Dynamic Linear Models for Stillbirth Surveillance

A Swedish case study using dairy cattle data

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Introduction

Dynamic Linear Models (**DLMs**) can be used to identify trends in mortality data. That makes them a useful tool for proactive outbreak detection, as well as **early warning** in **syndromic surveillance systems** in cattle. Despite their potential, these systems are not commonly used in Sweden.

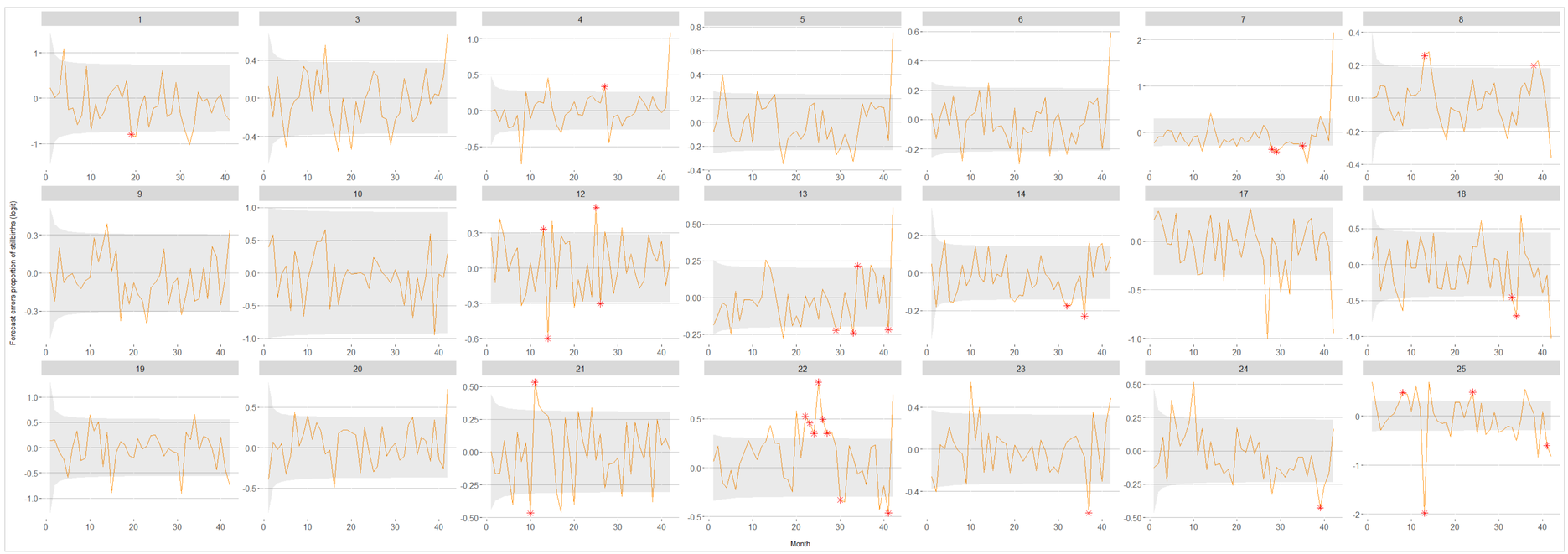
Our objective was to develop a DLM-based early warning system that monitors stillbirth data and provides alerts when observed values exceed expected levels.

Materials and Methods

- We analysed data from Växa's database from March 2016 to March 2021. Records included herd and animal IDs, calving information, monthly counts of lactating animals, and monthly milk yields.
- We employed three distinct DLMs, each stratified by a different variable: county, herd size, and milk yield. For each stratum, we calculated the monthly stillbirth proportion (number stillbirths/total births).
- Data was split into training (from March 2016 to April 2018) and test (from March 2018 to March 2021) sets.
- Each DLM incorporated Kalman filtering to produce forecast values updated according to new observations. Model performance was assessed using root mean squared errors, and Shewhart control chart was used to create alerts using forecast errors. Two out of three consecutive observations outside the two-sigma control limit was considered an alarm.

Results

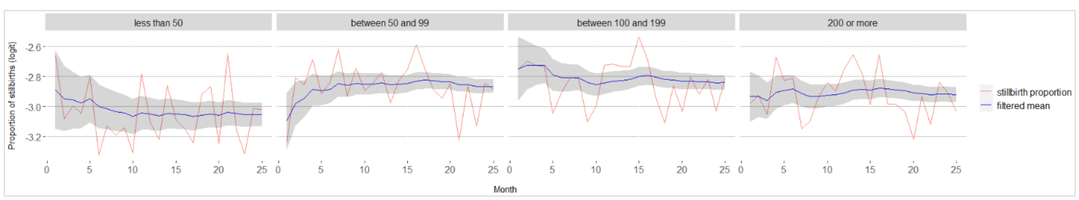
Results by county



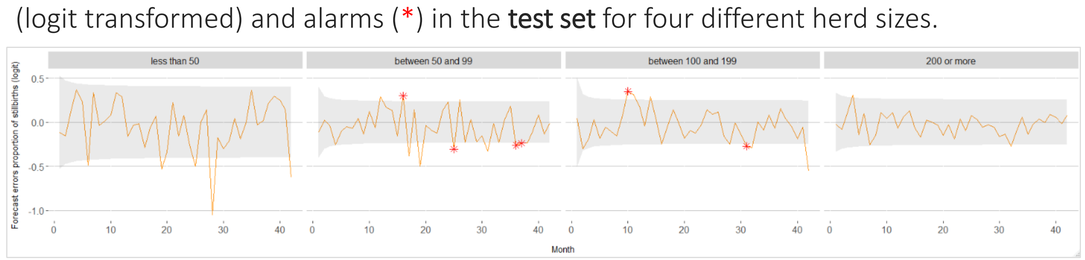
Shewhart control chart with forecast errors (95% C.I.) for the proportion of stillbirths (logit transformed) and alarms (*) in the **test set** for each county. Number of alarms are different across counties, and in some cases, alternative modelling approaches should be explored to reduce the number of false alarms.

Results by herd size

Monthly filtered mean (95% C.I.) estimated with a Kalman filter, and proportion of stillbirths (logit transformed) from the **training set** for four different levels of herd size.

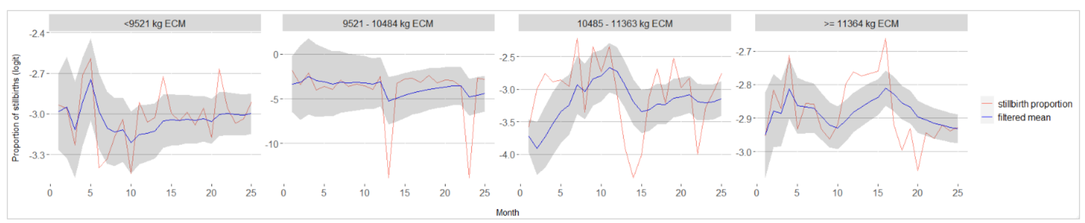


Shewhart control chart with forecast errors (95% C.I) for the proportion of stillbirths (logit transformed) and alarms (*) in the **test set** for four different herd sizes.

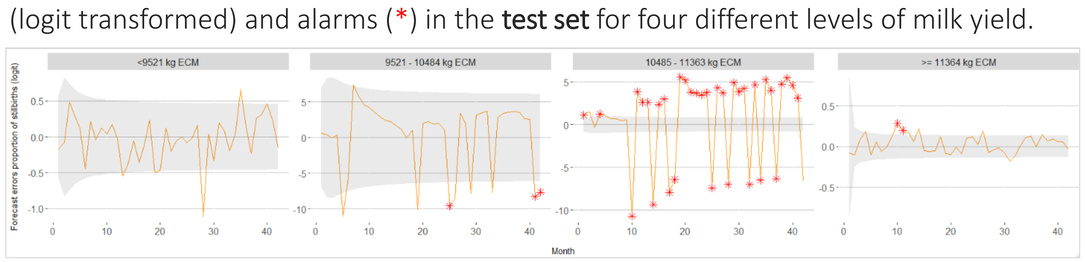


Results by milk yield

Monthly filtered mean (95% C.I.) estimated with a Kalman filter, and proportion of stillbirths (logit transformed) from the **training set** for four different levels of milk yield.



Shewhart control chart with forecast errors (95% C.I) for the proportion of stillbirths (logit transformed) and alarms (*) in the **test set** for four different levels of milk yield.



Conclusions

Our results suggest that stillbirth data can be used to develop syndromic surveillance models and generate alerts that take into account differences between counties, herd sizes, and milk yield.

Different counties, herd sizes, or milk yield groups may require different data aggregation levels. The final assessment of model performance should be validated with clinical records and prospective model evaluation.

Future work should identify thresholds and explore multivariate and hierarchical modelling approaches, including the addition of mortality rates in different age groups of calves, to fine-tune alerts and create a surveillance system suitable for the Swedish context.

DECIDE Consortium

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