Measles Outbreak Effectiveness against Quarantining

Zach Wheeler and Smaran Vallabhaneni

Question

Explanation of the question:

Measles is a highly infectious disease that has been spreading across parts of the United States, a country that had formerly eradicated it. Following the COVID 19 pandemic, wearing masks during an outbreak and self quarantining has become more commonplace. With the spike in measles outbreaks in the recent months, we found it necessary to ask the question: *In a measles outbreak, what percentage of the population would need to take appropriate measures, specifically self quarantining, to reduce the peak infected population by 50%?*

What type of question is this?

This would be a predictive question, based on the fact that it is aiming to predict how a measles outbreak would fare under certain conditions in the United States.

Why is this an important or interesting question?

This is an important question to ask right now, since the number of measles cases are spiking across the continental United States. This is due to a decreasing amount of people being vaccinated and the current government administration reducing funding for vital government-funded health sectors. As a result, we found it necessary to determine the percentage of the population that would have to follow the CDC's recommended protocol during an outbreak to significantly reduce the impact of the virus outbreak.

Background Information and References:

The background information necessary to understand our question and our modeling choices is general knowledge about what is happening with measles in the United States right now and how measles works. This can be found in the cited articles below, but a short summary is that measles cases are rising dramatically in the United States as measles outbreaks are occurring across the country. Additionally, measles is a solely airborne virus that generally cannot reinfect someone once they have had the virus due to the way the body builds immunity to the virus.

Articles / Papers:	CDC – Measles Cases & Outbreaks (2025)Link:https://www.cdc.gov/measles/data-research/index.html	CDC – Measles FAQs (2025)Link:https://www.cdc.gov/measles/about/questions.html	WHO – Measles United States Outbreak Report (2025)Link:https://www.who.int/emergencies/disease-outbreak-news/item/2025-DON561	PMC6207419 – Measles Globalization & Immunization (2018)Link:https://pmc.ncbi.nlm.nih.gov/articles/PMC6897527/	CDC – Mea Intervention (2025)Link:h www.cdc.go measles/ downloads/ measles- intervention outbreaks.p
Current Case Numbers:	1,544 U.S. cases, 42 outbreaks by Sept 2025	>1,300 U.S. cases by July 2025	378 U.S. cases Jan–Mar 2025	Notes global resurgence despite elimination goals	Simulation assumes 5 initial infecti

					in 15,000-pe community
Vaccination Coverage	U.S. MMR coverage 92.7% (below 95% herd immunity floor)	2 doses = 97% effective	92.7% coverage in 2023, pockets of <90%	Global coverage uneven	Model assu 85% immun baseline
Transmission & Risk Factors	Traveler cases & undervaccinated clusters	Travel & undervaccinated travelers	Border crossing travel	Travel sustain outbreaks	Without intervention rapid expon spread
Severity & Outcomes	3 deaths; hospitalizations vary	Complications: pneumonia & encephalitis	17% hospitalization rate, 2 deaths	Highlights measles as highly contagious, severe	Shows intervention reduce case to 98%
Public Health Response	CDC outbreak support, modeling	Guidance for individuals (travel & immunity)	WHO regional monitoring & CDC Level 3 response	Advocates global coordination & sustained vaccination	Isolation, quarantine, vaccination modeled & combined is effective
Global Context	U.S. elimination in 2000, but fragile	Emphasizes importation risk	Americas at high risk due to global circulation	Globalization undermines elimination, increased need for international cooperation	Reinforces t local interve matters eve global impo

Methods and Model

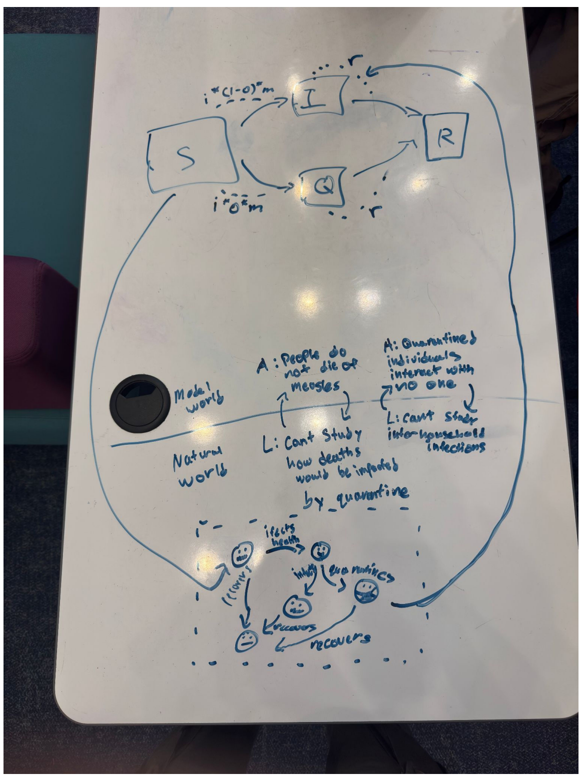
We are using an adapted version of an SIR model that has the following variables:

- Susceptible: People who are not immune but have not been infected yet
- Infected: People who are infected and can infect others
- Quarantined: A set of people that go into isolation and hence cannot infect anyone
- Recovered: People who have recovered and cannot infect others
- Infectivity Rate: Constant, infectivity rate of measles
- Recovery Rate: Constant, recovery rate of measles
- Obedience (Quarantining rate): How many people are quarantined. This is what we are searching for
- Mask Effectiveness: The effectiveness of a given mask between 0 and 1, where 0 is 100% effective and 1 is not effective at all (or no mask)
- Time: The time measured in weeks

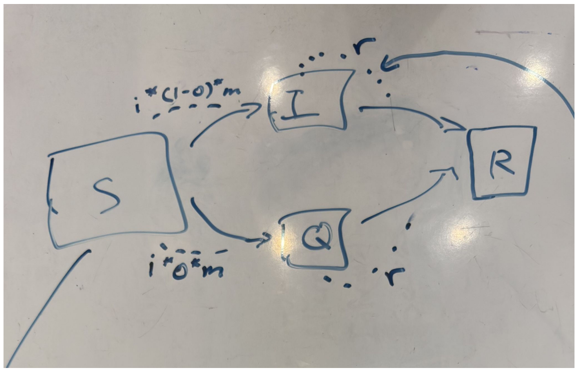
```
S_1 = 99; % Susceptible people
Q_1 = 0; % Quarantined people
```

```
I_1 = 1; % Infected people
R_1 = 0; % Recovered people

i = 0.9; % Infectivity rate is 90% according to the CDC
r = 0.0714; % The average person takes two weeks to recover

m = 0.05; % Mask effectiveness (1 is worst, 0 is best) (.05 is for a KN95 mask,
which has become standard after covid)

o = 0; %obedience, (1 means everyone is compliant). Also directly proportional to
quarantined population

t_end = 40; % Time simulation end, in weeks

countermeasure_reduction_value = 1-(m*o);
```

Tenchi diagram:



Stock-and-flow diagram:



Stock-and-flow equations:

```
% Original Model (SIR)
% S(t+1) = S(t) - (I(t) * S(t) * i)
% I(t+1) = I(t) + (I(t) * S(t) * i) - (I(t) * r)
% R(t+1) = R(t) + (I(t) * r)

% Mask, Quarantined, and Obedience Model (SQIRmo)
% S(t+1) = S(t) - (I(t) * S(t) * (1 - o) * i * m) - (S(t) * o * m * i * I(t))
% Q(t+1) = Q(t) + (S(t) * o * m * i * I(t)) - (Q(t) * r)
% I(t+1) = I(t) + (I(t) * S(t) * (1 - o) * i * m) - (I(t) * r)
% R(t+1) = R(t) + (I(t) * r) + (Q(t) * r)
```

Limitations:

This also does not take into account potential mutations or immunocompromised people. Also people cannot die of measles.

Parameter (constants) Definition:

Both the infectivity rates and recovery rates for measles were derived from the CDC's website. Infectivity rate is about 90% and recovery rate is 7.14% (a person will take two weeks to recover).

Baseline Dataset (N95 masks, no quarantining):

First we define our parameters for the baseline data set:

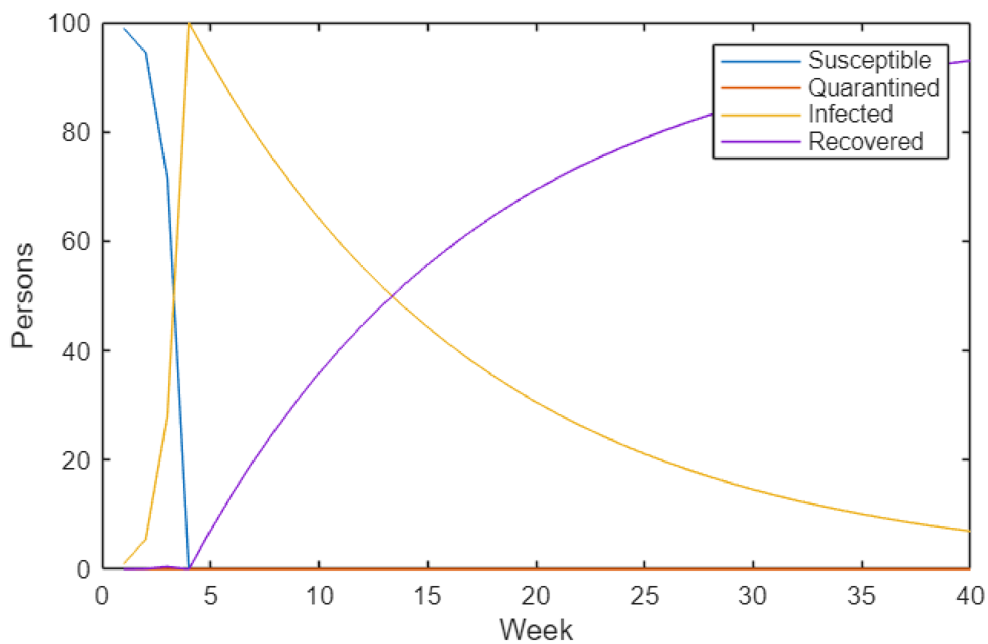
```
[S, Q, I, R, W] = simulate_sir(S_1, Q_1, I_1, R_1, m, o, i, r, t_end);

% ASSERT STATEMENTS
% Is the population constant (at 100)?
for index = 1:t_end
    % assert((floor(sum(S(index) + Q(index) + I(index) + R(index))) == 100), 'Total
population must stay constant');
    assert(S(index) >= 0, 'Susceptible cannot be negative');
    assert(Q(index) >= 0, 'Quarantined cannot be negative');
    assert(I(index) >= 0, 'Infected cannot be negative');
    assert(R(index) >= 0, 'Recovered cannot be negative');
end

% For later in our quarantining calculation
```

```
maxI = max(I);
idealI = maxI/2;
```

These equations allow us to model the spread of the disease and how quarantining will impact it, allowing us to do a comparison on how quarantining affects the spread of disease.

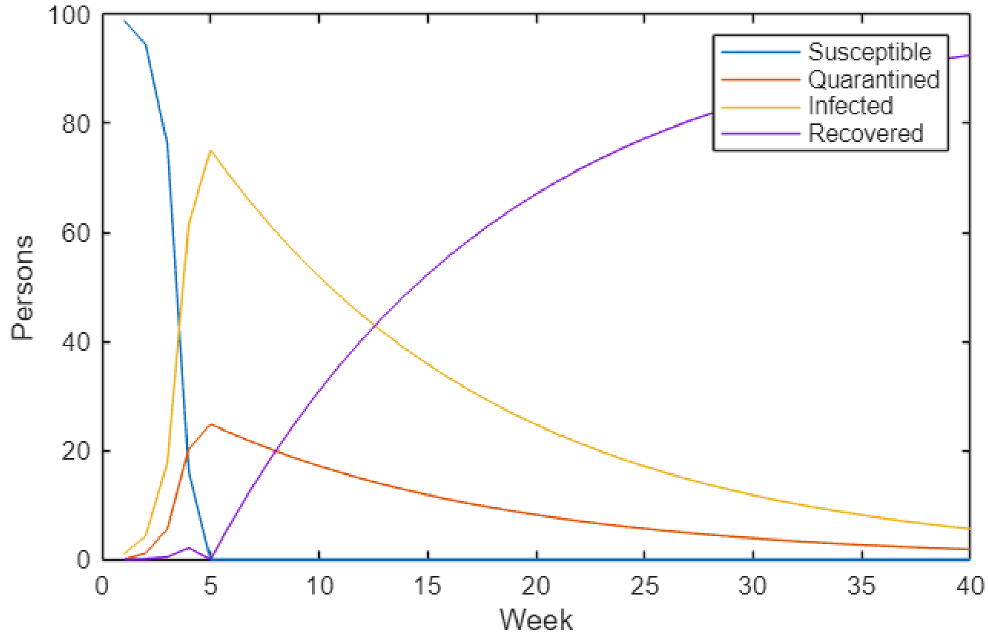
Now we get our baseline data plot with no quarantining:

```
% Plot - baseline
figure()
plot(W, S, 'DisplayName', 'Susceptible'); hold on
plot(W, Q, 'DisplayName', 'Quarantined')
plot (W, I, 'DisplayName', 'Infected')
plot(W, R, 'DisplayName', 'Recovered')

xlabel("Week")
ylabel("Persons")
legend()
```




```
% Plot - 25% Quarantining (test)
o = 0.25;
[S, Q, I, R, W] = simulate_sir(S_1, Q_1, I_1, R_1, m, o, i, r, t_end);

figure()
plot(W, S, 'DisplayName', 'Susceptible'); hold on
plot(W, Q, 'DisplayName', 'Quarantined')
plot (W, I, 'DisplayName', 'Infected')
plot(W, R, 'DisplayName', 'Recovered')

xlabel("Week")
ylabel("Persons")
```

```
legend()
```



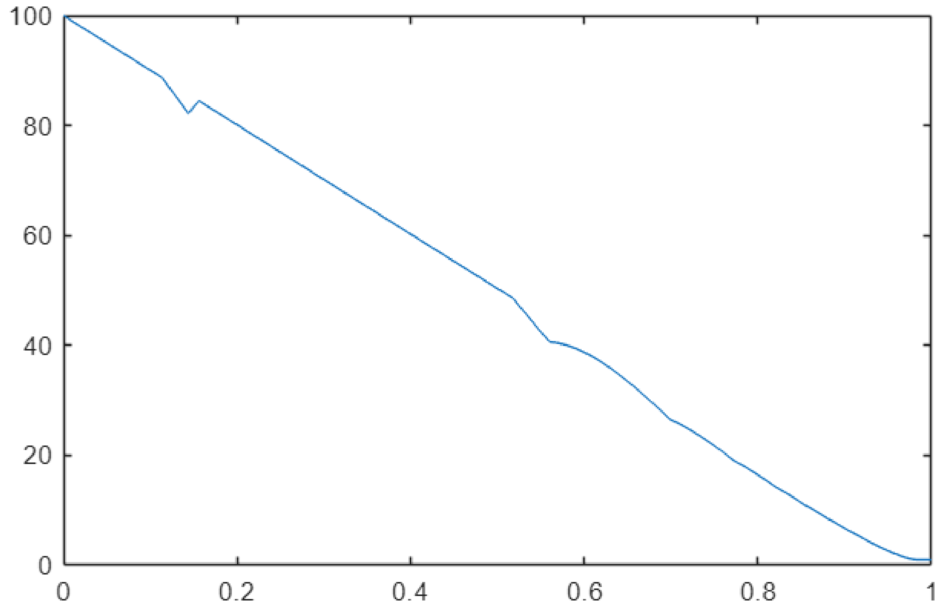
This data plot shows a large spike in infectivity right at the start, which aligns with the statement from the CDC about measles being one of the most infective diseases known to man, with a roughly 90% infectivity rate. The recovered population curves, as to be expected with it taking on average 14 days for an individual to fully recover, as stated by the CDC.

Results

Finding the quarantining ratio that cuts the peak infected number to 50% of the original value:

To find the quarantining value that would cut the peak infected population by 50%, we performed a parameter sweep by graphing a range of effectiveness values against their respective peak infected population until we find one that is 50% of the peak infected population when mask effectiveness is 0.05 (95% for N95/KN95 masks).

```
IxMax = zeros(1, 1000);
OiList = 0:0.001:1;
answer = 0;
count = 1;

mi = .05;

for oi = OiList
    [Sx, Qx, Ix, Rx, Wx] = simulate_sir(S_1, Q_1, I_1, R_1, mi, oi, i, r, t_end);
    IxMax(count) = max(Ix);
    count = count + 1;
end
figure()
plot(OiList, IxMax, 'DisplayName', 'paramter sweep')
```




```
for oi = OiList
    [Sx, Qx, Ix, Rx, Wx] = simulate_sir(S_1, Q_1, I_1, R_1, mi, oi, i, r, t_end);
    if idealI > max(Ix)
        answer = oi;
        break
    end
end

answer
```

```
answer =
0.5040
```

Interpretation

Our results show that a minimum of 50.4% of the population will need to be quarantined in order to reduce the peak infection rate by 50%, if everyone wears an N95/KN95 mask. However, the model does not take into account that people can die, the virus can mutate, immunocompromised people could reinfect, or how quarantine individuals could infect household members. This unfortunately means that our model cannot completely encapsulate how the virus would spread throughout a population or how death could impact the spread of the virus. In the future, we could modify our model to overcome these limitations by calculating when infected people would die and then removing them from the population with a sink.