Developing resilience indicator traits based on longitudinal data: opportunities and challenges

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What is resilience

Resilience

=

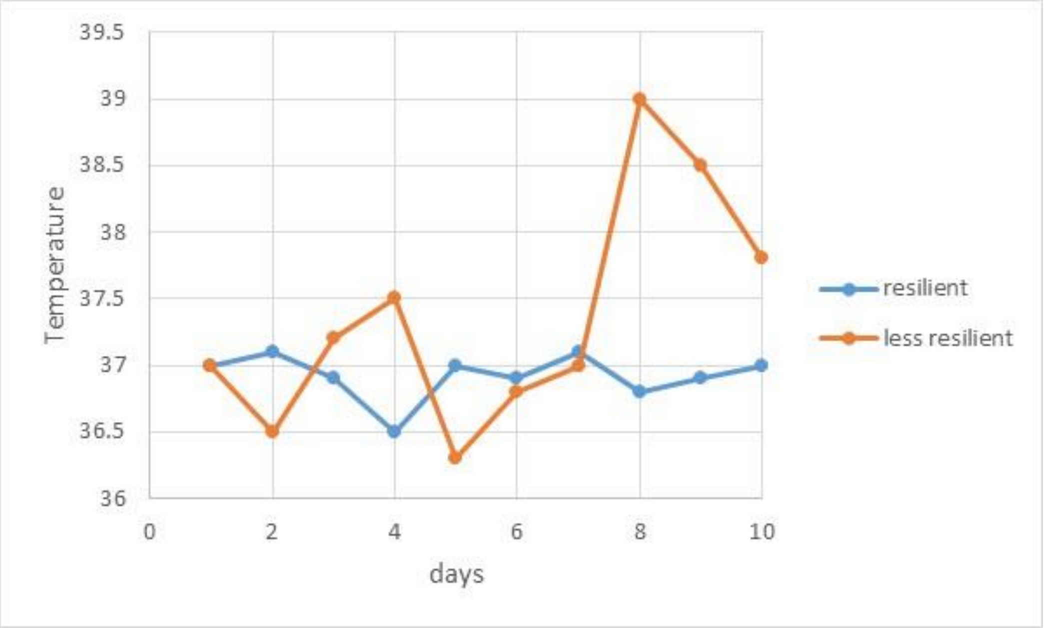
the ability of an animal to be minimally affected in its function by an external disturbance....

.... or to quickly return to the state that it had before the disturbance

Adapted from Colditz and Hine, 2016

Useful traits to study resilience

- Longitudinal profiles
  - Feed intake
  - Activity
  - Milk yield (or other performance trait)
  - Body temperature
  - …



Objectives

- To discuss development of resilience indicators
  - Which measures?
  - What do we know?
  - Opportunities
  - Challenges

- To define economic value of resilience

- To show benefits of resilience in breeding programs

Development of resilience indicators

Which statistical measures?

- The variance of deviations from a curve
- The skewness of deviations
- The lag-1 correlation of deviations

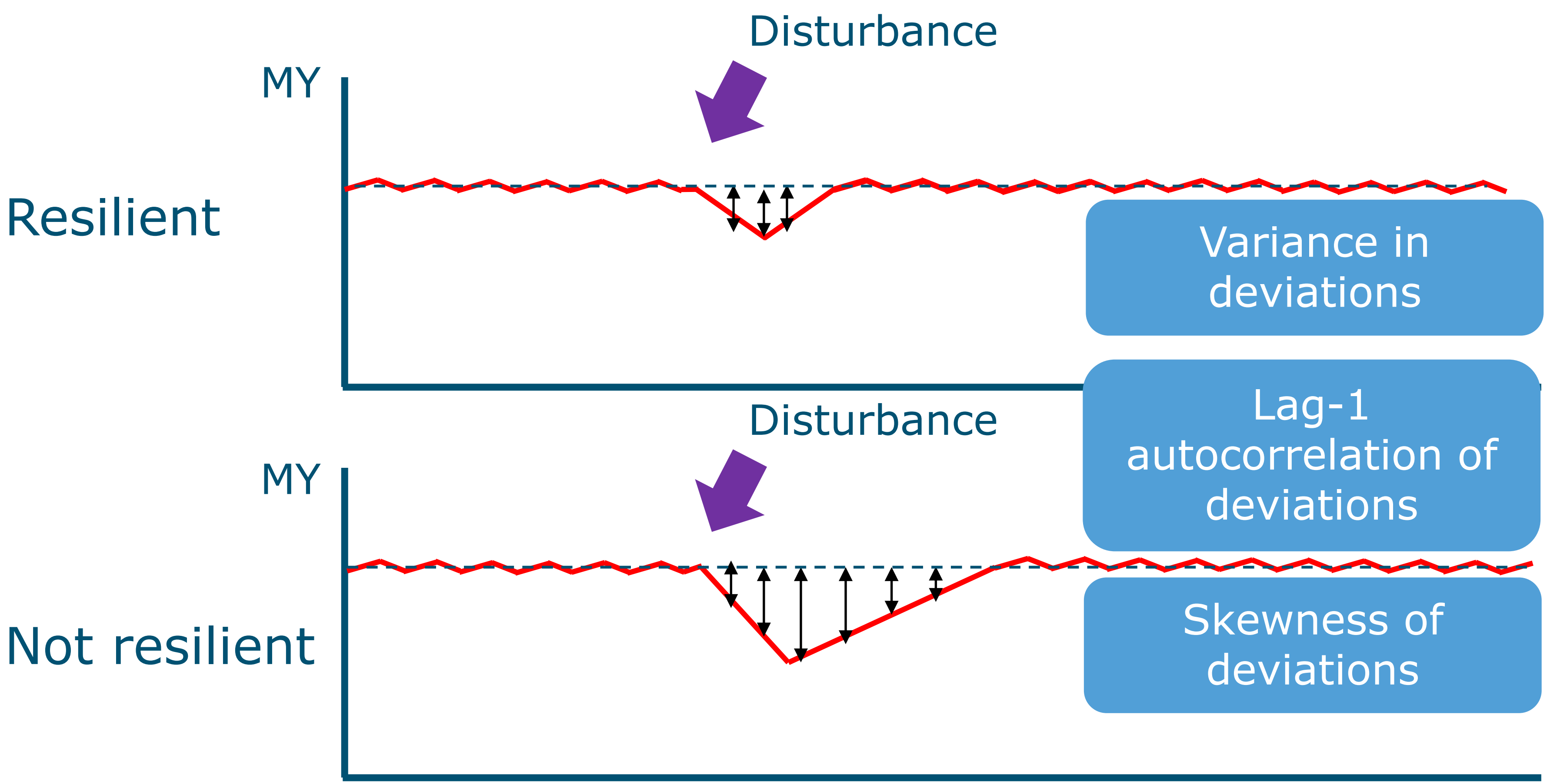
Different measures; same analysis

Different analysis

- Slope of a reaction norm on an environmental covariate
  - Temperature
  - CG-mean, e.g. HYS, herd-test-day

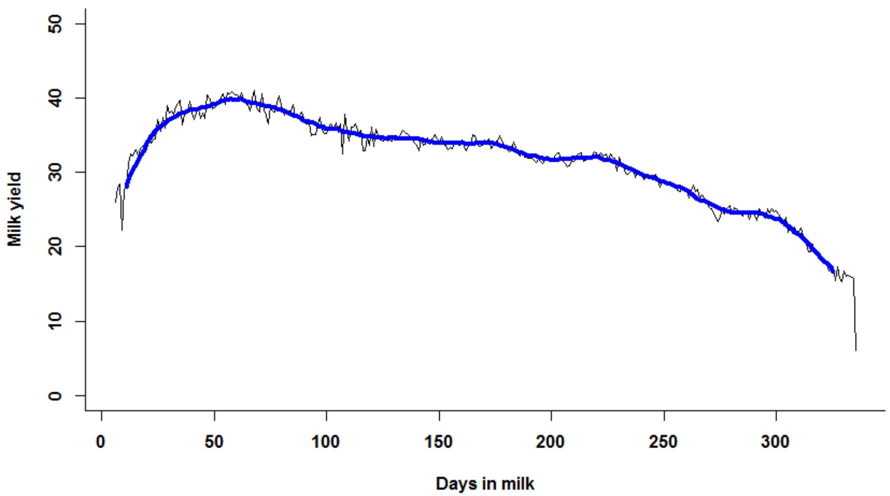
Berghof et al. submitted

How to measure resilience

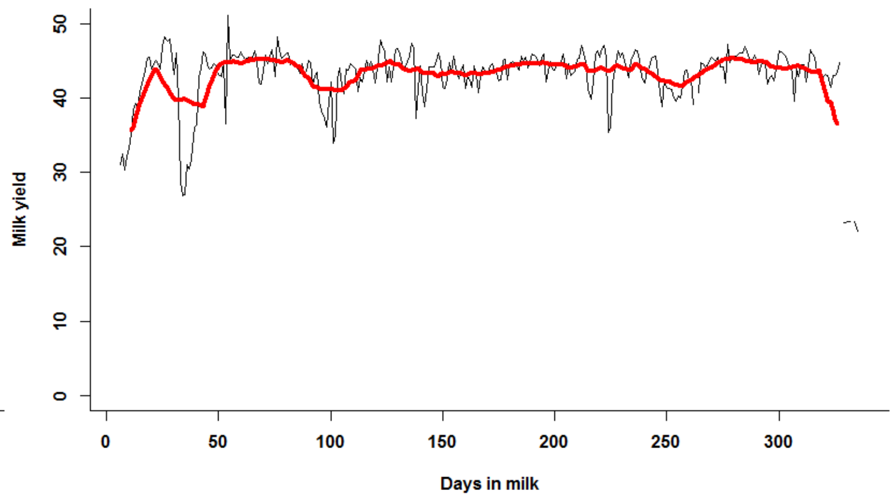


Variance, autocorrelation and skewness

Resilient cow: 115180



Less resilient cow: 974601



Animal	Variance	Lag 1 autocorrelation	Skewness
115180	0.66	0.25	-0.05
974601	7.29	0.62	-1.32

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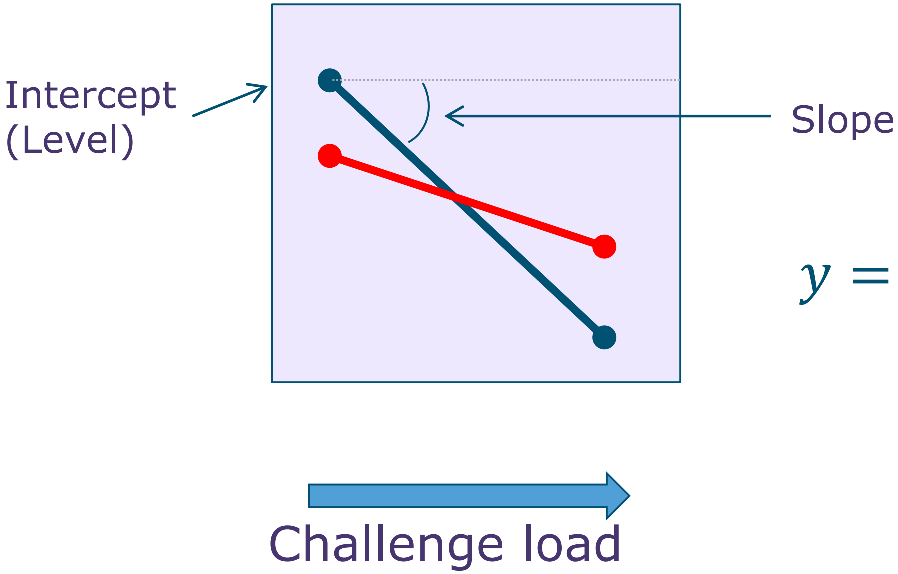
100years 1918 — 2018

See presentation Poppe et al. this session
See Berghof et al. session 63

Slope of a reaction norm



$$y = fixed + a_{int} + a_{sl}cl + e$$

Mathur et al., 2014. J. Anim. Sci. 92:5374-5381.
Herrero-Medrano et al., 2015. J. Anim. Sci. 93:1494-1502.

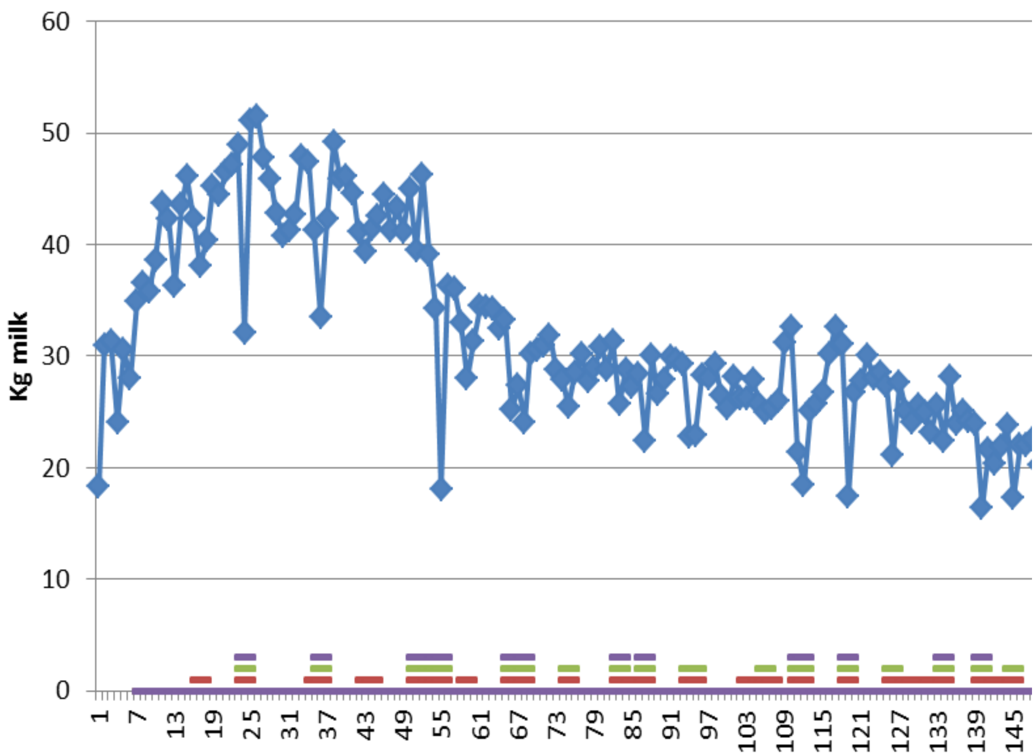
What do we know?
Heritability of variance

Trait	$\sigma^2_{A_V}$	GCV_{Ve}	h^2_v
milk NL	0.03	0.19	<0.01
milk Sweden	0.05	0.22	0.01
SCS Sweden	0.05	0.21	0.01
SCS Robustmilk farms	0.08	0.28	0.01
milk Belgium	0.03	0.17	<0.01
SCS Belgium	0.03	0.16	<0.01
SFA Belgium	0.01	0.12	<0.01
UFA Belgium	0.02	0.12	<0.01
C18:1 cis-9 Belgium	0.02	0.12	<0.01

Mulder et al. 2013. J. Dairy Sci. 96:7306-7317.
Mulder et al. 2013. GSE 45:23.
Vandenplas et al., 2013. J. Dairy Sci. 96:5977-5990.

Fluctuations in milk yield

Daily milk yields from automatic milking systems



Drops indicated by:

$$\alpha = 0.05$$

$$\alpha = 0.01$$

$$\alpha = 0.001$$

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100years 1918 — 2018

Elgersma et al. 2018. J. Dairy Sci. 101:1240–1250

Heritabilities

	h^2 (SE)
Drop average	0.076 (0.008)
Drop regression	0.060 (0.007)
LNvar	0.104 (0.010)
Average milk yield	0.385 (0.014)

Elgersma et al. 2018. J. Dairy Sci. 101:1240–1250

Genetic correlations among fluctuation traits

	Drop regression	LNvar	Milk
Drop average	0.87 (0.03)	0.25 (0.07)	-0.35 (0.05)
Drop regression		0.23 (0.07)	-0.08 (0.06)
LNvar			0.61 (0.04)

Elgersma et al. 2018. J. Dairy Sci. 101:1240–1250

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Genetic correlations with health and longevity

	Udder health	Claw health	Ketosis	Longevity
Drop average	-0.09	-0.03	-0.20	-0.08
Drop regression	-0.10	0.15	-0.15	0.10
LNvar	-0.36	-0.07	-0.52	-0.30
Milk	-0.12	-0.06	-0.25	-0.02

Elgersma et al. 2018. J. Dairy Sci. 101:1240–1250

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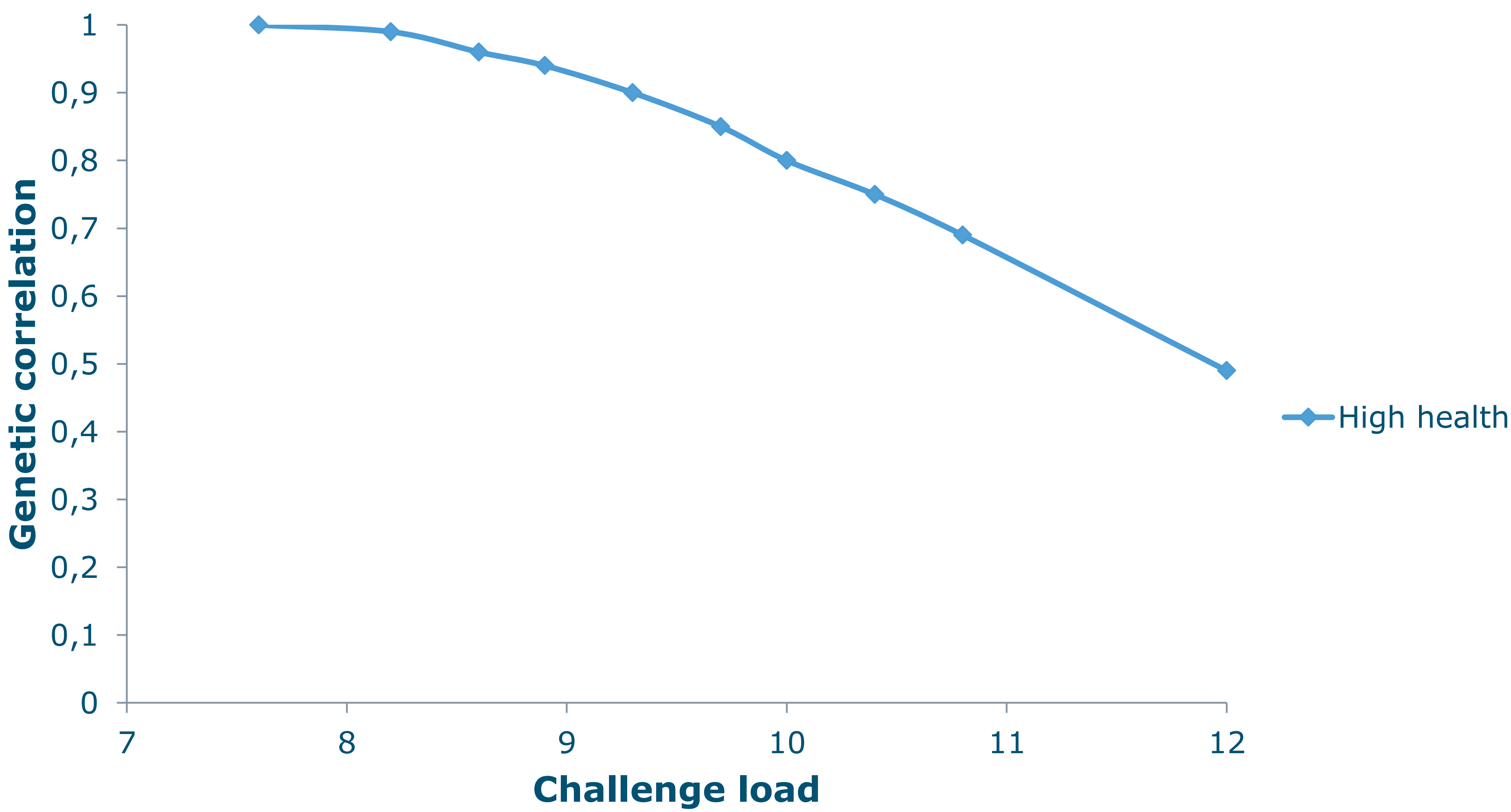
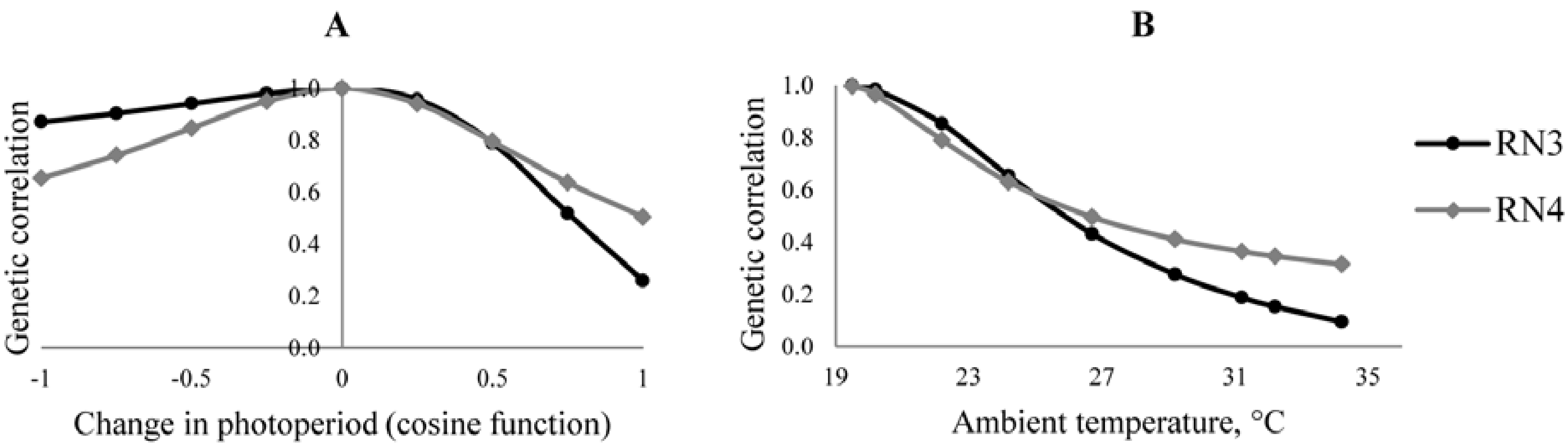
Genetic variance in slope of reaction norm = GxE between environments



Herrero-Medrano et al., 2015. J. Anim. Sci. 93:1494-1502

Multi-dimensional reaction norm

- Sows show lower farrowing rate when inseminated in summer



- Correlation slopes temperature/photoperiod: ~0.6

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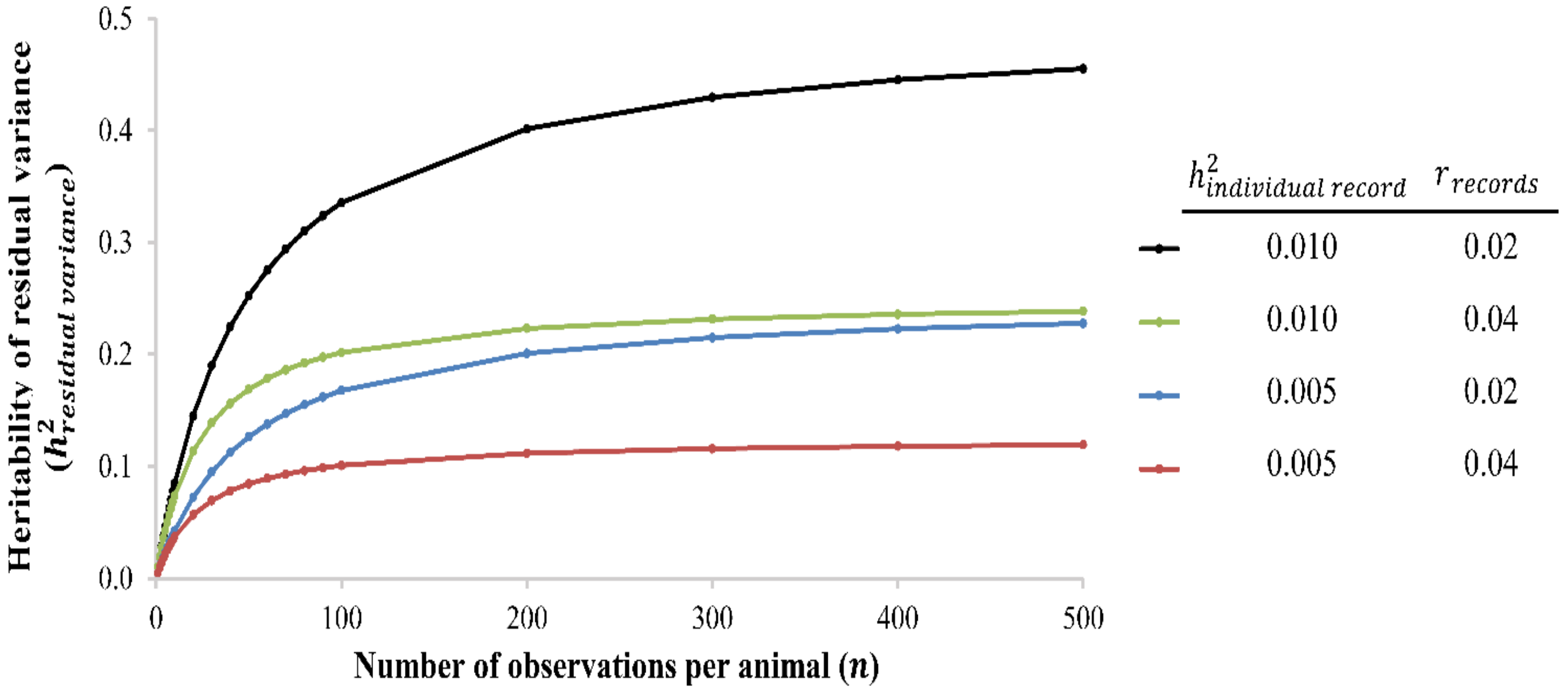
100years 1918 — 2018

Sevillano et al., 2016. J. Anim. Sci. 94:3185-3197

Opportunities

- Variance has low heritability on individual record level, but reasonable heritability with longitudinal profiles



Berghof et al. 2018; submitted

Challenges

- What is the best way of fitting the curve to get residuals?
  - See Poppe et al.
  - See Berghof et al.
- Golden standard
  - What is a truly resilient animal?
  - Validations needed

Comparison of resilience indicators

- Variance of deviations
  - Heritable
  - Need large numbers of records per individual
  - Captures both whole-farm disturbances and within-individual disturbances

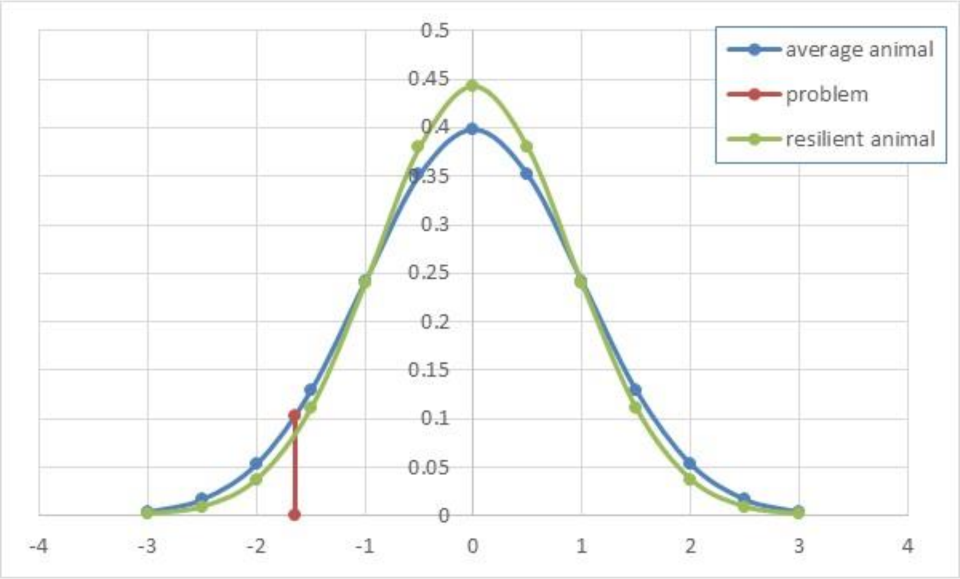
- Slope of reaction norm
  - Heritable, related to GxE
  - Need for covariate(s)
  - Captures only whole-farm disturbances

Define economic value for resilience

Resilience is related to labour

- With attention lists based on sensors, feed intake, activity, etc., or human eye
- Animals that are more resilient, have less attentions, less labour

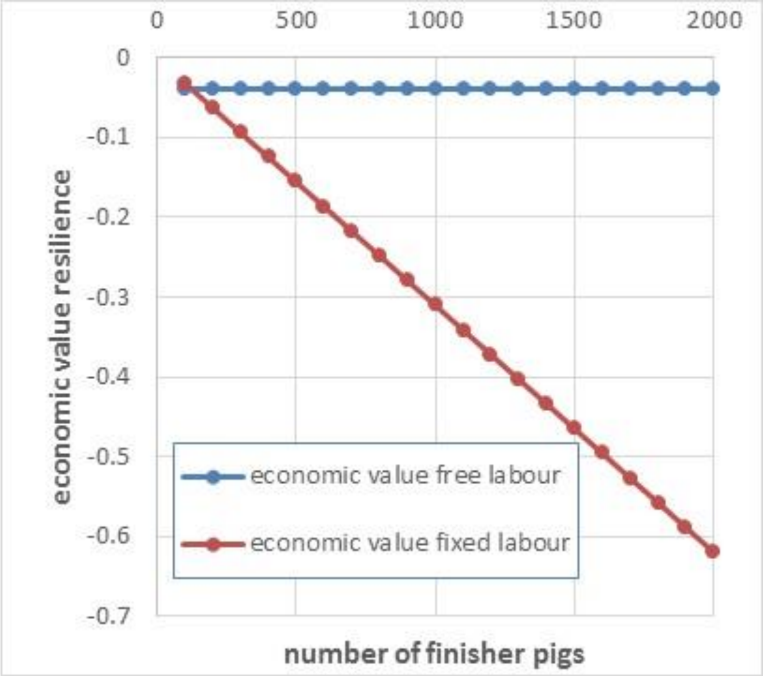
- Economic values derived
  - Free labour
  - Fixed labour



Berghof et al. 2018; submitted
Mulder et al. 2008; GSE 40:37-59

Economic value resilience

- 1% cut-off for attentions
- Each attention = 5 minutes work
- Labour cost = 15 euro/hour
- Profit per pig = 1 euro
- 8 hours/day labour available



- Economic value increases with farm size (absolute value)

Berghof et al. 2018; submitted

Benefits of resilience in breeding programs

Two breeding programs (pigs)

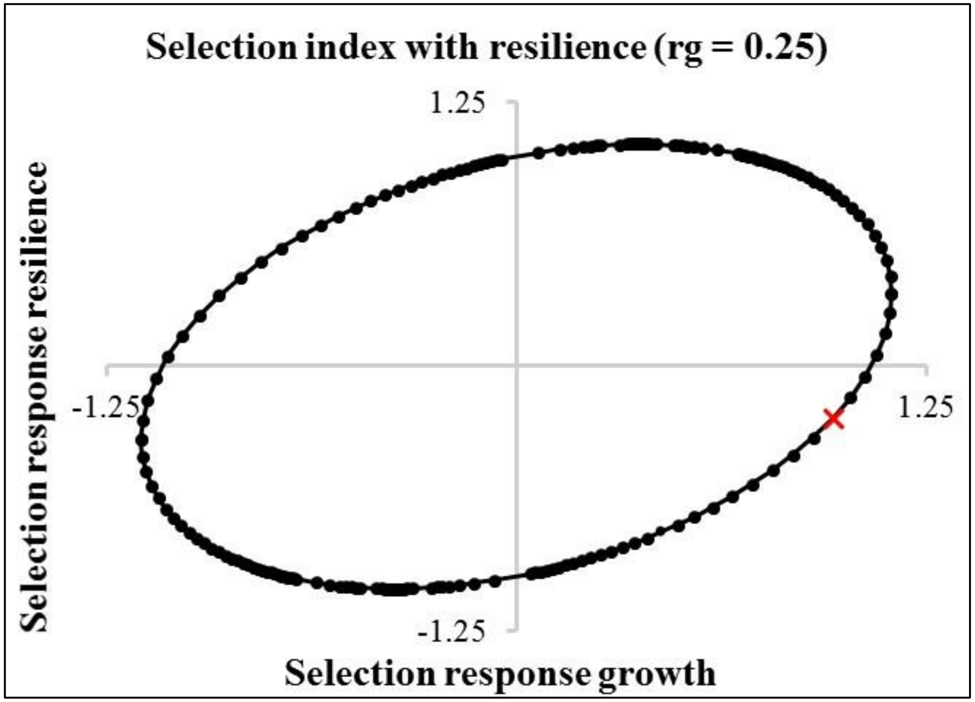
- Pig breeding example (sire line)
    - Breeding goal
        - Growth
        - Lower variance (= higher resilience)
    - Own performance, full and half-sibs, pedigree information and genomics

Berghof et al. 2018; submitted

Two breeding programs (dairy cattle)

- Dairy cattle example
  - Breeding goal:
    - Milk yield (30%)
    - Udder health (20%),
    - Longevity (30%)
    - Lower variance (= higher resilience) (20%)
  - Pedigree information and genomics

Pig breeding example



Trait	Change when including resilience in index
Growth	-15.4%
Resilience	-185.3%
% alerts	-24.7%

Substantial improvement possible without large loss in response in finisher traits

Berghof et al. 2018; submitted

Dairy cattle example

Trait	Change when including resilience in index
Milk production	−6.3%
Longevity	1.4%
Udder health	1.0%
Resilience	102.6%
Breeding goal (H)	3.0%
Alert probability	−8.4%

Berghof et al. 2018; submitted

Take-home message

- Resilience indicators based on deviations are promising
- Slopes of reaction norms capture variation in response to whole-farm disturbances
- Economic value of resilience increases when farm size increases
- Including resilience in breeding programs helps breeding trouble-free animals using genomics and big data

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WILEY Journal of Animal Breeding and Genetics

EDITORIAL

Is GxE a burden or a blessing? Opportunities for genomic selection and big data

Genomic selection and genomic prediction have been widely adopted in many livestock breeding programmes, including some fish schemes. Genomic prediction increases the accuracy of breeding values, especially for lowly heritable traits and traits that are difficult to measure. Genotype-by-environment interaction (GxE) is often seen as a *burden*

When the reference populations of cross-bred animals are made of animals raised in a wide range of environments, genomic selection for improved cross-bred performance is more efficient than with traditional selection relying on pedigree information. Such multi-environment reference populations could be easily combined with

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