Foundational Review of U.S. Female Fertility Trait Evaluations

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Abstract

The Council on Dairy Cattle Breeding provides four female fertility evaluations for U.S. dairy producers: daughter pregnancy rate (**DPR**), cow conception rate (**CCR**), heifer conception rate (**HCR**), and early first calving (**EFC**). These evaluations were first introduced in 2004 for DPR, 2009 for CCR and HCR, and 2019 for EFC. Currently, these traits are expressed on six different breed bases: Ayrshire, Brown Swiss, Guernsey, Holstein, Jersey, and Milking Shorthorn. Over time, the data and methods used to calculate these traits have evolved in response to changes in availability, recording practices, and management systems. In recent tri-annual evaluations, unexpected season fluctuations have been observed in the Sire Estimated Breeding Values (**EBV**) of recently born bulls. The objective of this project was to identify the cause of these fluctuations and implement changes to improve stability across evaluations. In collaboration with the USDA Animal Genomics and Improvement Laboratory, this project also involves the research and development of a potential new trait to be added to the fertility evaluation, First Service to Conception (**FSC**), and re-estimation of genetic parameters for all five traits. Comprehensive tests were conducted to refine models, pre-adjustments, and data edits, including the use of both truncated and full datasets. Although data truncation showed promise in mitigating historical biases, it introduced higher variability in smaller breeds (Guernsey and Ayrshire). Additional tested changes included stricter calving year restrictions, improved data extraction procedures, updated CCR and HCR pre-adjustments, the inclusion of a days-in-milk covariate at first insemination for CCR and FSC, and the addition of a random herd-by-sire effect. Tests also examined whether modeling days open to pregnancy rate as a linear or non-linear trait, modeling traits as uncorrelated, performing unweighted analyses, or stricter convergence criteria of the traditional evaluation mixed model equations solver were appropriate. While the findings suggest that current methodologies provide a robust foundation, ongoing work is required to address the persistent slight negative trends reported in young bulls, where the underlying causes remain unclear. The project team is well-positioned to further enhance the stability of female fertility trait evaluations for U.S. dairy producers.

Key words: conception rate, pregnancy rate, predicted transmitting ability, breeding value fluctuations, trait stability

Introduction

Female fertility traits play an important role in dairy cattle breeding by offering insight into the reproductive performance of animals across diverse management systems. In the United States (**U.S.**), Daughter Pregnancy Rate (**DPR**) was introduced in 2004 (VanRaden et al., 2004; Van Raden et al., 2002), Cow Conception Rate (**CCR**) and Heifer Conception Rate (**HCR**) in 2009, and Early First Calving (**EFC**) in 2019, providing producers with tools to select for female reproductive performance (CDCB, 2025a;

Miles et al., 2023). DPR is calculated by a non-linear transformation of days open to pregnancy rate. The trait predicts the percentage of non-pregnant cows that will become pregnant during each 21-day period (VanRaden et al., 2004). CCR and HCR predict the ability to conceive at each insemination for lactating cows and maiden heifers, respectively. EFC predicts the animal's ability to alter their female offsprings age at first calving in days. All traits are scaled to their breed base of six breeds: Ayrshire (**AY**), Brown Swiss (**BS**), Guernsey (**GU**), Holstein (**HO**), Jersey (**JE**), and Milking Shorthorn (**MS**). Traits are often re-evaluated for continued improvement as management changes or more data becomes available (Hutchison et al., 2013; Miles et al., 2023; Wiggans et al., 2005).

In recent years, subtle but consistent seasonal patterns have been observed in fertility evaluations, especially in spring (April) tri-annual evaluations. The dairy industry raised concern after noticing that the estimated breeding values (**EBV**) of individual young bulls, particularly for DPR, were gradually, but consistently declining from evaluation to evaluation as these bulls accumulated more information. This is unexpected because some bulls should change upwards and some downwards. These trends prompted a deeper look into whether the current evaluation system reflected modern management practices and phenotypic data accurately, or whether aspects of the modeling might be contributing to these shifts.

To investigate, the Council on Dairy Cattle Breeding (**CDCB**), in collaboration with the United States Department of Agriculture Animal Genomics and Improvement Laboratory (**USDA AGIL**), launched a focused review in early 2024. The objective was not to overhaul the fertility evaluation system, but to understand the source of these trends, test updates to improve consistency, and determine whether any adjustments were needed.

This paper outlines the investigative process, highlighting data handling improvements, model refinements, and ongoing questions that emerged over the course of this project.

Materials and Methods

Data:

Phenotypic records are routinely extracted from the National Cooperators Database managed by the CDCB every tri-annual evaluation (OFFICIAL; CDCB, 2025b). In order to make a direct comparison against four OFFICIAL that have already been conducted, the test-runs utilize the database from December 2023 (**2312**), April 2024 (**2404**), August 2024 (**2408**) and December 2024 (**2412**) to extract new phenotype files. As of the most recent extraction, 2412, phenotypes were available for 94,528,060 DPR, 39,599,925 CCR, 13,311,667 HCR, and 37,300,141 EFC records. Heifer records, HCR and EFC, only have one record per animal whereas DPR and CCR can have up to 5 records per animal, one per lactation. Lactational CCR and HCR are aggregated values from events, usually inseminations or diagnostics, that happened within the lactation. The earliest available calving dates were January 1960 for DPR and EFC, December 2002 for CCR and October 2003 for HCR. Insemination dates required for CCR and HCR calculations were not collected nationally until 2003 (VanRaden et al., 2004).

Modeling:

For each test, traditional evaluations were generated by the fertility pipeline which includes data extraction, phenotype creation, pre-adjustments, and mixed model analysis. Animal effects were calculated using a pedigree-based BLUP with a multiple-trait, animal model. DPR, CCR, and HCR were developed using single-trait models, but were developed into a multi-trait model in 2015 (VanRaden et al., 2014). DPR, CCR, and HCR are treated as correlated traits (Kuhn et al., 2006; VanRaden et al., 2014), while EFC is treated as uncorrelated. These tests followed the same steps as the traditional evaluation conducted during the OFFICIAL.

Test Scenarios:
Two sets of scenarios were developed for testing. The first included changes applied to the full datasets (CHG), and the second used the same changes, but truncated the historical DPR and EFC records to December 2002 (CHG_TR). This allowed the same period of data to be used across all four traits. Both test scenarios were compared to traditional results from OFFICIAL.

Changes Applied to Tests:
Several changes were applied in both CHG and CHG_TR. A stricter calving date restriction was implemented so that only records with at least 365 days between calving and data extraction were included compared to the current edit of ≥70 days described by Hutchison et al., 2013. If calving dates or days open information were missing, those records were removed from DPR rather than estimated. Extraction programs were revised for efficiency and formatting. Pre-adjustments applied to individual inseminations were updated for both CCR and HCR and were estimated within each evaluation instead of fixed across evaluations. A DPR record was removed if the cow's sire was unknown, aligning it with existing edits for CCR, HCR, and EFC. A new covariable, days-in-milk at first insemination, was added to the CCR model. Additionally, the convergence criteria for the mixed model equations solver (described in VanRaden et al., 2014) were also made stricter.

A proposed additional trait, days from First Service to Conception (**FSC**), developed by USDA AGIL, was included in the tests evaluation pipeline and modeled alongside the other four traits. Updated variance components were estimated for all traits by USDA AGIL and University of Connecticut collaborators as part of this work. However, results related to FSC and the re-estimated variance components are not presented here and will be reported separately.

Additional changes were explored but were excluded from further testing due to limited benefits or failure to converge. These included modeling DPR as a linear function of days open, using unweighted analyses, treating all five traits as correlated, and including a random herd-by-sire effect.

Results

Impact of Data Edits:
Applying a stricter calving date restriction removed 2–4% of records from recent years across traits. Removing records with missing days open or calving dates for DPR had a minimal effect on overall record count but was important for ensuring consistency in how phenotypes were calculated. Removal of records with unknown sires reduced record counts primarily in earlier years and among smaller breeds, with little effect in Holstein data.

Pre-adjustment updates for CCR and HCR led to moderate shifts in phenotype distributions, especially in the most recent years, where older adjustment factors may no longer have reflected regional and seasonal differences in management. The inclusion of days-in-milk at first insemination as a covariate also influenced the distribution of CCR values, likely among high-producing herds where voluntary waiting periods may be longer. Research on voluntary waiting periods by herd and years is in-progress.

Phenotypic Trends:
Phenotypic trends by year of calving were broadly consistent across OFF, CHG, and CHG_TR. For most traits, the use of truncated data slightly reduced phenotypic variability in early years but had limited impact in recent years. Among smaller breeds (Guernsey and

Ayrshire), the truncation of pre-2002 data for DPR and EFC led to a more noticeable reduction in available records and corresponding shifts in average values.

The updated edits resulted in smoother trends in recent years, especially for DPR and raw CCR (cow conception rate without pre-adjustments applied). Raw CCR or raw HCR values were easier to interpret and more transparent in terms of seasonal or year-based shifts. However, these trends without pre-adjustments on individual inseminations also showed greater variability, especially in recent years when data volume is lower. The application of updated pre-adjustments within each evaluation test helped reduce this instability and produced smoother trends over time.

EBV Trends:

The EBV of young cows with phenotypes were averaged by birth year and segmented by their sire's breed. Figure 1 has 9 graphs of OFFICIAL (top), CHG (middle), CHG_TR (bottom) and 2312 vs. 2404 (left), 2404 vs. 2408 (center), and 2408 vs. 2412 (right) for Holstein DPR by year of birth.

Across all test scenarios, the applied changes did not substantially alter the consistency of these breed-level averages. The seasonal fluctuations originally observed in these figures, especially in April evaluations, remained present to some extent but were not worsened by the new edits or data truncation.

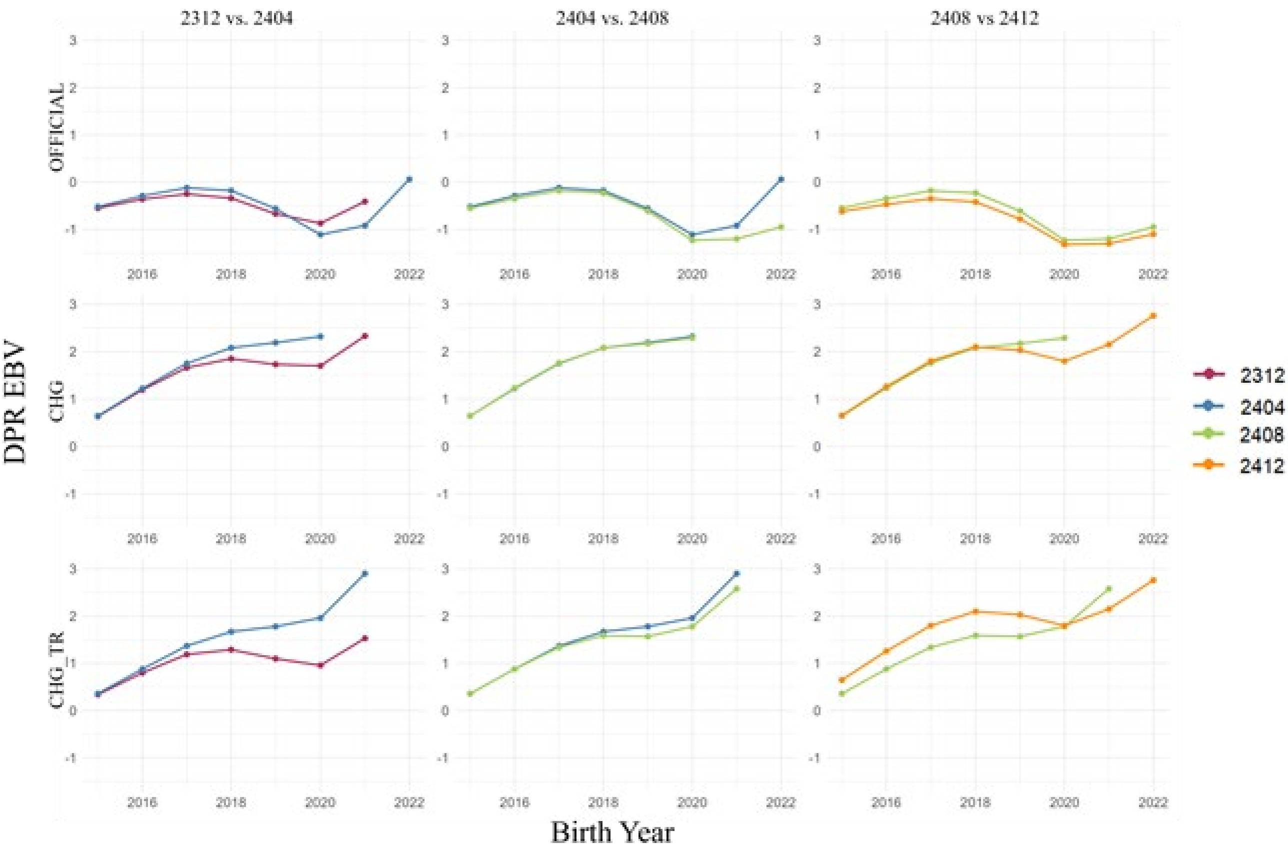

Figure 1. Mean daughter pregnancy rate (DPR) estimated breeding value (EBV) of young cows with Holstein sire official tri-annual evaluations (OFFICIAL; top), full data set with changes applied (CHG; middle), and truncated dataset with changes applied (CHG_TR; bottom) for multiple evaluations: December 2023 (2312), April 2024 (2404), August 2024 (2404) and December 2024 (2412).

Sire EBV Trends:
Although not shown in this report, future work will focus more directly on trends in the EBV of male animals. The industry concern prompting this investigation was centered on recent declines in DPR among young bulls. The exploratory analyses presented here did not fully resolve that concern but laid the groundwork for evaluating where those trends originate whether from the data, model assumptions, or something else.

Discussion

The goal of this review was to understand whether changes to the data pipeline or model structure could explain the seasonal variation observed in EBV for female fertility traits. While the test scenarios introduced several improvements, the comparisons among OFF, CHG, and CHG_TR suggest that the core evaluation system is already relatively robust, and that no single edit tested fully accounts for the observed patterns.

Across most traits and breeds, the CHG scenario which applied updated edits and model refinements without removing historical data showed the greatest internal consistency. Phenotypic trends were smoother, and changes to the pre-adjustments and model covariates helped reduce irregularities in CCR and DPR that often appear in more recent years. The edits removed relatively few records overall but targeted potentially less reliable data such as data including missing calving dates or undefined sires.

The CHG_TR scenario, in contrast, introduced greater variability, particularly in the smaller breeds. Truncating DPR and EFC records prior to 2002 ensured a uniform time range across traits, but the loss of early data reduced the sample size enough to destabilize trends for breeds like Guernsey and Ayrshire. For Holstein and Jersey, the impact of truncation was smaller, though not negligible. These results suggest that while historical data may introduce bias, it also contributes information for estimating trends, especially in populations with less data.

None of the edits tested in CHG nor CHG_TR substantially changed the EBV trends which reflect mean EBV of daughters grouped by their sire's breed. While these figures have been useful for monitoring population-level trends, they are not a substitute for direct evaluation of individual young male animals. The continued presence of seasonal fluctuations in these plots, even after updates, indicates that the source of variation may lie elsewhere.

The investigation also highlighted a recurring challenge in fertility evaluations: edits and model refinements often improve internal consistency but do not necessarily resolve the deeper patterns observed in young animal EBV. The inclusion of more refined covariates, like days-in-milk at first insemination, potentially helped account for some management-driven variability in CCR, but did not have an effect large enough to shift overall trends. Similarly, pre-adjustments estimated within each evaluation for CCR and HCR produced more stable results, but did not fully explain the seasonal fluctuations of interest.

The updates applied in CHG improved the evaluation pipeline and represent meaningful refinements. However, they did not resolve the underlying concern of declining EBV with consecutive evaluations in recently born bulls. Truncation (CHG_TR) introduced more variability than it removed and may be better suited for targeted applications rather than as a universal solution.

Conclusions

This project reviewed and tested a range of updates to the U.S. female fertility evaluation pipeline, with the goal of improving stability and addressing concerns about seasonal trends in the EBV of recently born bulls. While these trends remain an interest, the changes tested here did not appear to be the direct cause.

Edits implemented in the CHG scenario including stricter calving date filters, updated pre-adjustments, and improved handling of incomplete records contributed to smoother trends in phenotypes and improved consistency in recent years. These changes strengthened the overall foundation of the system and are candidates for future implementation. However, the comparison with CHG_TR showed that truncating historical data can introduce additional variability, especially for smaller breeds. This suggests that while older data may have some unanticipated effect, it continues to play a stabilizing role in multi-trait fertility evaluations.

Although the updates improved internal consistency and addressed specific improvement opportunities in the evaluation process, they did not resolve the seasonality of the trend observed in young bull EBV. Further work is needed to explore this issue more directly, particularly by evaluating how the actual EBV of male animals change across evaluations and whether changes in herd management, data recording practices, or model assumptions are contributing to the trend.

The results presented here represent a step forward in refining female fertility trait evaluations, but additional investigation is needed to fully understand and resolve the ongoing patterns observed in young animals.

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