Explaining infectious disease based on mobility obtained from RFID sensor data on free-range egg laying hens movements - preliminary analysis with a toy model

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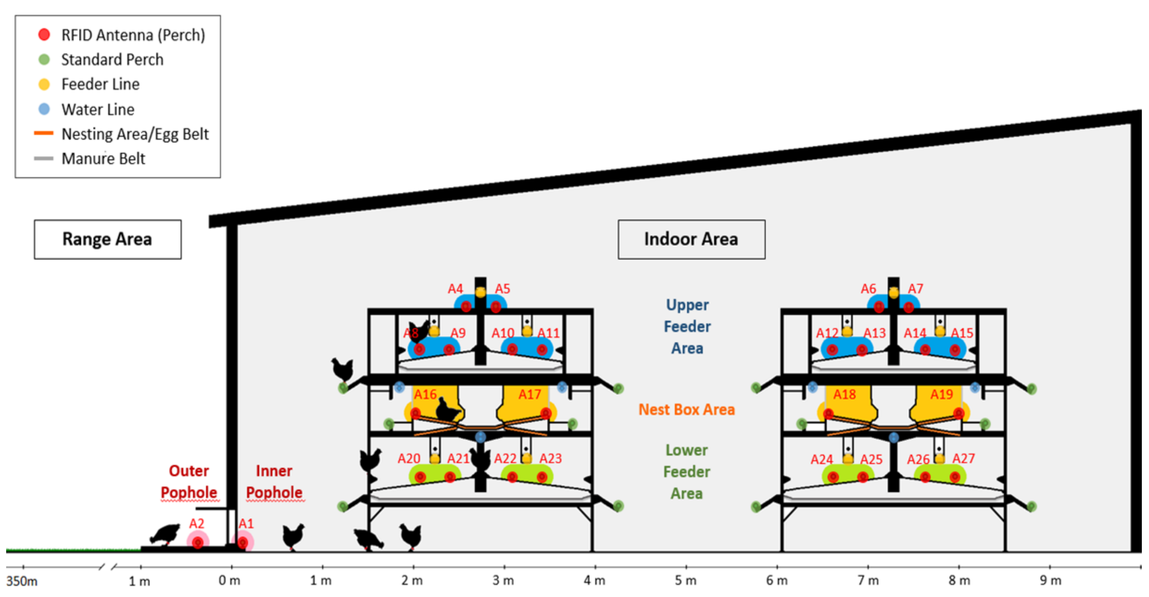
Summary

RFID sensors provide a promising technology for welfare and health conditions assessment in the egg production industry [1]. We analysed a dataset of free-range hens movements in Australia generated from 18 000 commercial laying hens housed in a multi-tier aviary system using an innovative custom-built RFID system. This allowed the tracking of individual hen movements on the range and in the hen house for the entire 56 week duration of the laying period. The dataset includes information about the mean time that individuals spent at the lower feeder area, upper feeder area, in the nest boxes, and on the range, calculated in seconds. The dataset was also used to calculate the mean number of times when hens would enter and leave one of these specific monitored areas. Furthermore, all hens were subject to necropsy at the end of their laying period and the presence or absence of some diagnosed diseases for each individual was included in the dataset. Three diseases were taken into account: Spotty Liver Disease, Ascaridia galli and Cestode Infection. Our study demonstrates that health and performance indicators enriched with the network analysis promise to improve hen well-being as well as allowing targeted interventions and optimise economical efficiency of the egg production industry.

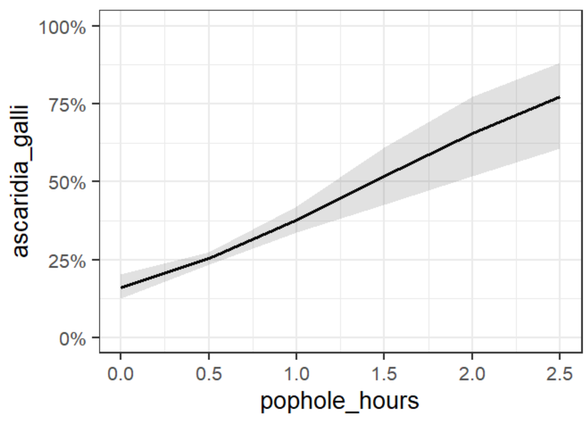
Data Processing and Methods

The aviary and sensor system (see graphical representation below) was described previously [1].



The main aim of this analysis was to detect whether the time spent in different locations as well as the number of events (encounters) could be associated with the presence/absence of a certain disease. Therefore three logistic models were implemented (one for each disease). A logistic regression was applied to give the structure of the data (the dependent variable was a binary 1/0 variable representing the presence/absence of the disease). The dataset was furthermore divided into a training and validating dataset, using a simple random sampling on the units (70% training and the remaining 30% for validation).

Prediction by exposure (wildlife) for Ascaridia Gali



The chance of infection increases with the daily time spent outside the main housing. The probability of infection increases by 25% per every hour spent in the range area.

References and Acknowledgement

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[2] Sibanda, T.Z., Belik, V., Jarynowski, A., Welch, M., Boshoff, J., Schneider, D., Ruhnke, I. (2022). Understanding time series of RFID sensor data for predicting mortality in laying hens. in Robinson, P.A. and McIntyre, K.M. (eds). Proceedings of the Society for Veterinary Epidemiology and Preventive Medicine annual meeting held in Belfast, Northern Ireland, SVEPM, ISBN 978-0-948073-65-6, pages 197-207 https://belik.userpage.fu-berlin.de/files/SIB22.pdf

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Spotty Liver Disease

Spotty liver

	spotty_liver		
Predictors	*Odds Ratios*	*CI*	*p*
(Intercept)	0.08	0.03 – 0.17	**<0.001**
pophole hours	1.26	0.76 – 2.06	0.368
lowerfeeder hours	1.07	1.01 – 1.14	**0.021**
nestbox	0.89	0.64 – 1.21	0.465
upperfeeder hours	1.06	0.96 – 1.17	0.230
events pophole	1.12	0.91 – 1.37	0.277
events lowerfeeder	1.00	0.99 – 1.00	0.204
events nestbox	1.11	0.99 – 1.25	0.064
events upperfeeder	1.00	0.99 – 1.00	0.223
Observations	2466		
R^2 Tjur	0.009		

Spotty Liver Disease is a common infectious disease of layer chickens. Looking at the odds ratio, infected hens spend more time in lower feeder area than healthy ones. Campylobacter hepatitis (causing agent) is transmitted via a fecal-oral track. Thus, the transmission path may be manifested by the data. However, the fit to the model predicting Spotty Liver is the weakest among the investigated infectious diseases, which suggests other factors not related to hens contacts and mobility may drive the dynamics.

Cestode Infection

Cestodes Infection

	cestodes_infection		
Predictors	*Odds Ratios*	*CI*	*p*
(Intercept)	1.44	0.75 – 2.75	0.270
pophole hours	0.60	0.38 – 0.95	**0.030**
lowerfeeder hours	0.88	0.83 – 0.92	**<0.001**
nestbox	1.06	0.81 – 1.37	0.668
upperfeeder hours	0.83	0.76 – 0.91	**<0.001**
events pophole	1.13	0.94 – 1.36	0.177
events lowerfeeder	1.01	1.00 – 1.01	**0.004**
events nestbox	0.89	0.79 – 1.00	0.060
events upperfeeder	1.00	0.99 – 1.00	0.776
Observations	2466		
R^2 Tjur	0.021		

Hens infected with Cestodes spend less time in the feeding area (possibly due to less food intake). Infected hens spent less time feeding than in the upper area. Here 2 competing mechanisms could play a role: 1) Eggs of tapeworm are passed with feces, thus we suggest that faces fall from upper aviary system. 2) However, weaker animals should go up, that this is not the case.
Thus, both the transmission path and effect of the disease are manifested by the data.

Ascaridia galli Infection

Ascaridia galli

	ascaridia_galli		
Predictors	*Odds Ratios*	*CI*	*p*
(Intercept)	0.04	0.02 – 0.08	**<0.001**
pophole hours	3.15	2.08 – 4.81	**<0.001**
lowerfeeder hours	1.15	1.10 – 1.21	**<0.001**
nestbox	0.73	0.55 – 0.96	**0.025**
upperfeeder hours	1.22	1.13 – 1.32	**<0.001**
events pophole	1.16	0.98 – 1.38	0.088
events lowerfeeder	1.00	0.99 – 1.00	0.056
events nestbox	1.20	1.08 – 1.33	**0.001**
events upperfeeder	1.00	0.99 – 1.00	0.059
Observations	2466		
R^2 Tjur	0.065		

Possible exposure due to going outside of the shed (the bird was exposed to the environment and vectors). Infected are preferring the upperfeeder, maybe they are weaker? There is interesting relation with the nestbox. Infected hens spend less time there but seem to move through nestbox a lot. Maybe due to sleeping/sitting problems? Thus, the transmission path and effect of the disease are evident within the data.

The model for Ascaridia was able to achieve an accuracy of 0.71 when predicting on the validation set, with an overestimation of false negatives. The AUC for the model was 0.653.

Future research

A further study is planned on the original dataset, implementing a linear mixed effect model to analyse the hen's daily time series information structure presented in the data.