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

Results as of 10-1-2020, 3:00pm

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 practices, which were impacted by the wildfires.

KEY FINDINGS

- Based on COVID-19 data through September 24, the model is consistent with transmission increases throughout May, followed by transmission decreases from late-June through late-July.
- During August and early in September, the effective reproduction number (Re) – the expected number of secondary cases that a single case generates – was estimated to be below 1. Indeed, the number of new diagnosed cases and severe cases (symptoms severe enough to warrant hospitalization) had been declining during that time.
- Recent trends in these outcomes suggest increases in transmission since early September, but the estimated increase varies by data source and each data source has limitations. It is unclear from hospitalization or death data if transmission changed after September 12 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 diagnoses is estimated to be 8 days. However, the number of cases diagnosed is dependent on testing practices and reporting, so changes do not necessarily reflect changes in transmission. For instance, we know that the wildfires and related evacuations and poor air quality impacted health care delivery and caused temporary reductions in testing. Concurrently, local universities have been increasing testing.
- Therefore, we made three different assumptions about the recent COVID-19 trends for our projections, as detailed below. We assumed 4,500 tests per day over the projection period for all scenarios.

    - <u>Optimistic scenario</u>: We assumed a 5 percentage point increase in transmission on September 5. This fit reported severe case trends well but underestimated diagnosed cases after September 15. Hence, this scenario assumed the remaining late increase in diagnosed cases did not reflect increased viral transmission but instead was attributable to changes in testing practices. If this level of transmission continues, by October 22:
        - The estimated number of new daily infections will increase from 680 on September 5 to 800.
        - Assuming we diagnose one-third of infections, the number of infections that are newly diagnosed each day (i.e., newly diagnosed cases) will be about 270.
        - The number of new severe cases each day will increase to 24.
        - There will be about 148,000 cumulative infections.
        - The Re will be about 1.04 (10th - 90th percentile estimates from 11 runs: 0.94 – 1.14).

- <u>Pessimistic scenario</u>: We assumed a 10 percentage point increase in transmission on September 5, thereby attributing some of the remaining increase in diagnosed cases after September 15 to increased viral transmission, rather than solely to changes in testing practices. This still fit reported severe cases well. If this level of transmission continues, by October 22:
    - There will be approximately 900 more new daily infections (1,700 vs. 800), 300 more new diagnosed cases each day (570 vs. 270), and 8 more severe cases each day (32 vs. 24) compared to the optimistic scenario.
    - There will be about 172,000 cumulative infections.
    - The Re will be 1.17 (10th - 90th percentile estimates from 11 runs: 1.09 – 1.25).

- <u>Moderate scenario</u>: We assumed a 7 percentage point increase in transmission on September 5, thereby attributing less of the remaining increase in diagnosed cases after September 15 to increased transmission than the pessimistic scenario. If this level of transmission continues, by October 22:
    - There will be approximately 380 more new daily infections (1,180 vs. 800), 120 more new diagnosed cases each day (390 vs. 270), and 1 more severe case each day (25 vs. 24) compared to the optimistic scenario.
    - There will be about 158,000 cumulative infections.
    - The Re will be 1.12 (10th - 90th percentile estimates from 11 runs: 1.03 – 1.18).

Conclusions

These results suggest that transmission increased substantially during May, then decreased in late-June through late-July causing the Re to decrease to less than 1. However, transmission appeared to increase again around Labor Day weekend. As of September 24, the Re was estimated to be greater than 1, even in our most optimistic scenario. If transmission remains at this level, the number of new infections will continue increasing. Given the virus is very sensitive to changes in transmission, Oregonians can achieve decreased trends in transmission and fewer cases if they redouble prevention efforts.

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 practices.

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 September 17, 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 September 28, but data after September 24 were considered incomplete because of lags in reporting and were not used.
- We are using a newer version of Covasim (version 1.7.2), which was updated on September 24.
- In the last report, we had observed an increased degree of inconsistency between “new” and “cumulative” outcome estimates in the scenarios. This issue was no longer apparent for the current model estimates of infections but remained for the severe case estimates. Since we relied on cumulative severe cases in the model calibration, in the scenarios we present cumulative estimates for severe cases and calculated new daily severe cases from those cumulative estimates. Accordingly, please interpret severe case estimates with more caution.

More information about the methods is in Appendix 1.

PUBLIC HEALTH INTERVENTIONS

Since the beginning of the pandemic, Oregon has implemented numerous public health measure 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 wellbeing – with not only direct client services (e.g., testing and contact tracing), but also policy implementation (e.g., face covering requirements, limits on gathering sizes), 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.

MAJOR WILDFIRE EVENTS

Beginning in September, Oregon experienced numerous wildfires throughout the state. These wildfires were unprecedented in scope: an estimated 500,000 people were living in areas with differing levels of evacuation orders in place (September 11 Press Release). An estimated 40,000 people (1%) of the population were evacuated from their homes, and many people moved to shelters. The potential effect these evacuations had on COVID-19 transmission is unclear (OHA guidance). Moreover, beginning September 8 virtually the entire state of Oregon experienced hazardous air conditions and residents were advised to stay indoors (September 8 Press Release). Since smoke is a respiratory irritant, it is not clear to what degree this exacerbated COVID-19 related symptoms (CDC guidance).

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 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 be attributed to any particular action (e.g., policy or event); 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

[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 6% of severe cases are non-hospitalized deaths.

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 provides evidence that transmission increased substantially during May, then decreased somewhat in late-June through late-July (Figure 1). Specifically:

- New severe cases stopped declining in mid-May before beginning to increase starting early in June. The trends were consistent with transmission increases of 5 percentage points 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 26 and by another 7 percentage points after July 30, bringing the effective reproduction number (Re) – the expected 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 declined during that time.
- Recent trends in these outcomes suggest increases in transmission since early September, but the estimated increase varies by data source and each data source has limitations. It is unclear from hospitalization or death data if transmission changed after September 12 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 diagnoses is estimated to be 8 days. However, the number of cases diagnosed is dependent on testing practices, so changes do not necessarily reflect changes in transmission. For instance, we know that the wildfires and related evacuations and poor air quality impacted health care delivery, causing temporary reductions in testing. Concurrently, local universities have been increasing testing.
- Therefore, we made three different assumptions about the recent COVID-19 trends for our calibrations, as detailed below.

- Optimistic calibration: We assumed a 5 percentage point increase in transmission on September 5.[3] This calibration fit reported severe case trends well but underestimated diagnosed cases after September 15. Hence, it assumed the remaining late increase in diagnosed cases did not reflect increased viral transmission but was attributable to changes in testing practices and/or reporting delays.

- Pessimistic calibration: We assumed a 10 percentage point increase in transmission on September 5, thereby attributing some of the remaining increase in diagnosed cases after September 15 to increased viral transmission, rather than solely to changes in testing practices and/or reporting delays. This still fit reported severe cases well.

- Moderate calibration: We assumed a 7 percentage point increase in transmission on September 5, thereby attributing less of the remaining increase in diagnosed cases after September 15 to increased transmission than the pessimistic calibration. This also fit reported severe cases well.

In Figure 1, we present the moderate calibration. The moderate calibration estimates that as of September 24, a total of 127,400 cumulative infections have occurred in Oregon, but only 32,800 have been diagnosed (i.e., diagnosed cases) according to available data.

Appendix 4 contains a comparison of the three calibrations with respect to diagnoses data. All of these calibrations under-estimated diagnoses since September 15 to some degree. We also tried a calibration with a 15 percentage point increase in transmission on September 5, which over-estimated recent severe cases while still under-predicting recent diagnosed cases. Since a transmission increase of over 15 percentage points seems unlikely, we think the model could be underestimating diagnosed cases due to data reporting lag of negative tests and/or an adjustment is needed to the model parameter that reflects testing practices. As described on September 25 (here), there was a recent processing error for thousands of negative test results. Given possible bias in reporting positive test results sooner than negative results, we have taken a cautious approach in interpreting recent diagnoses data as a possible indicator of increased transmission (and focusing primarily on severe cases); but we will make adjustments to testing parameters and/or transmission levels in future models, as appropriate.

Of note, the three calibrations fit the death data similarly, since deaths would not be affected by a September 5 transmission change until around September 28 (the average time between infection and a person dying is 23 days). The model calibrations slightly underestimated the number of deaths after August (Figure 1) but provided a much better fit than in the last modeling report.

[3] September 5 corresponds to the Saturday of Labor Day weekend, but dates slightly before or after produced similar model results. As with other modeled transmission changes, the specified dates and levels are not necessarily exact, and sometimes serve to model change that may have occurred over time (rather than overnight).

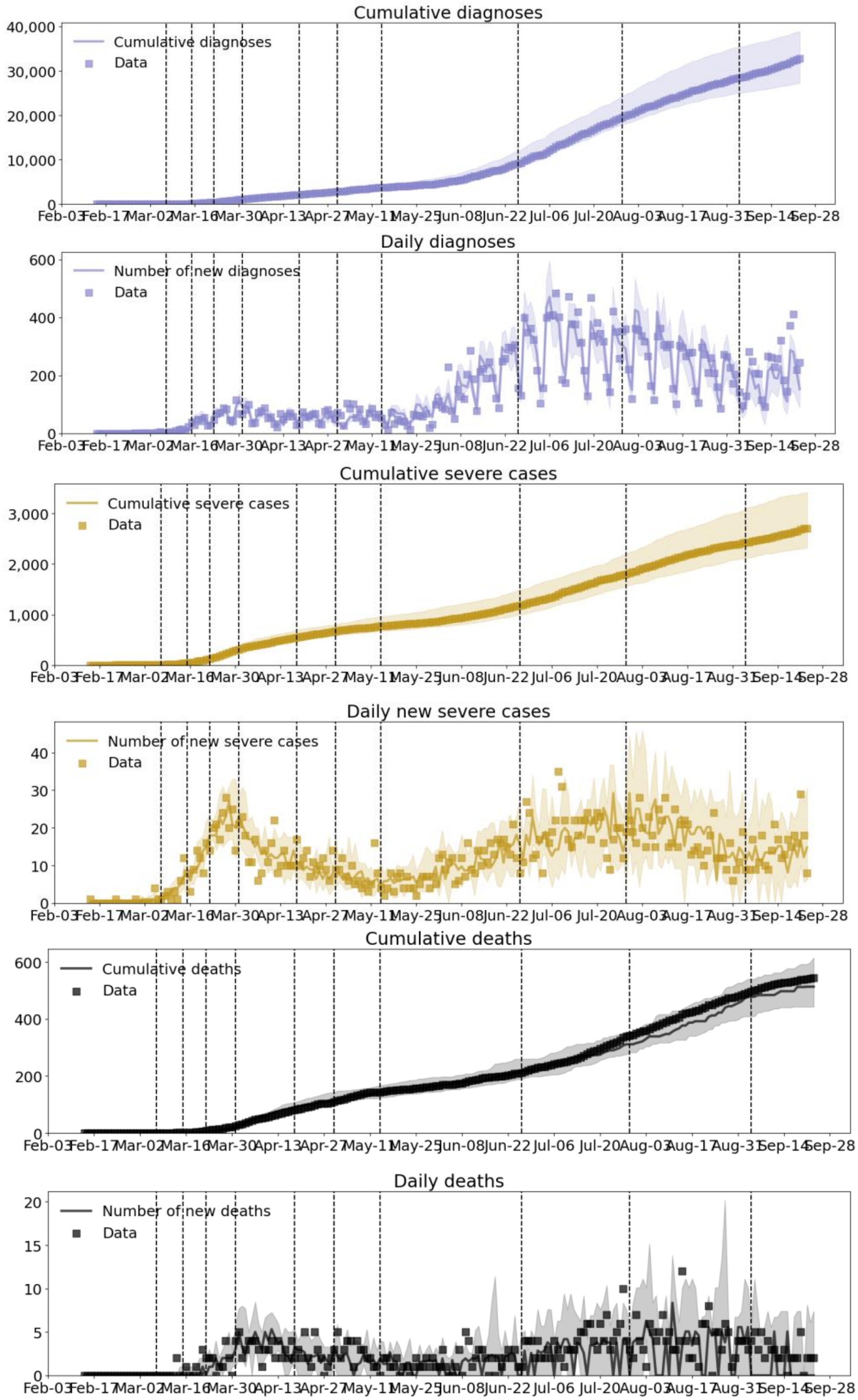

Figure 1: Moderate model calibration with Oregon data. Dotted vertical lines correspond, from left to right, to estimated reductions in transmission relative to baseline of 5% (March 8), 45% (March 16), 80% (March 23), 75% (April 1), 70% (April 19), 65% (May 1), 55% (May 15), 60% (June 26), 67% (July 30), and 60% (September 5). 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 future scenarios through October 22 based on the three different calibration assumptions described above (which diverged starting September 5). 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, do not know how adherence will change 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.[4] For all scenarios, we assumed 4,500 tests per day.

- Optimistic scenario: We assumed a 5 percentage point increase in transmission on September 5. If this level of transmission continues, by October 22:
  - The estimated number of new daily infections will increase from 680 on September 5 to 800.
  - Assuming we diagnose one-third of infections,[5] the number of infections that are newly diagnosed each day (i.e., newly diagnosed cases) will be about 270.
  - The number of new severe cases each day will increase to 24.
  - There will be about 148,000 cumulative infections.
  - The Re will be about 1.04 (10th - 90th percentile estimates from 11 runs: 0.94 – 1.14).

- Pessimistic scenario: We assumed a 10 percentage point increase in transmission on September 5. If this level of transmission continues, by October 22:
  - There will be approximately 900 more new daily infections (1,700 vs. 800), 300 more new diagnosed cases each day (570 vs. 270), and 8 more severe cases each day (32 vs. 24) compared to the optimistic scenario.
  - There will be about 172,000 cumulative infections.
  - The Re will be 1.17 (10th - 90th percentile estimates from 11 runs: 1.09 – 1.25).

- Moderate scenario: We assumed a 7 percentage point increase in transmission on September 5. If this level of transmission continues, by October 22:
  - There will be approximately 380 more new daily infections (1,180 vs. 800), 120 more new diagnosed cases each day (390 vs. 270), and 1 more severe case each day (25 vs. 24) compared to the optimistic scenario.
  - There will be about 158,000 cumulative infections.
  - The Re will be 1.12 (10th - 90th percentile estimates from 11 runs: 1.03 – 1.18).

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[4] "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).

[5] Based on recent diagnosis counts and the "moderate" scenario estimate of recent new infections, results suggest Oregon is diagnosing approximately one-third of new infections.

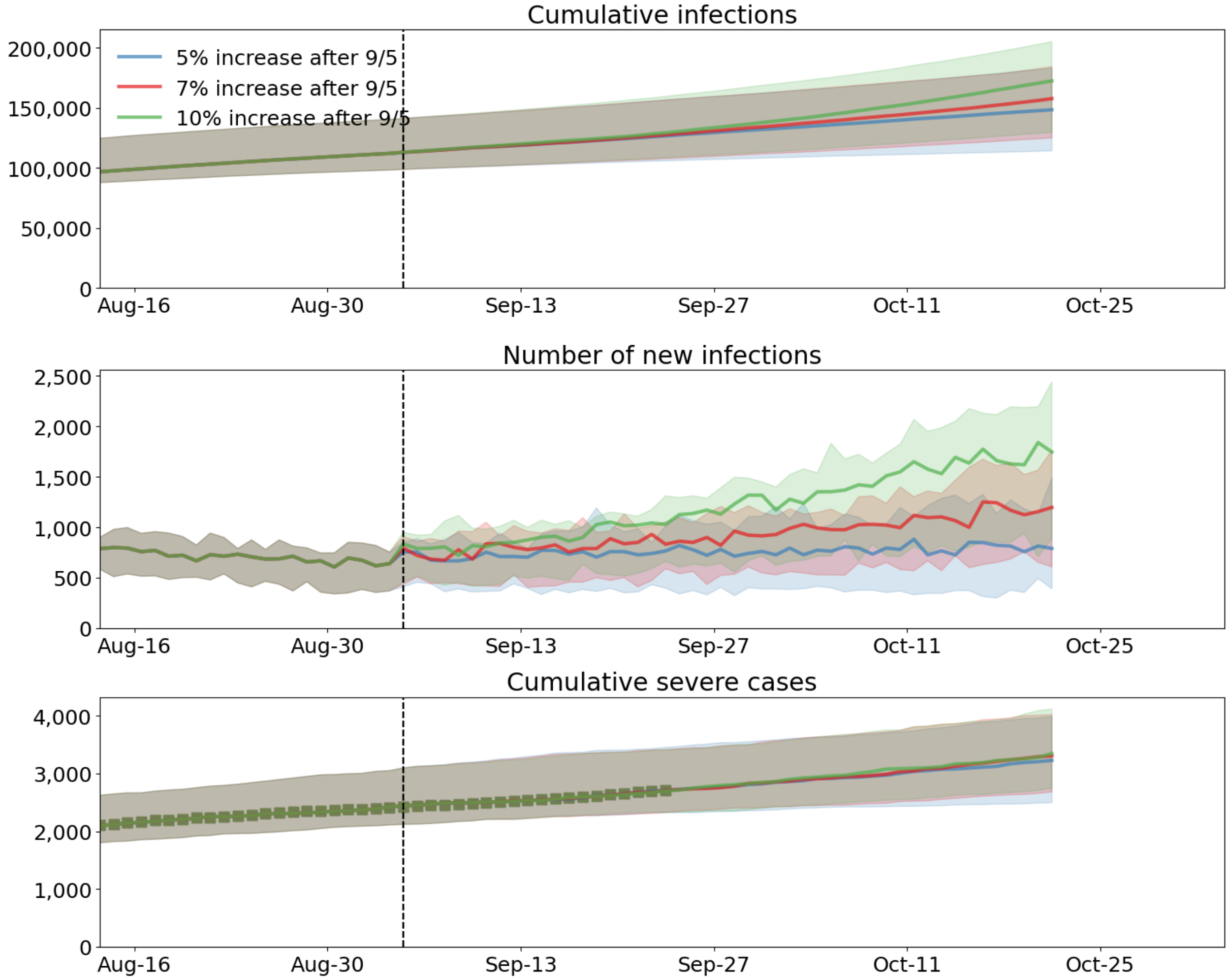


Figure 2: Model projections for the next 4 weeks, assuming that after September 5: 1) transmission increased by 5 percentage points (blue line), 2) transmission increased by 7 percentage points (red line), and 3) transmission increased by 10 percentage points (green line). The lines represent the median estimates from the 11 randomized runs. The lighter shaded areas in the cumulative infections chart correspond to the 10^{th} and 90^{th} percentiles of the projection.

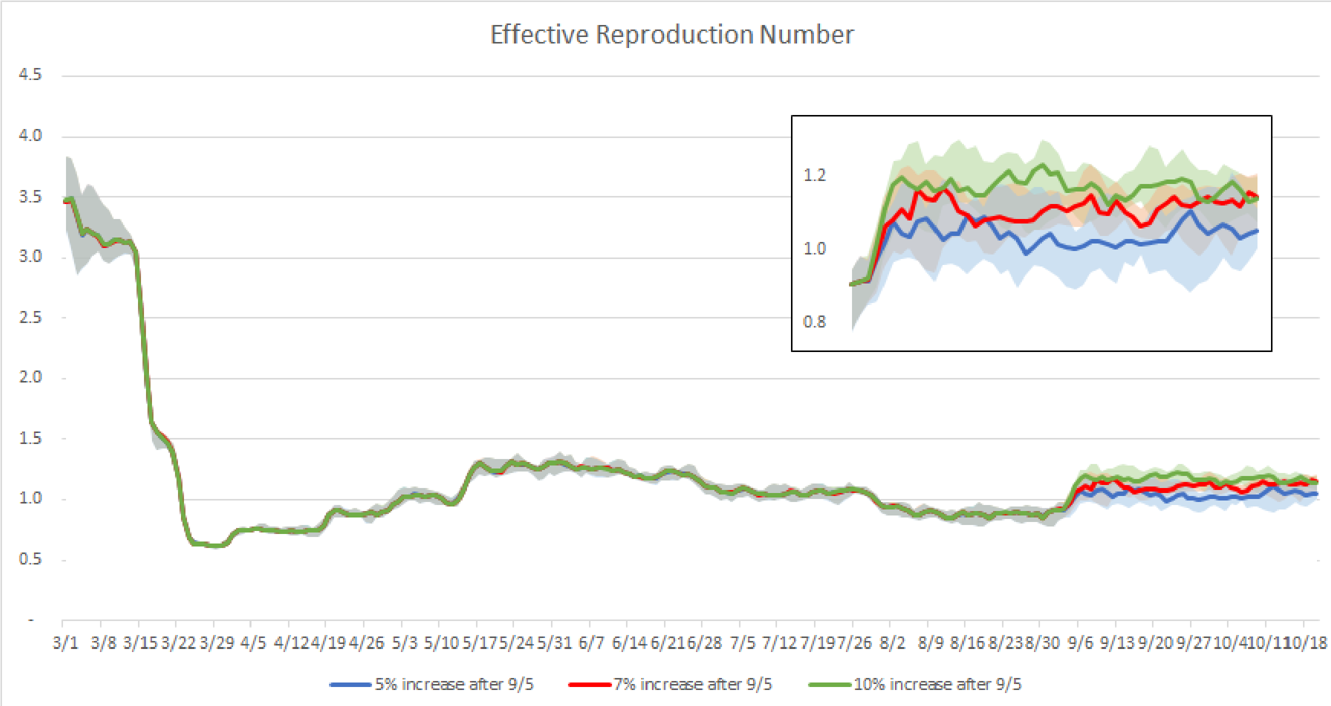


Figure 3: Projected effective reproduction number (Re) through October 18, assuming that after September 5: 1) transmission increased by 5 percentage points (blue line), 2) transmission increased by 7 percentage points (red line), and 3) transmission increased by 10 percentage points (green line). The 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 expected number of secondary cases that a single case generates; estimates vary day-to-day due to differences among randomized simulation outcomes.

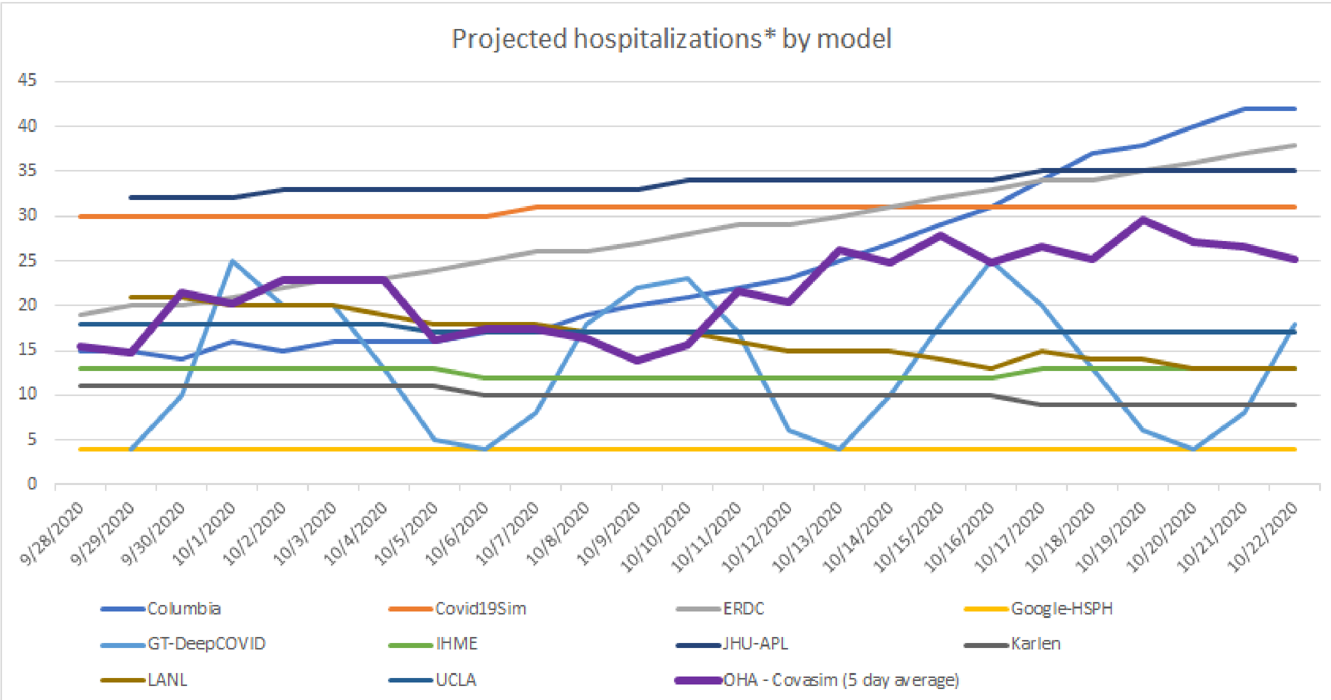
Comparison with other model results[6]

RT Live, covid19-projections.com, Covid Act Now, and CMMID estimate the Re (range or interval) for Oregon to be 1.06 (0.81 – 1.23), 1.07 (0.91-1.22), 1.11 (1.01-1.21), and 1.21 (0.87-1.64), respectively. Our three different calibrations estimated Re to be 1.04, 1.12, and 1.17, with the 10th and 90th percentiles of the projections ranging from 0.94 to 1.25.

CDC compiles hospital forecasts from numerous modelers. Compared to CDC's September 30 compilation, our "moderate" scenario appears toward the middle of other forecasts (Figure 4a).

CDC also compiles forecasts of newly reported cases. Compared to CDC's October 1 ensemble model, our "moderate" scenario predicts more weekly diagnosed cases and an upward trend (Figure 4b).

[6] These websites for Re mentioned in this section were accessed on 9/30/2020. The CDC's forecasts were accessed on 10/1/2020.



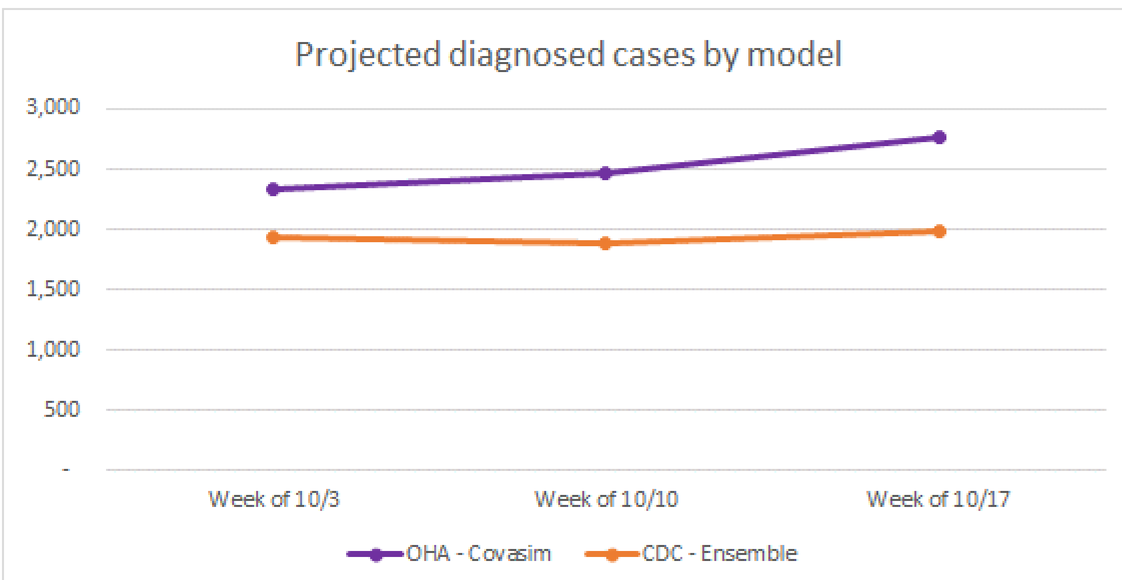


Figure 4a and b: Projected (a) daily new hospitalizations through October 22 and (b) weekly new diagnosed cases[7] through the week of October 17 in Oregon; estimates are from the current report's "moderate" scenario (OHA Covasim) and other models included in CDC's forecast compilations[8]. *Note: OHA forecast in (a) is for severe cases, of which approximately 6% led to non-hospitalized deaths.

[7] OHA diagnosed case projections are based on Covasim new infection estimates, assuming one-third of new infections are diagnosed.

[8] CDC compilation for new hospitalizations was dated September 30 and for new diagnosed cases was dated October 1. The Johns Hopkins model was not included in Figure 4a because recent projections were at a much higher level than observed data.

Recent trends in Oregon COVID-19 data

The Opera data file for this report was obtained on September 28, but data after September 24 were considered incomplete because of lags in reporting and were not used. Therefore, we lack data for the past week. Opera data as of October 1 do not suggest any new major changes in the trends in newly diagnosed cases or new severe cases.[9] In addition, trends in hospital occupancy in Oregon from the HOSCAP data system, which is updated daily, show a potential slight reduction in hospital-reported occupancy between September 24 and October 1.

Discussion

These results suggest that transmission increased substantially during May, then decreased in late-June through late-July causing the Re to decrease to less than 1. However, transmission appeared to increase again around Labor Day weekend. As of September 24, the Re was estimated to be greater than 1, even in our most optimistic scenario. If transmission remains at this level, the number of new infections will continue increasing. Our results are consistent with other researchers' Re estimates for Oregon. In addition, examination of Opera data since the data were pulled for this report (on September 28) do not suggest any recent major shifts in these upward trends, while the HOSCAP data show a potential slight reduction in hospital occupancy.

The state has a comprehensive approach to controlling this epidemic, but we still have work to do. This model projects statewide averages, 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 contract 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.

While increasing infections is discouraging, the virus is very sensitive to changes in transmission so Oregonians can achieve decreasing trends in transmission and fewer cases if they redouble prevention efforts, such as wearing facial coverings, avoiding large gatherings, and adhering to other 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 practices, which were impacted by the wildfires. In addition, we cannot confidently predict future COVID-19 trends because of significant gaps in knowledge. We do not have comprehensive measures of adherence to the physical distancing, face covering,

[9] It is important to note Opera data for severe cases on the OHA website is based on symptom onset date rather than hospital admission date.

hygiene, isolation, and quarantine guidance, do not know how adherence will change 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[10] of 0.021, instead of 0.016 (based on observed severe cases before interventions took effect).[11]
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.

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[10] 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).

[11] 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.

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 and July 13.

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.

Before Reopening

- On March 8, 2020: Governor Brown declared an emergency due to the public health threat, as detailed 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 detailed here.
- On March 16, 2020: Schools were closed statewide, as detailed 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 detailed here and here.
- On March 19, 2020: Non-urgent health care procedures were suspended to conserve personal protective equipment and hospital beds, as detailed 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, June 2 and again on August 14, 2020 (Revised testing guidelines).

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, as detailed here.
- 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 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.
- 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, as described here.
- 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.
- 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 10, 2020: OHA, in response to the unprecedented wildfire evacuations, 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.

Appendix 3: Limitations

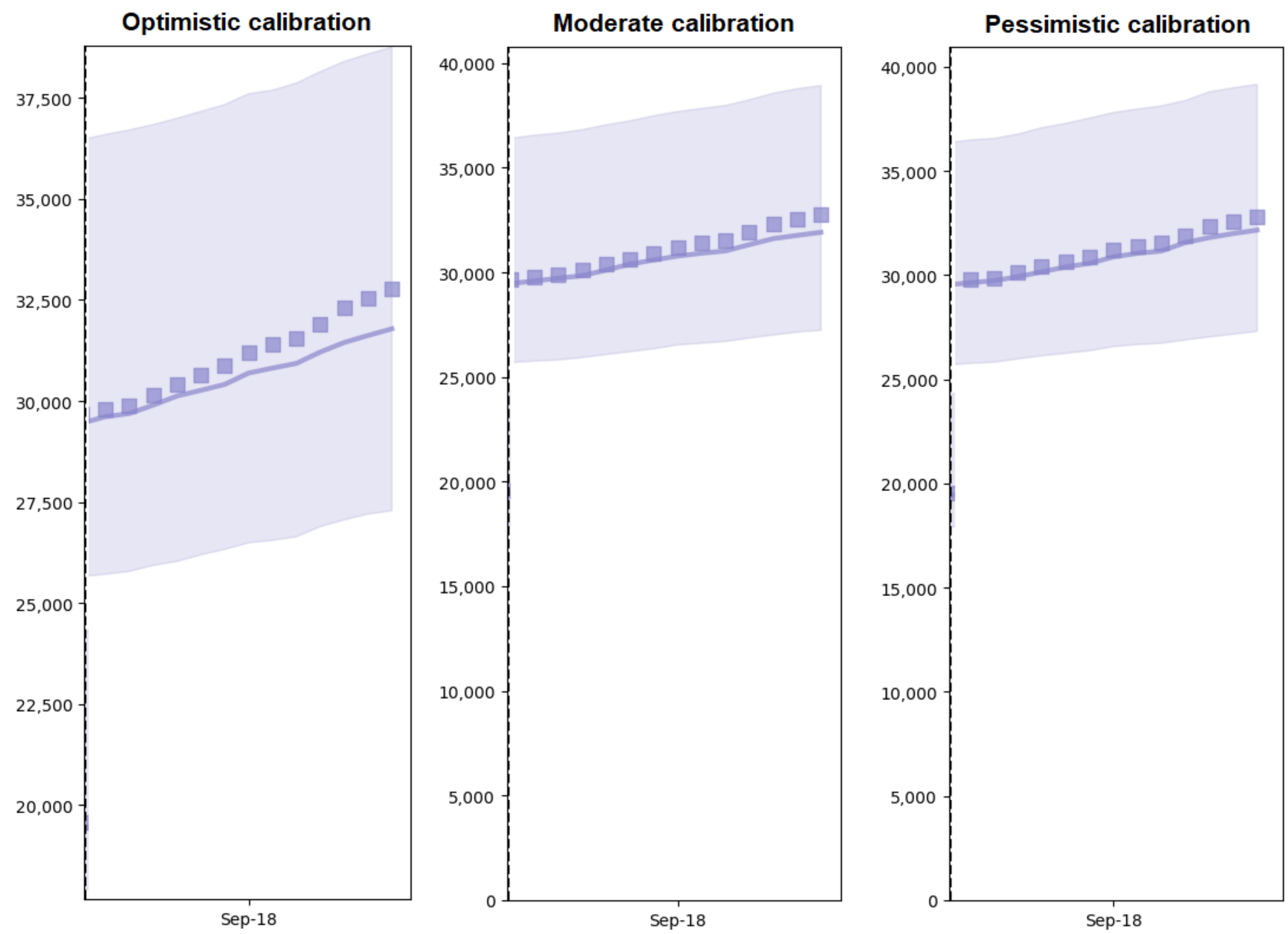
- The results in this report will be updated as more data become available, the science to inform the model assumptions expands, and modeling methods continue to be refined. The report uses the best available local data as of September 28, 2020; however, the local epidemiologic data on COVID-19 cases 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.
- 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.
- 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. 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.
- For calculating the estimated number of daily new severe cases for the scenarios, we used the model scenario estimates of cumulative outcomes, since we rely on cumulative outcomes in the model calibration. Our recent Covasim models have produced some inconsistency between “new” and “cumulative” outcome estimates. Since the last report (and an update to Covasim 1.7.2), this issue is no longer apparent for estimates of infections and diagnoses but is still present for severe case estimates. Accordingly, please interpret severe case estimates with more caution.

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

Appendix 4: Comparison of three calibrations' fit to number of cumulative diagnoses



Comparison of the three model calibrations for September 12 - 24. 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).