A MODELLING ASSESSMENT OF THE IMPACT OF CONTROL MEASURES ON HPAI TRANSMISSION IN POULTRY IN GREAT BRITAIN

ECMTB 2026 minisymposium: Modelling avian influenza dynamics

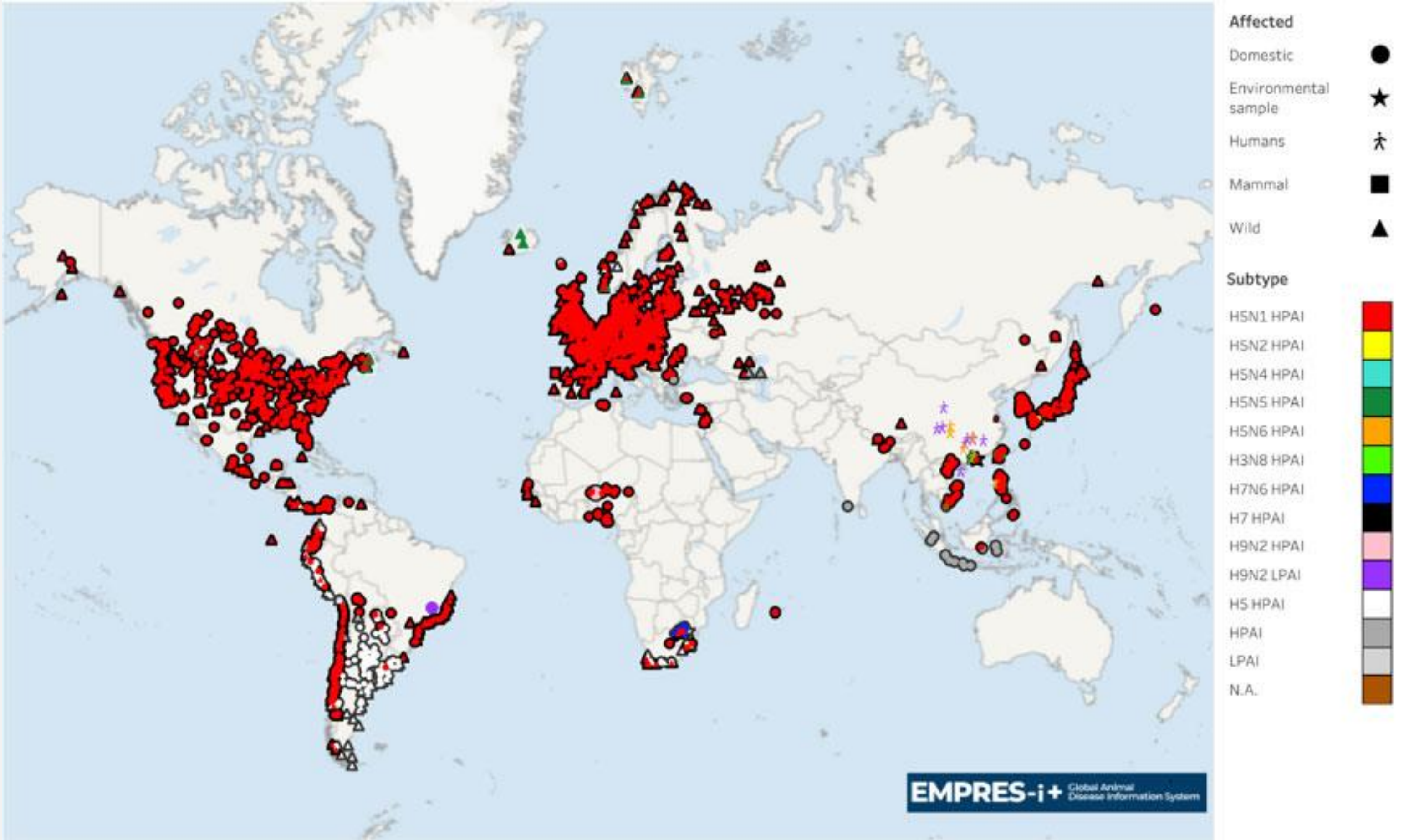
Presenter: Ed Hill (University of Liverpool, UK)

Co-authors: Chris Davis (UK Health Security Agency & University of Warwick, UK), Chris Jewell (Lancaster University, UK), Kristyna Rysava (University of Warwick, UK), Robin Thompson (University of Oxford, UK), Mike Tildesley (University of Warwick, UK).

16 July 2026

Highly Pathogenic Avian Influenza (HPAI)

- Since 2021, the emergence of H5N1 clade 2.3.4.4b has caused substantial outbreaks in both wild birds and poultry.
- Great Britain had its largest outbreak of H5N1 in the 2022–2023 season.
- HPAI has been circulating within Great Britain in the wild bird population with persistence over summer months.



Global distribution of AIV with zoonotic potential observed in the period 1 October 2022 to 30 September 2023. Source: https://www.fao.org/animal-health/situation-updates/global-aiv-with-zoonotic-potential/en

Aims of this project

Create a framework to fit a mathematical model to HPAI outbreak data in poultry that could be applied to future outbreaks.

Assess the spatial risk of HPAI outbreaks in poultry and how transmission might change in time.

Investigate the potential for spread within the poultry industry.

Consider the impact of potential interventions on the spread of HPAI.

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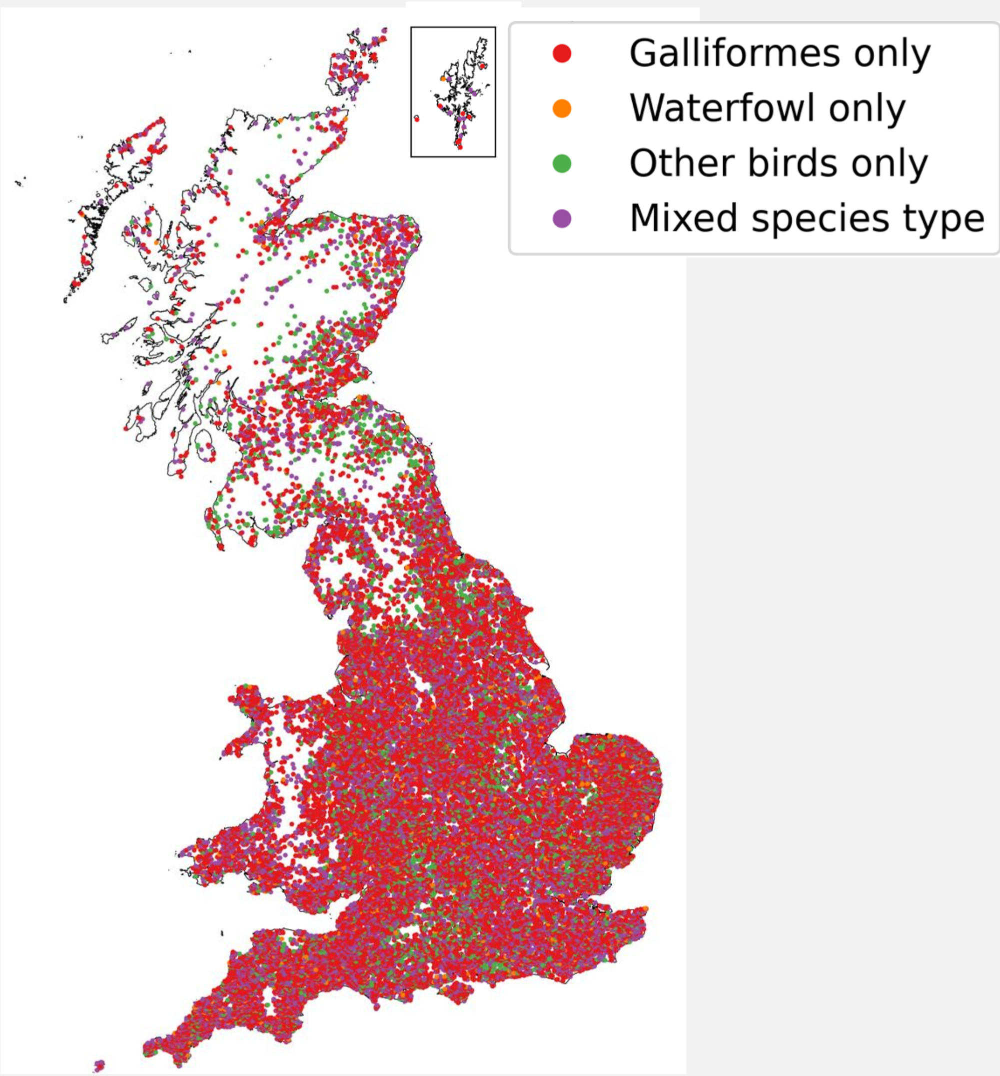
Poultry premises of Great Britain

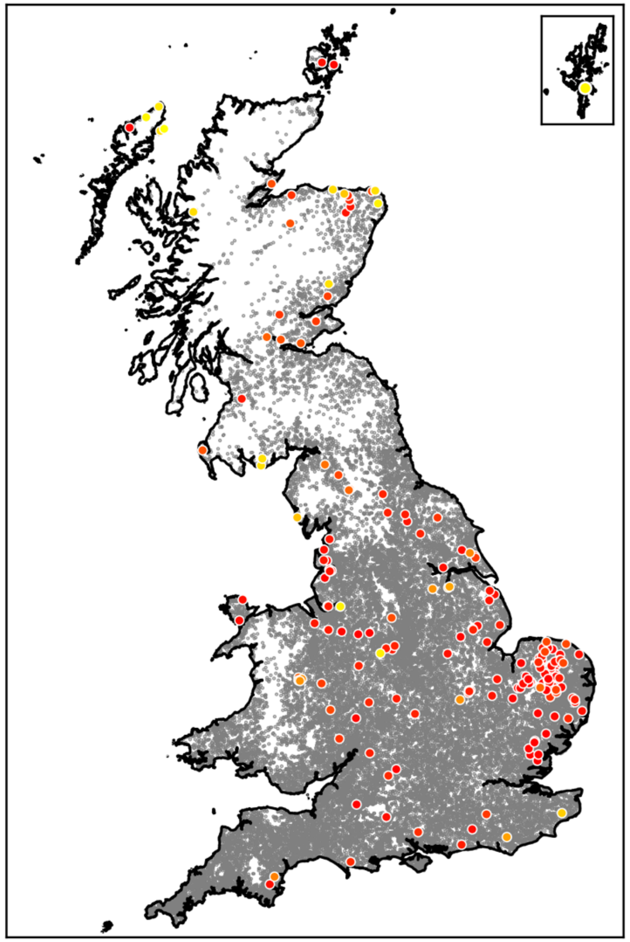
Demographic data – as registered on 01 December 2022.

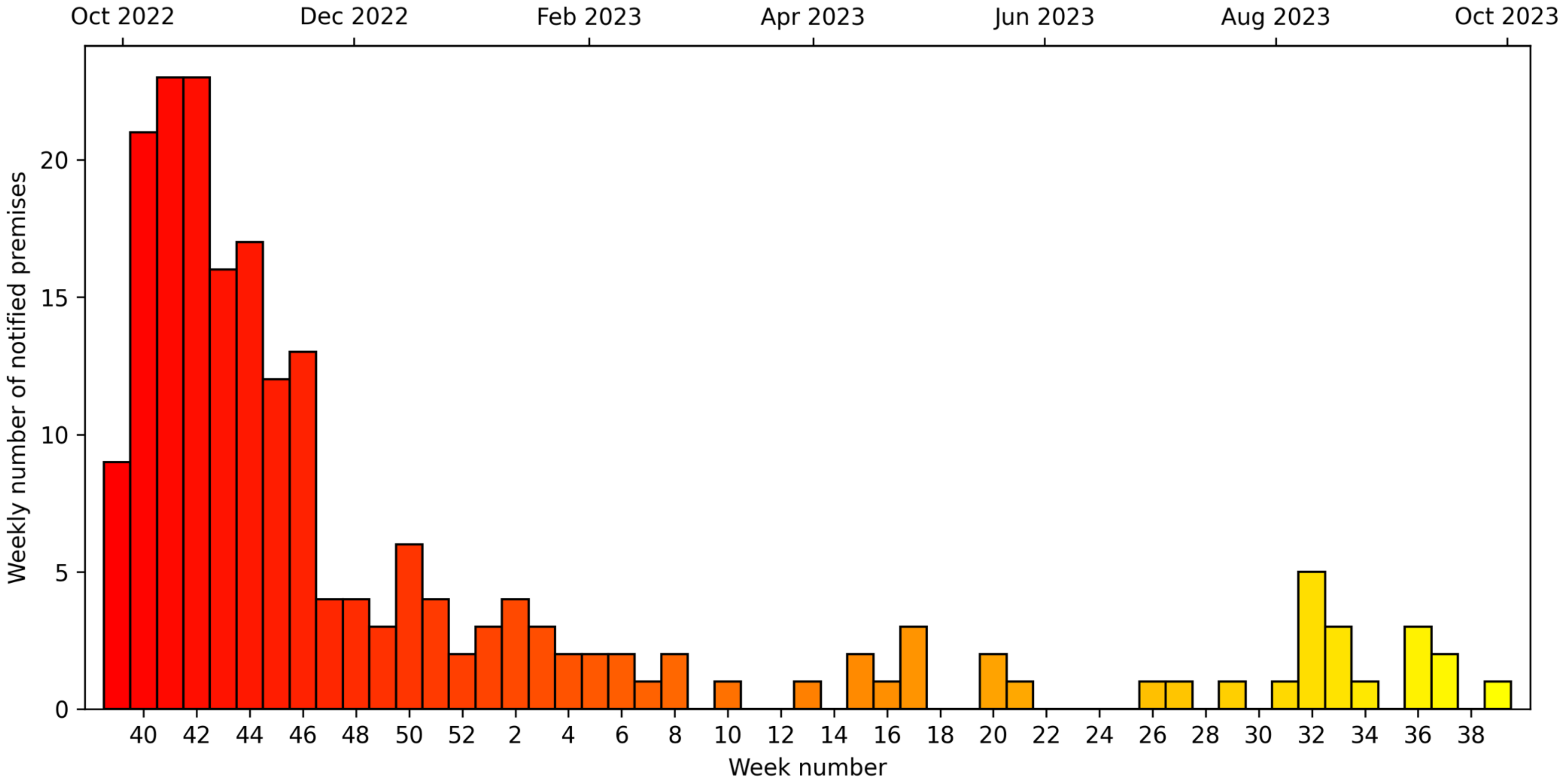
Bird type	Number of premises	Number of birds
Galliformes	26 013	281.8 million
Waterfowl	1 205	4.2 million
Other	4 871	43.2 million
Mixed	12 539	N/A
Total	**44 628**	**329.2 million**



With thanks to the Animal & Plant Health Agency for provision of data.

Weekly H5N1 infected premises (2022/2023)





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Modelling approach

Epidemiological unit

Poultry premises.

HPAI disease status

Compartmental model based on the time a premises changes infection state.

Species specific

Three bird species structure.

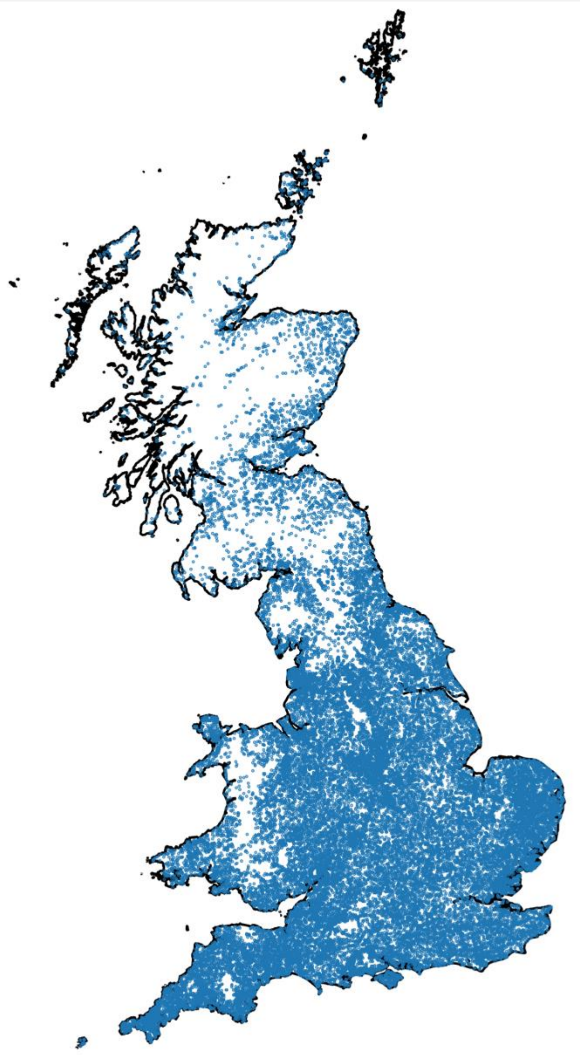
(Galliformes, waterfowl, other)

Spatially explicit

Distance kernel in the transmission rate.

Timestep

Simulate the model in discrete time in days.



https://doi.org/10.1371/journal.pcbi.1013874

Modelling approach

Poultry premises:

$$\lambda_j(t) = \varepsilon(t) + \sum_{i \in \mathcal{I}(t)} \beta_{ij} + \gamma_2 \sum_{i \in \mathcal{N}(t)} \beta_{ij}$$

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Modelling approach

Poultry premises:

Susceptible $\xrightarrow{\lambda_j(t)}$ **E**xposed $\xrightarrow{\text{4 days}}$ **I**nfectious $\xrightarrow{\eta_i \text{ days}}$ **N**otified $\xrightarrow{\text{3 days}}$ **R**emoved

Baseline infectious pressure

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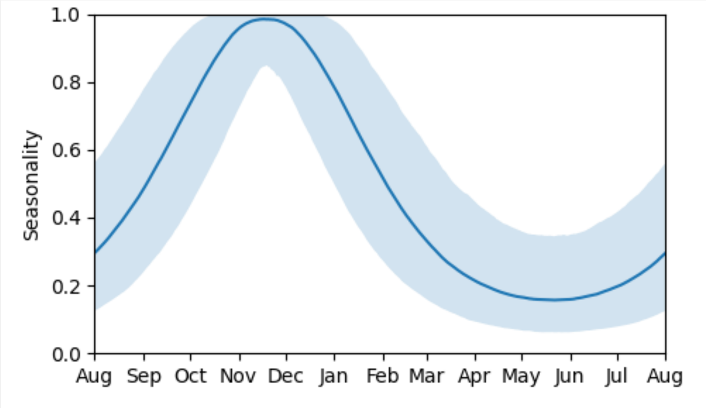

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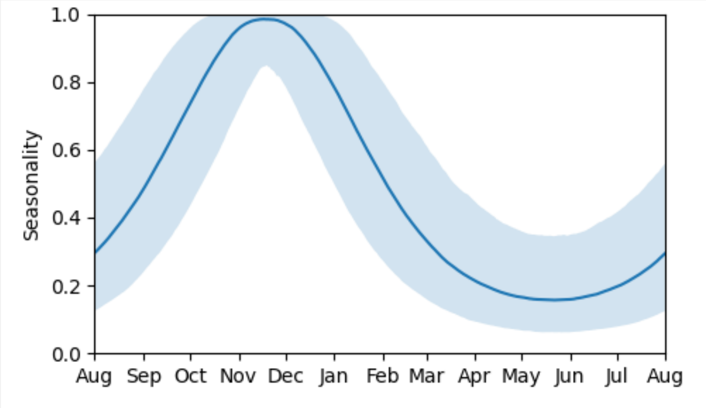
Baseline infectious pressure

Infection from infected premises

Infection from notified premises



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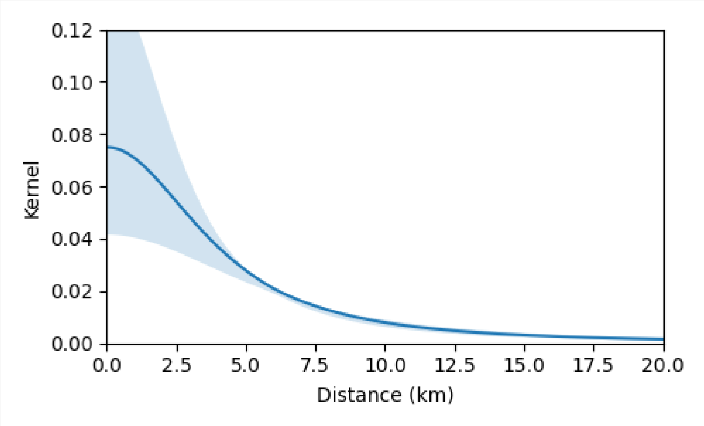

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Model fitting and simulations (2022/2023)

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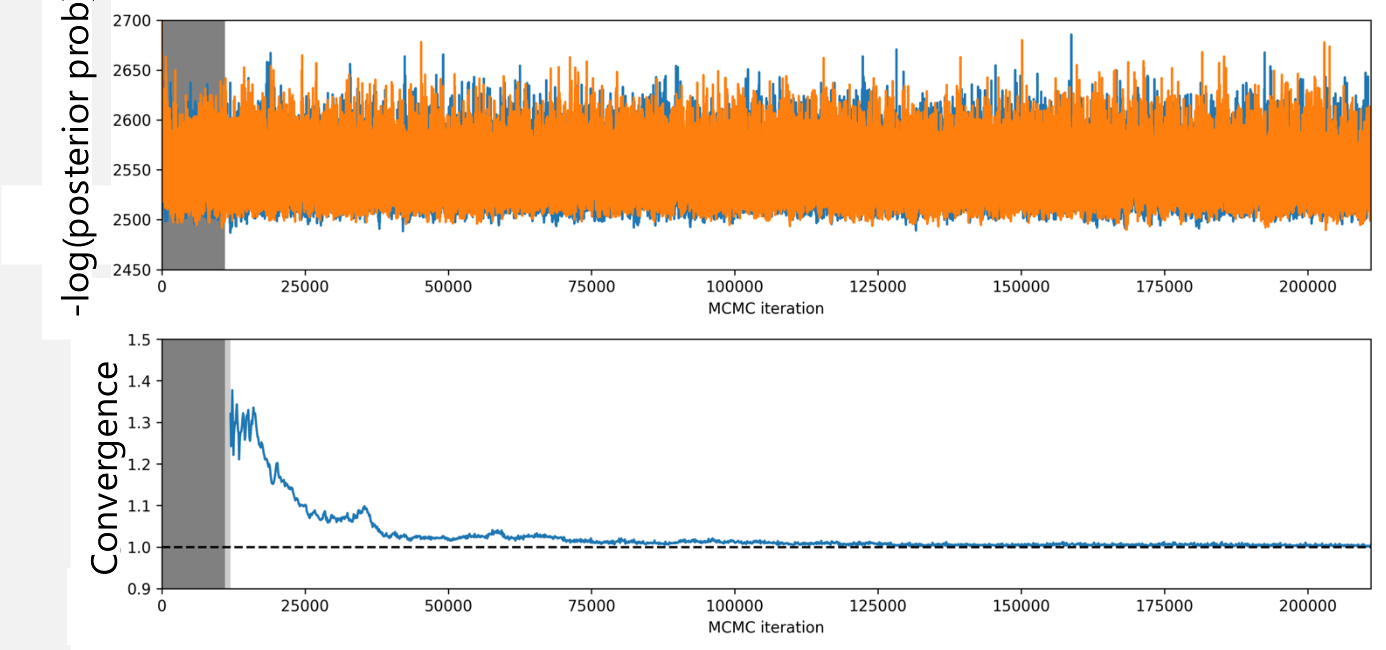
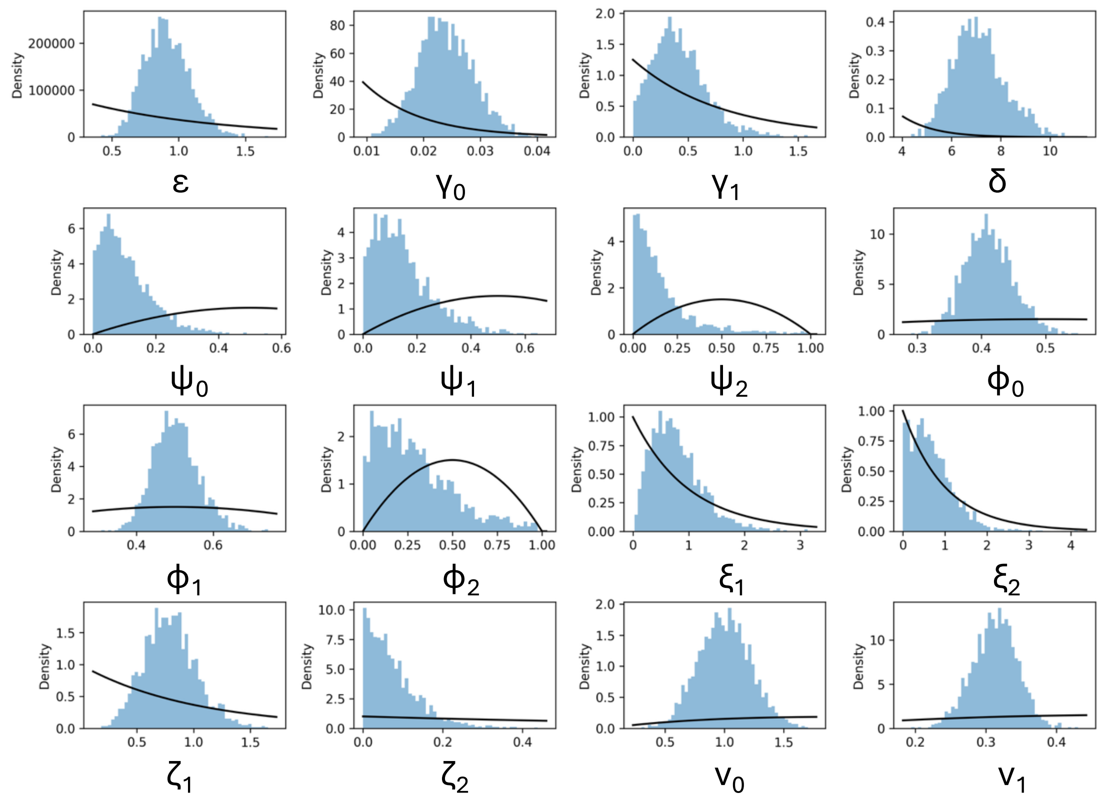
- Used reversible-jump Markov chain Monte Carlo (MCMC) to estimate 16 model parameters plus the time to notification for each infected premises.
- We used the obtained parameter estimates to run 10,000 model simulations.

MCMC chains



Posterior parameter distributions



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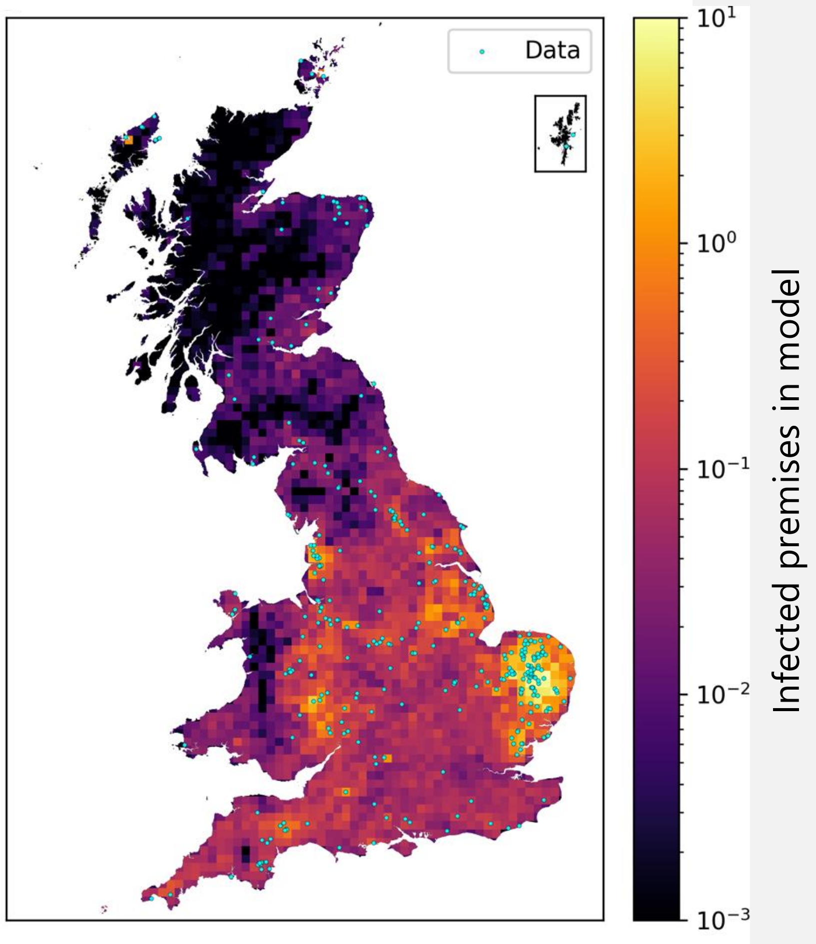
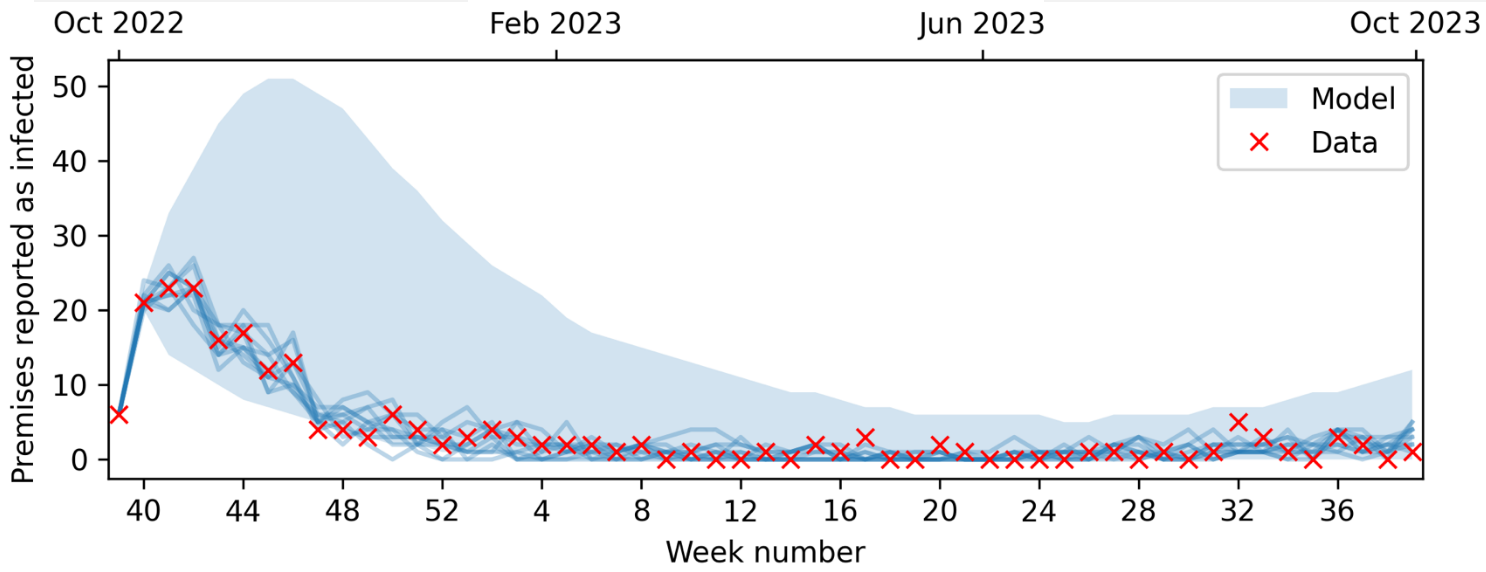
Spatial model fit



Temporal model fit



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Enhanced biosecurity

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Enhanced biosecurity in response to local infection could include:

- Increased cleaning and disinfection,
- Reduced contamination risk for water sources, feed storage and housing,
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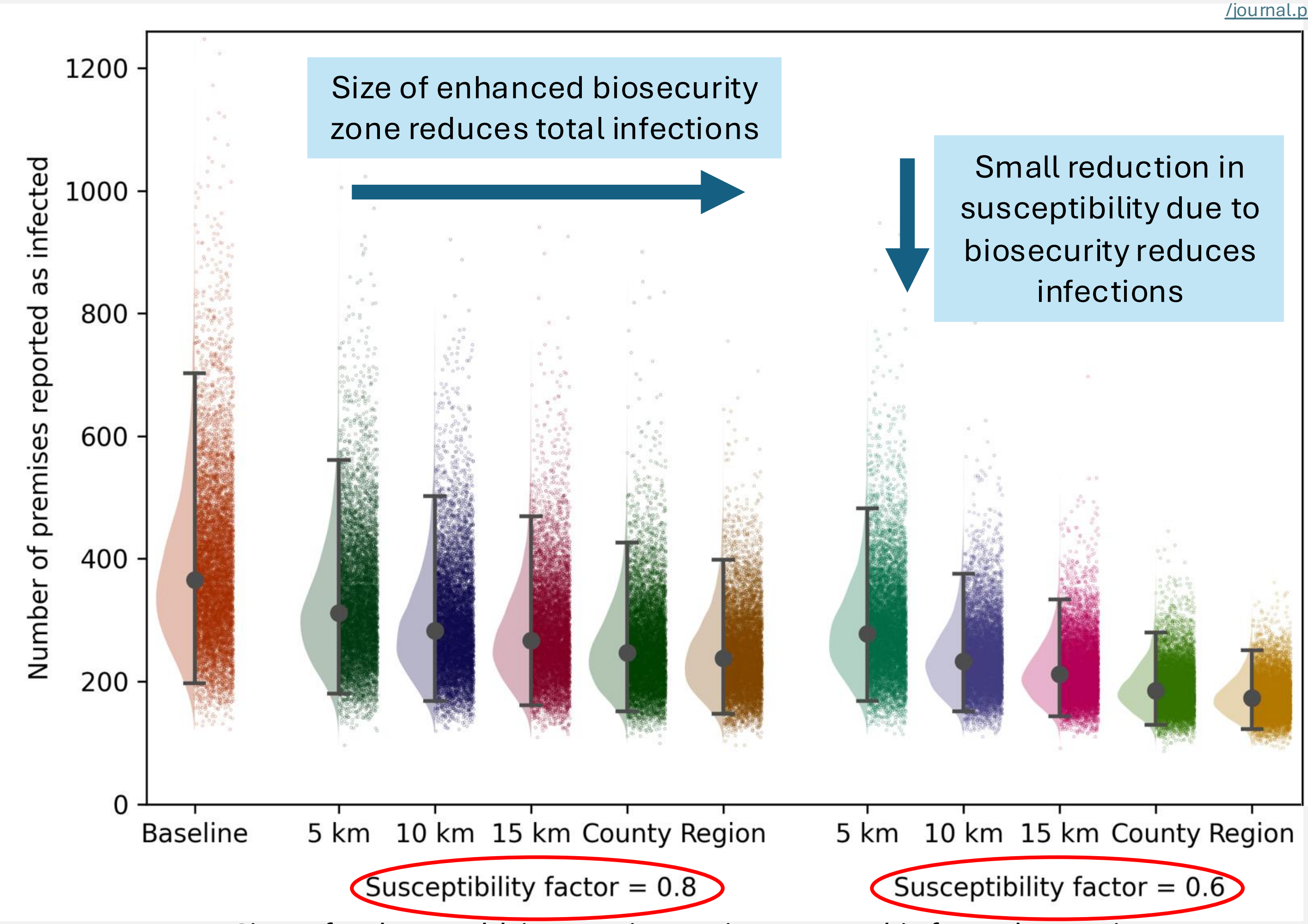
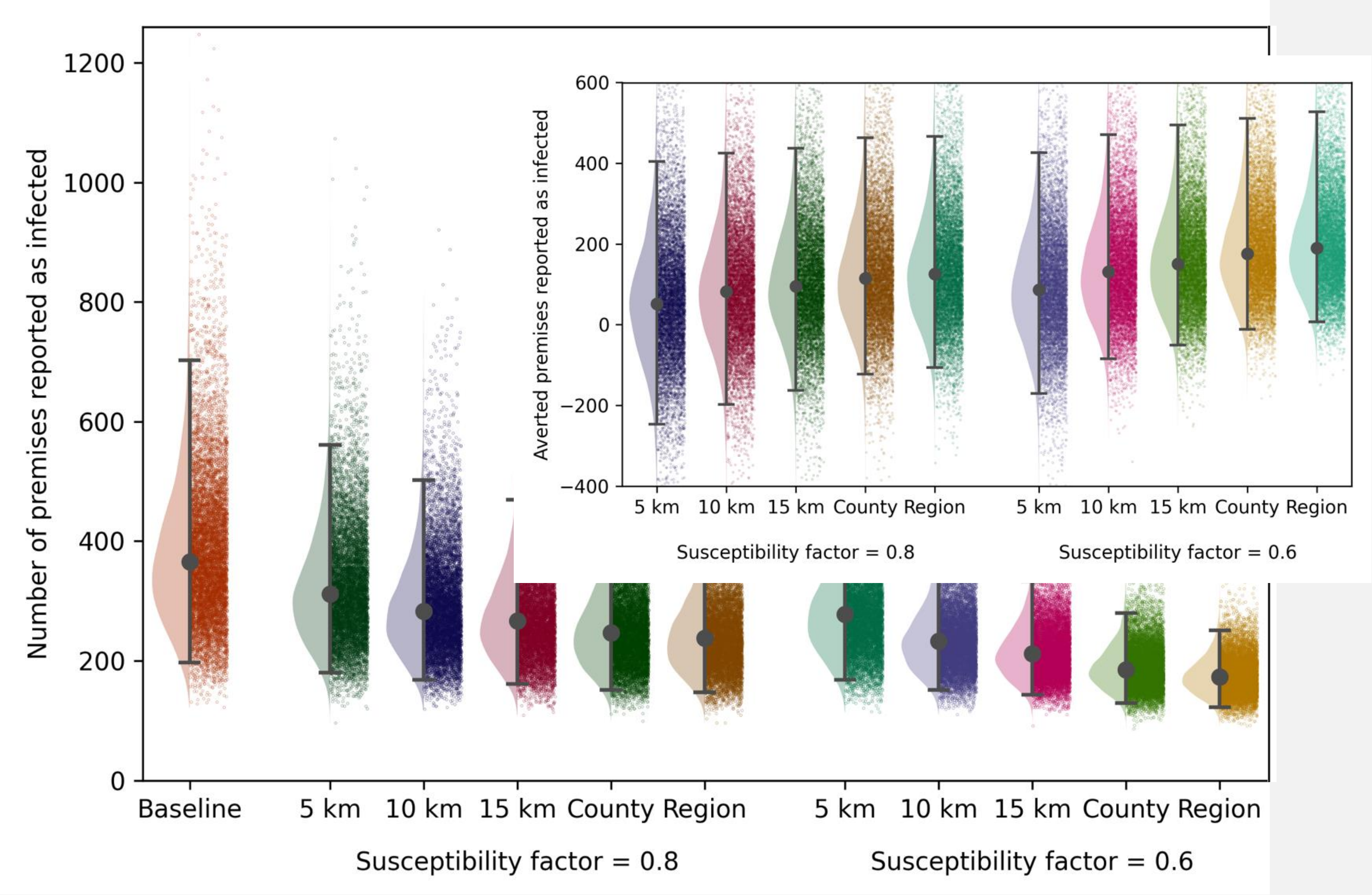


Size of enhanced biosecurity region around infected premises

Comparing strategies

- Enhanced biosecurity results in a reduction of susceptibility.
- This can only result in a reduction in infections.
- The mean simulated behaviour shows positive averted infections.
- Many individual simulations show negative number of averted infections.



Size of enhanced biosecurity region around infected premises

Sellke construction

Work in progress

Original method:

For susceptible premises j at time t, the probability of becoming infected by time $t + \delta t$ is:

$p_j(t) = 1 - e^{-\lambda_j(t)\delta t}$.

Using Sellke construction:

For susceptible premises, set thresholds $z_j \sim \mathrm{Exp}(1)$.

Premises j becomes infected at time T, the first time when $\sum_{t=0}^{T} \lambda_j(t)\delta t > z_j$.

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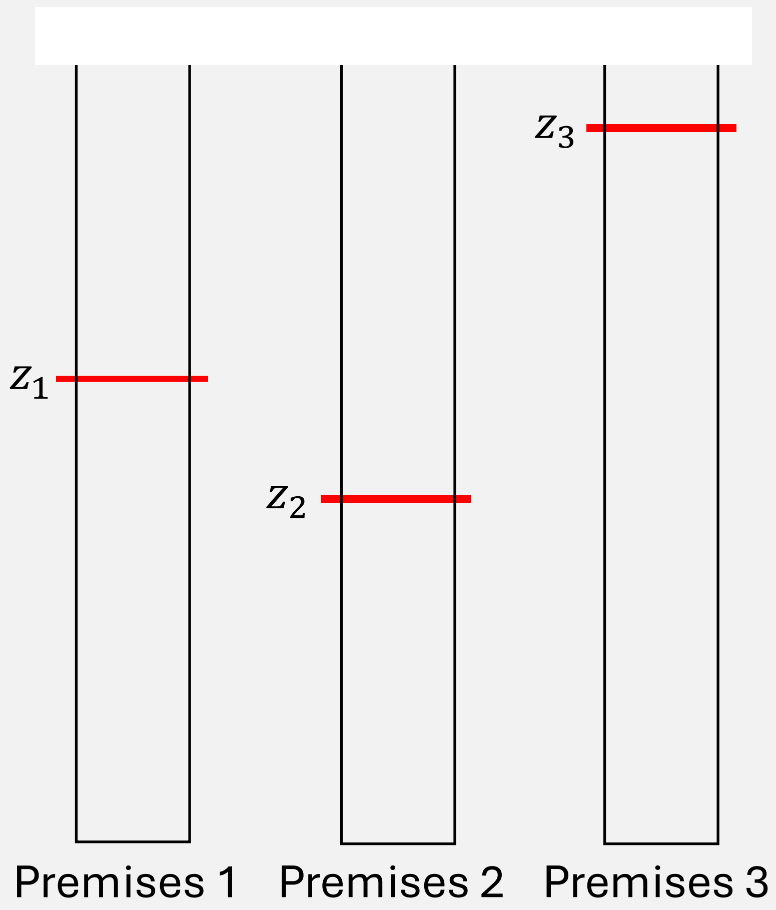

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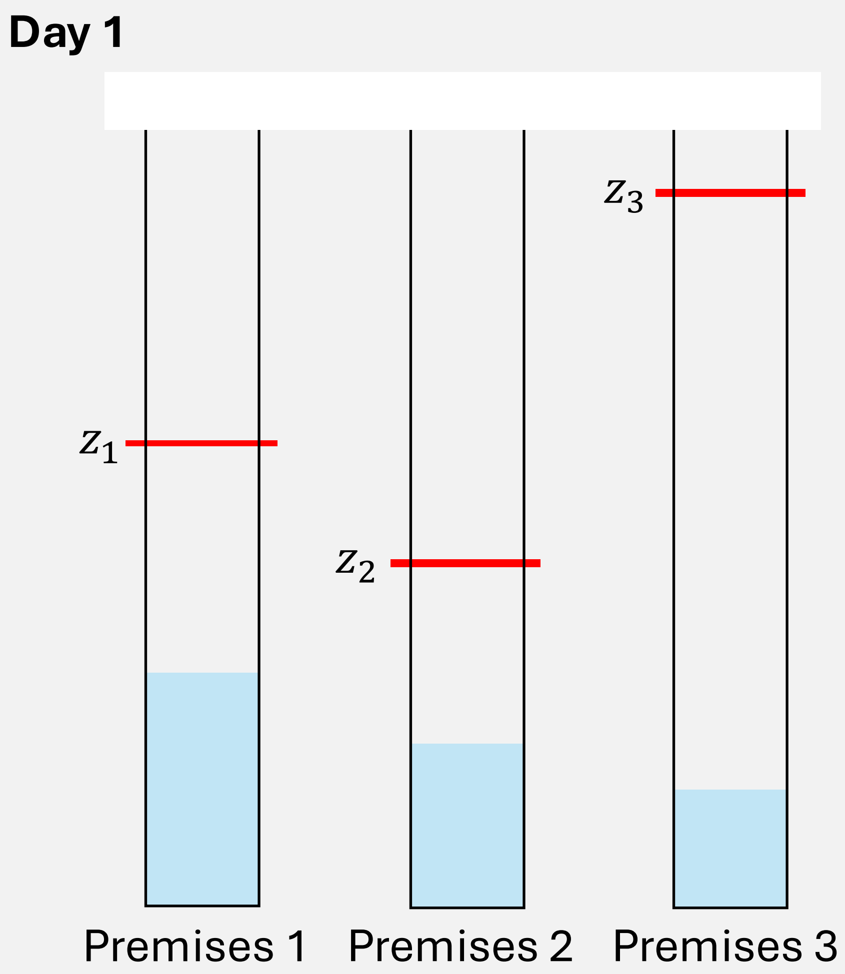

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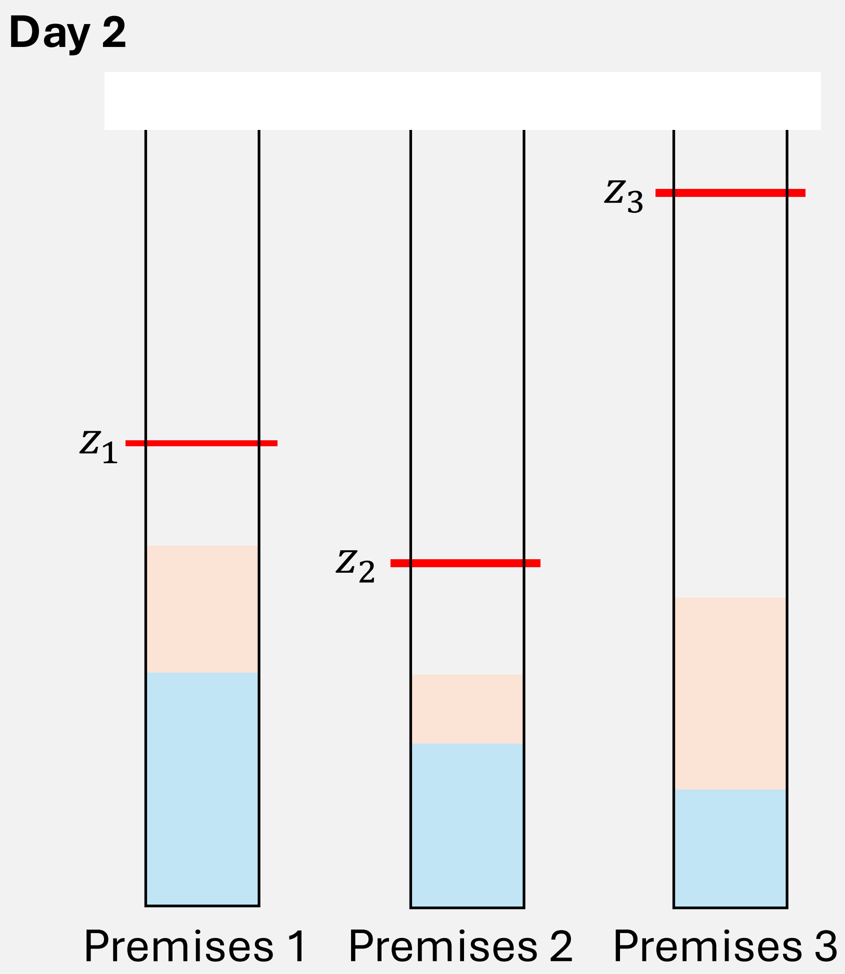

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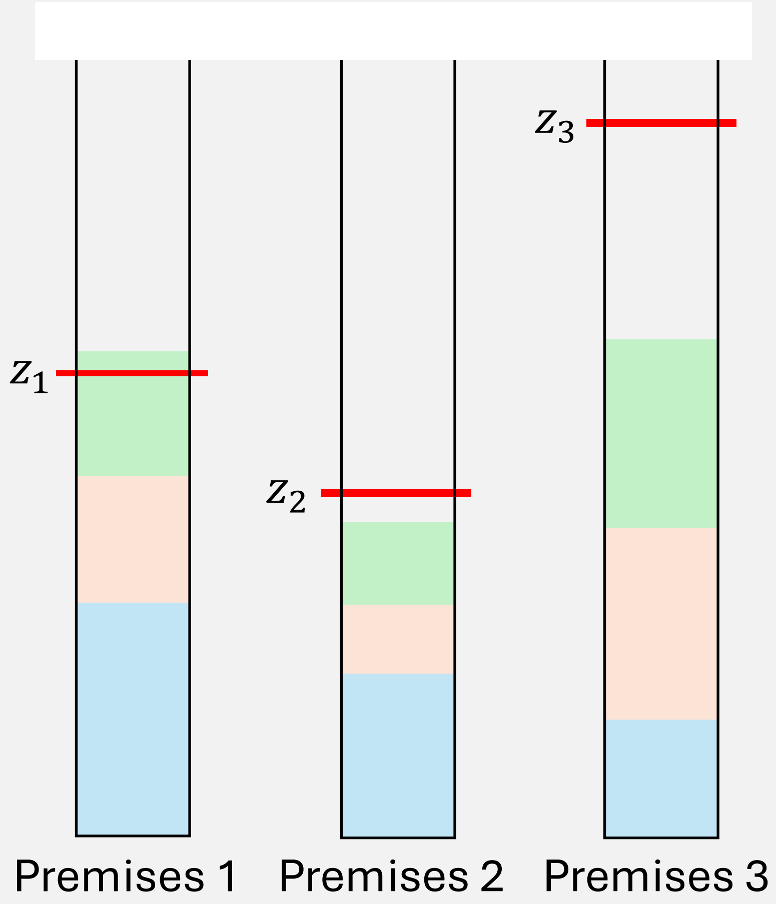
Day 3: Premises 1 infected



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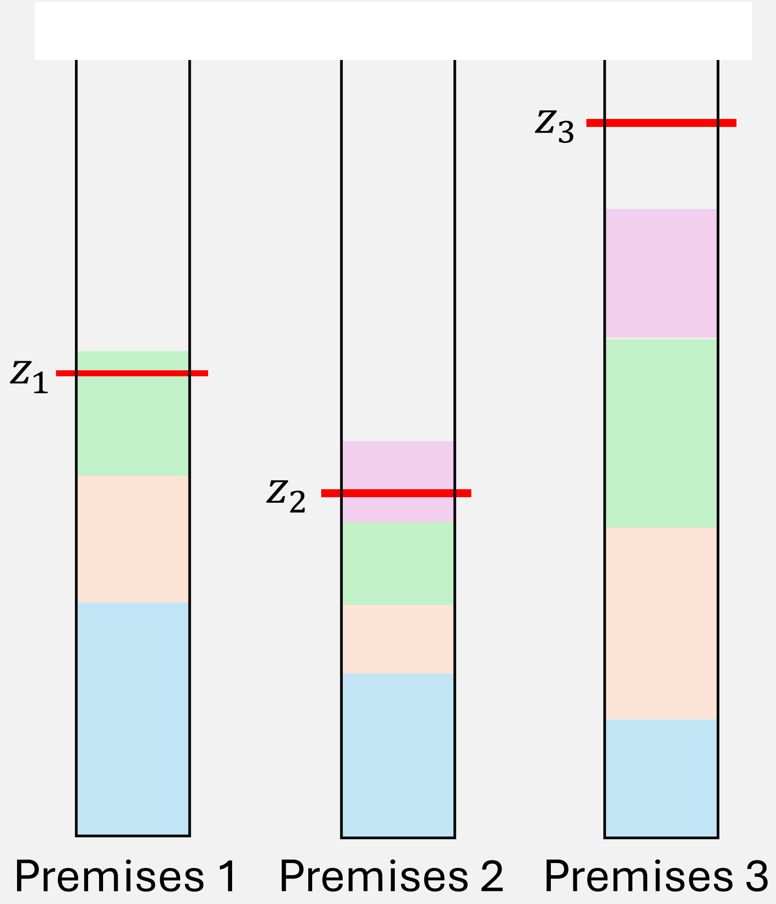
Day 4: Premises 2 infected



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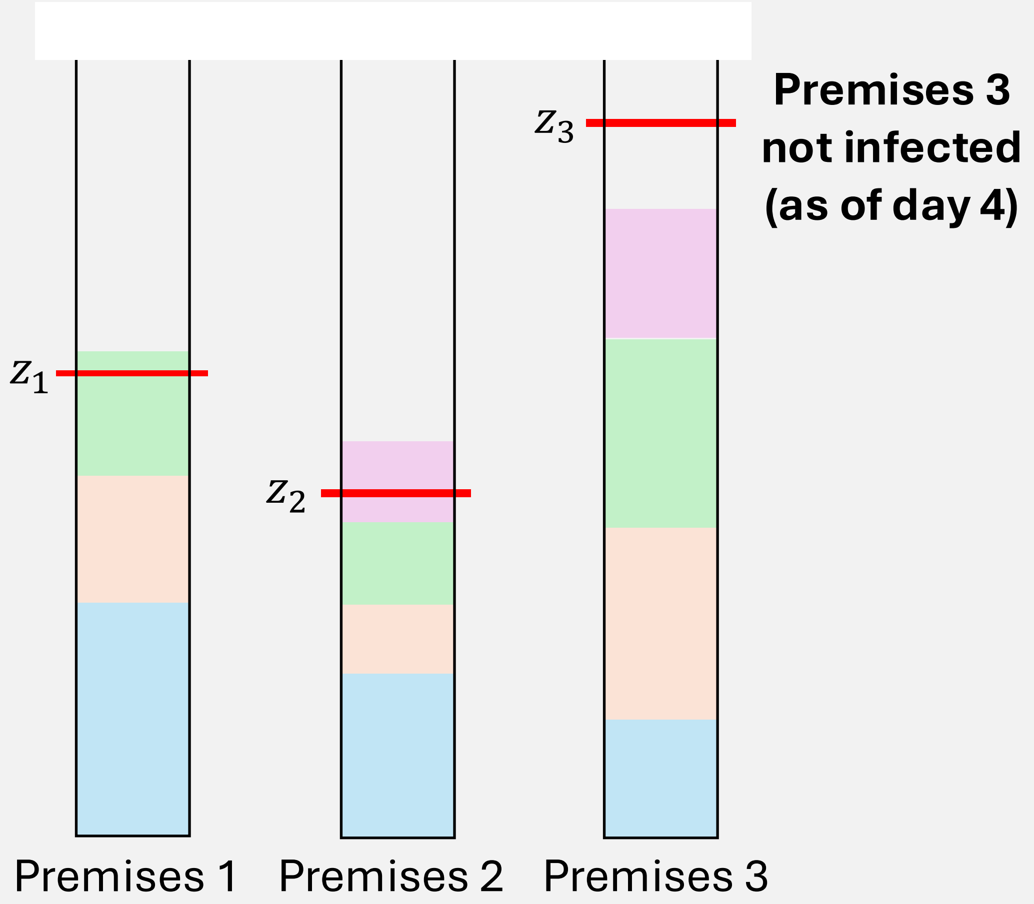

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Benefit of Sellke construction:

1) Algorithm encodes randomness to the values of the resistance thresholds z_j.
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Reduce susceptibility

Reduces infectious total pressure

Longer to reach thresholds

Fewer premises can be infected

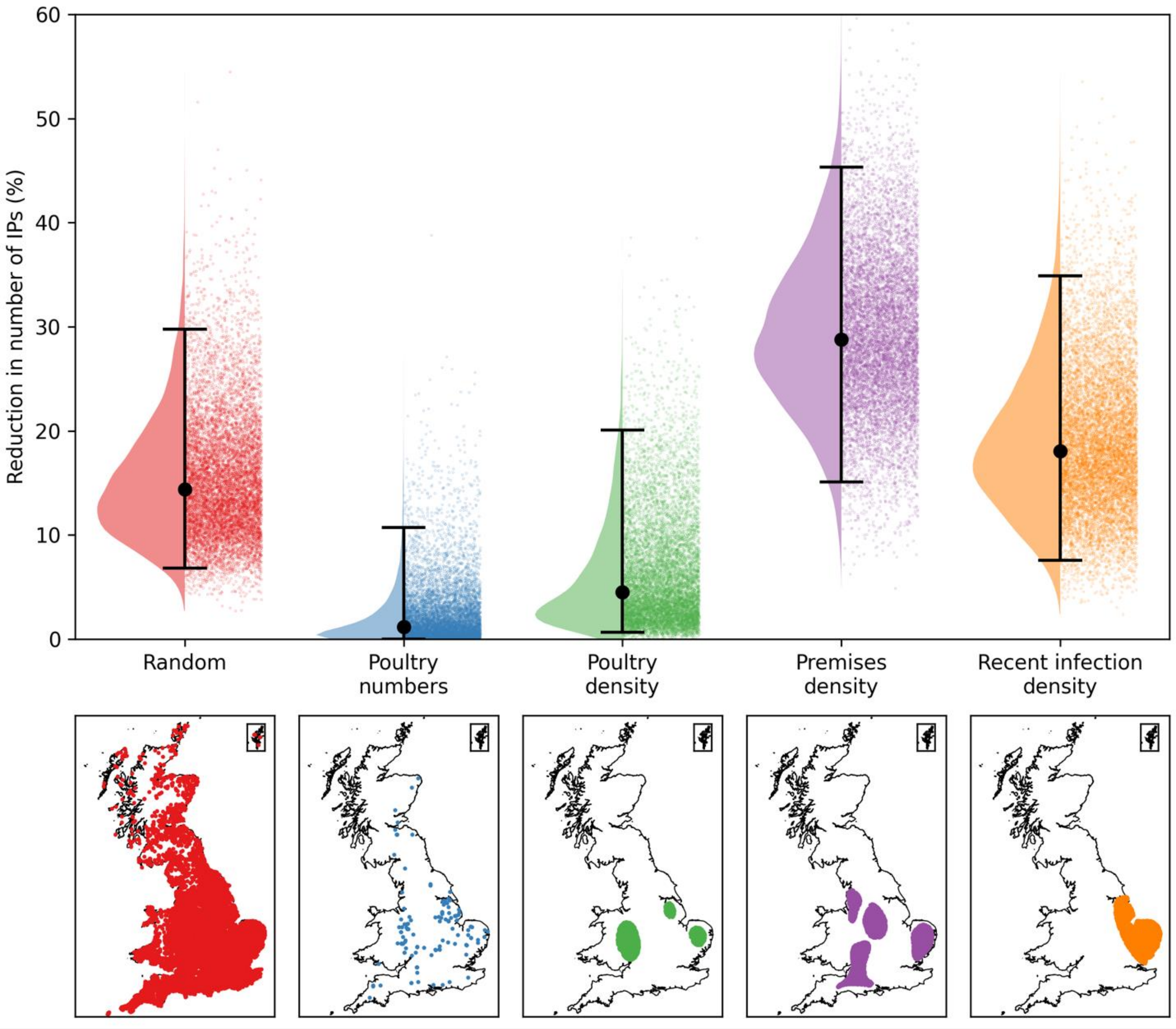
Preventative vaccination

Work in progress

In the UK, use of HPAI vaccinations in poultry is not currently permitted.

The benefits of vaccination are being considered in the UK, with programmes ongoing in European countries.

- Sellke construction used to compare different preventative vaccine strategy allocations.
- The reduction in number of infections is always positive.
- With capacity of 200,000 birds being vaccinated daily, vaccinating in areas with high premises density is the most effective strategy.



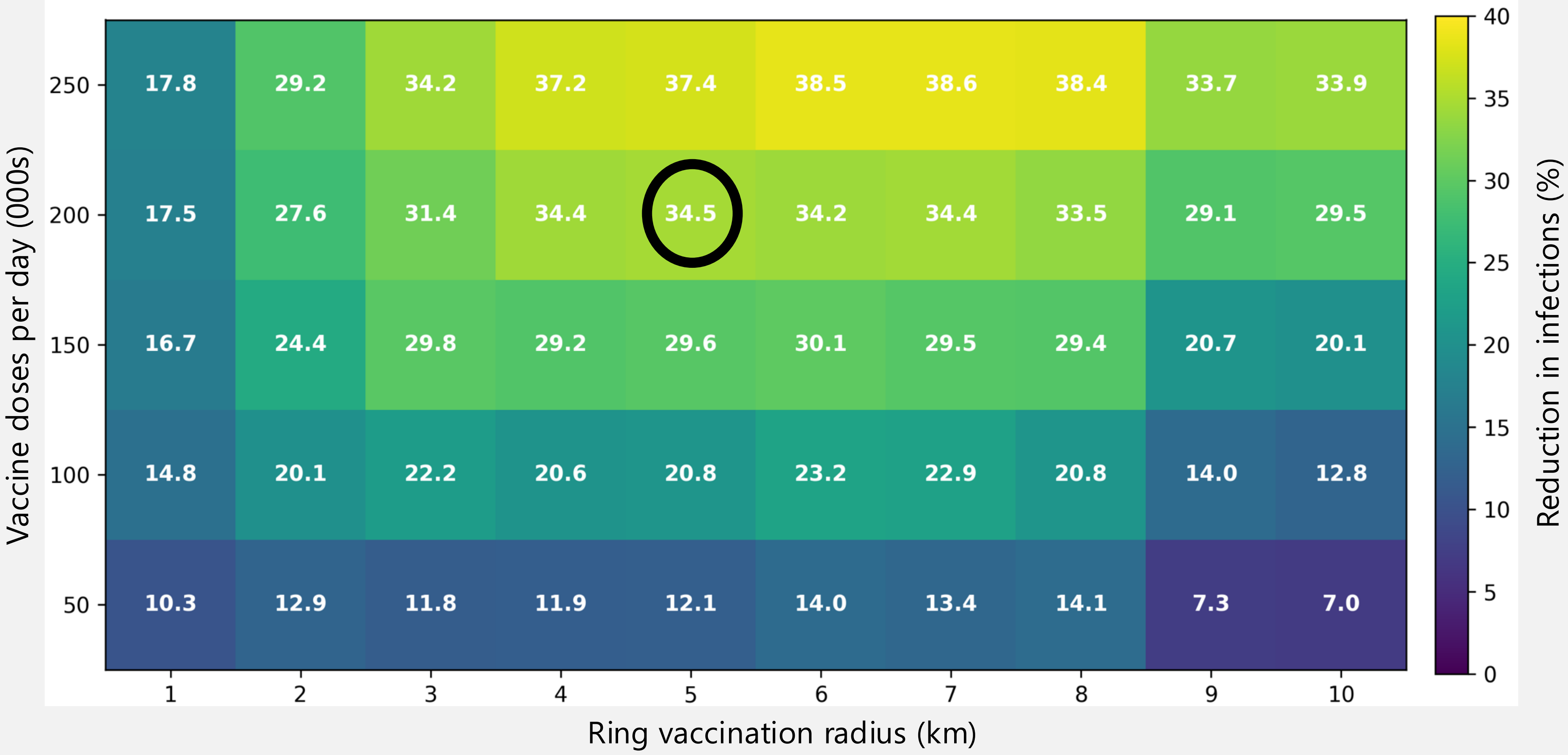
Emergency responsive vaccination

Work in progress

Ring vaccination could be used in response to infected premises.

We can determine optimal vaccination radius for a given number of doses.

For example, at 200,000 vaccine doses per day, of the tested ring vaccination radii a radius of **5km** gave the largest reduction in infections (on average).



Vaccination efficacy

Work in progress

We highlight the importance of a **robust surveillance system** and **high vaccine efficacy**.

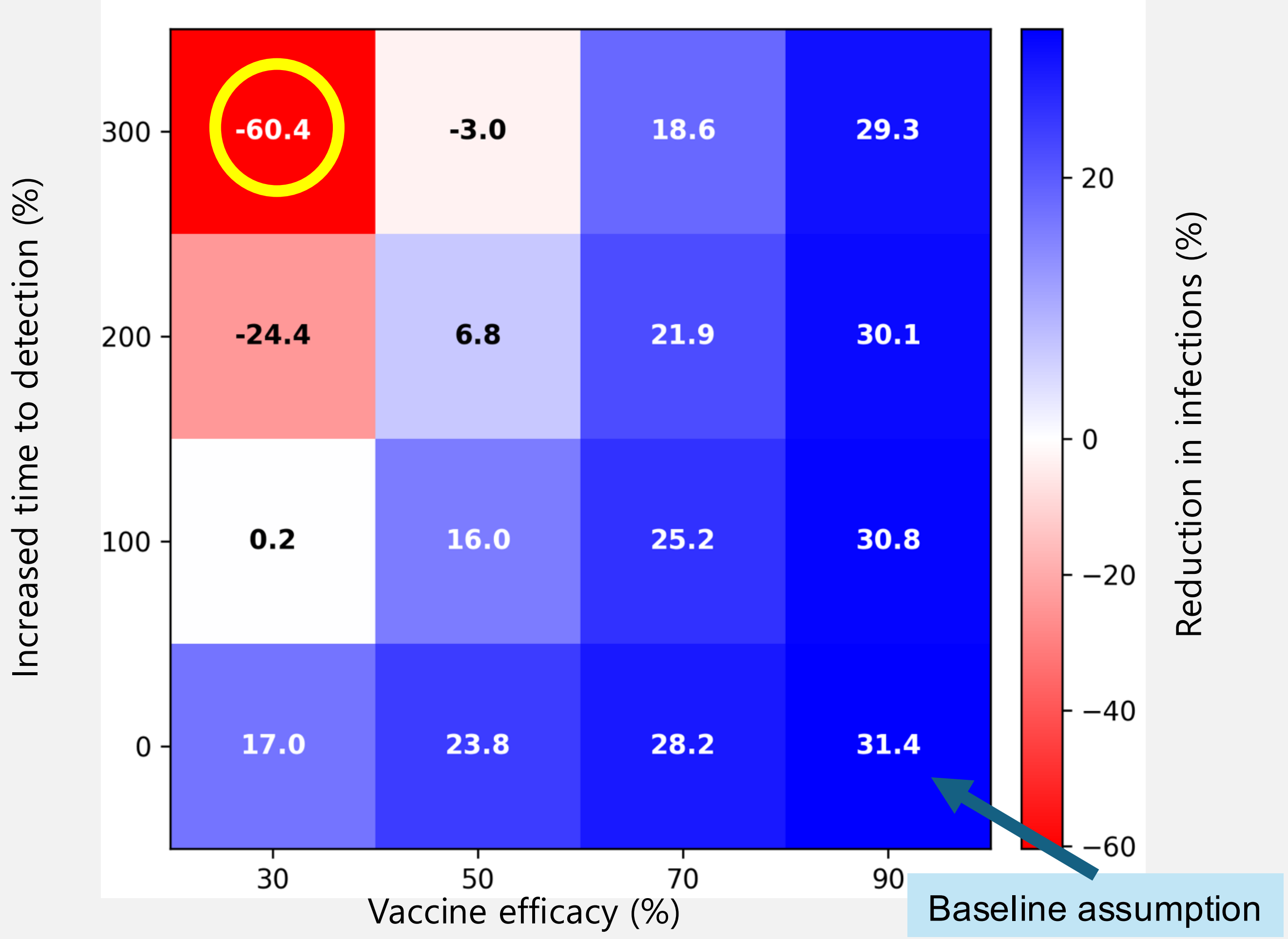
Vaccinated poultry can still become infected and transmit HPAI.

Poultry may show fewer symptoms.

This may increase time to detection for premises.

More *silent spread* may occur before detection.

Could lead to more total infections that without vaccination.

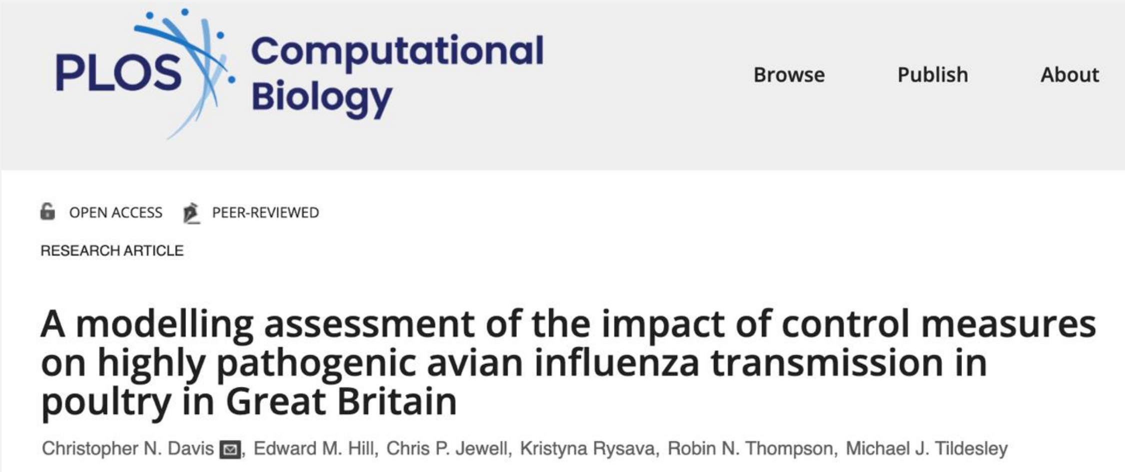


Conclusions

We constructed a spatial HPAI transmission model that was fit to 2022/2023 HPAI outbreak data in poultry in Great Britain.

We would like to investigate further the spatial heterogeneity of wild bird spillover into poultry farms and whether shared ownership of poultry farms increases the transmission risk.

Model can simulate different intervention strategies to assess their impact. Vaccination could be very beneficial reducing the number of infected premises (noting that we have not considered any costs).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RESEARCH ARTICLE

A modelling assessment of the impact of control measures on highly pathogenic avian influenza transmission in poultry in Great Britain

Christopher N. Davis, Edward M. Hill, Chris P. Jewell, Kristyna Rysava, Robin N. Thompson, Michael J. Tildesley

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Contact info

https://edmhill.github.io

https://www.linkedin.com/in/EdwardMHill/

edward.hill@liverpool.ac.uk

@EdMHill

EdMHill

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