Contributed paper

ASSESSING THE RELATIONSHIP BETWEEN BEEF CATTLE FERTILITY TRAITS AND NOVEL ENVIRONMENTAL DESCRIPTORS IN NORTHERN AUSTRALIA

J.P. Copley[1], B.N. Engle[1], S. Speight[1], G. Fordyce [1], E.M. Ross [1], K.P. Voss-Fels[1] and B.J. Hayes[1]

[1] Queensland Alliance for Agriculture and Food Innovation (QAAFI), the University of Queensland, St Lucia, QLD, 4069 Australia

SUMMARY

Fertility is a major challenge for beef producers in the harsh and diverse environmental conditions of Northern Australia. Two of the most significant environmental challenges facing breeding females are low and variable nutrition and exposure to severe heat stress. This paper aimed to define novel environmental descriptors that can be used to account for these effects when modelling fertility traits. Nutrition descriptors were based on rainfall records and average daily liveweight gain (ADWG). Heat stress descriptors were based on daily values for a temperature humidity index (THI). Three fertility phenotypes were collected as part of the Northern Genomics project; puberty (CL600), first pregnancy (PD1) and second pregnancy (PD2). The aims of this study were to examine the relationship between fertility traits and continuous environmental descriptors and confirm the importance of puberty attainment to subsequent reproductive success. Animals that were pubertal at CL600 were found to have increased odds of success in subsequent pregnancy recording. Environmental descriptors based on THI successfully defined an environmental gradient as the cumulative exposure to chronic heat stress. ADWG successfully modelled nutritional availability for PD1 and PD2 but descriptors based upon total rainfall were not successful.

INTRODUCTION

The Northern Australia beef industry contains 60% of Australia's national herd and is defined by diverse and challenging environmental conditions (McLean *et al.* 2014). These conditions negatively impact female fertility, an important driver of profitability. The environment represents more than location or a contemporary group, it is the sum-total of the temperature, rainfall, pasture availability and other factors to which animals are exposed. The environmental descriptors examined in this study were designed to account for environmental variation as a continuous variable based upon available weather information and animal weight gain performance. Also examined was the role of early attainment of puberty on subsequent pregnancy. Overall herd productivity is enhanced by large numbers of maiden heifers becoming pubertal, conceiving and subsequently calving early in the breeding season, giving maximum opportunity for lifetime reproductive success. The objectives of this study were to assess the relationship between fertility traits and novel, continuous environmental descriptors measured in Northern Australia.

MATERIALS AND METHODS

Phenotypes. The project utilized heifer data (n = 24,768) from 54 commercial herds from across Northern Australia, collected as part of the ongoing Northern Genomics project. The animals represented a diverse range of breeds including: Brahman, Angus, Belmont Red, Charolais, Droughtmaster, Shorthorn, Limousin, Santa Gertrudis, Boran and Wagyu (Hayes *et al.* 2019). Heifer reproductive maturity (CL600) was measured when approximately 50% of the contemporary herd was sexually mature, using a one-time ovarian scan via ultrasound to detect the presence of a *Corpus Luteum* (CL; n = 25,176), following the procedures outlined by Hayes *et al.* (2019). This trait was nominally measured at approximately 600 d of age. Heifers which displayed a CL or were pregnant, were deemed 'pubertal', the rest 'non-pubertal'. Heifer pregnancy status was measured as foetal age

in weeks (n = 20,989) at approximately 2.5 yrs of age, following the heifer's first breeding season, and the subsequent pregnancy (n = 10,072) at approximately 3.5 yrs of age (PD1 = first pregnancy and PD2 = second pregnancy). Animals were also recorded for liveweight (Wt), hip height (HH), body condition score (BCS) and a tail hair sample taken.

Environmental Descriptors. Weather data for each collaborating property was obtained using the NASAPOWER package in R 3.5.3 (Sparks 2018). NASAPOWER data is a publicly available global climatology database with a 0.5° by 0.5° arc of longitude and latitude (Sparks 2018). Based upon the coordinates provided for each collaborator, daily observations of rainfall, temperature and relative humidity data were downloaded for the 20 years preceding the date of trait recording.

The temperature (T**)** and relative humidity (RH**)** was used to calculate a daily temperature humidity index (THI) via using the formula from Wijffels *et al.* (2013).

$$THI = 0.8 * T + \big((RH * 0.01) * (T - 14.4)\big) + 46.4$$

To assess the impact of the severity of the environment in which the heifers were exposed, the number of days where THI was equal to or exceeded different thresholds (65-79) in the 6 months prior to trait recording (CL600) or conception date (PD1) was assessed. A THI value of 79 was used as it is considered to be the threshold of severe heat stress (Moran 2005; McGowan *et al.* 2014). Chronic heat stress was also modelled by calculating the area under the curve (AUC) of daily THI in the 120 d surrounding (60 d prior and 60 d post) trait recording/conception date.

Rainfall descriptors were based on the daily precipitation records. Three separate descriptors were calculated based on key dates in the breeding cycle: conception date (PD1) and trait recording date (CL600). Total rainfall (mm) in the 365 d prior to trait recording, total rainfall (mm) in the 120 d prior to trait recording and the standard deviation of rainfall in the 120 d prior to trait recording compared to the 20 yr average of the same period and location.

ADWG was calculated as the average daily gain from CL600 to PD1 (kg/day). The effect of ADWG was not modelled for CL600 as no Wt data prior to CL600 measurement was available.

Statistical Analysis. The *B.indicus* percentage and heterozygosity was calculated using the methods outlined by Hayes *et al.* (2019). The environmental descriptors were fitted as fixed effects in a generalized linear model. The equation of each generalized linear model was:

$$Fertility\ trait \sim HH + BCS + Wt + CG + BI\% + Het + \ Environmental\ Descriptor$$

CL600, PD1and PD2 were modelled as binary traits (0 = 'non-pubertal', 1 = 'pubertal' OR 0 = 'non-pregnant', 1 = 'pregnant') using a logistic regression. Statistical analysis was conducted using the glm.db package in R (Ripley *et al.* 2013). Additional analysis to examine the effect of puberty at CL600 on pregnancy was completed using a least squares mean test via the emmeans package in R (Lenth *et al.* 2020). The relationship between CL600 score and all environmental measures was also modelled using logistic regression (0 = "non-pubertal", 1 = "pubertal") using the glm.db package in R (Ripley *et al.* 2013).

RESULTS AND DISCUSSION

Effect of CL600 on pregnancy. Heifers that were pubertal at CL600 had increased log odds of pregnancy success at both PD1 (0.56) and PD2 (0.75) compared to non-pubertal heifers ($P < 0.05$). This study has reinforced the usefulness of early puberty as a heritable trait capable of being measured earlier in life and which has a positive and significant relationship to later-in-life pregnancy traits (Johnston *et al.* 2014; Corbet *et al.* 2018). Heifers that are pubertal at the commencement of joining conceive early, calve early and readily reconceive.

Effect of environmental descriptors on CL600. The effect of the number of days over THI 65 and 70 was significant and negative ($P < 0.05$. The cumulative daily THI for 120 d surrounding trait recording was significant and negative ($P < 0.05$). Each additional day of severe heat stress (THI >= 79) to which heifers were exposed was significant ($P < 0.05$) to puberty attainment but suggested a positive relationship, a results contrary to expectations. The results suggests that an increased heat

load, particularly chronic heat stress in the period prior to ovarian scanning will reduce the proportion of pubertal females. The reason for the lack of a relationship between acute heat stress and diminished puberty outcome is unclear. The secretion of hormones by the structures of the reproductive tract during estrus are subject to interference under high heat stress conditions, an effect that has been accounted for by these descriptors (Wolfenson and Roth 2018). The rainfall total and deviation of total rainfall from the long-term average and 12 mo rainfall in the preceding 12 mo were both not significant to the outcome of CL600. This result suggests that the rainfall descriptors did not conclusively account for the variability of nutrition.

Effect of environmental descriptors on PD1. The number of days to which animals were exposed to THI thresholds of 65 and 70 in the 120 d surrounding conception date had a significant impact ($P < 0.05$) and was associated with reduced pregnancy success. Area under the curve of daily THI measurements and the number of days over 75 were both not significant. Days over 79 again had a positive effect ($P < 0.05$). The results suggest that the THI descriptors adequately model chronic heat stress and the detrimental impact it has on early pregnancy and cyclicity (Gilad *et al.* 1993). Total rainfall and deviation from average were not significant to pregnancy outcome. The effect of ADWG was significant ($P < 0.05$), with increased ADWG being associated with improved pregnancy results.

Effect of environmental descriptors on PD2. THI descriptors had a universally negative relationship to second pregnancy and were significant ($P < 0.05$) for; AUC, and days over 75. This was consistent with results for PD1 and CL600 in that a stronger relationship was found to chronic heat stress rather than acute or severe heat stress. The lack of a significant relationship between acute heat stress (days over 79) may be due to several factors, including adaptation and confounding seasonal effects as peak THI typically coincides with the wet season, and thus peak nutritional availability, in Northern Australia. The relationship of PD2 outcome to ADWG and rainfall echoed the results from PD1, ADWG was significant ($P < 0.05$) while rainfall was not.

CONCLUSIONS

This study showed that heifers which were pubertal at CL600 had improved pregnancy outcomes at PD1 and PD2. This underscores the importance of breeding heifers that are early maturing. Heifers that are pubertal at the start of the joining period maximise the available time to conceive early in the joining period which in turn increase the available time to re-conceive.

THI-based descriptors to measure chronic heat stress had significant relationships with puberty attainment and heifer pregnancy. ADWG was found to have a significant relationship, in the expected direction, with first and second pregnancy. However, descriptors based upon rainfall had no significant relationship. The descriptors based upon ADWG and chronic heat stress satisfied the primary objective of the study, to define an environmental gradient based on these descriptors. Further refinement of rainfall descriptors is required.

ACKNOWLEDGEMENTS

The authors would like to thank the collaborating herds for participating in the Northern Genomics Project and the various DAF staff for their assistance. We also gratefully acknowledge the funding from The University of Queensland and the MLA Donor Company through project P.PSH.P0833.

REFERENCES

Corbet N., Allen J., Laing A., Fordyce G., McGowan M. and Burns B. (2018) *J. Anim. Prod. Sci.* **58(9):** 1735.

Gilad E., Meidan R., Berman A., Graber Y. and Wolfenson D. (1993) *J. Repro*. **99(2)**: 315.

Hayes B., Fordyce G. and Landmark S. (2019) *Proc. Assoc. Advmt. Anim. Breed. Genet.* **23:** 282.

Johnston D., Barwick S., Fordyce G., Holroyd R., Williams P., Corbet N. and Grant T. (2014) *J. Anim. Prod. Sci.* **54(1)**: 1-15.

Lenth R., Beurkner P., Herve M, Love J, Riebl H and Singmann H. (2020) 'Estimated Marginal Means, aka Least-Squares Means'. R package version 1.3.2.

McGowan M., McCosker K., Fordyce G., Smith D., O'Rourke P., Perkins N., Barnes T., Marquet L., Morton J. and Newsome T. (2014) 'North Australian beef fertility project: Cash Cow. Final Report'. Meat and Livestock Australia, Sydney.

McLean I., Holmes P. and Counsell D. (2014) 'The Northern beef report: 2013 Northern beef situation analysis'. Meat and Livestock Australia, Sydney.

Moran J. (2005) 'Tropical dairy farming: feeding management for small holder dairy farmers in the humid tropics'. Csiro publishing.

Ripley B., Venables B., Bates D. M., Hornik K., Gebhardt A., Firth D. and Ripley M.B. (2013) *J. Cran. R.* **538:** 113.

Sparks, A. H. (2018) 'nasapower: a NASA POWER global meteorology, surface solar energy and climatology data client for R'.

Wijffels G., Gaughan J., Revell D. and Allingham P. (2013) 'Heat Stress Nutrition: A comprehensive review and R&D program'. Meat and Livestock Australia, Sydney.

Wolfenson D. and Roth Z. (2018) *Anim. Front.* **9(1):** 32.