

Perturbed lactation model

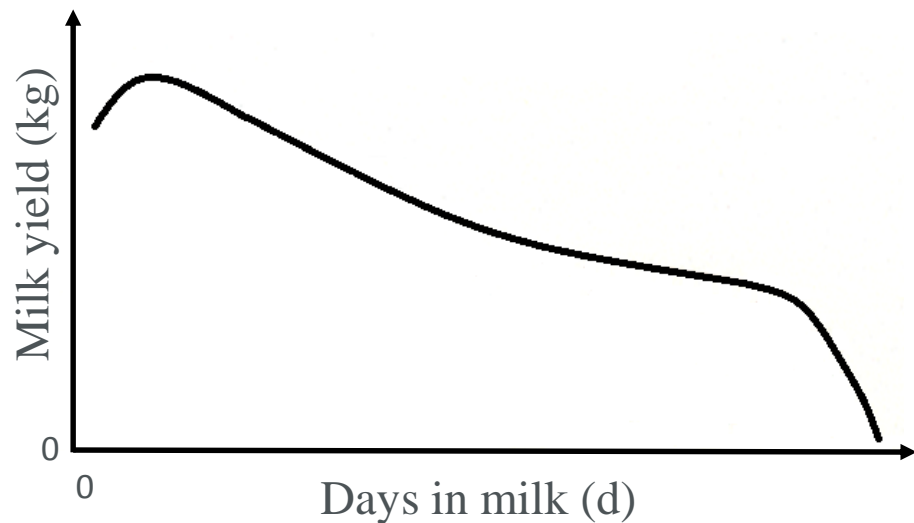
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L. Puillet¹, V. Berthelot¹, O. Martin¹

PhD supervisors: N. Friggens¹,
V. Berthelot¹, L. Broudiscou¹,
C. Gerard²

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AgroParisTech, Université Paris-Saclay, 75005, Paris, France

² NEOVIA, 56250, Saint-Nolff, France

INTRODUCTION AND CONTEXT



(Delage, Leroy & Poly, 1953)

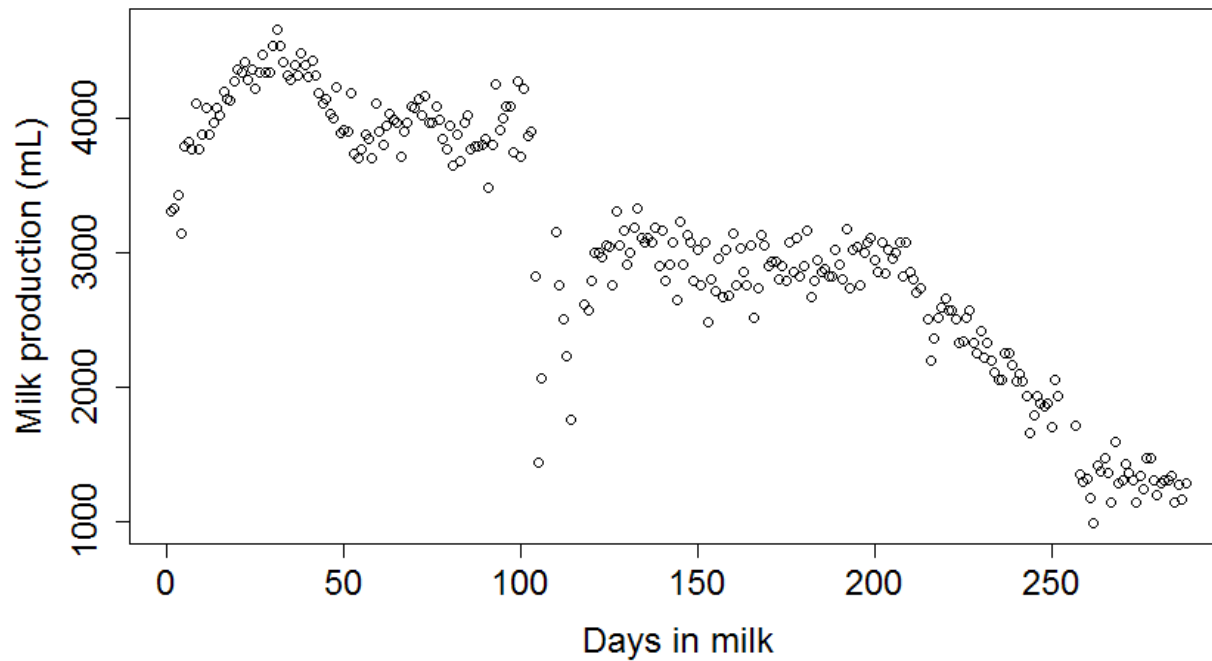


(Grossman & Koops, 2003)

INTRODUCTION AND CONTEXT



goat n°10096

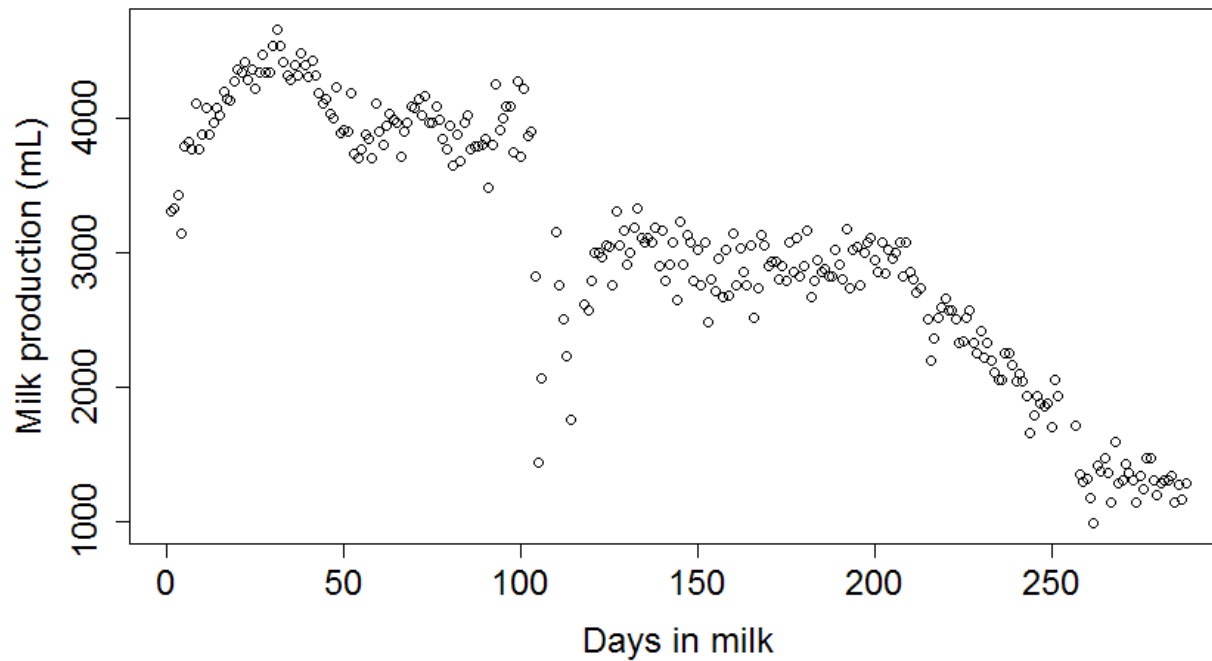


→ Ruminants are often confronted with perturbations.

INTRODUCTION AND CONTEXT



goat n°10096

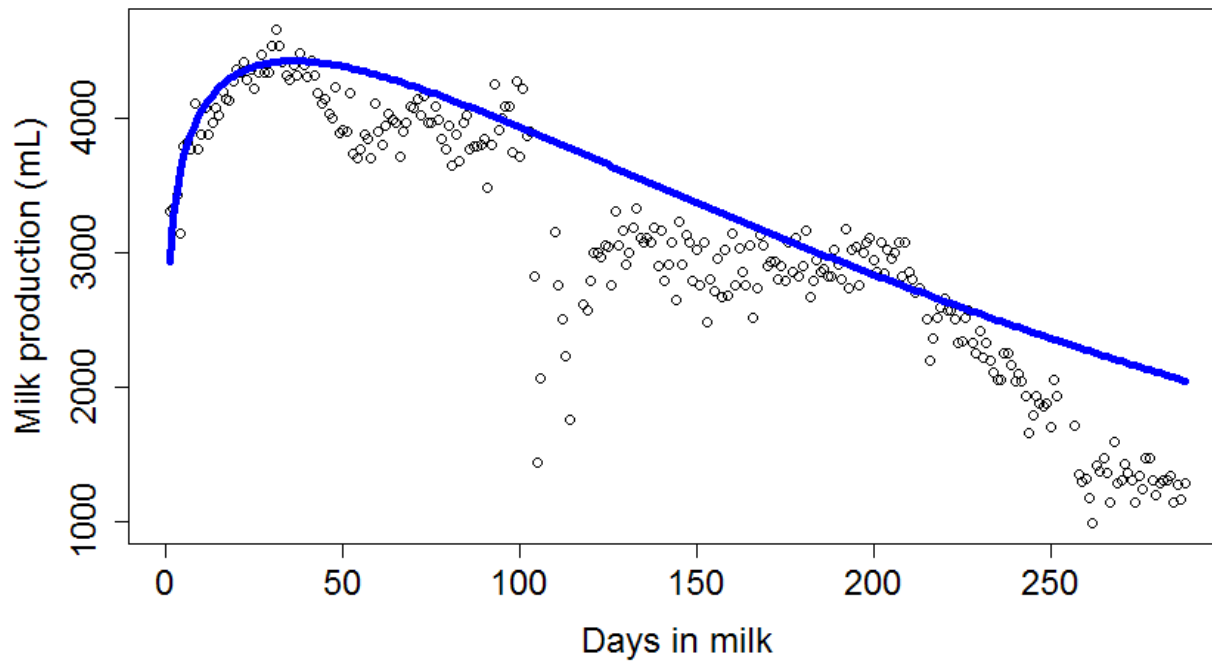


→ What is the dairy potential of this goat?

INTRODUCTION AND CONTEXT



goat n°10096

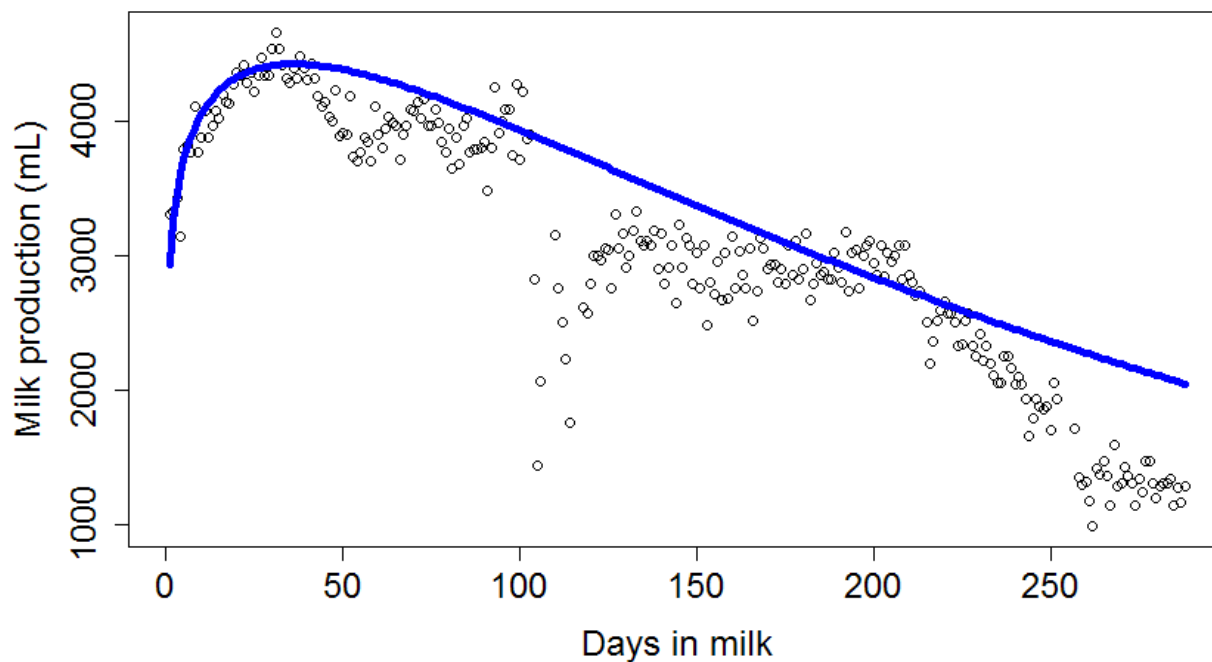


→ Inferred potential curve

INTRODUCTION AND CONTEXT



goat n°10096

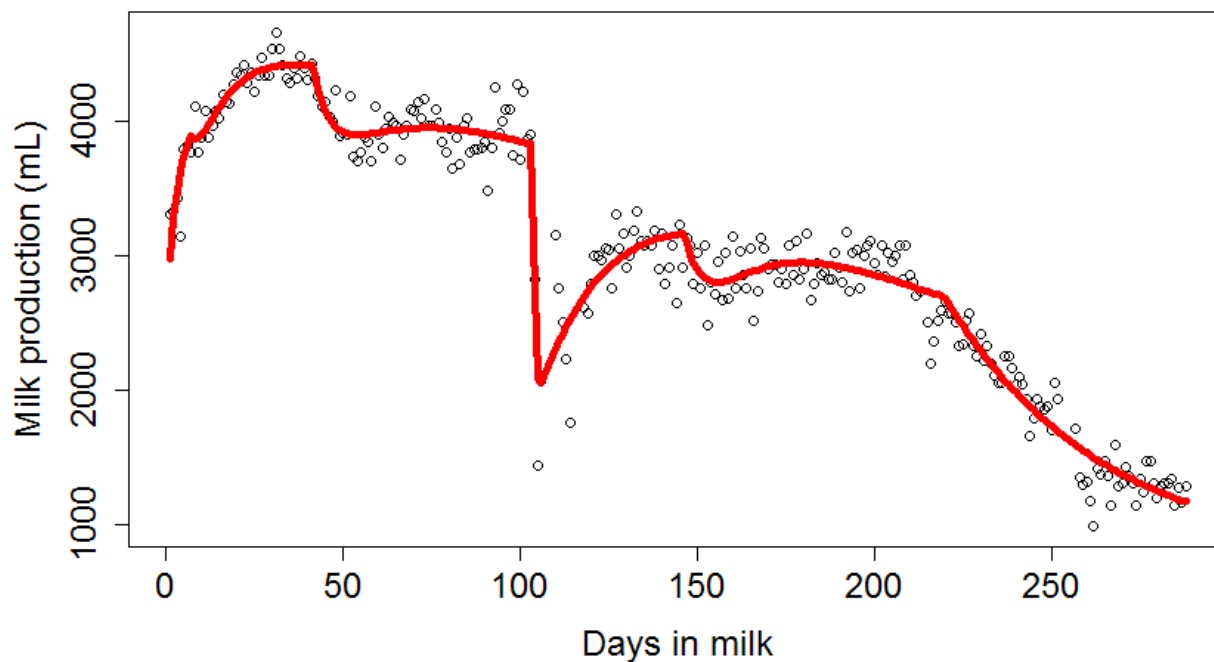


→ What is the perturbed dairy curve of this goat?

INTRODUCTION AND CONTEXT



goat n°10096



→ Perturbed curve

PLAN

- INTRODUCTION AND CONTEXT
- MODEL CONCEPT AND FORMALISM
- FITTING ALGORITHM
- SOME RESULTS
- PRACTICAL APPLICATIONS AND CONCLUSIONS



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INTRODUCTION AND CONTEXT



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- Evaluating the effect of these perturbations on milk yield could provide metrics to quantify how animals cope with their environment.
- It is necessary to transform raw data into useful information for technicians, farmers and researchers.

INTRODUCTION AND CONTEXT



- Data used: Lactation data obtained on 10 goats during a ruminal microbiota trial conducted by V. Berthelot and L. Broudiscou in 2014.
- Software used: prototyping with ModelMaker 3 (Cherwell, 2000) and implementation with R

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MODEL CONCEPT AND FORMALISM



- To describe perturbations affecting milk yield we use:

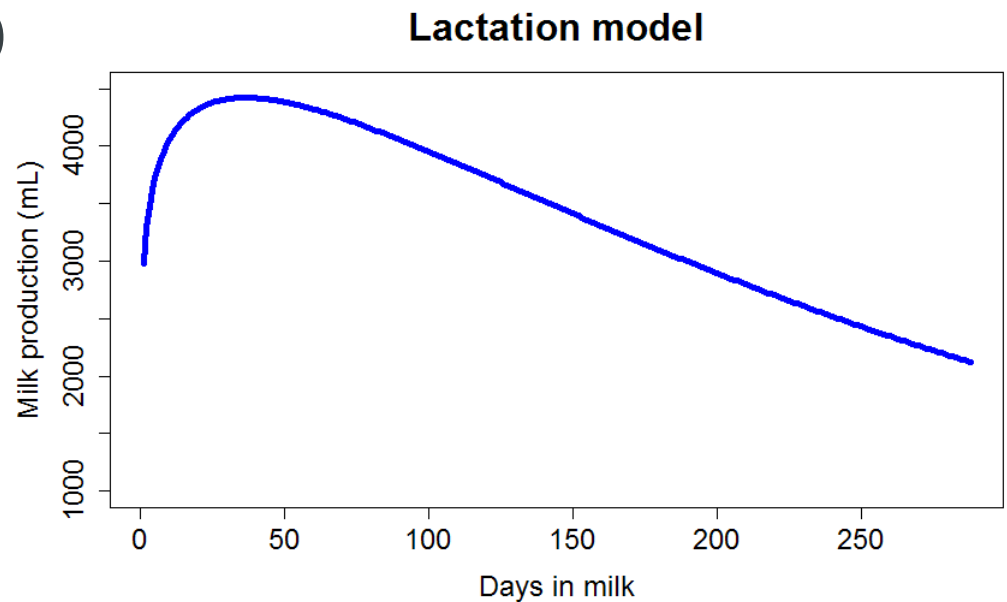
The combination of 2 models:

- a lactation model
- a model of perturbation



- The lactation model:
 - a dynamic mathematical model → Wood (1967)

$$W(t) = a \cdot t^b \cdot \exp(-c \cdot t)$$



MODEL CONCEPT AND FORMALISM



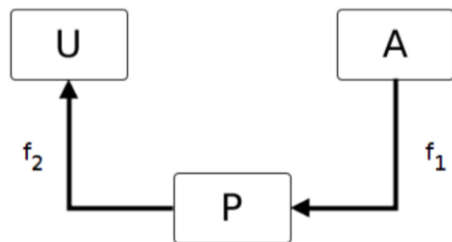
- The model of one perturbation:
 - a 3-compartment model (law of mass action) describing a single perturbation as a transient proportional decrease in milk yield, through a sequence of collapse and recovery.

MODEL CONCEPT AND FORMALISM



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Conceptual model



A: proportion affected by the perturbation

P: perturbation

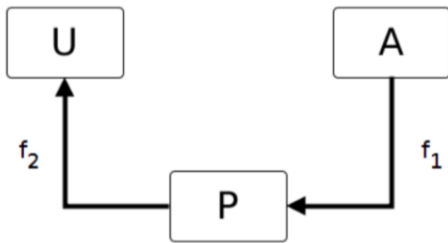
U: proportion unaffected by the perturbation

MODEL CONCEPT AND FORMALISM



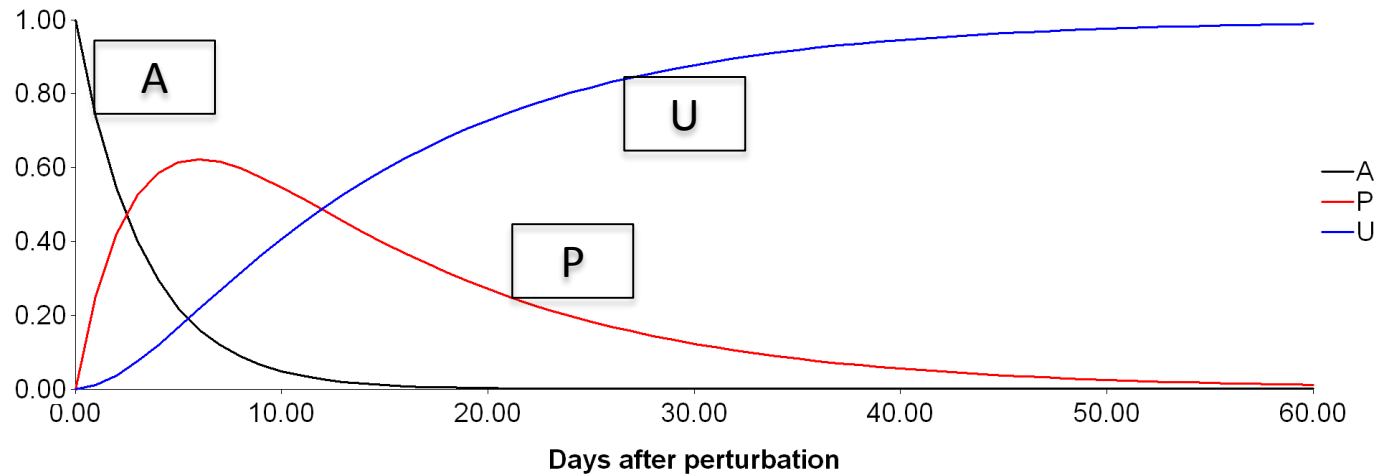
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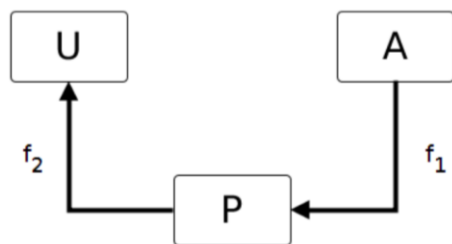


MODEL CONCEPT AND FORMALISM



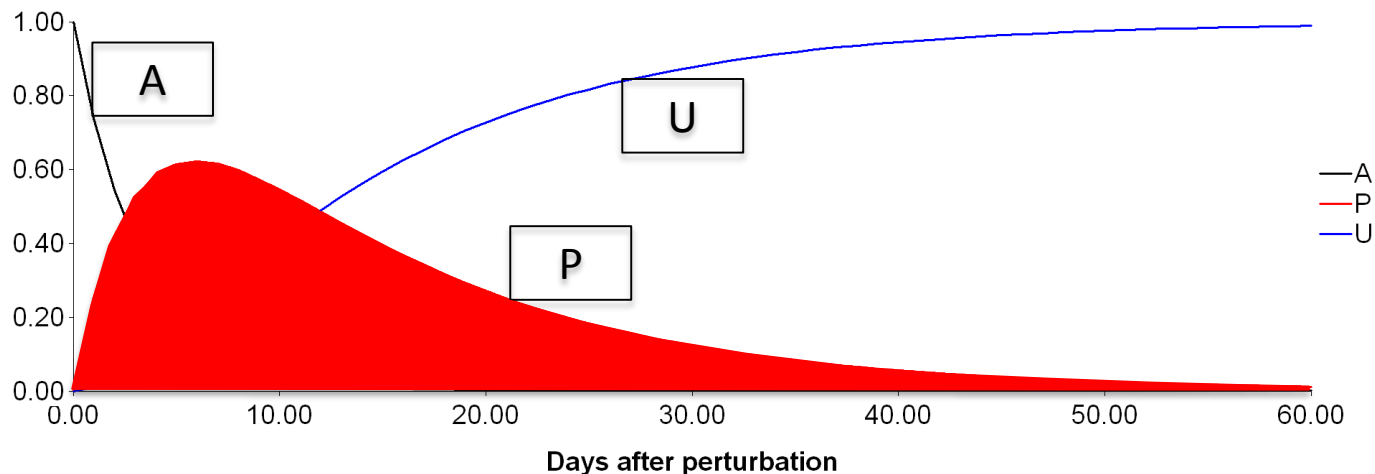
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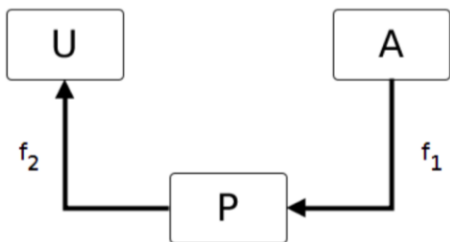


MODEL CONCEPT AND FORMALISM



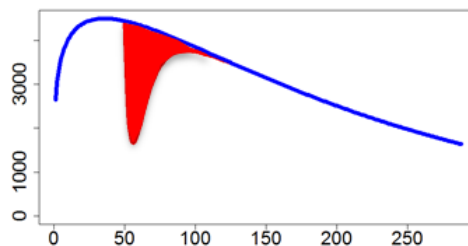
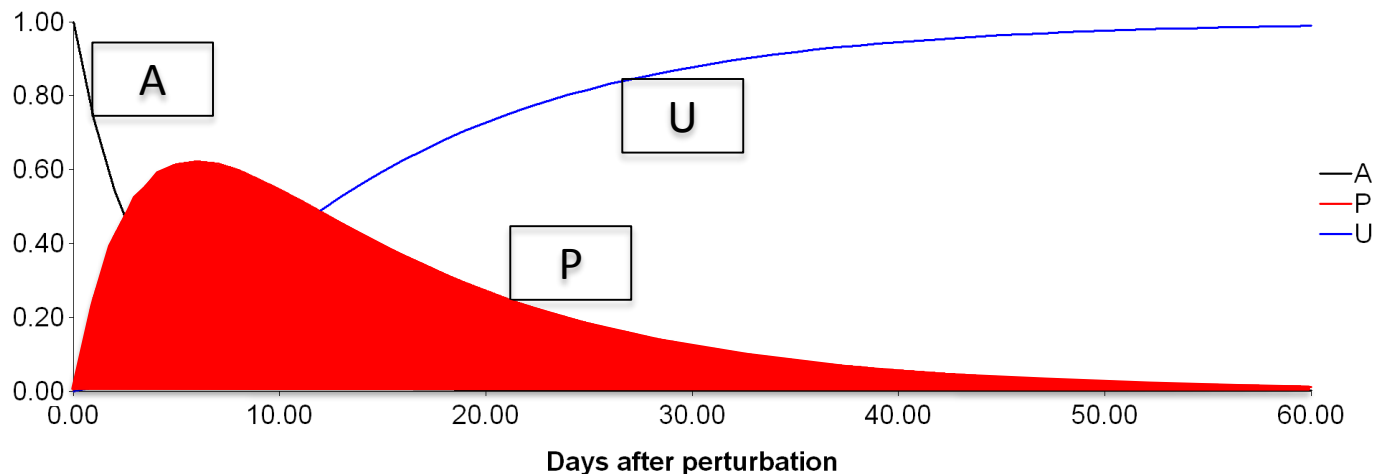
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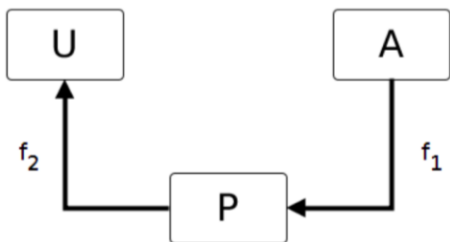


MODEL CONCEPT AND FORMALISM



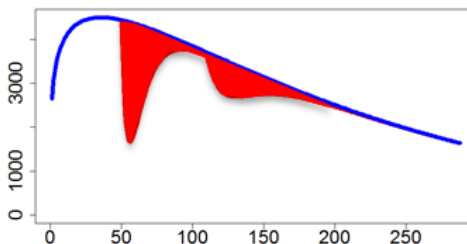
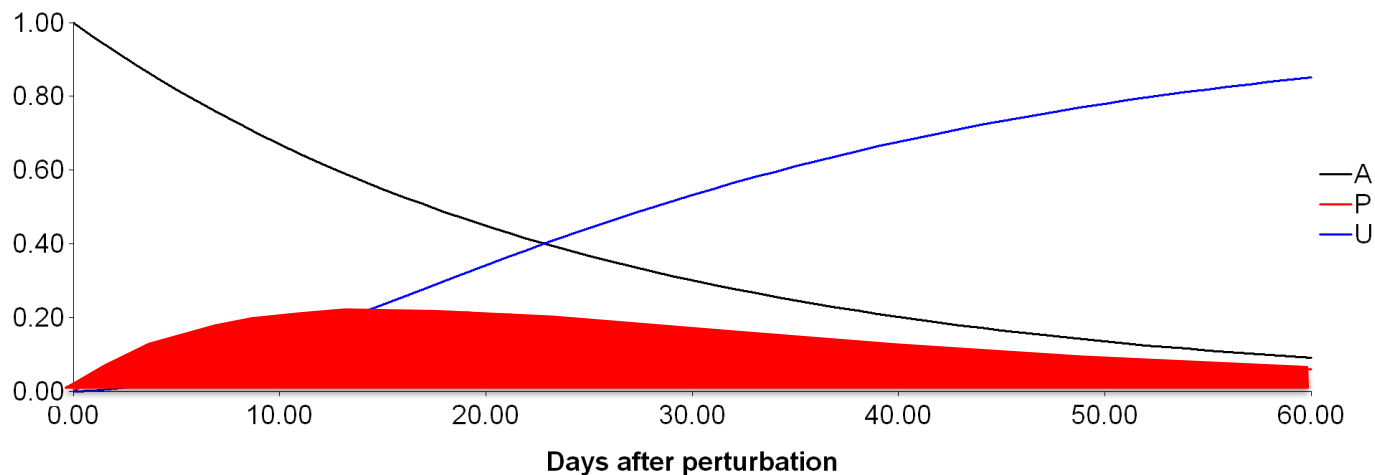
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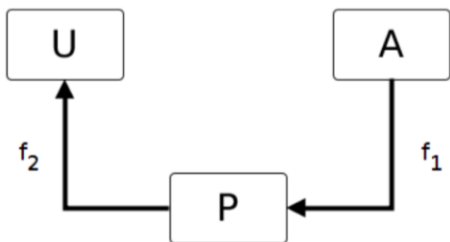


MODEL CONCEPT AND FORMALISM



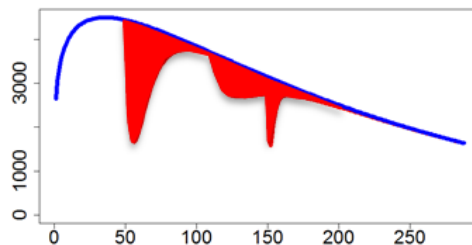
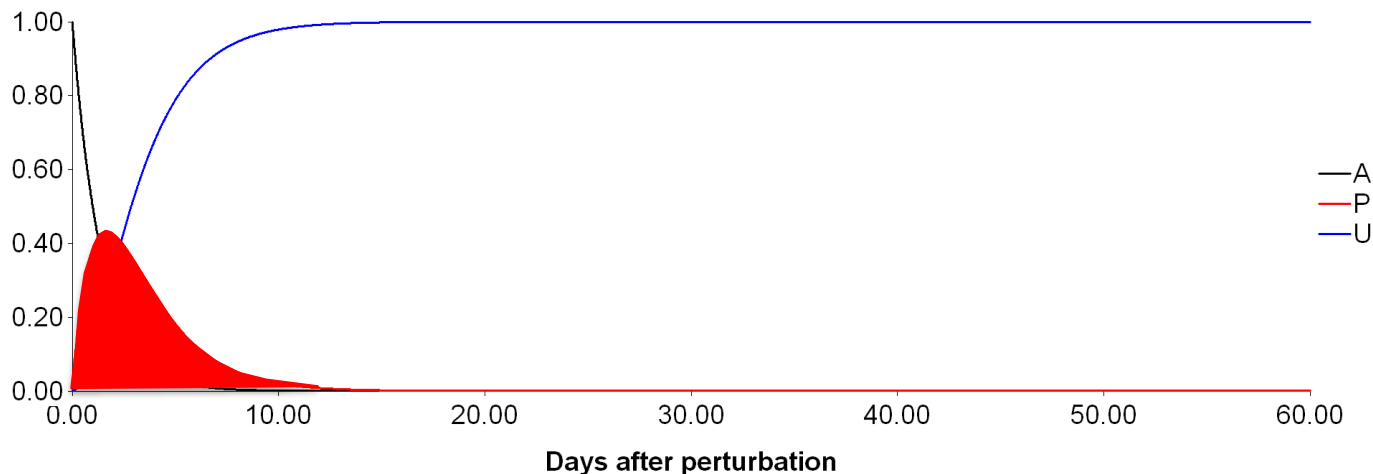
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MODEL CONCEPT AND FORMALISM



- The model of N perturbations: $Y(t) = W(t) \cdot \prod_{i=1}^n [1 - P_i(t)]$

With

$$\text{If } k_{i,1} \neq k_{i,2}: P_i(t) = \sum_{i=1}^n \left(\frac{k_{i,0} \cdot k_{i,1}}{k_{i,1} - k_{i,2}} \cdot (\exp(-k_{i,2} \cdot \Delta_i(t)) - \exp(-k_{i,1} \cdot \Delta_i(t))) \right)$$

$$\text{If } k_{i,1} = k_{i,2}: P_i(t) = \sum_{i=1}^n (k_{i,0} \cdot k_{i,1} \cdot \Delta_i(t) \cdot \exp(-k_{i,1} \cdot \Delta_i(t)))$$

$$\text{And } \Delta_i(t) = \begin{cases} 0 & \text{if } t < t_{p_i} \\ t - t_{p_i} & \text{if } t \geq t_{p_i} \end{cases}$$

Where:

i : perturbation number

t_{p_i} : time of start of the i^{th} perturbation

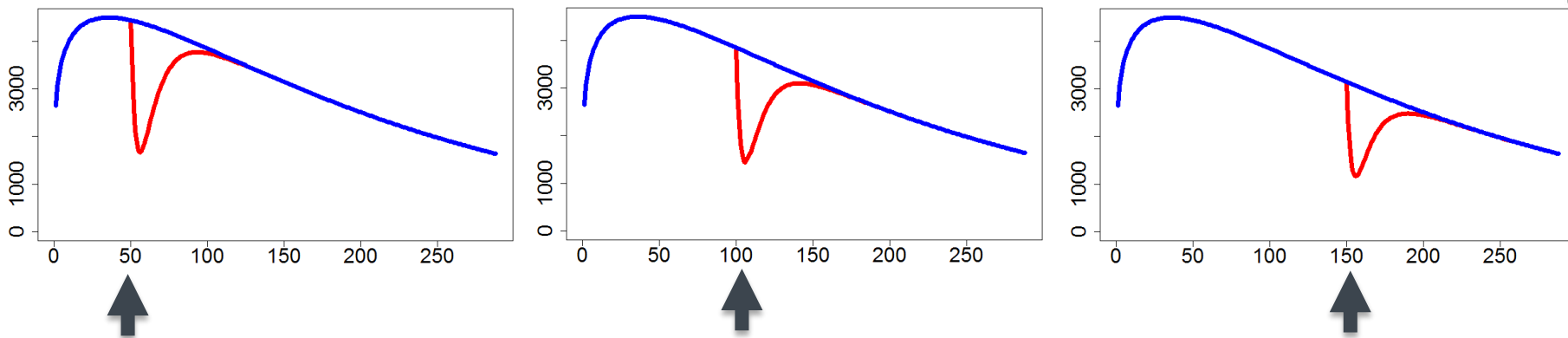
$k_{i,0}$: parameter of intensity of the i^{th} perturbation ($k_0 \in]0 ; 1]$)

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n : number of individual perturbations over t ranging from 0 to the end of lactation

MODEL CONCEPT AND FORMALISM



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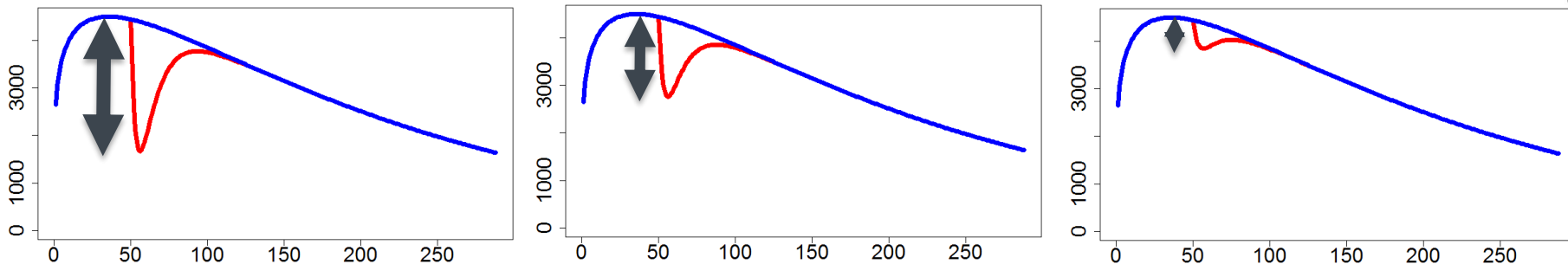
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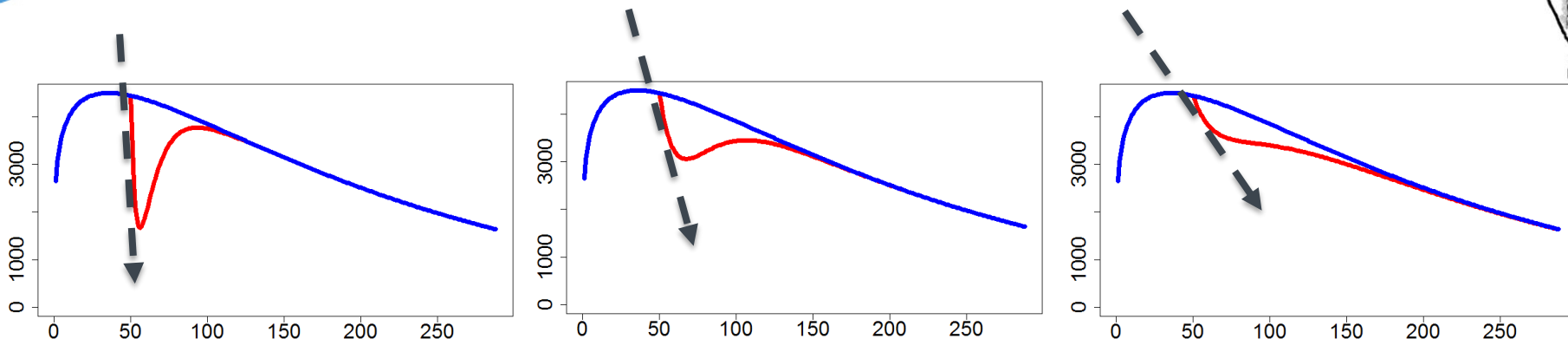
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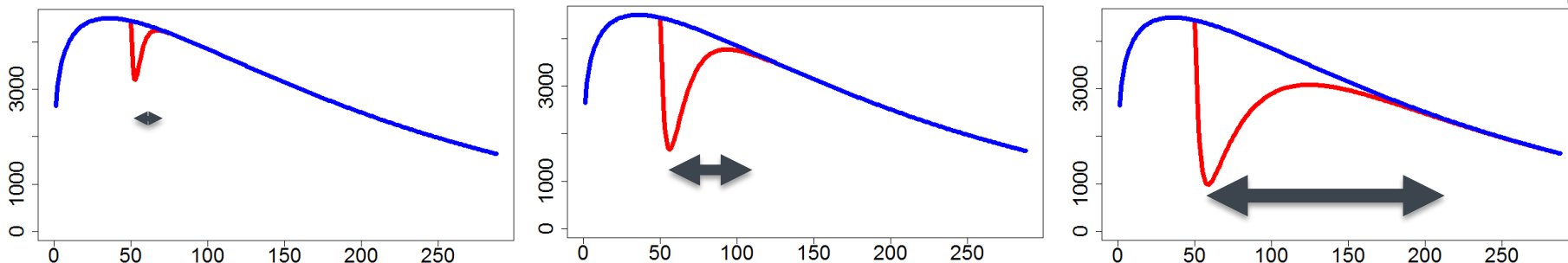
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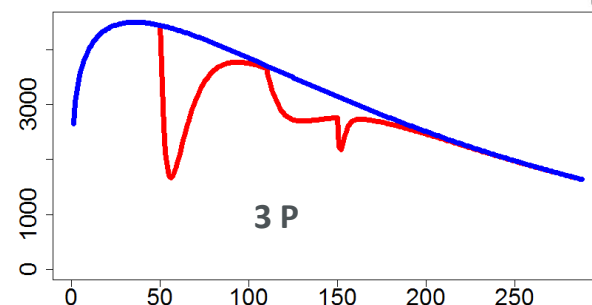
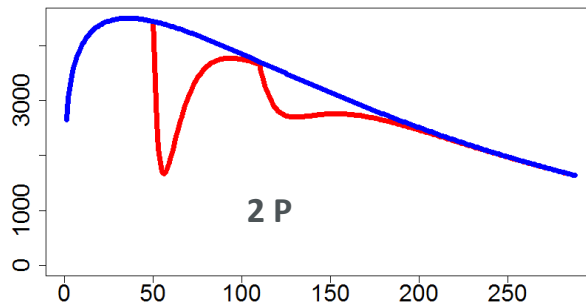
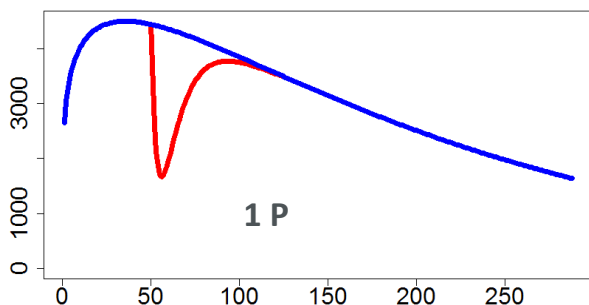
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FITTING ALGORITHM



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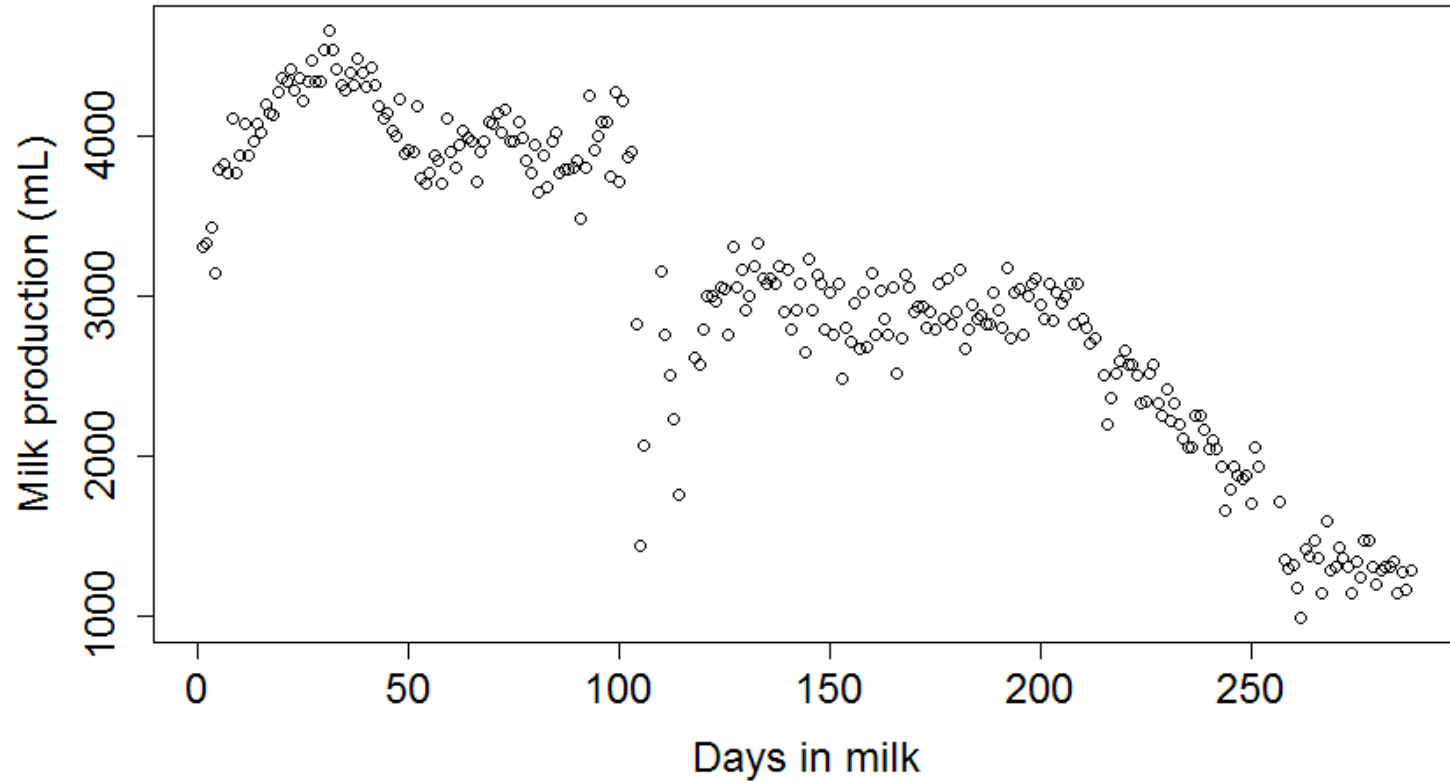


- $(3 + 4 \times N)$ parameters to adjust
 - Perturbations were fitted one after the other.
- PLM fitting algorithm is sensitive to parameter initial values
 - A screening step was therefore set up to tune initial values.

FITTING ALGORITHM



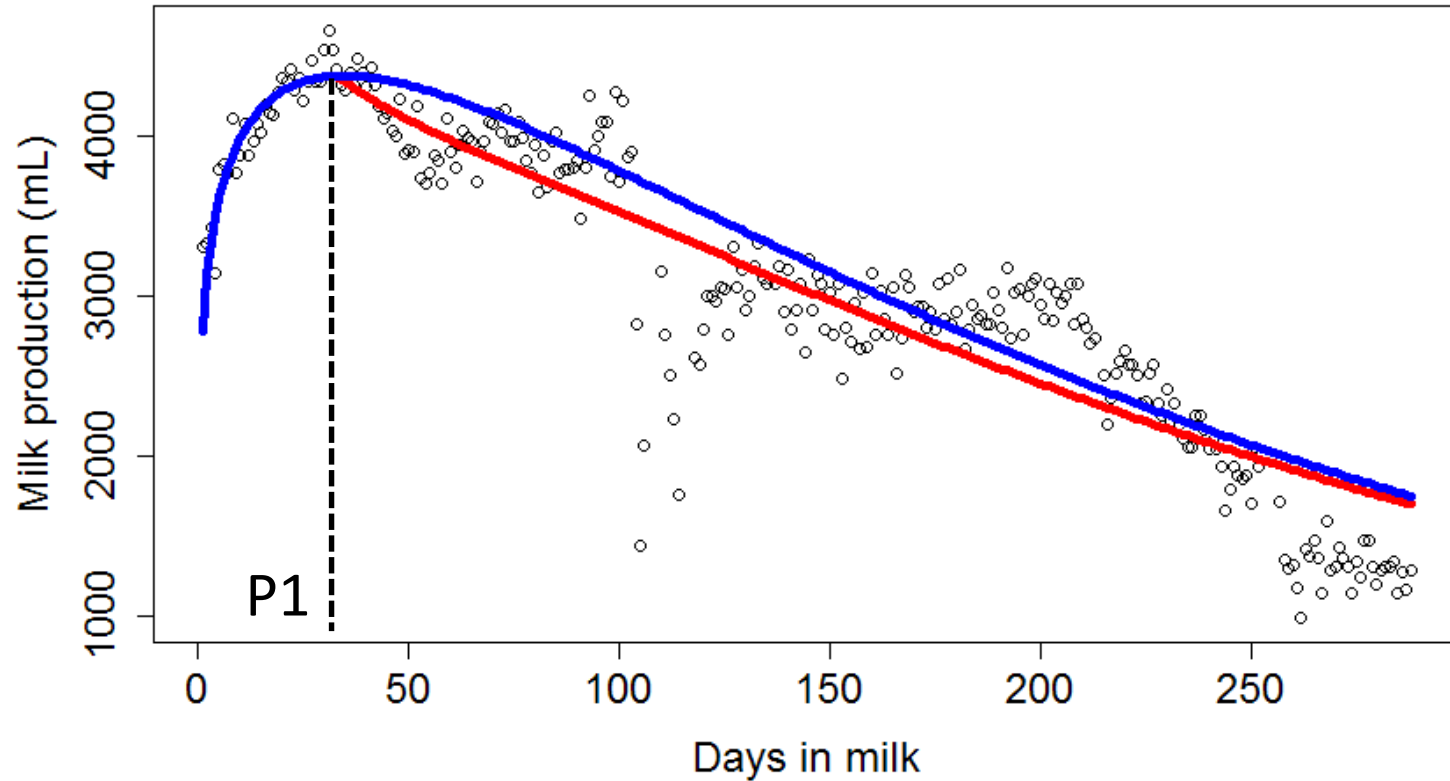
goat n°10096



FITTING ALGORITHM



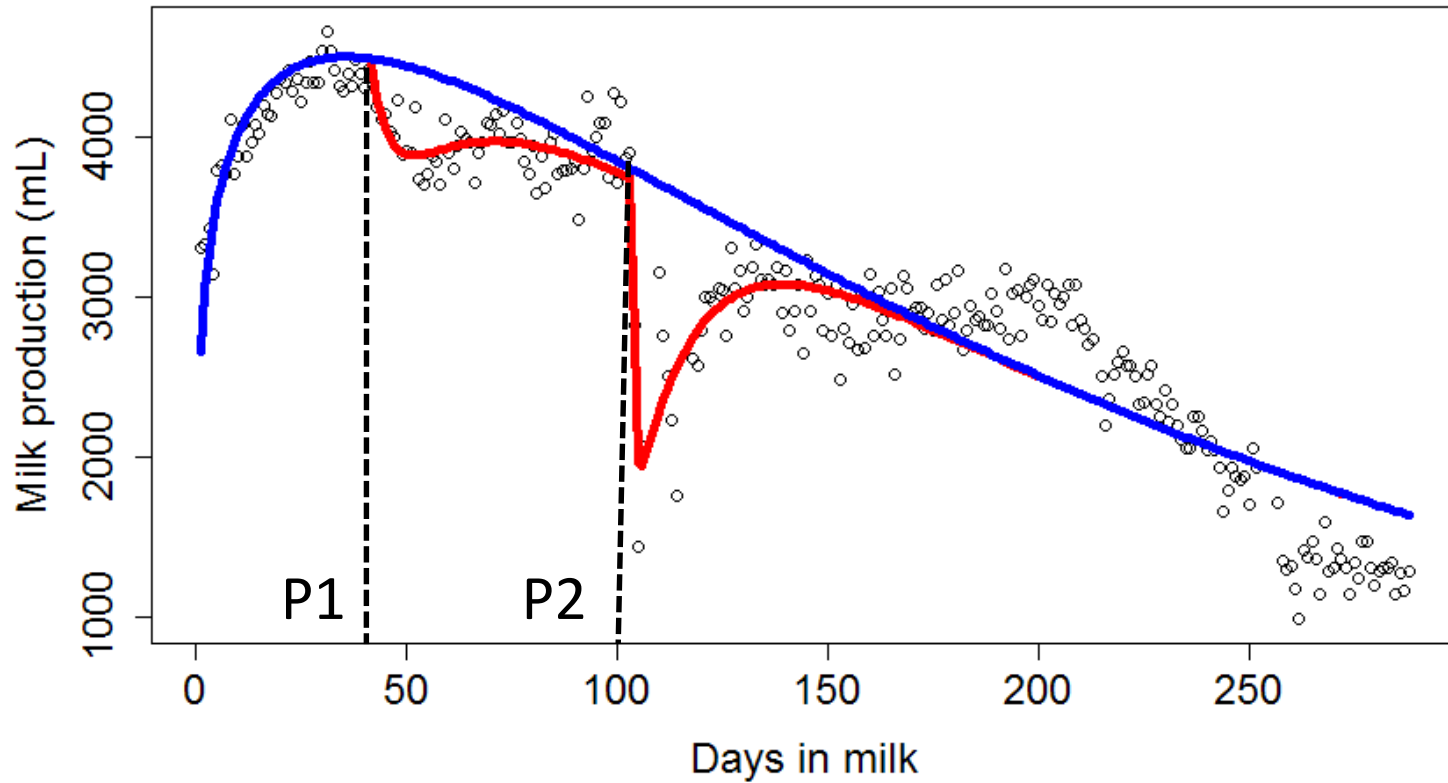
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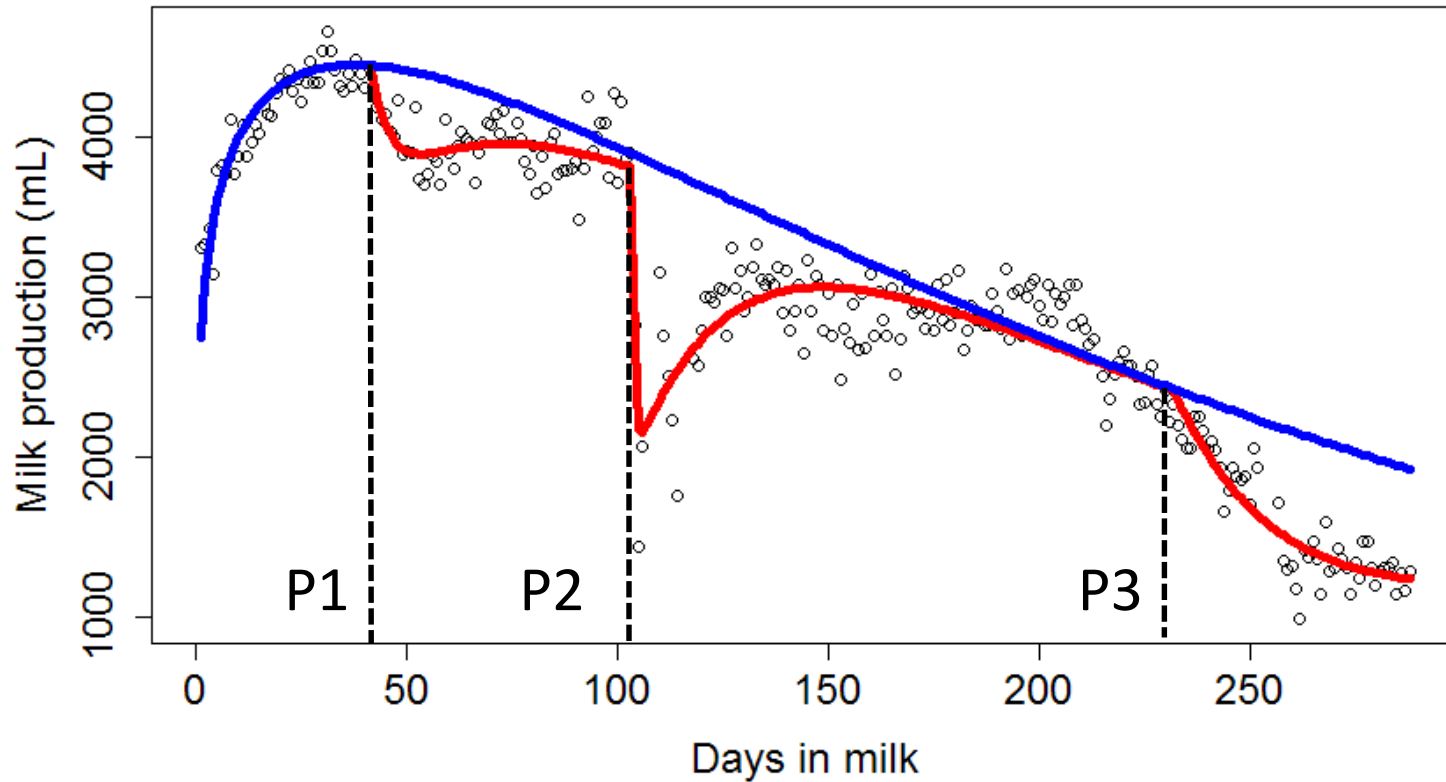
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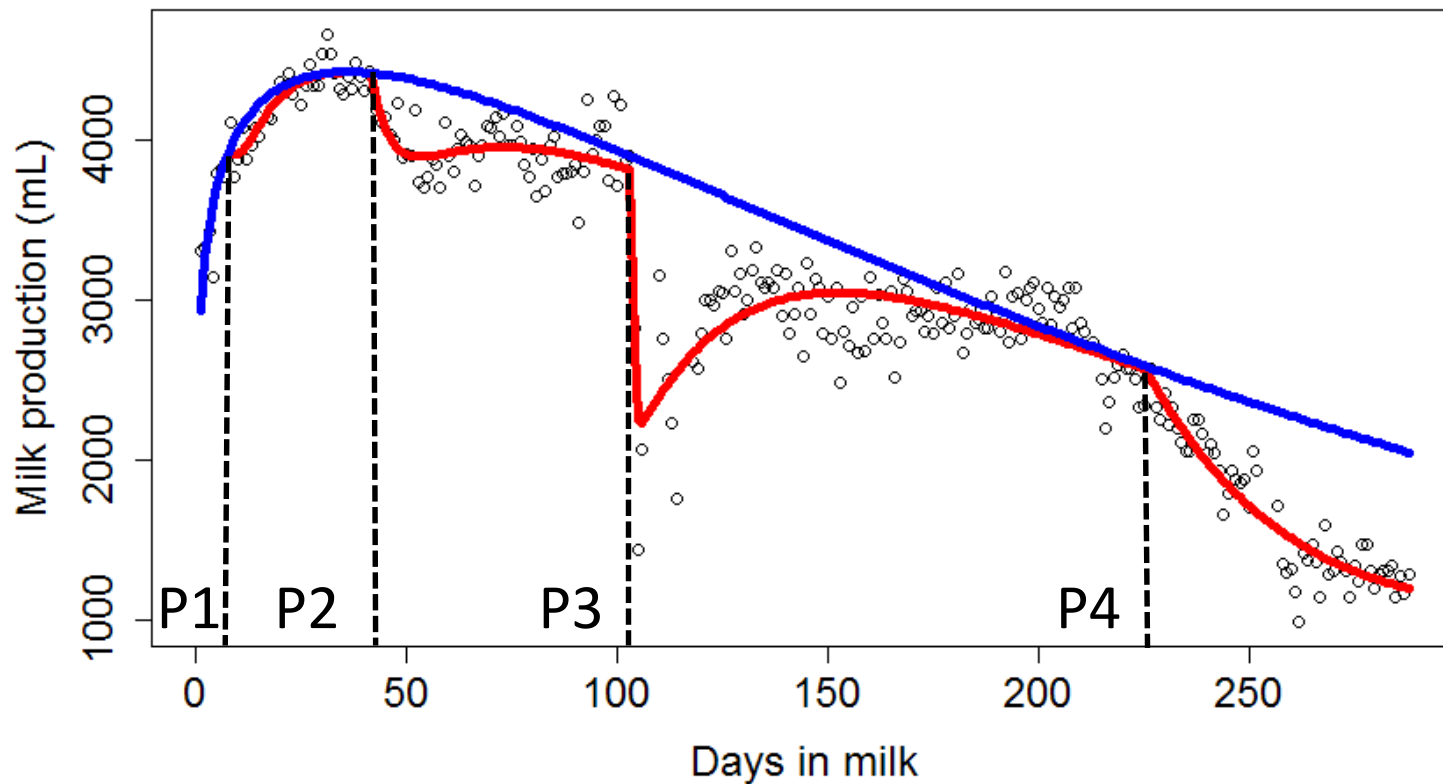
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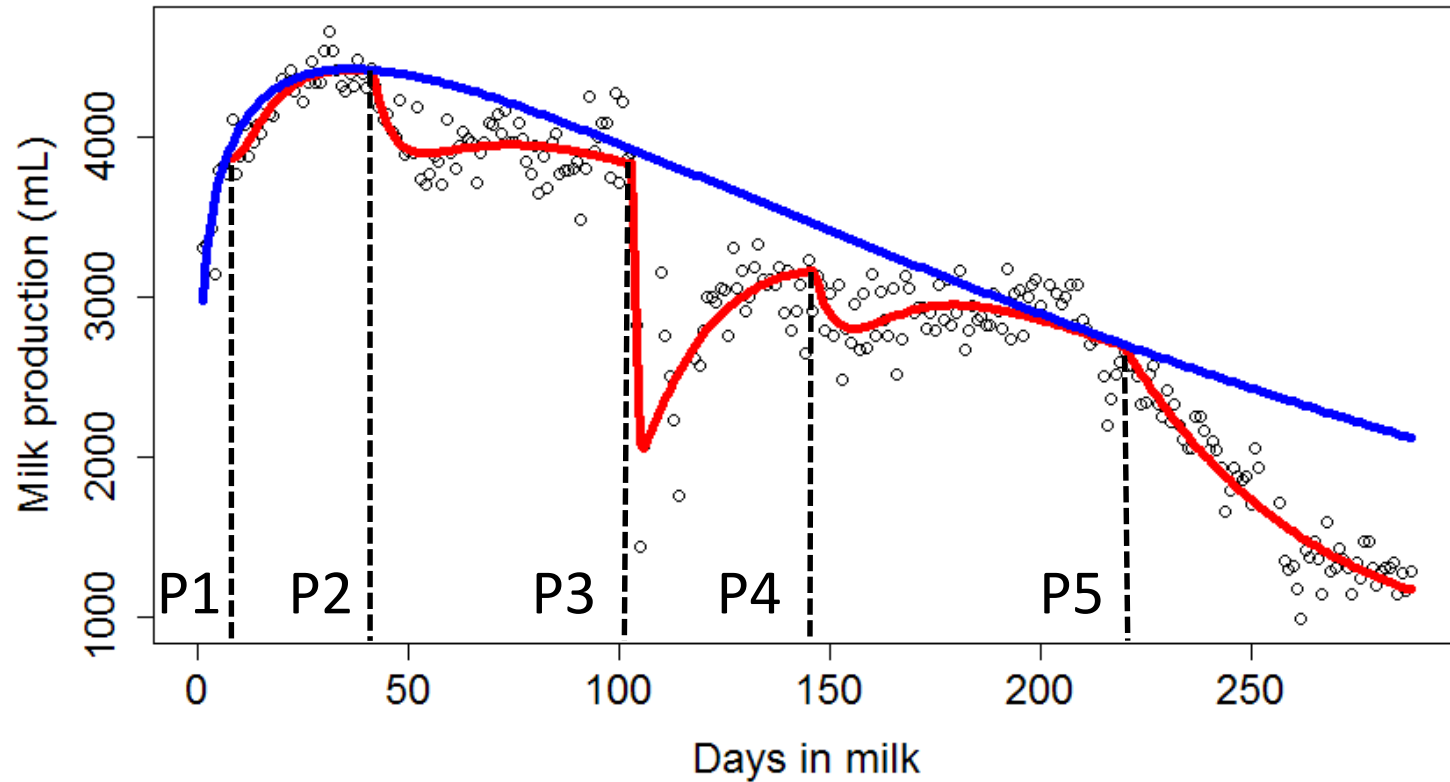
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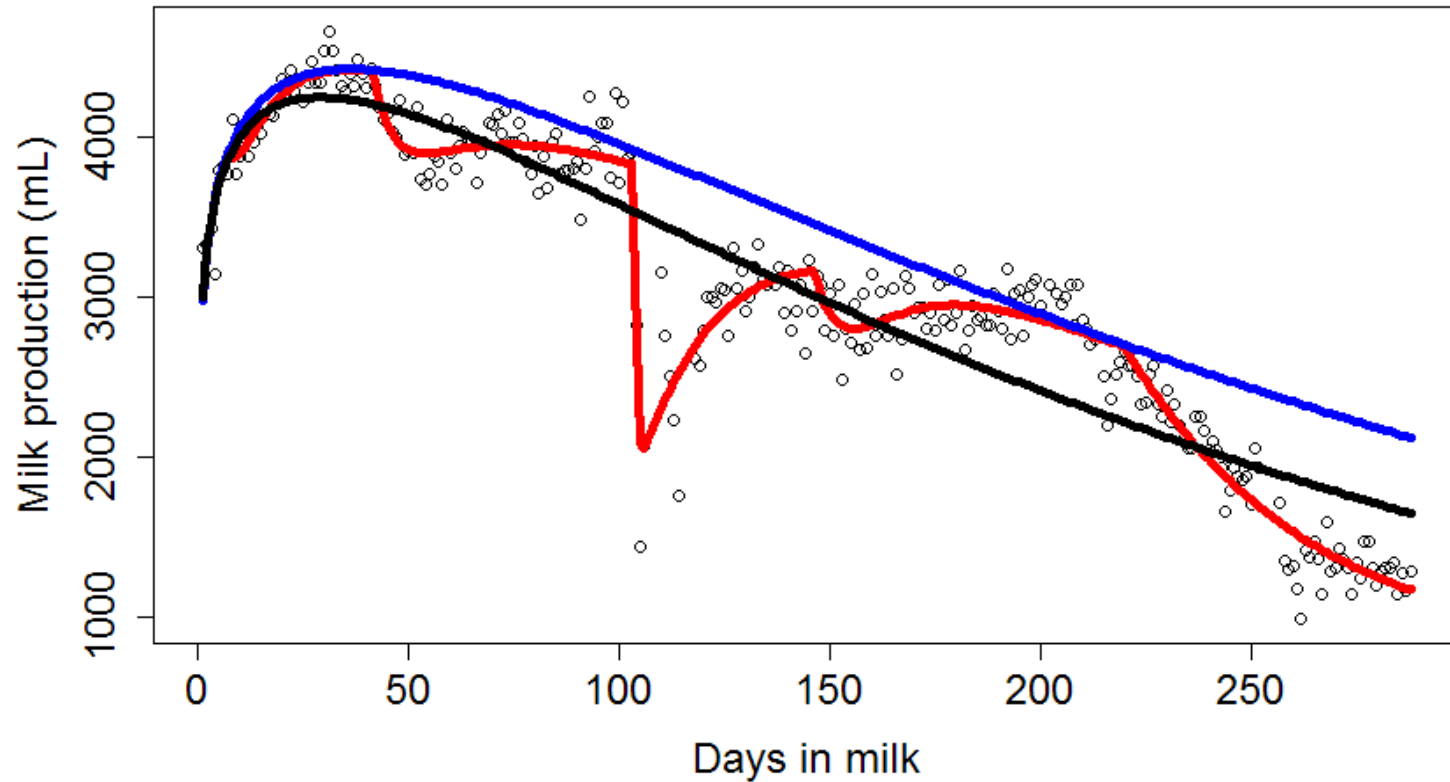
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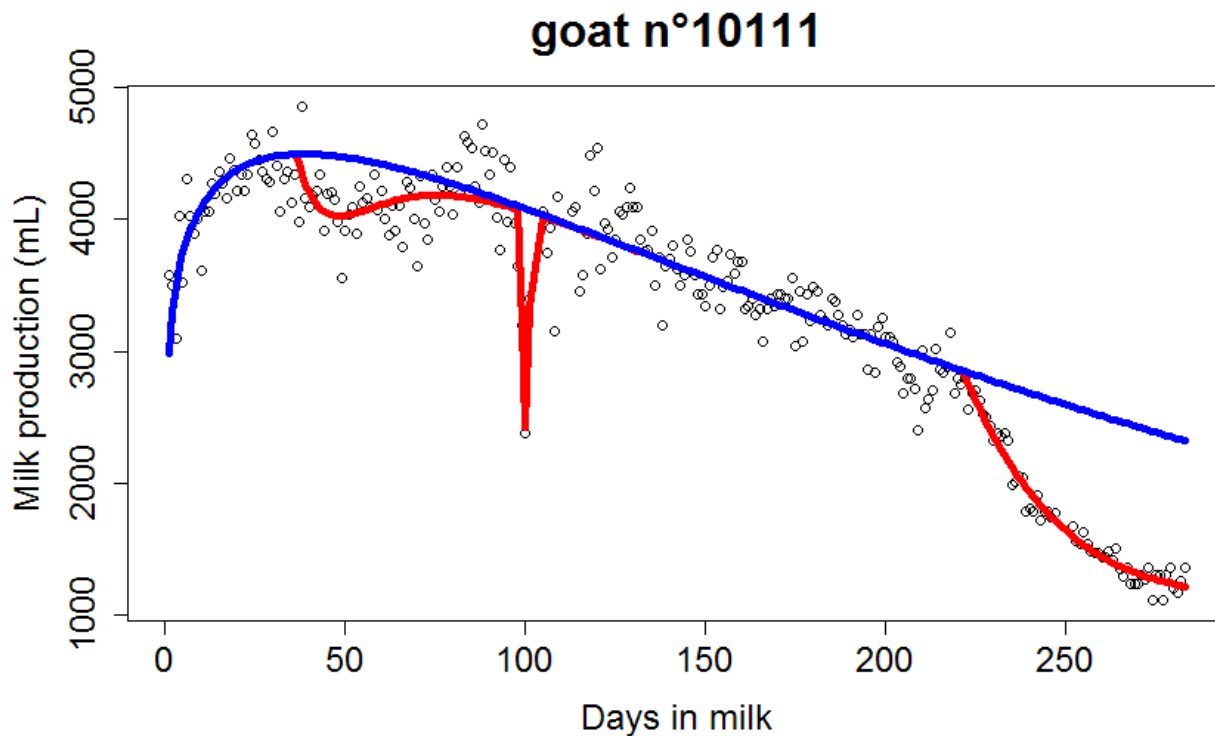


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SOME RESULTS

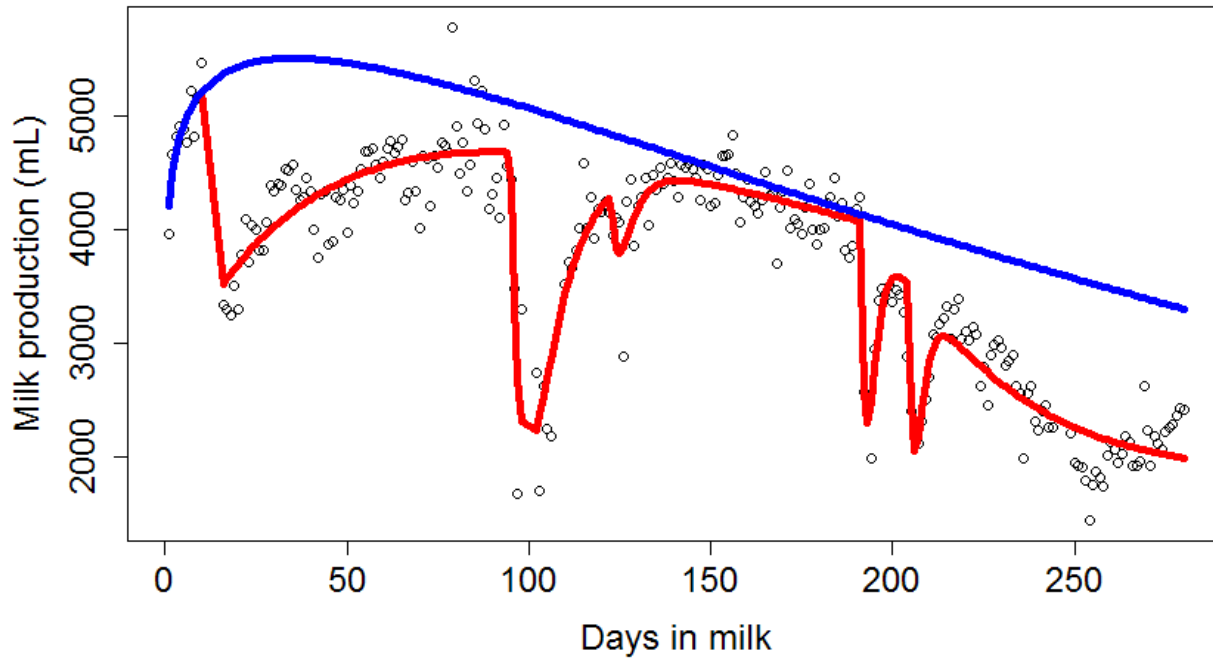


- 3 perturbations
- 273 data → 15 parameters
- 6.7 % of milk losses

SOME RESULTS



goat n°10140



- 6 perturbations
- 265 data → 27 parameters
- 18.9 % of milk losses

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PRACTICAL APPLICATIONS AND CONCLUSION



Conclusion:

- Characterize quantitatively animal responses to perturbations (robustness, resilience, ...).
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PRACTICAL APPLICATIONS AND CONCLUSION



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Perspectives:

- Work in progress (automation, improve fitting algorithm, application to different species, early warning signal).



THANK YOU FOR YOUR ATTENTION

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Cherwell Scientific Ltd 2000. Modelmaker user manual. Cherwell Scientific Ltd, Oxford, England.

Delage, J., Leroy, A. M., & Poly, J. (1953). *Une étude sur les courbes de lactation*.

Grossman, M., & Koops, W. J. (2003). Modeling Extended Lactation Curves of Dairy Cattle: A Biological Basis for the Multiphasic Approach. *Journal of Dairy Science*, 86(3), 988–998. [https://doi.org/10.3168/jds.S0022-0302\(03\)73682-0](https://doi.org/10.3168/jds.S0022-0302(03)73682-0)

Wood, P. D. P. (1967). Algebraic model of the lactation curve in cattle. *Nature*, 216(5111), 164–165. <https://doi.org/10.1038/216164a0>