Working paper
COVID-19 trends in Oregon: Preparing for opening up

Results as of 5/7/2020, 12pm

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Executive Summary

Purpose of this report: To estimate the number of people who are likely to have COVID-19 and need hospital services in Oregon over the next 6 weeks, assuming interventions with different levels of effectiveness are implemented.

Methods: This report uses available data from May 6, 2020 on confirmed positive diagnoses, number of tests completed, hospitalizations, intensive care unit (ICU) admittance, and deaths for Oregon to calibrate an agent-based COVID-19 model (Covasim), which is then used for projecting future epidemic trends.

Key Findings: Based on an 80% forecast interval, we predict that there have been between 4,350 and 14,550 infections in Oregon, of which 2,900 had been diagnosed by May 3rd. The aggressive interventions ("Stay Home, Save Lives") have been effective in dramatically reducing transmission rates. However, relatively small increases in transmission levels in the community could cause an increase in infections. We commend Oregon for planning to expand public health capacity for more testing, contacting tracing, and voluntary isolation and quarantine before incrementally loosening the current aggressive community mitigation strategies ("Stay Home, Save Lives").

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Methods

Orpheus data on COVID-19 cases were used. Orpheus is an integrated electronic disease surveillance system for public health to manage communicable disease reports (Orpheus description). The data file was obtained on May 6th, but data after May 3rd were considered incomplete because of lags in reporting.

We applied Covasim (Covasim code), an individual-based ("agent-based") COVID-19 transmission model with parameters informed by literature (assumptions given in the Appendix). The model was calibrated by modifying the assumptions to best fit data from Orpheus on confirmed positive COVID-19 diagnoses (now including presumptive cases, as well as positive tests), number of tests completed, hospitalizations (referred to as severe cases below), intensive care unit (ICU) admittance (referred to as critical cases below, and included in severe case counts), and deaths for Oregon. The model was then used for projecting future epidemic trends.

Interventions

Oregon has implemented numerous measures to slow the transmission of COVID-19 over time:

- On March 12, 2020: A large number of measures were put in place, such as bans on gatherings of more than 250 people; these are detailed here.
- On March 16, 2020: Schools were closed statewide, as detailed here. Further measures were put in place on March 16th, including the closure of restaurants and bars and gatherings of more than 25 people, as detailed here.
- On March 23, 2020: Aggressive interventions, namely the "Stay Home, Save Lives" recommendations, were put in place.
- On April 22, 2020: Testing guidelines were revised to allow for expanded testing, including testing of people who are asymptomatic and work in care settings or are in congregate settings; they were refined on May 1, 2020 (OHA revised testing guidelines.).
- On May 2, 2020: The use of face coverings encouraged (OHA statement about face coverings).

Since the beginning of the epidemic in Oregon, public health staff have routinely investigated diagnosed cases and then notified people who cases identify as close contacts of their exposure. Because of limited public health resources in Oregon to date, public health staff have only been able to actively follow up with contacts in households and congregate settings. Contacts have been asked to voluntarily stay in quarantine for 14 days after their last known exposure. Any diagnosed cases have been asked to voluntarily stay isolated for at least 72 hours after their symptoms resolve.
On May 1, 2020, Oregon announced plans for reopening, which include additional testing and contact tracing (OHA Reopening Plans May 1, 2020). On that same day, certain elective and non-urgent medical procedures resumed (Medical procedures May 1, 2020).

Results

The results provide evidence that Oregon's interventions -- combined with increased hygiene and other measures that appear to have begun earlier -- have dramatically reduced the burden of COVID-19 in Oregon (Figure 1). The data are consistent with a stepped reduction in transmission in Oregon, beginning with a 10% decrease in transmission by March 8th, through to a sustained decrease in transmission of approximately 70% after March 23rd. Indeed, while the interventions before March 23rd appeared to have slowed epidemic growth, the additional aggressive measures implemented on March 23rd (i.e., "Stay Home, Save Lives") appear to have reversed that growth. These results are consistent with large reductions in movement as shown in Google data for Oregon (Google mobility reports).

Of note, the model predicted a continued drop in new infections in the last two weeks (April 19th through May 2nd), but the number of new diagnoses appeared to be relatively steady during that time period (Figure 1). Because testing guidelines were updated April 22nd to expand testing, we might be seeing a temporary increase in number of new diagnoses. We suggest monitoring this pattern closely over time to see if this continues, if the effects of the interventions are waning, and/or if the model parameters about disease dynamics need to be adjusted.

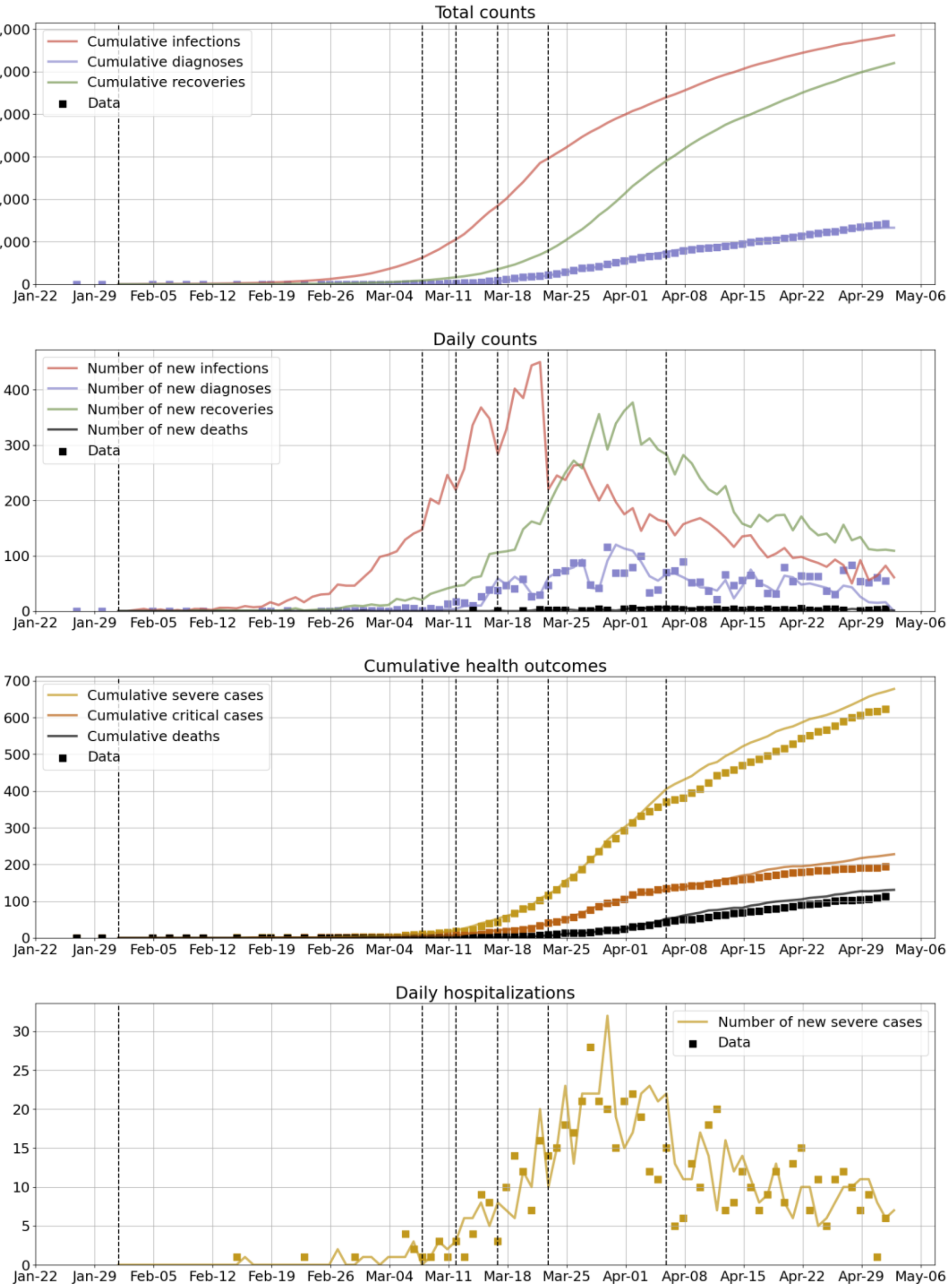

Figure 1: Best-fit model calibration with Oregon case data. Dotted vertical lines correspond to estimated reductions in transmission relative to baseline, from left to right, of 10%, 25%, 35%, 73, and 68%. The impacts of these interventions were estimated by calibrating to numbers of positive diagnoses (squares, top two plots), and to new severe cases (based on hospital admission date), new critical (intensive care unit (ICU)) cases, and deaths (bottom two plots). Note: The estimated effect of the moderate interventions is imprecise, given it was based on only one week of data. The estimate of the effectiveness of the aggressive interventions (since March 23rd) fluctuated slightly over time, possibly due to random fluctuations in the data, but was about 70% on average.

Scenario projections

The calibration above is based on running the model once, but to simulate the epidemic under future intervention scenarios and produce forecast intervals, we ran the forecast model 11 times (Figure 2).

These model simulations estimate that there have been between 4,350 and 14,550 cumulative infections in Oregon (80% forecast interval in Figure 2) by May 3rd, of which 2,900 had been diagnosed based on the local epidemiologic data.

We modeled three future scenarios from May 11th until June 14th, assuming interventions with different levels of effectiveness in reducing transmission:

- Interventions continue that reduce transmission by 70%: We assume interventions as effective as the current aggressive interventions are continued. This could be a combination of community mitigation strategies and expanded testing and contact tracing.
- Change to interventions that reduce transmission by 60% and 50%: We assume that some relaxation of community mitigation strategies, but continued expansion of testing and contact tracing together would reduce transmission by 60% or by 50%.

With continued aggressive interventions resulting in a 70% reduction in transmission, the number of cumulative infections is projected to slowly increase, while the number of those infectious slowly declines over the next 6 weeks (Figure 2).

However, this epidemic is clearly very sensitive to changes in policies or public adherence to community mitigation strategies. Under the scenario with interventions reducing transmission by 60% (vs. 70%), the model projects about 2,400 more cumulative infections (12,000 vs. 9,600), 100 more new infections per day (145 vs. 45), and 7 more new severe cases per day (10 vs. 3) by June 14th.[1] In addition, if Oregon were to implement interventions resulted in a 50% reduction in transmission on May 11th, cases would rise more quickly, resulting in about 6,200 more cumulative infections (15,800 vs. 9,600), 340 more new infections per day (385 vs. 44), and 14 more severe cases per day (17 vs. 3) by June 14th, compared to the 70% reduction scenario.[1] While these results can be used to understand the effects of different scenarios, it is important to note, that the 80% forecast intervals for these predictions are wide, reflecting their uncertainty.

[1] Per-day scenario differences are based on average of last 4 days (June 11th-14th) to stabilize estimates.

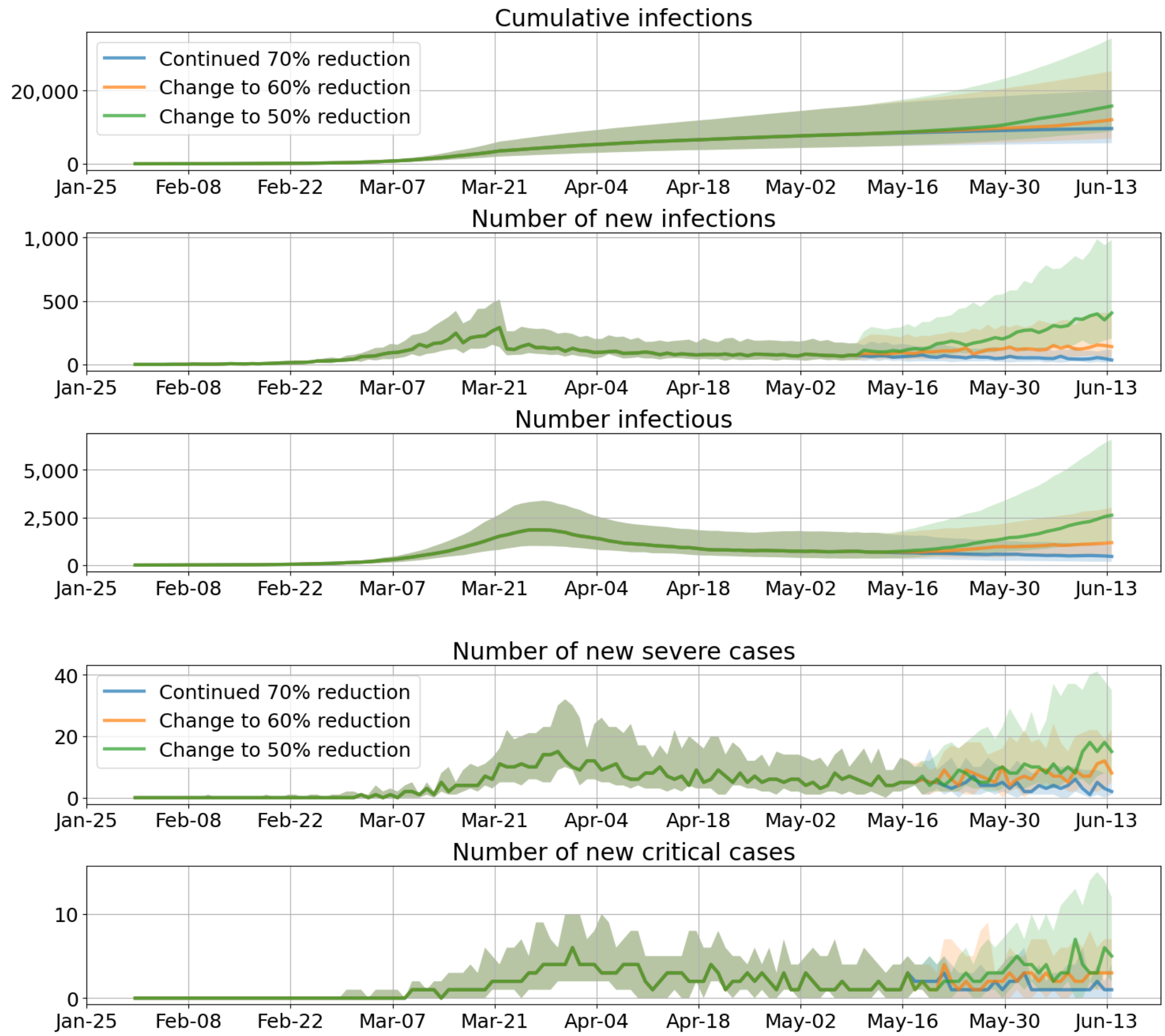

Figure 2: Model projections for the next 6 weeks, assuming that starting May 11th: 1) interventions continue that reduce transmission by 70% (blue line), 2) there is a change to interventions that reduce transmission by 60% (orange line), and 3) there is a change to interventions that reduce transmission by 50% (green line).The lighter shaded areas correspond to 80% forecast intervals ((i.e., 10th and 90th percentiles of the projection).

Limitations

These projections should be considered preliminary and subject to change as more data become available, the science to inform the model assumptions expands, and modeling methods continue to be refined. There are several limitations worth mention. First, the projections included in this report are based on the best available local data and evidence as of May 6th, 2020, but the local collection of epidemiologic data on COVID-19 cases may lag in ways we did not account for, and data improvement efforts are ongoing. Second, the model does not assume any cases are "imported" from elsewhere over time, but such cases would cause increases in local transmission. Last, there remain significant unknowns, including the proportion of asymptomatic infections, current extent of physical distancing, how public use of face coverings has changed, compliance with new interventions, and how these vary throughout the state.

Conclusions

Oregon's introduction of aggressive interventions early in the epidemic has been effective. Using Oregon data available on May 6th, we found that the current aggressive interventions have been effective in reducing the level of transmission by about 70%, with the case rates leveling off and even slowly declining. However, as we found in King County, Washington (IDM King County Report April 24, 2020) and others have found in Colorado (Colorado Modeling Report April 2020), the Oregon model simulations suggest that the future outcomes remain very sensitive to policy changes and public adherence to physical distancing guidelines. Indeed, our projections suggest that interventions with a 60% reduction in transmission would lead to a growth in cases in Oregon, with about 100 more new infections per day by June 14th, than interventions with a 70% reduction in transmission. These findings underscore the need to continue monitoring outcomes extremely carefully over time, especially in view of the difficulties in translating specific policies to percent reduction in transmission, and measuring adherence to those policies.

While "Stay Home, Save Lives" has been effective in reducing transmission, we recognize that there is an enormous economic and social cost to these aggressive community mitigation strategies, especially for low-income families, and a need for the state to start reopening. We commend Oregon for planning to expand public health capacity for more testing, contacting tracing, and voluntary isolation and quarantine before incrementally loosening the current aggressive community mitigation strategies (OHA Reopening Plans May 1, 2020) to keep transmission levels low in the state. Other models have suggested that physical distancing measures will likely need to continue to some extent even with extensive testing and contact tracing, given the challenges with the disease dynamics (e.g., Kretzschmar et al, 2020; Childs et al., 2020). Additional vigilance to reduce the risk of reintroduction if travel restrictions were relaxed would also require substantial testing capacities.

On April 27th (OHA April 27 press release), Governor Brown expressed her commitment to collaborating with Nevada, Colorado, Washington, and California governors in developing a coordinated plan for reopening as part of a Western States Pact. To inform these reopening plans, researchers have begun forecasting cases based on different scenarios (e.g., Colorado Modeling Report April 2020), and IDM is working with Washington State to quantify trade-offs among strategies with different costs, feasibilities, and benefits (IDM King County Report April 24, 2020). We will share those results with the

Western states when the analyses are completed. However, decision-making for leadership will continue to be challenged by large uncertainty due to limited and changing scientific evidence during this pandemic. In addition, even with excellent control measures, importations or other "escaped infections" will be inevitable, as the recent examples in Singapore and Taiwan have illustrated. To avoid the need to return to widespread lockdown after such an event, very good surveillance measures and high compliance with symptom-based testing will need to be in place.

Appendices

Appendix 1: Detailed transmission model methods

We applied Covasim version 0.29.9, an individual-based (i.e., "agent-based") COVID transmission model with parameters informed by the literature; the full source code is available on GitHub. The new version has been substantially updated from the versions used in our previous reports for Oregon; for example, it allows for viral load to vary over time, allows infectivity to vary across individuals, and includes updated parameter assumptions.

The model simulated a population based on American Community Survey 2018 single-year, age-specific estimates for Oregon. The simulation begins on 2020-02-01. It is not possible to calibrate the model with a single importation event near the date of the first diagnosis (2020-02-27), which is consistent with the fact that this case was community acquired, implying other infections occurred before this date. To match observed epidemic trends, five infected individuals are assumed by 2020-02-01. This indicates either multiple importation events, or a single importation occurring earlier.

Internally, COVID-19 (SARS-CoV-2) infection within each individual is represented by four stages: susceptible, exposed, infectious, recovered (SEIR). The exposed (latent) period prior to the onset of viral shedding is log-normally distributed with a mean of 4.6 days and standard deviation of 4.8 days. The infectious period is log-normally distributed with mean 8 days and standard deviation 2 days, based on measured upper-respiratory viral shedding after symptom onset (Zou et al., 2020). Viral transmission from one individual to the next proceeds on a fixed contact network with directed edges. The degree distribution of the network is Poisson-distributed with rate parameter lambda=20. Individual network edges are selected at random. On each day, infectious individuals expose susceptible "close contacts" (neighboring nodes in the graph) to possible infection. We began by assuming the daily probability of an infectious individual infecting each neighboring susceptible individual is binomially distributed with $p = 0.015$, but modified this to 0.019 to fit the pattern in the Oregon data. With an average of 20 contacts per individual per day and a mean duration of infectiousness of 8 days, this per-day probability roughly translates to R0 = 3.0. Before being diagnosed, all infected individuals with symptoms are assumed to be equally infectious; those who remain asymptomatic are assumed to have a daily probability of infecting another person of 80% that of a symptomatic individual. Once a case is diagnosed, they are assumed to be in isolation, so the transmission rate is reduced by 80%.

The probability of death for each infection is approximately 1.3%, dependent on age (Ferguson et al., 2020). Time from infection to death is drawn from a normal distribution with mean of 17 days and standard deviation of 4 days.

Testing probability in the model is based on an individual's symptoms.

Appendix 2: Healthcare system modeling methods

There is still a high degree of uncertainty about the healthcare needs of COVID-19 patients in the United States, since the clinical care protocols are rapidly evolving and will depend substantially on the comorbidities and level of opportunistic infections that are seen in a given patient population. With that in mind, we triangulated between several published sources in order to estimate starting parameters, and then modified those during the calibration process to best fit trends in the Orpheus data.

We extrapolated the symptomatic rate, the hospitalization rate, and the rate of ICU bed needs based on various sources. We assumed an overall symptomatic rate of 68%, similar to Ferguson et al (2020), and assumed the symptomatic rate was higher for older cases. Age-specific hospitalization rates were taken from Verity et al. (2020) and age-specific rates of ICU bed need from CDC COVID-19 Response Team (2020). Combining these sources and applying to the Oregon population, we estimate that 6.3% of all cases (symptomatic or not) require hospitalization (i.e., severe illness) and 2.1% of all cases require an ICU bed as part of an inpatient stay (i.e., critical cases). This translates to about 30% of hospitalized cases requiring an ICU bed, which is consistent with our local Hospital Capacity Web System (HOSCAP) data (Oregon COVID-19 Daily Update) and Bouadma et al. (2020). We assumed 6.6 days between symptom onset and developing severe illness, and 1 day between severe and critical illness.

The model is a discrete event simulation, which models each individual patient as they contract COVID-19 and subsequently seek hospital care. Patients arrive at the hospital with symptoms according to the pattern projected by the epidemiological model described above.

Appendix 3: Projections of the effective reproduction number (R_e) for interventions with 70%, 60%, and 50% reduction in transmission

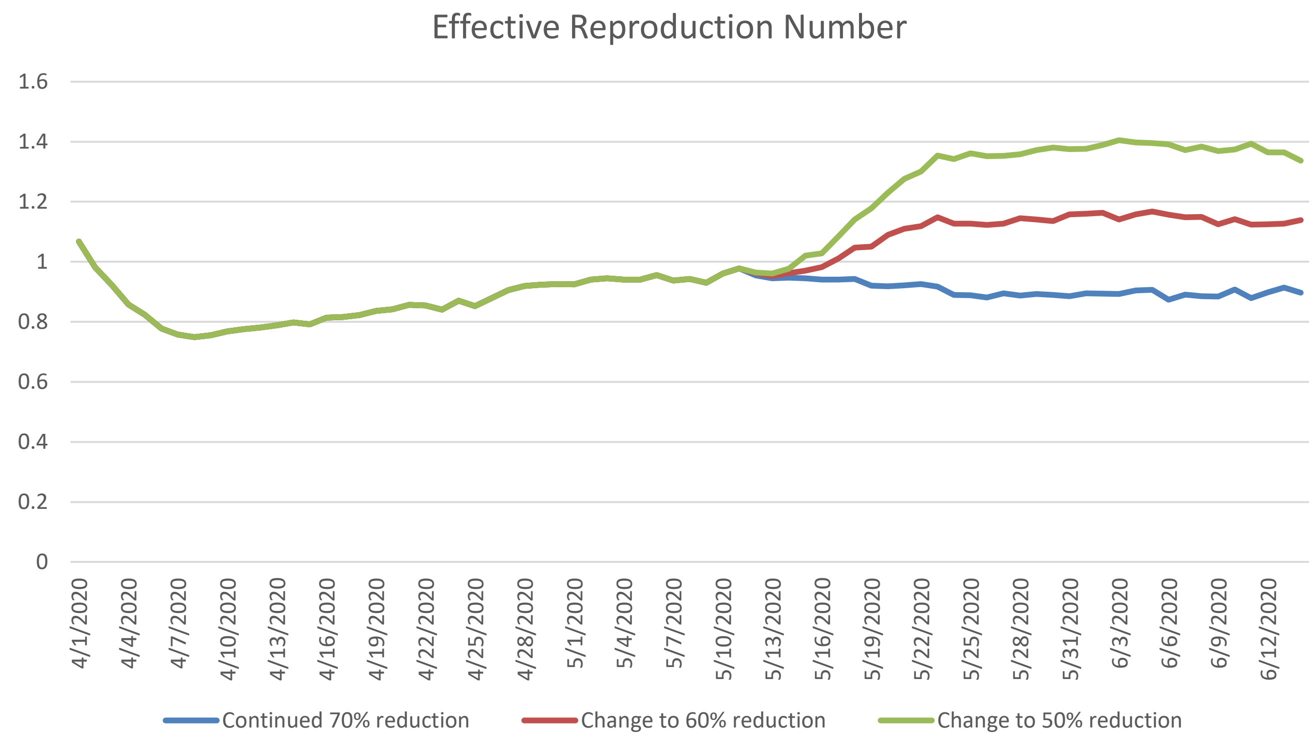

Figure 4: Projected effective reproduction number (Re) over the next 6 weeks, assuming that starting May 11th: 1) interventions continue that reduce transmission by 70% (blue line), 2) there is a change to interventions that reduce transmission by 60% (orange line), and 3) there is a change to interventions that reduce transmission by 50% (grey line). Re is the expected number of secondary cases that a single case generates.

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