OUTBREAK: SARS-Coronavirus-2

LOCATION: Minnesota, US

INVESTIGATION INITIATED: 04/10/2020

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1 Abstract

SARS-Coronavirus-2, the virus that causes the COVID-19 respiratory disease, is implicated in a global outbreak originating from Wuhan, China. The first case has been reported in Minnesota March 3,2020. Using compiled case data from state and county health departments outbreak parameters for the population of MN was estimated to determine the susceptibility of the state. The reproductive value was greater than 1.00 indicating outbreak potential (R = 1.28), and the force of infection continues to increase over time. The predicted incidence after April 10, 2020 without control measures has an exponential growth curve. Therefore, these first five weeks of data indicate that decrease the number of new infected and deaths resulting from COVID-19 control measures need to be implemented.

2 Background

The investigation was initiated on April 10, 2020. The first case was reported five weeks prior on March 3, 2020. There has been an ongoing outbreak of SARS-CoV2 (severe acute respiratory syndrome-associated coronavirus 2) throughout the United States. The first recorded case was in Wuhan, China in November 2019, and has since spread globally. The first case in the United States was identified in the state of Washington on January 15, 2020 (CDC-Covid-Response-Team et al. 2020). Since then, the virus has continued to spread. Since then SARS-CoV2 has been spreading across the United States and reached MN in March. COVID-19 is a respiratory disease that is caused by the SARS-Coronavirus-2 (SARS-CoV-2) virus. This respiratory disease includes symptoms ranging from: sneezing, fever, loss of taste/smell, and difficulty breathing. Patients may become ill enough where intensive care is needed for intubation. This virus is transmitted from person-to-person mostly through respiratory droplets from coughing, sneezing and talking. It is thought that this transmission occurs before the onset of symptoms (Nishiura, Linton, and Akhmetzhanov 2020). As of March 3, 2020, there have been almost 89,000 cases with over 3,000 deaths (Newspaper Article 2020). The Center for Disease Control and Prevention released a report that higher odds of death are associated with increased age. This disease needs to be controlled as quickly as possible.

As of April 1, 2019 ,the population of Minnesota was estimated to be close to 5.68 million, with around 131,913 residents living in close quarter living spaces such as dormitories, nursing homes, shelters and centers (Web Page 2020). The entire population is at risk of the disease, due to no previous exposure or vaccination for this virus. Compounding the effects of residents living in shared spaces, the population of Minnesota is unevenly distributed over the state with the Twin Cities (Minneapolis and St. Paul) containing a high proportion of the total population (Figure 2.1) (Web Page, n.d.). These close living quarters may contribute to quick spread of this person-to-person transmitted virus. Furthermore, minority populations are also centered in these high density regions. It has been documented that minority populations have higher odds of living in areas without access to quick medical care (Tung et al. 2019). Lastly, the rural low population density locations are not less-at-risk comparatively. Rural living provides less readily accessible high quality medical care needed for treatment, such as lack of insurance or facilities containing intensive care unit (ICU) beds (Weeks 2018; Loftus et al. 2018). Therefore, the outbreak of SARS-CoV-2 needs to be controlled and eradicated before state-wide expansion occurs.

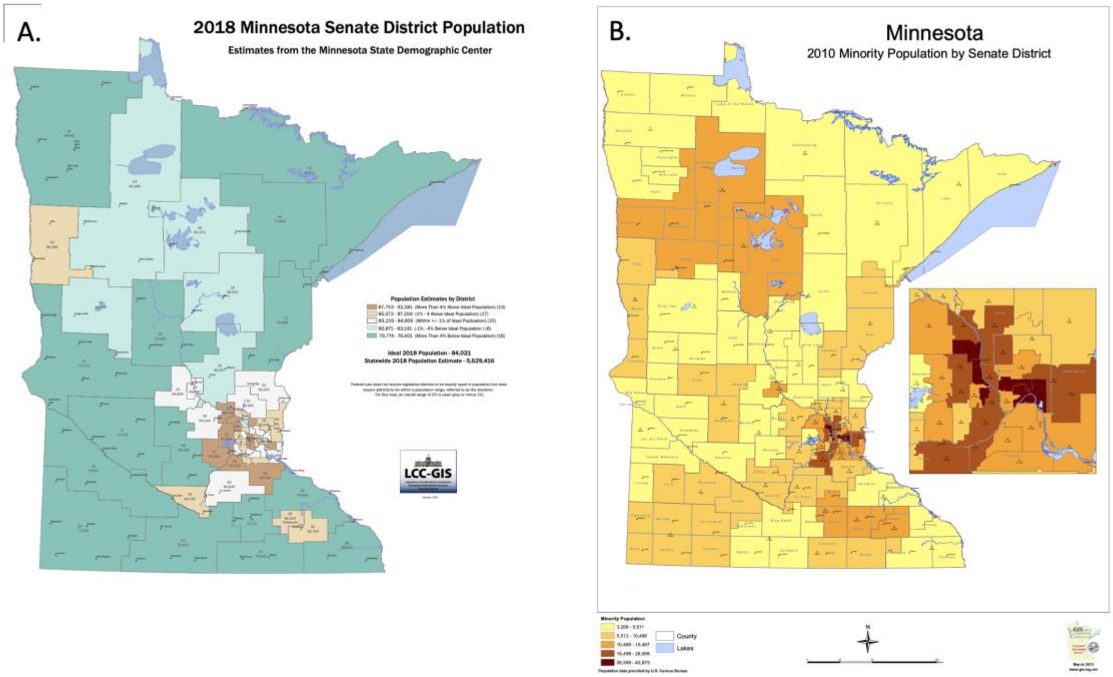

Figure 2.1: Minnesota total population in 2018 divided by senate districts (left; scale: green - low, white - medium, brown - high population count). The minority population in 2010 for Minnesota (right; scale: yellow - low, red - high population count).

3 Methods

The data used for the following analysis was collected from the New York Times COVID-19 online public database. This database contains cumulative case count data per day for US states and counties. The data was complied by journalists and originated from state and county health departments. The case numbers are the total number of confirmed and probable cases. The location is based on where the patient was treated and not where the patient resides.

Testing for SARS-CoV-2 varies widely throughout the state depending on which test manufacturer is chosen, and availability of tests, and availability of funding. The tests are designed to detect the genetic material of the virus, and allows physicians to determine if virus is present using polymerase chain reaction assays (PCR). However, testing capabilities are currently unable to meet demands due to supply and demand constraints (Newspaper Article 2020).

The mean and standard deviation of the serial interval (si) for the virus was previously estimated by Nishiura *et. al* using 28 infector-infectee pairs (2020). With a serial interval lower than the mean incubation time (5 days), this is suggestive of pre-symptomatic transmission.

Initially, the current case data was analyzed to determine the trend in new cases. Since the data was provided as cumulative, the previous day's recorded values were subtracted from each date to retrieve the incidence values per day. Then the incidence case data and estimates from Nishiura *et. al* were used to determine the serial interval and the basic reproductive number R nought using maximum likelihood estimation which was validated with resampling (n = 1000). The force of infection was estimated using data up until April 10, 2020 with a Poisson distribution. Finally the projected incidence was calculated for specifically 14, 30, 75, and 100 days from April 10, 2020 using the Minnesota-specific estimated serial interval and 1000 simulations. An overall estimated best exponential fit curve was plotted over the data in the form of $log(y) = r * t + b$, where y = incidence, r = growth rate, t = time (in days), and b = origin. The 95% confidence intervals were then determined.

4 Findings/Results

The incidence of SARS-CoV-2, as expected, has been increasing in Minnesota since the first case (Figure 4.1). Furthermore the number of reported deaths has also been increasing with the case load.

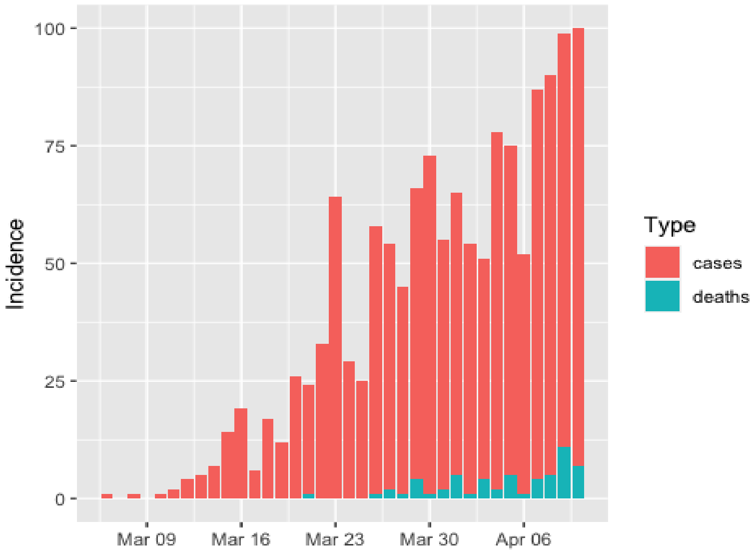

Figure 4.1: Incident daily confirmed cases and deaths of SARS-CoV-2 in Minnesota as determined through PCR testing and MN state and county department of health public reporting. New cases = red, death = teal.

From the this case data we were able to estimate the basic reproductive number for SARS-CoV-2 in Minnesota using the serial interval estimated to be between 4.8 with a standard deviation of 2.3 (Nishiura, Linton, and Akhmetzhanov 2020). The basic reproductive number (R) is transmission parameter that quantified the number of expected cases from one confirmed case. Generally, for a disease with an R value of 1, one confirmed case will transmit the disease to one susceptible person maintaining the disease progression. However, with an R value greater than 1 there will be more transmitted cases leading to an increase in the infected population. From our estimates the R value of SARS-CoV-2 in Minnesota is 1.281 (Figure 4.2). Furthermore, the serial interval that was estimated from the MN data agrees with the previously reported values in the literature (serial interval = 4.36).

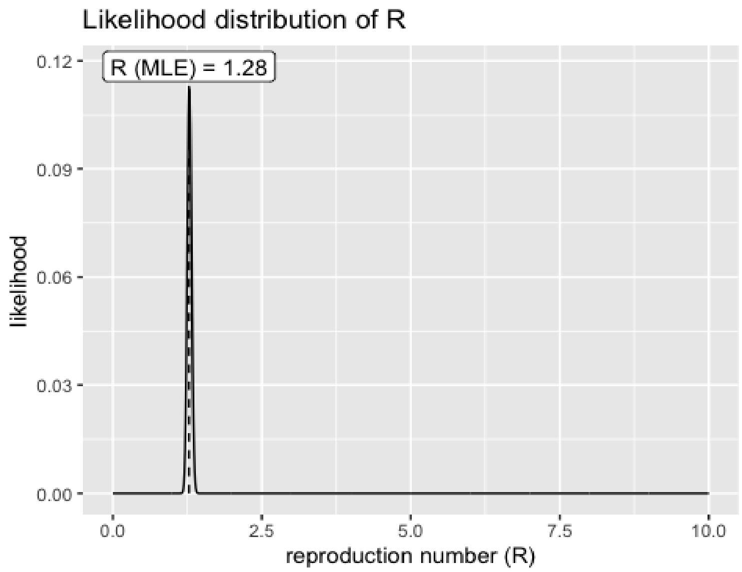

Figure 4.2: Maximum likelihood estimation for the reproductive number of SARS-CoV-2 in Minnesota from case data up until April 10, 2020 with a mean serial interval equal to 4.8 days and a standard deviation of 2.3 days (Nishiura, Linton, and Akhmetzhanov 2020).

This distribution of likely values of the reproductive number was then resampled (n = 1000) with replacement to obtain a sample of plausible reproductive numbers for Minnesota (Figure 4.3). The range of reproductive numbers ranged from 1.151 to 1.441. This range does not include or go below 1. Therefore, the transmission potential is high and this outbreak should be contained as quickly as possible.

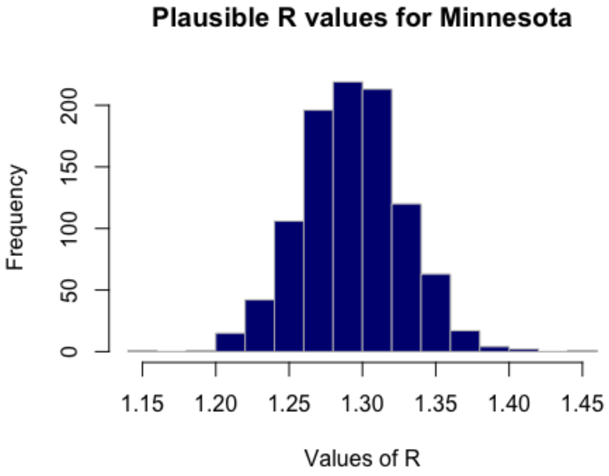

Figure 4.3: Plausible reproductive numbers of SARS-CoV-2 based on case data for Minnesota. Likelihood distributions for the estimated reproductive number was resampled, with replacement, 1000 times.

Along with the estimates of the reproductive number and serial interval, we are also able to estimate the force of infection. The force of infection is the rate that susceptible individuals become infected. Up to April 10, 2020 the force of infection is steadily increasing over time and is not starting to level off. This is potentially indicating that there is a large suscepible pool to be infected which falls in line with previous beliefs that pre-existing immunity does not exist. Therefore, preferably we would like to see the force of infection decline over time.

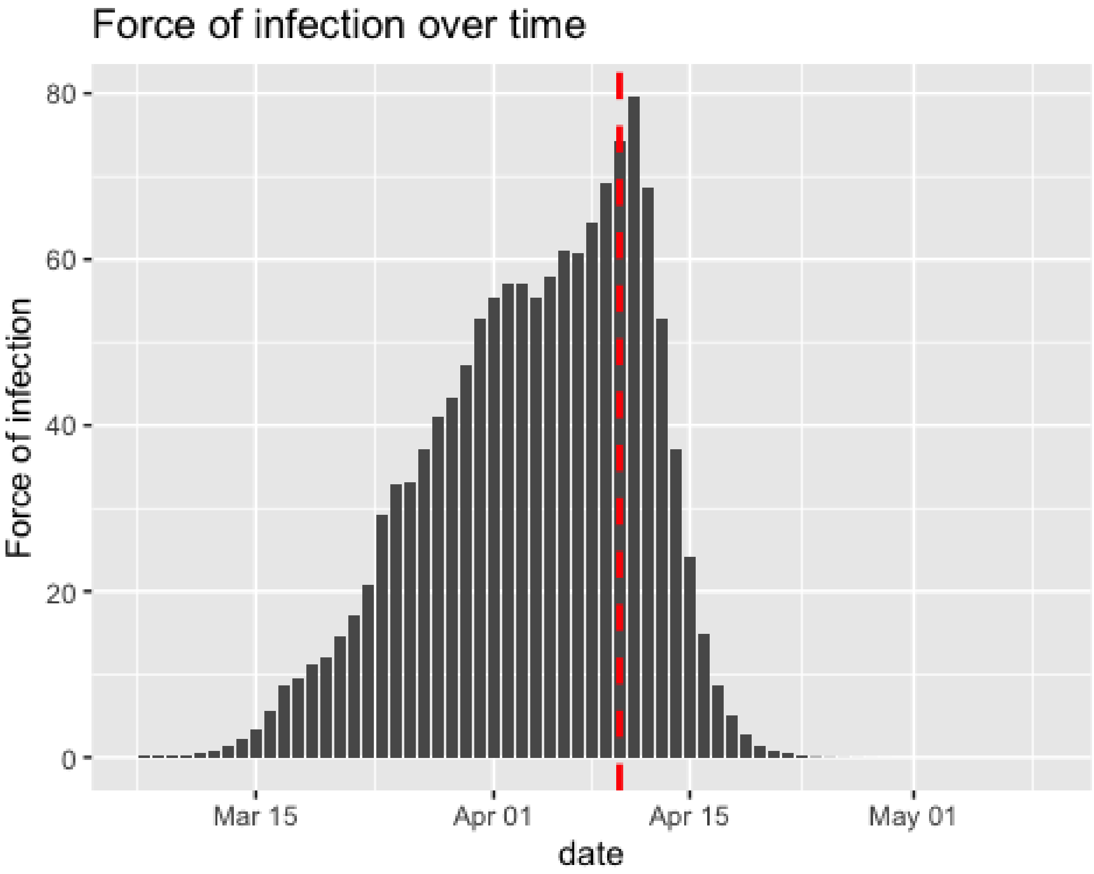

Figure 4.4: The force of infection of SARS-CoV-2 for cases in Minnesota from March 3, 2020 to April 10, 2020 (red dashed line). The maximum likelihood esimate for R was 1.28 with a serial interval of 4.8 and 2.3 standard deviation.

The number of future cumulative (Figure 4.5) and incident (Figure 4.6) cases was predicted using the serial interval estimated from the Minnesota case data (si = 4.36). From April 10, 2020 the incident cases for 14, 30, 75, and 100 increased over time. The mean incident cases increased from 215 from day 14 to 39,059 cases on day 100.

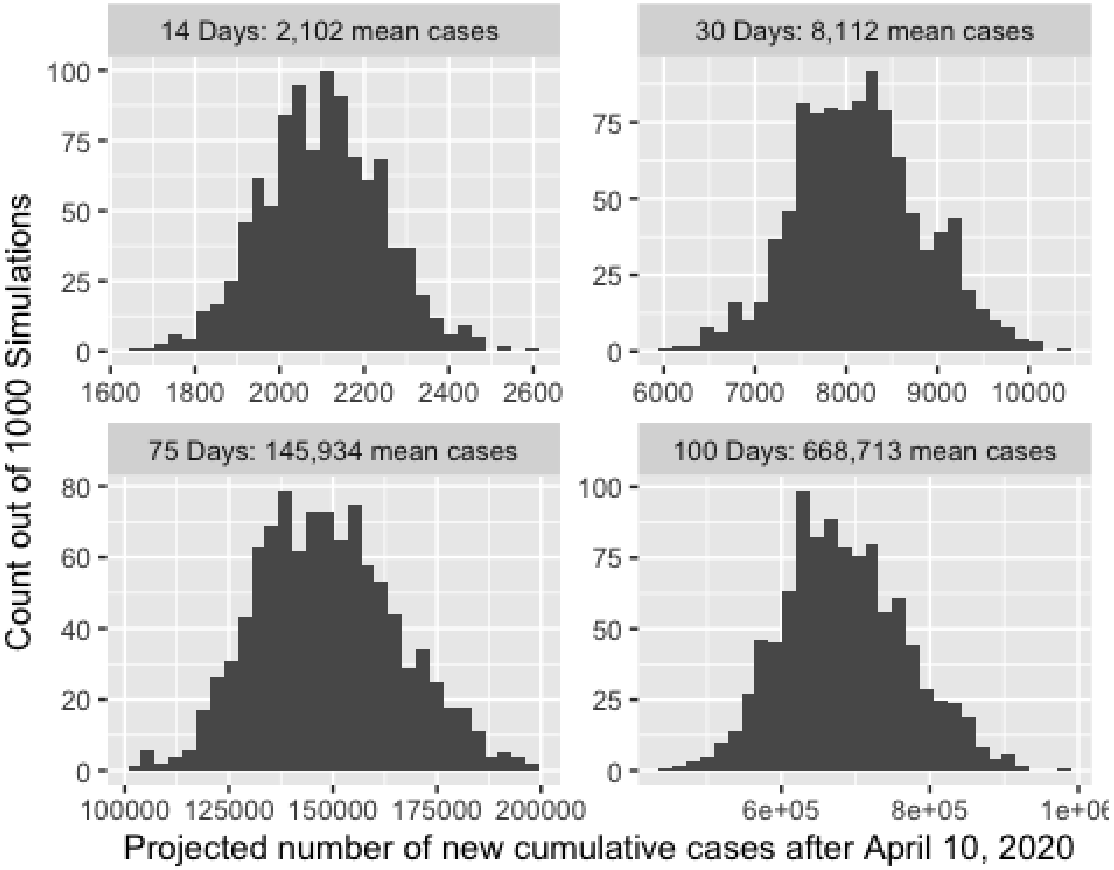

Figure 4.5: Predicted number of new cumulative cases over 14, 30, 75, and 100 days after April 10, 2020 for Minnesota. The mean number of incident cases of the 1000 simulations is provided in the title of each subgraph. The serial interval was estimated from Minnesota cases data (si = 4.36), and the maximum likelihood for the R value was 1.28.

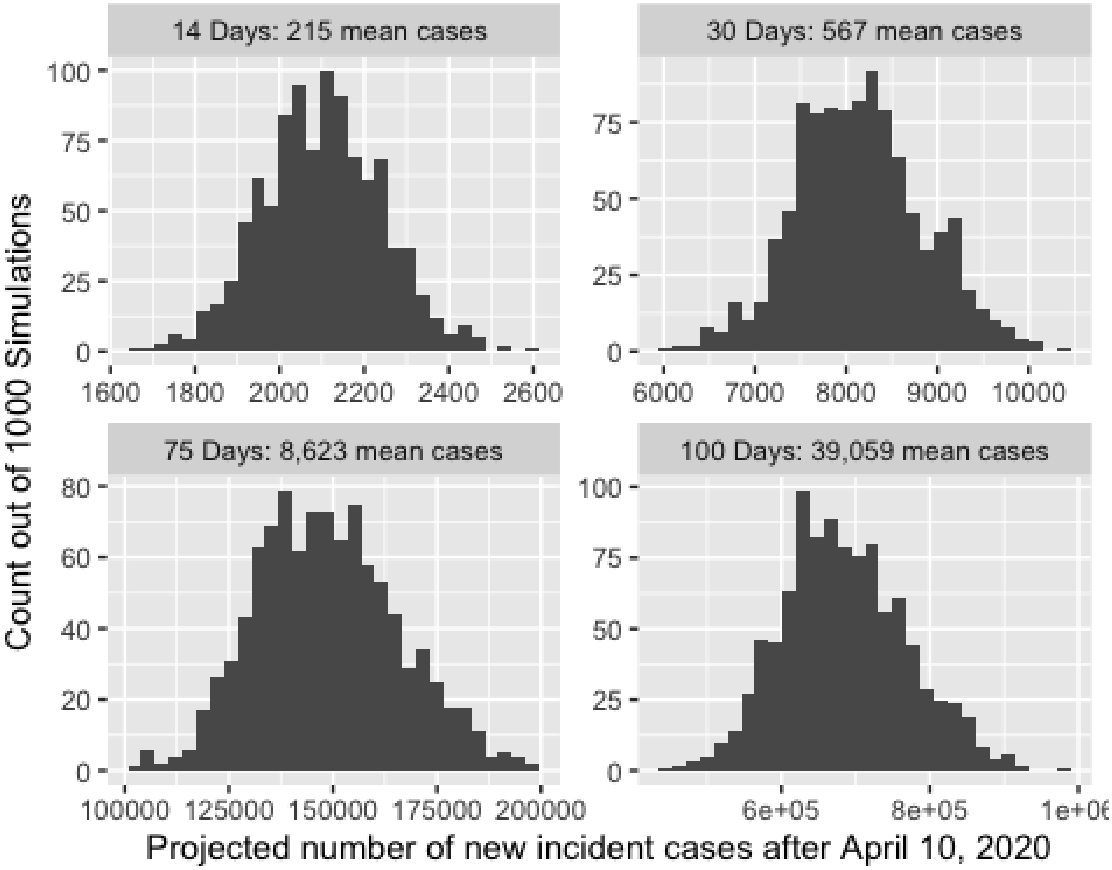

Figure 4.6: Predicted number of new incident cases for exactly 14, 30, 75, and 100 days after April 10, 2020 for Minnesota. The mean number of incident cases of the 1000 simulations is provided in the title of each subgraph. The serial interval was estimated from Minnesota cases data (si = 4.36), and the maximum likelihood for the R value was 1.28.

This increase in incident cases follows en exponential growth curve. As seen in Figure ?? the exponential growth model matches the existing incident case data from Minnesota. When this model is used to predict the incident cases out to thirty days there is an exponential increase. The range of the data is not very wide; on day 30 the range is between 400 and 700 new cases a day. When this model is expanded further out to 100 days past April 10, 2020 the incident cases continue to increase exponentially surpassing 6,000 cases a day (Figure 4.8).

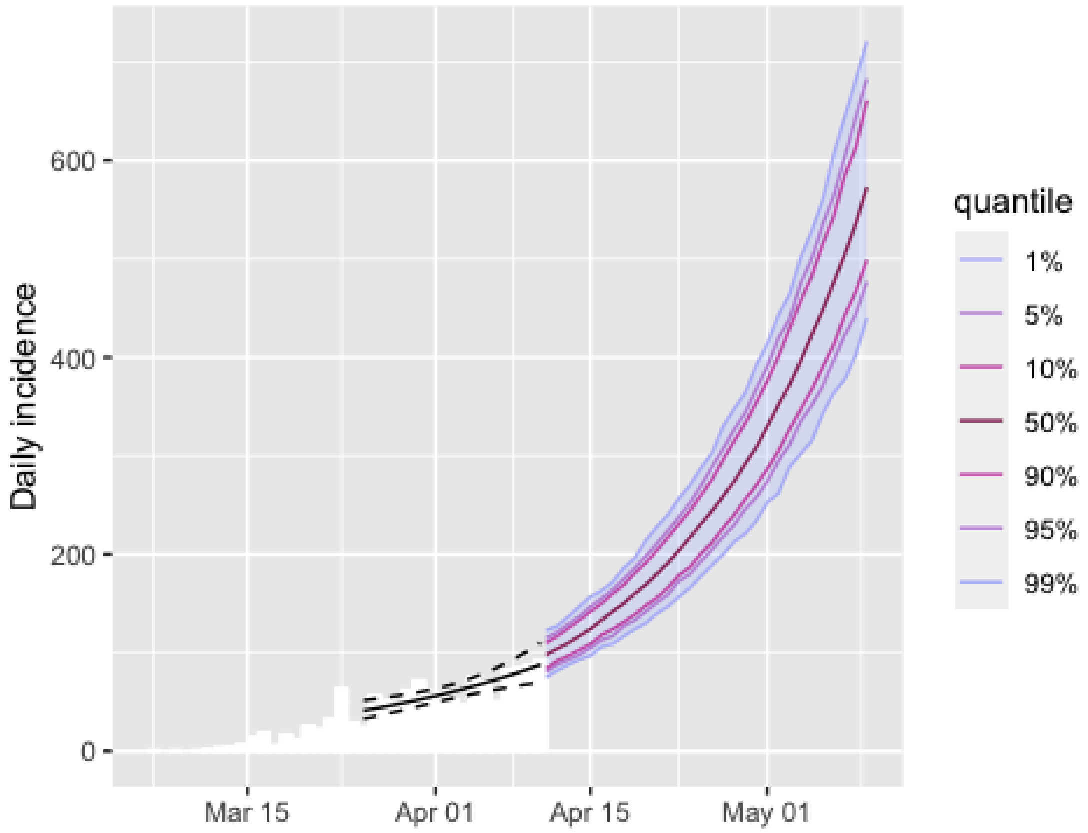

Figure 4.7: The projected incidence of SARS-CoV-2 in Minnesota overtime with the historical incidence data from March 3, 2020 to April 10, 2020 (white bars). An exponential model was fitted to the data and used to estimate the incidence (black solid line) with the 95% confidence intervals (black dashed line). The simulated incidence data is provided for thirty days after April 10, 2020 in quantiles based upon the exponential model. The used serial interval was estimated from Minnesota cases data (si = 4.36), and the maximum likelihood for the R value was 1.28. The total number of simulations was 1000.

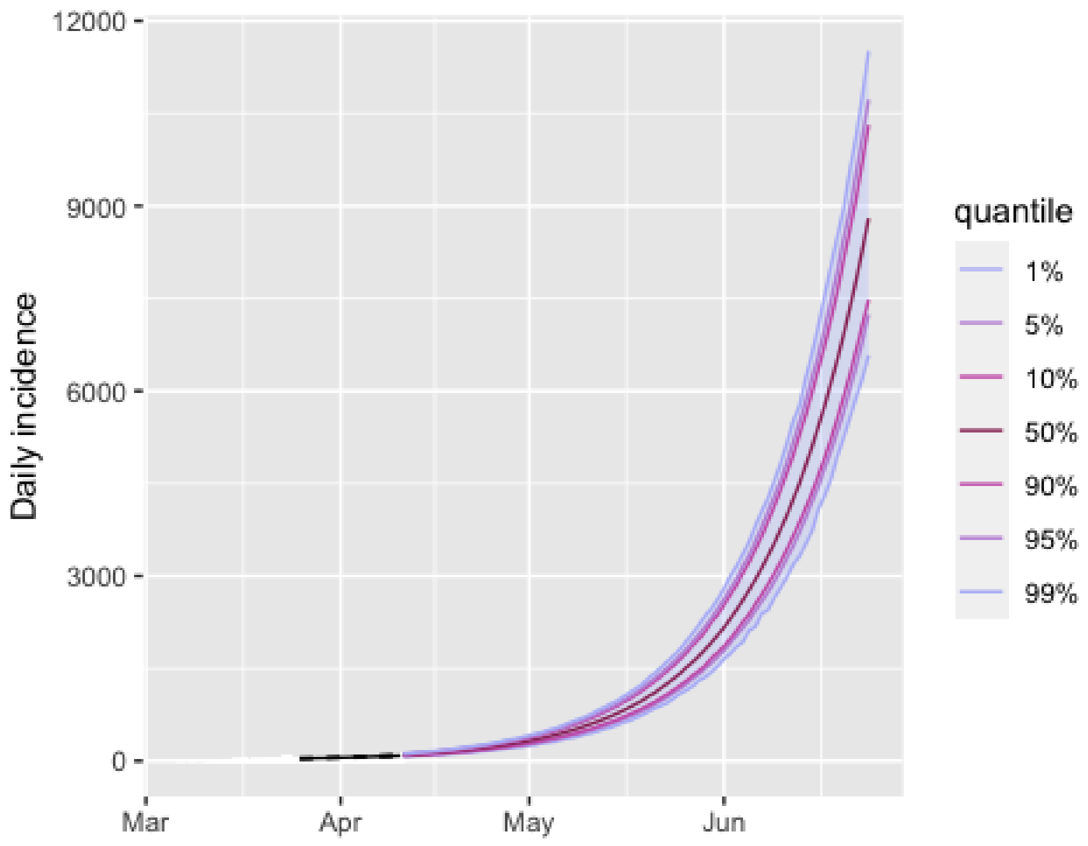

Figure 4.8: The projected incidence of SARS-CoV-2 in Minnesota overtime with the historical incidence data from March 3, 2020 to April 10, 2020 (white). The fitted exponential model used to estimate the incidence is plotted in black with the 95% confidence interval (dashed black). The simulated incidence data is provided for seventy-five days after April 10, 2020 in quantiles based upon the exponential model. The used serial interval was estimated from Minnesota cases data (si = 4.36), and the maximum likelihood for the R value was 1.28. The total number of simulations was 1000.

5 Discussion/Conclusions

The number of new SARS-CoV-2 cases in Minnesota is increasing daily with an increasing death incidence as well. Based on the data to date there is no indicator that the rates will decrease. The R value of the SARS-CoV-2 was estimated to be greater than 1 with a range between 1.15 and 1.40 indicating that an outbreak is possible within the Minnesota population. With the force of infection increasing over time more susceptible persons are becoming infected. These three factors are strong indicators that uncontrolled this disease will continue to rapidly spread.

The predictive daily incidence estimates and curves are based on uncontrolled SARS-CoV-2 outbreak. After 100 days there are an estimated 9000 new cases every day. Fortunaetley, these plots do not represent what will happen with interventions. Therefore, with intervention we expect the impact of the outbreak to be lessened.

However, one of the limiting factors of this analysis is the reported case data. Testing for SARS-CoV-2 is limited and not easily accessible. Therefore, not all cases are being detected and reported. Our analysis may underestimate how transmissible the virus is if there are infectious asymptomatic persons or ill persons who are unable or unwilling to recieve testings.

Lastly, the models provided are for incident cases and do not account for over the treatment duration that one case will be in the hospital or will be sick. For instance if one patient was put in the ICU they would remain there for 14 days until they recover. As the number of new cases being added to the ICU increases with increasing incidence the number of patients being removed from ICU does not increase. Therefore, we predict that there will be constraints on the hospitals to keep up with the influx of new cases, and the actual economic and societal burden will be greater than what can be estimated from incident cases.

6 Recommendations

Our main focus should be to decrease the force of the infection and decreasing the R value to less than 1.0. It is highly recommended that the counties experiencing outbreaks decrease person-to-person contact and inter- and intra-county transportation. Contact with the elderly, persons with pre-existing conditions, and immune-compromised should be minimized. Personal protective equipment such as face masks and hand hygiene should be utilized when ever possible. As a secondary goal, we recommend increasing the testing capabilities to confirm or add to the data already collected.

7 Cited work

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