**Application**

Perturbation periods at the pen level can be identified using high-frequency data, such as daily milk weights, and resilience is a heritable trait, with heritability increasing as the severity and duration of the challenge intensifies.

**Introduction**

Resilience is defined as an animal’s capacity to bounce back to normal functioning after a perturbation or maintain specific functions in the face of change or stress (Colditz & Hine, 2016; Scheffer et al., 2018). The increasing frequency of extreme weather events and persistent labor shortages highlight the need to identify and select animals that can maintain production in unpredictable environments. US dairy herds typically group cows into pens based on factors such as parity, lactation stage, reproductive status and milk production (Contreras-Govea et al., 2015). By coupling daily milk yield data with day-to-day pen location information, we can more precisely model management conditions and environmental stressors affecting groups of cows for each day of the lactation. It also allows us to detect management and environmental perturbations that may occur each day at the pen level and subsequently measure the responses of individual cows to these stressors over a particular period.

**Materials and Methods**

Our entire dataset included 62,580,945 daily milk weights and pen locations of 227,633 cows in parity 1, 2 and/or 3 from 204 herds representing 30 US states from 2018 to 2024. Individual lactation curves were fitted using polynomial quantile regression with a 0.5 quantile to derive expected lactation curves. Perturbation periods were identified using a data driven detection method and were based on residuals between mean expected and mean observed daily milk weights at the pen level. The initial dataset was stratified based on the severity and duration of the perturbation periods, considering 40 combinations that included severity levels from ≥ 3% to ≥ 7% and durations ranging from ≥ 3 days to ≥ 14 days. Our resilience phenotype, delta milk yield (ΔMY) was measured as the change in a cow's mean daily milk production relative to her mean expected daily milk yield during an identified perturbation period. The statistical model used to estimate variance components, heritabilities and repeatabilities for ΔMY included calving age, days in milk, parity and herd-year-season as fixed effects, along with herd-pen-milking\_date, additive genetic and permanent environmental effect as random effects. Sire PTA Pearson correlations with TempVar (i.e., consistency) were calculated to assess the relationship between resilience and consistency traits. Additionally, sire PTA Pearson correlations were estimated within comparable severity thresholds to determine the genetic correlations between sire PTA during perturbations with similar characteristics.

**Results**

Estimated heritability of ΔMY during perturbations ranged from 0.01 (0.00) to 0.20 (0.08) depending on the severity and duration of the perturbation, while sire PTA Pearson correlations between ΔMY and TempVar ranged from -0.31 to -0.06 indicating that cows that are more consistent have lower milk loss during perturbations. Our findings suggest that animals differ in their response to perturbations at the pen level in comparison to their contemporaries within the group, and this measure of resilience using daily milk data is heritable.

**Conclusions**

Identifying perturbations at the pen level of varying severities and durations can more effectively capture the management and environmental conditions affecting an individual cow at a given time, and resilience can be measured by comparing how her response differs from that of her contemporaries. This enables the selection and management of more adaptable and sustainable cows capable of handling diverse challenges through a data-driven approach to detecting perturbations.

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**References**

Colditz, I.G., & Hine, B.C. (2016). Anim. Prod. Sci. 56:1961–1983.

Contreras-Govea, F.E., Cabrera, V.E., Armentano, L.E., Shaver, R.D., Crump, P.M., Beede, D.K., & VandeHaar., M.J. (2015). Journal of Dairy Science 98:1336–1344.

Scheffer, M., Bolhuis, J.E., Borsboom, D., Buchman, T.J., Gijzel, S.M.W., Goulson, D., Kammenga, J.E., Kemp, B., van de Leemput, I.A., Levin, S., Martin, C.M., Melis, R.J.F., van Nes, E.H., Romero, L.M., & Olde Rikkert, M.G.M. (2018). Proceedings of the National Academy of Sciences.