Community Immunity

Does Clustering of Unvaccinated Individuals and a Low Level of Vaccination Increase Measles Infection in a Given Population: A Model

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Hypothesis:

Increased level of clustering of unvaccinated individuals and lower vaccination rate will lead to a higher infection level when compared to an even spread of unvaccinated individuals within the population.

Background:

Measles is a contagious viral disease only spread between humans, that can be lethal[1]. 90% of unvaccinated people in contact with an infected person will contract the disease[1].

Clusters of unvaccinated people are more likely to get the disease and transmit it[2]. 6/13 US measles outbreaks in 2019 were associated with these communities[3].

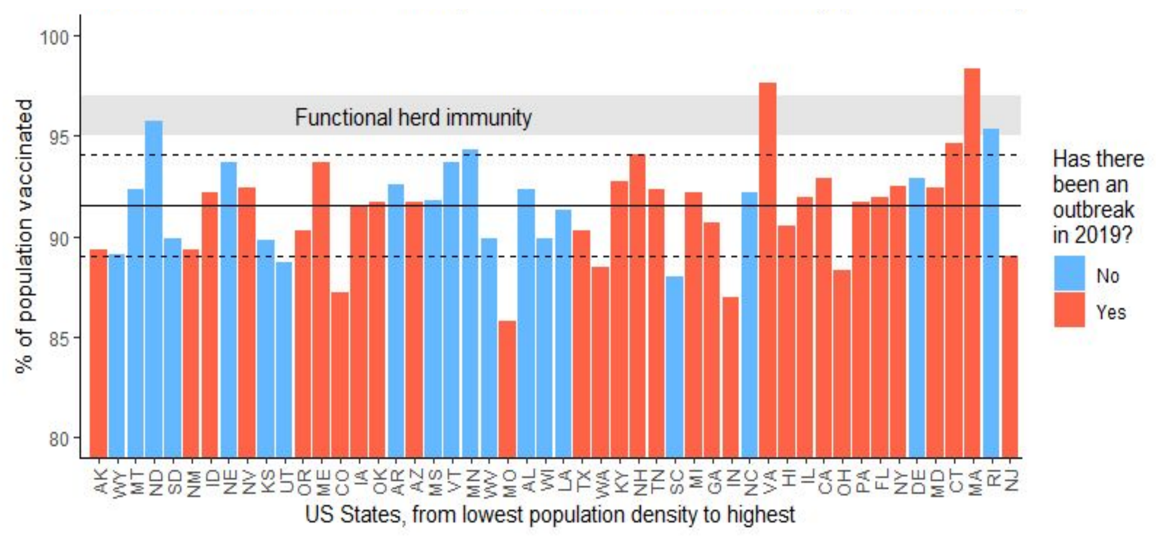


Fig. 1: Measles vaccinations rates and recorded outbreaks in 2019 by US state in order of population density. Average vaccination rates show no correlation to the incidence of outbreaks.

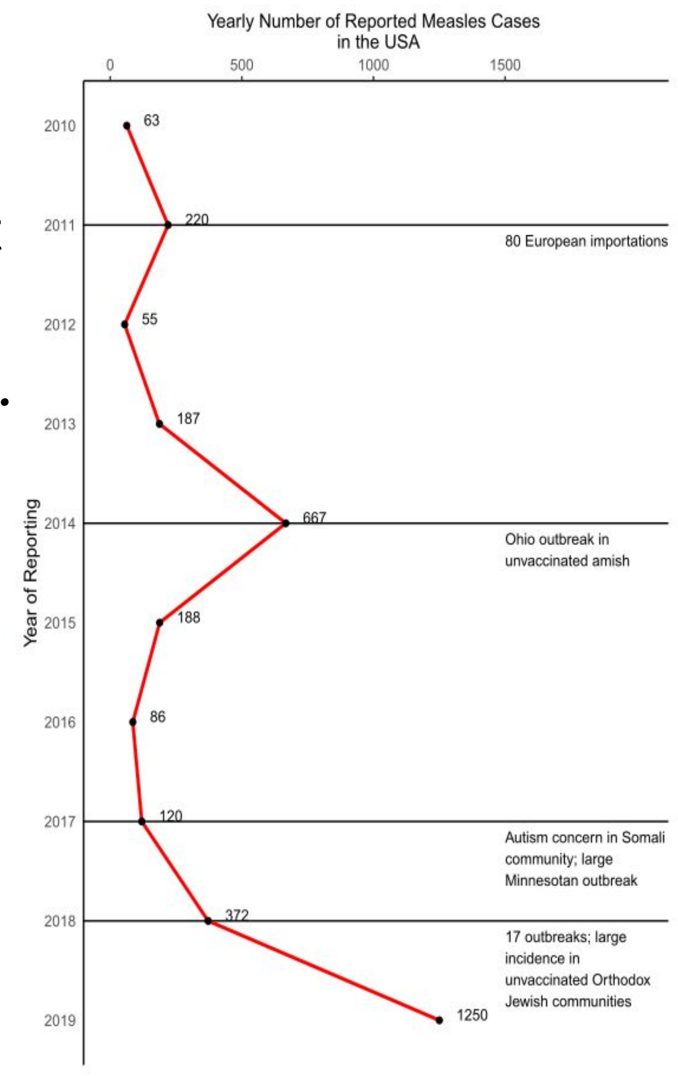
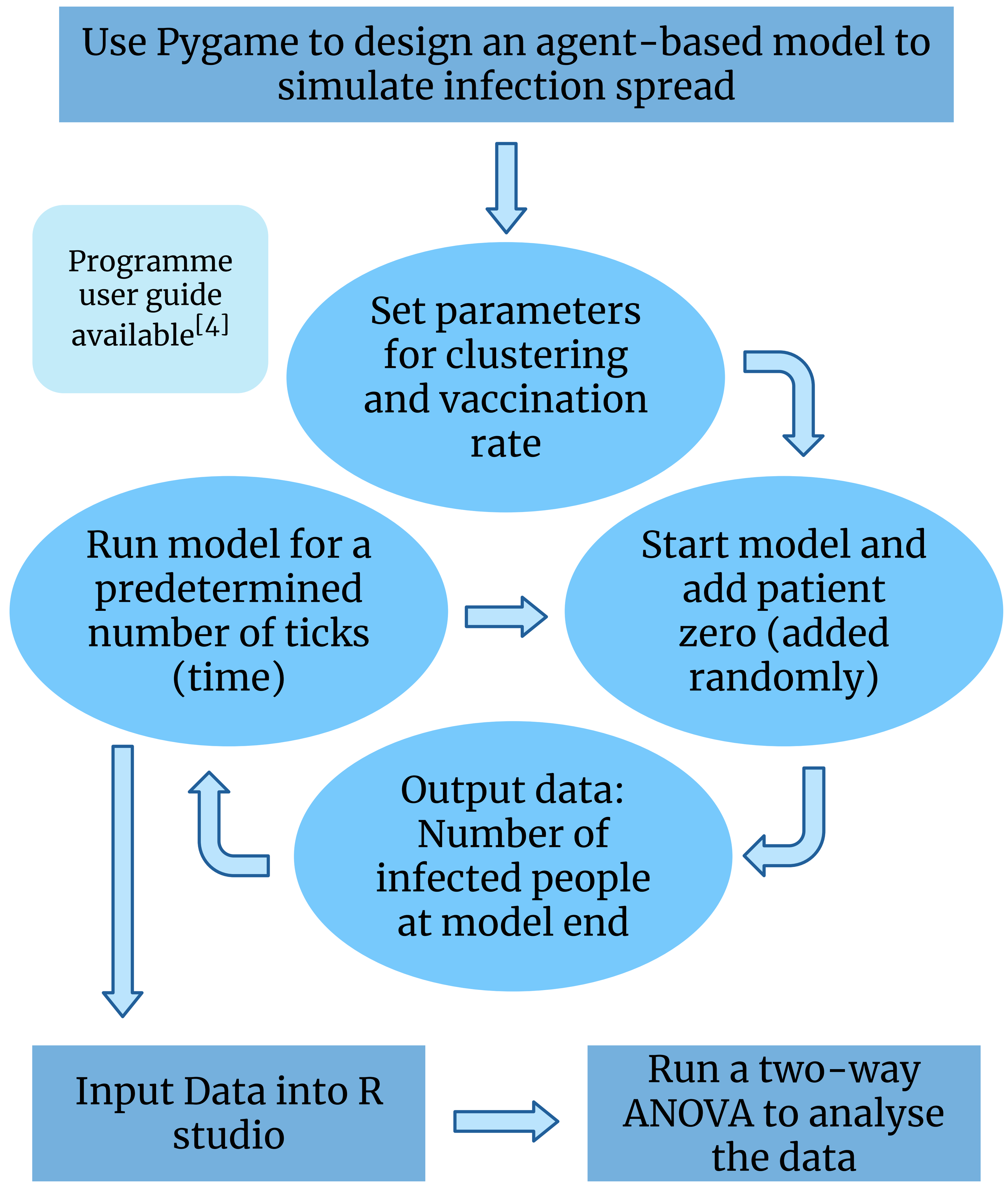


Fig. 2: shows a recent surge in recorded measles cases in the USA.

Method:



Results:

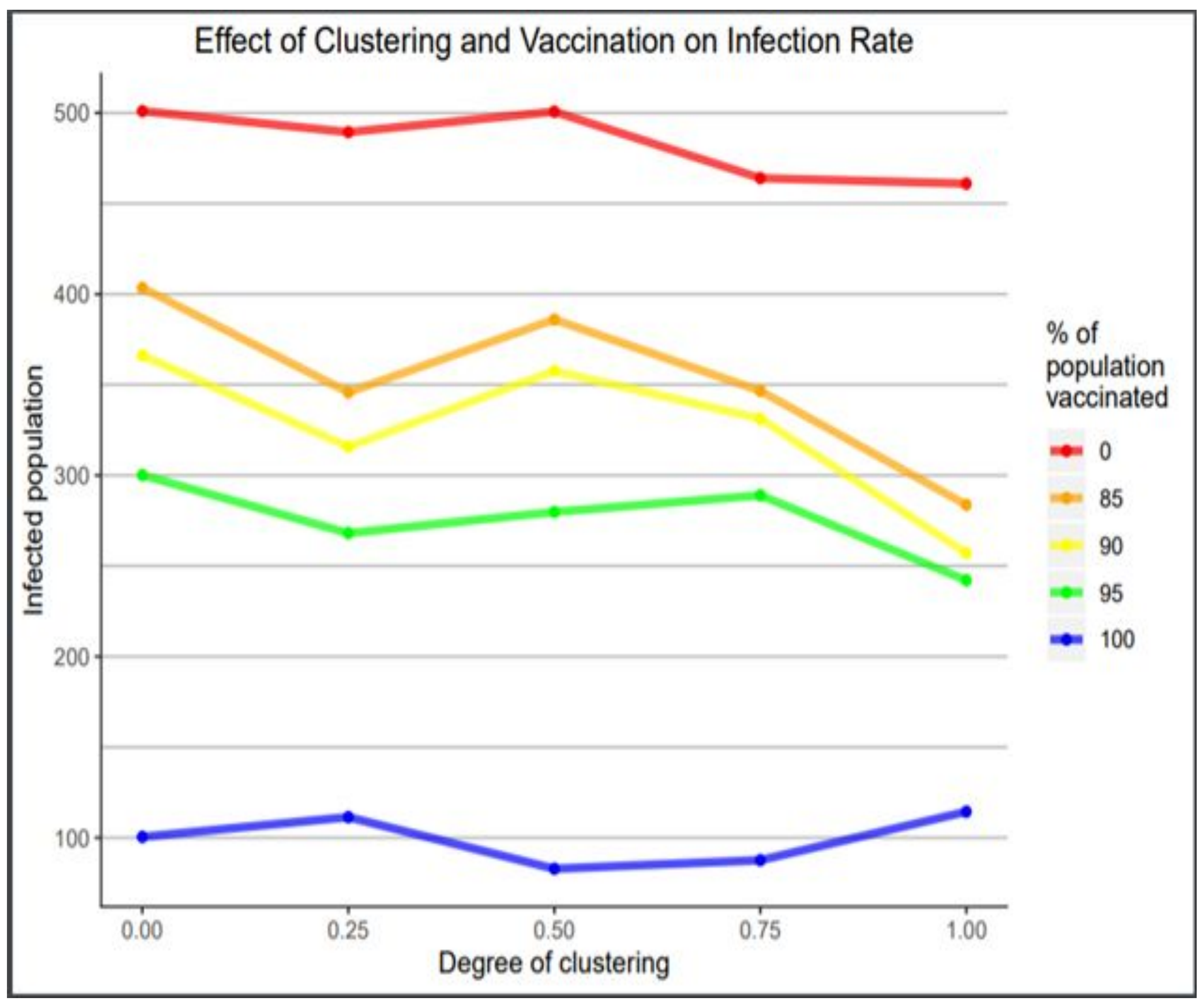
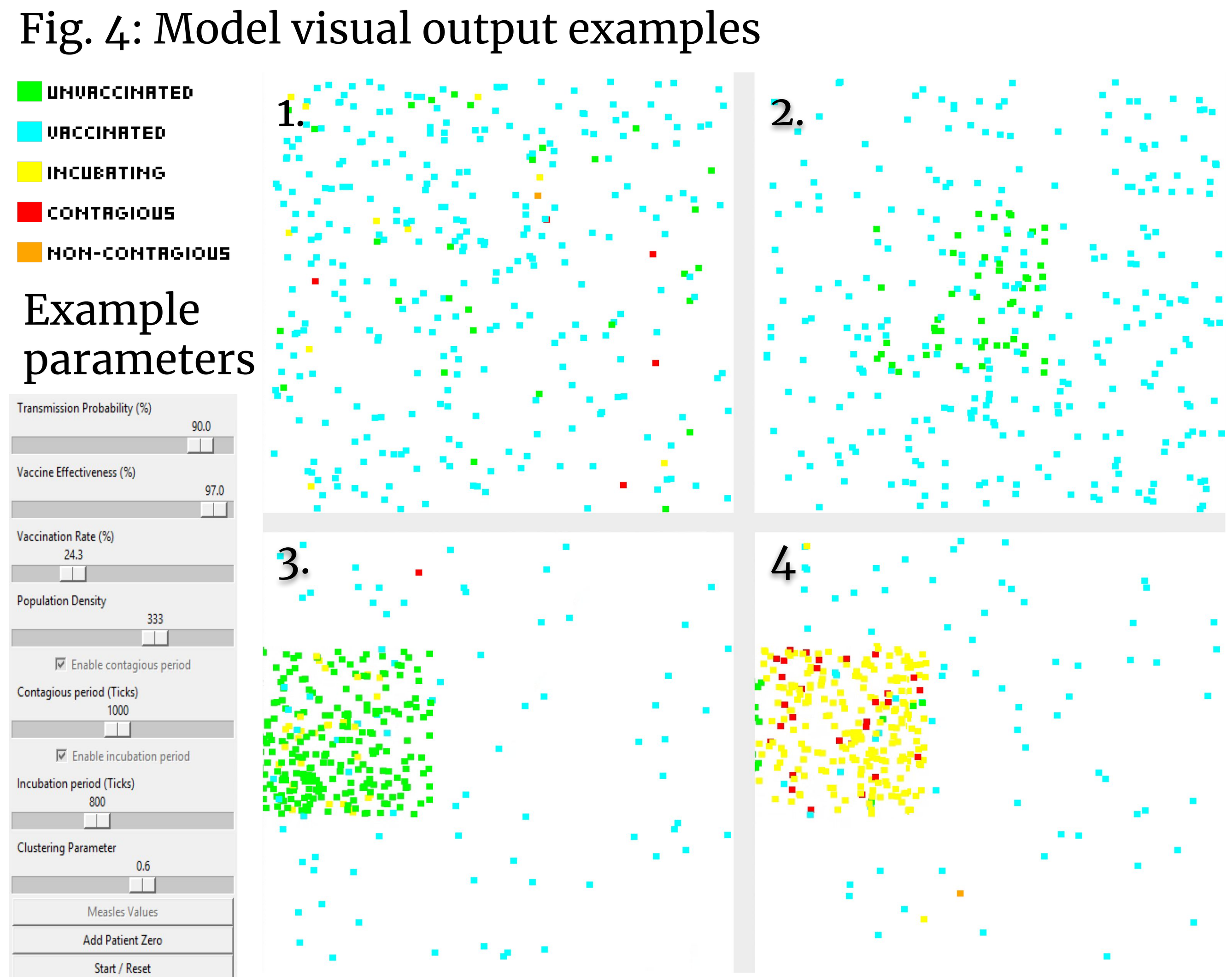


Fig. 3: Both increased levels of vaccination and clustering leads on average to fewer infected individuals in the population after 7500 ticks.

- For every unit increase in clustering, the number of infected individuals decreases significantly by a factor of 0.916 (as reflected in fig. 3).
- Model suggests that both vaccination rate (χ^2 = 20396.5, df = 1, p = 2.2e-16) and clustering (χ^2 = 3065.0, df = 1, p = 2.2e-16) significantly decrease the number of measles infections in the model.
- Both parameters interact significantly (χ^2 = 527.1, df = 1, p = 2.2e-16) to reduce the number of infected individuals.

Fig. 4: Model visual output examples



1: High vaccination rate, no clustering, 1502 ticks.
2: High vaccination rate, clustering, no ticks.
3: Low vaccination rate, clustering, 551 ticks.
4: Low vaccination rate, clustering, 1405 ticks.

Discussion:

Increased vaccination rates and clustering, contrary to our hypothesis, individually and cooperatively led to lower levels of infection in the population.

This discrepancy may be due to limits in our model, which assumes that vaccination is fully effective and each vaccinated individual is equally likely to contract measles when in reality, individual traits also affect transmission. Moreover once an individual is in a cluster, it cannot leave, in effect removing infected individuals from the general population, causing a quarantine effect. The model population was also limited by size.

Further models should expand upon our initial findings by creating a more realistic clustering parameter and larger population, to enable prediction of disease outbreak and epidemic in different populations worldwide.

References:

1. CDC: Transmission of Measles [Internet]; 2018 Feb 5 [cited 2019 Nov 08]. Available from: https://www.cdc.gov/measles/transmission.html
2. R. Silverman, No More Kidding Around: Restructuring Non Medical Childhood Immunization Exemptions to Ensure Public Health Protection; Annals of Health Law 2003, Vol. 12 Article 7
3. CDC: Increase in Measles Cases – United States, January 1–April 26, 2019 [Internet]; 2019 May 3 [cited 2019 Nov 08]. Available from: https://www.cdc.gov/mmwr/volumes/68/wr/mm6817e1.htm
4. R. Knight, Infection Spread: Programme User Guide [Internet] Available from: bit.ly/infectionspread

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