Modélisation systémique et analyse multi-échelles à l'unité MoSAR : savoir-faire et perspectives

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Modélisation systémique et analyse multi-échelles à l'unité MoSAR : savoir-faire et perspectives

- modélisation systémique
- PNA, D. Sauvant

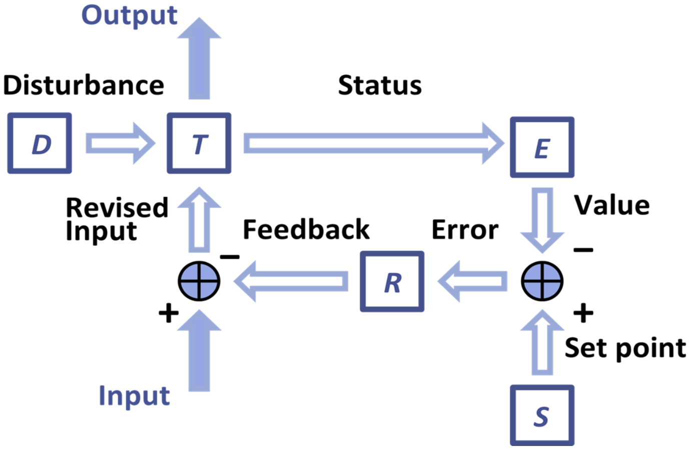
- MoSAR aujourd'hui, thèmes d'études
- trois exemples de modèles : nutrition, repro, troupeau

- trois approches analytiques
  phénotypage fonctionnel, caractérisation des individus et *latent variables*
- perspectives

Modélisation systémique

- systémique *vs* cartésien
- systèmes ouverts et régulés
- téléologie

Ludwig von Bertalanffy



PNA, D. Sauvant

La modélisation systémique en nutrition *

D Sauvant

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(Reçu le 12 septembre 1991; accepté le 22 janvier 1992)

Résumé — Les organismes vivants peuvent être assimilés à des systèmes complexes ouverts, à l'état stable, traversés par des flux de matières qui subissent un ensemble de transformations qui constituent la nutrition. L'approche systémique et la modélisation s'appliquent à la nutrition comme aux autres secteurs scientifiques bien que les exemples d'application en soient encore rares. La synthèse présentée précise les composantes de la complexité des être vivants considérés comme des systèmes nutritionnels et indique des moyens de la simplifier. Une partie est ensuite consacrée à une étude comparative des principaux types de modèles (empirique *vs* mécaniste, statique *vs* dynamique) appliqués aux systèmes nutritionnels. Les autres sujets abordés concernent la modélisation des systèmes régulateurs de la nutrition (homéostase, homéorhèse), la validation des modèles, ainsi que des commentaires succints sur les modèles d'application et de recherches.

modélisation / nutrition / système nutritionnel

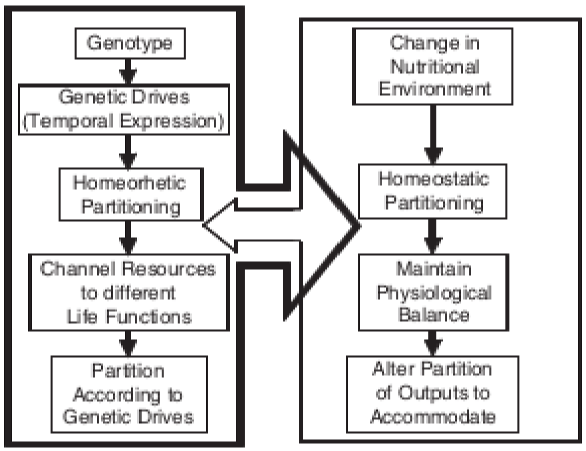
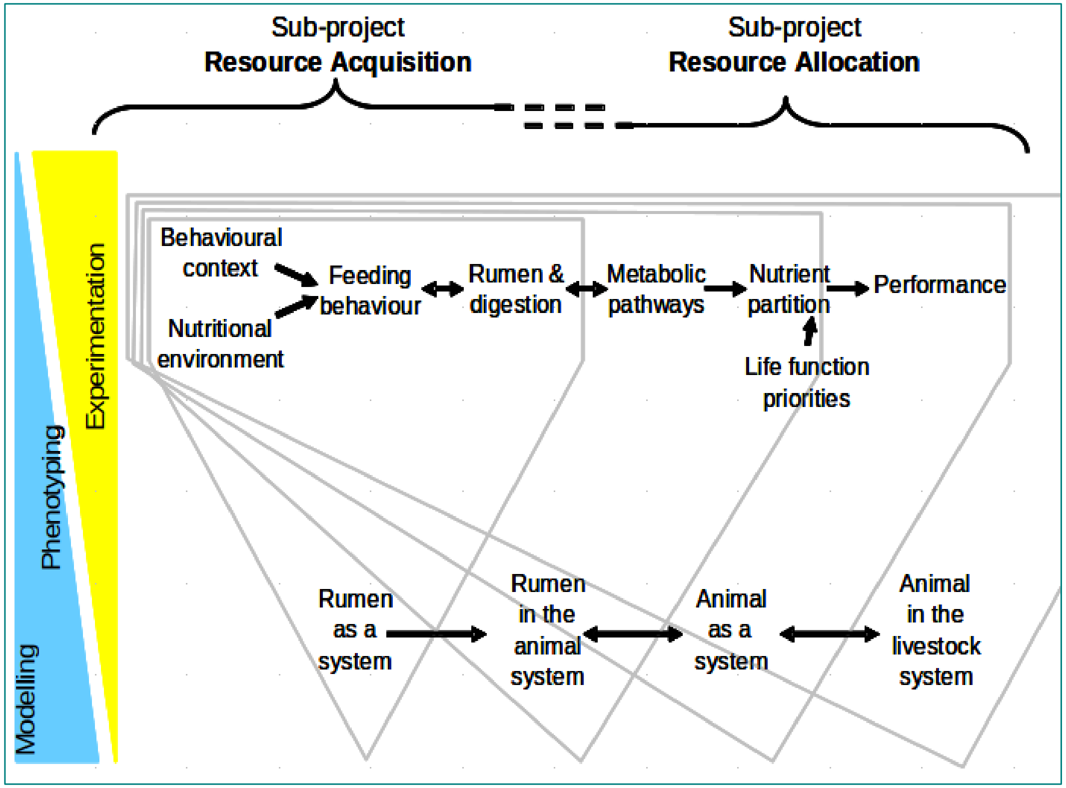
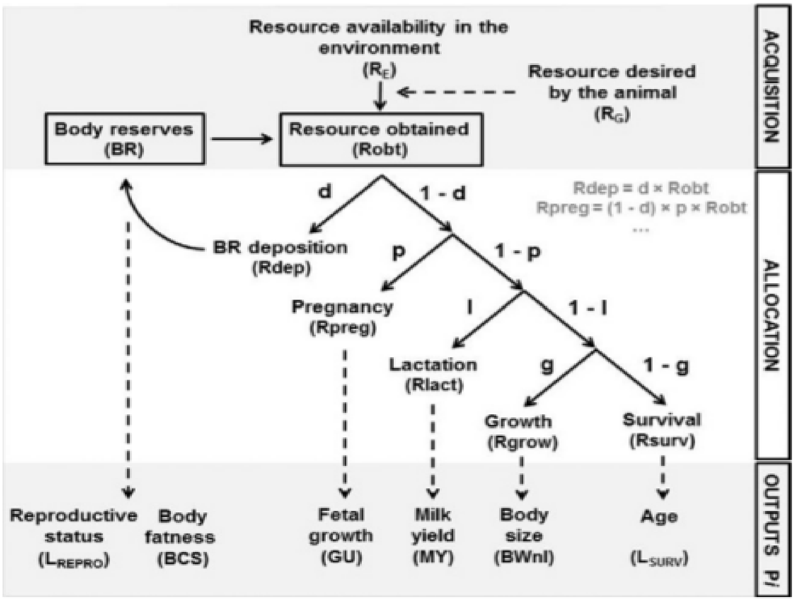


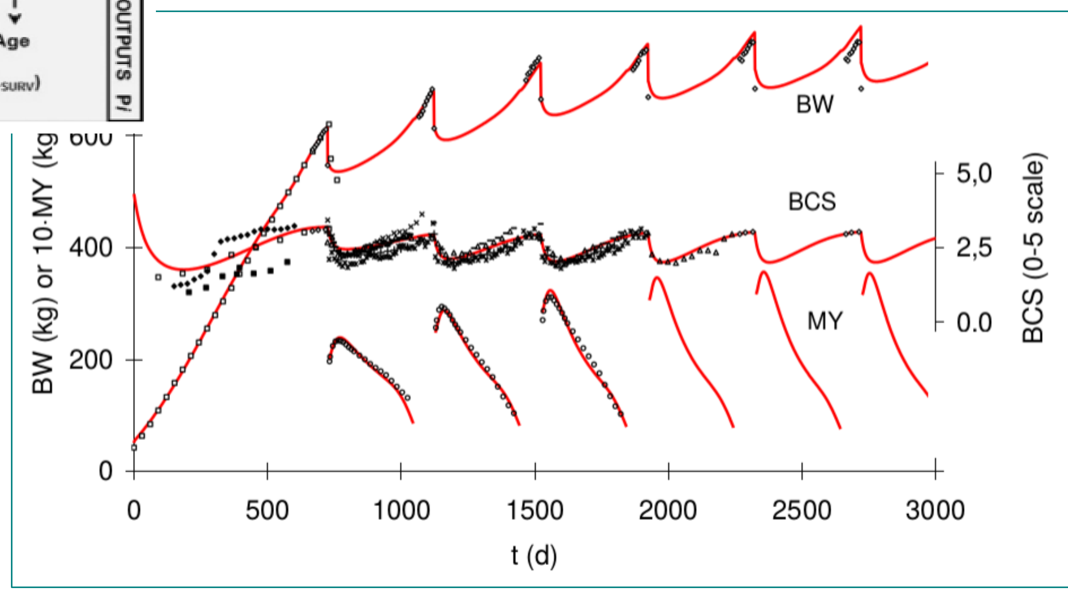
Figure 1 A schematic representation of the main challenge for improving prediction of nutrient partition: that is, to incorporate partition according to genetic drives in models that partition nutrients to maintain physiological balance. The reverse arrow represents the fact that the nutritional environment can affect gene expression and thus genetically driven partition.

MoSAR, thèmes d'étude



Exemple 1 : nutrition





Martin et Sauvant, 2010
Douhard *et al*, 2014

Exemple 1 : nutrition

Table A2. List of biological constants used in the animal model

Name	Value	Units	Definition
Resource acquisition			
Parameters of resource obtaining from the environment ($Robt_E$)			
a_{Size}	0.65	$MJ \cdot kg^{-1} \cdot d^{-1}$	Unitary potential of acquisition (per kg of BWnl)
a_{Off}	0.65	$MJ \cdot kg^{-1} \cdot d^{-1}$	Unitary potential of acquisition (per kg of BWoff)
a_{Seas}	8	MJ/d	Unitary potential of acquisition (per unit of Seas)
k_{BWoff}	0.16	wk^{-1}	Decay constant used for BWoff
$k_{OffWean}$	0.034	wk^{-1}	Decay constant used for the weaning
X_{BWpart}	1	kg/kg	Scaling factor for BWoff
a_{BCS}	0.09	$MJ \cdot points^{-1} \cdot d^{-1}$	Unitary feedback effect on acquisition of a BCS deviation from BCS*
BCS*	2.5	points	Target BCS
Parameters of resource mobilization (Rmob)			
a_{mobG}	0.5	$MJ \cdot kg^{-1} \cdot d^{-1}$	Unitary potential of mobilization $Rmob_G$ (per kg of BW_{part})
k_{mobG}	0.4	wk^{-1}	Decay constant used for $Rmob_G$
Rat_{mobE}	15	unitless	Rate for $Rmob_E$

nal constraint SAT used for $Rmob_E$
l of mobilization $Rmob_E$ (per kg of BWnl)
ocated to the gravid uterus for fetal development (remaining part $1 - u_0$ allocated to BR)
cation ($cmod_G$)
ised for allocation to BR deposition during the normal lactation phase ($0 < t_{lact} \leq T_{ELACT}$)
ised for allocation to BR deposition during extended lactation
ised for allocation to lactation during the normal lactation phase
ised for allocation to lactation during extended lactation
r the extended lactation effect on allocation to lactation
ised for allocation to growth
allocation ($cmod_E$)
allocation to BR deposition
allocation to pregnancy
allocation to lactation
allocation to growth
cted milk
elihoods
ikelihood

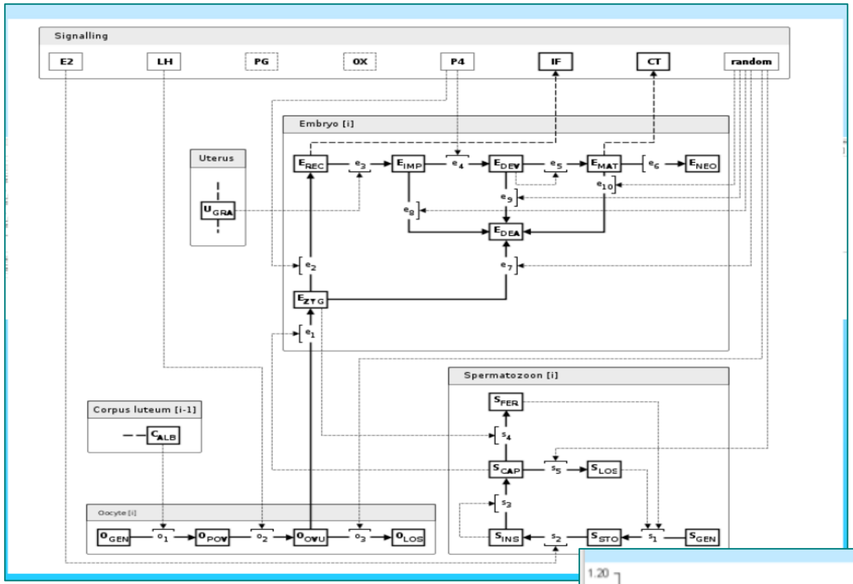
Table A1. List of variables used in the animal model

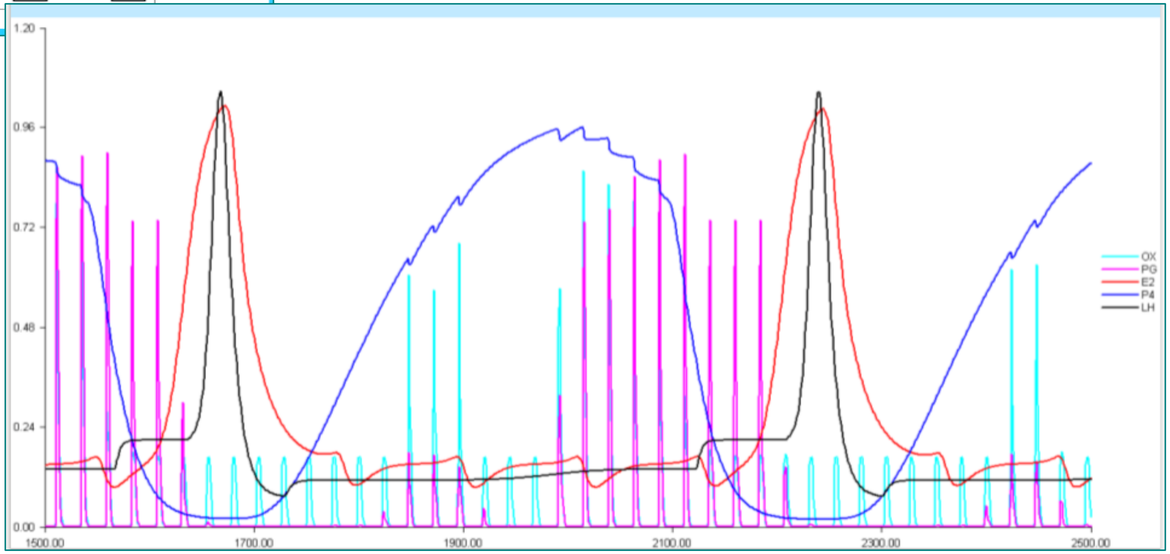
Variable	Unit	Definition	Equation
Status			
LIV (*t*)	unitless	Living status at time *t*	= 1 if living, 0 else
LACT (*t*)	unitless	"Normal" lactation status at time *t*	= 1 if lactating for less than T_{ELACT} wk, 0 else
ELACT(*t*)	unitless	Extended lactation status at time *t*	= 1 if lactating for at least T_{ELACT} wk and PREG = 0, 0 else
PREG (*t*)	unitless	Pregnancy status at time *t*	= 1 if pregnant, 0 else
BRpart	kg	Amount of BR at parturition	= BR value when $t_{lact} = 1$
BWpart	kg	BWnl at parturition	= BWnl value when $t_{lact} = 1$
Time variables			
age (*t*)	wk	Age at time *t*	= age $(t-1)$ + LIV (t)
t_{lact} (*t*)	wk	"Normal" lactation stage at time *t*	$= [t_{lact}(t-1) + 1] \times LACT(t)$
t_{elact} (*t*)	wk	Extended lactation stage at time *t*	$= [t_{elact}(t-1) + 1] \times ELACT(t)$
t_{preg} (*t*)	wk	Pregnancy stage at time *t*	$= [t_{preg}(t-1) + 1] \times PREG(t)$
Resource acquisition			
Desired resource acquisition			
R_G	MJ/d	Desired resource acquisition	
R_{G0} (age)	MJ/d	Base level of R_G at a given a	
R_{GSize}	MJ/d	Variations of R_G related to b	
R_{GOff}	MJ/d	Postpartum variation of R_G t growth	
R_{GSeas}	MJ/d	Variations of R_G due to seas	
BWoff	kg	Evolutionary drive for offspr	
Weaning	unitless	Natural weaning function in	
Seas	unitless	Seasonal cued driver	
TranSeas (t_{lact})	unitless	Transition function amplifyi lactation is extended	
Resource obtaining from the environment			
$Robt_E$	MJ/d	Resource obtained from the	
SAT	unitless	Energetic status	
Resource obtaining from body reserves mobilization			
$Rmob_G$	MJ/d	Resource mobilized from BR	
$Rmob_E$	MJ/d	Resource mobilized from BR driven	
Robt	MJ/d	Total amount of resource obt	

Table A1. (cont.).

Variable	Unit	Definition	Equation
Resource allocation (following the general model $c = c_0 \times cmod_G \times cmod_E$, in which c_0 are values of potential allocation)			
Temporal modifications of allocation priority genetically driven ($cmod_G$)			
dmod	unitless	For BR deposition	$= 1 - \exp(-k_{dep} \times t_{lact}) \times LACT + \exp(-k_{depSeas} \times t_{elact}) \times ELACT$
pmod	unitless	For pregnancy	$= (t_{preg}/T_{preg})^4$
lmod	unitless	For lactation	$= \exp(-k_{lact} \times t_{lact}) \times LACT + X_{lactSeas} \times \exp(-k_{lactSeas} \times t_{elact}) \times ELACT$
gmod	unitless	For growth	$= \exp(-k_{grow} \times age)$
Modifications of allocation due to the environment ($cmod_E$)			
$cmod_E$	unitless	For all functions the same model with different SAT_{c0} values	$= 1/\{1 + \exp[-Rat_{cmodE} \times (SAT - SAT_{c0})]\}$
Resources allocated			
Rdep	MJ/d	To BR deposition	$= d \times Robt$
Rpreg	MJ/d	To pregnancy	$= (1 - d) \times p \times Robt$
Rlact	MJ/d	To lactation	$= (1 - d) \times (1 - p) \times l \times Robt$
Rgrow	MJ/d	To growth	$= (1 - d) \times (1 - p) \times (1 - l) \times g \times Robt$
Rsurv	MJ/d	To survival	$= (1 - d) \times (1 - p) \times (1 - l) \times (1 - g) \times Robt$
Rpreg_foet	MJ/d	To fetal development after pregnancy allocation	$= u_0 \times Rpreg$
Rpreg_dep	MJ/d	To BR deposition after pregnancy allocation	$= (1 - u_0) \times Rpreg$
Resource conversion			
dBR	kg/d	Net variation in BR	$= dt \times [(Rdep + Rpreg\_dep)/E_{BRdep} - (Rmob_E + Rmob_G)/E_{BRmob}]$
dGU	kg/d	Variation in fetus mass	$= dt \times Rdep\_foet/E_{GU}$
MYcor	kg/d	Energy corrected milk yield	$= dt \times Rlact/E_{MYcor}$
dBWnl	kg/d	Variation in nonlabile BW	$= dt \times Rgrow/E_{BWnl}$
BR (age)	kg	Body reserves weight	$= BR(age - 1) + dBR$
R_{GSeas}	MJ/d	Variations of R_G due to seasonal factors	$= a_{Seas} \times Seas$
BWoff	kg	Evolutionary drive for offspring growth	$= [1 - \exp(-k_{BWoff} \times t_{lact})] \times X_{BWpart} \times BWpart \times weaning$
Weaning	unitless	Natural weaning function in BWoff	$= \exp(-k_{OffWean} \times t_{lact})$
Seas	unitless	Seasonal cued driver	$= TranSeas(t_{lact}) \times [(1 + \sin\{[2 \times \Pi \times (t_{lact} - LagSeas)]/WaveSeas\})/2]$
DMI	kg/d	Dry matter intake	$= Robt_E/10.2$

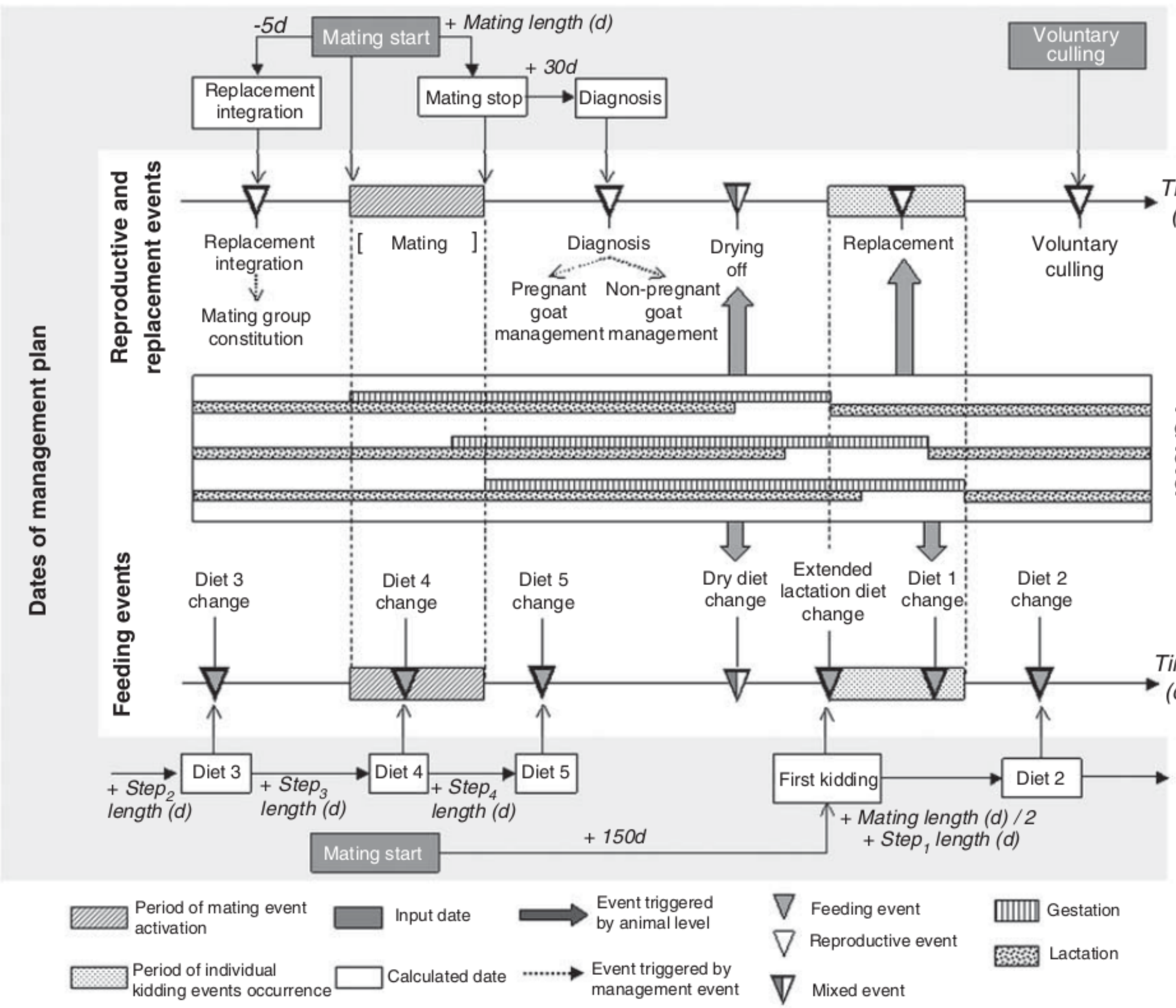
Exemple 2 : reproduction





Martin *et al*, 2015 (in preparation)

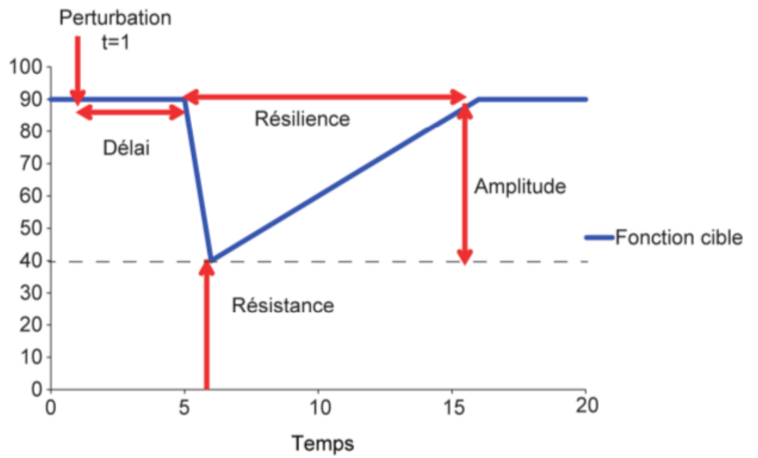
Exemple 3 : gestion du troupeau

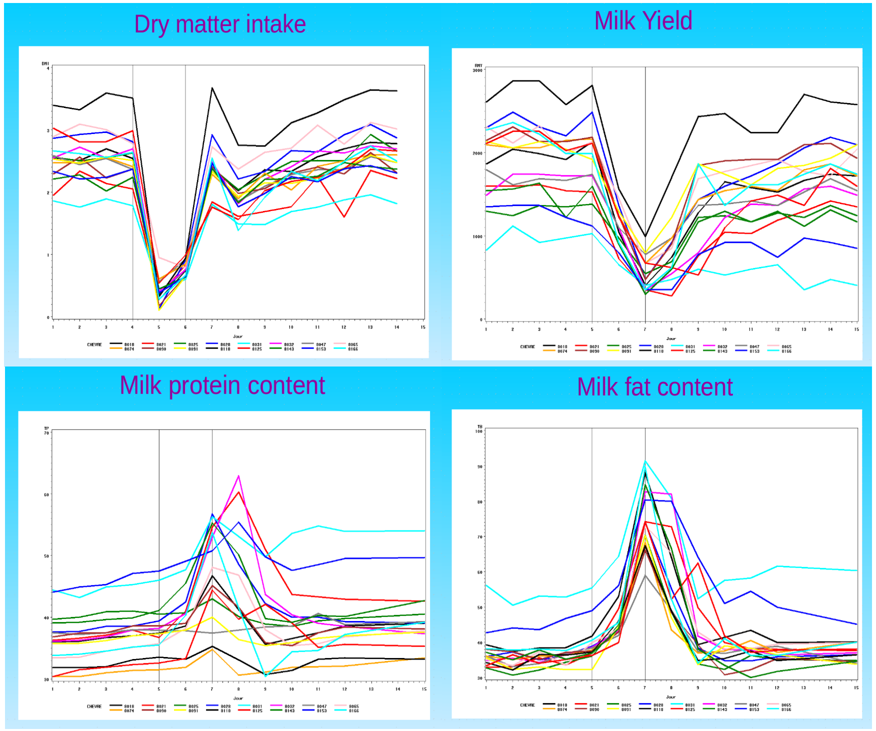


Puillet *et al*, 2010

Approche multi-échelles : phénotypage fonctionnel

Figure 3. *Dynamique de réponse d'une fonction cible (production, reproduction, survie…) de l'animal à une perturbation de son environnement (d'après Martin et Sauvant 2010a).*

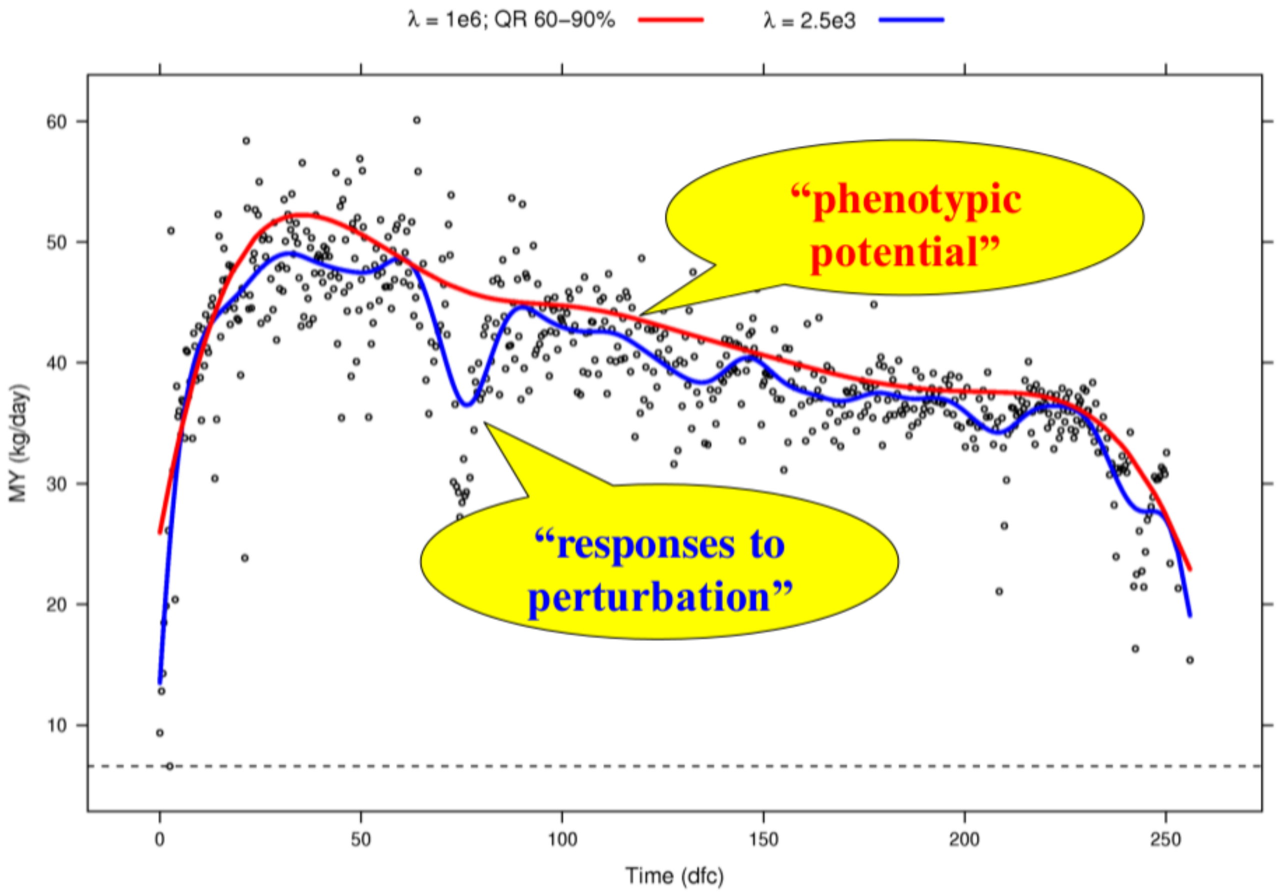




piece-wise Gaussian mixture model

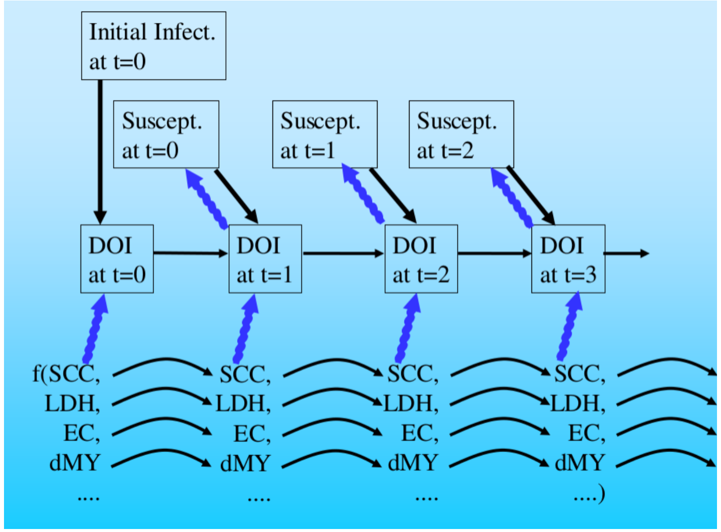
Friggens *et al*, 2015 (in preparation)

Approche multi-échelles : caractérisation des individus



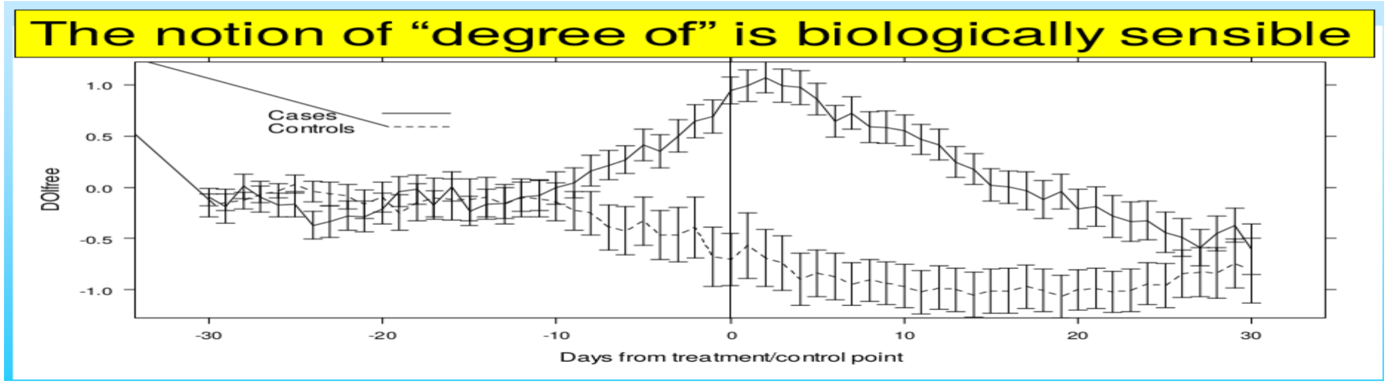
lissage (FDA) et régression quantile

Approche multi-échelles : *latent variables*



$$y^k(t_j) = \beta^k(t_j) + \lambda^k DOI(t_j) + v^k(t_j)$$

- $\beta^k(t_j)$ Long-term trend
- $r^k(t_j)$ Short-term fluctuation
- $v^k(t_j)$ Error term
- λ^k Proportionality constant

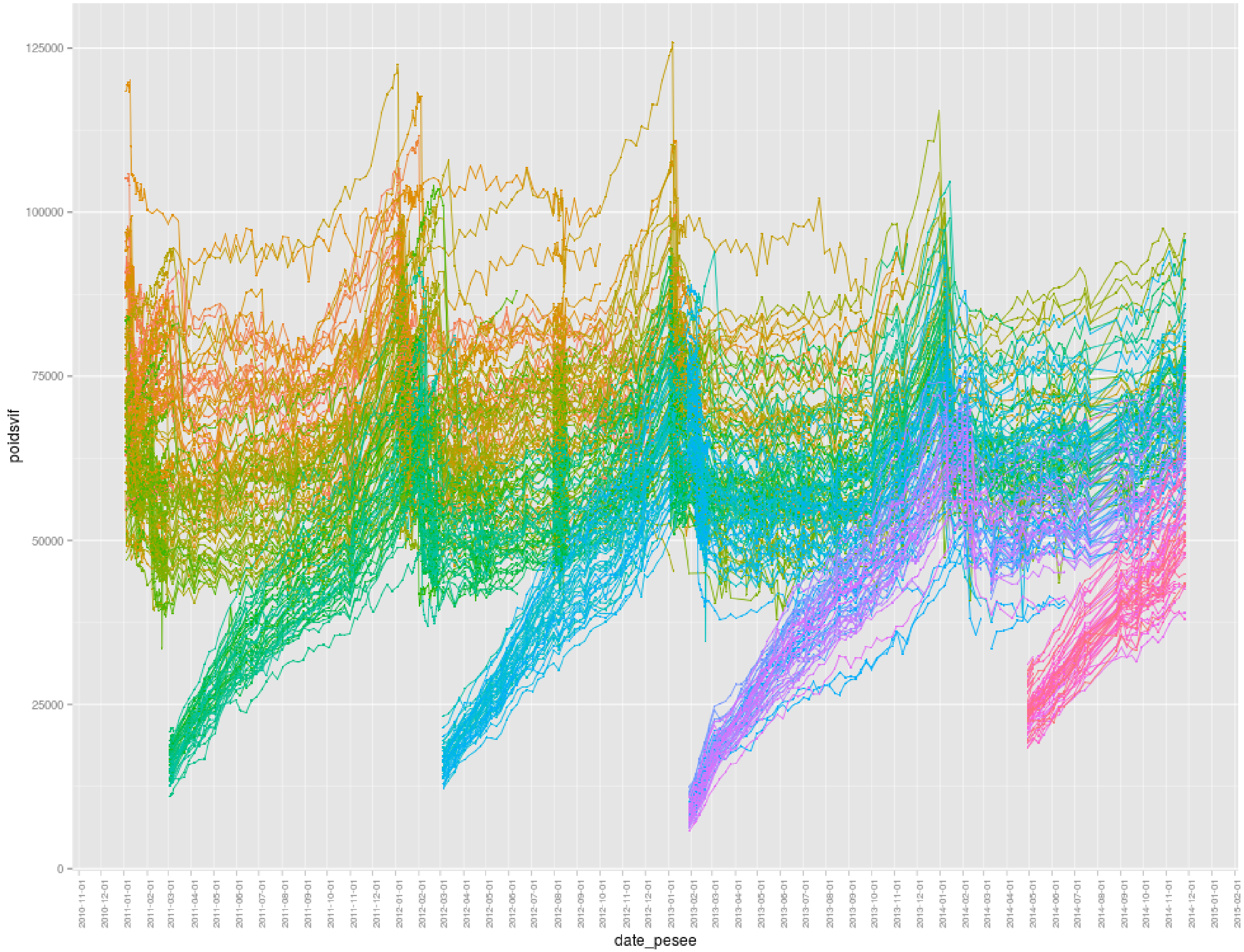


Approche multi-échelles : encore des données !

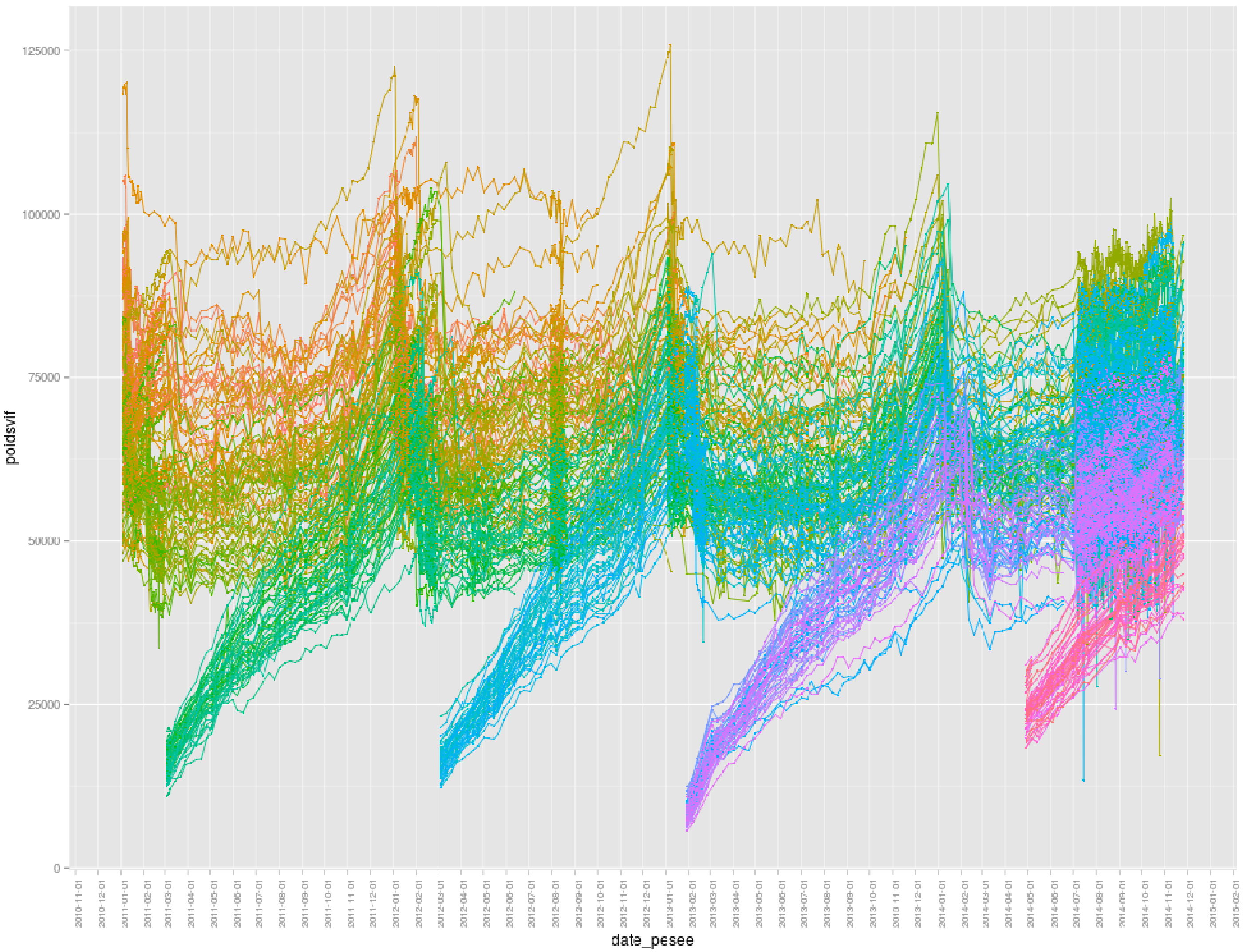
- alimentation (calculée, analysée), poids vif/pesée bi-journalière, NEC
- traite, cinétiques de traite, contrôle laitier
- évènements sanitaires

- eau ingérée (chevrettes + chèvres)
- accéléromètres

Exemple, données de poids vif, 2011-2014



Exemple, données de poids vif



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Merci !

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