

Comparing COVID-19 dynamics in King and Yakima counties

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What do we already know?

In previous reports, we estimated COVID-19's [effective reproductive number for King County](#) and for the [western and eastern halves of Washington state](#). We found that while both halves of the state slowed transmission down since early March, eastern Washington had not fallen definitively below the critical $R_e = 1$ threshold for declining transmission at any time. Meanwhile, others have observed that the epidemic has been growing in Yakima County, which in early May experienced the [highest case rate](#) of any county in the West Coast. The relative differences in the epidemiological situation between King and Yakima counties has been noted in [news reports](#), with the observation that more of Yakima's population has continued traveling to physical workplaces.

What does this report add?

In this report, we update our estimates of the effective reproductive number and prevalence in King County and also add these for Yakima County using data from the [Washington Disease Reporting System](#) compiled on May 24. We find that R_e declined in both counties throughout March and early April, but those declines plateaued at different levels, with Yakima above 1, and King likely slightly below. **Specifically, we estimate that on May 10 R_e was between 1.17 and 1.55 in Yakima County. This is reflective of a growing epidemic in Yakima County, with a case rate nearly 3-times the statewide average.**

We also begin to explore potential reasons for the different epidemic trajectories observed in the two counties, though we note that our findings are descriptive and explore only a subset of possible explanations. Using data from cell-phones, we find, coarsely, that **average levels of mobility in Yakima County never declined to the levels reached in King County**. Within both counties, **time at home was strongly associated with average area household income**. Household income is one factor associated with mobility differences but the relationship is not simple. Overall household incomes are higher in King County, but matched across income categories, there is more mobility in Yakima County, **suggesting there are behavioral differences not explained by differences in income**. Workforce data indicate that the most common fields of employment in King County are professional, scientific, and technical services and in Yakima County are agriculture, forestry, fishing, and hunting. As such, **a larger proportion of King County's workforce is able to work from home compared to Yakima**.

What are the implications for public health practice?

While physical distancing based on encouraging people to stay at home has been the main public health intervention for suppressing COVID-19, there exists differential feasibility and willingness to comply among different populations within Washington State, as exemplified by the comparison between King and Yakima counties. Today, with more information at hand, it is increasingly possible for public health policy to identify and serve vulnerable populations by means that are sensitive to their needs and to address attitudes and behaviors that limit policy effectiveness.

Executive summary

Shortly after the first confirmed COVID-19 death in Seattle, a broad array of physical distancing policies were implemented throughout Washington State in March, including school closures, bans on large gatherings, and stay-at-home orders. [In a previous report](#), we quantified the concurrent changes in COVID-19 transmission in eastern and western Washington, and we found that the effective reproductive number, R_e , a metric for the average level of transmission in a community, was consistently lower in the western part of the state. This heterogeneity across the state suggested that the success of policy recommendations, and individuals' ability and willingness to comply with them, varied considerably depending on local conditions.

The epidemiological implications of Washington's heterogeneity have become increasingly clear. In particular, others have observed that the epidemic is growing in Yakima County, which in early May recorded the [highest case rate](#) of any county on the west coast. In stark contrast, we have [reported](#) on continuing declines in COVID-19 prevalence in King County. Understanding the nature of this contrast is an important issue for public health, with significant implications for the success of future COVID-19 suppression efforts in the state.

In this report, we use transmission models informed by COVID-19 testing and mortality data from the WDRS to quantify and better understand the contrast between King County and Yakima County. We find that physical distancing policies in March likely slowed transmission in both counties; however, we estimate that transmission in Yakima County has at no time been contained, with R_e falling but never definitively below 1. Meanwhile, in King County, we estimate that there were periods of sustained transmission decline, particularly in early April. As a result, we estimate that the prevalence of active COVID-19 infections on May 18 in Yakima County was between 0.43% and 3.2% of the population while in King County we estimate that prevalence was between 0.08% and 0.44% at the same time.

Understanding why suppression efforts were more successful in King County than in Yakima County is critical for the success of future interventions and for achieving more equitable outcomes. Unfortunately, our analysis in this report does not provide definitive conclusions. We find that cell-phone tracking data can be used to coarsely relate transmission to time spent at home in both King and Yakima counties, and that time spent at home is closely related to societal factors such as income and place of employment. However, factors that are not clearly related to economics are also at play. Overall, our analysis highlights that no single societal difference between King County and Yakima County is likely to completely explain the differences in COVID-19 burden. To curtail the growing epidemic in Yakima County, tailored interventions will need to be sensitive to persistent vulnerabilities in specific populations and be able to address barriers and attitudes that limit the effectiveness of implemented policies.

Key inputs, assumptions, and limitations of our 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 transmission modeling 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 24, and to hedge against delays in reporting, we analyze data up to May 18 in King County and up to May 15 in Yakima County.**
- Estimates of R_e describe average transmission rates across large regions, and **our current work does not separate case clusters associated with super-spreading events from diffuse community transmission.**

In this report, we contextualize our epidemiological results with mobility data from [SafeGraph](#). SafeGraph produces anonymized and aggregated datasets on physical distancing and foot traffic at the census-block-group (roughly 600 to 3000 people) level by processing cell-phone location data.

- To study associations of mobility with income, we combine SafeGraph data with census information on median incomes in census block groups to better understand movement across the population in Yakima County and King County. This [ecological analysis](#) **describes average income-mobility associations at the group level and may be biased with respect to specific individual-level factors.**
- **We specifically use a mobility metric that measures “time at home”** based on a home location inferred by SafeGraph from cell-phone location data. We choose this metric for interpretability reasons, but it is not clear how well this metric captures mobility variation across types of housing or for [houseless populations and individuals who live in non-traditional housing](#). These groups [may be at high-risk for COVID-19](#), both in home locations and away from home, and better understanding their role in COVID-19 transmission is work currently in progress.
- Additionally, **we do not describe associations with race, ethnicity, age, and other demographic factors.** These factors have complex associations with employment, opportunity to isolate at home, comorbidities, access to healthcare, and other risk factors that affect COVID-19 transmission, severity, and testing. Ongoing work is focused on addressing these limitations.
- **Because of the limitations of ecological analysis and incomplete demography, all associations described here are descriptive and should not be interpreted causally without additional information.**

Also in this report, we comment on employment data by industry in King and Yakima counties. The number of workers in each industry is based on the Census 2018 American Community Survey (ACS) [table B24050](#). Percent unemployed in each industry was calculated as the number unemployed due to COVID-19 in each industry divided by the number of employees in the industry in the county. Number unemployed due to COVID-19 was calculated as the product of:

- [Percent distribution of unemployment by industry](#): The number unemployed in the industry divided by total number unemployed, in each county. These are new claims from after March 21, which we expect to represent the industry distribution for COVID unemployment.
- [Percent of people unemployed in WA due to COVID-19](#): The unemployment rate as of May 2 minus average unemployment rate in all of 2019.
- Civilian Employed Population 16 Years and Over in state from 2018 ACS [table B24070](#).

Transmission models help us quantitatively assess the differences in COVID-19 burden experienced by different communities

Model-based estimates of the effective reproductive number, R_e , are one way to characterize differences in COVID-19 transmission while accounting for differences in population, testing volume, and case reporting. In Figure 1, we compare R_e in King County (blue, 2 standard deviation error bars) and in Yakima County (orange, 2 standard deviation error bars). Overall, while uncertainty is considerable throughout, we find that recent transmission in Yakima County is occurring at a higher rate than in King County.

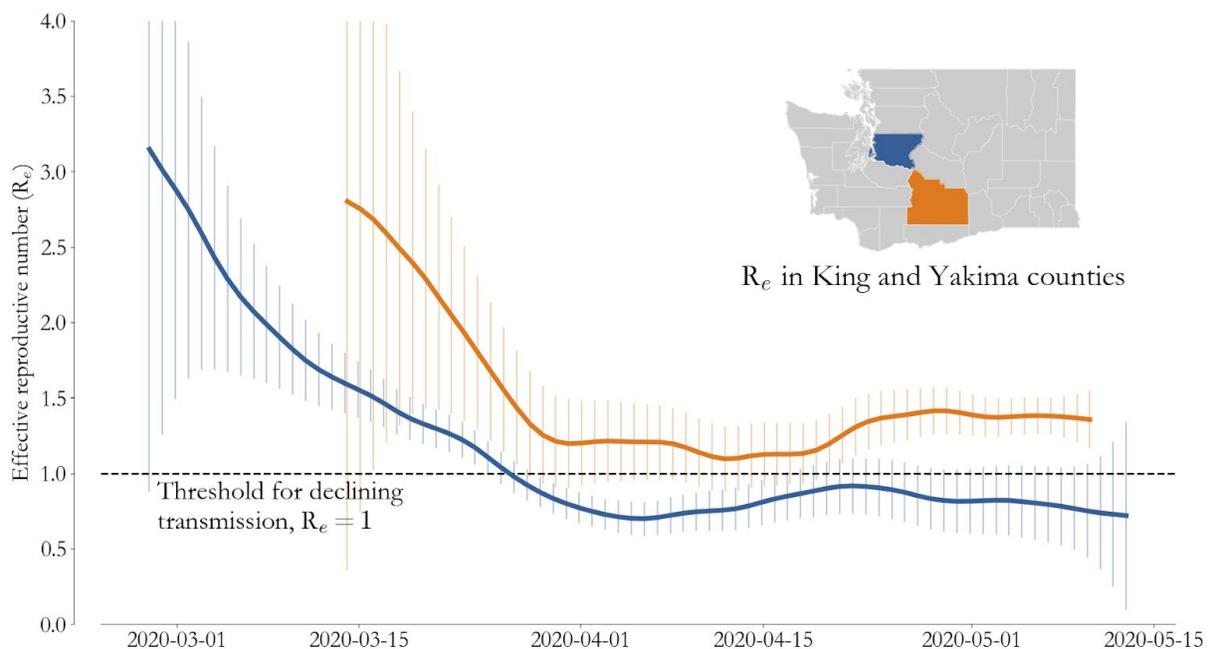


Figure 1: Effective reproductive number estimates in King County (blue, 2 standard deviation error bars) and Yakima County (orange, 2 standard deviation error bars). While transmission has slowed in both counties since Early March, we find that COVID-19 transmission has persisted at higher levels in Yakima County than in King County.

More specifically, in Yakima County, we find that R_e declined considerably through late March, from a best estimate of roughly 2.80 on March 14 to a best estimate of 1.20 on March 31. Since then, however, progress to suppress COVID-19 transmission has saturated and even potentially reversed. On May 10, we estimate that R_e was between 1.17 and 1.55, with best estimate 1.36, likely higher than levels from late March and early April. Moreover, we find that R_e was not definitively less than 1 throughout the entire analysis period, suggesting that transmission in Yakima County was at no time contained.

This transmission metric has key differences in King County. Notably, transmission reduction efforts throughout March were more successful overall, bringing R_e from roughly 3.01 in late February to levels definitively below 1 in late March and early April. Just as in Yakima County, progress has also likely saturated; however, it's done so at a level where our best estimates remain below $R_e = 1$. As a result, in contrast to the situation in Yakima County, transmission in King County has been on a path toward increasing containment.

Our models give us a platform to quantify this difference in terms of COVID-19 burden. We do so in terms of the prevalence of active COVID-19 infections in Figure 2, where King and Yakima are in blue and orange respectively and 50%, 95%, and 99% uncertainty intervals are shaded in progressively lighter colors. With R_e likely less than 1 in King County, we estimate overall prevalence declines from a peak in late March to an estimate on May 18 between 0.08% and 0.44% of the population. Meanwhile, in Yakima, with R_e definitively above 1, prevalence has continued to increase over time to an estimate on May 18 between 0.43% and 3.2% of the population, not yet reaching a peak. Thus, we find that recent population prevalence is likely higher in Yakima County than in King County and may even be higher than King County's peak prevalence from late March. But in both counties, the vast majority of the population has not yet been infected and so substantial transmission remains possible without effective control efforts.

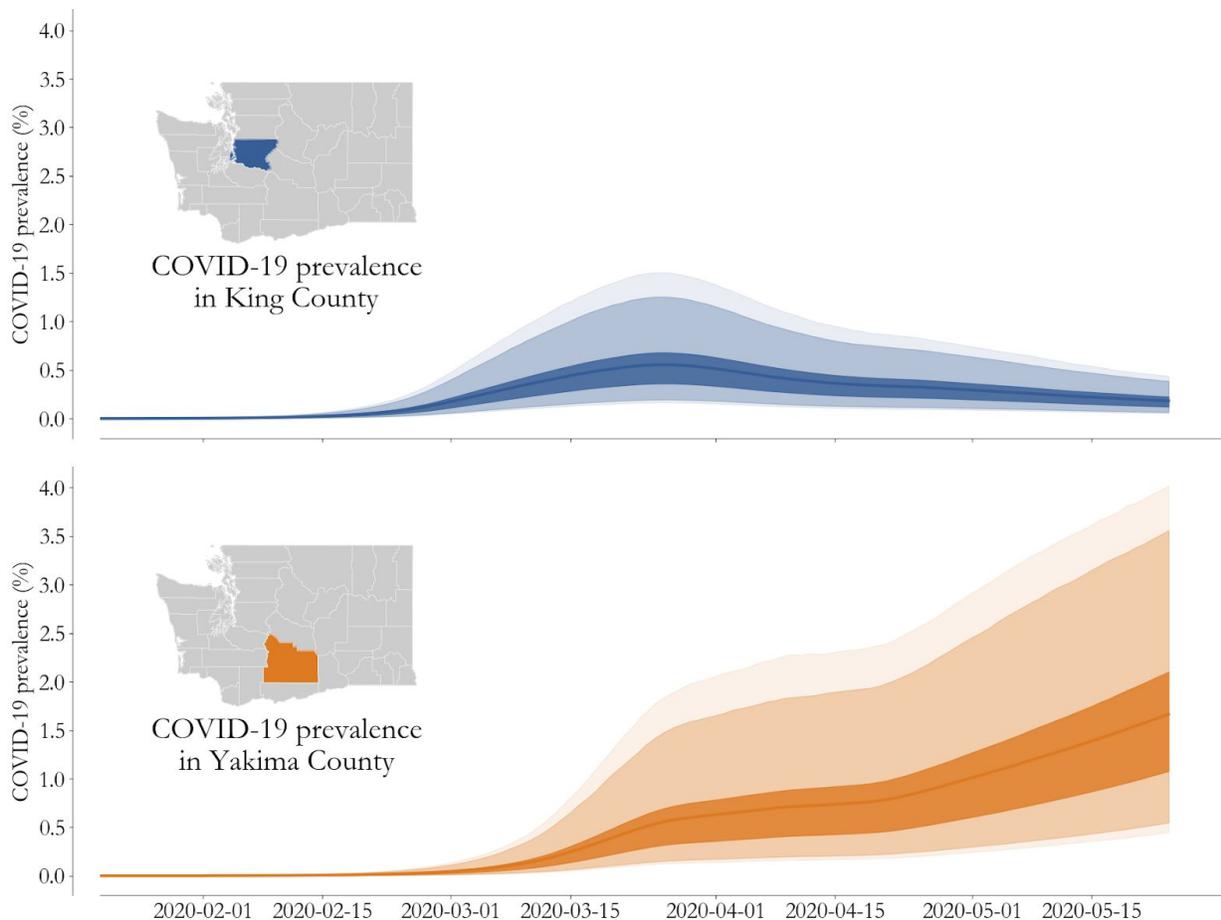


Figure 2: Model-based estimates of COVID-19 prevalence, the fraction of the population with active infections, in King County (blue) and Yakima County (orange), with 50%, 95%, and 99% CIs shaded. We estimate that prevalence in Yakima has continued to grow, potentially above peak levels seen in King County.

Many differences between King and Yakima counties may be driving differential transmission

Understanding the drivers of these epidemiological differences is critical to developing effective

strategies for mitigating COVID-19 transmission across Washington. Between King County and Yakima County, differences in demographics, industries, social factors, and individual attitudes and behaviors all potentially contribute to the overall picture of COVID-19 epidemiology that we see in our models.

A thorough understanding of how these differences influence transmission will require data on the routes of transmission specific to each community. Those data are currently being collected by WADoH, and we are working towards describing transmission pathways and risk more specifically for populations across the state. In the meantime, we can make some high-level progress by analyzing cell phone mobility and employment data from King and Yakima counties. Doing so helps demonstrate the complexity of the issue while highlighting some of the contributing factors.

Time spent at home is closely related to transmission in both King and Yakima counties

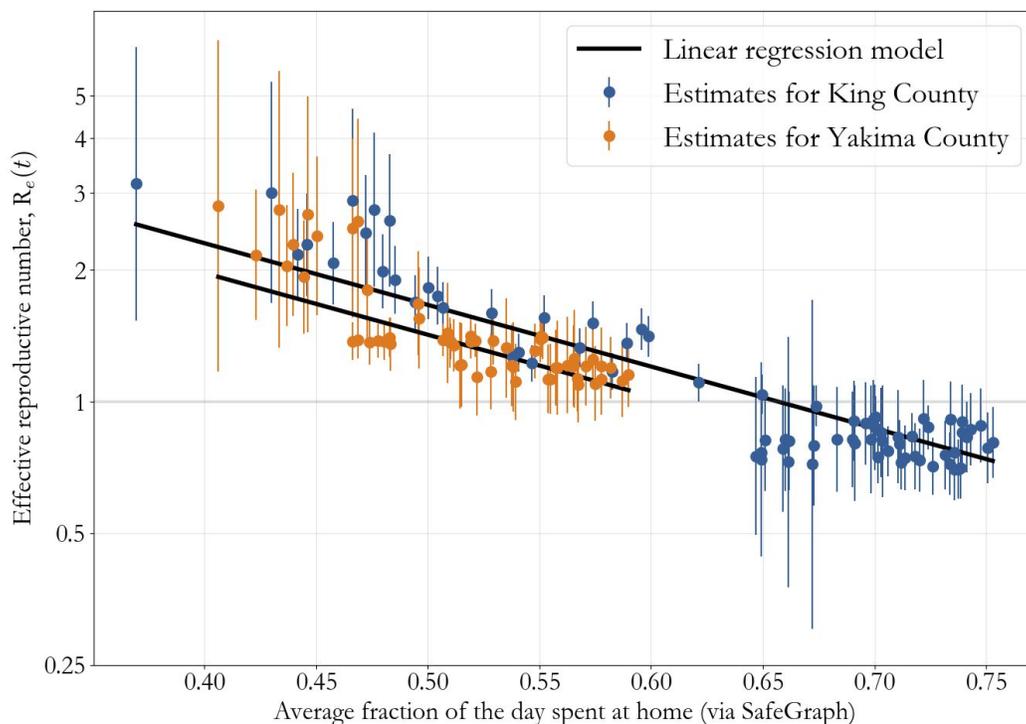


Figure 3: Connecting R_e in King County (blue, 2 standard deviation error bars) and Yakima (orange) to the population averaged fraction of the day spent at home as measured by SafeGraph. Linear regression with distinct King and Yakima intercepts fit the data well (weighted $R^2 = 0.85$) with the same slope in both counties, showing that more average time spent at home is associated with less community transmission and that differences in transmission between counties are associated with differences in the average time spent at home.

We start by connecting model-based estimates of COVID-19 transmission to a measure of behavior that is more intuitive and easily interpretable. Specifically, we build a statistical relationship between R_e and cell-phone based measures of the average time spent at home in each county on a given day, which is available from [SafeGraph](#). However, we want to emphasize that this isn't the only choice that could explain the observed trends in transmission. We choose it because it offers a useful connection between transmission and behavior that we can start to interpret in terms of societal differences. (See [this IDM](#)

[report](#) and [this independent analysis by the Surgo Foundation](#) for two examples of other ways to look at mobility and risk.)

This is summarized in Figure 3. We assume that daily R_e in both counties (blue for King, orange for Yakima) is log-linearly related to daily estimates of the fraction of time spent at home, with intercepts for each county to coarsely account for essential differences in transmission, like population density, not captured by mobility alone. Our regression model (black lines) captures the overall trend in the data (weighted $R^2 = 0.85$) with a lower intercept for Yakima County. The shared common slope indicates that R_e responds similarly to changes in mobility across the two counties.

Viewing transmission through the lens of the regression model helps contextualize the epidemiological differences between the counties. Early on, before physical distancing measures were widespread and therefore time spent at home was relatively low, both King County and Yakima County had R_e roughly between 2 and 3 and people in both counties spent 40 to 50% of the day at home on average. Later, as physical distancing policies led to declines in R_e in both counties, the average time at home went as high as 75% in King County but stayed under 60% in Yakima County. The relationship between transmission and mobility suggests that the observed gap in time at home could explain the COVID-19 transmission decline in King County and the concurrent transmission growth in Yakima County.

Multiple factors likely contribute to an individual's time at home

The statistical approach used above can, at best, translate transmission differences between the two counties into differences in time spent at home. In other words, we are left trying to understand how societal differences between King County and Yakima County contribute to differences in daily mobility.

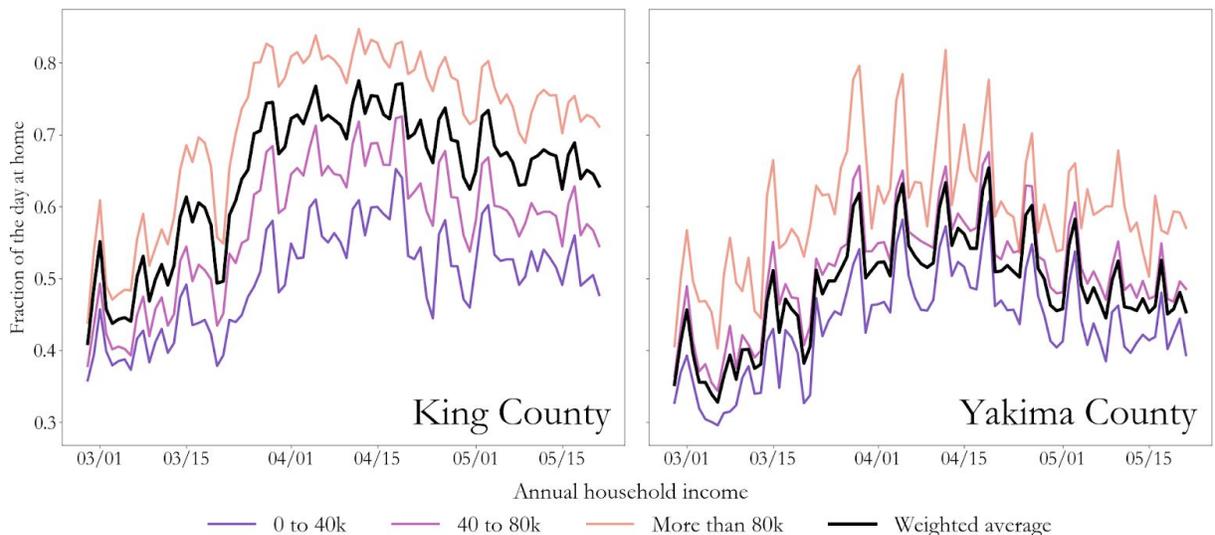


Figure 4: The fraction of the day spent at home in King County (left) and Yakima County (right). By comparing data across census block groups binned by median household income, we see a clear correlation between household income and time at home (colored lines). King County residents have higher incomes on average than Yakima County residents, and this is associated with higher average time at home (black lines). Simultaneously, comparisons across panels matched by income show that Yakima County residents are spending less time at home than those in King County for reasons not explained by income alone.

Inspecting the SafeGraph mobility data by census block groups (CBGs), where we also have information

on median household income through the 2016 American Community Survey (ACS), offers some perspective on this issue. This is shown in Figure 4, where time spent at home is averaged in CBGs grouped by median household income for each county. Time at home is unevenly distributed across socioeconomic class in both counties, suggesting that people who live in CBGs with households that have higher annual income (red lines) have fewer barriers to remaining at home than others in their communities with lower incomes (blue and purple lines). Critically, average household income is higher overall in King County than in Yakima County, and the population weighted averages of time spent at home in each county (black) reflect this difference, falling closer to high income in King than in Yakima.

While we see that people living in CBGs with higher median income are spending more time at home on average, Figure 4 also offers a comparison of time at home between counties while controlling for income. For example, comparing the highest income brackets in both counties shows that peak time at home was roughly similar, around 80% for weekend days, in early April. Since then, Yakima County's highest income groups have dropped their average time at home to roughly 60% of the day, substantially less than their counterparts in King County. In addition weekend and weekday behavior is different in the two counties. From late March to mid-April, both counties showed similar weekend average time spent at home, but Yakima county showed lower time at home during weekdays. But since mid-April, Yakima county residents average consistently less time at home on both weekends and weekdays than King County residents. Similar differences appear across all income categories. While this data cannot tell us the cause of these differences, which may be reflective of a variety of differences between individuals in each county, these particular features of the data suggest that behavioral factors not explained by the relationship between income and time at home also play a role in Yakima's COVID-19 transmission.

Large differences in employment offer more perspective on the differences in movement

One key difference between King and Yakima counties which also likely contributes to the differences in mobility described above is the distribution of industries in which people are employed. Using data from the 2018 ACS, we see in Figure 5 that in King County the industry with the highest employment is professional, scientific, and technical services (13% of the population) and few are employed in agriculture, forestry, fishing, and hunting (0.4% of the population). We see the opposite in Yakima County, where only 2% of the population are employed in professional, scientific, and technical services and the dominant industry is agriculture, forestry, fishing, and hunting (14% of the population). People in professional, scientific, and technical services industries are much more likely to have [the ability to work remotely](#) (76%) than people in agriculture, forestry, fishing, and hunting (5%).

For industries in which employees are unlikely to be able to work remotely, we expect mobility to remain high when unemployment in that industry is low because employees will have to travel to work. The unemployment rate due to COVID-19 differs across industries. In both counties, there is high unemployment in accommodation and food services as well as construction; and arts, entertainment, and recreation are particularly hard-hit in Yakima County. However, in the industries that employ the largest number of people in King and Yakima counties, professional, scientific, and technical services and agriculture, forestry, fishing, and hunting, respectively, unemployment remains relatively low (both 5%). Employees in the agriculture, forestry, fishing, and hunting industries in Yakima County are likely to maintain a high level of necessary employment mobility that does not take place in King County.

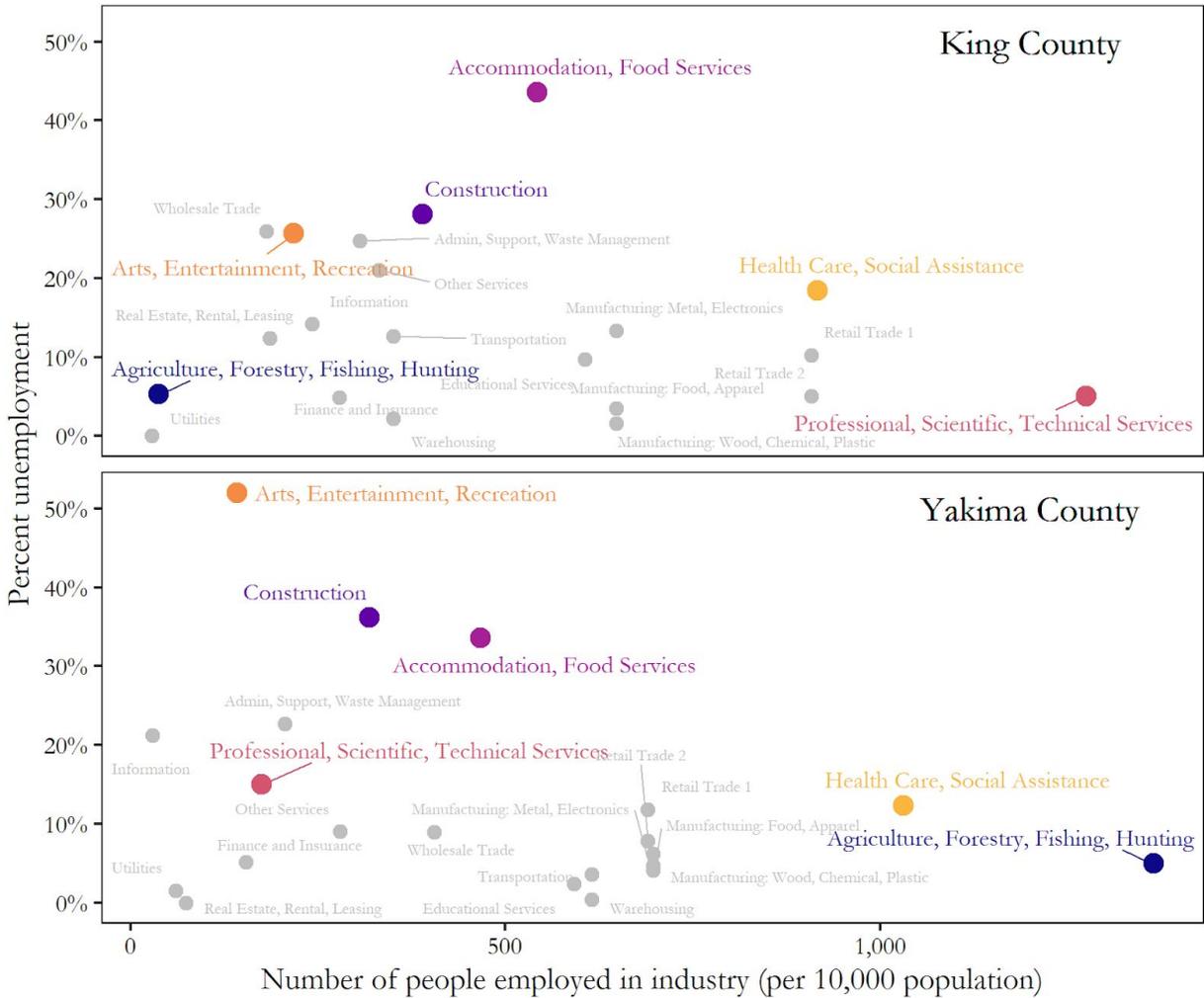


Figure 5: Number of workers employed in each industry in King (top) and Yakima (bottom) counties before COVID-19, and percent unemployed in each industry in each county due to COVID-19. In King County the industry with the highest employment is professional, scientific, and technical services. In Yakima County the industry with the highest employment is agriculture, forestry, fishing, and hunting. In both of these industries unemployment is relatively low, as opposed to construction, accommodation and food services, and arts, entertainment, and recreation.

Context-appropriate interventions are likely needed to curtail exponential growth in Yakima

The evidence is clear that broad stay-at-home policies have not successfully contained COVID-19 in Yakima County, and we return to our transmission model to highlight this point. In Figure 6 we compare modeled projections of COVID-19 test positives under two scenarios (inset) assuming testing practices remain roughly unchanged in the future. In green is our projection under the assumption that our May 10th R_e estimate is maintained, showing that disease burden is capable of rapid growth in Yakima County. Meanwhile, in grey, we demonstrate that if R_e is reduced by 30% to roughly 0.95 starting June 1, it is possible to curtail exponential growth and decrease Yakima's COVID-19 burden. Overall, this comparison suggests that Yakima County's COVID-19 susceptibility is high enough to support a wide range of outcomes. In light of the societal differences between King and Yakima counties, it is clear that

successful mitigation efforts in Yakima County will need to look considerably different than in King County, taking into account the context-specific needs in the community.

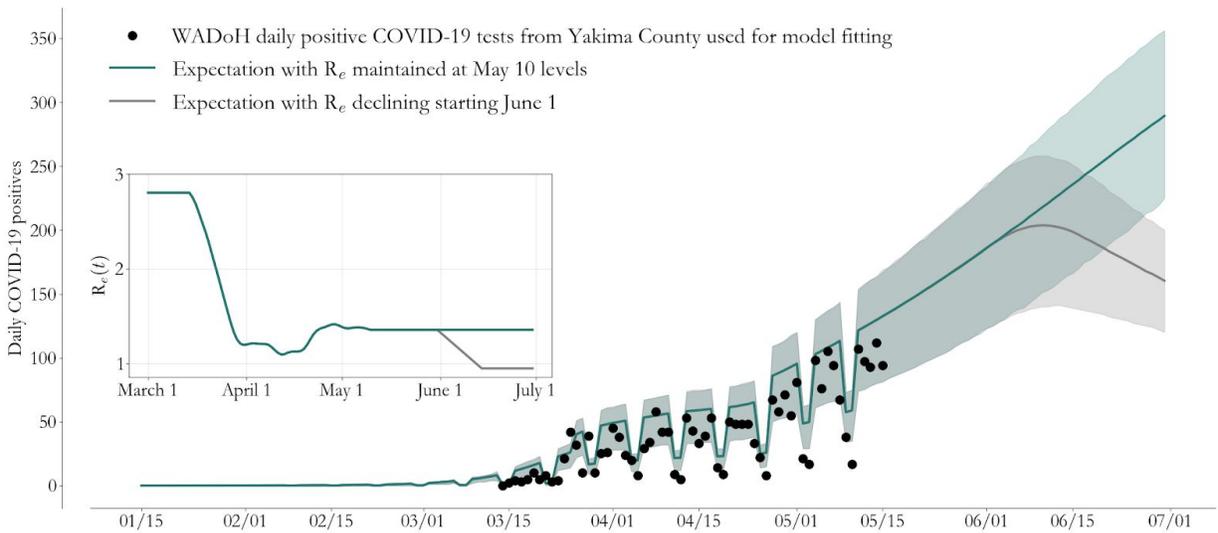


Figure 6: Model based projections for COVID-19 test positives in Yakima County under 2 scenarios, shown in the inset. If transmission rates stay similar, we expect continued exponential growth (green) since susceptibility in Yakima remains high. However, with context-appropriate interventions, it is possible to curtail the growth in COVID-19 burden (grey).

Conclusions

Using a transmission model informed by WDRS testing and mortality data compiled on May 24, we quantified the differences in COVID-19 burden in King County and in Yakima County. In particular, we found that past transmission suppression efforts were overall more successful in King than in Yakima, and our best estimates for the effective reproductive number in Yakima County have been consistently above 1, suggesting that COVID-19 transmission has never been contained there. This is in contrast to the situation in King, where we find evidence for sustained transmission declines starting in late March.

Understanding why transmission suppression efforts were more successful in King County than in Yakima County is an important question with serious implications for future interventions across the state. Unfortunately, we cannot yet provide a definitive answer to this question, and it is unlikely that an answer will be found until more information on community-specific transmission routes is collected and understood in association with COVID-19 cases.

That said, our exploration of mobility data offers some insight. In particular, we showed that transmission rates are closely related to the overall time spent at home in both communities, framing our epidemiological questions in terms of an interpretable mobility metric. We further found that since the implementation of social distancing policies, the population-averaged fraction of the day spent at home has been considerably higher in King County than in Yakima County.

Many factors contribute to this difference in mobility. We explored three:

- Income is correlated with time spent at home. This suggests that lower-income individuals are not able to stay at home, and that a larger portion of the Yakima County's population will encounter these challenges than in King County.
- Differences in industries and employment between the counties are another contribution to the

differences in the ability to work from home.

- Matched for income across King and Yakima counties, there is more mobility in Yakima County, which suggests there are behavioral differences that are unrelated to economic factors.

There is no simple story for why these differences exist. The association of median income with average mobility and broad differences in employment do not explain all individual differences in behavior. Both of the measures described here are proxies that are related to one-another and affected by other societal factors, including a wide range of personal values and structural inequalities that differentially impact communities based on race, ethnicity, and sex. As a result, these three explorations provide an incomplete picture.

If this analysis accomplishes anything, it's that it exposes that any single societal factor is unlikely to explain the differences we see in COVID-19 transmission, and in that way COVID-19 transmission is a reflection of society's preexisting complexities and inequalities. Early in the epidemic, public health policy was required to be implemented quickly and with broad strokes. In the intervening weeks, it has become clear that there exists differential ability and desire to comply with public health interventions across different populations, and that not all high-exposure situations are adequately addressed by current policies. This has borne out the inequitable outcomes we are witnessing: an epidemic getting under control in King County and a growing one in Yakima County. Today, with more information at hand, it's increasingly possible for public health policy to identify and more specifically serve vulnerable populations by means that are sensitive to their respective needs. Supporting that effort will require widespread commitment to transmission suppression activities by all of us who are able to comply, and doing so will simultaneously make everyone in Washington safer and healthier.

Appendix 1: Assessing the Yakima model's quality

In this appendix, we demonstrate that our transmission model fits the case and mortality data from Yakima, and we use the model to further describe aspects of Yakima's COVID-19 epidemiology. For an in-depth description of the modeling approach, see our [methods focused report](#).

The model is fit to COVID-19 test positives and mortality reported to the WDRS. These fits are shown in Figure S1. In the top panel, the model (orange) captures a gradual rise in mortality, consistent with the data (black dots) and with increasing COVID-19 prevalence. From the perspective of the model, mortality data is used primarily to estimate the number of introductions into the community before testing was available. Note that we constrain introductions into Yakima County to February 1. This is out of necessity since trade-offs between the timing and number of introductions lead to equivalent fits to the mortality data. In this case, our best fit requires roughly 12 introductions.

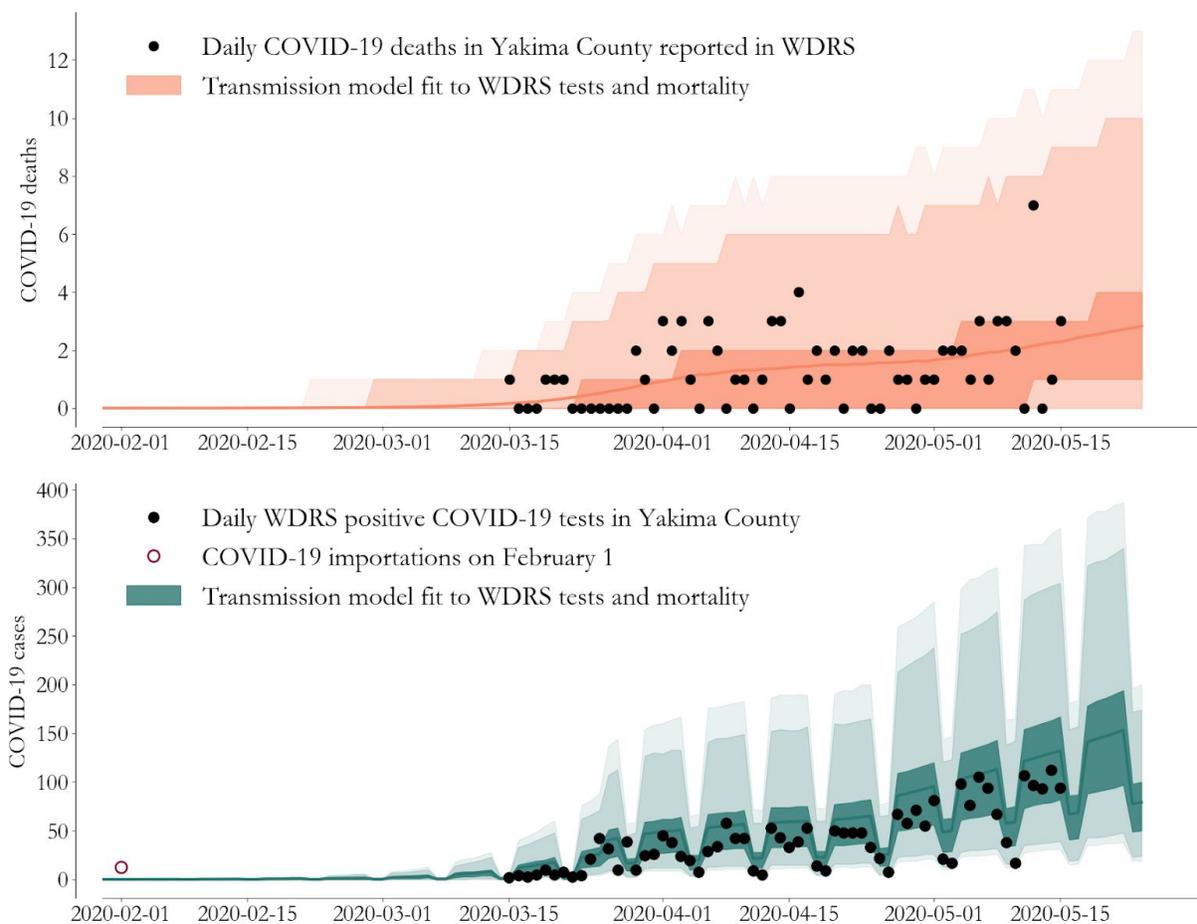


Figure S1: Transmission model fit to data from Yakima County. (Top panel) Model based estimates of COVID-19 mortality (orange, 50%, 95%, and 99% CIs) capture the gradual rise in observed mortality (black dots). (Bottom panel) Estimates of daily COVID-19 test positives (green) capture the rise in cases (black dots) by estimating the probability of infections being tested and accounting for weekend decreases in testing.

In Figure S1's bottom panel we compare the model (green) to observed COVID-19 test positives (black dots). Making this comparison requires us to estimate the daily probability that active COVID-19 infections are tested, and we assume that probability changes in distinct testing epochs: before March

25, between March 25 and April 26, and after April 26. We also account for decreases in this probability over weekends, which gives rise to a saw-tooth pattern in our estimates.

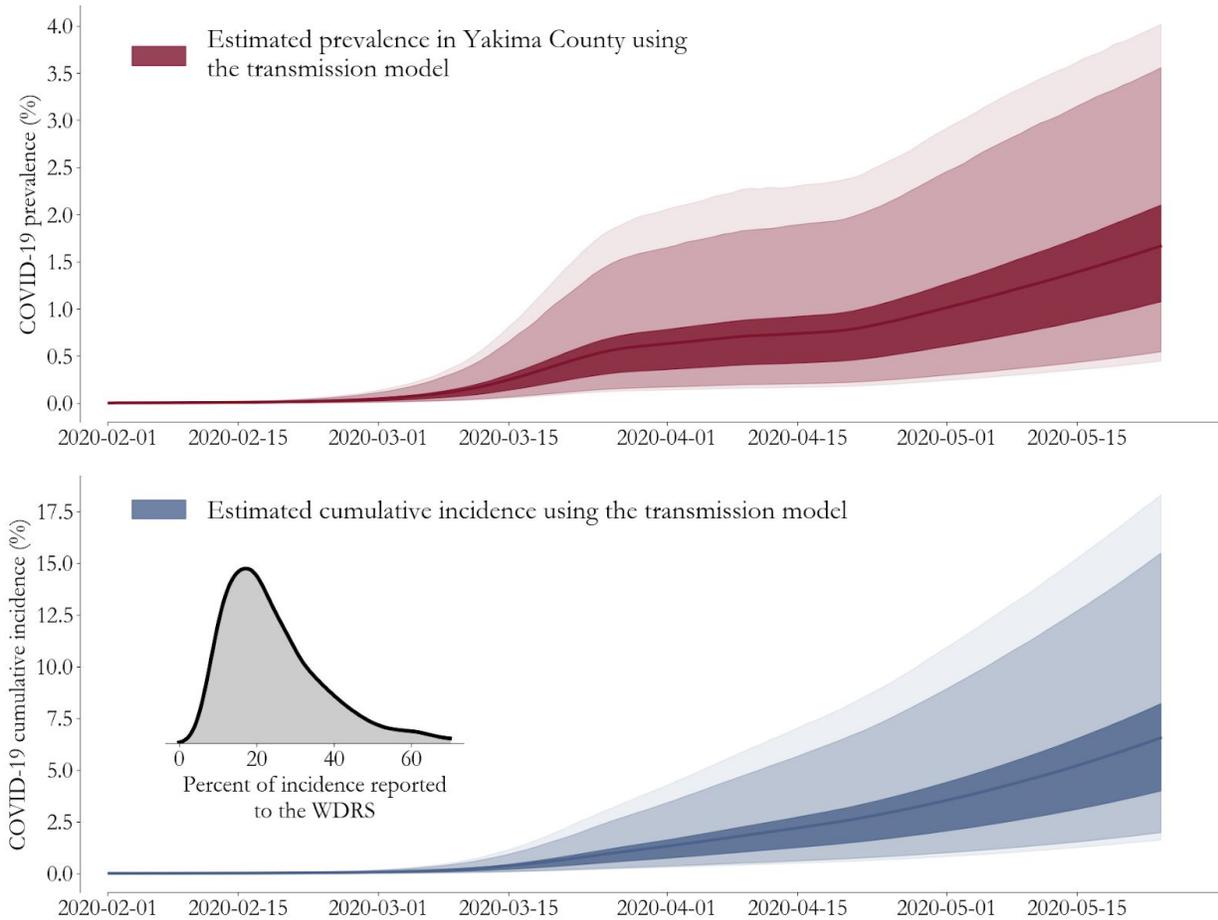


Figure S2: COVID-19 prevalence and incidence in Yakima County. (Top panel) Model based estimates of prevalence (purple, 50%, 95% and 99% CIs shaded) grow from February onward. (Bottom panel) Cumulative incidence estimates, which can be compared to observed cases to estimate the percent of incidence tested (inset), show that a large percent of Yakima County’s population is likely still susceptible to COVID-19.

The fitted model can be used to estimate COVID-19 prevalence and cumulative incidence over time in Yakima County. This is shown in Figure S2. In the top panel, the prevalence of active infections (as plotted in Figure 2 in the main text) grows over time, with a period of slower growth from late March to early April reflective of mitigation efforts. Meanwhile, in the second panel, we estimate the cumulative fraction of the population no longer fully susceptible to COVID-19. On May 15, we estimate that between 1.5% and 12.7%, with best estimate 5.2%, of Yakima County’s population had been exposed to COVID-19. Comparing this estimate to observed cases, we find in the inset that between 8% and 64%, with a best estimate of 25.4%, of infections eventually tested positive. Overall, a large fraction of Yakima County’s population is likely still completely susceptible to COVID-19, and context-specific mitigation efforts will be necessary to bring the growth in burden under control.