650. Understanding the genetics of fertility and temperament in Northern beef cattle using genomic technologies

J.P. Copley[1*], N.J. Corbet[2], J.M. Allen[3], A.R. Laing[4], G. Fordyce[1], M.R. McGowan[5], B.M. Burns[6], R.E. Lyons[7] and B.J. Hayes[1]

[1]Queensland Alliance for Agriculture and Food Innovation, Centre for Animal Science, University of Queensland, 306 Carmody Rd, St Lucia, QLD, 4072, Australia; [2]CQ University, Rockhampton North Building 361 – G20 CQIRP, 4700 Rockhampton, Australia; [3]University of New England, Agricultural Business Research Institute, Armidale, 2351, NSW, Australia; [4]Queensland Government, Department of Agriculture and Fisheries, Ayr, 4087 QLD, Australia; [5]University of Queensland, School of Veterinary Science, University of Queensland Gatton Campus, 4343 Lawes QLD, Australia; [6]Queensland Government, Department of Agriculture and Fisheries, Rockhampton, 4702 QLD, Australia; [7]Neogen Australasia, University of QLD, Gatton Campus, 4343 Lawes, Australia; james.copley@uq.edu.au

Abstract
Fertility and temperament are important drivers of productivity in the beef industry of northern Australia. The purpose of this study was to determine the heritability of temperament and fertility traits and to estimate the genetic correlation between these traits using a gBLUP analysis. Fertility phenotypes, Post-partum anoestrus interval (PPAI) and age at puberty (AGECL, Tscore) were recorded in Brahman (n=936), Tropical composite (n=1,097) and Smart Futures Heifers (n=3,696). Flighttime records totalled 4,645. The genotype data was imputed from 35k to 800k SNP. Heritability was 0.56(0.08), 0.37(0.08), 0.44(0.11), 0.24(0.08), 0.19(0.03) and 0.33(0.03) for AGECL(Brahman), AGECL (Tropical composite), PPAI (Brahman), PPAI (Tropical composite), Tscore (Smart Futures Heifers) and Flighttime respectively. Genetic correlation was -0.01(0.10), -0.06(0.11), -0.03(0.07) and 0.32(0.09) between AGECL and Flighttime, PPAI and Flighttime, Tscore and Flighttime and PPAI and AGECL respectively. The result suggests that selecting for improved temperament would not improve fertility.

Introduction
Fertility of beef breeding females, measured by pregnancy, weaning rates and age at puberty is poor in northern Australia. Whilst environment is a significant contributing factor, the heritability of fertility traits indicates that substantial gains could be made in fertility through targeted selection. Fertility traits are, however, time-consuming, expensive and in some cases, completely unfeasible to measure in the extensive environments of northern Australia. Temperament is also heritable and is comparatively simple to measure. A potential, beneficial genetic correlation between temperament and fertility would allow for fertility to be improved through measurement of temperament only. The first objective of this project was to verify the heritability of individual temperament and fertility traits. The second and primary objective was to probe a potential genetic correlation between temperament and fertility.

Materials &methods
Animal data. The data utilised in the project stems from research undertaken by the Cooperative Research Centre for Cattle and Beef Quality (CRC) as part of the Northern Australian breeding project (Johnston *et al.*, 2009). The animals were located on seven commercial beef operations located across Northern Australia – four for BRAH and three for TROPCOMP, as well as data from the 'Belmont' research station in Central Queensland (Johnston *et al.*, 2009). Data from the SmartFutures (SF) project was also included (Burns *et al.* 2013).

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Age at first *Corpus Luteum* (AGECL) was used to measure age at puberty. AGECL measurements in BRAH and TROPCOMP cohorts were obtained through multiple ovarian ultrasound scans of heifers conducted at 4-6 week intervals, commencing when heifers reach ~200 kg at 10-12 months (Johnston *et al.*, 2009). Length of Post-partum anoestrus interval (PPAI) measured the period of non-cyclicity following calving. Records in the BRAH and TROPCOMP cohorts were obtained similarly to AGECL, scanning commenced post-calving and continually every four weeks up until weaning (Johnston *et al.*, 2009). Tscore was an analogous measure to AGECL taken from a single ovarian ultrasound scan conducted at ~600 days of age using the procedures outlined by Corbet *et al.* (2017) in the SF cohort. Temperament was measured by Flighttime, using the standard practice outlined by Fordyce *et al.* (1988).

Statistical analysis. The statistical model fitted to the AGECL data set (separately for TROPCOMP and BRAH) was:

$y=X\beta+Zu+e$

Where; y = vector of phenotypes X= design matrix allocating phenotypes to fixed effects, β = vector of fixed effects, including age as a covariate, contemporary group, and percentage *Bos indicus*, Z= design matrix allocation records to animal effects, u = vector of (random effect) additive breeding values, one for each animal, distributed Normal $(0,G\sigma_u^2)$, e = vector of residual errors, distributed $N(0,\sigma_e^2)$. The G matrix is the genomic relationship matrix among the animals, calculated from the SNP data, following the formulas of VanRaden *et al.* (2008). GCTA was the software used to calculate the G matrix and to estimate the variance components, σ_u^2 and σ_e^2 (Yang *et al.* 2010). The heritability of the traits were calculated as $h^2 = \sigma_u^2/(\sigma_u^2+\sigma_e^2)$.

Results

The heritability of individual temperament and fertility traits are presented in Table 1.

Genetic correlations amongst fertility and temperament traits are given in Table 2.

Table 1. Heritability of fertility and temperament traits from the G-REML analysis. Standard errors are given in brackets.

Trait	n	Range	Std	h^2
AGECL (BRAH)	922	423-1,169	138.53	0.56 (0.08)
AGECL (TROPCOMP)	999	344-945	120.40	0.37 (0.08)
PPAI (BRAH)	582	17-484	108.44	0.44 (0.11)
PPAI (TROPCOMP)	822	19-473	109.89	0.24 (0.08)
Tscore	3,696	0-5	1.29	0.19 (0.03)
Flighttime	4,645	39-528.8	54.90	0.33 (0.03)

Table 2. Genetic correlations among fertility and temperament traits from G-REML analysis. Standard errors are given in brackets.

Trait	AGECL	PPAI	Tscore	Flighttime
AGECL	-	0.58 (0.10)	-	-0.01 (0.10)
PPAI	0.58 (0.10)	-	-	-0.06 (0.11)
Tscore	-	-	-	-0.03 (0.07)
Flighttime	-0.01 (0.10)	-0.06 (0.11)	-0.03 (0.07)	-

Discussion

The heritability estimates of AGECL across the BRAH and TROPCOMP datasets indicated that the trait was moderately to highly heritable. This confirmed that direct selection for AGECL is possible. The results aligned closely to those derived by Johnston *et al.* (2009) for the same trait (0.57) and Vargas *et al.* (1998) (0.45). The heritability in TROPCOMP was lower than the estimate by Johnston *et al.* (2009) (0.52). The minor divergence between these results was potentially due to differences in the fixed effect modelling in the respective datasets. The Tscore measurement used for the SF dataset was a related, but less precise measure of age at puberty compared with AGECL. It interpreted the development of the uterine tract of heifers from a single measurement taken at 600 days. The obtained result for Tscore aligned closely with estimates made by Corbet *et al.* (2017) (0.18-0.32). Tscore, while a less precise measurement of puberty, is potentially a viable alternative to the multiple scannings required for AGECL, allowing puberty traits to be recorded in larger herds from more extensive, commercial businesses. This approach has been utilised in studies such as Hayes *et al.* (2019).

The estimated heritability of PPAI in both the BRAH and TROPCOMP datasets suggested PPAI was moderately to highly heritable. The results compared favourably to estimates by Johnston *et al.* (2013) who found heritability of PPAI to be 0.52(0.14), 0.20(0.12), 0.24(0.14) for *Bos indicus* females aged three, four and five years respectively. PPAI was found to be sufficiently heritable as to warrant direct selection in targeted breeding programs. In productive beef herds where breeding females should ideally produce one calf every twelve months, reducing PPAI is vital to improving reproductive success (Shatz *et al.*, 2011).

Flighttime was estimated to be moderately heritable. Numerous other results by Burrow *et al.* (2001), Burrow *et al.* (1988) and Burrow and Corbet (2000), all using pedigree rather than genomic data in their estimates, found the heritability of Flighttime to be 0.40, 0.26, 0.35 and 0.48 respectively. Estimates by Valente *et al.* (2015) and Valente *et al.* (2017) found the heritability to be lower, 0.27(0.07) and 0.22(0.02). The estimate obtained by this study emphasises Flighttime is a low to moderately heritable trait suggesting that selection would be possible. Selection for any trait relies on the collection of precise data using repeatable and objective methods. Temperament has been subjectively measured using metrics such as 'crush score' and 'temperament score', however, using the objective measure of Flighttime avoids issues stemming from human error and unconscious bias (Curley *et al.*, 2006). The potential for selection of improved temperament would be welcomed in Northern Australia, where temperament impacts directly on productivity (Fordyce *et al.*, 1988).

Estimated genetic correlation between PPAI and AGECL was positive and high, 0.58(0.10), suggesting the possibility of indirect selection. The previous results indicated that both these traits are highly heritable on an individual basis. The estimated correlation between PPAI and AGECL for TROPCOMP, closely matched results obtained by Johnston *et al.* (2014) who found correlation to be 0.72(0.07) and 0.31(0.18) for Tropical composite and Brahman females respectively. This result suggests females with earlier puberty tend to have shorter PPAI and are thus more likely to reconceive and calve again within the ideal 12-month cycle. Puberty, either AGECL or Tscore, can be measured earlier in an animals life, this combined with the favourable genetic correlation means that reduced PPAI can be reliably selected for without waiting for the animals to conceive and subsequently calve.

The second objective was to investigate if superior temperament, expressed as longer Flighttime in female beef cattle, can be used as a proxy trait to select indirectly for fertility. The estimated genetic correlation between Flighttime, and all fertility traits was effectively zero. This result of low, negative correlations between temperament and fertility traits was similarly observed by Valente *et al.* (2015) who found the correlation between Flighttime and early puberty in males and early pregnancy in females to be -0.09(0.09) and -0.07(0.08). Burrow *et al.* (2001) found no genetic correlation between Flighttime and fertility traits including pregnancy status and early puberty. Cooke *et al.* (2011) and Burrow *et al.* (1988) found a positive relationship, between temperament and success rate of artificial breeding programs, however this was evaluated to be caused by easier management of quieter cattle rather than these cattle being inherently more fertile. A significant genetic correlation would have allowed direct selection for temperament traits to lead to indirect selection for fertility traits. Temperament and fertility appear to be independent traits. To improve fertility, temperament cannot be used as indicator trait, rather fertility must be measured and selected for directly.

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