HenTrack

Improving breeding programs with superior behavior and welfare phenotypes

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#293: A genome-wide association study to identify novel genomic regions associated for aviary with winter garden usage by laying hens

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Poultry Science

Volume 103, Issue 3, March 2024, 103369

Genetic parameter estimates for the use of an aviary with winter garden by laying hens

Bayode O. Makanjuola *, Sabine G. Gebhardt-Henrich †, Michael J. Toscano †, Christine F. Baes * ‡

https://doi.org/10.1016/j.psj.2023.103369

Breeding for cage-free housing

Current methods are based on small groups/individuals

Behavioral Structure (Individual profiles)

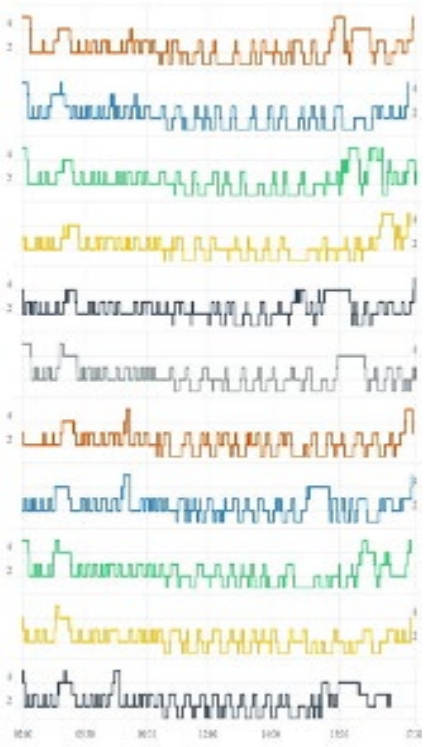
Zone 5: Highest Tier
Feed, water, perches
Nighttime roosting

Zone 4: Middle Tier
Nestboxes, perches

Zone 3: Lowest Tier
Feed, water, perches

Zone 2: Floor
Litter

Zone 1: Wintergarden
Litter, Water, perches



Article | Open Access | Published: 17 August 2018

Finding hens in a haystack: Consistency of movement patterns within and across individual laying hens maintained in large groups

C. Rufener, I. Berezowski, F. Maximiano Sousa, Y. Abreu, L. Asher & M. J. Toscano

Scientific Reports 8, Article number: 12303 (2018) | Cite this article

HenTrack Aims

- To provide methodologies for the phenotyping and selection of individual laying hens that perform robustly within cage-free housing systems

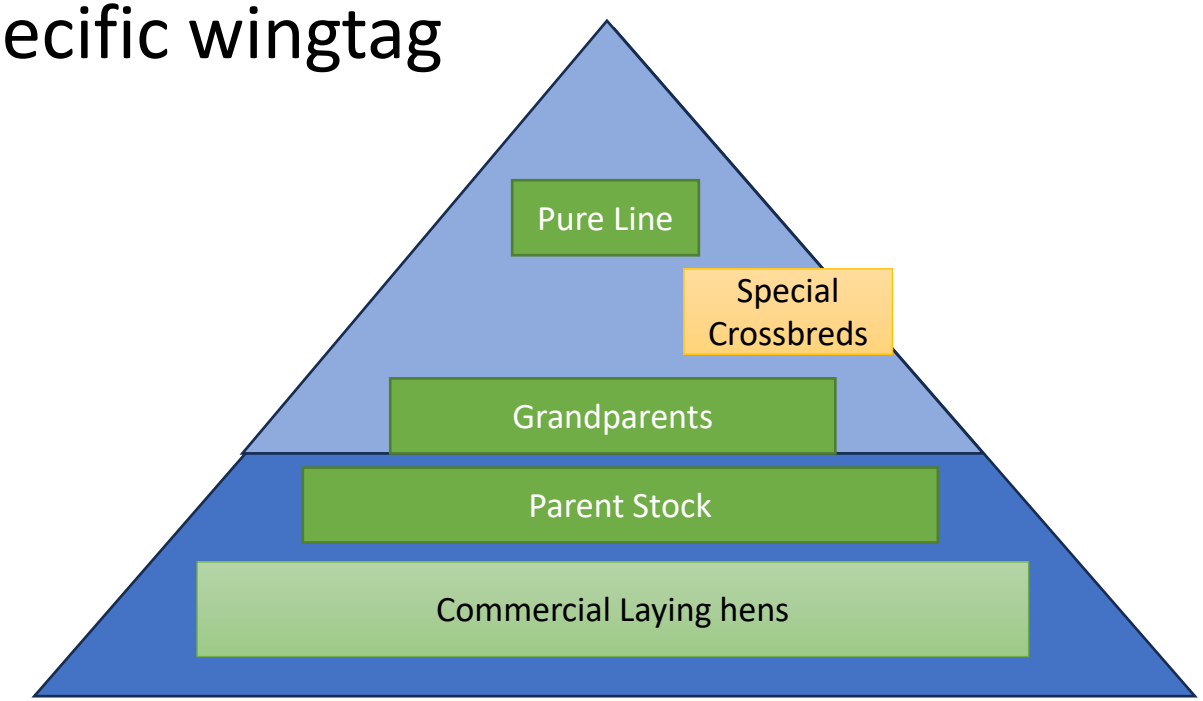
- Partnered with
  - Lohmann Breeders
  - Hendrix Genetics

HenTrack
research driving impact

Methods

4800 hen chicks reared on site (per flock)

- Pure Line matings
- Full and half sibs with sire-specific wingtag
- Hendrix and Lohmann



Methods

Sires

1	2	3	. . . .	25
Hen1.1	Hen2.1	Hen3.1		Hen25.1
Hen1.2	Hen2.2	Hen3.2		Hen25.2
Hen1.3	Hen2.3	Hen3.3		Hen25.3
Hen1.4	Hen2.4	Hen3.4		Hen25.4
Hen1.5	Hen2.5	Hen3.5		Hen25.5
Hen1.6	Hen2.6	Hen3.6		Hen25.6
Hen1.7	Hen2.7	Hen3.7		Hen25.7
Hen1.8	Hen2.8	Hen3.8		Hen25.8
Hen1.9	Hen2.9	Hen3.9		Hen25.9

X 5 pens/cross

10 Lohmann pens
10 Hendrix pens

3 flocks

Housing and Tracking

- Tracked for entire laying period
  - 85-95 WOA
  - Now testing in rear as well
- Entry/exit into each area for each hen
  - Upper tier
  - Middle tier
  - Lower tier
  - Floor
  - Wintergarden
- Health assessments
  - Keel bone fracture (30-45 WoA)
  - Feather quality/Toe&foot health (50-70 WoA)

Results so far . . . . Durations

σ^2_e	σ^2_a	Σ^2_{pe}	h^2 (%)	Re
40,901.3	5,779.5	13,867.1	9.5 (1.7)	32.4 (1.0)
292.8	42.5	36.4	11.4 (1.4)	21.2 (0.9)
29,034.0	1,919.5	5,308.1	5.2 (1.0)	19.9 (0.7)
5,805.7	3,402.5	3,151.0	27.5 (3.2)	53.0 (1.3)
722.3	103.1	235.3	9.7 (1.8)	31.9 (1.0)

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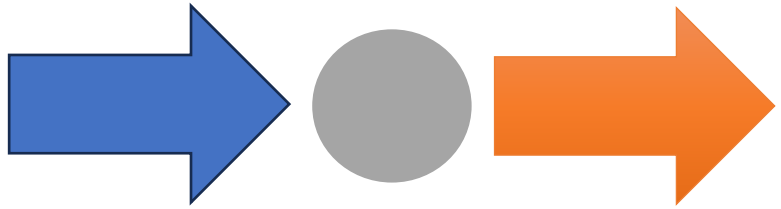
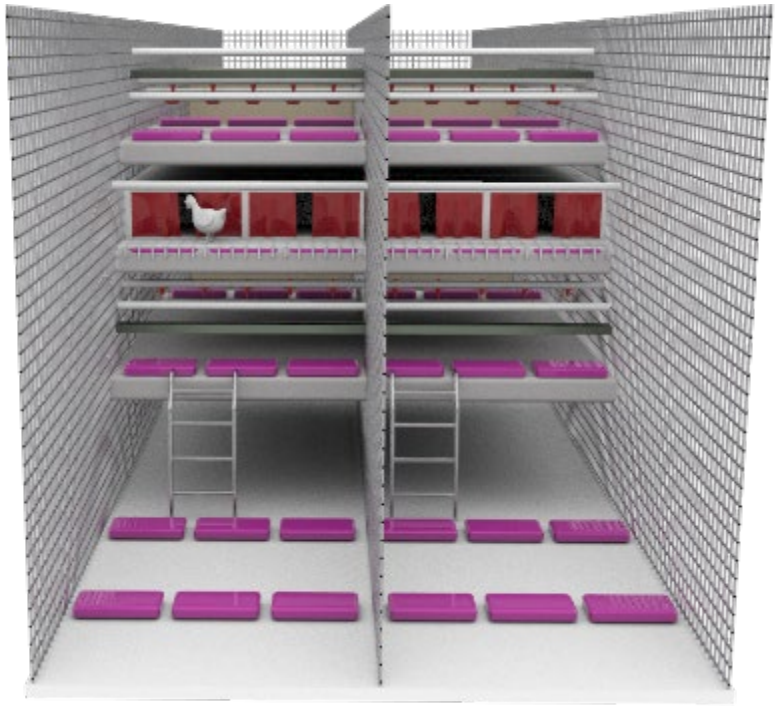
Better metrics with sensor technology

- Egg size, body mass, ... Movement predictability?
- Far greater resolution and detail
- Proxies when direct measures are not possible
  - Disturbing birds with invasive procedure (bone fracture)
  - Difficulties to see (feeding)
- Indicators of:
  - Disease/injury/poor welfare
  - Style/ability to recover

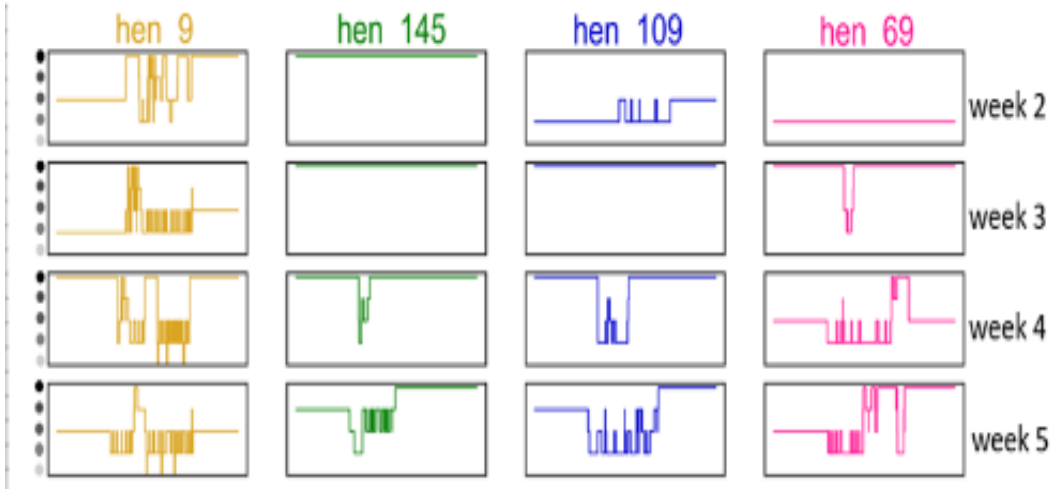


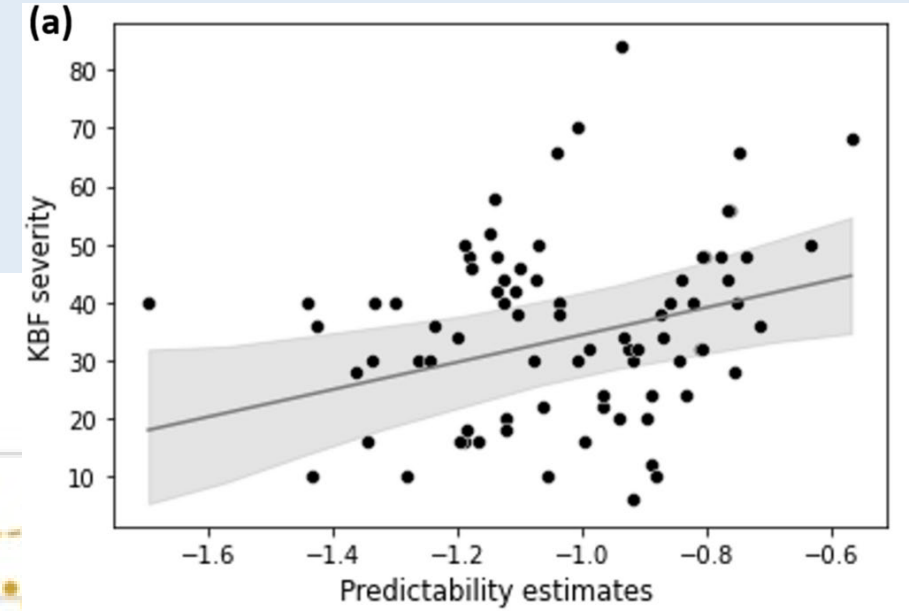
New Phenotypes

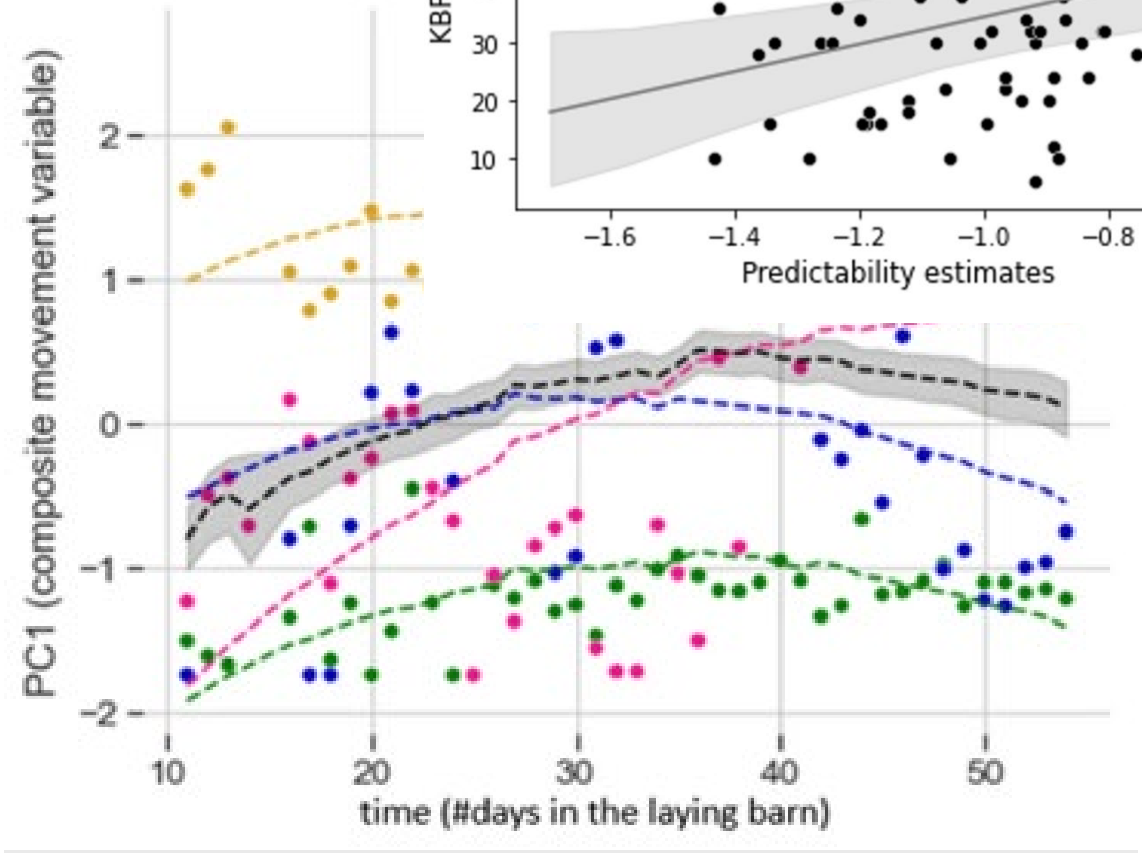


Antennae/Zone
Time/Date

Metrics of variation







Daily (movement)

- Duration in each zone
- Transitions in each zone
- Vertical distance per hour
- Wintergarden use (0-15 min)
- Sleeping position

Montalcini, C.M., *et al.* Intra-individual variation . . . *Sci Rep* **13**, 2377 (2023).
https://doi.org/10.1038/s41598-023-29587-9

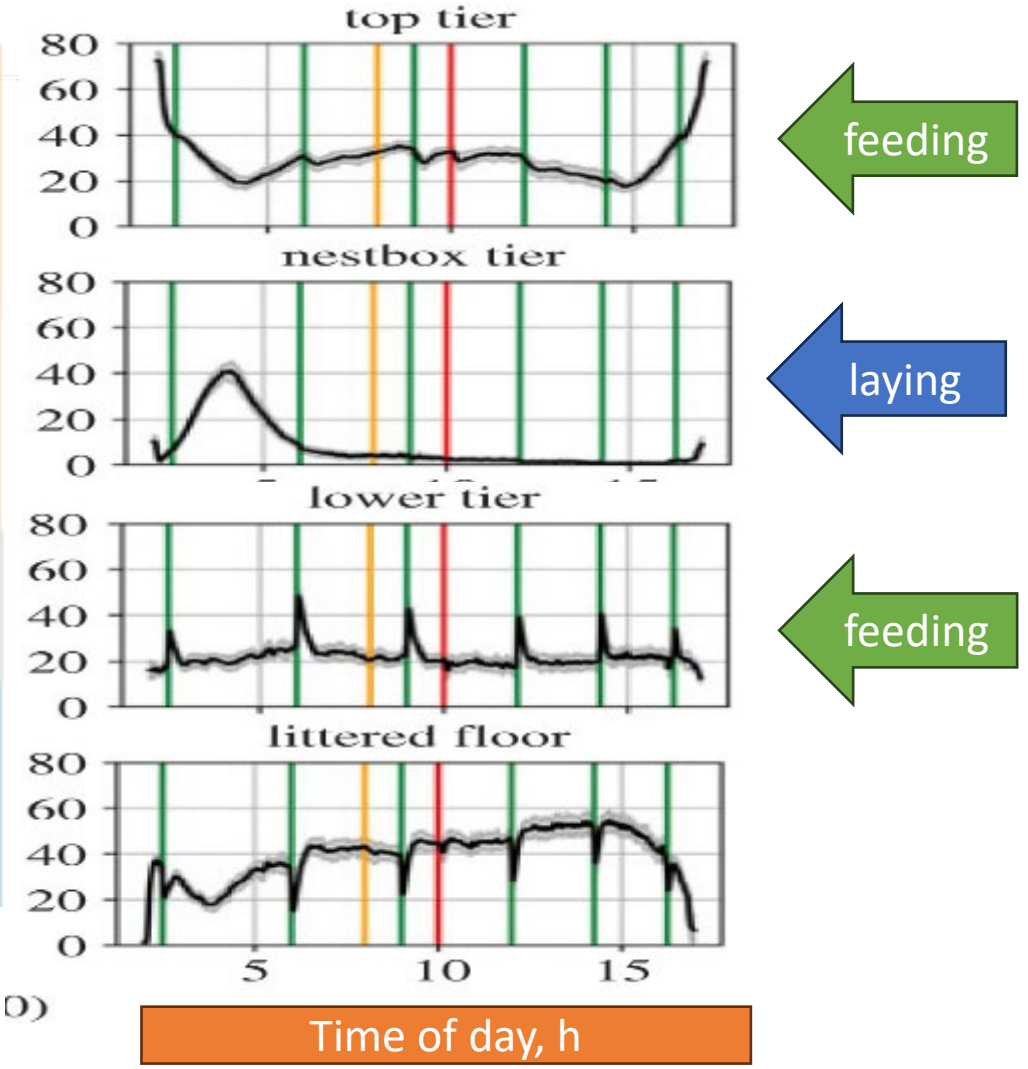
New phenotypes – Proxies

Zone 5: Highest Tier
Feed, water, perches
Nighttime roosting

Zone 4: Middle Tier
Nestboxes, perches

Zone 3: Lowest Tier
Feed, water, perches

Zone 2: Floor
Litter

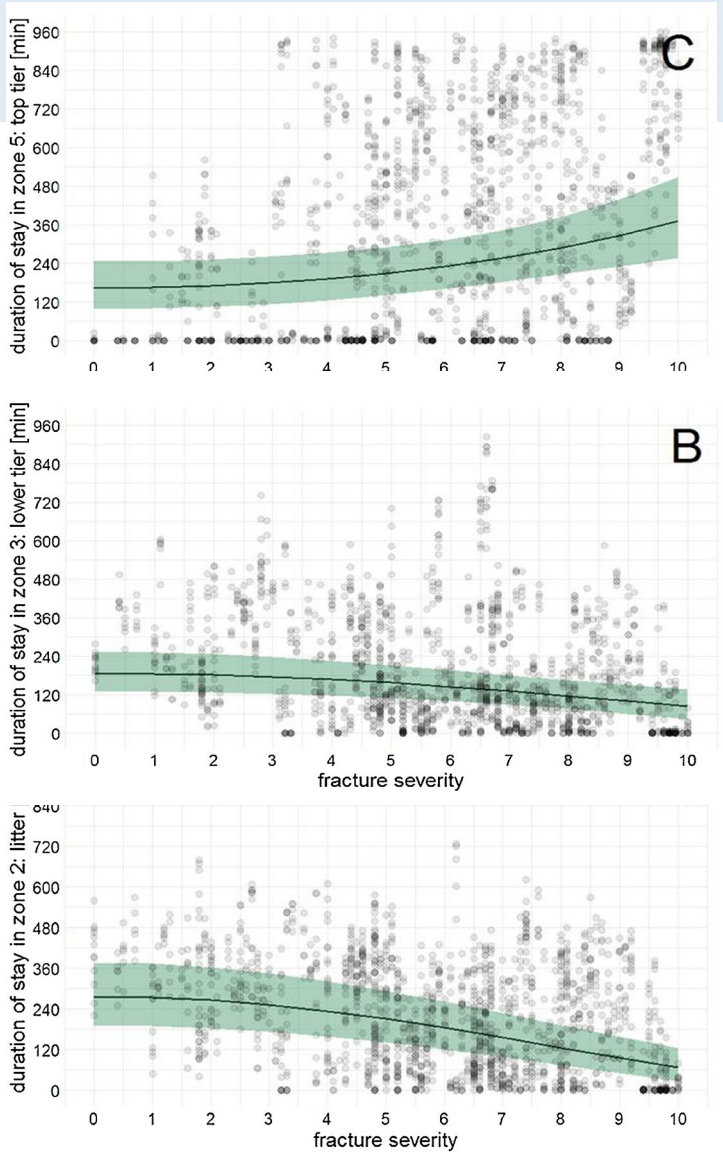


feeding

laying

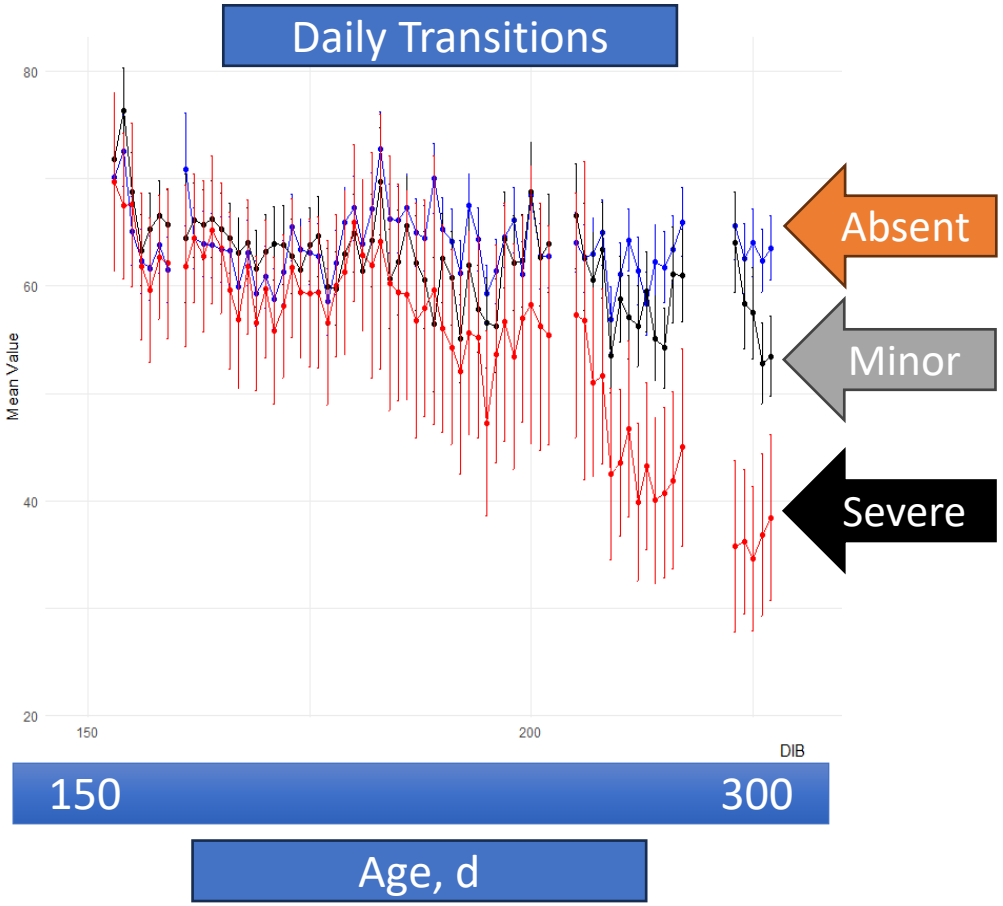
feeding

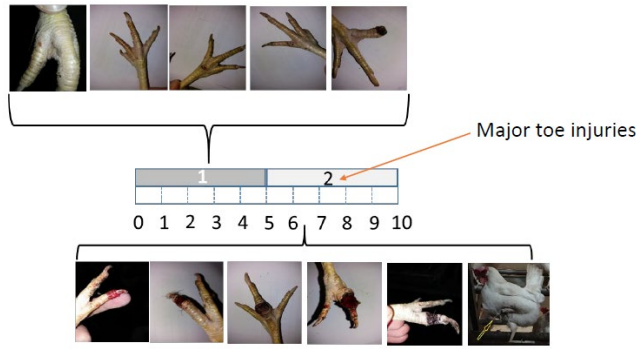
Refuges as phenotypes

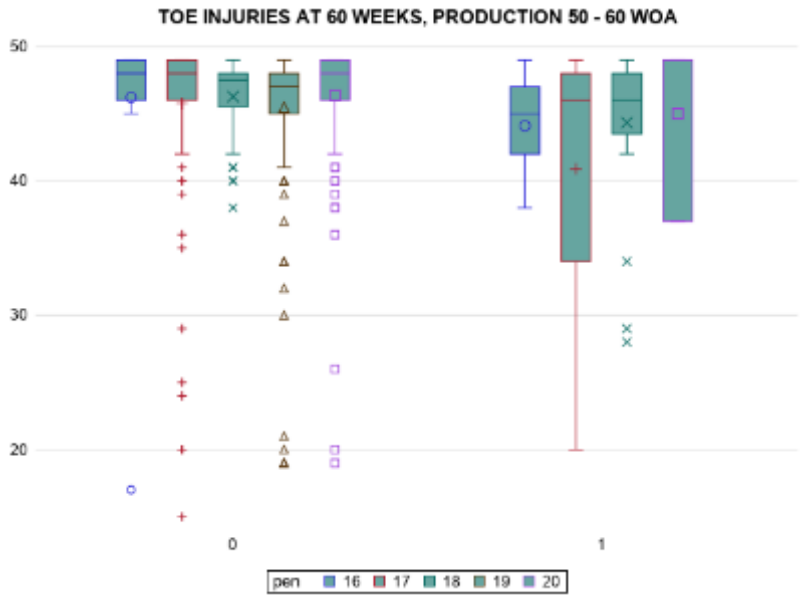


Rufener et al., 2019. https://doi.org/10.1016/j.applanim.2019.05.007

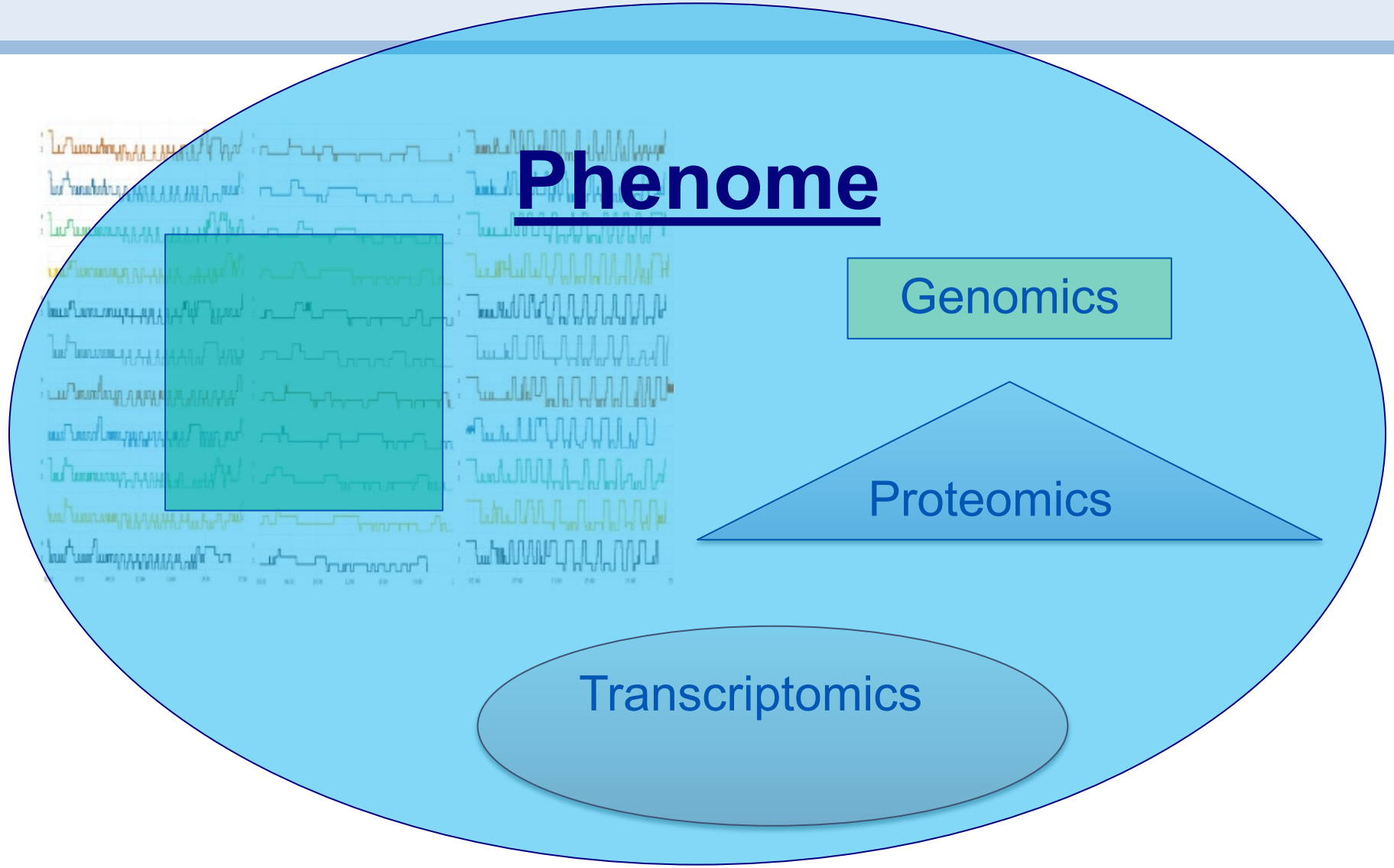
Toe injuries:
Movement & Egg production (proxy)







A important part of the phenome



Questions?

Research Aims (Long term)

- To investigate movement and location patterns of individual hens within commercially –relevant, cage-free housing
- Explore factors that control the observed variation
  - Rearing and development
  - Environmental factors, e.g. housing type
  - Genetic and epigenetic
  - Disease states
- Implications for animal welfare
  - Resilience and recovery
  - Positive and negative affect

Specific Project Objectives

- Establish heritability of basic movement metrics
- *Explore relationships between movement and health characterizations*

Methods

Laying phase

- 1,124 pullets from 25 of the 100 sires selected for observation
  - Variation in feed efficiency and feather coverage
- Fitted with Radio Frequency Identification transponder leg ring (125 kHz)
- Allocated to five pens of 225 birds
- Stratified for sire and rearing pen
- Tracked until 61 WoA

Methods

Sires

1	2	3	. . . .	25
Hen1.1	Hen2.1	Hen3.1		Hen25.1
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X 5 pens

Analysis

- Multivariate mixed model using repeated records to estimate genetic parameters for zone duration
- Best linear unbiased prediction (**BLUP**; Henderson, 1975) to derive the genomic relationship matrix
  - genomic best linear unbiased prediction (**GBLUP**) VanRaden (2008).
  - performed using the restricted maximum likelihood method in ASReml 4.1. (Gilmour et al., 2015)

Multivariate mixed model

$$\boldsymbol{y} = \boldsymbol{Xb} + \boldsymbol{Za} + \boldsymbol{Wpe} + \boldsymbol{e}$$

- *y:* vector of the five measured traits (duration in each zones) (within hens)
- *b:* vector of fixed effects
  - overall mean
  - days since transfer
  - pen
  - number of visits to the zone
- *a:* vector of random additive genetic effect
- *pe:* vector of random permanent environment effect
- *e:* random error term
- *X, Z,* and *W:* incidence matrices relating the fixed effects, random genetic effect and random permanent environment effect to the phenotype

Going forward . . . .

- Bigger
- Better
- Cooler

New PhD opportunity

- Tracking in rearing and continuing into lay
- Development of novel phenotypes
  - Egg laying
  - Feeding response
  - Wintergarden usage

Many thanks

All ZTHZ, past and present

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  - The Open Philanthropy Project
  - Egg Industry Center
  - Hendrix Genetics

Extras

Theory to practice

Small groups (5-120+ hens / group)

- Adaptable pens
- Focused observations

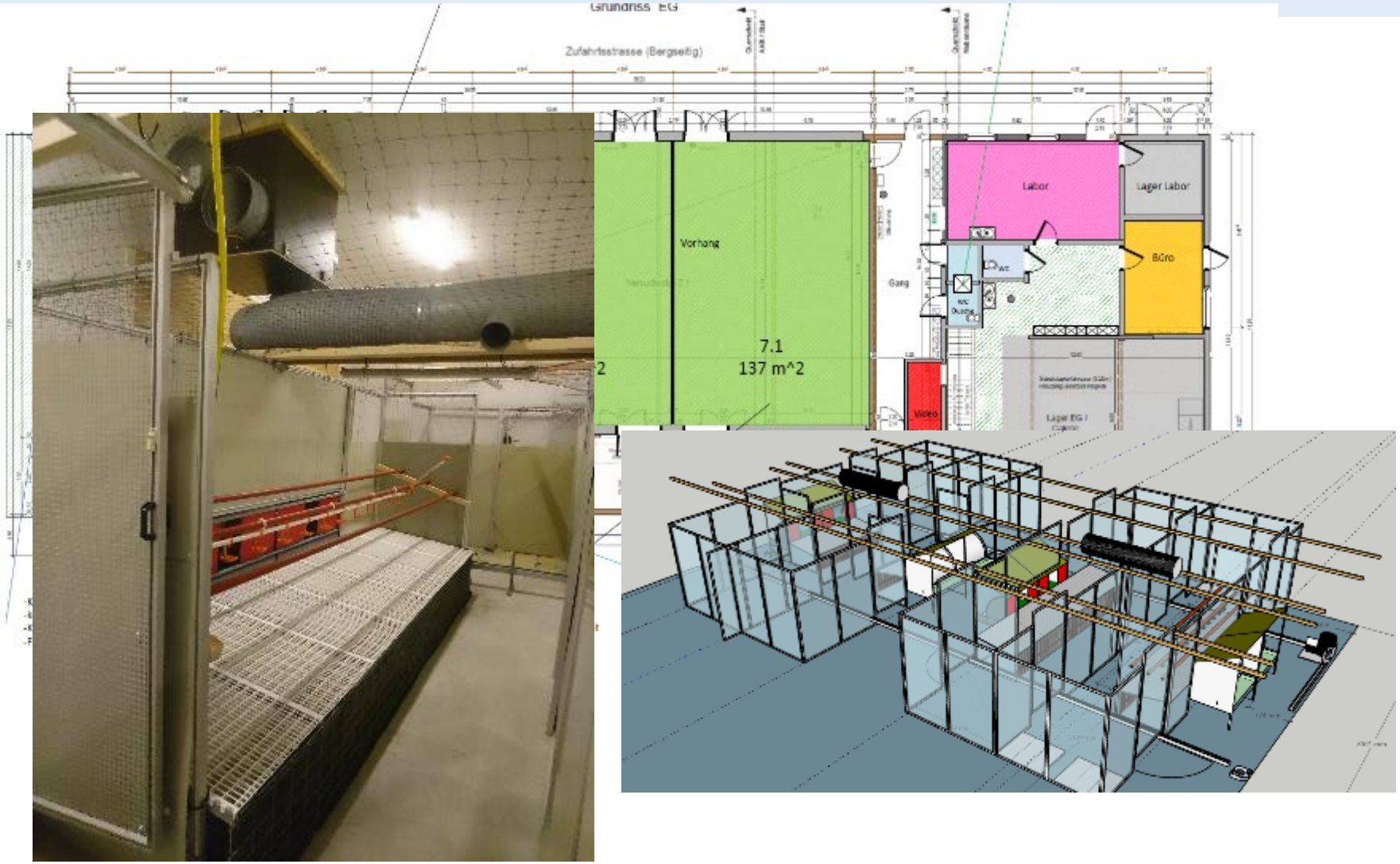
Medium sized groups (200- 360 hens / group)

- Commercially relevant
- Focused observations
- Control over conditions

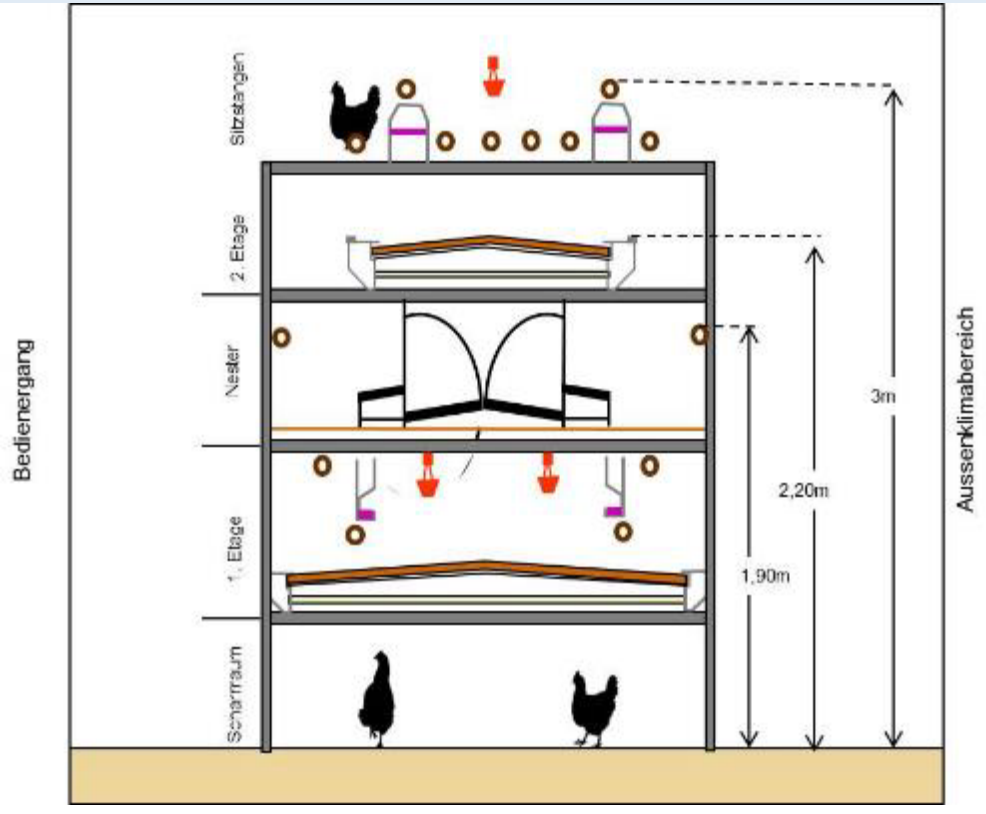
Commercial barns (2000+ hens)

- Good producer relationships
- Possibilities for limited observations

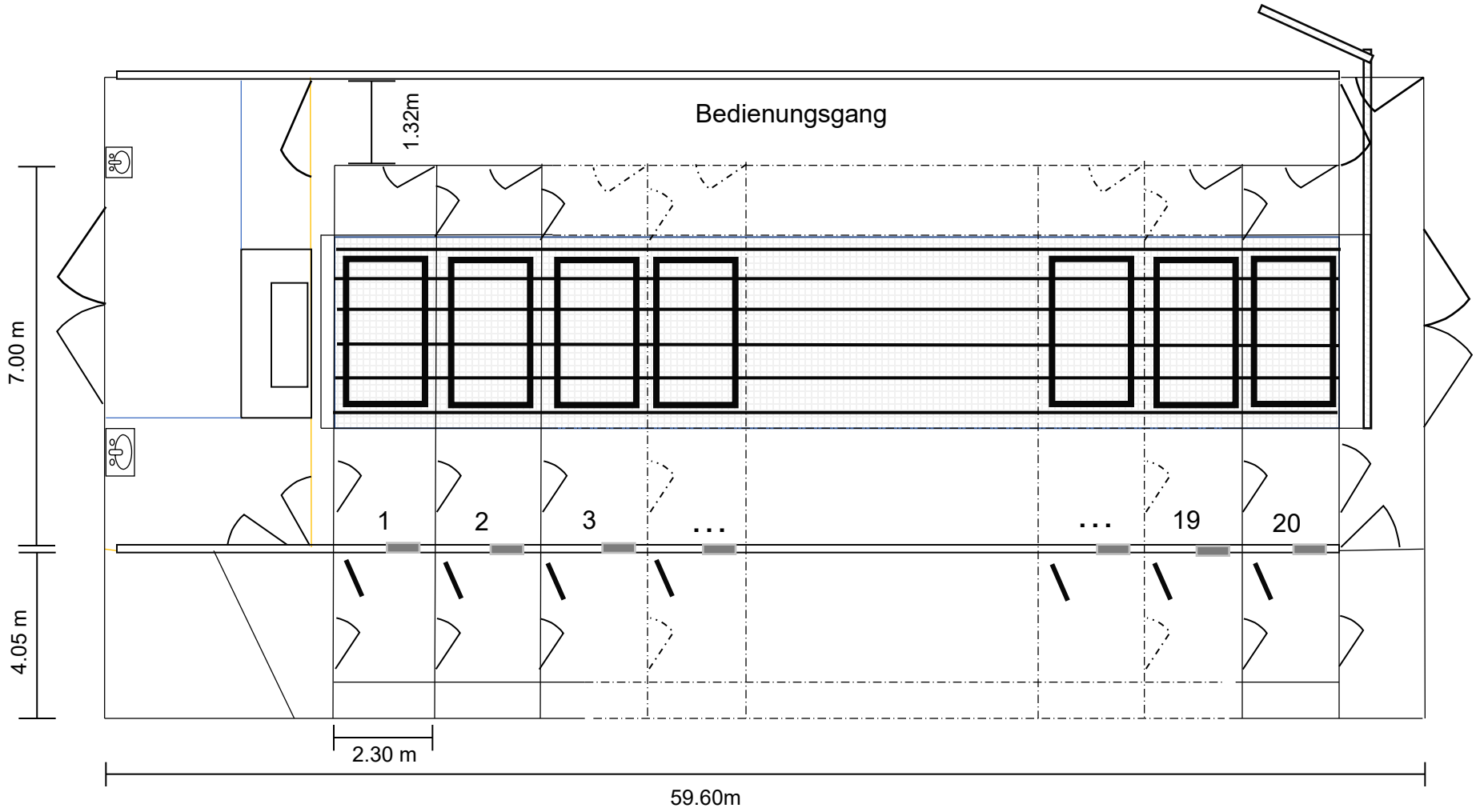
Small groups



Medium sized groups



Replicate pens (200-225 hen/pen)



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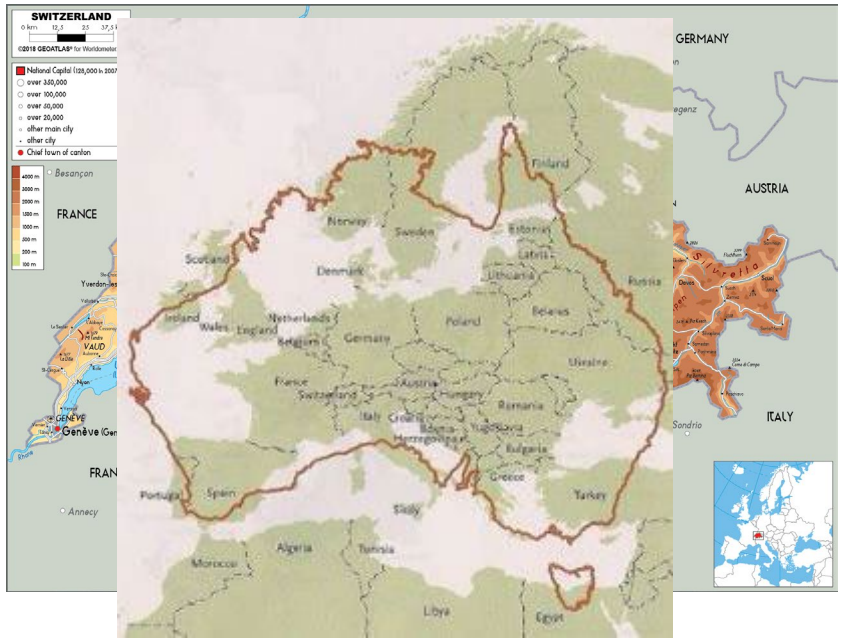
Commercial farms

Good relationships with producers (12-30 farms)

- Depopulation
- Piling
- Toe Pecking



Multiple projects, larger datasets

HenTrack

- 4,500 hens
- Continuous tracking
- 420+ days

Quantifying variation seen

An unending task

Matt Petelle

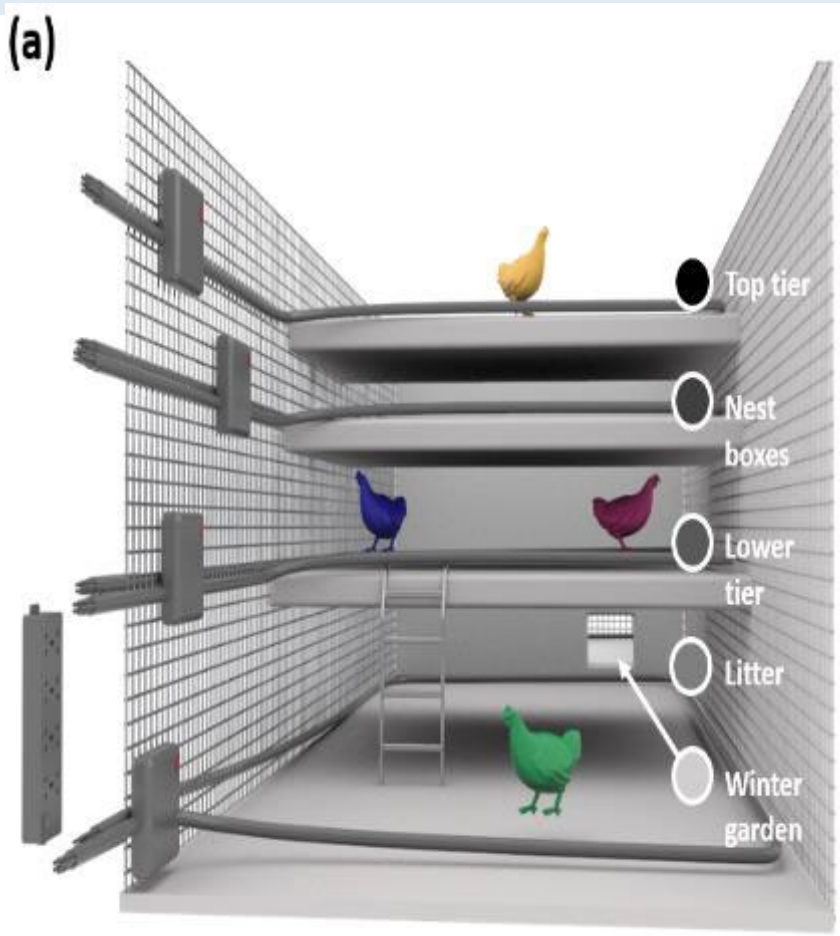
Camille Montalcini

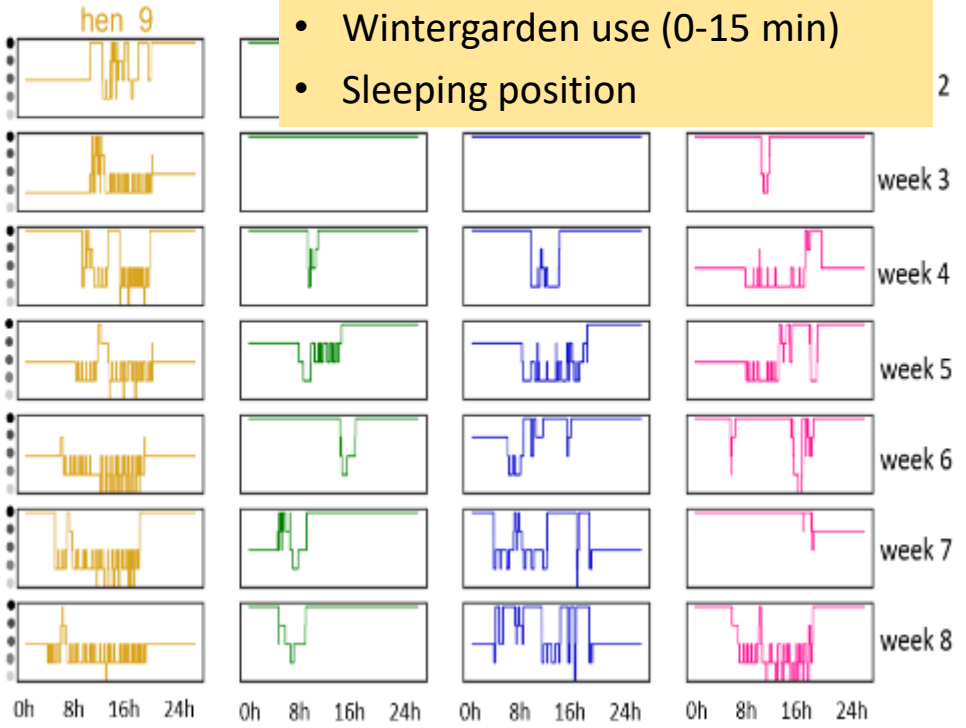
https://doi.org/10.1098/rsos.230043, https://doi.org/10.1038/s41598-023-29587-9

Methods

- 80 hens tracked continuously
- 54 days following transfer to the laying barn
- Bolegg Terrace aviary
- Low-power, active tracking system
  - Gantner Solutions GmbH, Schruns, Austria
  - Transponders in backpacks

Principal Component Movement





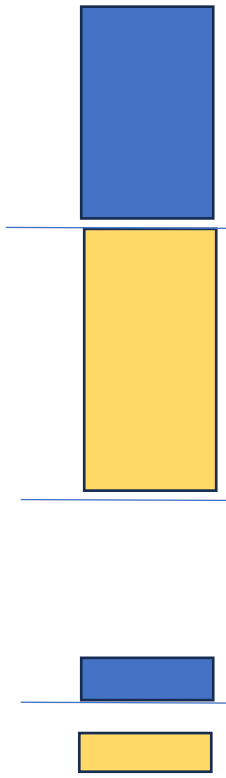
Daily

- Duration in each zone
- Transitions in each zone
- Vertical distance per hour
- Wintergarden use (0-15 min)
- Sleeping position

Methods

- Aggregated daily variables by extracting a linear composite variable from a correlation-based principal component analysis (PCA) using the psych package in R
- Included first day only of each week to account for isolated missing data points
- Observations projected onto the subspace spanned by PC1 to obtain daily movement scores for each hen
  - Average
  - Plasticity
  - Intra-individual variation

Principal Component (Movement)



	PC1	PC2	PC3
daily percentage of duration in the top tier	**-0.90**	0.08	0.29
daily percentage of duration in the nestbox tier	0.16	**0.67**	-0.02
daily percentage of duration in the lower tier	**0.73**	-0.17	-0.36
daily percentage of duration in the litter floor	**0.75**	-0.25	-0.36
number of stays in the top tier /h	0.10	**0.81**	0.32
number of stays in the nestbox tier /h	0.33	**0.88**	0.19
number of stays in the lower tier /h	**0.92**	0.20	-0.16
number of stays in the litter floor /h	**0.93**	-0.20	-0.02
sleeping height	-0.31	0.11	0.30
vertical travelled distance /h	**0.83**	**0.48**	-0.02
daily percentage of duration in the winter garden	**0.48**	-0.32	**0.70**
Number of stays in the winter garden /h	**0.57**	-0.32	**0.65**
went in the winter garden (yes/no)	**0.46**	-0.27	**0.56**

Methods

Individual-level estimates extracted

- intercept, temporal plasticity, and predictability
- increasing complexity of linear mixed-effects model
  - Slope
  - Intercept
- “best linear unbiased prediction” (BLUPS) to estimate random effects

Predictability: extended the RS2 model to allow estimations of residual intra-individual variation using a double hierarchical model

Results

44% of variance (after controlling for fixed effects) attributed to differences between individuals

Hens with initially lower movement increased their movement more rapidly than hens with higher initial movement.

- negative correlation between individual intercepts and linear random slopes
  - − 0.79, bootstrap 95% CI − 0.82 to − 0.78
- positive correlation between random intercept and quadratic random slope
  - 0.41, bootstrap 95% CI 0.37–0.54
- negative correlation between linear and quadratic random slopes
  - − 0.89, bootstrap 95% CI − 0.93 to 0.89