Critical weaknesses in shielding strategies for COVID-19

Cameron Smith[1], Christian Yates[1] and Ben Ashby[1,2,3]
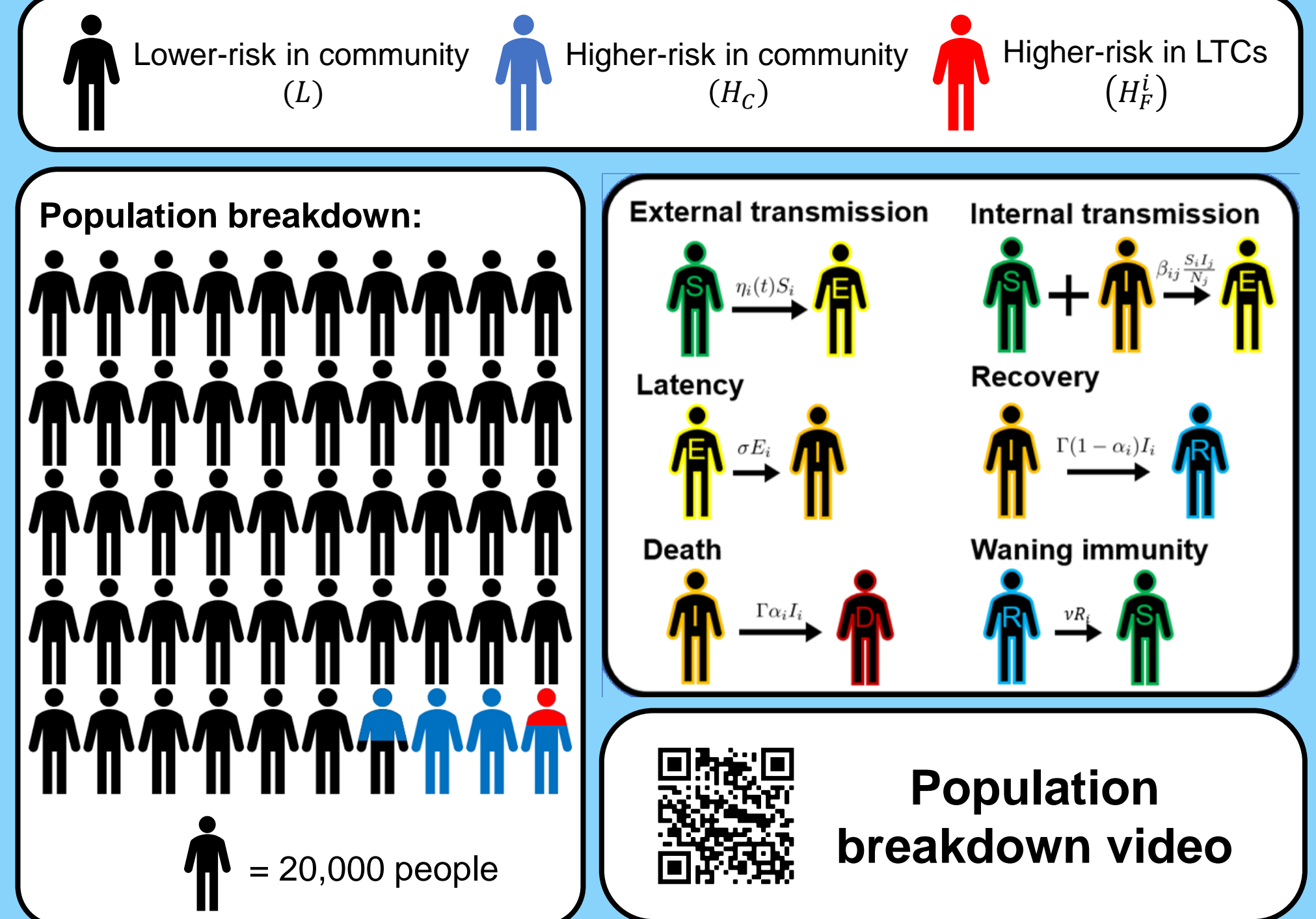
Motivation

Shielding strategies[1-3] – protecting the elderly and infirm to leverage the uneven risk profile for COVID-19 – have been suggested as alternatives to damaging lockdowns and other non-pharmaceutical interventions (NPIs) throughout the pandemic.

We aim to establish the viability of such strategies, whether there are **consequences** to ending shielding, and to understand the effects of behaviours such as **voluntary reductions in contacts** or **external infections** entering the population.

We use a **stochastic SEIR** model on a location- and risk-stratified population.

Population and interactions

Lower-risk in community (L)   Higher-risk in community (H_C)   Higher-risk in LTCs (H_F)

Population breakdown:

= 20,000 people

External transmission   Internal transmission
Latency   Recovery
Death   Waning immunity

Population breakdown video

Shielding matrix

q_{ij} - Effectiveness of shielding between type i and j contacts. 0 is no contact, 1 is all usual contacts.

Characterised by six values:

q_1 - ($L \leftrightarrow L$); q_2 - ($H_C \leftrightarrow H_C$); q_3 - ($H_F \leftrightarrow H_F$);
q_4 - ($L \leftrightarrow H_C$); q_5 - ($L \leftrightarrow H_F$); q_6 - ($H_C \leftrightarrow H_F$).

No shielding:
$q_k = 1$, for every k.
Perfect shielding:
$q_1 = 1, q_k = 0$ for $k \neq 1$.
Imperfect shielding:
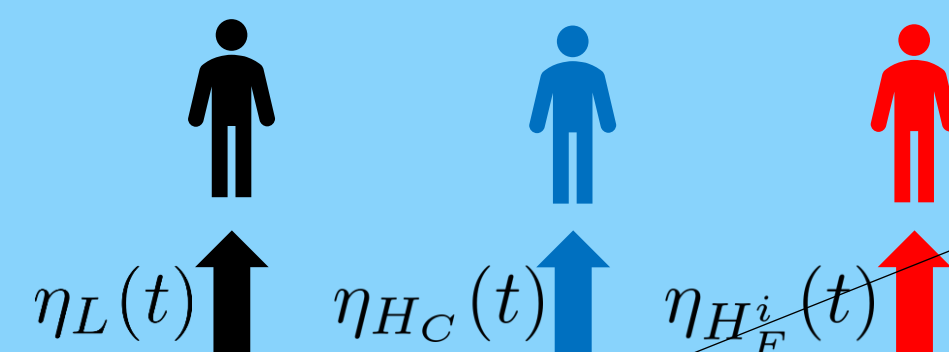$q_1 = 1, q_6 = 0, q_k = 0.2$ for $k \neq 1,6$.

External infections

$\eta_i(t)$ - External infection rate:

Can only affect the **community**.

No external infection while shielding.

Constant rate while shielding interventions are not in force.

$\eta_L(t)$ $\eta_{H_C}(t)$ $\eta_{H_F^L}(t)$

Transmission

β_{ij} - The transmission rate for a person of type j to type i:

$$\beta_{ij} = \beta_0 \, r \, p_{ij} \, q_{ij}$$

Transmission rate per contact.
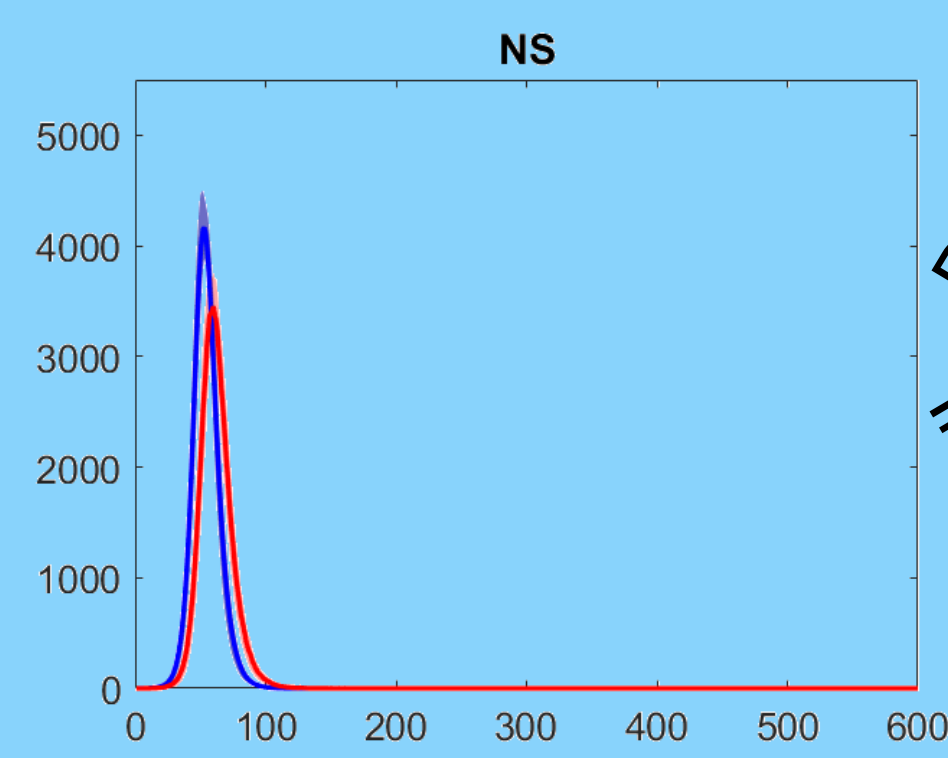
Average number of contacts.

Shielding matrix.

Proportion of a type i's contacts which are with a type j individual.

Within LTC: $p_{ij} = \lambda \approx 1$.
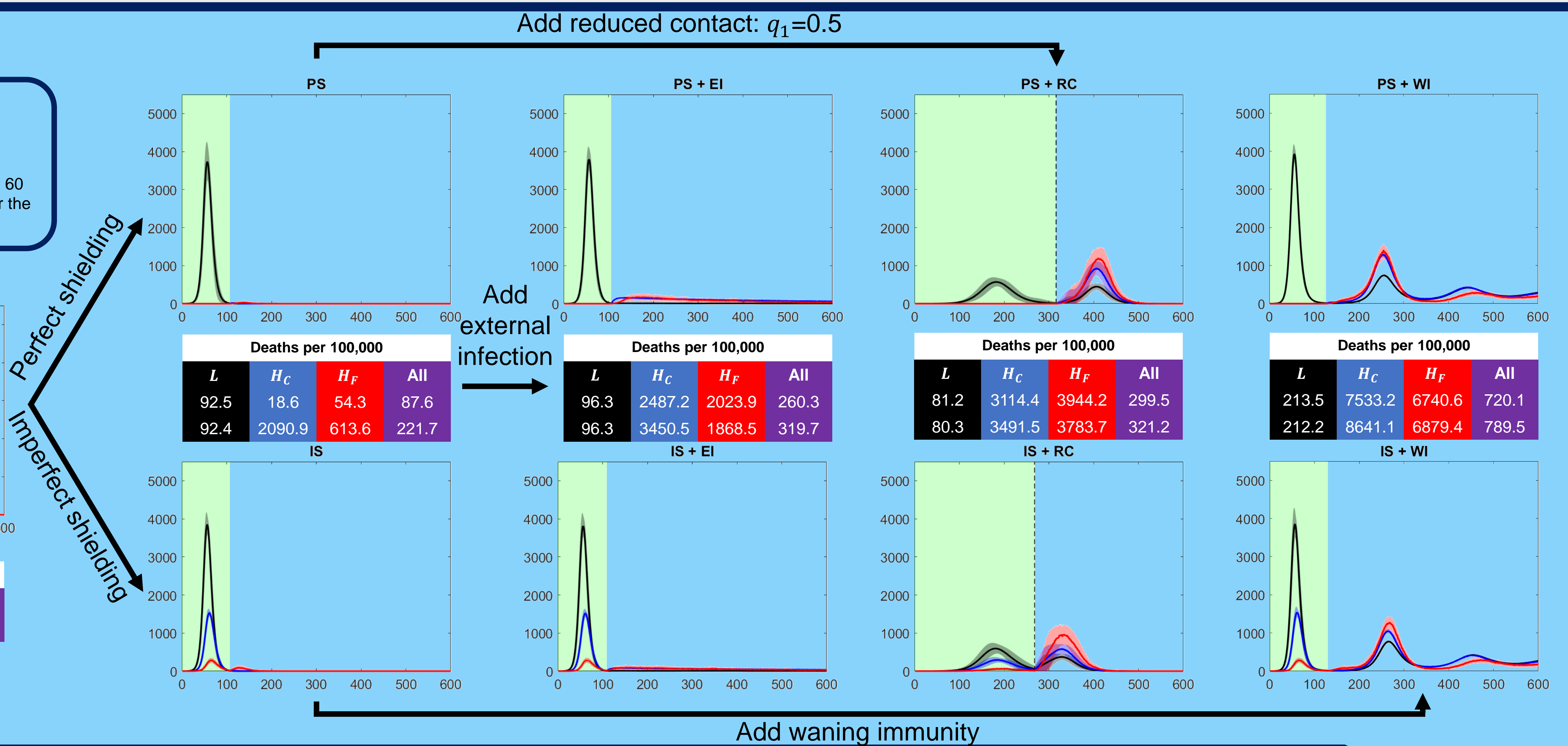No inter-LTC mixing.
Other values proportional to proportion of remaining population.

Results

Add reduced contact: q_1=0.5

x-axis: Time (days).

y-axis: Cases per 100,000 (by group).

Shading ends when we have fewer that 60 cases per 100,000 in the population over the course of a week.

Perfect shielding

Imperfect shielding

Add external infection

Add waning immunity

NS

Baseline case

Deaths per 100,000

L	H_C	H_F	All
93.7	4702.1	4532.6	415.1

PS — **Deaths per 100,000**

L	H_C	H_F	All
92.5	18.6	54.3	87.6
92.4	2090.9	613.6	221.7

PS + EI — **Deaths per 100,000**

L	H_C	H_F	All
96.3	2487.2	2023.9	260.3
96.3	3450.5	1868.2	319.7

PS + RC — **Deaths per 100,000**

L	H_C	H_F	All
81.2	3114.4	3944.2	299.5
80.3	3491.5	3783.7	321.2

PS + WI — **Deaths per 100,000**

L	H_C	H_F	All
213.5	7533.2	6740.6	720.1
212.2	8641.1	6879.4	789.5

IS   IS + EI   IS + RC   IS + WI

References

[1] N. G. Davies *et al., Lancet Public Health*, **5** (2020), doi:10.1016/S2468- 2667(20)30133-X.

[2] Z. Neufeld *et al., Infect. Dis. Model.*, **5** (2020), doi:10.1016/j.idm.2020.04.003.

[3] B. A. D. van Bunnik *et al., Philos. Trans. R. Soc. Lond., B, Biol. Sci.*, **376** (2021), doi:10.1098/rstb.2020.0275.

[4] N. M. Ferguson *et al.*, (2020), doi:10.25561/77482.

[5] H. Ward *et al., Nat. Commun.*, **12** (2021), doi:10.1038/s41467-021-21237-w.

[6] W. Yang *et al., medRxiv* (2020), doi:10.1101/2020.06.27.20141689.

[7] J. D. Annan *et al., medRxiv* (2020), doi:10.1101/2020.04.14.20065227.

Conclusions

Perfect shielding is effective at protecting those at higher-risk, **but is unrealistic** – requires those at risk to have no contact with any others.

Making the shielding 80% effective (**imperfect shielding**) causes **large increases in deaths** in the higher-risk subpopulations.

External infections again cause **higher death numbers**, this caused by **uneven protection of herd immunity**.

The lower-risk population **reducing their contact** also causes **significant outbreaks** as the **herd immunity threshold is not reached**.

Parameters

Name	Value	Ref.
Population size, N	10^6	
Prop. high-risk, h	0.07	
Prop high-risk in community, c	0.897	
Transmission rate, $\beta_0 r$	1.5* (day^{-1})	
Latency period, $1/\sigma$	5 (day)	[4]
Recovery period, $1/\Gamma$	2 (day)	[4]
Prob. death, low-risk, α_L	0.001	[5,6]
Prob. Death, high-risk, α_H	0.05	[5,6]
External infection, $\eta_{\cdot}(t)$	10^{-3}	
Prop. Within-LTC contacts, λ	0.9	
Waning immunity, ν	1/185 (day^{-1})	

*Chosen so that $R_0 = 3$[7].

Natural Environment Research Council

1 UNIVERSITY OF BATH
2 Milner Centre for EVOLUTION
3 SFU SIMON FRASER UNIVERSITY

Get in touch:

cs640@bath.ac.uk

@C_A_Smith50

https://people.bath.ac.uk/cs640

eco-evo theory