

COVID-19 Regional Models for Colorado

09/22/2021

Prepared by the Colorado COVID-19 Modeling Group

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Summary

Key messages in this report are:

- COVID-19 hospitalizations and estimated new infections are increasing in four regions: Central Mountains, Northwest, San Luis Valley and Southeast, and are flat in three regions.
- We estimate the prevalence of infections are highest in the Central, East Central, Northeast, Northwest, South Central and Southeast regions. Contacts are particularly risky in these regions. These estimates are for September 6th.
- Southeast has the lowest percentage of the population that is fully vaccinated (35%). Vaccinations are also low in East Central (36%). Vaccination is highest in the Central Mountains (64%) and Metro (62%) regions.
- These estimates are based on hospitalization data through 09/13/2021 and vaccination data through 09/19/2021. Due to lags between infection and hospitalization, these estimates do not capture major changes in transmission after approximately 8/31/2021.
- The regional models were updated this week to account for variants of concern in Colorado including the increased virulence of the Alpha (B.1.1.7) and Delta variants.

Introduction

This report provides the results of epidemic models for regions of Colorado, using methods similar to that used for the state-level model. Estimates are presented for the 11 Local Public Health Agencies (LPHAs) regions in the state and for 8 selected counties with populations that are sufficiently large to allow for county-level estimates. The model results are subject to greater uncertainty than those for the entire state because there are fewer hospitalizations and cases in each region than in the state as a whole. Estimates are most uncertain for the regions with the smallest population size. We use the model as well as COVID-19 hospital, and vaccination data to generate four measures for each region. These measures can be used to gauge the current state of SARS-CoV-2 in each region.

- **The effective reproduction number (R_e)** is a measure of how rapidly infections are spreading or declining in a region.
- **Infection prevalence** is an estimate of the portion of the population currently infected and capable of spreading infections. It can be used to gauge how risky contacts are.
- **The percent of the population fully vaccinated to date** is based on data provided by CDPHE and includes all people who have received one dose of Johnson and Johnson or two doses of Pfizer or Moderna vaccine. Because it takes approximately a month to develop immunity, some of these individuals

may not yet be immune to the virus.

- **The percent of population estimated to be immune** is estimated from the number of individuals immune due to vaccination combined with the individuals immune due to infection. These estimates account for the time between vaccination and immunity and the efficacy of the vaccine. As the immune population grows, due to vaccination or prior infection, the spread of infection slows.

Table 1. The estimated effective reproductive number, prevalence of infections, percent of the population immune and vaccinated to date by region. These metrics are estimated using hospitalization data from the Colorado COVID Patient Hospitalization Surveillance (COPHS). Effective reproductive number (Re) reflects hospitalization data through 09/13/2021. The prevalence of infections and percent of the population immune is estimated for 09/06/2021. The percent vaccinated estimates are based on data provided by CDPHE through 09/19/2021 and reflect the proportion of the population that is fully vaccinated as of that date.

	Are infections increasing or decreasing?		How many people are infectious?			
	Re	Infections are...	Prevalence per 100,000	People infectious	Percent of Population Estimated Immune	Percent of Population Fully Vaccinated
LPHA Regions						
Central	1.0	Flat	1,464	1 in 68	69.9	50.9
Central Mountains	1.1	Increasing	513	1 in 195	65.4	63.6
East Central	0.6	Decreasing	3,050	1 in 33	75.0	36.2
Metro	0.9	Decreasing	851	1 in 117	72.7	62.3
Northeast	0.9	Decreasing	1,745	1 in 57	71.3	51.7
Northwest	1.1	Increasing	1,179	1 in 85	67.5	44.9
San Luis Valley	1.1	Increasing	549	1 in 182	58.7	46.2
South Central	1.0	Flat	1,890	1 in 53	73.9	45.0
Southeast	1.8	Increasing	1,118	1 in 89	55.7	34.6
Southwest	0.6	Decreasing	583	1 in 171	66.3	56.2
West Central Partnership	1.0	Flat	673	1 in 149	57.2	48.2
Eight select counties						
Adams	0.9	Decreasing	1,047	1 in 95	80.0	55.8
Arapahoe	0.7	Decreasing	949	1 in 105	73.9	59.4
Boulder	1.1	Increasing	732	1 in 137	71.2	68.6
Broomfield	0.1	Decreasing	133	1 in 752	67.1	68.3
Denver	1.0	Flat	688	1 in 145	78.1	64.8
Douglas	0.8	Decreasing	691	1 in 145	65.6	61.1
El Paso	1.0	Flat	1,685	1 in 59	72.8	51.1
Jefferson plus	1.1	Increasing	552	1 in 181	66.7	64.7

Due to the small population sizes of Gilpin and Clear Creek counties, these counties are combined with Jefferson County. Jefferson County comprises 97% of the population in the Jefferson plus county cluster.

Due to lags between infection and hospitalization, the estimated effective reproductive number (Re) reflects the spread of infections approximately two weeks prior to the data of the last observed hospitalization.

Immunity from vaccination is based on assumptions that the Moderna and Pfizer vaccines are 52% effective after 14 days and 90% effective a week after the second dose; the Johnson and Johnson vaccine is assumed to be 72% effective 28 days after the first dose. In the model, it is assumed that immunity due to infection wanes after 6 months if an individual has an asymptomatic infection, 12 months if symptomatic. Age distribution of vaccination by region is inferred from state-level age distribution data.

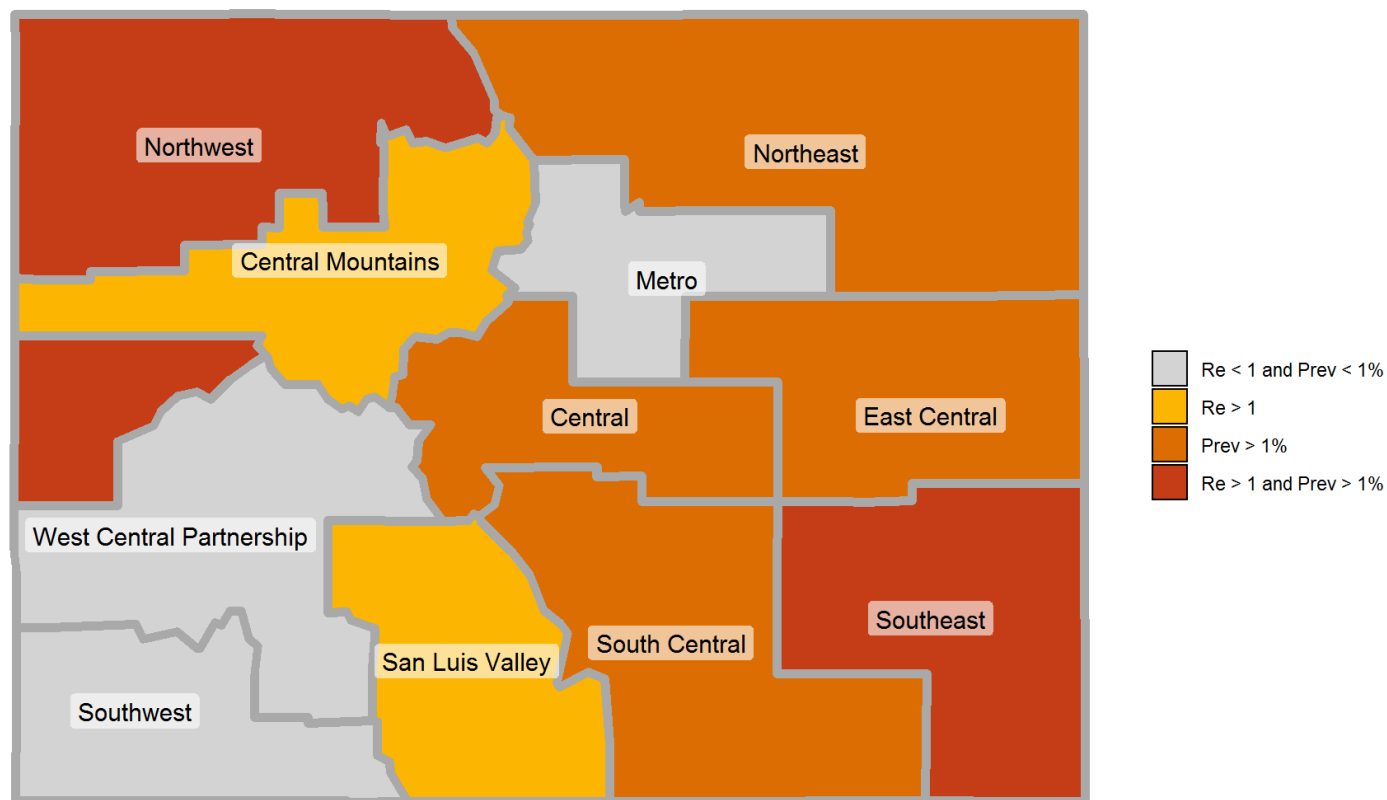


Figure 1. Map showing the 11 LPHA regions for which estimates were generated. Regions in yellow (effective reproductive number > 1), orange (prevalence $> 1\%$), or red (both effective reproductive number > 1 and prevalence $> 1\%$) indicate areas of concern.

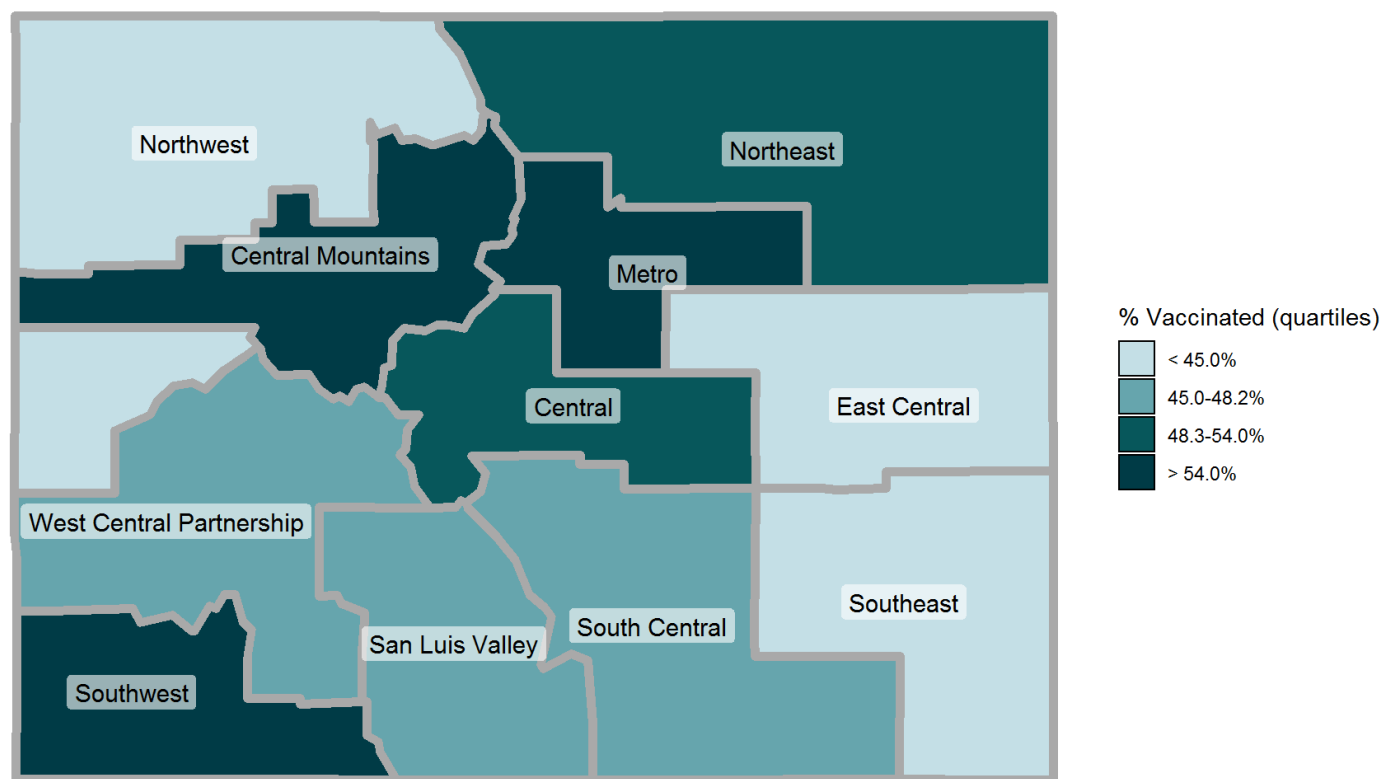


Figure 2. Map showing the percent of the population fully vaccinated by LPHA region. Estimates are based on data provided by CDPHE through 09/19/2021 and reflect the proportion of the population that has received one dose of Johnson and Johnson or two doses of Pfizer or Moderna vaccines as of that date. Darker colors indicate a higher proportion of vaccinated residents.

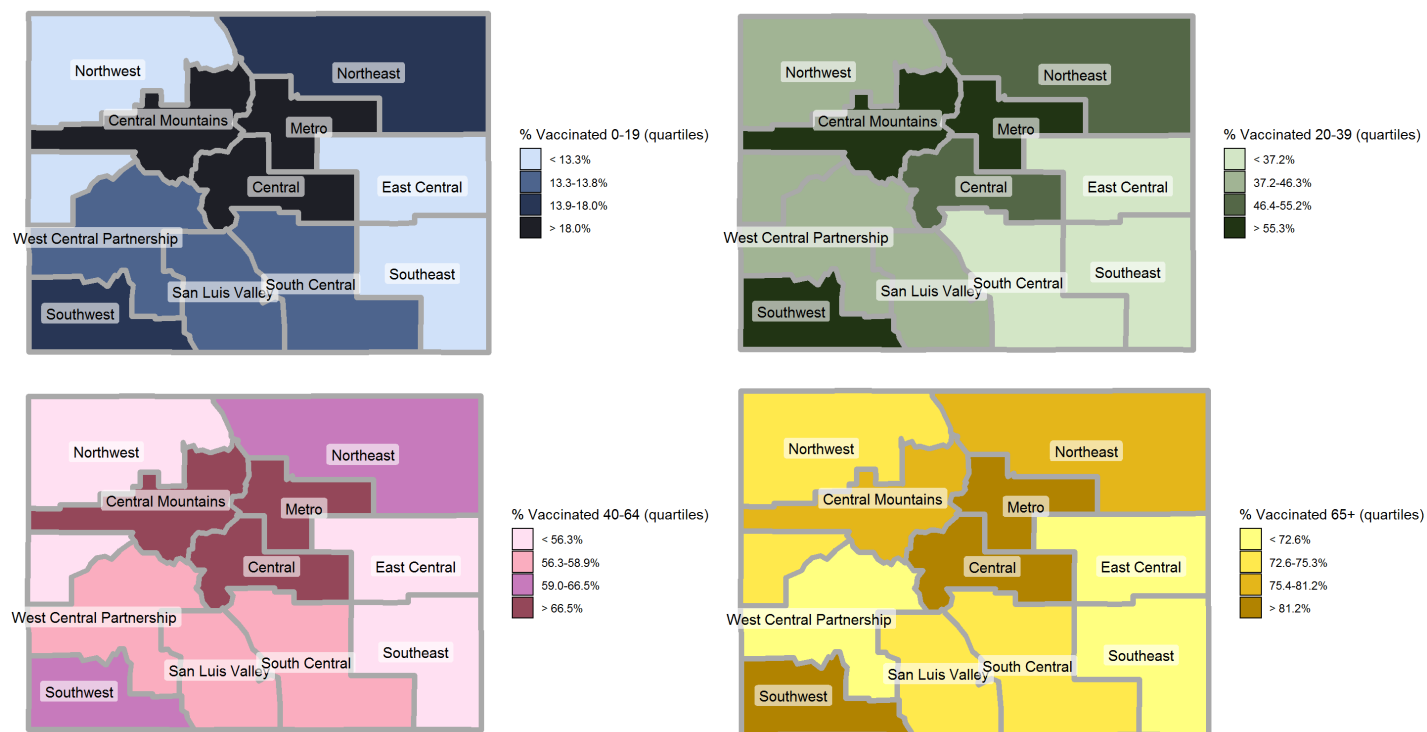


Figure 3. Map showing the percent of the population fully vaccinated by age group and LPHA region. Estimates are based on data provided by CDPHE through 09/19/2021 and reflect the proportion of the population that has received one dose of Johnson and Johnson or two doses of Pfizer or Moderna vaccines as of that date. Darker colors indicate a higher proportion of vaccinated residents.

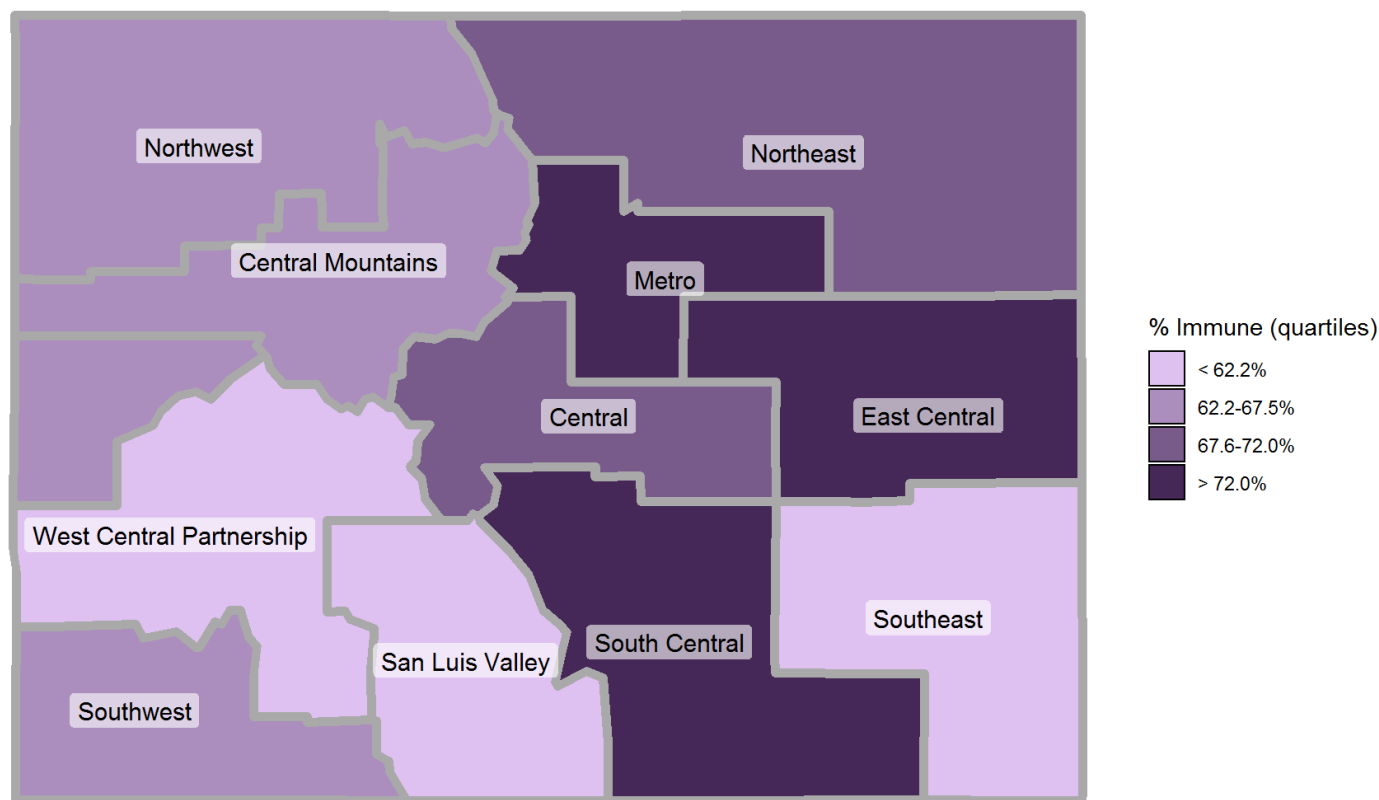


Figure 4. Map showing the percent of the population immune by LPHA region. Estimates are based on data provided by CDPHE through 09/06/2021. Darker colors indicate a higher proportion of vaccinated residents.

Effective Reproductive Number

The figure below shows the estimated effective reproductive number for each region since March.

The effective reproduction number (R_e) is a measure of how rapidly infections are spreading or declining in a region at a given point in time. When the effective reproductive number is below 1, infections are decreasing. When the effective reproductive number is above 1, infections are increasing.

The effective reproductive number is estimated using our age-structured meta-population model fit to hospitalization data. Because we base our parameter estimates primarily on COVID-19 hospitalization data, and hospitalizations today generally reflect infections occurring approximately 13 days prior, our most recent estimates of the effective reproductive number likely reflect the spread of infections occurring on approximately

08/31/2021.

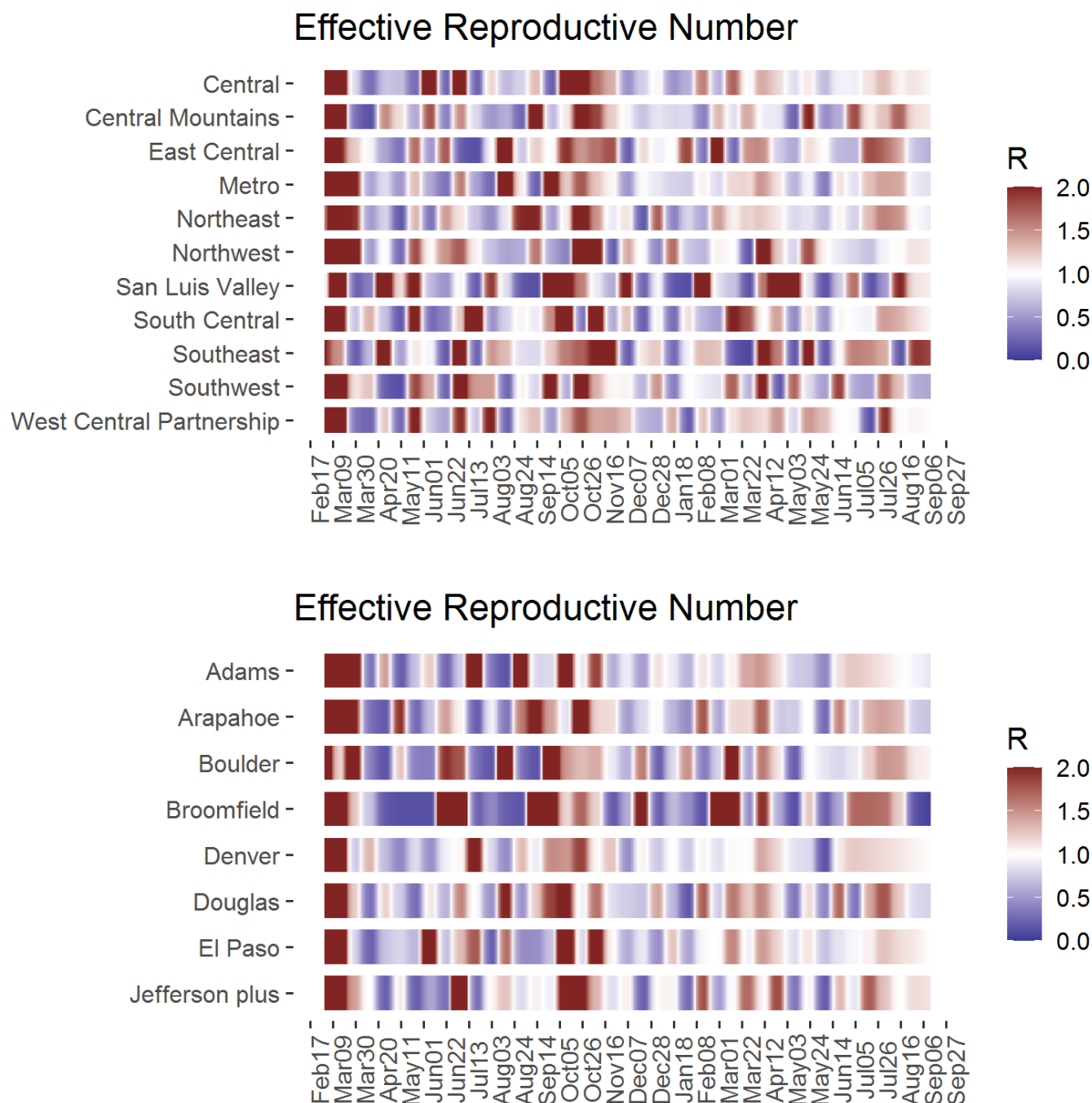


Figure 5. Estimated effective reproductive number (R_e) over time in the 11 LPHA regions in Colorado, and 8 selected counties and county clusters. Estimates shown using COVID-19 hospitalization data through 09/13/2021.

Infection prevalence

Infection prevalence provides an estimate of the proportion of the population that is currently infected with SARS-CoV-2 and capable of spreading infections. At higher levels of infection prevalence, individuals are more likely to encounter infectious individuals among their contacts. Because many people experience no symptoms or mild symptoms of COVID-19, many infections are not identified by surveillance systems. The estimates we present here are intended to provide an approximation of all infections, including those not detected by the Colorado Electronic Disease Reporting System (CEDRS).

The figure below shows the estimated infection prevalence per 100,000 individuals for each region. These are estimated from the age-structured meta-population model.

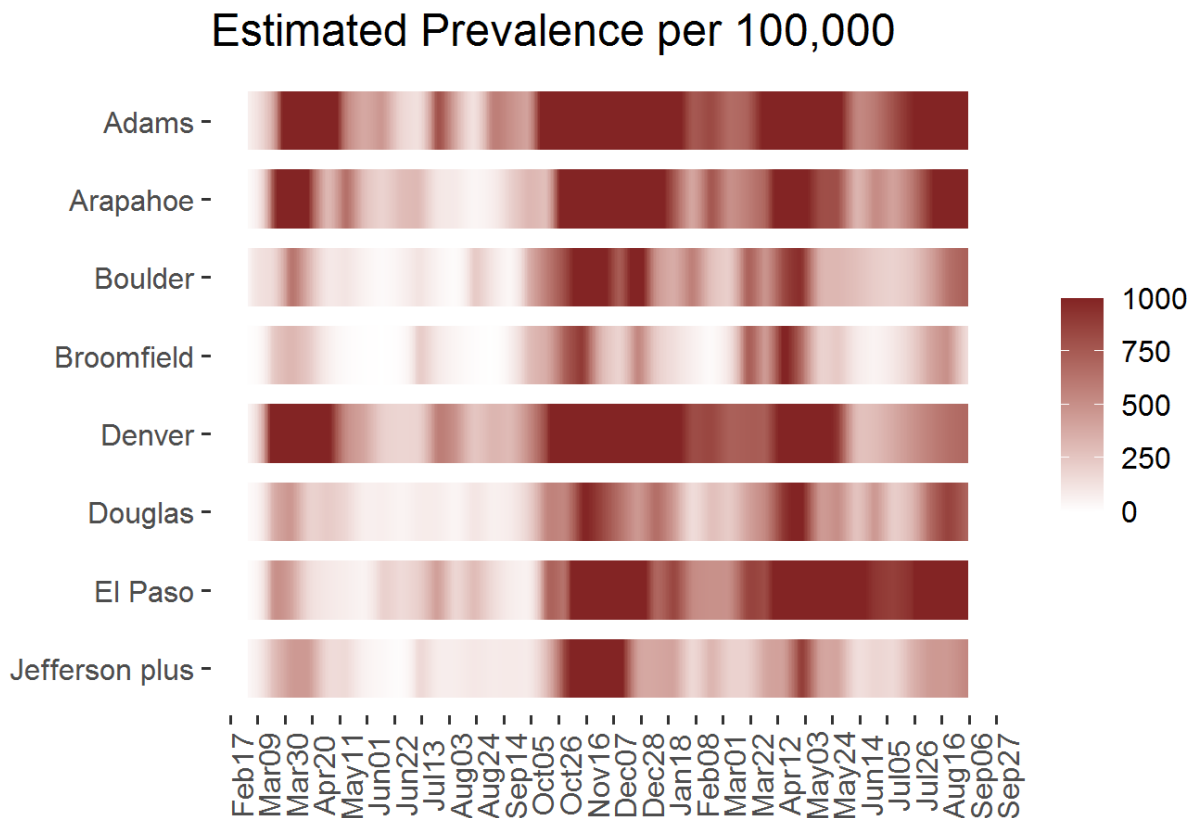
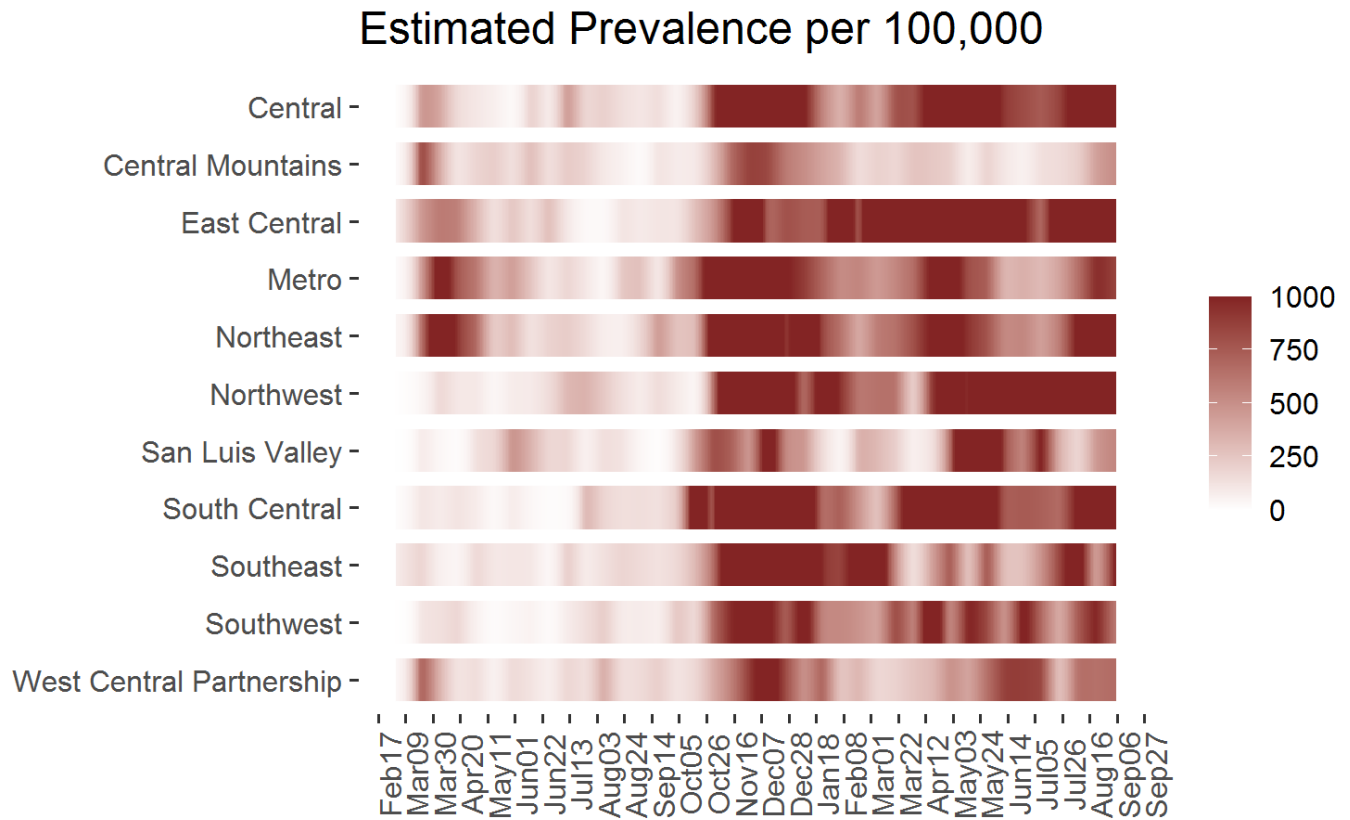


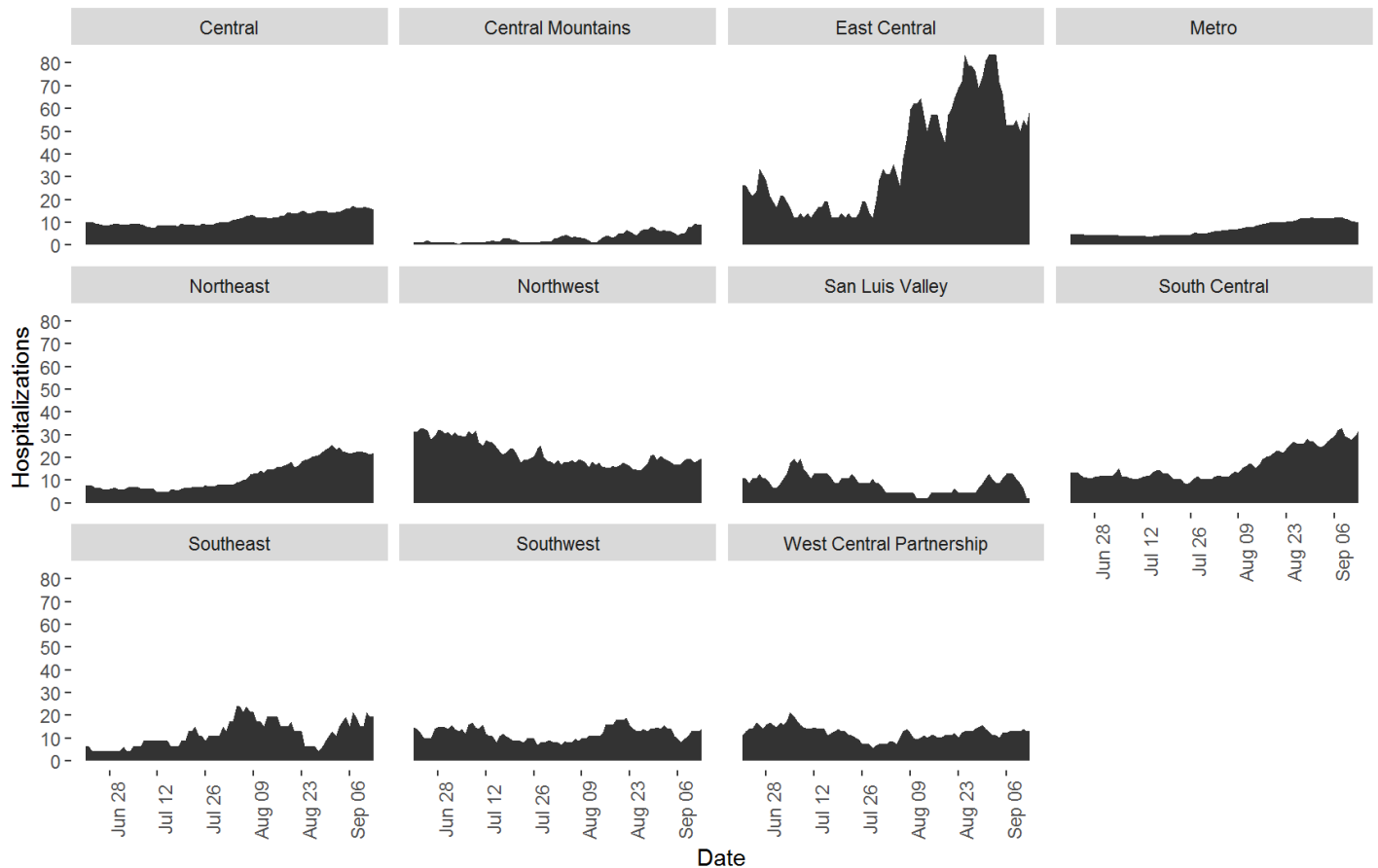
Figure 6. Estimated prevalence per 100,000 population for each of the 11 LPHA regions (top), plus the 8 selected counties and county clusters (bottom). All prevalence values over 1,000 per 100,000 are shown in dark red. Prevalence values estimated up to 09/06/2021.

COVID-19 hospitalizations

The figures below show the daily number of individuals hospitalized with COVID-19 from each region. Hospitalization data are from the COVID Patient Hospitalization Surveillance (COPHS) maintained by the Colorado Department of Public Health and the Environment (CDPHE). Each COVID-19 patient is assigned to a region based on their home zip code. COVID-19 hospitalizations are shown per 100,000 population to allow comparability across regions.

COVID-19 hospitalizations are a sensitive measure of SARS-CoV-2 transmission and are an important indicator of the severity of infections in a region. While many SARS-CoV-2 infections are not captured by state surveillance systems, we expect that almost all COVID-19 hospitalizations are identified.

COVID-19 Hospitalizations per 100,000 over the past 12 weeks



COVID-19 Hospitalizations per 100,000 over the past 12 weeks

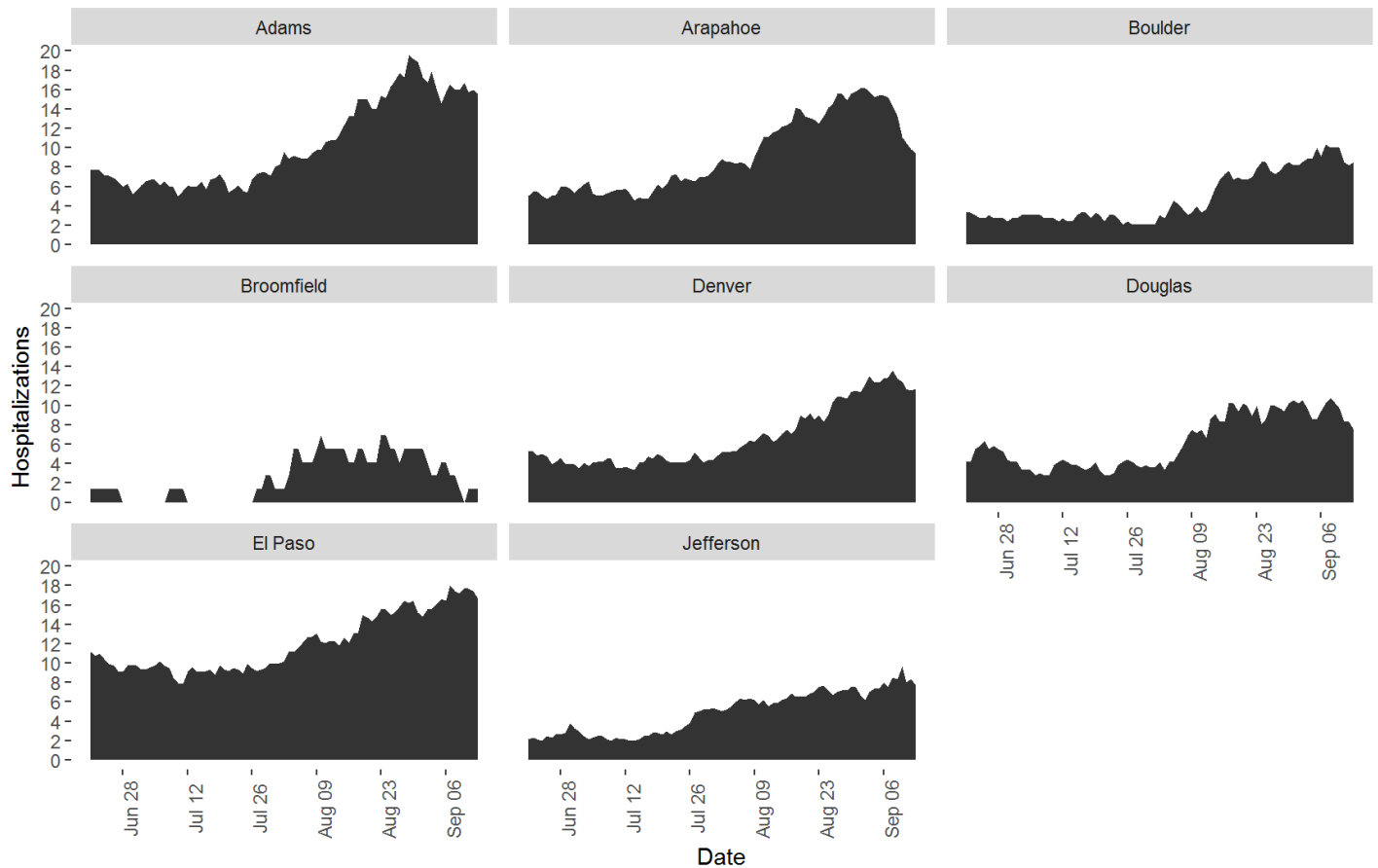
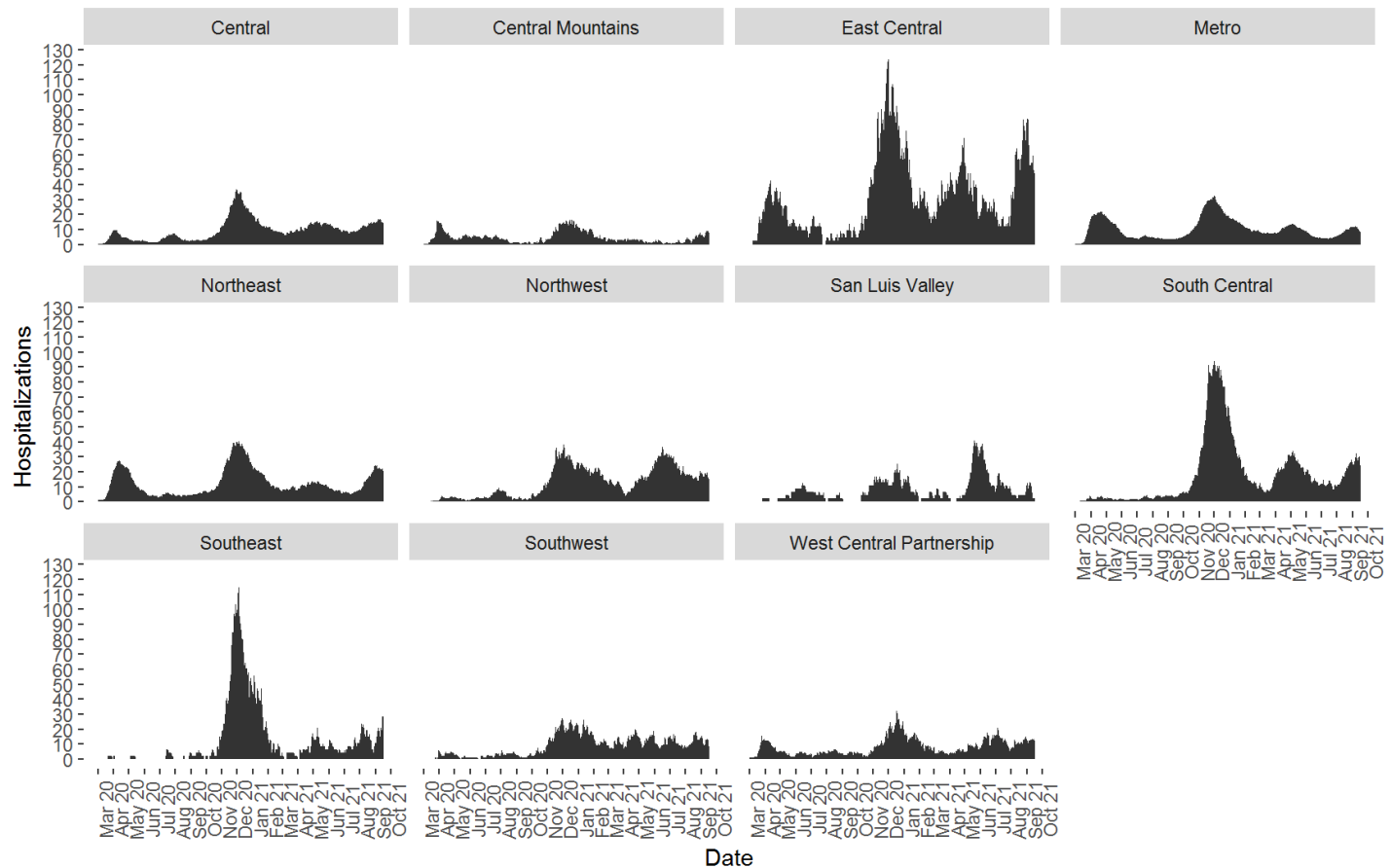


Figure 7. The daily number of people hospitalized with COVID-19 per capita for the 11 LPHA regions and the 8 selected counties and county clusters in Colorado over the past 12 weeks. Hospitalization data are from the COPHS hospital census data through 09/13/2021.

COVID-19 Hospitalizations per 100,000 since March 2020



COVID-19 Hospitalizations per 100,000 since March 2020

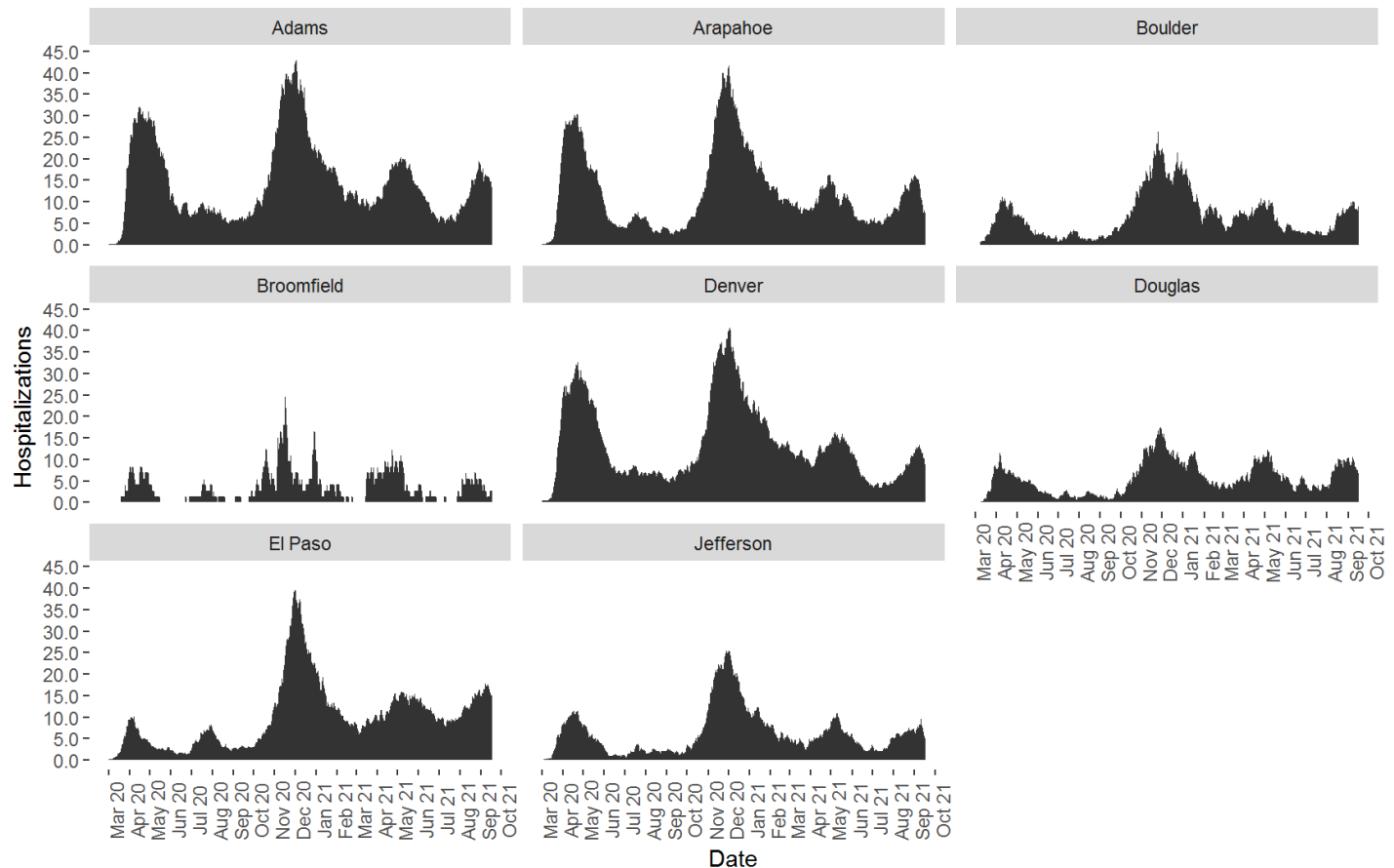


Figure 8. The daily number of people hospitalized with COVID-19 hospitalizations per capita for the 11 LPHA regions and the 8 selected counties and county clusters in Colorado since the first case was reported in March 2020. Hospitalization data are from the COPHS hospital census data through 09/13/2021.

Technical Summary

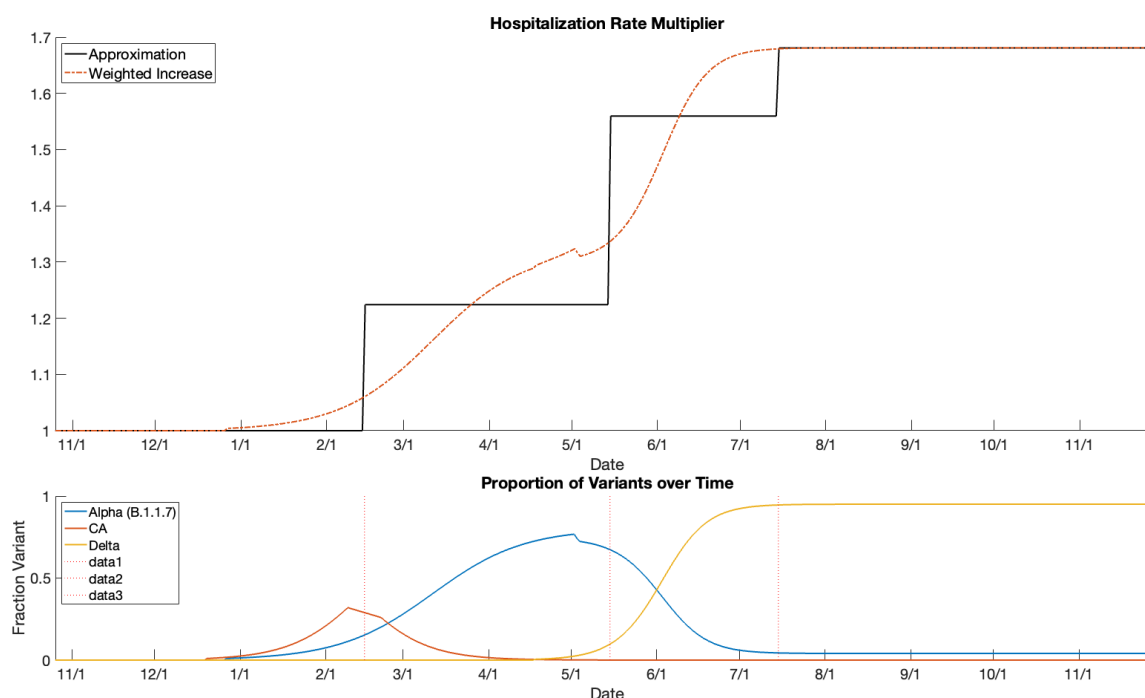
Within the State of Colorado, as for other states, the spread of SARS-CoV-2 varies across the regions of the state, differing between urban and rural locations and resort and non-resort areas, for example. The modeling carried out by the Colorado COVID-19 Modeling Group was initiated at the state level providing a picture that does not give detail at the regional or county-level. Such detail is needed for public health planning and action.

To provide the needed detail, the Modeling Group developed regional-level models, using approaches similar to those for the overall Colorado model. To date, we have used scaled-down versions of the state-wide SEIR model to generate estimates of the effective reproductive number, infection prevalence, and the cumulative number of people infected in the 11 LPHA regions and 8 select counties with larger population size.

Model updates this week. The model has been updated to account for the presence of variants of concern in Colorado that may increase the rate of hospitalization. In the model, we now include the assumptions that the Alpha (B.1.1.7) and Delta COVID-19 variants increase the rate at which symptomatic individuals are hospitalized by 40 and 70 percent, respectively, consistent with the state-level model and based on scientific evidence to date. These updates impact our estimates of disease prevalence regionally. Though we do not expect that variant strains spread uniformly across the state, an alternative cannot be verified with the available data, and thus we assume that the regional proportion of each variant matches the statewide distribution as described by CDPHE. To implement these changes, the original hospitalization rate is scaled by the sum of the relative rate increases, weighted by the proportion of the corresponding variant in the population, that is,

$$\text{hospitalization_rate_with_variants} = \text{original_hospitalization_rate} \times [1 \times \text{percent_of_wild_type_cases} + 1.4 \times \text{percent_of_Alpha_cases} + 1.7 \times \text{percent_of_Delta_cases}]$$

While the proportion of each variant changes continuously, we approximate the necessary scaling factor over three time intervals corresponding to (1) the arrival of variants, (2) Alpha dominance, and (3) Delta dominance, shown in the plot below.



Methods. We use data on COVID-19 hospitalizations, mobile-phone based mobility data and an age-structured meta-population model of SARS-CoV-2 transmission to estimate the current state of infections in each region. The model is similar in many ways to the state-wide model, in that it accounts for differences in the severity of infection by age and uses Colorado-specific demographic and clinical data. For example, the length of time a COVID-19 patient spends in the hospital varies by age and is based on data provided by Colorado hospitals. A full description of the model and estimation approaches are provided in the documentation, available here (<https://agb85.github.io/covid-19/SEIR%20Documentation.pdf>). Prior modeling reports and documentation can be found here (<https://agb85.github.io/covid-19/>).

Data Sources: COVID-19 hospitalizations are obtained from COPHS reported through 09/17/2021. Due to lags in reporting, these data are cleaved 4 days prior such that hospitalizations through 09/13/2021 are used in modeling and shown in this report. A new case definition for COVID-19 hospitalizations was introduced on August 13, 2021 and was applied retroactively to all previously reported hospitalizations. Patients admitted or under observation status for 24 hours or more and meet one of the following criteria: admission diagnosis of COVID-19, discharge diagnosis of COVID-19, or received positive COVID-19 diagnostic test (antigen, rapid molecular, or PCR) during the hospitalization are reported to COPHS as a COVID-19 hospitalization. SARS-CoV-2 vaccination data by county are provided by CDPHE weekly. Age distribution of vaccination by region is inferred from state-level age distribution data.

Case data are based on CEDRS through 09/18/2021. Due to lags in reporting, these data are cleaved ten days prior on 09/08/2021. These data sources are provided by CDPHE.

Population movement between regions is estimated from weekly aggregated cell-phone data, provided by xmode, through 09/12/2021.

Limitations: The regional model estimates are subject to greater uncertainty than those for the entire state because there are fewer hospitalizations in each region than in the state as a whole. Estimates are most uncertain for the regions with the smallest population size. This model uses real-time mobility to account for the flow of populations between regions. It remains an open question in the scientific community how to use measures of population movement to accurately model the spread of infections

Region	Population	Counties
LPHA Regions		
Central	801,025	Chaffee, El Paso, Lake, Park, Teller
Central Mountains	179,767	Eagle, Garfield, Grand, Pitkin, Summit
East Central	41,837	Cheyenne, Elbert, Kit Carson, Lincoln
Metro	3,274,440	Adams, Arapahoe, Boulder, Broomfield, Clear Creek, Denver, Douglas, Gilpin, Jefferson*
Northeast	764,381	Larimer, Logan, Morgan, Phillips, Sedgwick, Washington, Weld, Yuma
Northwest	202,304	Jackson, Mesa, Moffat, Rio Blanco, Routt
San Luis Valley	45,988	Alamosa, Conejos, Costilla, Rio Grande, Saguache
South Central	242,903	Custer, Fremont, Huerfano, Las Animas, Pueblo

Region	Population	Counties
Southeast	46,073	Baca, Bent, Crowley, Kiowa, Otero, Prowers
Southwest	100,155	Archuleta, Dolores, La Plata, Montezuma, San Juan
West Central Partnership	106,628	Delta, Gunnison, Hinsdale, Mineral, Montrose, Ouray, San Miguel
Eight select counties		
Adams	520,268	Adams
Arapahoe	656,618	Arapahoe
Boulder	328,562	Boulder
Broomfield	72,481	Broomfield
Denver	736,522	Denver
Douglas	360,940	Douglas
El Paso	728,076	El Paso
Jefferson plus	599,049	Clear Creek, Gilpin, Jefferson

Table 2: Description of the regions used in this report, including the 11 LPHA Regions. Population estimates are based on 2020 US Census Projections provided by the Colorado Demography Office.

*Clear Creek, Gilpin Counties and Jefferson counties are modeled as a single unit due to the small population of Clear Creek (9,379 residents) and Gilpin (5,924 residents) – populations too small to allow for stable estimation.

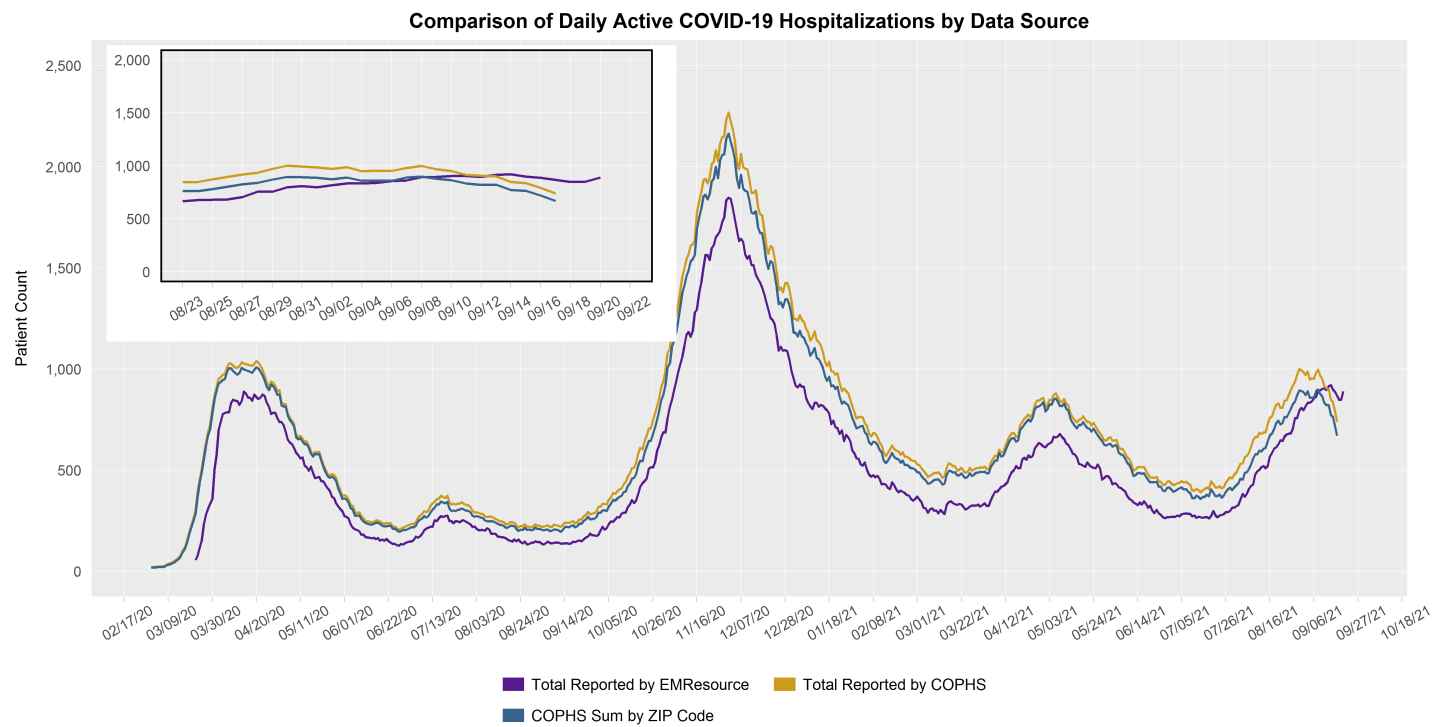


Figure 9. Comparison of daily active COVID-19 hospitalizations by data source.