COVID-19 transmission was likely rising through April 22 across Washington State

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What do we already know?

In our previous report, we estimated that COVID-19's effective reproductive number (R_e) in King County, WA was confidently below 1 from March 29 through April 15. This implied that transmission was falling, leading to decreases in the prevalence of active COVID-19 infections in the community. We estimated that prevalence was between 0.1% and 0.68% of King County's population on April 20, and, consistent with this estimate in the model, we found that more than 95% of King County's population was fully susceptible to COVID at that time.

What does this report add?

In this report, we update our estimates of the effective reproductive number in King County using data from the Washington Disease Reporting System through April 27. We find that, after declining steadily through April 6, R_e was no longer declining, and our most likely estimates of R_e indicate an increase through April 22, with an estimate on April 22 between 0.47 and 1.32 (best estimate 0.89), no longer definitively below the critical $R_e = 1$ threshold for declining transmission. These new estimates are consistent with the uncertainty in our previous report and are powered by the recent data. We further find that the estimated rise in transmission is concordant with observed increases in King County's highway traffic. Finally, new to this report, we estimate R_e on average across the whole of Eastern and Western WA. In Eastern WA, we find that R_e had not fallen confidently below 1 at any time through April 18. In Western WA, we infer that R_e had dropped confidently below 1 by late March but has since increased, showing a similar pattern in the region as in King County.

What are the implications for public health practice?

Physical distancing policy is still our main tool for addressing COVID-19's spread in Washington. Our results highlight that sustained adherence will be critical to its success. Moreover, as we learn more about heterogeneity in infection rates across the state, policy interventions tailored to these differences may be necessary to achieve continued transmission reductions. Because we always learn about COVID transmission after it occurs, and policy needs to evolve with the data, instability in our day-to-day lives will be a persistent feature of our pandemic response in the months to come.

Executive summary

In response to early COVID-19 case detections, physical distancing behaviors began in earnest in King County, WA as early as March 2. Since then, we've seen persistent reductions in COVID transmission, leading eventually to reductions in daily case reports and daily deaths. Now, over 2 months later, sustained physical distancing is proving to be difficult to maintain. Unfortunately, we are not in a position to relax physical distancing completely: epidemiological evidence suggests that the vast majority of Washington State residents remain fully susceptible to COVID, putting us in a position where increases in transmission would lead to exponential growth in cases and mortality.

In this report, we update our quantitative assessment of COVID-19 transmission in King County. Previously, we found that the effective reproductive number in King County was between 0.28 and 1.0, with best estimate 0.64, on April 15. Now, with updated WDRS data through April 27, we estimate that R_e in King County likely increased and very likely no longer declined between April 6 and April 22, from best estimate 0.70 (range 0.58 to 0.82) to best estimate 0.89 (range 0.47 to 1.32). As of April 22, this is no longer definitively below the critical $R_e = 1$ threshold for declining transmission. Moreover, this trend of likely increasing transmission roughly mirrors recent increases in regional traffic as measured by the Washington State Department of Transportation, and these traffic pattern changes have continued into early May. These results, driven by more recent data, offer an important reminder that cases and deaths are indicators of past transmission and that conditions will change in response to behavioral changes in ways that are currently challenging to measure.

New in this report, we also analyze large-scale trends across Eastern and Western WA. The aggregate pattern in the counties west of the Cascade crest is consistent with that seen in King County, with R_e dropping below 1 in late March, followed by increases through April 22, where our best estimate of R_e is 1.0 (and ranging between 0.61 and 1.39). In Eastern WA, we find that R_e has likely plateaued slightly above 1 since late March and has never dropped below, and we estimate that R_e on April 18 was between 0.96 and 1.32, with a best estimate 1.14.

Finally, we are continuing to work on understanding how changes in testing volume, targeting, and reporting may affect our results in ways not yet accounted for. As the epidemic progresses and more is learned, it will be important to consider details of the epidemiology that are currently averaged over in our model to map observations onto specific transmission events and policy actions. For example, as we learn more about where and when transmission occurs, policies targeting high-risk settings and relaxing restrictions on low-risk settings may be warranted.

Key inputs, assumptions, and limitations of our modeling approach

We use a COVID-specific transmission model fit to testing and mortality data to estimate the effective reproductive number over time and the associated COVID-19 prevalence and incidence. The key modeling assumption is that individuals can be grouped into one of four disease states: susceptible, exposed (latent) but non-infectious, infectious, and recovered.

- For an in-depth description of our approach and its assumptions and limitations, see our recent detailed report.
- In this report, we use data provided by Washington State Department of Health through the Washington Disease Reporting System (WDRS). **We use the WDRS test and death data compiled on May 2, and to hedge against delays in reporting, we analyze data up to April 27 in King County.**
- In this report, **we also include model-based estimates of R_e for Eastern and Western WA. To hedge against reporting delays, we use data up to April 27 in Western WA and up to April 23**

in Eastern WA. This difference is reflective of observed heterogeneity in reporting lags across the state as monitored by WADoH.

- Estimates of R_e describe average transmission rates across large regions, and **our current work does not separate case clusters associated with known super-spreading events from diffuse community transmission.**
- We estimate prevalence through modeling the relationship between observed cases, deaths, and literature-derived estimates of the infection-fatality-rate (ranging from 0.2 to 2.4%) and the delay from exposure to death (mean 19 days).
- Finally, we include a visualization of highway traffic data provided by the Washington Department of Transportation through the [COVID-19 Multimodal Transportation System Performance Dashboard](). This data was obtained on May 5.

Through April 22, the effective reproduction number in King County was no longer declining and was likely increasing

Figure 1 is our current daily estimates of R_e in King County (black dots, 2 standard deviation error bars). We find that R_e has steadily increased from a minimum between 0.58 and 0.82, with best estimate 0.70, on April 6 to an estimate between 0.47 and 1.32, with best estimate 0.89, on April 22. Starting on April 19, our estimates are no longer confidently below 1, implying the recent epidemiological data is consistent with increasing transmission rates in mid-April.

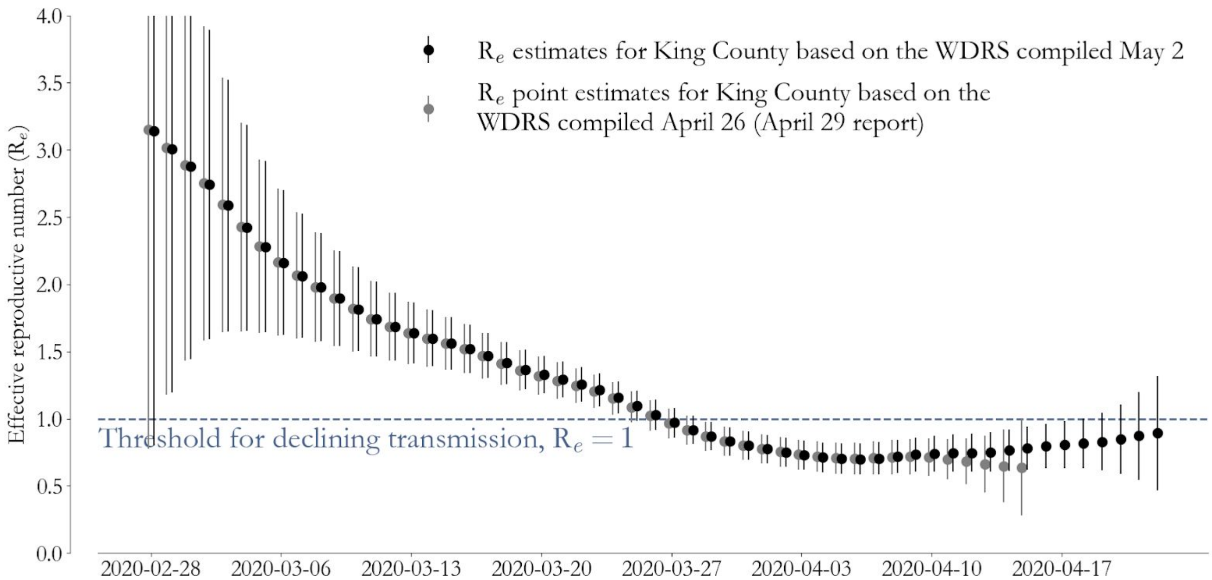

***Figure 1**: Black dots are our most recent estimates of the effective reproductive number in King County (2 standard deviation error bars). Meanwhile, in grey, we have our previous estimates for comparison. Although consistent in terms of uncertainty, recent data reverses the trend in R_e point estimates from April 10 to April 15 relative to our last report.*

Comparing our most recent estimates to our previous estimates (grey dots, 2 standard deviation error bars) highlights the critical role of uncertainty, particularly when evaluating trends. Estimates from our previous report are consistent with our current estimates every day, but in our previous report, we saw a slight downward trend in our best R_e estimates from April 10 to April 15 while uncertainty increased over the same period. The additional week of data analyzed in this report clarified this uncertainty, leading to more confident estimates consistent with increasing transmission. This comparison is an important reminder that updated data will clarify the current estimates from April 19 to April 22.

Along similar lines, changes in testing volume add additional, difficult-to-quantify uncertainty to these estimates. In particular, from early March onwards, there is a steady increase in the number of tests conducted daily in King County. We account for this rise by estimating R_e based on an epidemiological curve that incorporates the fraction of tests that are positive, which tends to fall as testing volume increases (see Appendix 1 for details). Still, the effects of changes in testing volume and testing eligibility are not completely clear, and we anticipate learning more as more data at higher testing volumes becomes available over time.

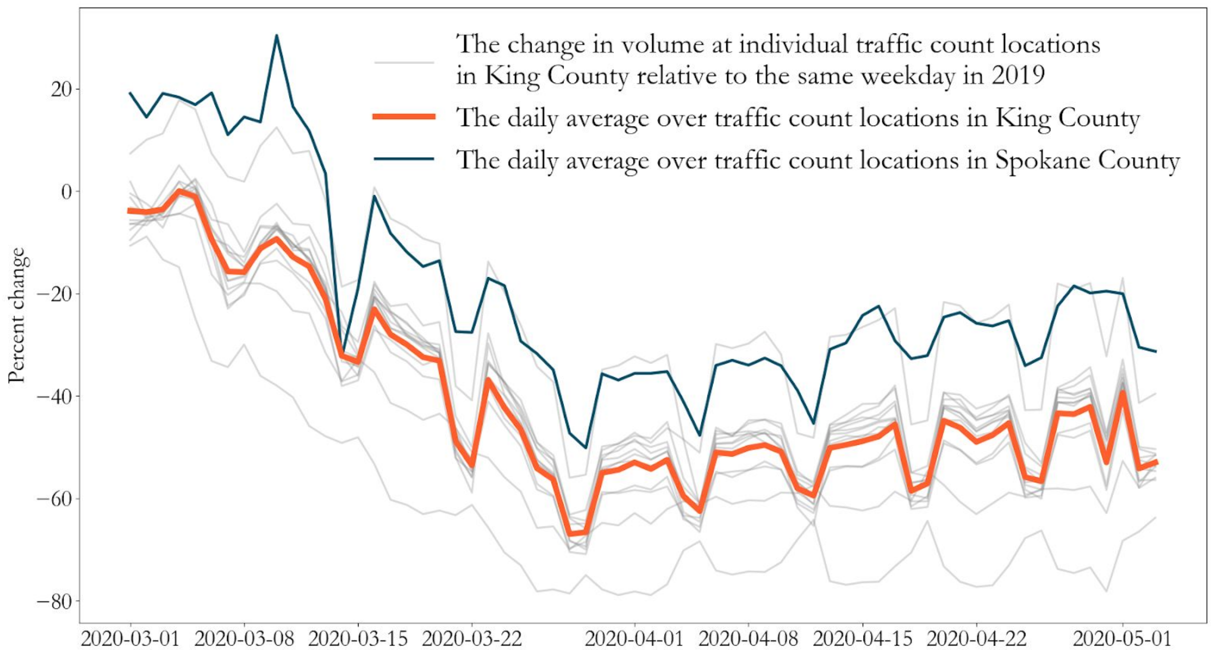

Figure 2*: Traffic volume relative to baseline across WADoT count locations in King County (grey). Daily averages (red) show a clear reversal in trend from March to April. Meanwhile, in similar daily averages from Spokane (blue), we see qualitatively equivalent behavior.*

Given our uncertainty, we consulted data on mobility in King County to better understand the trend in R_e. In particular, we used measures of highway traffic from WADoT, obtained via their dashboard, as shown in Figure 2. Traffic volume at 13 count locations in King County (grey lines) fell relative to volume at the same locations on the same weekday of the same month in 2019 throughout March, likely in response to physical distancing policies. In early April, however, this trend reverses, indicating that travel throughout the county has been steadily increasing. A similar pattern is seen across a number of metrics maintained by the Maryland Transportation Institute. While we do not fully understand the connection between mobility and COVID transmission in King County, as described previously, the corroboration of this trend gives us some confidence in the estimated increasing trend in R_e despite the uncertainty.

Increases in transmission slow the decline in estimated COVID-19 prevalence in King County

The fitted model can be used to estimate recent prevalence and incidence in King County. This is shown in Figure 3, where we estimate that between 0.11% and 0.71% of King County's population, with best estimate 0.32%, were actively infected with COVID on April 27. The total fraction of the population that has been infected, known as cumulative incidence, consistent with the prevalence estimate from the model is shown in Figure 3's lower panel (blue). On April 27, we infer that between 0.8% and 5.4% of the population, with best estimate 2.3%, are no longer fully susceptible to COVID-19. As a result, King County remains in a position far from herd immunity, and exponential growth in cases and mortality can still be sustained if transmission increases.

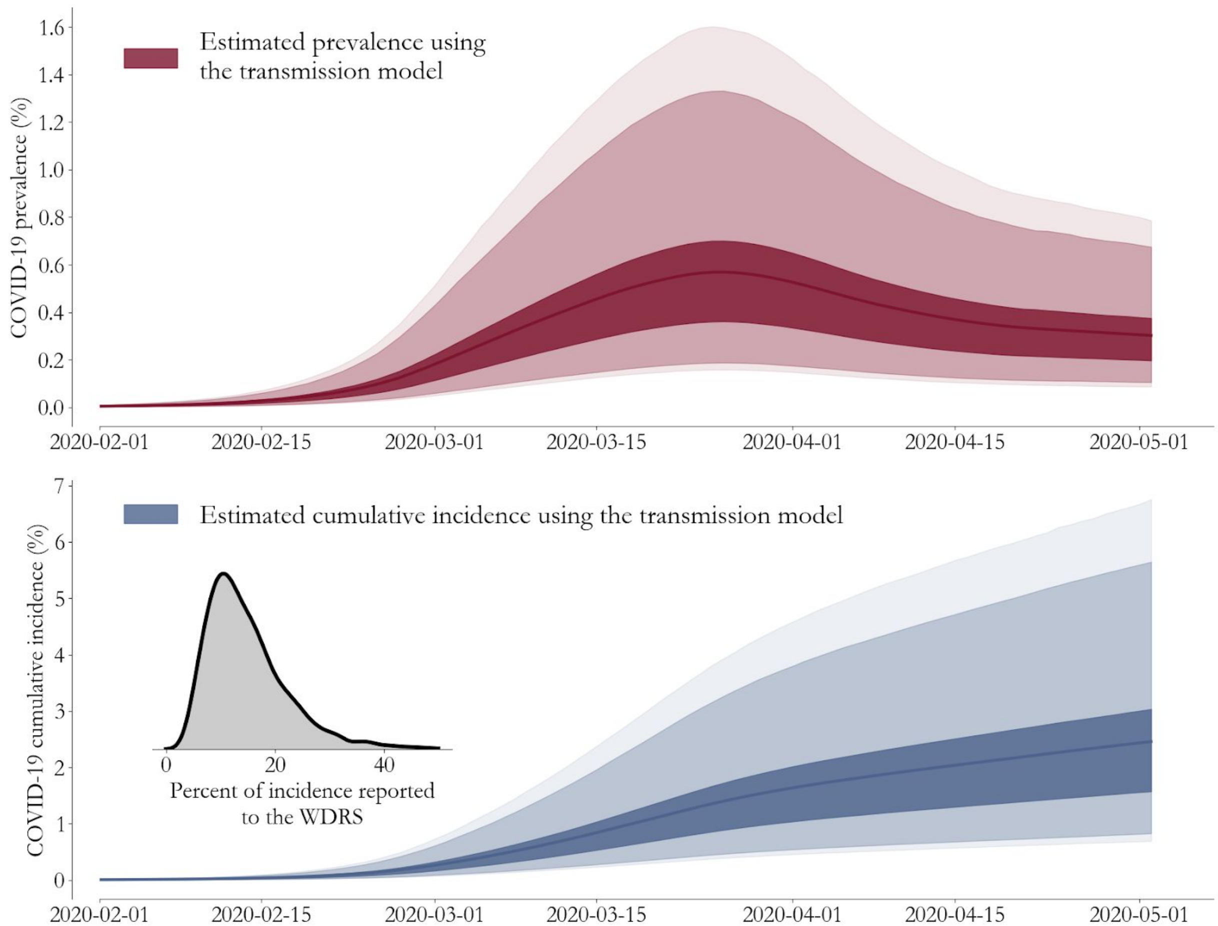

Figure 3*: (Top panel) Model-based estimates of daily COVID-19 prevalence in King County (purple, 50%, 95%, and 99% CI in progressively lighter shades) show slowing declines in prevalence. (Bottom panel) Cumulative incidence shown in blue. In the inset, model incidence is compared to the total cases reported to WDRS, and we estimate that between 5.1% and 35.4%, with best estimate 15.1%, of infections in King County eventually test positive and get reported.*

Model-based projections for King County still depend entirely on future behavior

High susceptibility to COVID-19 puts King County in a dangerous position. This is illustrated in Figure 4 where model-based projections of daily cases are compared across 3 scenarios under the assumption that testing practices remain roughly the same going forward. We find that maintenance of current transmission levels (green, 50% CI) leads to a slow decline in cases over time. However, if the recent trend in R_e continues until transmission returns to mid-March levels (grey), we see that cases begin to rise exponentially.

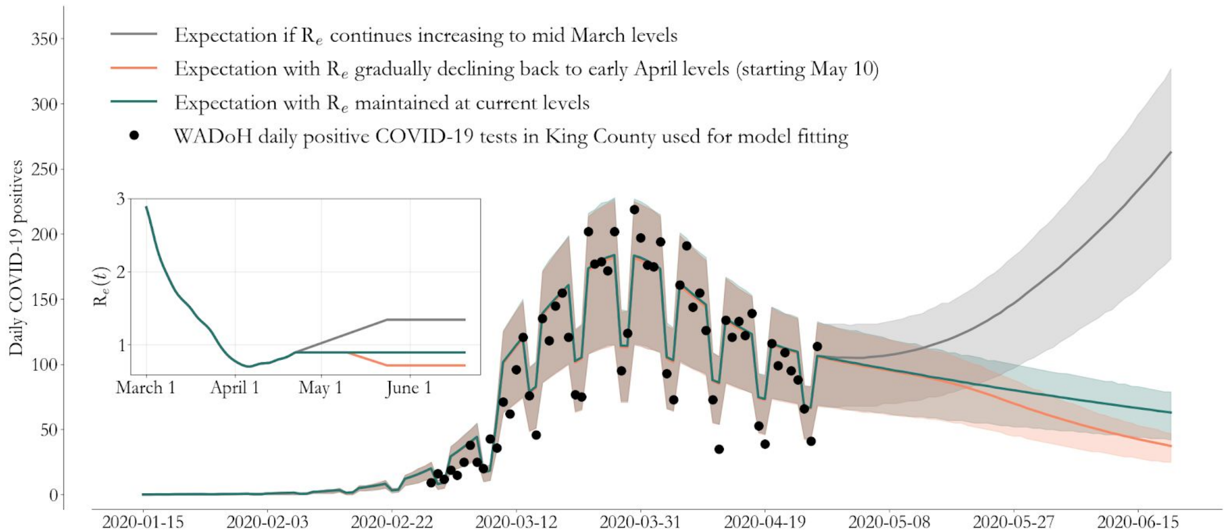

Figure 4*: Model-based projections of daily COVID-19 positives under 3 scenarios, shown in the inset. Maintenance of recent transmission levels (green), increases consistent with recent trends in R_e (grey), and transmission decreases to previous, relatively low levels (red) all lead to dramatically different outcomes. With high susceptibility in King County, exponential growth in cases is still a possibility.*

Trends in the effective reproductive number (inset) depend entirely on our behavior, and these trends dictate future outcomes in terms of COVID positives and mortality. While the potential for exponential growth in infections remains, it is also possible to return to early April transmission levels (red) and speed up the decline in cases.

Models of Eastern and Western WA highlight transmission increases to varying degrees across the state

New to this report, we apply our model to WDRS data aggregated into two regions in WA, Eastern and Western WA, and we estimate the effective reproductive number over time in each region. Based on testing volume and reporting lags, we used data from March 8 to April 23 in Eastern WA and from March 2 to April 27 in Western WA.

Our results are summarized in Figure 5. Trends in Western WA (purple) are similar to those from King County (Figure 1), which represents 54% of the cases in the region. We find a steady increase in R_e from roughly April 6 to April 22, where our best estimate of R_e is 1.0 (95% CI between 0.61 and 1.39). Meanwhile, in Eastern WA, we find that declining transmission rates started later and did not fall as far from baseline, similar to the traffic pattern differences that also appears in the WADoT data (see Figure 2), and we estimate that the effective reproductive number on April 18 is between 0.96 and 1.32, with best estimate 1.14. This suggests that R_e has likely remained above 1 in Eastern WA and that increasing disease burden throughout the region is likely without further transmission reduction.

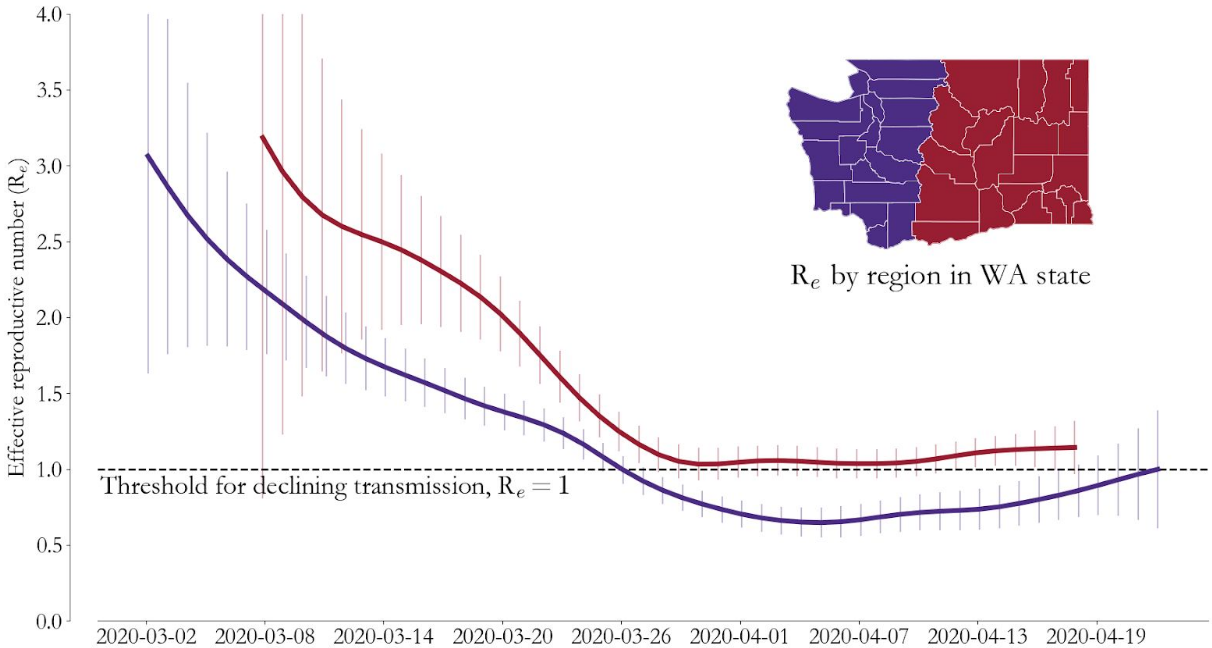

***Figure 5**: R_e estimates for Eastern (red) and Western (purple) WA, with 2 standard deviation error bars. In Western WA, we find that the effective reproductive number had fallen confidently below 1 in late March but has since returned to roughly 1 on April 22, on the cusp of increasing transmission. Meanwhile, in Eastern WA, we find that increasing transmission is highly likely as recently as April 18. This illustrates heterogeneity across the state.*

Conclusions

Using updated WDRS data through April 27, we estimate that COVID-19's effective reproductive number in King County has likely been increasing through the second and third weeks of April, with our most recent estimate on April 22 no longer definitively below the critical $R_e = 1$ threshold for declining transmission. Similar trends also appear in traffic data from WADoT.

In this report, we also applied the model to data aggregated across counties in Eastern and Western WA. We found that transmission rates through April 18, as measured by the effective reproductive number, remained persistently higher across Eastern WA relative to Western WA and that R_e has recently increased on average in both regions, suggesting that transmission increases have been widespread throughout the state.

When interpreting these results, it is important to note that the model describes average transmission dynamics across regions and does not distinguish the contributions of large transmission clusters from diffuse regional spread. The inferences here are intended to describe these aggregate conditions, and more detailed epidemiological understanding is important for mapping changes in transmission onto specific behaviors and population subgroups.

As we experiment with relaxing physical distancing policies in Washington, we will see increases in COVID-19 transmission. Epidemiological modeling can be used to interpret data and determine if transmission has increased to a point where COVID-19 infections will grow exponentially. However, since behavior changes today appear clearly in the epidemiological data weeks later, and there are no established and validated metrics that provide early warning signals, successful policy intervention will have to be as reactive as possible. This is a difficult ask, not just for policy makers and scientists, but for everyone in Washington: **instability in our day-to-day lives will be a persistent feature of our pandemic response in the months to come.**

Appendix 1: Accounting for changes testing volume and eligibility

As COVID testing becomes more available in King County, daily testing volume has increased and the criteria for eligibility have become less strict. Accurately distinguishing epidemiological changes in the data from testing changes is a methodological challenge that we're continuing to work on.

As it is, our current process is described in Figure S1. Rather than take positive cases at face value (top panel, black dashed line), we smooth total tests with a 3-day correlation time to correct for weekends and day-to-day variation in testing volume (middle panel). Then, combining the observed fraction of tests that are positive (bottom panel) with smoothed tests gives us the epidemiological curve in the top panel (red) that we use for effective reproductive number estimation and model fitting. For details on that process, see the appendix in our previous report.

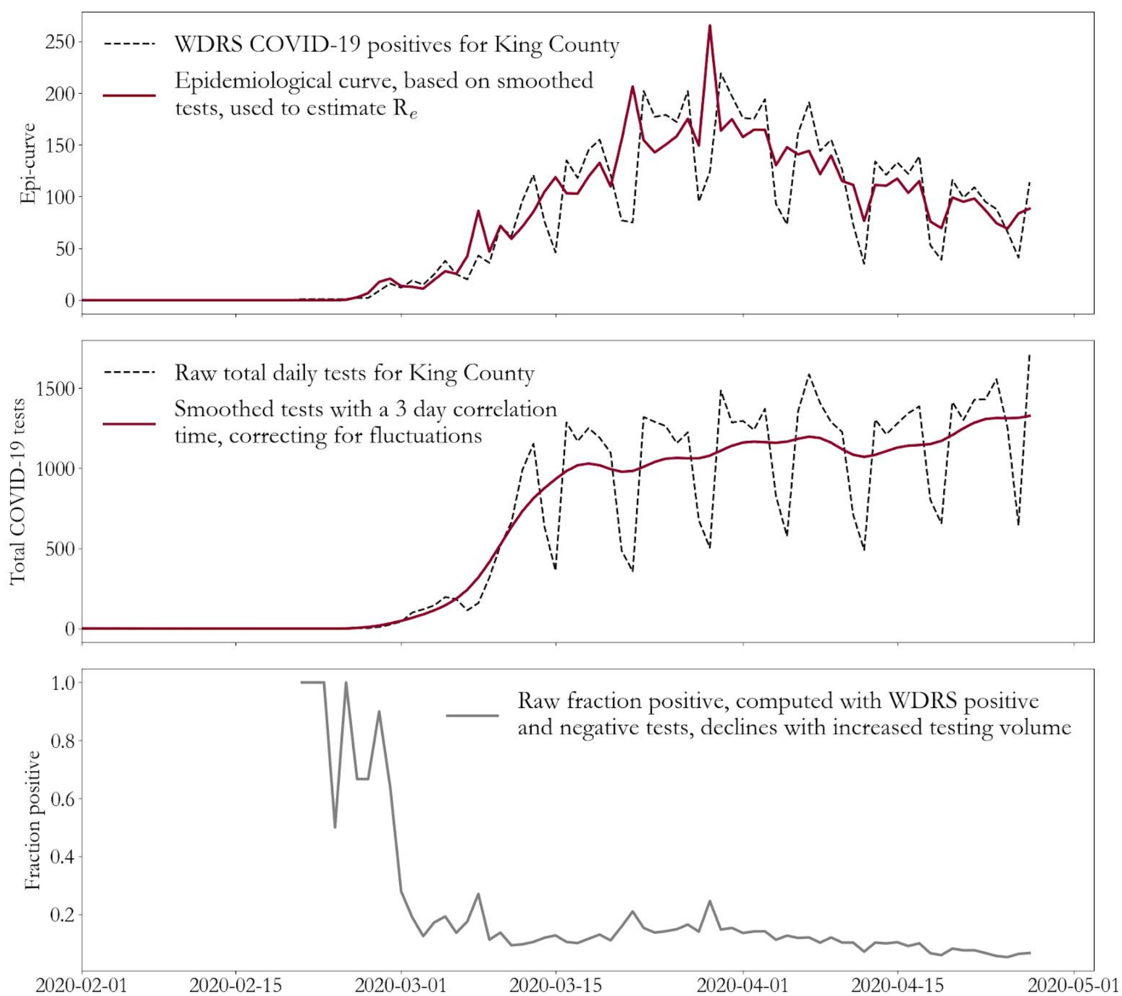

Figure S1. *Accounting for changes in testing. (Bottom panel) The fraction of tests that are positive in the WDRS has declined as testing volume increases. (Middle panel) We smooth the actual number of daily tests (black dashed line) to account for* *weekends and day-to-day variation (red). (Top panel) Using smoothed tests, we construct an epidemiological curve (red) corrected for testing variation. This follows the overall trend in positive cases (black dashed line) but leads to more robust, less uncertain epidemiological inference.*

Our approach is geared towards correcting for weekend effects, and it is unclear how well it accounts for persistent testing rises and changes in testing eligibility. As mentioned in the main text, daily testing rises are offset by decline in the observed fraction positive. As a result, we've found that the epidemiological curve we use for inference is robust to reasonable changes in the corrected number of daily tests (red curve, middle panel). That said, more sophisticated modeling of changes in testing policy may be needed, especially to account for targeted testing increases in high-risk subpopulations, and we plan to continue research on this issue.

Appendix 2: Comparing previous projections to updated data

In our previous report, we used a transmission model to forecast 3 scenarios under similar assumptions as the projections above. In Figure S2, we revisit those projections and compare them to recent data.

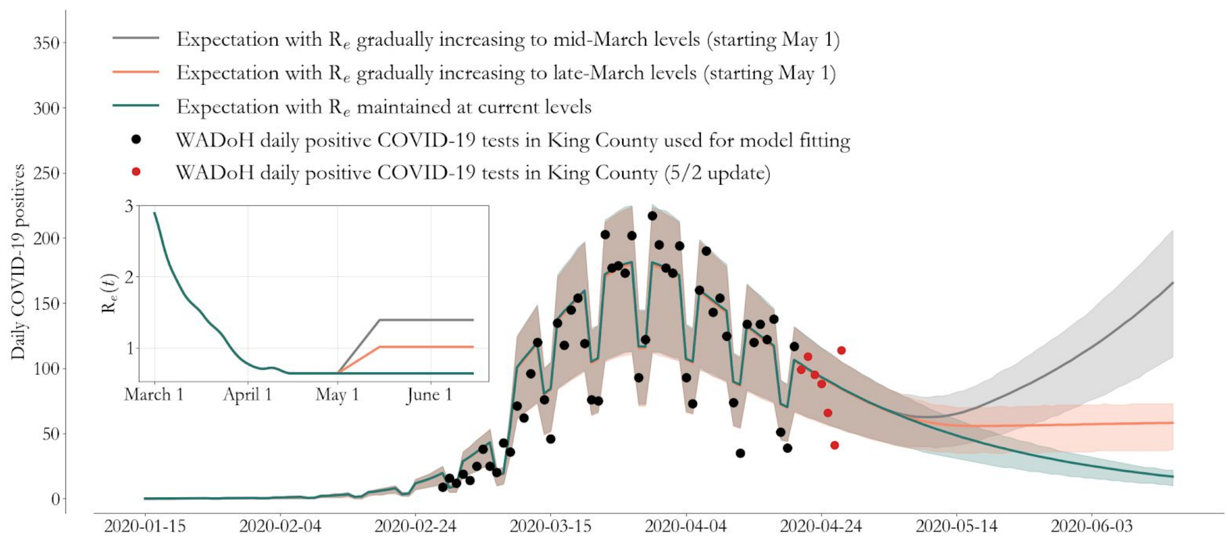

Figure S2. *Previous model-based projections under 3 scenarios, shown in the inset. Here, we considered maintenance of low, early April levels of transmission (green), increases to late March levels (red), and increases to mid March levels (grey). Updated data (red dots), show that all 3 scenarios are still consistent with observations.*

The three scenarios we considered were: (1) maintenance of relatively low transmission levels (green), (2) gradual increases in transmission to late-March levels (red), and (3) gradual increases in transmission to mid-March levels (grey). All three projections capture new case data (red dots) well, highlighting that changes in transmission take days appear unambiguously in the testing data we have.