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

Results as of 10-29-2020, 4pm

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 support and technical assistance to OHA. OHA 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.

RESULTS UPDATED BIWEEKLY

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 are updated biweekly as more data become available, the science to inform the model assumptions expands, and modeling methods continue to be refined. The results are not intended to be predictive, but rather to be used for planning purposes. While these results can be used to understand the potential effects of different scenarios, point estimates should be interpreted with caution due to considerable uncertainty behind COVID-19 model assumptions, limitations to the methods, and recent changes in COVID-19 testing volume.

KEY FINDINGS

Changes since Oregon began to reopen

- Based on COVID-19 data through October 22, the model is consistent with transmission increases throughout May, followed by transmission decreases from late-June through late-July. This transmission reduction caused the estimated effective reproduction number (Re) – the average number of secondary cases that a single case generates – to decrease below 1.
- Throughout August, the Re was estimated to remain below 1. Indeed, the number of new diagnosed cases and severe cases (those with symptoms severe enough to warrant hospitalization) had been declining.
- Cases began to increase again in September. The model suggests that transmission increased in early September, with an estimated Re of around 1.2.
- Severe cases appeared to peak in early October and then to flatten. The broader severe case trend was consistent with a mid-September transmission decrease in the model, after which the model's estimated Re fluctuated around 1 (averaging 1.02). The data on diagnosed cases are consistent with this trend.
- It is unclear from severe case data if transmission changed after October 10 because it takes an estimated 12 days, on average, from when a person becomes infected until they develop severe disease. In addition, hospitalization status is obtained through case investigation and is sometimes not known for weeks after the admission date. Trends in diagnosed cases can be an earlier indication of transmission changes, since the average time between infection and diagnosis is estimated to be 8 days, but the number of cases diagnosed is dependent on testing practices and reporting.

Future scenarios

We modeled three future scenarios with different assumptions about transmission starting October 23 and continuing over the next month. For all scenarios, we assumed 5,500 people tested per day.

- <u>Transmission continues as-is</u>: If we assume transmission continues at the current level over the next month, COVID-19 outcomes will stay at a relatively steady level. The model projects that by November 19:
    - The number of new daily infections will remain at around 1,000.
    - The number of existing infections that are newly diagnosed each day (i.e., newly diagnosed cases) will increase slightly from 340 to 380, assuming current testing practices continue.
    - The number of new severe cases each day will be about 22.
    - There will be about 186,000 cumulative infections.
    - The Re will be about 1 (10^{th} and 90^{th} percentile estimates from 11 runs: 0.93 and 1.08).

- Transmission increases: If we assume that transmission increases by 5 percentage points and continues at that level over the next month, adverse COVID-19 outcomes will increase. The model projects that by November 19:
    - There will be approximately 700 more new daily infections (1,700 vs. 1,000), 140 more diagnosed cases each day (520 vs. 380), and 9 more new severe cases each day (31 vs. 22) compared to the continued as-is scenario.
    - There will be about 197,000 cumulative infections.
    - The Re will be 1.16 (10^{th} and 90^{th} percentile estimates:1.08 and 1.22).

- Transmission returns to August level: If we assume transmission decreases by 6 percentage points, thereby returning to the estimated August level, and continues at that level over the next month, COVID-19 outcomes will start to decrease again. The model projects that by November 19:
    - There will be approximately 400 fewer new daily infections (600 vs. 1,000), 150 fewer new diagnosed cases each day (230 vs. 380), and 6 fewer new severe cases each day (16 vs. 22) compared to the continued as-is scenario.
    - There will be about 175,000 cumulative infections.
    - The Re will be 0.82 (10^{th} and 90^{th} percentile estimates: 0.76 and 0.89).

Each of these scenarios is based on different assumptions, as indicated above. The scenarios are meant to illustrate the effect of changing transmission on COVID-19 trends and should not be interpreted as a forecast range.

Conclusions

These results suggest that transmission has fluctuated considerably since reopening began in May. Recent trends suggest the estimated Re was below 1 in August, increased to about 1.2 in early September, but then decreased again in mid-September, fluctuating around 1.0 (averaging 1.02). However, these results only reflect transmission through October 10, and are subject to data reporting lag; severe counts for the last few days of modeling data may be incomplete, and thus transmission higher than estimated.

If the Re is about 1 over the next month, the estimated number of new daily infections will remain steady at about 1,000, with about 380 diagnoses each day assuming recent testing practices continue. Unfortunately, epidemiologic data and hospital occupancy data over the last few days suggest that cases have been increasing again rather than remaining steady. However, given that the virus is very sensitive to changes in transmission, Oregonians can drive down these trends; if they redouble prevention efforts and return to the August transmission level, cases will start declining.

The results in this report are not intended to be predictive, but rather to be used for planning purposes. Model point estimates should be interpreted with caution, given considerable uncertainty behind COVID-19 model assumptions, limitations to the methods, and recent changes in COVID-19 testing volume.

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 October 15, 2020 report, with some key updates:

- Newer data from Oregon Pandemic Emergency Response Application (Opera) on COVID-19 cases (Opera description) were used. The Opera data file for this report was obtained on October 26, but data after October 22 were considered insufficiently complete because of lags in reporting and were not used.
- To reflect recently-increased testing levels, we assumed 5,500 people tested per day in the model scenarios.

More information about the methods is in Appendix 1.

PUBLIC HEALTH INTERVENTIONS

Since the beginning of the pandemic, Oregon has implemented numerous public health measures to slow the transmission of COVID-19. Appendix 2 lists dates of specific interventions before and after reopening (reopening plans were announced on May 1, 2020). Together, these efforts comprise a comprehensive approach to protect the public's health and well-being – with not only direct client services (e.g., testing and contact tracing), but also policy implementation (e.g., face covering requirements, limits on the size of gatherings), educational campaigns, culturally responsive approaches, support of community action, systems change to address barriers and inequities, and ongoing epidemiologic monitoring and evaluation. These interventions continue to evolve as the science expands, we learn about specific community needs, and more funding becomes available. As with other comprehensive public health interventions, it is difficult to determine the contribution of any one component because each is essential and they act synergistically; and, in the case of COVID-19, various components were implemented simultaneously or in quick succession.

RESULTS

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 3 for information on the limitations). The models simulate the spread of COVID-19 in Oregon statewide under different scenarios. They do not model regional variability, and 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 1) by modifying the assumptions from the literature to best fit data from Opera on cumulative counts of COVID-19 total diagnosed cases[1], tests completed, severe cases[2], and deaths for Oregon. The model was calibrated to observed data based on median daily values from 11 randomized runs. The early dates on which model transmission levels change were selected based on key policy enactment dates, but after March 23 they were based on data observation. The degree of changes in transmission were informed by the COVID-19 data, not by the assumed effect of any policy. It is important to note that the estimated reductions in transmission over time are imprecise and cannot easily be attributed to any particular action (e.g., policy or event), given some are based on few data points and sometimes multiple actions co-occurred.

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). Specifically:

- The data are consistent with a stepped reduction in transmission in Oregon, beginning with a 5% decrease in transmission after March 8, up to a maximum 80% decrease in transmission after March 23. Indeed, while the interventions before March 23 appeared to have slowed epidemic growth, the additional aggressive measures implemented on March 23 (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 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 in April, but the number of new daily infections was still declining until early-May.

The current calibration suggests that transmission has fluctuated considerably since reopening began in May (Figure 1). Specifically:

- New severe cases stopped declining in mid-May before beginning to increase starting in early June. The trends were consistent with transmission increases of 5 percentage points

[1] Total diagnosed cases include confirmed cases (positive test) and presumptive cases (symptoms with epidemiologic link).
[2] Severe cases include both cases admitted to the hospital and individuals who died but were not hospitalized. Approximately 7% of severe cases are deaths that were not hospitalized or of unknown hospitalization status.

after April 1, April 19, and May 1, followed by a 10 percentage point increase after May 15 (the start of reopening). Transmission appeared to have then decreased by 5 percentage points after June 28 and by another 7 percentage points after July 26, bringing the estimated effective reproduction number (Re) – the average number of secondary cases that a single case generates – to below 1.

- Throughout August, the Re was estimated to remain below 1. Indeed, the number of new diagnosed cases and severe cases (those with symptoms severe enough to warrant hospitalization) had been declining.
- Cases began to increase again in September. The model suggests that transmission increased in early September, with an estimated Re of around 1.2.
- Severe cases appeared to peak in early October and then to flatten. The broader severe case trend was consistent with a mid-September transmission decrease in the model, after which the model's estimated Re fluctuated around 1 (averaging 1.02). The data on diagnosed cases are consistent with this trend.
- It is unclear from hospitalization or death data if transmission changed after October 10 because it takes an estimated 12 days, on average, from when a person becomes infected until they develop severe disease. In addition, hospitalization status is obtained through case investigation and is sometimes not known for weeks after the admission date. Trends in diagnosed cases can be an earlier indication of transmission changes, since the average time between infection and diagnosis is estimated to be 8 days, but the number of cases diagnosed is dependent on testing practices and reporting.

The model calibration slightly underestimated the number of deaths during August and September, but as of October 22 closely tracks the total number of cumulative deaths (Figure 1).

Based on the model calibration, we estimate that as of October 22, a total of 155,500 cumulative infections have occurred in Oregon, but only about 42,000 have been diagnosed (i.e., diagnosed cases) according to available data.

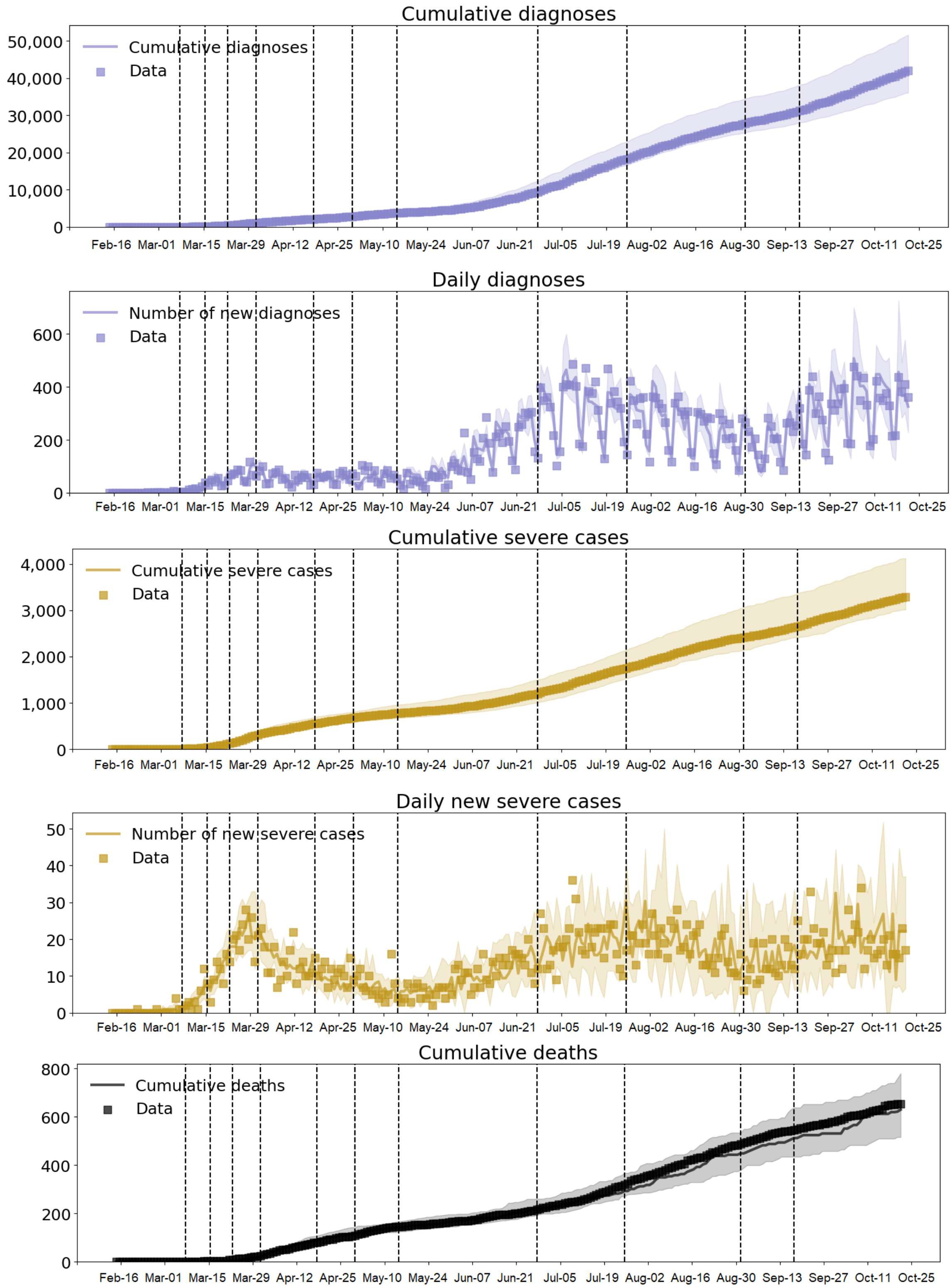

Figure 1: Model calibration with Oregon data. Dotted vertical lines correspond, from left to right, to estimated reductions in transmission relative to baseline of 5% (March 8), 45% (March 16), 80% (March 23), 75% (April 1), 70% (April 19), 65% (May 1), 55% (May 15), 60% (June 28), 67% (July 26), 57% (September 1), and 61% (September 18). Raw data are presented as squares; estimates from the calibration are presented as lines. The shaded areas represent variability among calibration runs (i.e., 10th and 90th percentiles of the calibration).

Scenario projections

We modeled three scenarios through November 19 based on the calibration. Scenarios are meant to illustrate the effect of different transmission levels on COVID-19 trends and should not be interpreted as a forecast range. It is not possible to confidently predict future COVID-19 trends because of significant gaps in knowledge. For example, we do not have comprehensive measures of adherence to the physical distancing, face covering, hygiene, isolation, and quarantine guidance over time, and do not know what the effects of seasonal changes will be.

The estimates are based on results from 11 randomized runs. We present the median from those runs as a point estimate and present the 10th and 90th percentile estimates as an interval.[3] For all scenarios, we assumed 5,500 people tested per day, a conservative estimate, given the increase in access to antigen testing (described here and here). We will take expanded testing into account in future reports, as we learn what proportion of these are positive.

- Transmission continues as-is: If we assume transmission continues at the current level over the next month, COVID-19 outcomes will stay at a relatively steady level. The model projects that by November 19:
    - The number of new daily infections will remain at around 1,000.
    - The number of existing infections that are newly diagnosed each day (i.e., newly diagnosed cases) will increase slightly from 340 to 380, assuming current testing practices continue.
    - The number of new severe cases each day will be about 22.
    - There will be about 186,000 cumulative infections.
    - The Re will be about 1 (10th and 90th percentile estimates from 11 runs: 0.93 and 1.08).[4]

- Transmission increases: If we assume that transmission increases by 5 percentage points and continues at that level over the next month, adverse COVID-19 outcomes will increase. The model projects that by November 19:
    - There will be approximately 700 more new daily infections (1,700 vs. 1,000), 140 more diagnosed cases each day (520 vs. 380), and 9 more new severe cases each day (31 vs. 22) compared to the continued as-is scenario.
    - There will be about 197,000 cumulative infections.
    - The Re will be 1.16 (10th and 90th percentile estimates from 11 runs: 1.08 and 1.22).

[3] "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 Covasim report).

[4] The average Re decreases slightly in the scenario, possibly due to chance, as well as our assumption that more infections are diagnosed and isolated than historically with the higher testing volume since October (5,500 per day).

- Transmission returns to August level: If we assume transmission decreases by 6 percentage points, thereby returning to the estimated August level, and continues at that level over the next month, COVID-19 outcomes will start to decrease again. The model projects that by November 19:
    - There will be approximately 400 fewer new daily infections (600 vs. 1,000), 150 fewer new diagnosed cases each day (230 vs. 380), and 6 fewer new severe cases each day (16 vs. 22) compared to the continued as-is scenario.
    - There will be about 175,000 cumulative infections.
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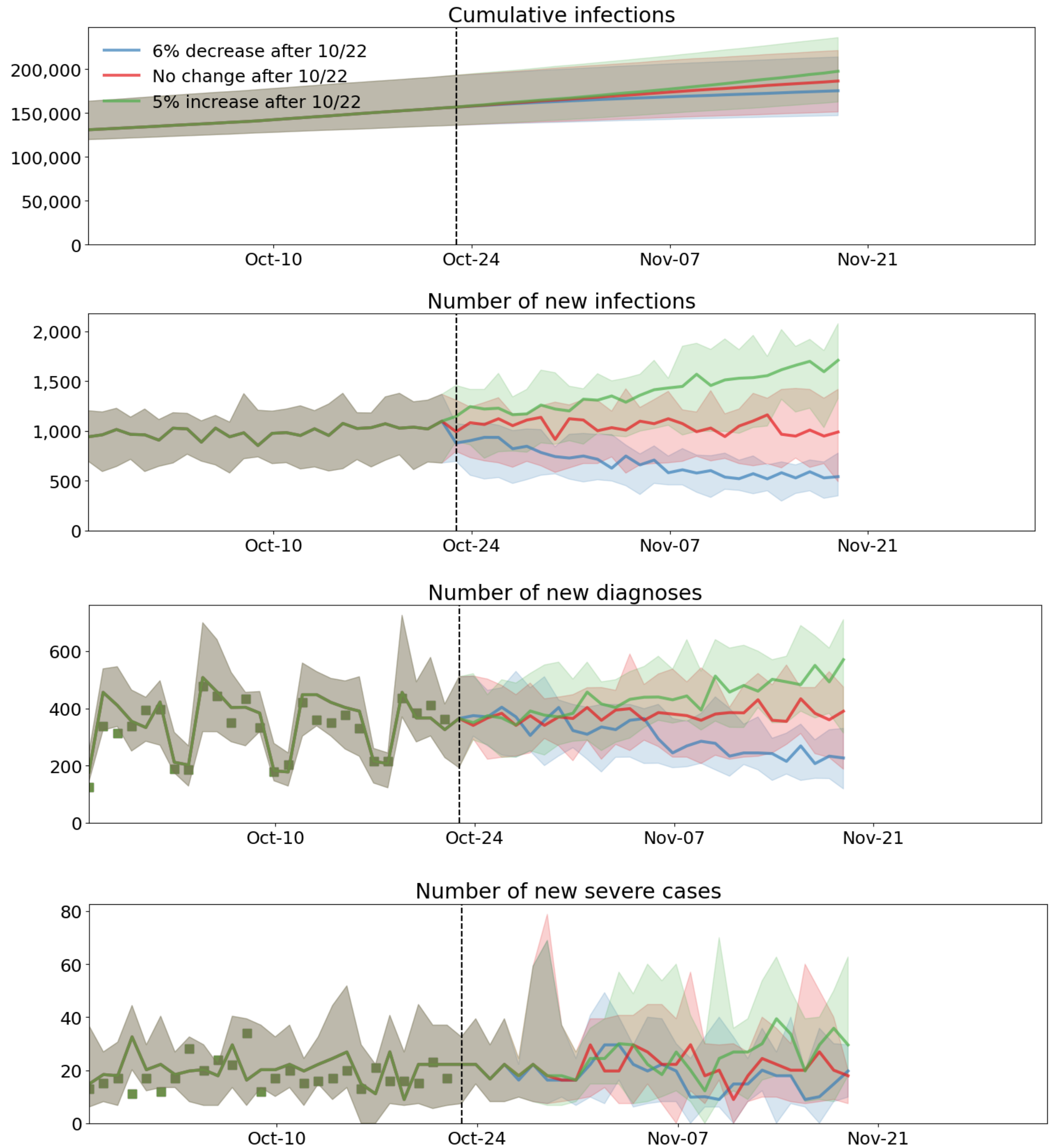


Figure 2: Model projections for the next 4 weeks, assuming after October 22 that transmission: 1) returns to August levels (i.e., decreases by 6 percentage points) (blue line), 2) does not change (red line), and 3) increases by 5 percentage points (green line). The lines represent the median estimates from the 11 randomized runs. The lighter shaded areas correspond to the 10th and 90th percentiles of each projection.

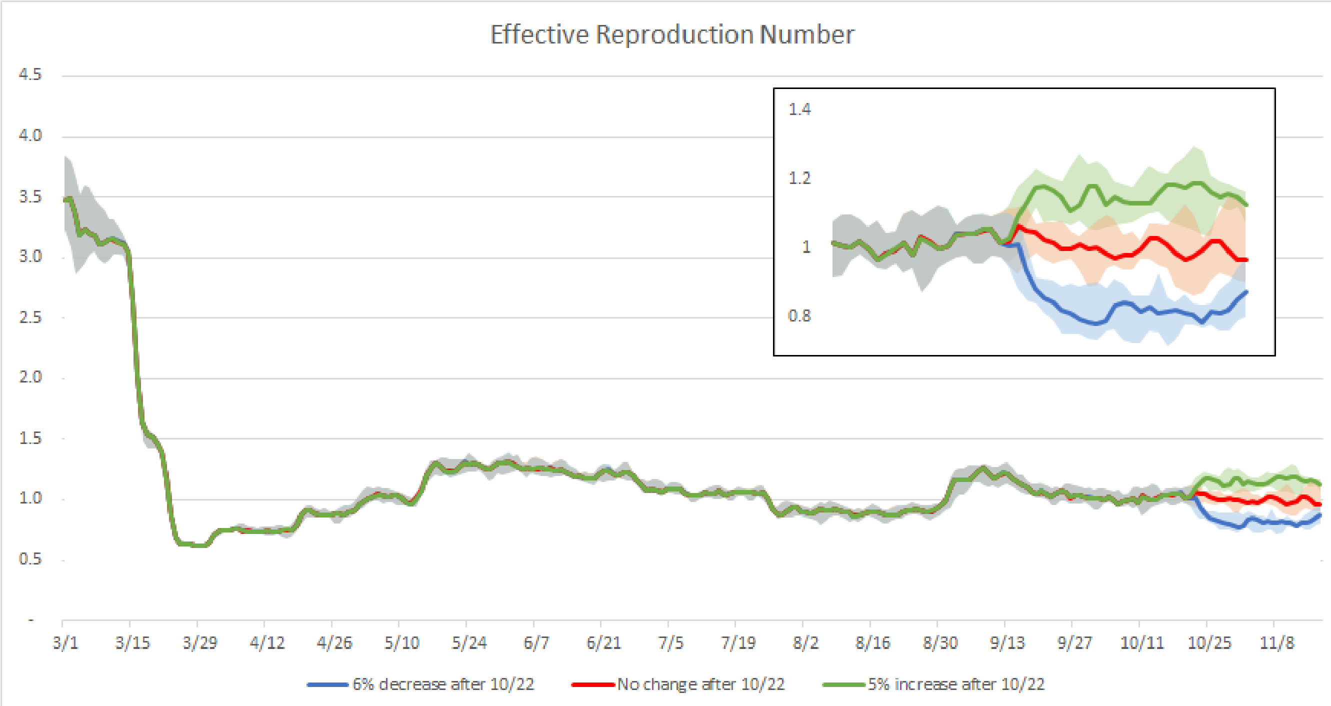


Figure 3: Projected effective reproduction number (Re) through November 17, assuming after October 22 that transmission: 1) returns to August levels (i.e., decreases by 6 percentage points) (blue line), 2) does not change (red line), and 3) increases by 5 percentage points (green line). The lines represent the median estimates from the 11 randomized runs. The lighter shaded areas correspond to the 10th and 90th percentiles of the projection. Re is the average number of secondary cases that a single case generates; estimates vary day-to-day due to differences among randomized simulation outcomes.

Comparison with other model results[5]

RT Live, Covid Act Now, and CMMID estimate the Re (range or interval) for Oregon to be 1.03 (0.78 – 1.24), 1.04 (0.94 – 1.14), and 1.0 (0.9 – 1.2), respectively. These estimates are similar to the average Re estimate in our Covasim model since the last transmission change on September 18 (1.02, with 10th and 90th percentiles of 0.96 and 1.10).

As part of a sensitivity analysis, we fit another calibration in Covasim assuming a 6 percentage point decrease in transmission on September 18 (instead of 4 percentage points). This calibration still fit the cumulative severe case curve fairly well but resulted in a lower Re (0.97, with 10th and 90th percentiles of 0.90 and 1.04). This analysis highlights the lack of precision in the model's point estimates, but still suggests the Re is approximately 1.0.

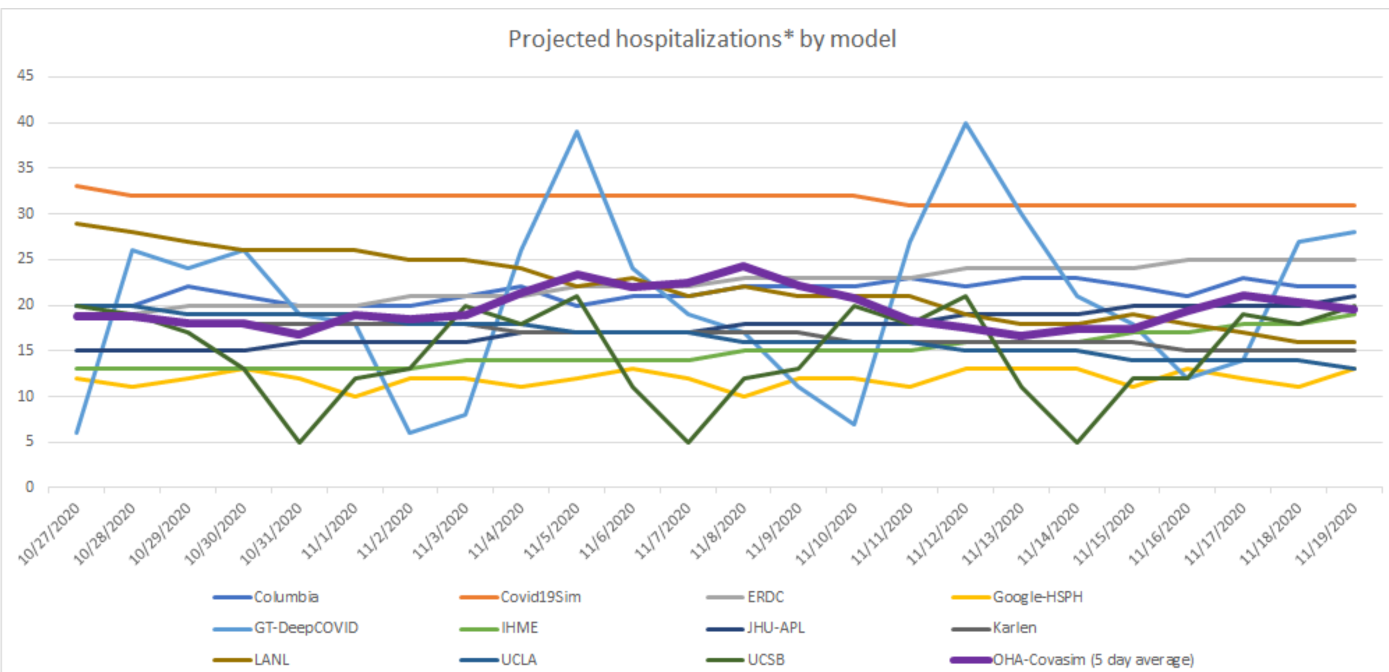
We have begun to explore alternative software with which to conduct modeling for Oregon. Covasim has much more complex capabilities than the trend analyses and basic projections in this report, e.g., simulating different contact tracing strategies. Because of its complexity and

[5] These websites for Re mentioned in this section were accessed on 10/28/2020. The CDC's forecasts were accessed on 10/28/2020.

how it incorporates chance into the modeling, the calibration using Covasim is very time consuming and not ideally suited for tracing through many months of historical performance; considerably different patterns of transmission over time can result in a similar calibration fit.[6] Therefore, we are assessing alternative IDM software, Rainier, designed specifically for algorithmically-fitting historical estimates of Re over time, generating "nowcasts," and conducting simple projections. Rainier is being used for regular reporting for the State of Washington (Example Washington Report). We fitted a Rainier model with the Oregon COVID-19 data; based on preliminary analyses, the general trends in the estimated Re over time appeared consistent with our Covasim findings but Rainier is able to more easily detect small changes. To date, it appears Rainier could provide as useful information for planning in a more efficient manner than Covasim.

CDC compiles hospital forecasts from numerous modelers. Compared to CDC's compilation of October 26 models, our "continues as-is" scenario predicts a level and trend of hospitalizations similar to the average of other forecasts (Figure 4a).

CDC also compiles forecasts of newly reported cases. Compared to CDC's ensemble forecast based on models updated October 19, our "continues as-is" scenario predicts a similar number of diagnosed cases but less of a decreasing trend (Figure 4b). Their updated forecast will likely be published on October 29.



[6] As an example, an increase in transmission of 6 percentage points on August 21 and remaining at that level also resulted in a calibration with a good fit to the data (the calibration presented in the results had an increase in transmission of 10 percentage points on September 1 and a decrease of 4 percentage points on September 18).

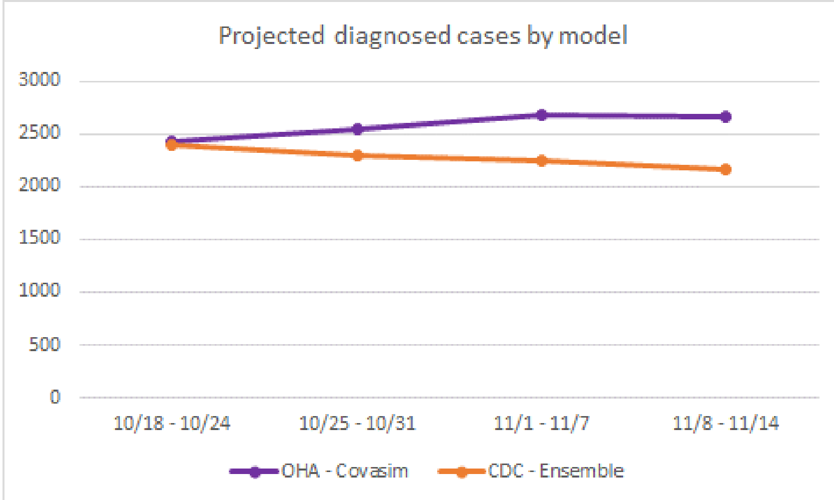


Figure 4a and b: Projected (a) daily new hospitalizations through November 19 and (b) weekly new diagnosed cases through the week ending November 14 in Oregon; estimates are from the current report's "continues as-is" scenario (OHA Covasim) and other models included in CDC's forecast compilations.[7] *Note: OHA forecast in (a) is based on forecast for severe cases, but scaled by 0.93 to adjust for the expected percentage of severe cases that are not hospitalized.

Recent trend in hospital occupancy

The Opera data file for this report was obtained on October 26, but data after October 22 were considered insufficiently complete because of lags in reporting and were not used. Therefore, we lack data for the past week. Counts of hospital occupancy during the past week in Oregon from the HOSCAP data system, which is updated daily, show a similar level of hospital-reported occupancy between October 22 and October 27, followed by a rapid increase (+22%) in the subsequent two days. As of October 29, HOSCAP-reported occupancy is at a higher point than at any time during summer or fall.

Discussion

These results suggest that transmission has fluctuated considerably since reopening began in May. Most recent trends suggest the estimated Re was below 1 in August, increased to about 1.2 in early September, but then decreased again in mid-September, fluctuating around 1.0 (averaging 1.02). These results only reflect transmission through October 10, and are subject to data reporting lag; severe counts for the last few days of modeling data may be incomplete, and thus transmission higher than estimated.

If the Re is about 1 over the next month, the estimated number of new daily infections will remain steady at about 1,000, with about 380 diagnoses each day assuming recent testing practices continue. Unfortunately, epidemiologic data and hospital occupancy data over the last few days suggest that cases have been increasing again rather than remaining steady.

[7] CDC compilation for new hospitalizations was updated October 27 and for new diagnosed cases was dated October 21.

However, given that the virus is very sensitive to changes in transmission, Oregonians can drive down these trends; if they redouble prevention efforts and return to the August transmission level, cases will start declining.

This model projects statewide averages in case trends, but examining disparities is critical to inform interventions. For example, case trends vary by county (Data dashboard), and the Latinx and other communities of color have been disproportionately impacted (OHA Weekly COVID Report). In addition, even with testing, treatment, and contact tracing, transmission levels are still dependent on adherence to the guidance regarding physical distancing, face coverings, hygiene, self-quarantining of contacts, and self-isolation of cases. Collaborating with community partners to understand the structural, workplace, social network, and individual-level barriers to adherence to that guidance and addressing those barriers is essential to reducing transmission.

In addition, it is important to note that Re is an average: the average number of secondary cases that a single case generates. However, other COVID-19 research (e.g., here and here) suggests that many people do not spread this virus to anyone; rather, this virus spreads in bursts and sometimes by people without symptoms. For example, outbreaks in Oregon have occurred in indoor social gatherings. These patterns highlight the need for everyone, including those without symptoms, to adhere to public health guidance.

Model point estimates should be interpreted with caution, given considerable uncertainty behind COVID-19 model assumptions, limitations to the methods, and recent changes in COVID-19 testing volume. In addition, we cannot confidently predict future COVID-19 trends because of significant gaps in knowledge. For example, we do not have comprehensive measures of adherence to the physical distancing, face covering, hygiene, isolation, and quarantine guidance over time, and do not know what the effects of seasonal changes will be. The results in this report are not intended to be predictive, but rather to be used for planning purposes.

APPENDICES

Appendix 1: Detailed transmission model methods

We applied Covasim version 1.7.2, 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 Opera on cumulative numbers of COVID-19 total cases, tests completed, and severe cases (hospitalizations and deaths) for Oregon.

Our model assumed random network connections, zero noise, and used default Covasim parameters, 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[8] of 0.021, instead of 0.016 (based on observed severe cases before interventions took effect).[9]
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 proportions of infections that become severe as 2.8% prior to May, and 2.0% for May-onward.
4) We adjusted Covasim’s age-specific probability of death parameters based on local ratios of deaths to severe cases by age.
5) 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 severe cases in Oregon over two time periods: February-April and May-July. The susceptibility odds ratios used in these respective time periods were: [2.84, 3.40] for age 0-9, [0.66, 1.19] for age 10-19, [1.17, 1.03] for age 20-29, [0.46, 0.52] for age 30-39, [0.50, 0.43] for age 40-49, [0.86, 0.66] for age 50-59, [0.77, 0.40] for age 60-69, [0.87, 0.54] for age 70-79, and [1.12, 0.88] 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 severe cases have become younger over time in Oregon, implying a lower overall severe case risk among infections and thus more total infections per severe case in recent months.

[8] 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).
[9] With Covasim defaults of 20 contacts per individual per day and front-loaded infectiousness over time, this transmission probability translates to a basic reproduction number (R0) of approximately 3.5.

6) To assess our parameter assumptions, we compared our model estimates of cumulative infections with what we might expect from a local seroprevalence study. That study (MMWR article) reported a crude seroprevalence of 1.0% (95% confidence interval: 0.2% – 1.8%) among a sample of people in Oregon interacting with the medical system between May 11 and June 15, 2020. Given the seroprevalence in that study varied by age and the sample was older than the general Oregon population, we calculated an age-adjusted seroprevalence for comparison and found it to be slightly lower (0.6%), but within the confidence bounds of the crude estimate. In the current report, the model estimated about 30,200 cumulative infections on May 15. This would translate to a seroprevalence of 30,200 / 4.2 million = 0.7%, which is similar to the seroprevalence estimate from the MMWR article.
7) We determined transmission levels through mid-July based on severe case incidence 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 diagnosed case counts given our inputted number of tests, with changes in relative odds occurring on April 7, July 13, and September 8.

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 trend, we started the model with 75 infected individuals on February 15, 2020.

Appendix 2: Public Health Interventions in Oregon

Oregon has implemented numerous measures to slow the transmission of COVID-19. Since the beginning of the epidemic in Oregon, the state and local public health system has:

- Implemented educational campaigns to increase public awareness about the epidemic and to encourage adherence to guidance.
- Gathered and reported data, as part of public health surveillance, to inform interventions.
- Collaborated with the health care systems, local public health, and other sectors (e.g., education).
- Conducted outbreak investigations and implemented control measures to prevent future outbreaks in similar settings (e.g., congregate settings, workplaces).
- Collaborated with the federal government and health systems to expand access to key supplies (e.g., personal protective equipment (PPE), testing, and medications).
- 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 early in the epidemic, public health staff had only been able to actively follow up with contacts in households and congregate settings. Contact tracing efforts expanded starting with reopening plans, as mentioned below. Contacts have been asked to voluntarily stay in quarantine for 14 days after their last known exposure. Any diagnosed cases were originally asked to voluntarily isolate for at least 72 hours after symptoms resolve, but this changed over time: they are now asked to voluntarily isolate for at least 10 days after diagnosis or 24 hours after symptoms resolve, whichever is longer.

Specific dates for interventions are given below.

Early interventions: March-April 2020

- On March 8, 2020: Governor Brown declared an emergency due to the public health threat, as described here.
- On March 12, 2020: A large number of measures were put in place, such as bans on gatherings of more than 250 people, as described here.
- On March 16, 2020: Schools were closed statewide, as described here. Further measures were put in place on March 16 and 17, including the closure of restaurants and bars for dine in, banning of gatherings of more than 25 people, recommendation to avoid gatherings of 10 people or more, and DHS restriction of visitors to long-term care and residential facilities, as described here and here.
- On March 19, 2020: Non-urgent health care procedures were suspended to conserve personal protective equipment and hospital beds, as described here.
- 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.

Reopening: May-August 2020

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, as described here.
- On May 2, 2020: The widespread use of face coverings was encouraged, as described here.
- On May 5, 2020: Some parks, outdoor recreation facilities, and areas across Oregon were opened for day use, as described here.
- 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 described here and here. Briefly:
    - On May 15, 31 of the 36 counties in Oregon had been approved for Phase 1 of reopening.
    - By June 1, 35 counties were approved for Phase 1 reopening. The most populous county (Multnomah) had not yet reopened.
    - On June 5 and 6, 28 counties were approved for Phase 2 reopening, as well as one more on June 8.
    - On June 11, due to a rise in COVID-19 cases, the Governor temporarily halted approvals for additional phased reopening.
    - On June 17, 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. October 6, DHS announced the initial baseline COVID-19 testing of staff and consenting residents in 683 long-term care facilities statewide has been completed achieving the first of two objectives set by Governor Kate Brown's testing plan, 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 1, 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, as described here.
- On July 23, 2020: OHA announced grants to more than 170 community-based organizations (CBOs) to help respond to COVID-19 in culturally- and linguistically-responsive ways. Their work will include outreach and community engagement; contact tracing together with local public health authorities; and providing people with social services/wraparound supports, as described here.
- On July 24, 2020: Face coverings were required for exercising indoors, and they became required for all children over 4 years old. Capacity limit for restaurants, gyms, venues was reduced to 100. Bars and restaurants were required to close at 10pm, as described here.
- On July 28, 2020: The Governor released metrics to guide school district decisions about when it is safe to resume in-person instruction, and when a transition to comprehensive distance learning is necessary, as described here.
- On July 31, 2020: Morrow County returned to Phase 1, and Umatilla County returned to Baseline/Stay Home because of increases in cases, as described here.
- On August 1, 2020: Governor Brown announced the launch of a new source of financial assistance for agricultural workers who must self-quarantine to slow the spread of COVID-19, as described here.
- On August 13, 2020: New face covering guidance required individuals to wear face coverings in any area within an office where six feet of distance cannot be consistently maintained, including in hallways, bathrooms, elevators, lobbies, break rooms and other common spaces.
- On August 14, 2020: Testing guidelines were revised.
- On August 17, 2020: Malheur County returned to Phase 1 because of increases in cases, as described here.
- On August 21, 2020: Umatilla County succeeded in reducing the spread of COVID-19 to the point that it was moved from Baseline Stay Home status to Phase 1, as described here.
- On August 28, 2020: Oregon Department of Education's Early Learning Division released the new "Health and Safety Guidelines for Child Care and Early Education Operating in COVID-19." The updated guidelines take effect Tuesday, September 1, 2020, as described here.

Interventions During the Fall: September-October 2020

- On September 1, 2020: Governor Kate Brown extended the COVID-19 State of Emergency for 60 days, as described here.
- On September 3, 2020: Governor Brown announced new requirements for entering Phase 2, as described here. The original prerequisites for Phase 2 were based on trend-based metrics; however, the prerequisites now include that counties must have their case counts reduced to 100 cases or fewer per 100,000 population per week. Therefore, both Morrow and Umatilla Counties remained in Phase 1.
- On September 8, 2020: Oregon experienced numerous wildfires throughout the state in early September; beginning September 8 virtually the entire state of Oregon experienced hazardous air conditions and residents were advised to stay indoors (September 8 Press Release).
- On September 10, 2020: In response to the unprecedented wildfire evacuations affecting over 40,000 people (September 11 Press Release), OHA issued guidance for shelters for how to limit the spread of COVID-19 within their facility, as described here.
- On September 11, 2020: OHA issued guidance for wildfire evacuation for people quarantining or isolating due to COVID-19, as described here.
- On September 14, 2020: Oregon began receiving between 60,000 and 80,000 rapid point-of-care antigen tests per week, expected through the end of December. The new tests are being distributed statewide, as described here and here. Briefly,
    - Tests are first being distributed to counties and long-term care facilities that have been affected by wildfire evacuations.
    - Tests are then being distributed for symptomatic people and their close contacts.
    - Testing is being prioritized for communities disproportionally impacted by COVID-19 and those living in congregate settings.
    - Tests will also be distributed to school-based health centers and other health care partners working with K-12 schools, as well as colleges and universities, to support the testing of symptomatic students and staff, testing of close contacts of cases, and outbreak investigations.
- On October 6, 2020: OHA broadened its testing guidelines to identify additional cases among contacts and in preparation for large expansion of test availability, as described here.
- On October 12, 2020: OHA released guidance on using BinaxNOW point-of-care antigen COVID-19 tests in the general population. Specific guidance regarding the use of point-of-care antigen testing in long-term care facilities is available here. This guidance is considered provisional; it will be updated as evidence-based information about test performance emerges, as described here.
- On October 19, 2020. Governor Brown released new guidance which requires that people wear face coverings in all private and public workplaces, including classrooms, offices, meeting rooms and workspaces, unless someone is alone in an office or in a private workspace. In addition, the guidance states: “Oregon Health Authority now recommends wearing a face covering/mask instead of a face shield (except in limited

situations when a face shield by itself is appropriate, like talking to someone who is Deaf or hard of hearing and needs to read lips to communicate)," as described here.

- On October 23, 2020: Testing guidelines for the Oregon Health Plan were revised to add that antibody (serology) testing is covered for diagnostic workup of multisystem inflammatory syndrome for hospitalized persons, as described here.
- On October 27, 2020: Governor Kate Brown extended her declaration of a state of emergency regarding COVID-19 for an additional 60 days, until January 2, 2021, as described here.

Appendix 3: 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 October 26, 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 proportions of all infections (diagnosed or not) that become severe cases was based on CDC's hospitalization-among-symptomatic estimates and Covasim default symptomatic-among-infection estimates, then adjusted to observed local severe cases 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 (diagnosed or not), while overestimating would deflate the number.
- After the initial imported infections, the model assumes that no additional infections were imported from elsewhere over time. Any such infections would inflate local transmission levels, though any actual resulting diagnosed and severe cases in Oregon from imported infections 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).
- We assumed that individuals who were diagnosed subsequently reduced their transmission by 80%, but this reduction may vary as social norms change.
- Our model assumed that diagnosed cases 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.
- We have observed past instances of positive test results being reported sooner than negative results. When there is a recent discrepancy between predicted and actual diagnosed cases, we consider this a potential lead indicator of a change in transmission but interpret this with caution due to potential reporting bias. Our calibration is based primarily on severe cases.
- Although our model was calibrated to track actual numbers of tests and diagnosed cases, it assumed that diagnosed cases occurred largely 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.
- Trends in cases and the age distribution (and therefore prognosis) can be sensitive to a single large outbreak or super spreader event. However, outbreaks and clusters appear to make up a smaller proportion of Oregon cases now than earlier in the epidemic, with

sporadic cases and household transmission becoming more common (OHA Weekly COVID Report).

- These models simulated the spread of COVID-19 in Oregon statewide under different scenarios. They did not take into account regional variability, nor 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 the OHA Weekly COVID Report.
- Our model includes COVID-19 deaths who were never hospitalized as severe cases. However, available data do not allow us to account for cases who reach severe medical status but recover without hospitalization.

Finally, significant unknowns remain, including information about public adherence to guidance (e.g., physical distancing, face coverings, hygiene, isolation, quarantine) over time, 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.”