# Potential effect of school closure on a UK COVID-19 epidemic

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## Model used

We use an adapted version of the individual-based simulation previously used to inform UK influenza pandemic planning (1,2). To briefly summarise, this model has the following features:

- Spatially explicit and individually based: models the entire population of England, Scotland and Wales (64.4 million).
- Transmission in households, school/work locations, and other spatially local included.
- Distribution of schools and workplaces and distances travelled to each matched against national data.
- Household size and age distributions are matched to UK census data.
- Spatially localised transmission modelled using a gravity model to represent probability of contact, parameterised against GB mobility data, accounting for age variation.
- Proportion of transmission occurring in households and schools matched to influenza data. Transmission in workplaces assumed to occur at half the efficiency of schools. All other transmission assumed to be spatially local and mass action.
- In the absence of immunity, approximately 1/3 of transmission occurs in each of (a) households, (b) schools and workplaces, and (c) other spatially local contacts.
- The simulation includes an explicit representation of absenteeism- both due to sickness, and due to caring for sick (or well, in the case of school closure) children in the household.
- School holidays are included.
- The model broadly reproduces the age-dependent mixing rates seen in POLYMOD and similar data.

## COVID-19 specific parameterisation

- For COVID-19, assume incubation period with mean 5.1 days, SD 4.4 days (estimated from traveller case data).
- Infectiousness assumed to start 0.5 days before symptom onset, follows a time varying infectiousness profile (which peaks 0.5 days after symptom onset) to give an overall generation time with mean 6.5 days, SD 3.8 days. This matches current estimates from contact tracing studies.
- We model exponentially growing seeding of infection into the UK, with a 5-day doubling time. This study is not intended to examine the impact of case isolation, and results regarding school closure are not sensitive to seeding assumptions.
- 2/3 of all infections assumed to be symptomatic (at least mildly). 25% of symptomatic children assumed to attend school, 50% of symptomatic adults to attend work.
- Symptomatic infections 1.5-fold more infectious than asymptomatic, but 50% as likely to make spatially local contacts.

- $R_0$ =2.1 gave a 5-day epidemic doubling time.
- We explore 3 parameter scenarios to examine the impact of school closure:
  A. Children and adults equally susceptible to infection and equally likely to transmit. Closure of schools increases household contact rates by 25%, has no effect on other transmission.
  B. Children and adults equally susceptible to infection and equally likely to transmit. Closure of schools increases household contact rates by 50%, increases spatially local other contacts by 25%.
  C. Only 20% of under 20-year-olds symptomatic, average susceptibility of those under 20 assumed to be 75% of that of adults (increasing with age). Closure of schools increases household contact rates by 50%, increases spatially local other contacts by 25%.

## School closure scenarios examined

We consider national school closure triggered by national weekly symptomatic disease incidence triggers. We assume 90% of symptomatic disease can be detected (e.g. via a community-based surveillance system such as FluSurvey). We explore incidence triggers between 100 and 6000 cases per 100,000 of population per week, and durations of closure between 2 weeks and 32 weeks. We vary $R_0$ between 1.7 and 2.9.

We evaluate impacts of school closure via three summary statistics: (a) reduction in cumulative final symptomatic attack rate; (b) reduction in peak symptomatic incidence; (c) extent to which peak incidence is delayed.

## Results

Figure 1 illustrates the timing and impact of school closure for the three parameter scenarios explored and different trigger incidence thresholds. The longest duration of closure examined (32 weeks) is shown, for the central estimate of $R_0$ (2.1) given the serial interval assumed (giving an epidemic doubling time of 5 days). A visual representation of the epidemic for $R_0$=2.1 and no deliberate school closure is shown in the Appendix Figure.

Figure 2 summarises the impact of school closure for the three different parameter scenarios and a range of trigger incidence thresholds and durations of school closure.

Figure 3 summarises sensitivity to $R_0$ for parameter scenario B (other scenarios show similar patterns).

## Conclusions

- School closure needs to be carefully timed and started early, when incidence is <5% of its peak value (e.g. 300 cases per 100,000 per week) for maximum impact.
- 8-12 weeks of closure are required for maximum reduction of peak incidence.
- However, such a closure period is predicted to achieve a reduction in peak incidence of >40% for the central estimate of $R_0$ examined (2.1).
- School closure can achieve up to a ~20% in overall attack rate, but this typically requires 16 or more weeks of closure.
- For closure initiated early, peak incidence can be delayed by 1 to 3 weeks depending on scenario, for $R_0$=2.1.
- Impact is reduced for larger $R_0$ values, increased for smaller ones.

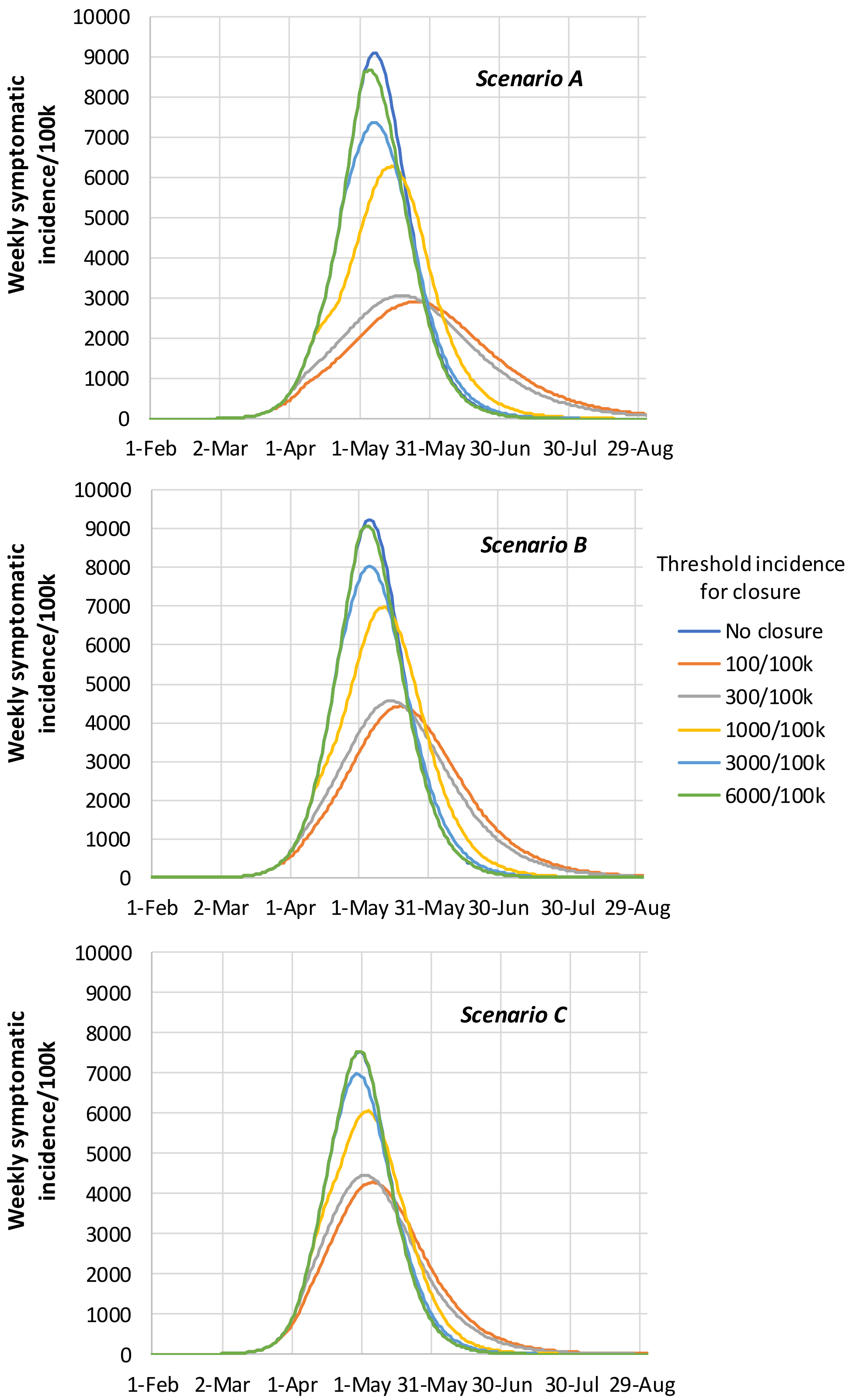



**Figure 1: Impact of 32 weeks of school closure for a range of incidence triggers, for parameter Scenarios A-C and $R_0$=2.1. Model has been only crudely calibrated to expected importations, so peak timing is approximate, and may occur later.**

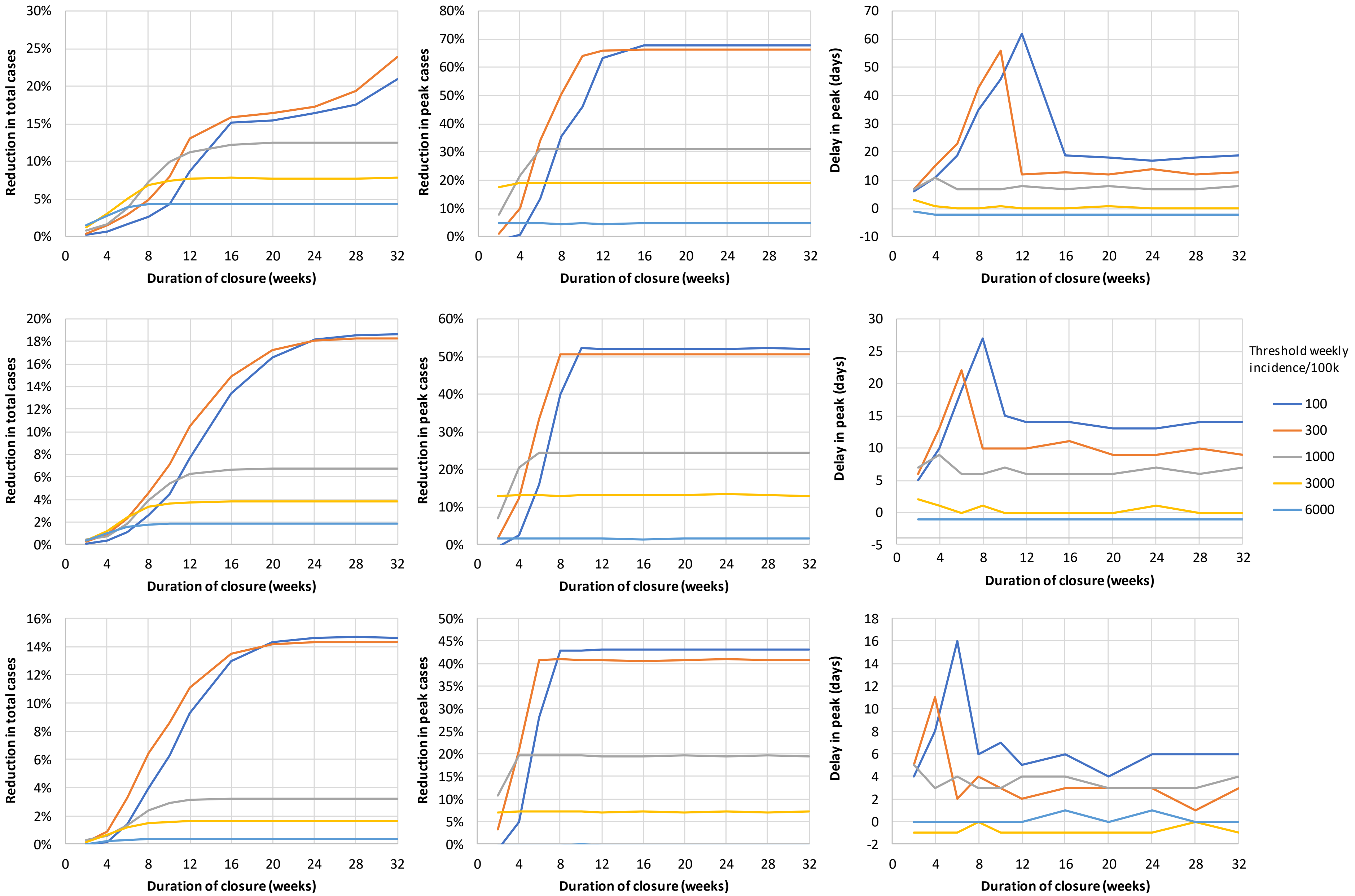



**Figure 2: Impact of school closure for a range of incidence triggers, for parameter Scenarios A-C (top row to bottom) and $R_0$=2.1. Right column shows impact on overall attack rate in first 18 months, middle column impact on peak incidence, and right column on epidemic peak timing. Spikes in the delay in peak (right column) are caused by double-peaked epidemics.**

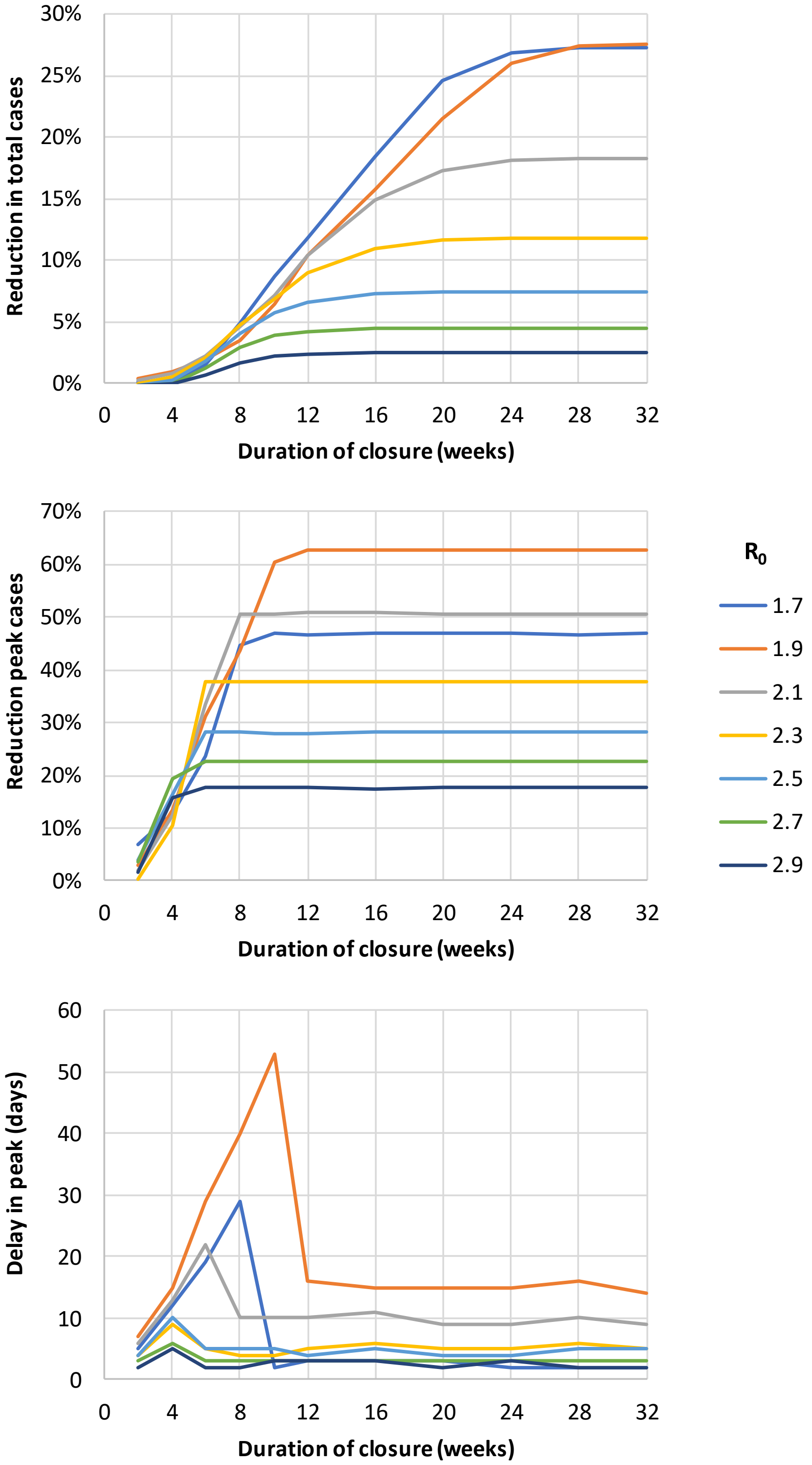



**Figure 3: Impact of school closure for an incidence trigger of 300/100k per week, for parameter Scenario B and a range of values of $R_0$. Top shows impact on overall attack rate in first 18 months, middle row impact on peak incidence, and bottom on epidemic peak timing.**

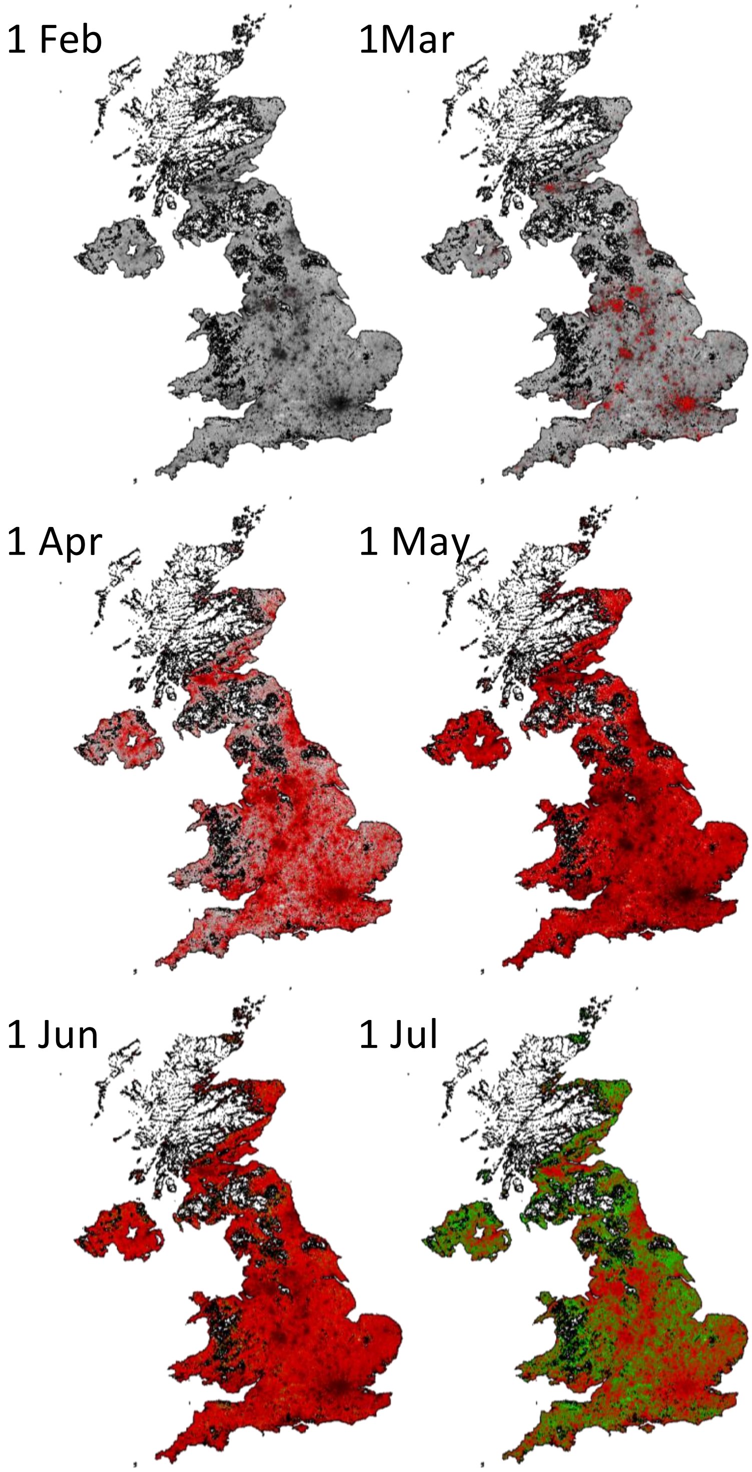
## References

1. Ferguson, N.M., D.A. Cummings, S. Cauchemez, C. Fraser, S. Riley, A. Meeyai, S. Iamsirithaworn, and D.S. Burke, *Strategies for containing an emerging influenza pandemic in Southeast Asia.* Nature, 2005. **437**(7056): p. 209-14.

2. Ferguson, N.M., D.A. Cummings, C. Fraser, J.C. Cajka, P.C. Cooley and D.S. Burke, *Strategies for mitigating an influenza pandemic*. Nature 2006;**442**(7101):448-52.

## Appendix Figure

Visualisation of monthly snapshots of the simulated epidemic without deliberate school closure, for $R_0$=2.1



## Appendix II Figure

Impact of school closure on peak incidence, for a range of values of $R_0$ and for parameter scenarios A-C. Results for optimal trigger in each case shown.