Assessing intervention responses against H5N1 avian influenza outbreaks in Bangladesh

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1. The Problem

Highly pathogenic avian influenza H5N1 remains a **persistent public health threat**, capable of causing infection in humans with a high mortality rate while simultaneously **negatively impacting the poultry production sector**. One of several countries in South and Southeast Asia gravely affected is **Bangladesh**, one of the most densely populated countries in the world [1] and a country that has suffered from recurrent H5N1 outbreaks in poultry as recently as 2012 [2]. Since 2007, there have been over 550 commercial poultry premises infected and 8 human cases.

2. Research Question

In anticipation of re-emergent H5N1 outbreaks, it is critically important to assess **the effectiveness of proposed control measures** in limiting spread between poultry premises and curbing zoonotic transmission risk.

We evaluate the predicted impact of a variety of **ring culling**, **ring vaccination** and **active surveillance** control measures, under the following considerations:

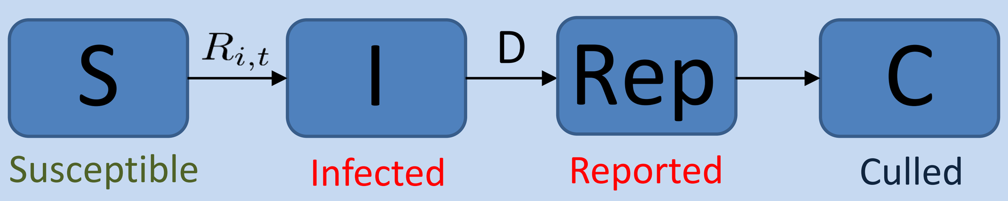
INTERVENTION SEVERITY | RESOURCE CONSTRAINTS | WHAT IS THE SPECIFIC CONTROL OBJECTIVE?

3. Model Description

Interventions assessed via simulations of a H5N1 transmission model, **previously fitted**** to historical H5N1 epidemic data from the **Dhaka division**.

i. Poultry component

Individual compartment based spatial model at the **premises level.**



Force of infection:

$$R_{i,t} = \left(\sum_{j \in \text{infectious on day } t} N^p_{c,i} \times t_c N^q_{c,j} \times K(d_{ij}) \right) + \epsilon$$

Notification Delay: D = 7 days

where $N_{c,i}$ - flock size on premises i, t_c - individual poultry transmissibility, d_{ij} - distance between premises i and j, K - transmission kernel, ϵ - spark term.

ii. Zoonotic transmission component

Daily Infection Rate:

$$\lambda(t) = \beta I_b(t) + \epsilon_h$$

Daily Event Probability:

$$1 - \exp(-\lambda(t))$$

with:

I_b - number of infected poultry,
ϵ_h - human case spark term.

**For further details of the model fitting procedure, we refer the reader to:
EM Hill et al. (2017) Modelling H5N1 in Bangladesh across spatial scales: Model complexity and zoonotic transmission risk. *Epidemics, **20C**: 37-55.* doi: 10.1016/j.epidem.2017.02.007

4. Intervention overview

Under three levels of capacity constraints (see Tables), tested these measures:

Baseline strategy: Culling of reported premises only

Ring culling/Ring vaccination: Premises within a specified distance of each location with confirmed infection are listed for culling/vaccination.

Ring radii: 1-10km (1km increments)**; Prioritisation:** Outside-to-centre
Vaccine efficacy: 70% of flock protected/unable to transmit infection;
Vaccine effectiveness delay: 7 days

Active surveillance: For targeted premises, notification delay reduced **(D = 2 days)**

Four prioritisation schemes analysed

- 'Reactive by distance', 'Reactive by population', 'Proactive by population', 'Proactive by density'

Interventions at poultry-human interface: Human targeted measures

- Captured by scaling ϵ_h (50%, 75%, 100% reduction)

Tables: Control capacity constraint scenarios for **(a)** culling/vaccination (daily limits); **(b)** Active surveillance.

(a)

	Birds	Premises
Low	20,000	20
Medium	50,000	50
High	100,000	100

(b)

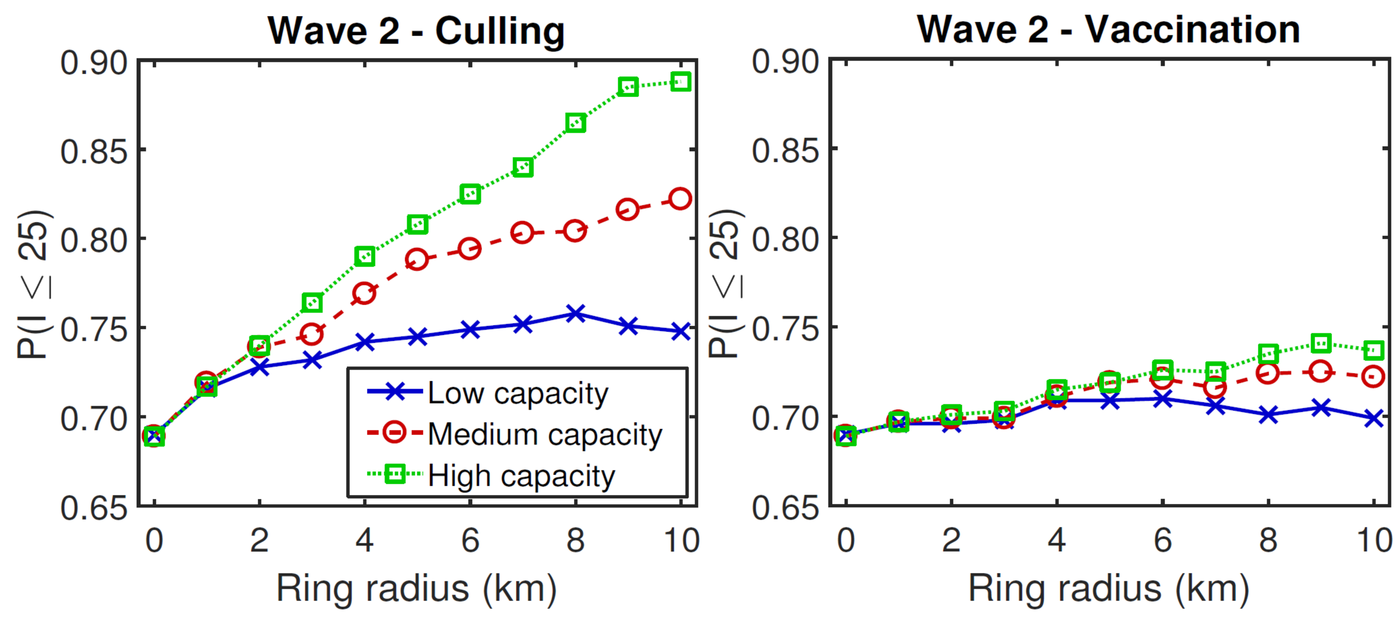
	Reactive scheme (per outbreak)	Proactive scheme (% premises popn.)
Low	25	5%
Medium	50	10%
High	100	25%

5. Results: Poultry transmission

Ring culling/Ring vaccination

– For case size control objective, culling **outperforms** vaccination (Fig. 1).

Fig. 1: Predicted probability of outbreak size being 25 premises or less.



– If minimising poultry culled, ring vaccination is preferred. **Disparities across capacity constraints** appear from 3km and above (Fig. 2).

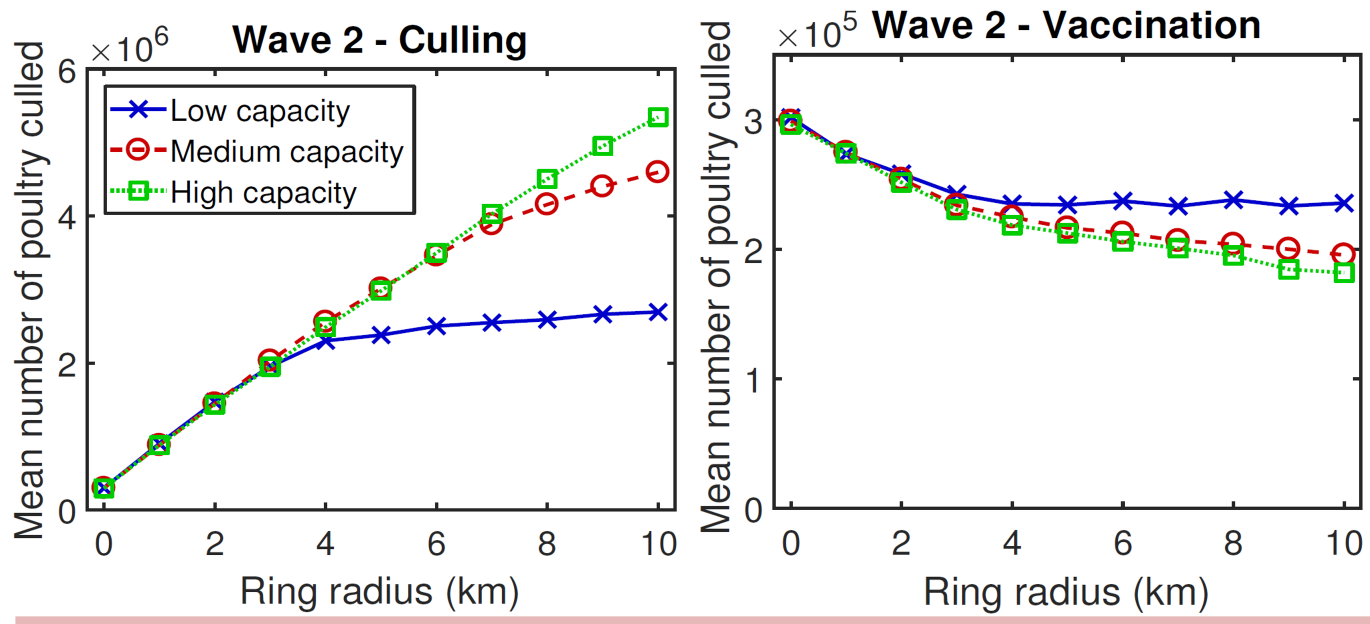
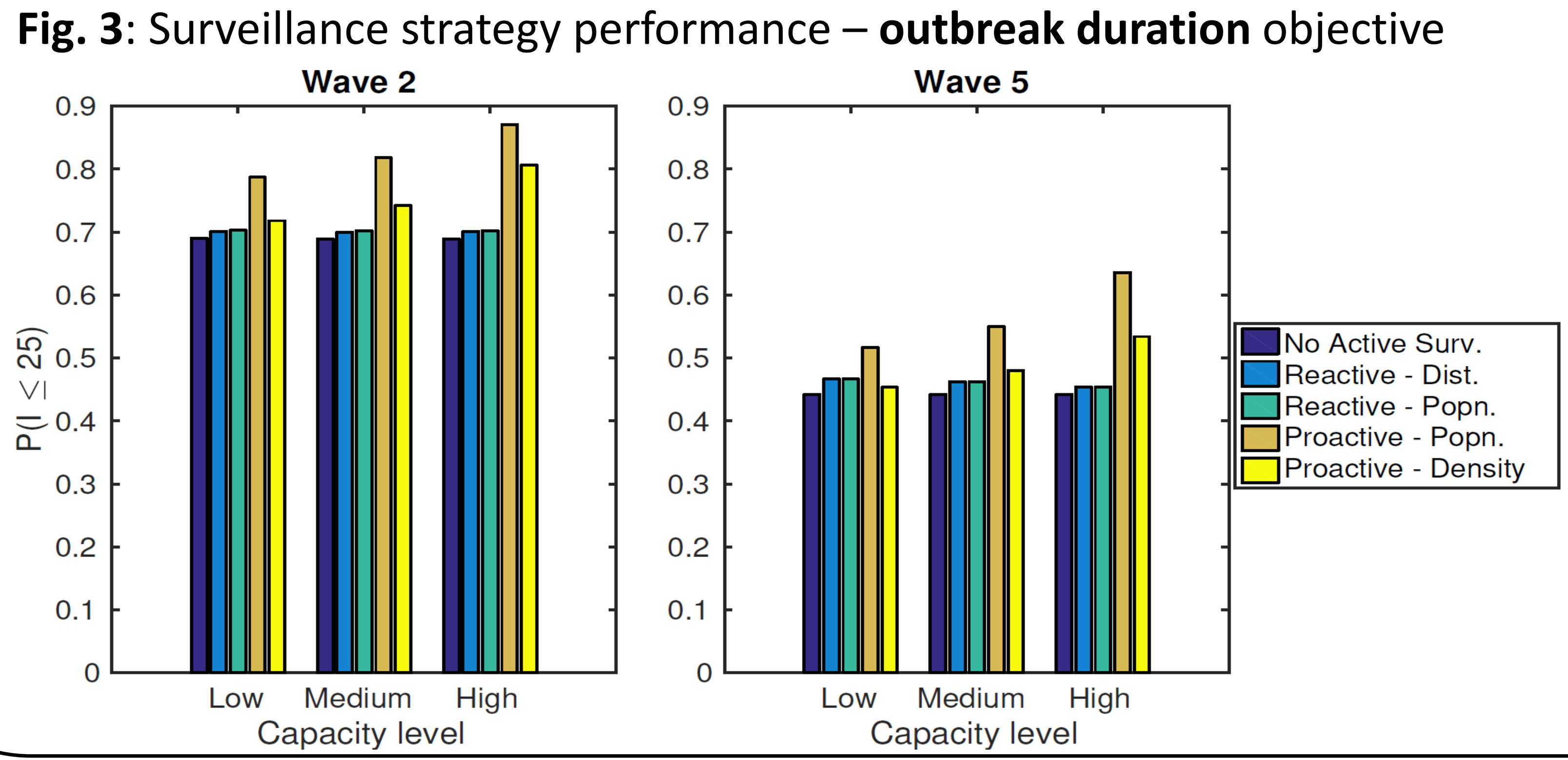


Fig. 2: Mean number of poultry culled, under various ring culling/vaccination radii.

Active surveillance

– Across control objectives and capacities, **'proactive by population'** the top performing surveillance option (one example shown in Fig. 3).

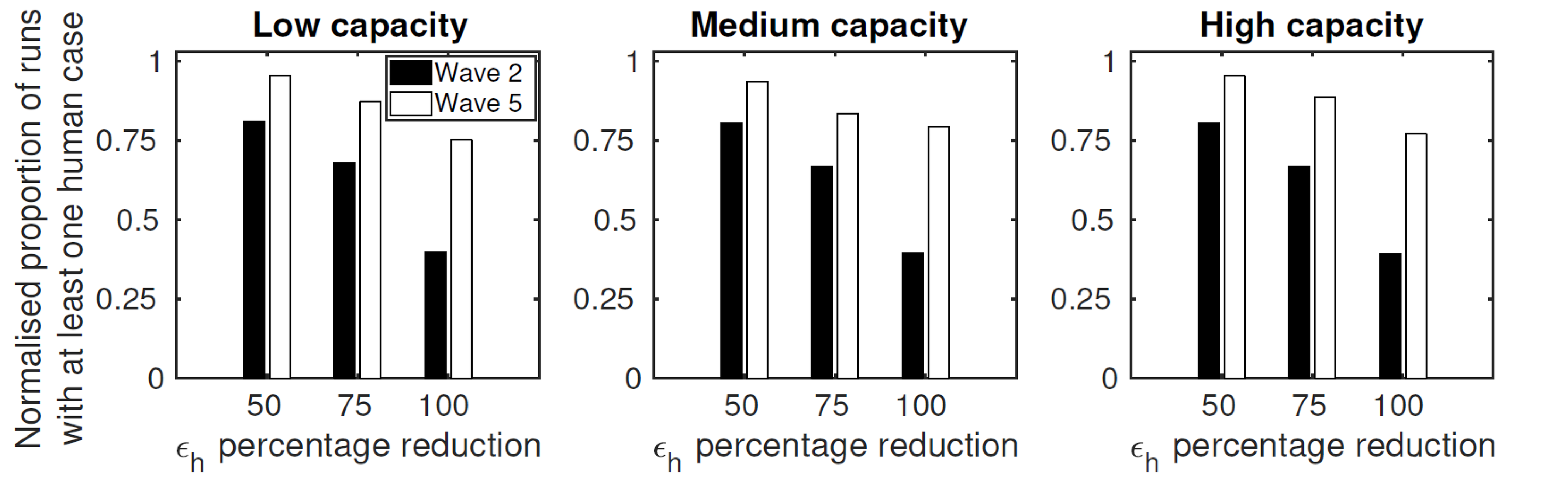
Fig. 3: Surveillance strategy performance – **outbreak duration** objective



6. Results: Zoonotic spillover

- Under wave 2 type outbreak dynamics, **potential for vast cuts** in spillover risk (Fig. 4).

Fig. 4: Zoonotic spillover intervention performance



7. Conclusions

- Reactive culling and vaccination control policy impact **highly dependent** upon epidemiological characteristics, control objectives and capacities.
- Proactive surveillance schemes **significantly outperform** reactive procedures.
- Human targeted control measures can **severely diminish** the risk of spillover events.

Further work:

Compare these conventional schemes with innovative interruption strategies that modify the poultry production system (e.g. intermittent government purchase plans).

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References

A preprint of this work is available on *bioRxiv*: EM Hill et al. (2017) The impact of surveillance and control on highly pathogenic avian influenza outbreaks in poultry in Dhaka division, Bangladesh. *bioRxiv.* doi: 10.1101/193177

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