Exploring the Path Of Influenza from Wild Birds to Horses

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Introduction

- This project uses a stochastic SIR model to analyze how influenza virus fitness (R_0) and the risk of introduction from wild birds affect the spread of influenza in Mongolia.
- Data from 2021-2022 samples from Mongolia are used to match model predictions and understand the potential transmissibility, influenced by seasonal exposure and waning immunity.

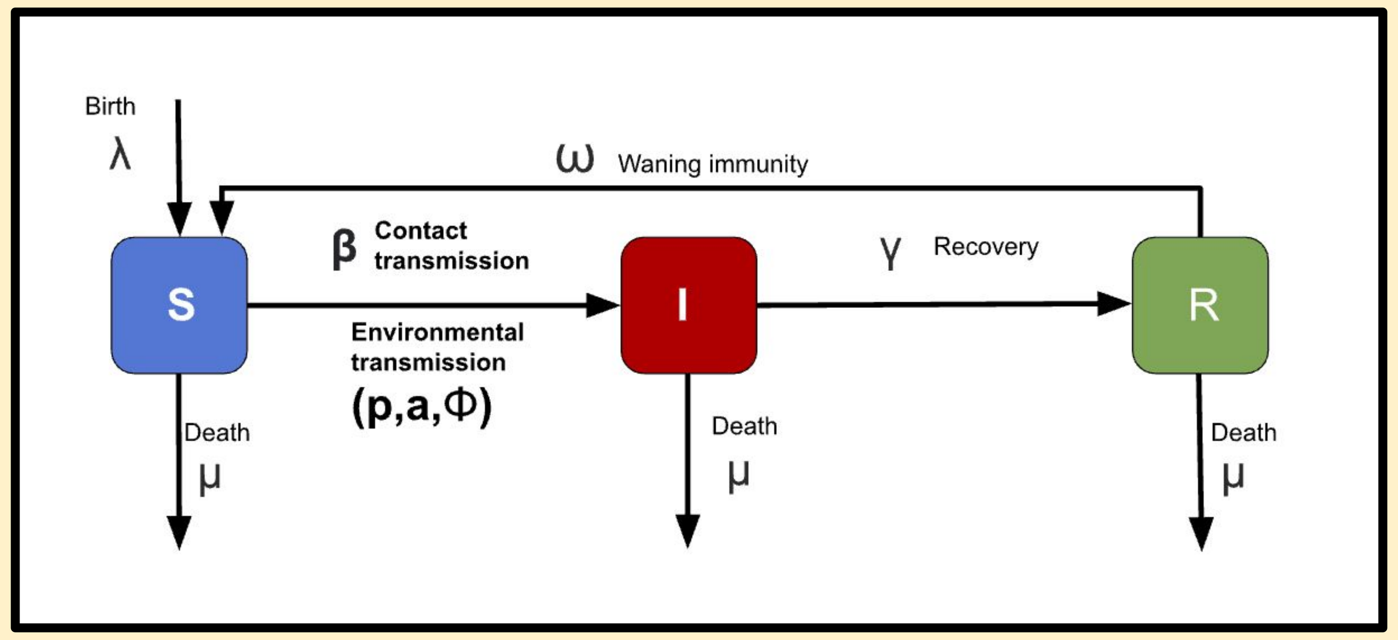
Research Questions

I. How do seasonal transmission dynamics and risk of pathogen introduction influence the spread of influenza?

II. What parameter values best replicate the data observed in the field?

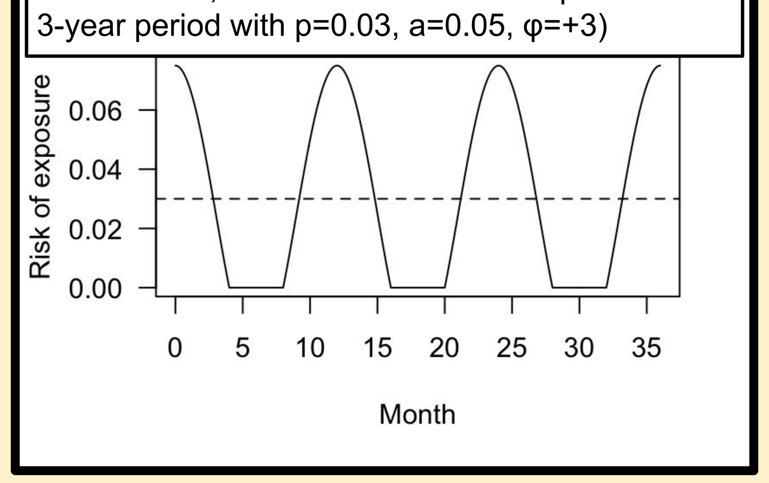
Methods

- SIR model includes seasonal pathogen exposure from the environment (p,a, φ - detailed below)), between-horse transmission (β), recovery (γ), and waning immunity (ω) along with horse demography (λ,μ).
- Literature-based parameter estimates were collated and explored within plausible ranges in order to assess the positivity rate, R/(S+I+R), over time.



- Fully factorial experimental design includes variable levels that were changed in the model such as pathogen introduction risk, amplitude of seasonality, and baseline environmental transmission.

Seasonal risk of exposure to influenza from the environment, with an illustrative example over a 3-year period with p=0.03, a=0.05, φ=+3)



Results & Findings

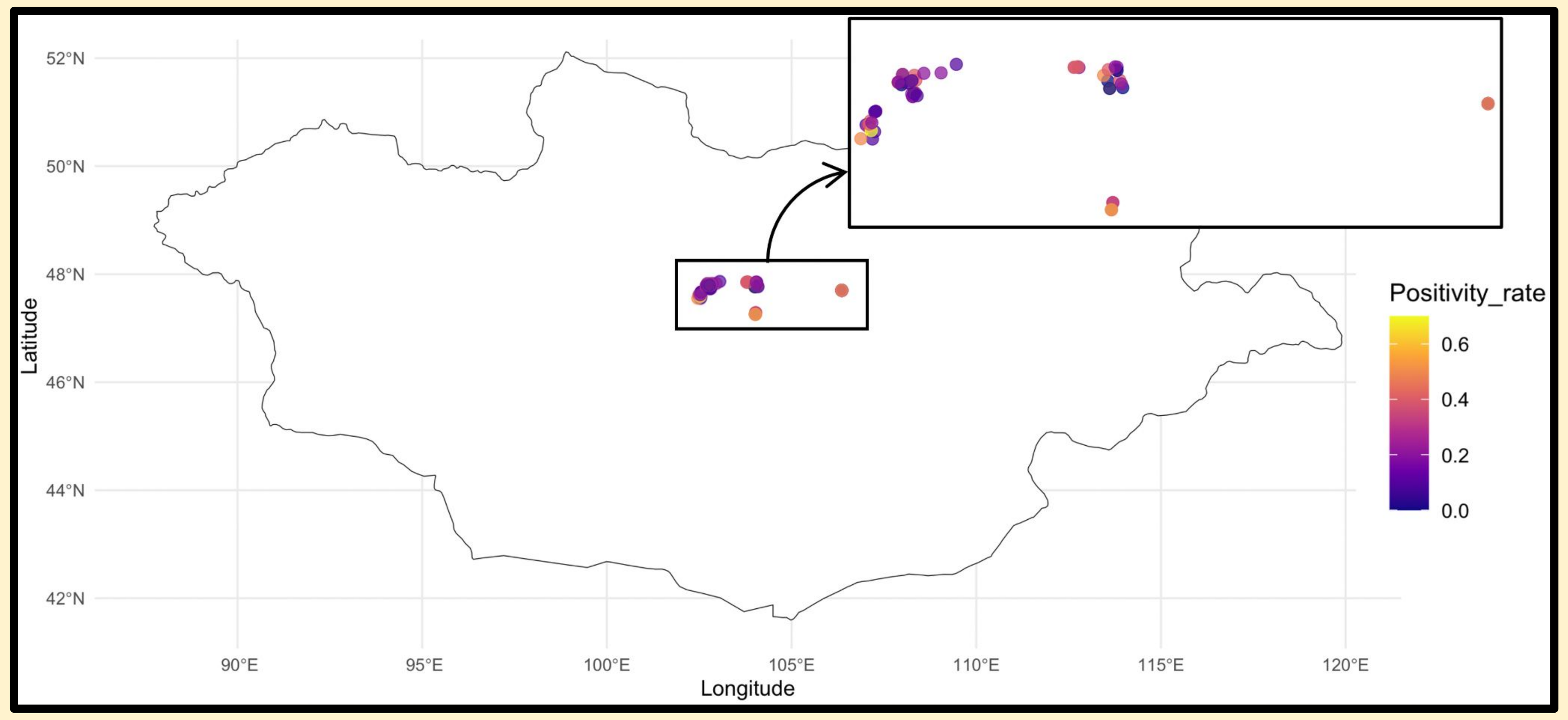


Fig. 1: Map of influenza positivity rates in horse populations in Mongolia

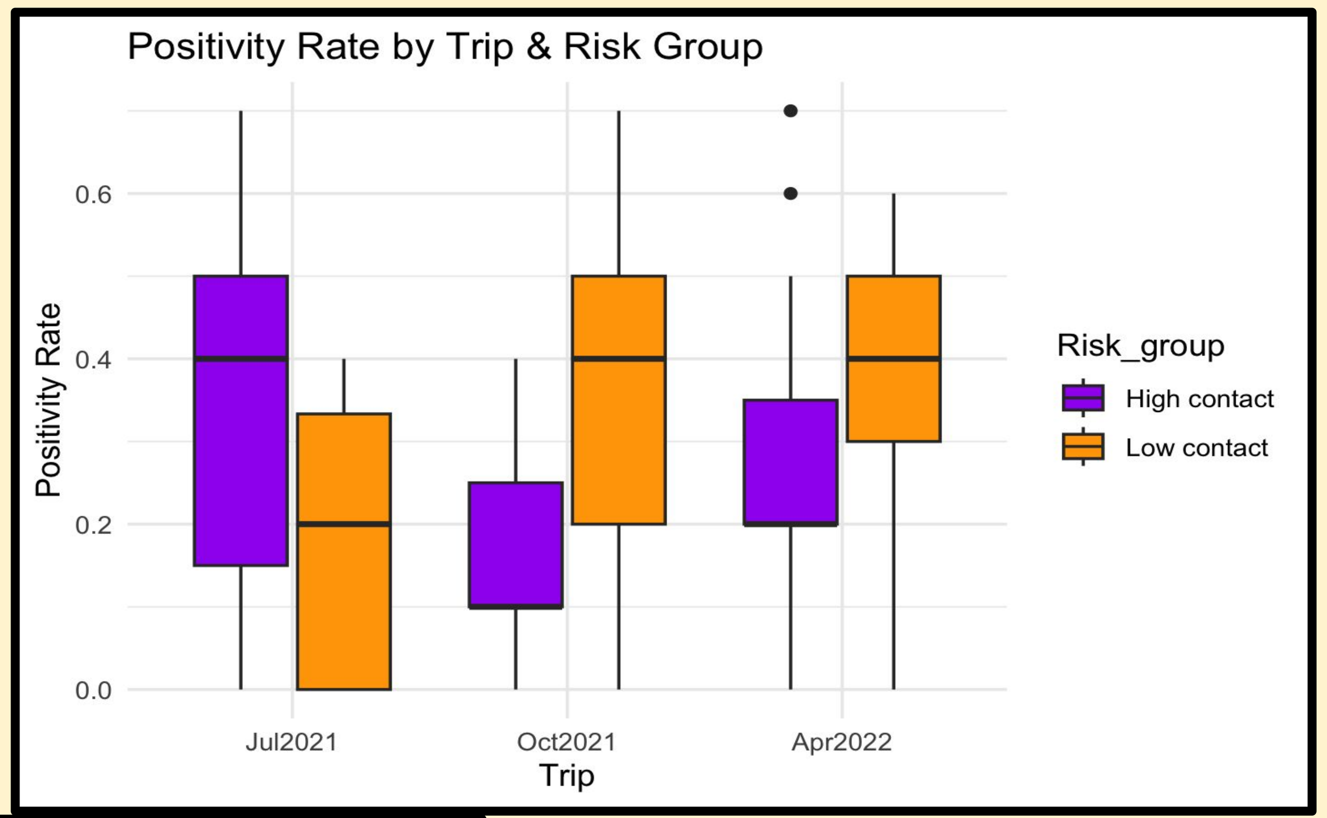


Fig. 2: Boxplot of positivity rates in Mongolian horse populations organized by risk group and trip date

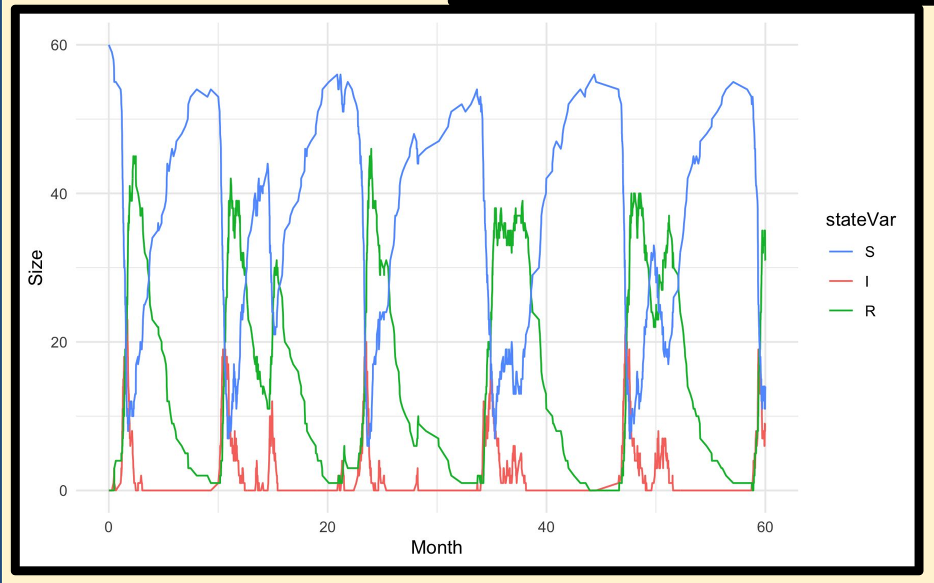


Fig. 3: Example SIR dynamics from the model with parameters mu=1/120, β=0.2, γ=4.0, λ=0.5, ω=0.5, p=0.025, a=0.05 and initial conditions S=60, I=0, R=0

- Across sites, there is variation in influenza positivity rates, from 0.0 to ~0.7 (**Fig. 1**).
- In July 2021, the positivity rate is higher among the high contact population compared to the low contact population (**Fig. 2**).
- In October 2021 and April 2022, the positivity rate is higher among the low contact population compared to the high contact population (**Fig. 2**).
- Stochastic models can use data-informed parameters to evaluate influenza dynamics and test hypotheses (**Fig. 3**).
- Models assuming strong contact transmission and seasonal exposure captured the range of observed positivity rates (**Fig. 4**).
- Additionally, this model reveals that the time of year in which populations are sampled determines whether differences in risk groups are distinguishable (**Fig. 4**).

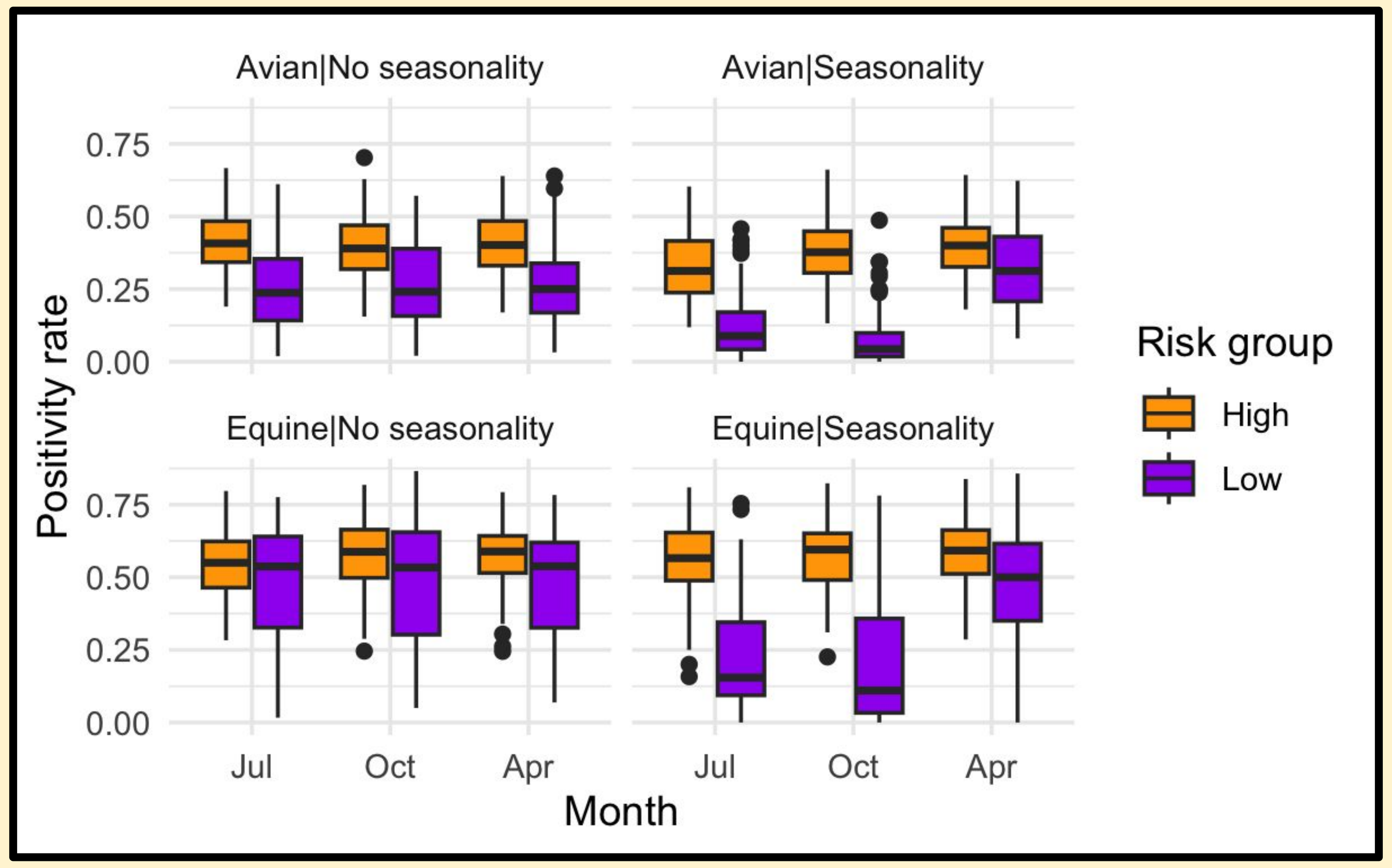


Fig. 4: Boxplot of model-generated (50 reps) influenza positivity rates according to (i) equine (R_0=3) vs. avian (R_0=1.5) strains, (ii) high risk (p=0.1) vs. low risk (p=0.025) groups, (iii) no seasonal (a=0) vs. seasonal (a=0.05) transmission, φ= +3

Conclusions

- Influenza positivity rates vary by sampling date and by risk group
- Data-informed models can generate realistic dynamics of influenza in horses
- These models suggest that influenza strains in horses are well adapted (R_0~3)
- Winter seasonal transmission recreates similar results to those observed in Mongolia (e.g., virus survives well in colder water)

References

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