BRIEF REPORT: COVID-19 EPIDEMIC TRENDS AND PROJECTIONS IN OREGON

Results as of 7/22/2020 – 6:00pm

CORRECTION 8/5/2020: In the Figure 1 legend, the percentages for the last three transmission changes were incorrect. These were accurately described elsewhere in the report.

ACKNOWLEDGEMENTS

This is an update to the Oregon Health Authority's (OHA's) previous modeling reports. This report was based on Covasim modeling software, developed by the Institute for Disease Modeling (IDM). IDM provided OHA with initial programming scripts for the models, and has provided extensive support and technical assistance to OHA. OHA especially wishes to thank Cliff Kerr, Katherine Rosenfeld, Brittany Hagedorn, Dina Mistry, Daniel Klein, Assaf Oron, Prashanth Selvaraj, Jen Schripsema, and Roy Burstein at IDM for their support (Contact: covid@idmod.org).

RESULTS SUBJECT TO CHANGE

Please note that the COVID-19 data used for the modeling are continually being updated. (For daily up-to-date information, visit the OHA COVID-19 webpage.) The results in this brief will be updated as more data become available, the science to inform the model assumptions expands, and modeling methods continue to be refined. While these results can be used to understand the potential effects of different scenarios, it is important to note that the 80% forecast intervals for these predictions are wide, so point estimates should be interpreted with caution.

KEY FINDINGS

Changes after Oregon has begun to reopen

- Based on data through July 16th, the models indicate that transmission has increased since reopening began on May 15th. Specifically, trends in new hospitalizations are consistent with an increase in transmission of 20 percentage points after May 15th and an additional 10 percentage points after May 20th. These increases were followed by transmission decreases around June 4th (5 percentage points) and June 18th (10 percentage points).
- After these changes, the estimated transmission appears to be 15 percentage points above the pre-May 15th level. The corresponding effective reproduction number (Re) – the expected number of secondary cases that a single case generates – is estimated to be approximately 1.15.
- Because it takes an estimated 12 days on average from when a person becomes infected until they might be hospitalized, it is still unclear from hospitalization data if transmission changed after July 4th. Recent diagnosis data does not, by itself, suggest a change in transmission.

Future scenarios

- We modeled three future scenarios with different assumptions about transmission.
    - Transmission continues as-is: If we assume transmission continues at the current level over the next month, the estimated number of new daily infections increases steadily over the next 4 weeks (from 1,000 to 1,600), and the number of daily new severe (i.e., hospitalized) cases increases by a smaller amount (from 20 to 27). The model projects 99,700 cumulative infections by August 13th. The Re is projected to be approximately 1.15.
    - Transmission decreases: If we assume that transmission decreases by 10 percentage points starting July 17th and continues at that level over the next month, the estimated number of new infections decreases over time. The model projects approximately 16,500 fewer cumulative infections (83,200 vs. 99,700), 1,000 fewer new infections per day (600 vs. 1,600), and 10 fewer new severe (i.e., hospitalized) cases per day (17 vs. 27) by August 13th than the continued as-is scenario. The Re is estimated to decrease to about 0.9.
    - Transmission increases: If we assume that transmission increases by 10 percentage points starting July 17th and continues at that level over the next month, the estimated number of new infections per day increases more dramatically. Compared to the continued as-is scenario, the model projects approximately 29,200 more cumulative infections (128,900 vs. 99,700), 2,300 more new infections per day (3,900 vs. 1,600), and 19 more new severe cases per day (46 vs. 27) by August 13th. The Re is estimated to be about 1.5.

Conclusions

The results indicate that transmission increased substantially after reopening, then decreased somewhat, and is now about 15 percentage points higher than immediately before reopening. Our model estimates the Re is currently about 1.15. If transmission remains at current levels, we expect continued growth in infections; however, a reduction of 10 percentage points may be sufficient to stop growth.

PURPOSE OF THIS REPORT

This report describes trends in COVID-19 since Oregon began to re-open, and projects trends over the next month assuming different scenarios. This report complements the extensive epidemiologic data (e.g., demographic trends in cases, testing patterns) available at the OHA COVID-19 webpage.

METHODS

This report presents analyses conducted using methods consistent with the previous July 9th, 2020 report, with some key updates:

- Newer data from Orpheus on COVID-19 cases (Orpheus description) were used. The Orpheus data file was obtained on July 20th, but data after July 16th were considered incomplete because of lags in reporting and were not used.

More information about the methods is in Appendix 1.

INTERVENTIONS

Oregon has implemented numerous measures to slow the transmission of COVID-19, including:

- On March 8, 2020: Governor Brown declared an emergency due to the public health threat.
- On March 12, 2020: A large number of measures were put in place, such as bans on gatherings of more than 25 people, as detailed here.
- On March 16, 2020: Schools were closed statewide, as detailed here. Further measures were put in place on March 16th and 17th, including the closure of restaurants and bars and gatherings of more than 25 people, as detailed here.
- On March 19, 2020: Non-urgent health care procedures were suspended to conserve personal protective equipment and hospital beds.
- On March 23, 2020: Aggressive interventions, namely the "Stay Home, Save Lives" recommendations, were put in place.

- On April 21, 2020: Testing guidelines were revised to allow for expanded testing, including testing of people who are asymptomatic and work in care settings or live in congregate settings; they were refined on May 1, 2020 and again on June 2, 2020 (Revised testing guidelines).
- Since the beginning of the epidemic in Oregon: Public health staff have routinely investigated diagnosed cases, asked those cases to identify their close contacts, and then notified those contacts of their exposure (i.e., contact tracing). Because of limited public health resources in Oregon, public health staff had 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 isolate for at least 72 hours after symptoms resolve (i.e., quarantine). Contact tracing efforts started to expand with reopening plans, as mentioned below.

REOPENING

On May 1, 2020, Oregon announced plans for phased relaxation of community mitigation strategies, with additional expansion of testing and contact tracing to keep transmission low (Reopening Plans May 1, 2020). Some key changes have included:

- On May 1, 2020: Certain elective and non-urgent medical procedures resumed (Medical Procedures May 1, 2020).
- On May 2, 2020: The widespread use of face coverings was encouraged.
- On May 5, 2020: Some parks, outdoor recreation facilities, and areas across Oregon were opened for day use (Parks May 5, 2020).
- On May 7, 2020: Governor Brown published detailed guidance on reopening. This included requirements for counties to reopen, such as having sufficient capacity for testing and contact tracing. The guidance also called for the widespread public use of face coverings, maintaining physical distance of six feet between individuals as much as possible, and following good hygiene and disinfection practices (Reopening Guidance May 7, 2020).
- On May 15, 2020: Some counties began to reopen, and certain restrictions were eased statewide, such as allowing social gatherings of under 10 people and cultural/civic/faith gatherings of up to 25 people with physical distancing, as detailed here and here). Briefly:
  - On May 15th, 31 of the 36 counties in Oregon had been approved for Phase 1 of reopening.
  - By June 1st, 35 counties were approved for Phase 1 reopening. The most populous county (Multnomah) had not yet reopened.
  - On June 5th and 6th, 28 counties were approved for Phase 2 reopening, as well as one more on June 8th.

    - On June 11th, due to a rise in COVID-19 cases, the Governor temporarily halted approvals for additional phased reopening.
    - On June 17th, the Governor approved Multnomah County's plan for Phase 1 reopening, starting on Friday, June 19.
- On June 23, 2020: An update on the expansion of contact tracing efforts was issued here, reporting about 600 county and state contact tracers.
- On June 24, 2020: Implementation began of a new plan for testing at long-term care facilities, as described here.
- On June 25, 2020: The Governor required people living in Oregon's seven most populous counties to wear a face covering when in indoor public spaces, with some exceptions (e.g., young children, people with disabilities, while eating), as described here. This requirement extended to all Oregon counties on July 1st, as described here.
- On July 15, 2020: Face coverings became required outdoors in situations where people are unable to maintain a distance of at least six feet from others, and most indoor gatherings of more than 10 people were not allowed.

RESULTS

As with previous modeling reports, the results in this brief report will be updated as more data become available, the science to inform the model assumptions expands, and modeling methods continue to be refined (see Appendix 2 for information on the limitations). The models simulate the spread of COVID-19 in Oregon statewide under different scenarios. They do not take into account the complex disease spread or intervention effectiveness within and between specific populations over time, such as for communities of color, workers in certain occupations, or people in congregate settings. The models use average transmission levels; hence they do not, for example, model outbreaks in work settings differently than other types of transmission.

Epidemiologic trends to date

The model was calibrated (Figure 2) by modifying the assumptions from the literature to best fit data from Orpheus on confirmed positive COVID-19 diagnoses, number of tests completed, and number of people hospitalized (referred to as "severe cases" below) for Oregon. The dates on which model transmission levels change were selected based on key policy enactment dates, with the following exceptions: 4/6/2020 (based on data observation), 5/20/2020 (based on data observation and corresponding to the Wednesday before Memorial Day weekend), 6/4/2020 (based on data observation), and 6/18/2020 (based on data observation). The degree of changes in transmission were informed by hospitalization and diagnoses data, not by the assumed effect of any policy. The model was calibrated to observed data based on the average of 11 randomized runs.

As in previous modeling reports, the calibration provides evidence that Oregon's aggressive interventions -- combined with increased hygiene and other measures that appear to have begun earlier -- dramatically reduced the burden of COVID-19 in Oregon during the spring (Figure 1).

- The data are consistent with a stepped reduction in transmission in Oregon, beginning with a 5% decrease in transmission by March 8th, up to a maximum 75% decrease in transmission 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”) appeared to have further curtailed that growth. The reductions were likely due to people spending more time at home, as well as an increase in hygiene and disinfection practices, wearing of face coverings, and physical distancing outside the home; however, the data to determine the relative contribution of each change are lacking.
- The data suggest that these dramatic reductions in transmission waned somewhat after early-April, but the number of new daily infections was still declining through mid-May.

Consistent with the previous report, the current calibration provides evidence that transmission has increased since reopening began on May 15th.

- As seen in Figure 1, hospitalizations increased starting in early June. Given the approximate two-week delay between infection and hospitalization, this early June increase is reflective of earlier transmission: it is consistent with a 20 percentage point increase in transmission after May 15th and an additional 10 percentage point increase in transmission after May 20th (the Wednesday before Memorial Day).
- Transmission appeared to then decrease around June 4th and further around June 18th -- as reflected by the growth in hospitalizations slowing somewhat after mid-June -- but was still 15 percentage points higher than before May 15th. This corresponds to an effective reproduction number (Re) – the expected number of secondary cases that a single case generates – of approximately 1.15.
- The effects of changes in transmission after July 4th on hospitalization numbers may not be apparent until after our July 16th data cutoff, given potential reporting delays and an assumed average of 12 days between people becoming infected and hospitalized.
- We would expect changes in transmission after July 3rd to be reflected in new diagnoses about eight days later, on average (after July 11th). Daily diagnoses (Figure 1) after July 11th are thus far consistent with no change in transmission, assuming testing practices have stayed the same.

The model estimates that, as of July 16th, there have been a total of 64,000 cumulative infections in Oregon (80% forecast interval: 50,700 – 89,800), but only 14,700 have been diagnosed according to available data.

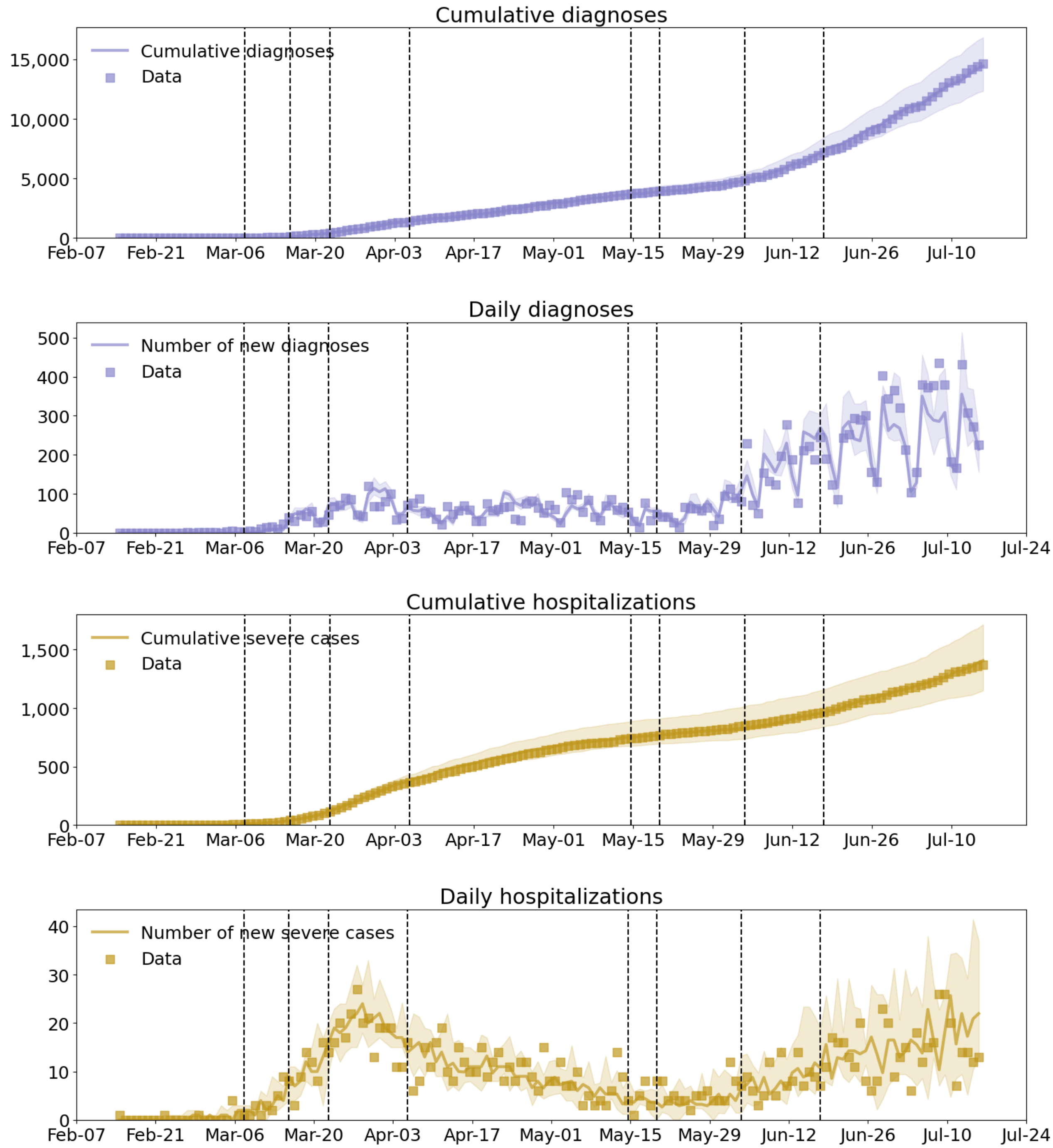

Figure 1: Model calibration with Oregon data. Dotted vertical lines correspond, from left to right, to estimated reductions in transmission relative to baseline of 5% (March 8th), 50% (March 16th), 75% (March 23rd), 70% (April 6th), 50% (May 15th), 40% (May 20th), 45% (June 4th), and 55% (June 18th). Raw data are presented as squares; estimates from the calibration are presented as lines. Note: The estimated reductions in transmission are imprecise, especially given some are based on few data points. The shaded areas represent variability among the calibration runs.

Scenario projections

Because we do not know how adherence to the physical distancing, face covering, and hygiene guidance will change over time, it is not possible to confidently predict future transmission levels. Recent data points also suggest some amount of uncertainty: while average daily diagnoses continue to increase, new hospitalization growth may be slowing. Therefore, we modeled three future scenarios through August 13th by making different assumptions about future transmission.

For all scenarios, we assumed 4,500 tests per day to reflect recent testing levels (July 7 Testing Summary). The estimates and forecast intervals are based on results from 11 randomized runs.

- Transmission continues as-is: If we assume transmission continues at the current level over the next month, the estimated number of new daily increases steadily over the next 4 weeks (from 1,000 to 1,600), and the number of daily new severe (i.e., hospitalized) cases increases by a smaller amount (from 20 to 27). The model projects 99,700 cumulative infections by August 13th. The Re is projected to be approximately 1.15 (Figure 3).[1]

- Transmission decreases: If we assume that transmission decreases by 10 percentage points starting July 17th and continues at that level over the next month, the estimated number of new infections decreases over time. The model projects approximately 16,500 fewer cumulative infections (83,200 vs. 99,700), 1,000 fewer new infections per day (600 vs. 1,600), and 10 fewer new severe (i.e., hospitalized) cases per day (17 vs. 27) by August 13th than the continued as-is scenario. The Re is estimated to decrease to around 0.9 (Figure 3).

- Transmission increases: If we assume that transmission increases by 10 percentage points starting July 17th and continues at that level over the next month, the estimated number of new infections per day increases more dramatically. Compared to the continued as-is scenario, the model projects about 29,200 more cumulative infections (128,900 vs. 99,700), 2,300 more new infections per day (3,900 vs. 1,600), and 19 more new severe cases per day (46 vs. 27) by August 13th. The Re is estimated to be about 1.5 (Figure 3).

[1] Re increased slightly over time in this and the increased-transmission scenario because, as new infections increase, a gradually smaller proportion are assumed to be diagnosed and to subsequently reduce their transmission, since testing is assumed to stay at the same level.

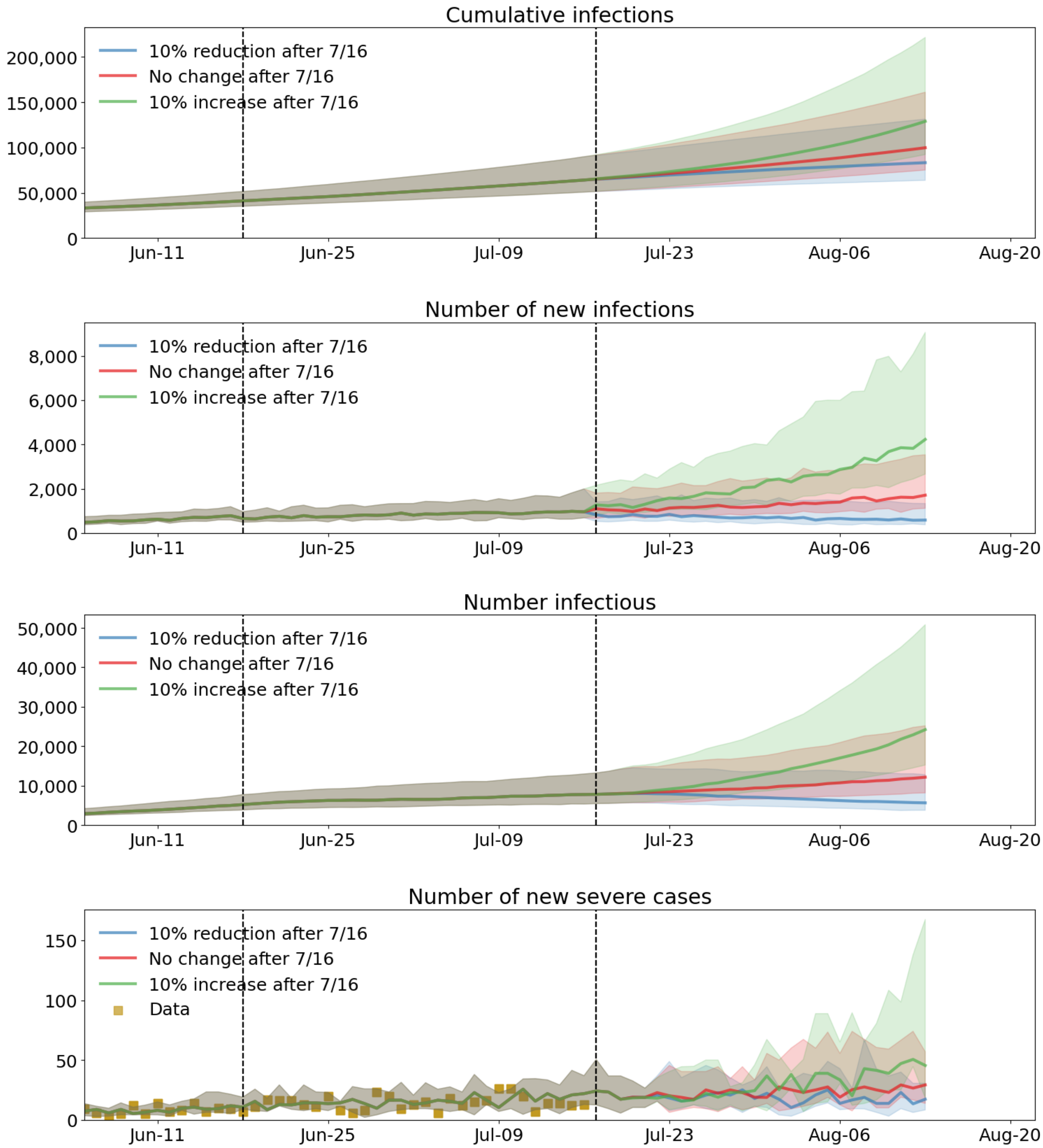

Figure 2: Model projections for the next 4 weeks, assuming that after July 16th: 1) transmission does not change (red line), 2) transmission decreases by 10 percentage points (blue line), and 3) transmission increases by 10 percentage points (green line). The lighter shaded areas correspond to 80% forecast intervals (i.e., 10th and 90th percentiles of the projection).

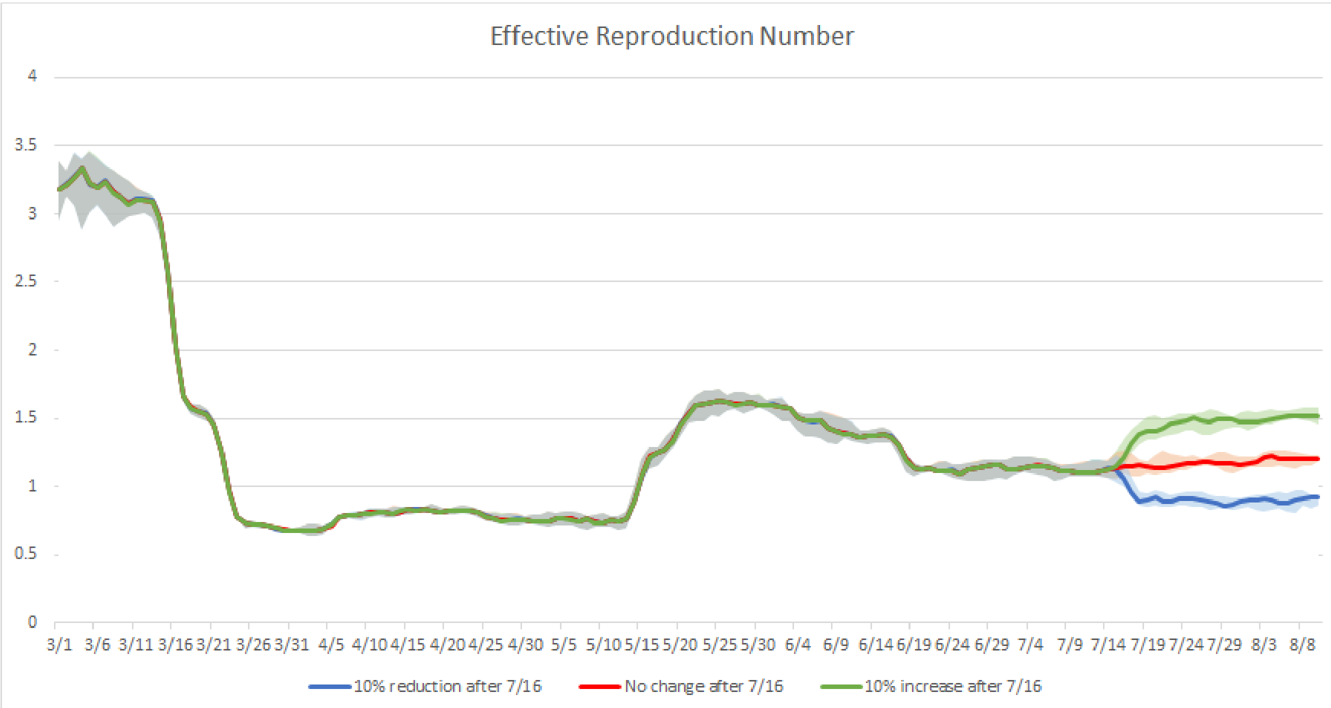

Figure 3: Projected effective reproduction number (Re) through August 10th, assuming that starting July 17th: 1) no change in transmission (red line), 2) transmission decreased by 10 percentage points (blue line), and 3) transmission increased by 10 percentage points (green line). The lighter shaded areas correspond to 80% forecast intervals (i.e., 10th and 90th percentiles of the projection). Re is the expected number of secondary cases that a single case generates.

Summary of Results

While these results can be used to understand the potential trends in COVID-19 under different scenarios, it is important to note that the 80% forecast intervals for these predictions are wide, reflecting their uncertainty.[2]

The results indicate that transmission increased substantially after reopening, then decreased somewhat, and is now about 15 percentage points higher than immediately before reopening. Our model estimates the Re is currently about 1.15. If transmission remains at current levels, we expect continued growth in infections; however, a reduction of 10 percentage points may be sufficient to stop growth.

Even with testing, treatment, and contract tracing, transmission levels are still dependent on adherence to the guidance regarding physical distancing, face coverings, hygiene, self-

[2] "The forecast intervals used correspond to the 10th and 90th percentiles of the simulated trajectories. Although these forecast intervals bear some similarities to confidence or credible intervals, since they are typically produced through a combination of stochastic variability and parameter uncertainty, they do not have a rigorous statistical interpretation." (p 18 of IDM report)

quarantining of contacts, and self-isolation of cases. Understanding the system, workplace, social network, and individual-level barriers to adherence to that guidance and addressing those barriers is essential to reducing transmission.

Comparison with other model results

The latest results from Imperial College London, CovidActNow and RT Live[3] estimate the Re for Oregon to be 1.18, 1.12 and 0.98, respectively, compared to our estimate of 1.15.

CDC compiles hospital forecasts from numerous modelers. From CDC's July 14th compilation, our scenario that assumed transmission continues as-is most closely resembles the forecasts from Georgia Institute of Technology (GT-DeepCOVID), Columbia University (CU-Select), and US Army Engineer Research and Development Center (ERDC) (Figure 4).

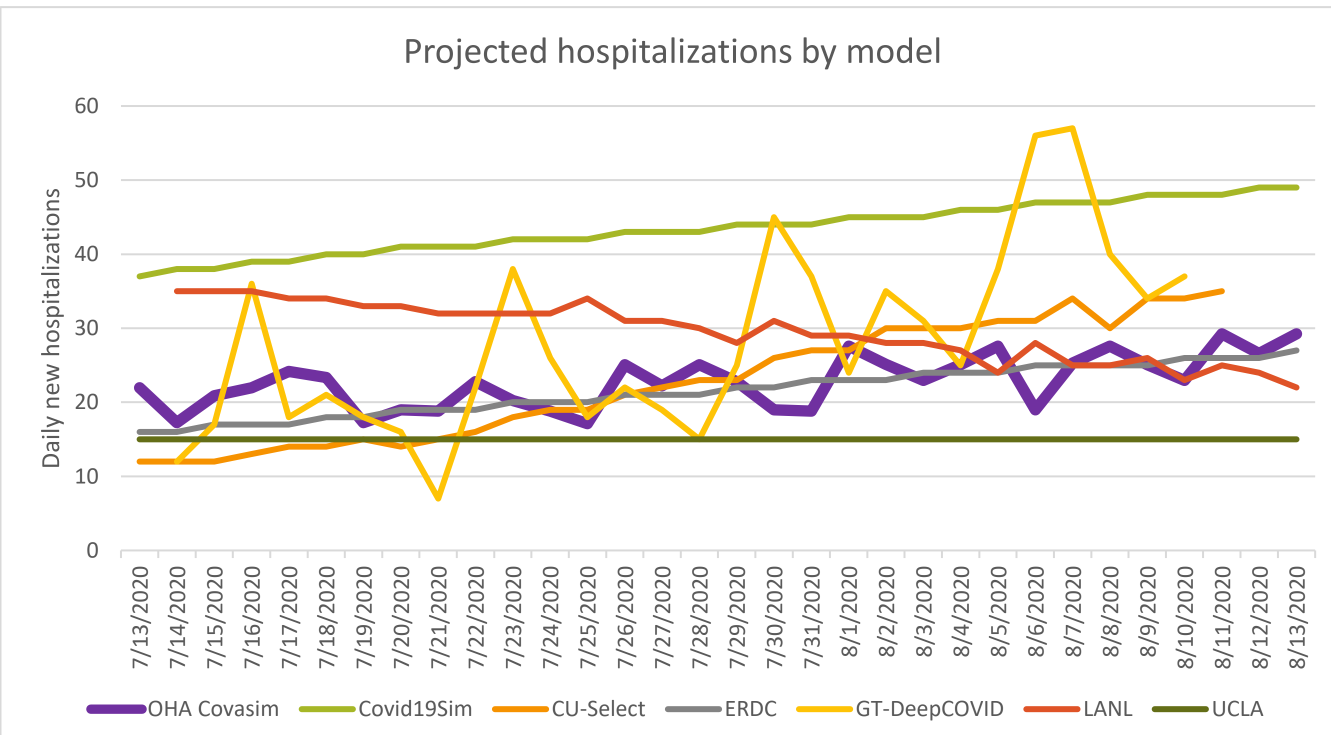

Figure 4: Projected daily new hospitalizations in Oregon through July 30th for the current report's scenario that assumed estimated transmission "continues as-is" (OHA Covasim) and other models included in CDC's hospital forecast compilation[4], as of July 13th.

[3] These websites accessed 7/22/2020.
[4] One model (Johns Hopkins) was not included because projections for recent dates were at a much higher level (about 80 per day) than observed data.

APPENDICES

Appendix 1: Detailed transmission model methods

We applied Covasim version 1.4.7, 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 methods and assumptions for Covasim are described in detail here.

The model was calibrated by modifying the assumptions to best fit data from Orpheus on confirmed positive COVID-19 diagnoses, number of tests completed, and hospitalizations (referred to as severe cases below) for Oregon.

Our model assumed random network connections, had scenario noise set at zero, and used default parameters from Covasim version 1.4.7, except for the following changes:

1) Population age distribution was based on American Community Survey 2018 single-year estimates for Oregon. We used a simulation population size of 420,000 with Covasim’s population rescaling functionality enabled.
2) The COVID-19 virus had a pre-intervention Beta value[5] of 0.021, instead of 0.016 (based on observed hospitalizations before interventions took effect).[6]
3) We adjusted Covasim’s age-specific severe outcome probability parameters among all infections to be consistent with CDC’s suggested parameter values for pandemic planning scenarios (CDC Planning Scenarios as of May 20, 2020). Specifically, we used the CDC parameter values for age-specific hospitalization probabilities among symptomatic infections, and adjusted them based on Covasim’s age-specific symptomatic probability parameters. After applying Oregon’s age distribution and time-varying age-specific susceptibility ratios (see point #4), our model estimates overall hospitalization rates (among infections) of 3.1% prior to May, and 2.2% for May-onward. These rates are lower than in reports before July due to the incorporation of Covasim symptomatic assumptions and a change in the age-adjustment methodology.
4) Parameter assumptions were modified to vary susceptibility by age and time, such that the age distribution of severe cases in the model follows that of cases diagnosed and subsequently hospitalized in Oregon over two time periods: February-April and May-June. The susceptibility odds ratios used in these respective time periods were: [2.42, 3.05] for age 0-9, [0.51, 1.28] for age 10-19, [1.08, 1.05] for age 20-29, [0.48, 0.55] for age 30-39, [0.63, 0.51] for age 40-49, [1.05, 0.80] for age 50-59, [0.93, 0.46] for age 60-69, [1.02, 0.49] for age 70-79, and [1.19, 0.62] for age 80 and higher. These ratios may partially correspond to biological susceptibility by age but are also a reflection of social behavior and testing activity. The populations of both diagnosed and hospitalized cases

[5] Whenever a susceptible individual comes into contact with an infectious individual on a given day, transmission of the virus occurs according to probability Beta (β).
[6] 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 a basic reproduction number (R0) of 3.

have become younger over time in Oregon, implying a lower overall hospitalization rate and more total infections per hospitalization in recent months.

5) To assess our new parameter assumptions, we compared our model estimates of cumulative infections with what we might expect from seroprevalence studies. CDC's study in Western Washington State of people seeking medical care suggests that only about 9% of infections as of April 1st had been reported (CDC Seroprevalence Studies). Our current model had similar results: cumulative diagnoses on April 1st in Oregon made up about 7% of the estimated cumulative infections on that date (1,070 cumulative diagnoses /15,400 estimated cumulative infections).
6) We determined transmission levels through mid-June based on hospitalization levels and adjusted the assumptions about testing practices to reflect the observed test positivity rates. Specifically, the relative probability of symptomatic individuals being tested was adjusted to match actual diagnoses counts given our inputted number of tests, with changes in relative odds occurring on April 23rd and June 4th.

It is not possible to calibrate the model with a single importation event near the first diagnosis (February 21, 2020), which was a community acquired infection. To match observed epidemic trends, we started the model with 75 infected individuals on February 15th, 2020; this date was moved forward and the number of infections increased from reports before June to produce narrower forecast intervals.

Appendix 2: Limitations

- The results in this report will be updated as more data become available, the science to inform the model assumptions expands, and modeling methods continue to be refined. The report uses the best available local data as of July 20th, 2020; however, the local epidemiologic data on COVID-19 cases may lag in ways we did not account for. Data improvement efforts are ongoing.
- Our parameter assumption for the proportion of all infections (diagnosed or not) that are hospitalized was based on CDC's hospitalization-among-symptomatic estimates and Covasim default symptomatic-among-infection estimates, then adjusted to observed local hospitalizations by age. However, there is considerable variability in this estimate in the literature. Underestimating this proportion would inflate our estimates of total number of infections, while overestimating would deflate the number. After the initial imported cases, the model assumes that no additional cases were imported from elsewhere over time. Any such cases would inflate local transmission levels, though any actual resulting diagnoses and hospitalizations in Oregon from imported cases are included in the data used for model calibration.
- For simplicity, we assumed random network connections and a combined effect of various interventions for the future scenarios (e.g., physical distancing, expanded testing and contact tracing) on overall transmission, but Covasim does have the ability to incorporate more complex network dynamics and specific intervention effects (as described here).
- Estimated reductions in transmission over time are imprecise and not necessarily due to any particular action (e.g., policy or event); some are based on few data points and sometimes multiple actions co-occurred.
- We assumed that individuals who were diagnosed subsequently reduced their transmission by 80%, but this reduction may vary as social norms change.
- Our model assumes that diagnoses occur uniformly among individuals experiencing symptoms. On any given day, those with mild symptoms were assumed to be as likely to be diagnosed as those with more severe symptoms. We do not expect this to have a major effect on the model's estimate of transmission, however, because although severe cases are infectious longer, they are assumed to be less infectious over time.
- Although our model was calibrated to track actual numbers of tests and diagnoses, it assumed both occurred entirely among symptomatic individuals. It also did not explicitly account for reduced transmission from individuals who are not tested but undergo quarantine due to contact tracing efforts.
- Given the fairly low number of cases in Oregon, trends in cases and the age distribution (and therefore prognosis) are sensitive to a single outbreak or super spreader event. Such outbreaks would be expected to affect a younger population than outbreaks in nursing homes, which occurred beginning early in Oregon's epidemic (OHA Weekly COVID-19 Report).
- These models simulated the spread of COVID-19 in Oregon statewide under different scenarios. They did not take into account the complex disease spread or intervention

effectiveness within and between specific populations over time, such as for communities of color, workers in certain occupations, or people in congregate settings. However, the demographics of cases diagnosed over time in Oregon have been changing, as documented in OHA's weekly COVID-19 report found here.

Finally, significant unknowns remain, including information about public adherence to guidance (e.g., physical distancing, face coverings, hygiene), the disease dynamics, and treatment. As CDC stated (CDC Planning Scenarios) "new data on COVID-19 are available daily; information about its biological and epidemiological characteristics remain limited, and uncertainty remains around nearly all parameter values."