Influenza A has many strains and inhabits many hosts. It is critically important to understand how likely it is that more lethal strains will cause a pandemic in the human population. One such example is H5N1 avian influenza, which has had a devastating impact in South-east Asia. In particular, since 2007, Bangladesh has had at least 550 commercial poultry premises infected and 8 human cases.

2. Objectives

i. Develop a model framework incorporating zoonotic transmission.

ii. Fit a set of models to three H5N1 avian influenza epidemic waves in Bangladesh, focussing on the Dhaka region (Fig. 1), to determine the key factors that best capture the observed cases. We used waves 2, 5 & 6 (from 2008, 2011 and 2012 respectively).

Fig. 1: Division and district boundaries of Bangladesh

Division boundaries, with Dhaka division in red.

District boundaries, with Dhaka district in red.

3. Model Formulation

Our modelling framework consists of two components:

i. Poultry component

Individual compartment based spatial model at the premises level.

- Susceptible
- Infected
- Reported
- Culled

- Compared a set of nested models, of varying complexity, for the force of infection (see Model boxes below).
- Various fixed values for delay in reporting infection: 2, 4, 7 days.
- Reporting to culling times known from data.

ii. Zoonotic transmission component

Currently assume human case occurrence is a Poisson process:

Daily Infection Rate: \( \lambda(t) = \beta I(t) + \epsilon_h \)

Daily Event Probability: \( 1 - \exp(-\lambda(t)) \)

where \( I(t) \) number of infected poultry, \( \epsilon_h \) human case spark term.

Parameter inference was performed using MCMC methods and plotting likelihood surfaces. Stochastic simulations were used to verify our model fitting procedure.

4. Results: Poultry Model

Competing models were compared using deviance information criterion (DIC). Preferred models are summarised below:

- **District**
  - Infected to Reported time: 7 days preferred.
  - (Wave 2) Model D; (Wave 5) Model A.

- **Division**
  - Infected to Reported time: 7 days preferred.
  - Model B, including exponents on premises populations.

- District level simulations obtained good correspondence with case size data (Fig. 2).
- Division level simulations found the areas infected most often lay north of the main band of observed infected premises (Fig. 3).

Fig. 2: Simulated epidemic size distribution versus observed wave 2 data at the district level.

Fig. 3: Model verification for Dhaka division wave 5 data.

(left) Observed spatial infection profile; red squares for infected premises, green circles for uninfected premises. (right) Simulated risk of infection, aggregated at a subdistrict level.

5. Results: Zoonotic Transmission

- Wave 2
- Wave 5
- Wave 6

Fig. 4: Likelihood surfaces for the zoonotic transmission model.

- Suggestion of differing causal mechanisms for human cases (Fig. 4).
  - Wave 5 suggests strong dependence on infected poultry.
  - In contrast, waves 2 and 6 gave little support to that factor.

6. Future work

Investigate the impact of control strategies applied across both humans (quarantine, anti-viral medication, vaccination) and animals (culling, vaccination, movement bans).

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