Using sensor-derived estrus dates to improve the genetic evaluation of fertility in the New Zealand dairy industry

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Abstract

Reproductive performance remains a cornerstone for farm profitability in New Zealand's pasture-based dairy systems. Most NZ farmers maintain a strictly annual and tightly condensed calving period to synchronize herd feed demand with seasonal pasture growth. The interval from calving to first estrus (post-partum anestrus interval; PPAI) has been recognized as a useful candidate predictor trait for fertility EBVs, but widespread phenotype collection has historically been hindered by the expense and logistical challenges associated with serial blood testing or vigilant visual observation. With the advent and rapid adoption of activity sensors, LIC now has available a large and expanding dataset of estrus events, enabling efficient and scalable derivation of a range of fertility-related traits, including PPAI. Preliminary analyses demonstrate that PPAI has a heritability of around 0.12 and exhibits a moderate genetic correlation of -0.57 with timing of pregnancy (i.e. conception success within the first 42-d of the breeding period is associated with shorter PPAI). These preliminary results support PPAI as a useful predictor phenotype for fertility EBVs. Furthermore, the availability of routinely recorded estrus dates for individual cows creates new opportunities for investigating other novel fertility phenotypes, such as length and regularity of estrous cycles, early confirmation of pregnancy and differentiation of conception-failure and early pregnancy loss. Integrating sensor-based estrus detection into the national fertility evaluation is likely to increase the rate of genetic improvement for fertility in the NZ dairy herd, driving improved reproductive performance, and therefore cow longevity.

Key words: Fertility, Cattle, post-partum, anestrus

Introduction

New Zealand's seasonal dairy production system places considerable emphasis on reproductive efficiency. Herds are typically managed to calve over a concentrated period in spring, allowing lactation-driven energy requirements to coincide with the seasonal availability of pasture (Macdonald et al., 2010). Maintaining this annual pattern requires cows to return to reproductive cyclicity quickly following calving and become pregnant within a restricted mating period. Fertility is therefore an important component of the national breeding objective (Harris, 2005). Genetic improvement of fertility is challenging, however, because conventional fertility phenotypes, including pregnancy outcomes, have low heritability and are not available until comparatively late in an animal's life (Pryce et al., 2014).

The interval from calving to the resumption of ovarian activity is an important component of reproductive performance. Cows that return to estrus earlier after calving may be on their second or third estrus cycle at the start of the seasonal breeding period, making conception to their first insemination more likely (Friggens and Labouriau, 2010). Postpartum anestrus interval (PPAI), defined here as the interval from calving to first detected estrus, may therefore provide an informative predictor of subsequent fertility outcomes. Historically, however, routine collection of PPAI phenotypes at the scale required for national genetic evaluation has been impractical. Methods such as serial progesterone testing or visual

observation of estrus have provided evidence of the value of PPAI as a predictor of fertility (Royal et al., 2002; Nyman et al., 2014), but are labor-intensive and costly, and consequently have not generated sufficiently large datasets for widespread genetic evaluation.

The increasing adoption of wearable technologies on New Zealand dairy farms provides a new opportunity to overcome this limitation. Activity-monitoring systems can detect behavioral changes associated with estrus and generate individual-animal estrus dates, allowing PPAI phenotypes to be derived. The volume of these data is increasing rapidly: the number of cows for which LIC received wearable-derived estrus records increased from approximately 42,000 in 2022 to more than 680,000 in 2025. This growing data resource provides an opportunity to evaluate reproductive physiology at a scale that was previously not feasible and to investigate whether sensor-derived phenotypes can add useful information to existing fertility evaluations.

The objective of this study was to provide a preliminary assessment of the potential for sensor-derived PPAI to improve genetic evaluation of fertility in New Zealand dairy cattle. We characterized the available PPAI phenotype, and estimated genetic covariances between PPAI and pregnancy success phenotypes (pregnancy rate within the first 42d of the seasonal breeding period) using our current dataset of wearable-derived estrus event phenotypes.

Materials and Methods

Data

The estrus data described and analyzed in this study were obtained from the Livestock Improvement Corporation (LIC) animal and herd recording database. This database contains routinely collected dairy cattle records, including calving dates, insemination dates, and milk production and composition data. Much of this information is recorded directly by New Zealand dairy farmers through LIC's herd management software 'MINDA', while additional data are received from third-party providers. Wearable-derived estrus events are one example of data supplied to LIC by third parties. Farmers using wearable technologies can elect to integrate these data with their existing MINDA herd records. In 2025, New Zealand had approximately 4.68 million dairy cows (10,370 herds), of which 681,558 (1,117 herds) had wearable-derived estrus records integrated with MINDA. In total 813,330 unique cows had wearable-derived estrus records integrated with MINDA between 2021 and 2025.

Prior to our analysis, we applied quality-control filtering to remove herds with limited wearable data or records indicative of poor data quality. Herds were excluded if the average number of recorded estrus events was fewer than five per cow (n = 345,964 cows) or if the average duration of wearable-derived records was less than 90 days (n = 355,058 cows). The biological plausibility of intervals between consecutive estrus events was also assessed. Each interval was assigned a score of 1 if it was either 16–27 days, representing a plausible interval between successive estrus events, or 60–390 days, representing a biologically plausible prolonged absence of recorded estrus events (i.e. a likely pregnancy). All other intervals were assigned a score of 0. Interval scores were averaged within cow and subsequently across cows within herd, and herds with an average score <0.5 were excluded (n = 137,630 cows). Finally, PPAI phenotypes of less than 10 days or greater than 150 days were excluded, and contemporary groups were required to contain at least five animals. Many herds failed more than one quality-control criterion. To maintain alignment with phenotypes used in the national fertility evaluation, only records from the first three parities were retained. Following these filtering steps, the final dataset comprised PPAI phenotypes from 298,335 cows.

Wearable-derived estrus event data are received from third party providers as the date

on which an animal was predicted to have been in estrus, based on changes in her behavior. Several wearable technology providers offer integration with MINDA, and the proprietary algorithms used to detect estrus events likely differ among providers. Postpartum anestrus interval (PPAI) was defined as the number of days between an animal's calving date and the date of her first recorded postpartum estrus event. PPAI records were restricted to intervals between 10 and 150 days, animals with PPAI outside these intervals had their phenotype set to missing. To increase confidence that an identified event represented a true estrus event, the first postpartum estrus event was required to be followed by a subsequent estrus event 18–24 days later.

Pregnancy rate in 42 days (PR42) is a binary trait denoting whether a cow calved within the first 42 days of her herds seasonal calving period. Pregnancy records were coded as 1 for pregnancies attained within 42d and 0 for pregnancies attained after this period. Non-pregnant cows were also coded as 0. While our analysis was restricted to herds recording with LIC, pregnancy phenotypes were obtained from the national fertility extract, which contains all phenotypes used in the national fertility evaluation. The PR42 phenotypes are calculated based on an animal's mating dates, with conception confirmed by a calving date (accounting for gestation length of the sire). Therefore, many animals with only first lactation PPAI phenotypes were missing PR42 phenotypes when our data was extracted. A total of 76,870 cows had both a PPAI phenotype and a PR42 phenotype.

The national dairy herd in NZ consists predominantly of Holstein-Friesian and Jersey and Holstein-Friesian Jersey cross cattle. Our dataset was reflective of these demographics, with 55,899 Holstein-Friesian, 11,149 Jersey, 222,526 Holstein-Friesian Jersey cross, 514 Ayrshire and 8,247 other cattle.

Genetic analysis

Phenotypic data were pre-processed in Python using the Polars library. Genetic analyses were conducted using APEX, a standalone software package for fitting linear mixed models (Boerner, 2026). Pedigree-based animal models were used to estimate genetic parameters for postpartum anestrus interval (PPAI) and pregnancy within the first 42 days of mating (PR42). Variance components and heritabilities were estimated using univariate models, while genetic and residual covariances between PPAI and PR42 were estimated using a bivariate model.

For each trait, the model was:

$$y = Xb + Za + Wp + e \qquad \text{(equation 1)}$$

where y is the vector of phenotypic observations, b is a vector of fixed effects, a is the vector of additive genetic animal effects, p is the vector of permanent environmental animal effects, and e is the vector of residual effects. Additive genetic effects were modelled using the pedigree-derived numerator relationship matrix. Fixed effects included contemporary group, age at calving, Friesian, Jersey, Holstein and Red Dairy Cattle breed proportions, pairwise breed heterosis proportions, and inbreeding coefficient.

Results & Discussion

Adoption of wearable devices on New Zealand dairy farms

Wearable technologies are becoming increasingly widespread on New Zealand dairy farms. In 2025, LIC received wearable-derived estrus records from 681,558 individual cows, up from just 42,045 cows in 2022 (Table 1). These figures likely underestimate the true scale of adoption, as they exclude herds that do not record animals with LIC or that use wearable technologies without integrating the resulting data with their LIC herd records.

The increasing availability of routinely recorded estrus events provides an opportunity to derive PPAI at a scale that has not previously been practical. Beyond PPAI, longitudinal estrus records may also enable the development of additional fertility phenotypes, including

measures of estrous cycle length and regularity, conception failure, and early pregnancy loss. These traits may provide complementary information on different components of reproductive performance and warrant further investigation.

Table 1: Count of cows with wearable-derived estrus events recorded in LIC's herd recording database, by year.

Year	Animal Count
2022	42,045
2023	231,773
2024	378,606
2025	681,558

(Co)Variance parameters of PPAI and pregnancy rate

PPAI was more heritable than PR42 ($h^2 = 0.12$ vs 0.017), while the two traits showed negative genetic and residual correlations (−0.57 and −0.18, respectively), indicating that shorter PPAI was associated with greater six-week pregnancy success (Table 2).

The heritability estimate for PPAI indicates that there is meaningful additive genetic variation in the interval from calving to resumption of estrous activity. Our result is consistent with previous heritability estimates for PPAI (Ismael et al., 2015; Lefebvre et al., 2021) and suggests that PPAI would respond to genetic selection. In contrast, the substantially lower heritability of PR42 is consistent with the generally low heritability of conventional fertility traits derived from calving, mating and pregnancy data (Amer et al., 2016; Stephen et al., 2024), which are influenced by a wide range of genetic and non-genetic factors.

The moderate negative genetic correlation between PPAI and PR42 ($r = -0.57$) indicates that animals genetically predisposed to resume estrous activity sooner after calving also tend to have superior genetic merit for pregnancy within the first 42 days of the breeding period. This relationship is biologically plausible, as earlier resumption of ovarian activity provides cows with more opportunity to establish regular estrus cycles, be detected in estrus, inseminated, and become pregnant during a restricted seasonal breeding period. Shorter PPAI may also reflect more rapid recovery of reproductive function following calving, including uterine recovery and restoration of normal hypothalamic–pituitary–ovarian activity. Consequently, some of the physiological processes contributing to a shorter PPAI may also favor subsequent conception and establishment of pregnancy (Gautam et al., 2010). The correlation was, however, substantially less than unity, indicating that PPAI and PR42 are related but genetically distinct traits. PPAI therefore captures one component of reproductive performance rather than serving as a direct replacement for PR42.

Table 2: Estimated heritabilities and correlations between postpartum anestrus interval (PPAI) and six-week pregnancy rate (PR42). Heritability estimates are presented on the diagonal, with the genetic correlation below the diagonal and the residual correlation above the diagonal.

Trait	PPAI	PR42
PPAI	**0.12**	-0.18
PR42	-0.57	**0.017**

Conclusions

These results support PPAI as a promising predictor trait for fertility evaluation in New Zealand dairy cattle. PPAI was more heritable than PR42 and showed a moderate genetic correlation with PR42. As wearable technologies continue to generate increasing volumes of routinely recorded estrus data, PPAI offers a practical opportunity to strengthen genetic evaluation for reproductive performance. Further work is required to quantify the potential improvement in breeding value accuracy by incorporating PPAI into the national fertility evaluation.

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