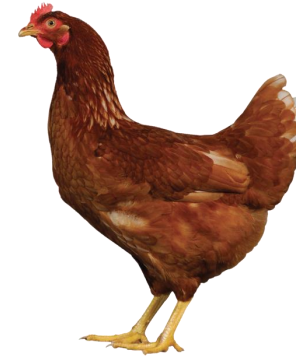


➤ No G×E on egg qualities and body weight between cage and floor systems, implications for breeding programmes in laying hens.



@Big Dutchman



@Novogen



@Big Dutchman

**N. Bédère<sup>1</sup>, L. Bécot<sup>1,2</sup>, T. Burlot<sup>2</sup> and P. Le Roy<sup>1</sup>**

## ➤ Are there important GxE between cage and cage-free systems?

- Many commercial settings, examples of major systems:



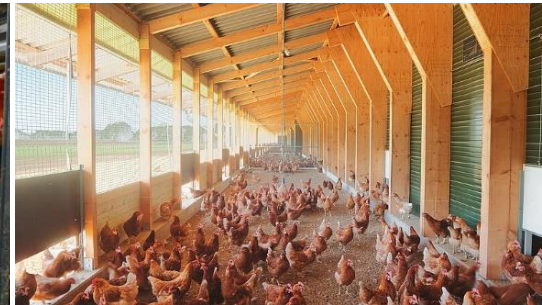
@Big Dutchman



@Big Dutchman



@Nicolas Goualan



@Big Dutchman



@Novogen

- Some regions are moving away from cage systems rapidly (E.U. hens in cage-free systems: 30% in 2009 → 52 % in 2020).
- Some of the selection criteria (e.g. egg production related traits) are sensitive to GxE (Icken et al., 2008; Mulder, 2017)

Assuming breeding program could look alike,

**Is a breeding program dedicated to cage-free systems needed ?**

# ➤ Is a breeding program dedicated to cage-free systems needed ?



@Novogen

Rhode Island Red  
Nucleus of the breeding company Novogen  
5 batches from 2018 to 2020  
pedigree  $\geq$  5 generations

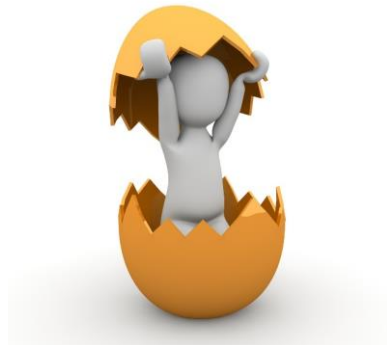
**Collective Cages**  
Of 5 full-sibs  
Hens only  
n = 1,633 cages / batch

**Floor system**  
Individual electronic nest  
Hens and roosters  
n = 365 hens / batch



**Body weight**  
n = 10,266 records

**Egg quality traits**  
Eggshell colour  
Eggshell strength  
Eggshell shape index  
Haugh value  
Egg weight  
n = 18,524 records



## ➤ Is a breeding program dedicated to cage-free systems needed ?

### Bivariate analyses

$$\begin{bmatrix} \text{trait}_{\text{cage}_{ij}} \\ \text{trait}_{\text{floor}_{ij}} \end{bmatrix} = \begin{bmatrix} \mu_{\text{cage}} \\ \mu_{\text{floor}} \end{bmatrix} + \begin{bmatrix} \text{FixedEffects}_{\text{cage}} \\ \text{FixedEffects}_{\text{floor}} \end{bmatrix} + \begin{bmatrix} \mathbf{a}_{\text{cage}_i} \\ \mathbf{a}_{\text{floor}_i} \end{bmatrix} + \begin{bmatrix} e_{\text{cage}_{ij}} \\ e_{\text{floor}_{ij}} \end{bmatrix}$$

where:

$$\begin{bmatrix} \mathbf{a}_{\text{cage}} \\ \mathbf{a}_{\text{floor}} \end{bmatrix} \sim N \left( \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \mathbf{A} \times \begin{bmatrix} \sigma_{\mathbf{a}_{\text{cage}}}^2 & \sigma_{\mathbf{a}_{\text{cage}}, \mathbf{a}_{\text{floor}}} \\ \sigma_{\mathbf{a}_{\text{cage}}, \mathbf{a}_{\text{floor}}} & \sigma_{\mathbf{a}_{\text{floor}}}^2 \end{bmatrix} \right) \text{ with } \mathbf{A} \text{ the relationship matrix}$$

And

$$\begin{bmatrix} e_{\text{cage}} \\ e_{\text{floor}} \end{bmatrix} \sim N \left( \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{bmatrix} \mathbf{I}_{\text{cage}} \sigma_{e_{\text{cage}}}^2 & \mathbf{0} \\ \mathbf{0} & \mathbf{I}_{\text{floor}} \sigma_{e_{\text{floor}}}^2 \end{bmatrix} \right) \text{ with } \mathbf{I}_{\text{cage}} \text{ and } \mathbf{I}_{\text{floor}} \text{ identity matrices}$$

## ➤ The traits displayed moderate to high heritabilities

Traits	$h^2_{cage}$	$h^2_{floor}$
Eggshell colour	0.55 (0.03)	0.74 (0.02)
Eggshell strength	0.33 (0.02)	0.31 (0.04)
Eggshell shape index	0.47 (0.03)	0.58 (0.03)
Haugh value	0.29 (0.02)	0.45 (0.03)
Egg weight	0.62 (0.03)	0.77 (0.01)
Body weight	0.61 (0.02)	0.50 (0.01)

- Moderate to high heritabilities consistent with previous studies on the same traits (Beaumont et al., 2010; Mulder et al., 2016; Picard Druet et al., 2020)
- Heritabilities floor  $\geq$  heritabilities cages:
  - $\geq$  additive genetic variances
  - $\leq$  residual variances
  - Bias due to design (repeated measures not accounted for: 2eggs/hen, 88% data from cage)

➤ The traits displayed a very high genetic correlation between the cage and floor systems

Traits	$h^2_{cage}$	$h^2_{floor}$	$r_{(cage,floor)}$
Eggshell colour	0.55 (0.03)	0.74 (0.02)	0.79 (0.05)
Eggshell strength	0.33 (0.02)	0.31 (0.04)	0.93 (0.05)
Eggshell shape index	0.47 (0.03)	0.58 (0.03)	0.92 (0.04)
Haugh value	0.29 (0.02)	0.45 (0.03)	0.96 (0.04)
Egg weight	0.62 (0.03)	0.77 (0.01)	0.93 (0.03)
Body weight	0.61 (0.02)	0.50 (0.01)	0.87 (0.04)

It is often admitted that when a genetic correlation between two traits is higher than 0.80, these two traits are genetically similar enough to consider only one of them in the breeding program.

But, none of the genetic correlation are 1.00

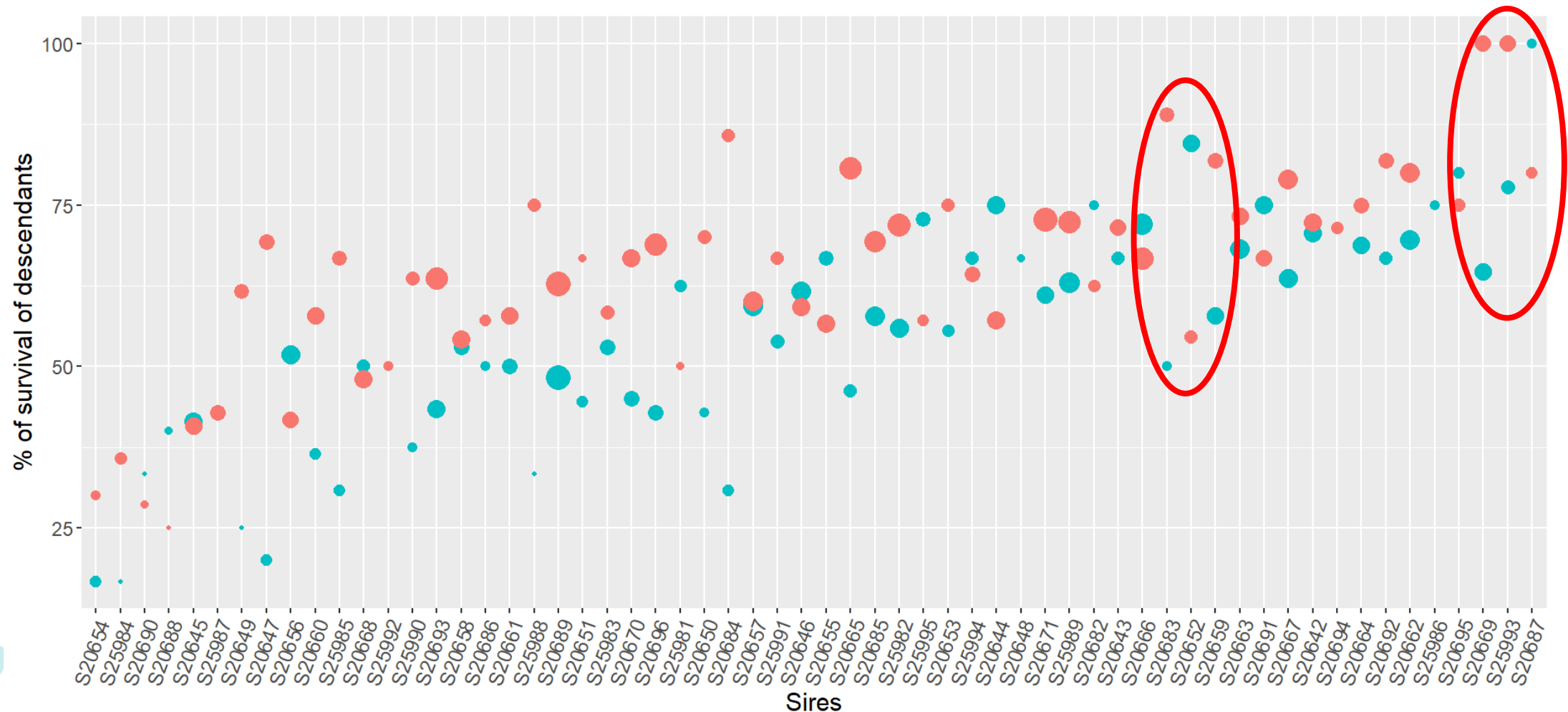
Re-ranking may still occur and influence the choice of selection candidate.



## ➤ Example of GxE evidence despite a high genetic correlation

Besson et al. (WCGAL 22): Selective breeding for survival to *Vibrio harveyi* in European seabass is robust to different diets

$$r_{(\text{plant-based diet}, \text{fish-based diet})} = 0.88$$



# ➤ Is a breeding program dedicated to cage-free systems needed ?

## Random regression analyses

Let's assume the farming system can be scored on a continuous scale of environmental gradient, with 0.00 as the cage system and 1.00 as the floor system. Then, the trait can be studied as:

$$trait_{ij} = \mu + FixedEffects + \beta_1 x_{ij} + \mathbf{a}_{int_i} + \mathbf{a}_{slp_i} x_{ij} + e_{ij}$$

Genetic for the level      Genetic sensitivity to environmental gradient

where:

$$\begin{bmatrix} \mathbf{a}_{int} \\ \mathbf{a}_{slp} \end{bmatrix} \sim N \left( \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \mathbf{A} \times \begin{bmatrix} \sigma_{a_{int}}^2 & \sigma_{a_{int}, a_{slp}} \\ \sigma_{a_{int}, a_{slp}} & \sigma_{a_{slp}}^2 \end{bmatrix} \right) \text{ with } \mathbf{A} \text{ the relationship matrix}$$

And

➔ We can calculate a correlation between the two genetic effects

$$\begin{bmatrix} \mathbf{e}_{cage} \\ \mathbf{e}_{floor} \end{bmatrix} \sim N \left( \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{bmatrix} \mathbf{I}_{cage} \sigma_{e_{cage}}^2 & 0 \\ 0 & \mathbf{I}_{floor} \sigma_{e_{floor}}^2 \end{bmatrix} \right) \text{ with } \mathbf{I}_{cage} \text{ and } \mathbf{I}_{floor} \text{ identity matrices}$$





## ➤ Is a breeding program dedicated to cage-free systems needed ?

### Random regression analyses

How can we interpret the genetic correlation between the intercept and the mean of a random regression?

$$r(int,slp) = \frac{\sigma_{a_{int}, a_{slp}}}{\sqrt{\sigma_{a_{int}}^2 \times \sigma_{a_{slope}}^2}}$$

$r(int,slp) \geq 0$ : animals with high breeding values in the reference environment are more sensitive

$r(int,slp) \leq 0$ : animals with high breeding values in the reference environment are less sensitive

*/!\ with quite some “if”, please check Falconer’s theories for details*

- The traits displayed a very either insignificant or not important genetic correlation between the level and the sensitivity.

Traits	$h_{cage}^2$	$h_{floor}^2$	$r_{(cage,floor)}$	$r_{(int,slp)}$
Eggshell colour	0.55 (0.03)	0.74 (0.02)	0.79 (0.05)	-0.03 (0.09)
Eggshell strength	0.33 (0.02)	0.31 (0.04)	0.93 (0.05)	0.15 (0.23)
Eggshell shape index	0.47 (0.03)	0.58 (0.03)	0.92 (0.04)	0.19 (0.18)
Haugh value	0.29 (0.02)	0.45 (0.03)	0.96 (0.04)	0.04 (0.26)
Egg weight	0.62 (0.03)	0.77 (0.01)	0.93 (0.03)	0.27 (0.13)
Body weight	0.61 (0.02)	0.50 (0.01)	0.87 (0.04)	-0.69 (0.08)

Not different than 0  
➔ no genetic sensitivity

- For Egg weight, the higher the BV for level, the higher the genetic sensitivity... BUT: the breeding goal is not to increase egg weight but to keep it within a range
- The opposite is found for body weight... BUT again, the breeding goal is not to increase body weight but to keep it within a range



- We found no evidence of G×E on egg qualities and body weight between cage and floor systems

What are the implications for breeding companies?

**There is no need to maintain a breeding program per system...**

Remember, other major traits are known to be under the influence of G×E in laying hens (e.g. egg number...).

**...if the breeding goals are truly the same between the two systems, which is unlikely (e.g. behaviour)**



INRAE

➤ Thank you for listening, any question?

or via [nicolas.bedere@inrae.fr](mailto:nicolas.bedere@inrae.fr)

