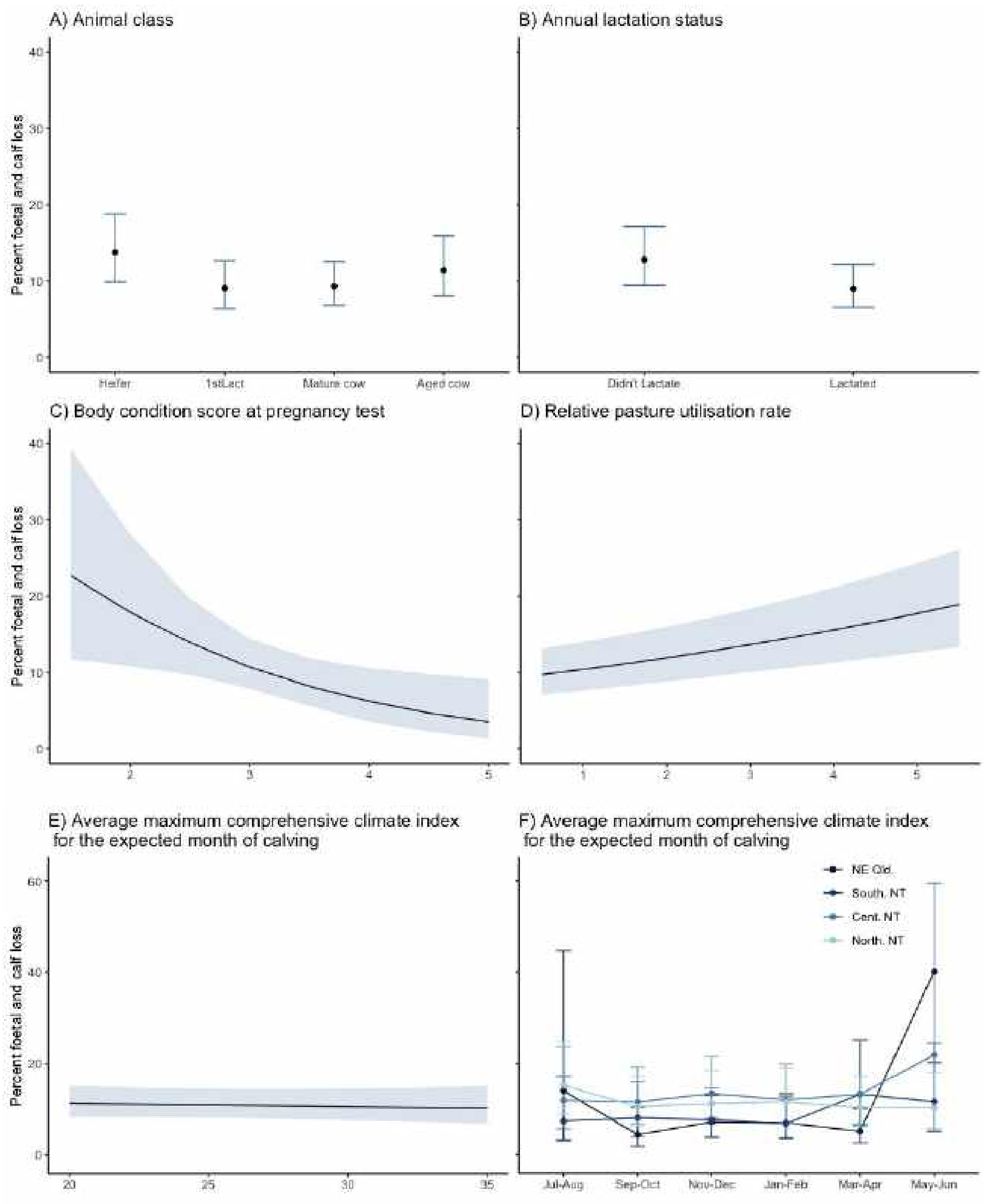

Figure 1: Predicted mean (and 95% confidence limits) occurrence calf mortality across levels of risk factors and their significant interactions identified in the final multilevel logistic regression model. Predictions are based on estimated marginal means adjusted for all variables in the model. Subfigures represent individual risk factor effects or interactions: A) animal class; B) annual lactation status; C) body condition score; D) relative pasture utilisation rate E) average maximum CCI during expected month of calving and interaction between predicting calving period and region.

Counterintuitively, heat stress indices during calving months showed no significant association with calf loss. This absence of a direct relationship may reflect limitations in the resolution of the dataset: monthly averaged CCI values could obscure short-term, acute heat stress events critical to neonatal survival. Alternatively, heat stress impacts may be indirectly mediated through correlated variables in the model, such as calving period, which encapsulates seasonal shifts in both climatic extremes and pasture conditions. Future research should integrate finer-scale heat stress metrics and direct physiological markers (e.g., colostrum IgG levels / calf vigor / actual birth events) when assessing the effects of heat stress on extensively managed beef females.

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