Estimating epidemic risks using branching process models

Robin Thompson

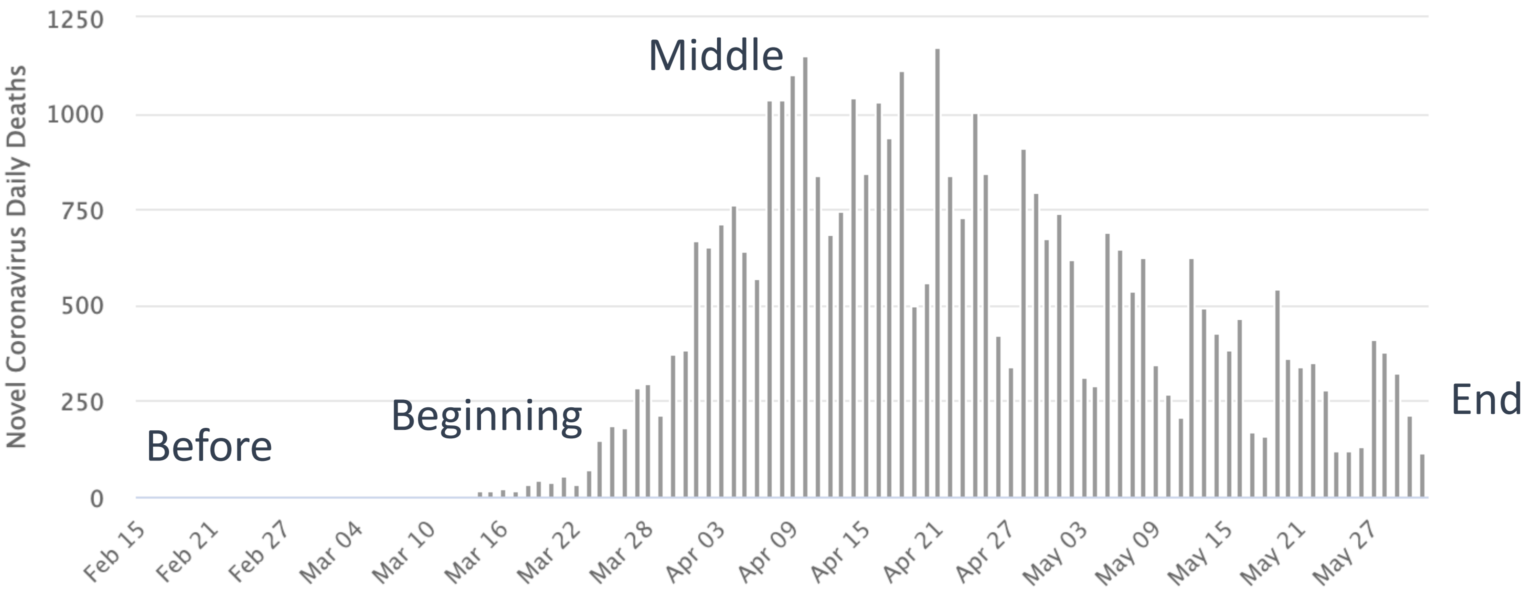
Associate Professor, Mathematical Institute and St Hilda's College, University of Oxford

Modelling for real-time outbreak response






Modelling for real-time outbreak response



Before

- Where is an outbreak most likely to occur?
- Where should surveillance resources be deployed?

Beginning

- Will initial cases lead to a major epidemic?
- Which interventions reduce the epidemic risk?

Middle

- How effective are current interventions?
- Which interventions will minimise numbers of cases?

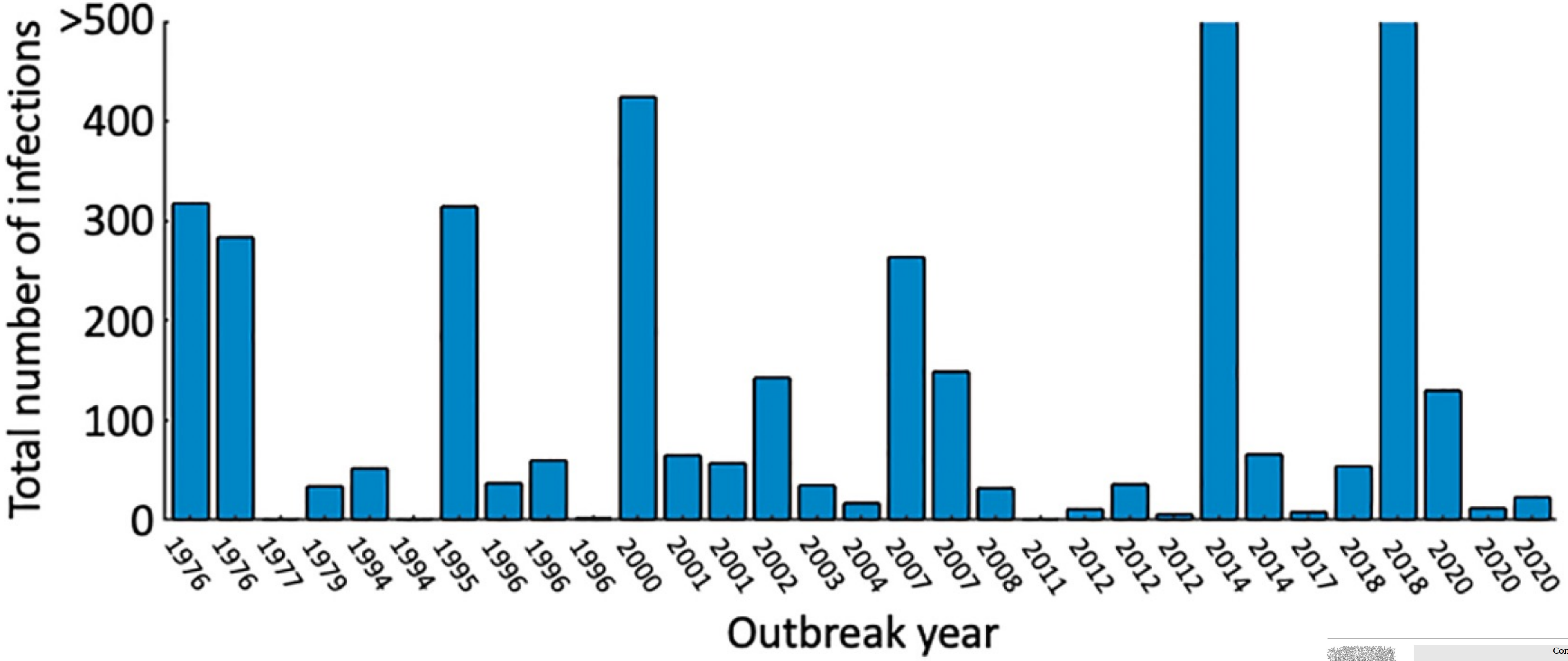
End

- How should interventions be lifted?
- Is the epidemic over?

Assessing the risk of a major epidemic

When a pathogen first arrives in a new host population,
will initial cases fade out, or will they lead to sustained local transmission?

Assessing the risk of a major epidemic



Contents lists available at ScienceDirect

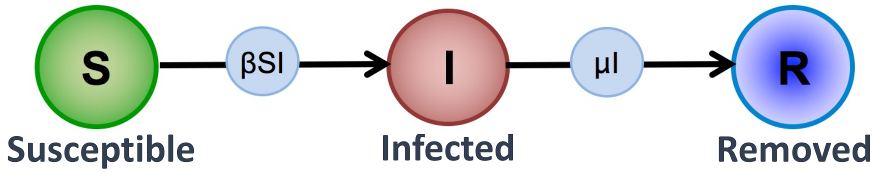
Journal of Theoretical Biology

journal homepage: www.elsevier.com/locate/yjtbi

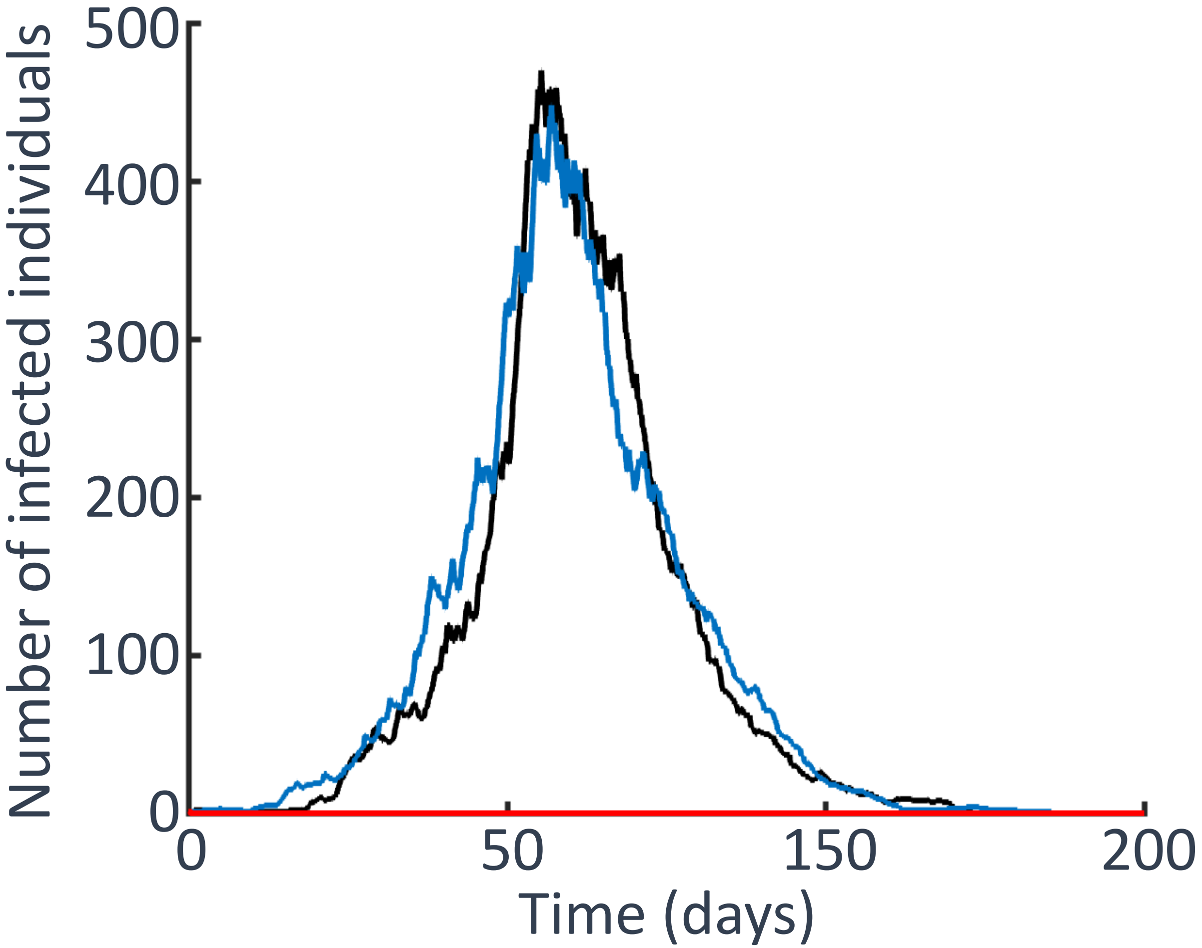
A practical guide to mathematical methods for estimating infectious disease outbreak risks

E. Southall [a,b], Z. Ogi-Gittins [a,b], A.R. Kaye [a,b], W.S. Hart [c], F.A. Lovell-Read [c], R.N. Thompson [a,b,*]

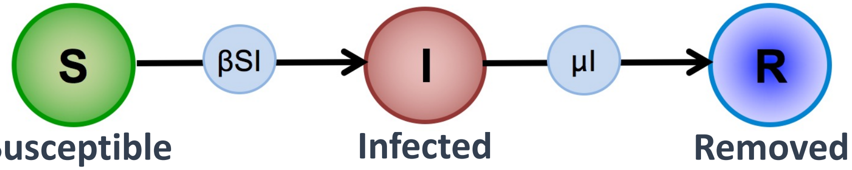
Assessing the risk of a major epidemic



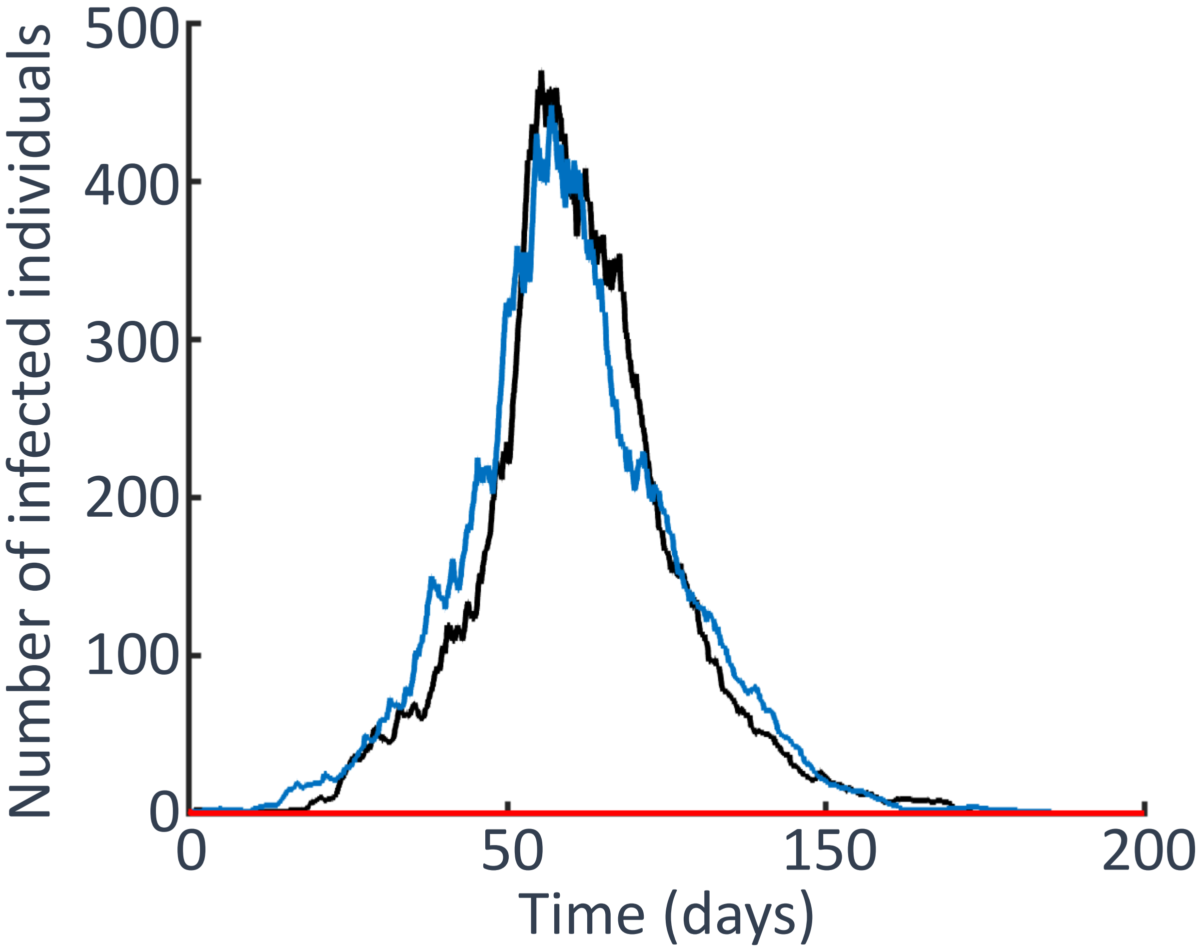
When a pathogen first arrives in a new population, there are two possibilities for what happens next

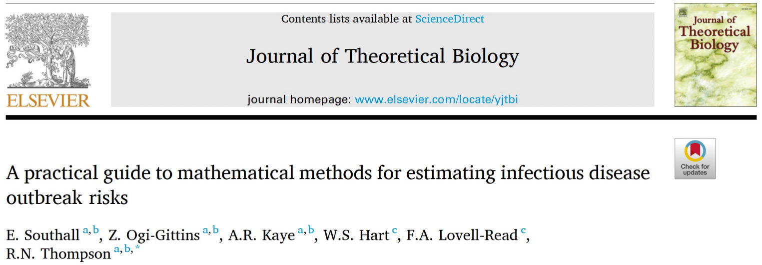


Assessing the risk of a major epidemic



Epidemic Risk: Can be calculated analytically using "branching processes"





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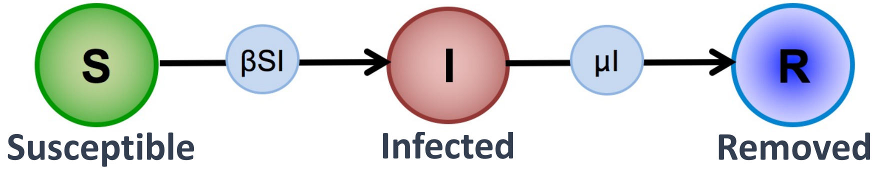
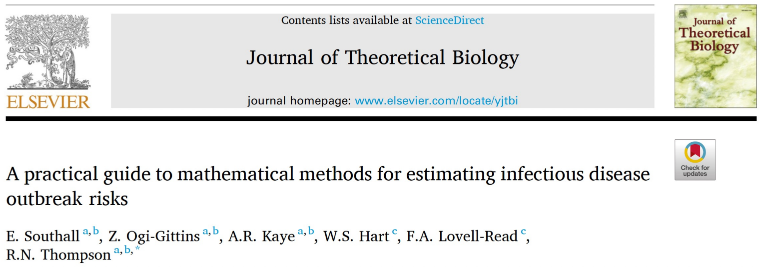
Assessing the risk of a major epidemic



- Assume we start with one infected individual
- Denote q_i = Prob(<u>no</u> major epidemic starting from *i* infected individuals)
- Want to find $1 - q_1$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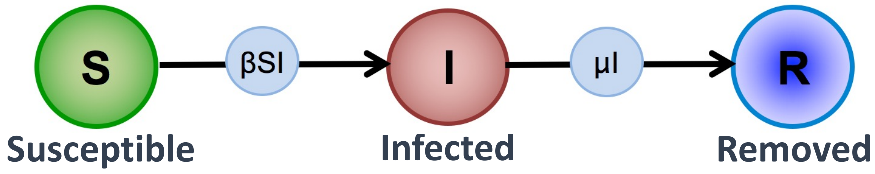
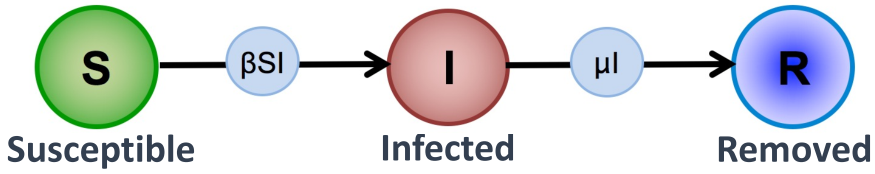


Two possibilities for the next event: infection or recovery

$$q_1 = \mathbb{P}(\text{infection}) \times q_2 + \mathbb{P}(\text{recovery}) \times q_0$$

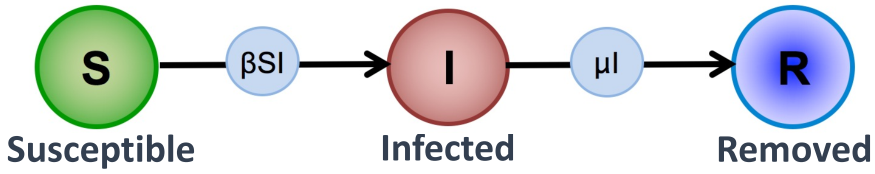
Assessing the risk of a major epidemic



Two possibilities for the next event: infection or recovery

$$q_1 \approx \mathbb{P}(\text{infection}) \times {q_1}^2 + \mathbb{P}(\text{recovery})$$

Assessing the risk of a major epidemic



Two possibilities for the next event: infection or recovery

$$q_1 \approx \mathbb{P}(\text{infection}) \times {q_1}^2 + \mathbb{P}(\text{recovery})$$

$$q_1 = \frac{1}{R_e} \text{ or } 1 \qquad ER = 1 - q_1 = 1 - \frac{1}{R_e}$$

INTERFACE

royalsocietypublishing.org/journal/rsif

Research

Will an outbreak exceed available resources for control? Estimating the risk from invading pathogens using practical definitions of a severe epidemic

R. N. Thompson[1,2], C. A. Gilligan[3] and N. J. Cunniffe[3]

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INTERFACE

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Research

Interventions targeting non-symptomatic cases can be important to prevent local outbreaks: SARS-CoV-2 as a case study

Francesca A. Lovell-Read[1,†], Sebastian Funk[3], Uri Obolski[4,5], Christl A. Donnelly[2,6] and Robin N. Thompson[1,3,7,8]

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Estimating local outbreak risks and the effects of non-pharmaceutical interventions in age-structured populations: SARS-CoV-2 as a case study

Francesca A. Lovell-Read[a,*], Silvia Shen[a,b], Robin N. Thompson[c,d]

PLOS COMPUTATIONAL BIOLOGY

RESEARCH ARTICLE

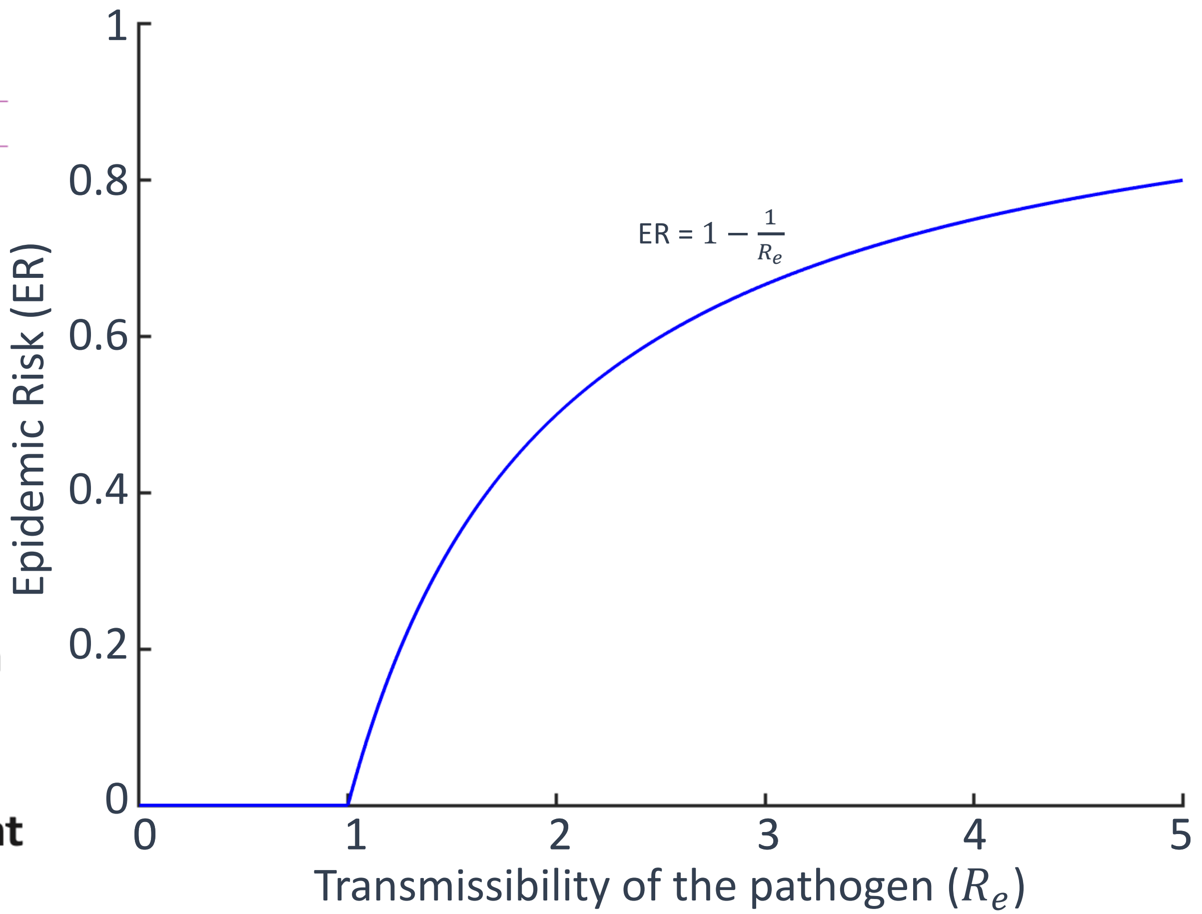
Detecting Presymptomatic Infection Is Necessary to Forecast Major Epidemics in the Earliest Stages of Infectious Disease Outbreaks

Robin N. Thompson*[a], Christopher A. Gilligan, Nik J. Cunniffe

Sustained transmission of Ebola in new locations: more likely than previously thought

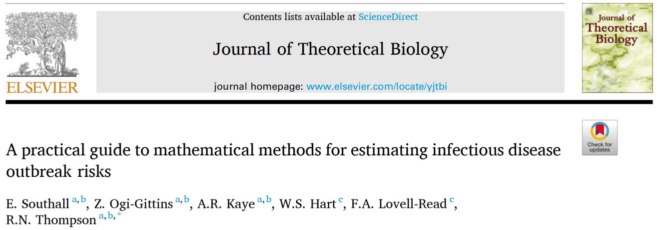
THE LANCET Infectious Diseases

*Robin N Thompson, Katri Jalava, *Uri Obolski*



Initial steps

1. Review methods for estimating epidemic risks using branching processes



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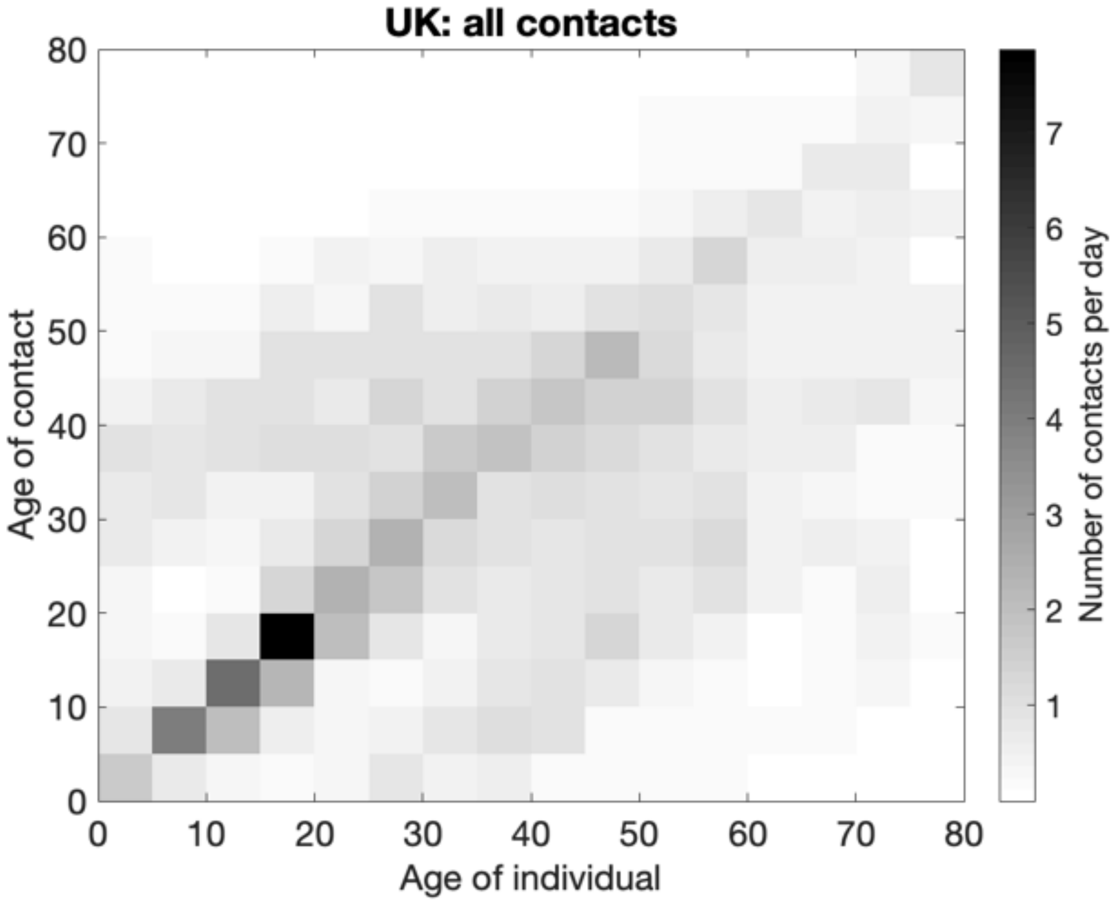
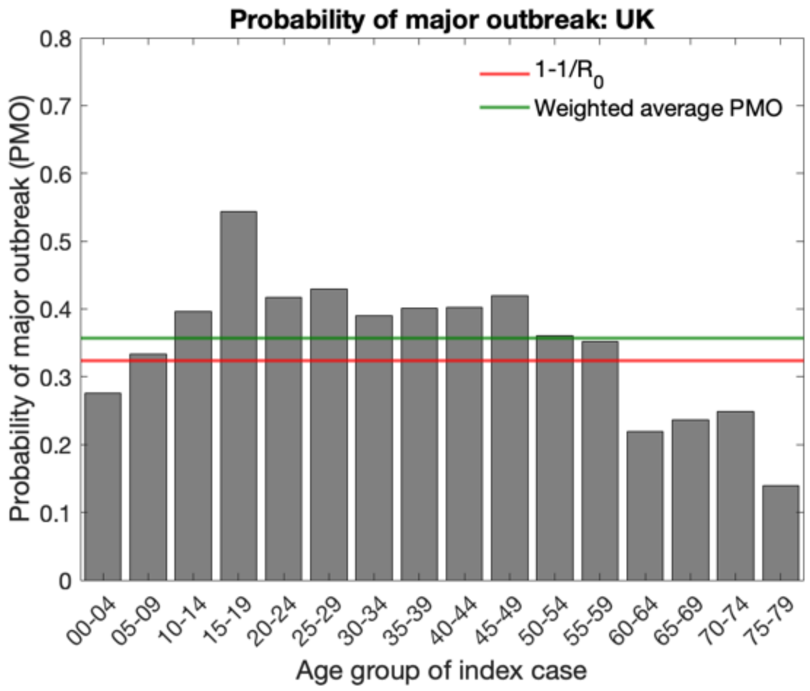
2. Code up stochastic SIR model, and calculate the epidemic risk: i) Analytically; ii) Using model simulations

3. Extend the approach to a more complex model

Age structure

$$q_{i,j,k,\dots} = \text{Prob}(\text{no major epidemic} \mid i \text{ in age group } 1, j \text{ in age group } 2, k \text{ in age group } 3, \dots.)$$





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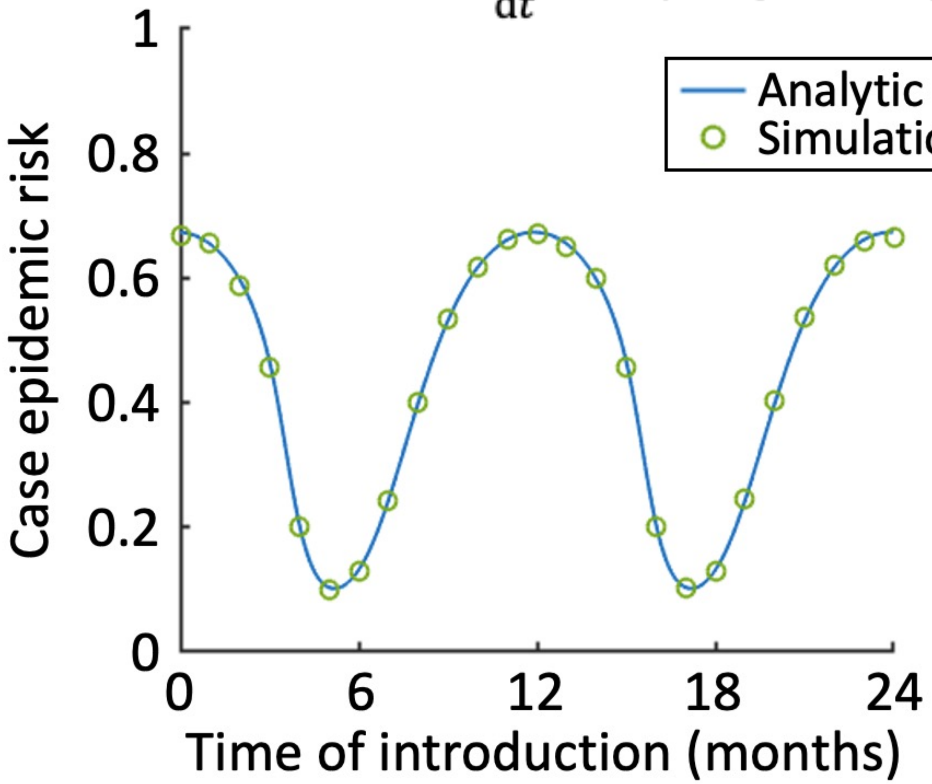
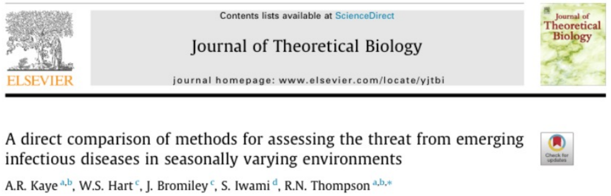
Francesca A. Lovell-Read [a,*], Silvia Shen [a,b], Robin N. Thompson [c,d]

Time-dependence

$$q(1,t) = q(2,t+\Delta t)\beta(t)N\Delta t + q(0,t+\Delta t)\mu\Delta t + q(1,t+\Delta t)(1-\beta(t)N\Delta t - \mu\Delta t).$$

$$\frac{\mathrm{d}q_1(t)}{\mathrm{d}t} = -\beta(t)q_1(t)^2 + (\beta(t)+\mu(t))q_1(t) - \mu(t).$$

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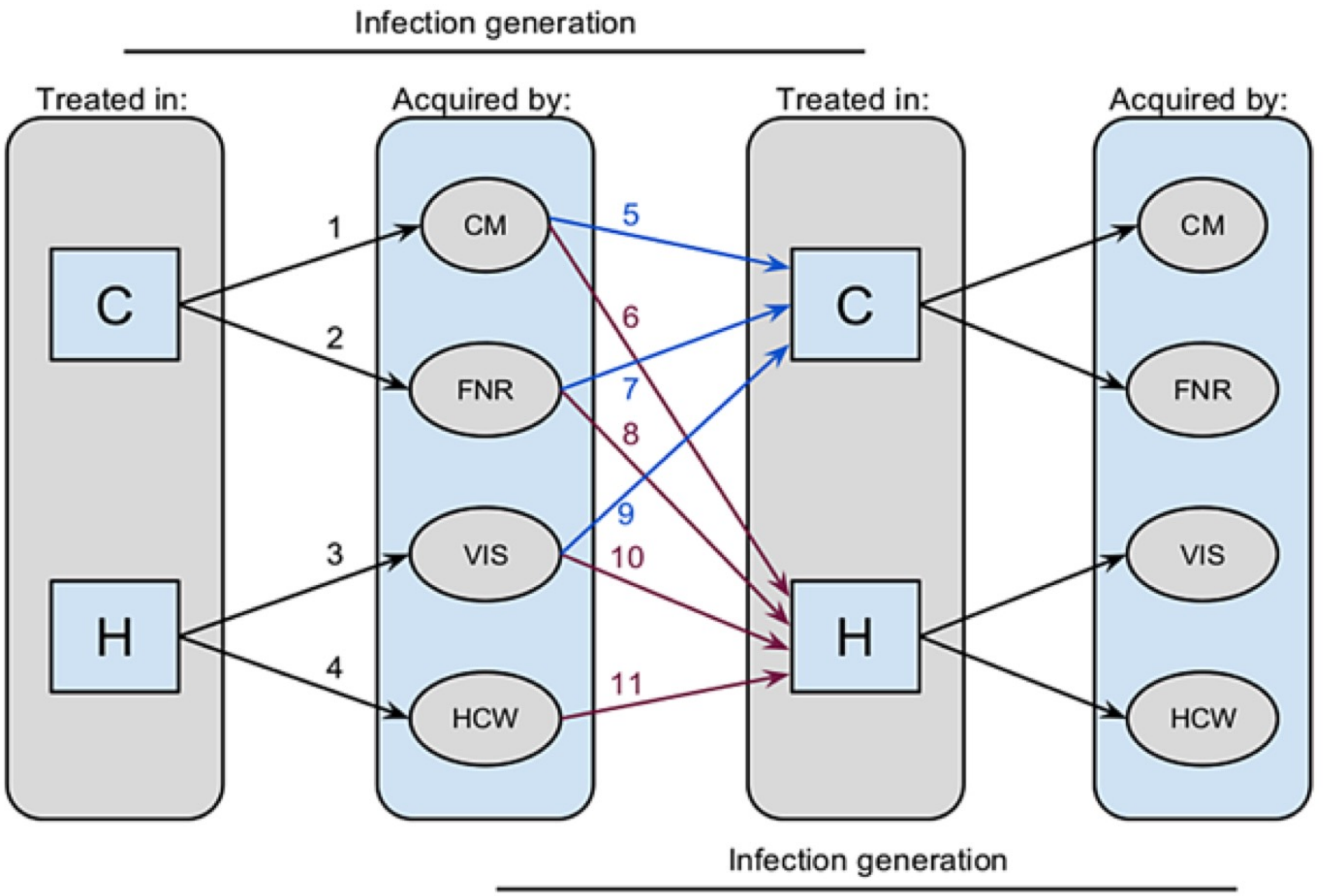
A direct comparison of methods for assessing the threat from emerging infectious diseases in seasonally varying environments

A.R. Kaye [a,b], W.S. Hart [c], J. Bromiley [c], S. Iwami [d], R.N. Thompson [a,b,*]

Possible direction for the project?



PLOS | BIOLOGY

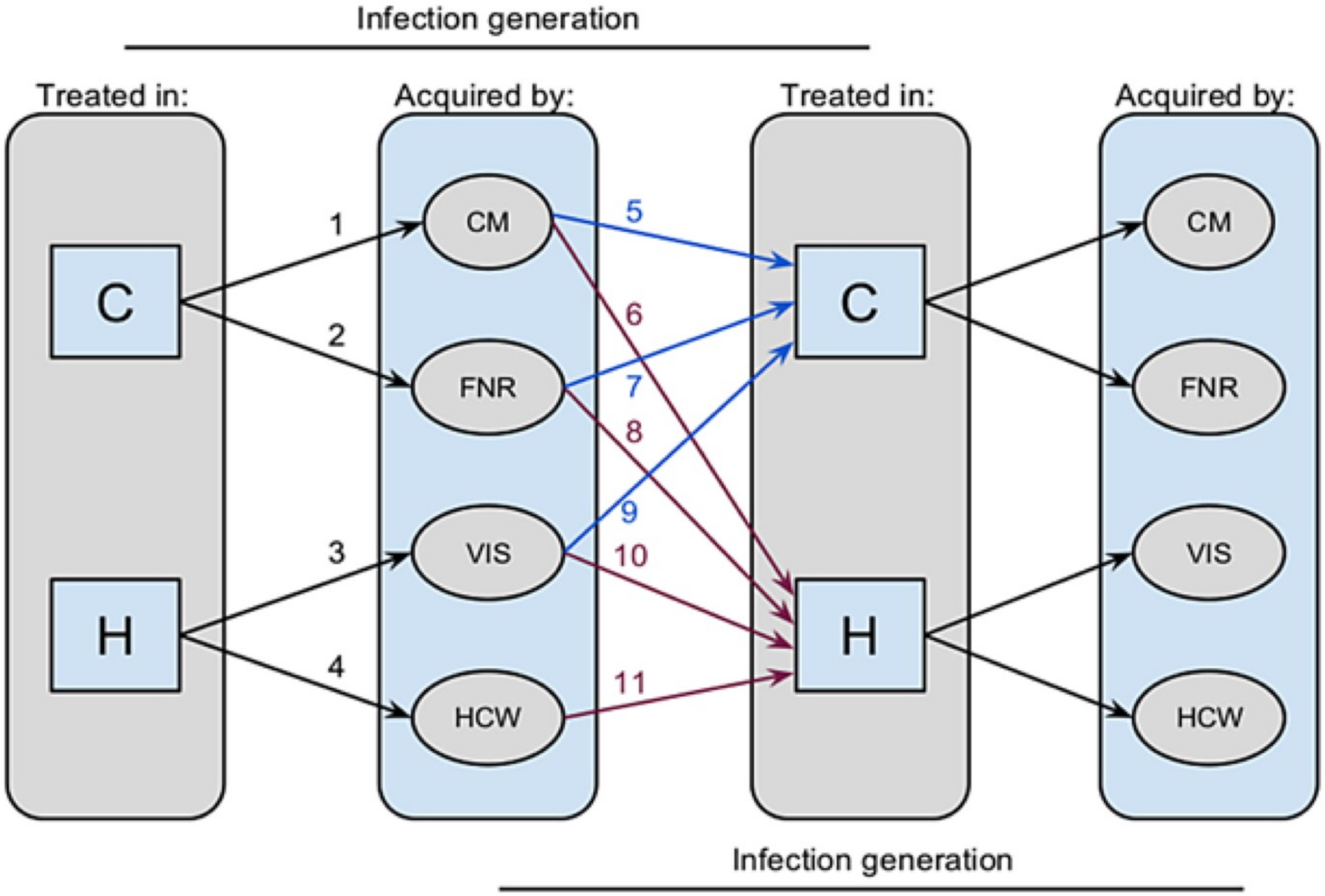
RESEARCH ARTICLE

Ebola Cases and Health System Demand in Liberia

John M. Drake[1]*, RajReni B. Kaul[1], Laura W. Alexander[1], Suzanne M. O'Regan[1], Andrew M. Kramer[1], J. Tomlin Pulliam[1], Matthew J. Ferrari[2], Andrew W. Park[1,3]

Aim 1: Calculate the epidemic risk for this model!

Possible direction for the project?



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Aim 2: Use the model to test a range of interventions:
- safe burials
- restrictions in hospital
- vaccination
- viral treatment

Thank you!

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robin-thompson.co.uk/publications

X @RobinNThompson