

# COVID-19 Regional Models for Colorado

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## 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 3 LPHA regions: Central Mountains, San Luis Valley and West Central Partnership. Estimated infections are decreasing in 7 LPHA regions and flat in 1 LPHA region.
- We estimate more than 1 in 100 people are infectious in San Luis Valley, South Central and Southeast Regions. Contacts are particularly risky in these regions. These estimates are for February 22nd.
- East Central has the lowest percentage of the population that has received at least one vaccine dose (12%). Vaccination is highest in the Southwest (23%), West Central Partnership (22%) and San Luis Valley (22%) regions.
- These estimates are based on hospitalization data through 3/1/2021 and vaccination data through 3/7/2021. Due to lags between infection and hospitalization, these estimates do not capture major changes in transmission after approximately February 16th.

## 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, case 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.
- **Percent of population infected to date** and the **percent of the population vaccinated to date** together provide an approximation of the proportion of the population immune to SARS-CoV-2. As the immune population grows, due to vaccination or prior infection, the spread of infection slows. We do not know how

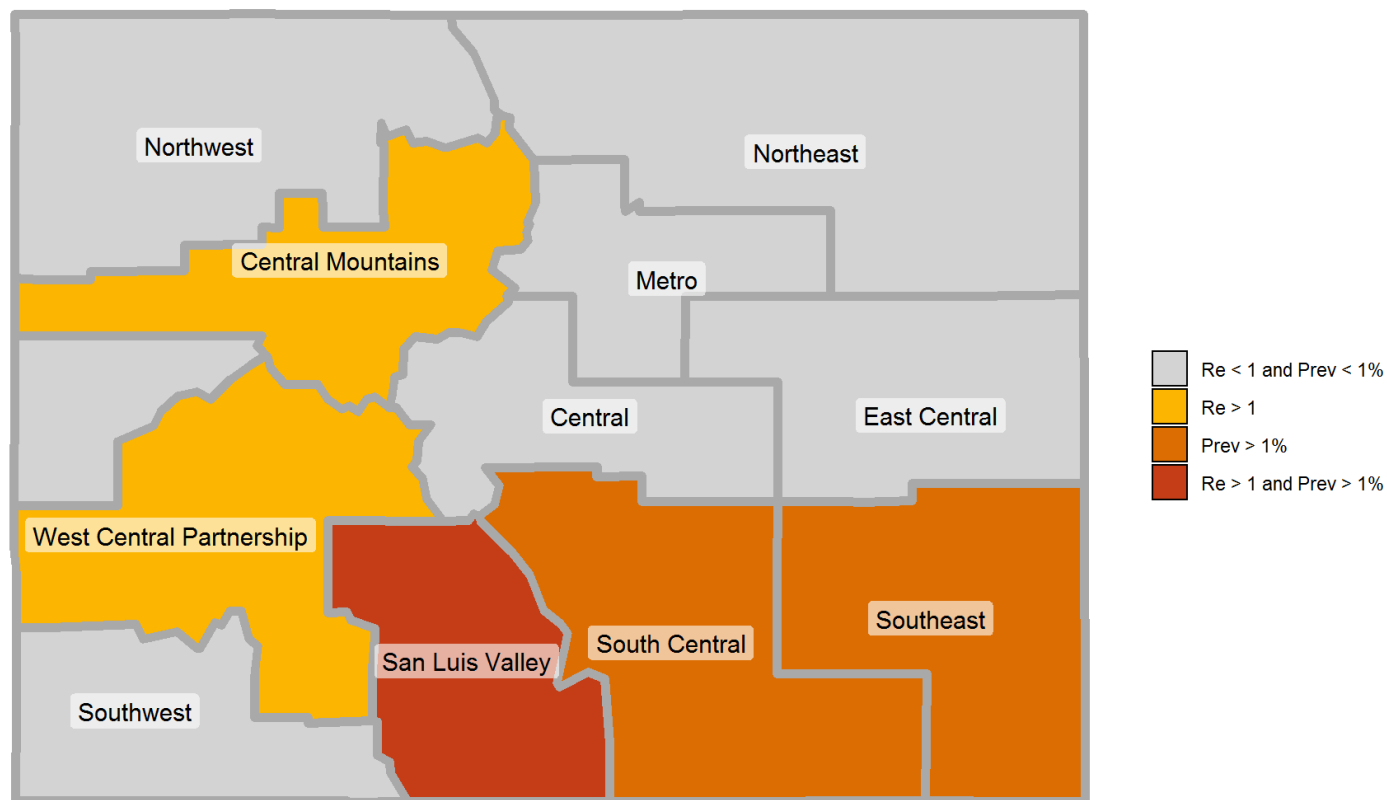
long immunity lasts after infection or vaccination with SARS-CoV-2. We do know that vaccination boosts immunity in people who were previously infected.

**Table 1.** The estimated effective reproductive number, prevalence of infections, percent of the population infected 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 03/01/2021. In regions with smaller populations, reported cases are also used to generate these estimates. The percent vaccinated estimates are based on data provided by CDPHE through 3/07/2021 and reflect the proportion of the population that has received at least one vaccine dose as of that date. The prevalence of infections and percent of the population infected is estimated for 02/22/2021.

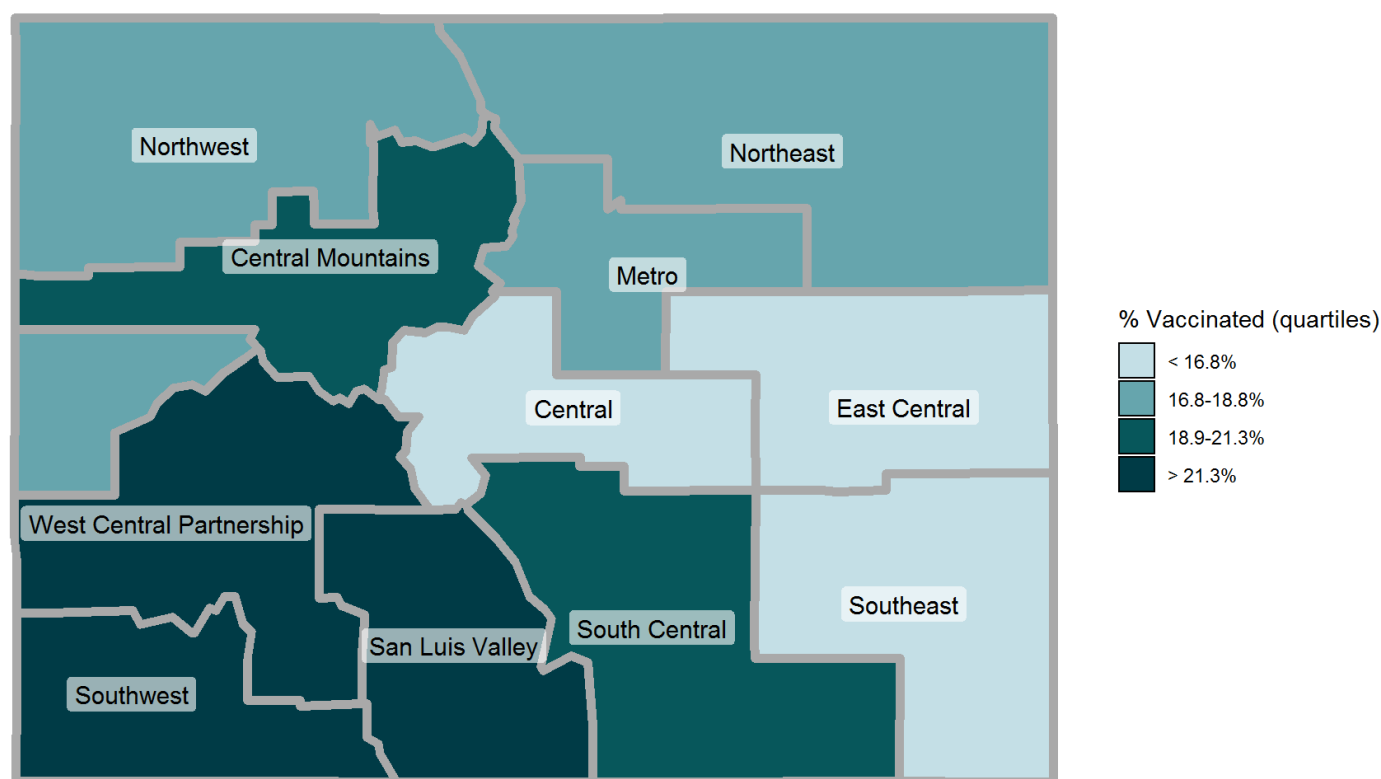
	Are infections increasing or decreasing?		How many people are infectious?		How many people have been infected to date?		
	Re	Infections are...	Prevalence per 100,000	People infectious	Cumulative Infections to Date	Percent of population infected to date	Percent of population vaccinated
LPHA Regions							
Central	0.8	Decreasing	367	1 in 272	143,000	17.6	14.8
Central Mountains	1.1	Increasing	237	1 in 422	21,200	11.6	20.8
East Central	0.6	Decreasing	834	1 in 120	23,600	54.9	12.0
Metro	0.9	Decreasing	521	1 in 192	823,000	25.0	17.6
Northeast	0.8	Decreasing	428	1 in 234	220,000	28.8	17.0
Northwest	0.6	Decreasing	604	1 in 166	39,300	19.3	18.8
San Luis Valley	1.2	Increasing	1,128	1 in 89	9,440	20.3	21.7
South Central	1.0	Flat	1,174	1 in 85	93,500	38.4	19.8
Southeast	0.9	Decreasing	1,599	1 in 63	20,900	44.6	16.5
Southwest	0.6	Decreasing	235	1 in 426	11,300	11.1	23.4
West Central Partnership	1.1	Increasing	344	1 in 291	12,700	11.9	22.2
Eight select counties							
Adams	1.2	Increasing	856	1 in 117	211,000	39.9	13.5
Arapahoe	0.8	Decreasing	626	1 in 160	198,000	29.7	16.2
Boulder	0.3	Decreasing	263	1 in 381	48,400	14.6	20.0
Broomfield	1.6	Increasing	407	1 in 245	10,900	15.0	20.9
Denver	0.9	Decreasing	772	1 in 130	274,000	37.1	17.2
Douglas	1.0	Flat	349	1 in 286	48,900	13.8	17.8
El Paso	0.8	Decreasing	366	1 in 273	146,000	19.9	14.1
Jefferson plus	0.7	Decreasing	207	1 in 482	74,300	12.3	21.3

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.



**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 proportion of the population vaccinated by LPHA region. Estimates are based on data provided by CDPHE through 3/07/2021 and reflect the proportion of the population that has received at least one vaccine dose as of that date. Darker colors indicate a higher proportion of vaccinated residents.

## Effective Reproductive Number

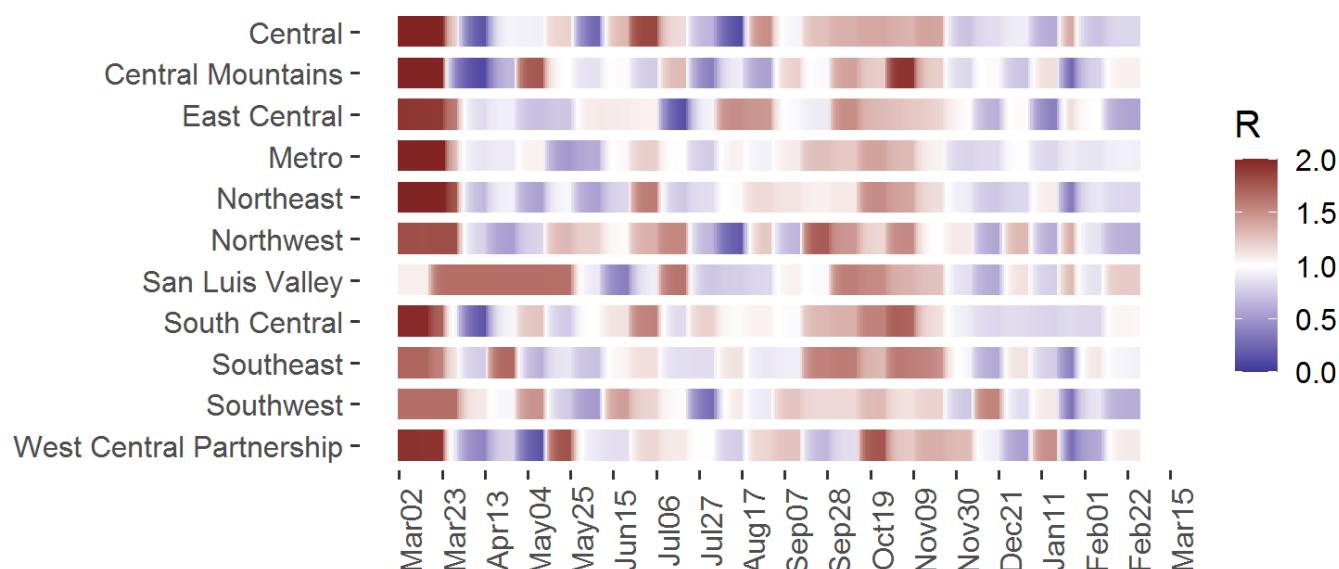
The figure below shows the estimated effective reproductive number for each region since March.

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.

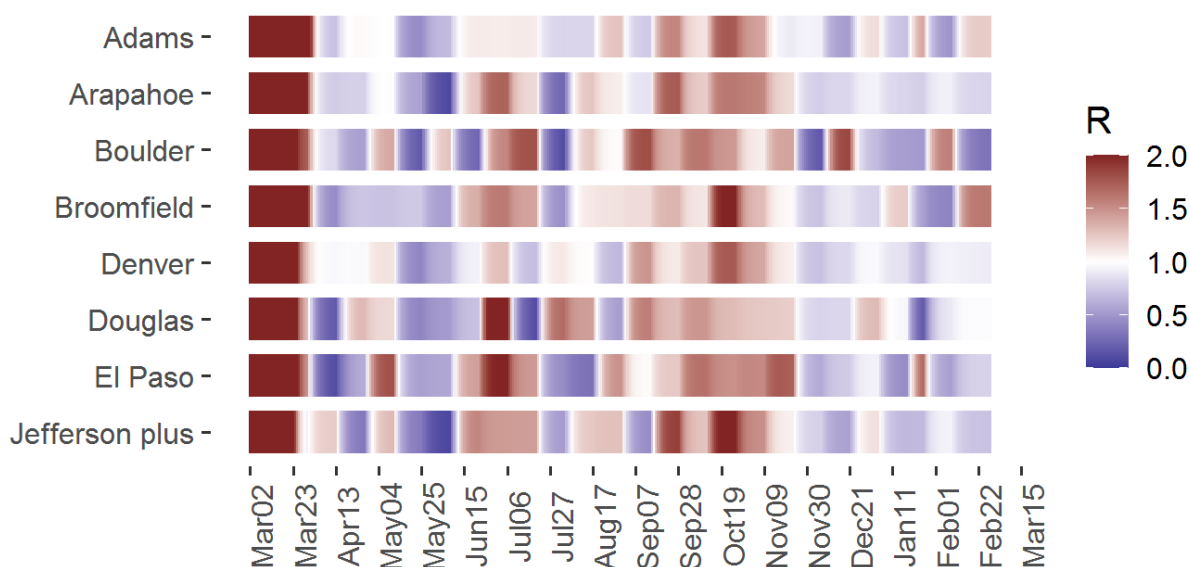
The effective reproductive number is estimated using our age-structured SEIR model fit to hospitalization data. In the four LPHA regions with smaller populations, reported SARS-CoV-2 case data are also used (San Luis Valley, Southeast, Southwest, and West Central Partnership). Because we base our parameter 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 02/16/2021.

## Effective Reproductive Number



## Effective Reproductive Number



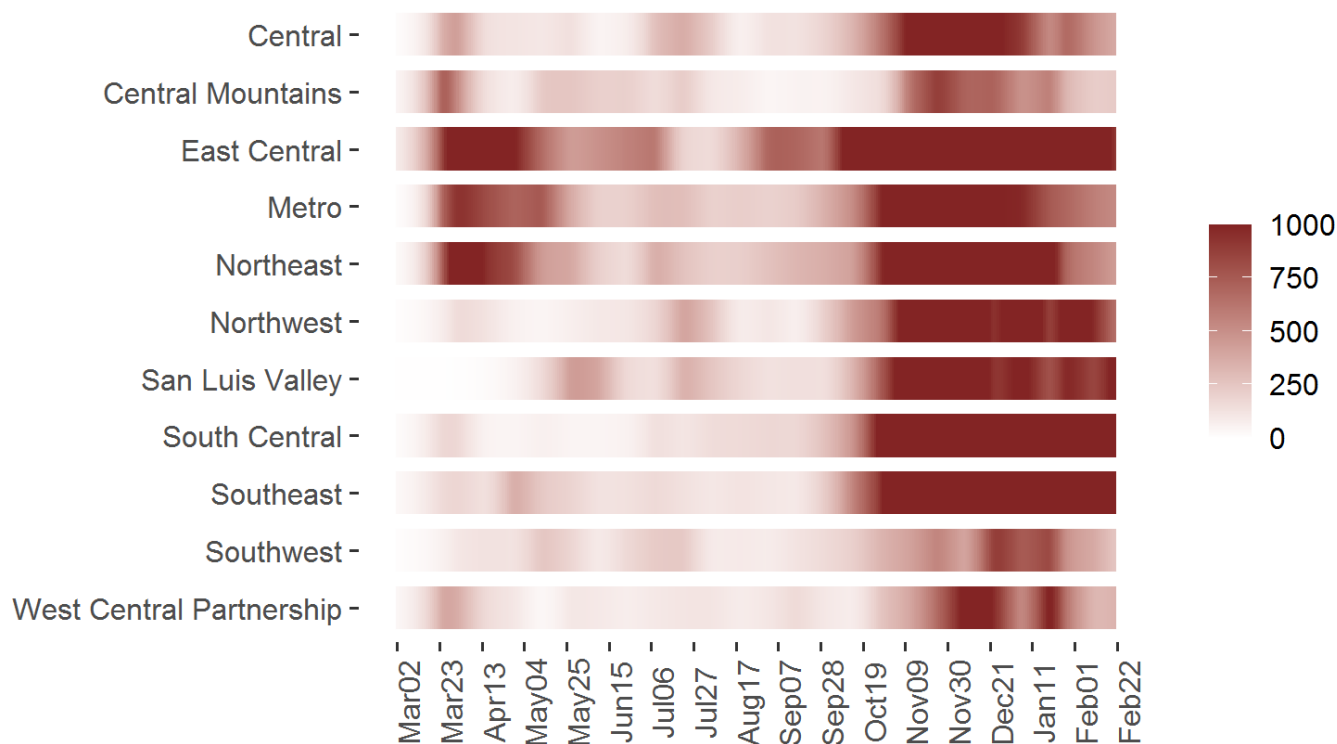
**Figure 3.** The estimated effective reproductive number ( $R_e$ ) over time in the 11 LPHA regions in Colorado, and 8 selected counties and county clusters. Estimates shown using COVID-19 hospitalization data through 03/01/2021.

## Infection prevalence

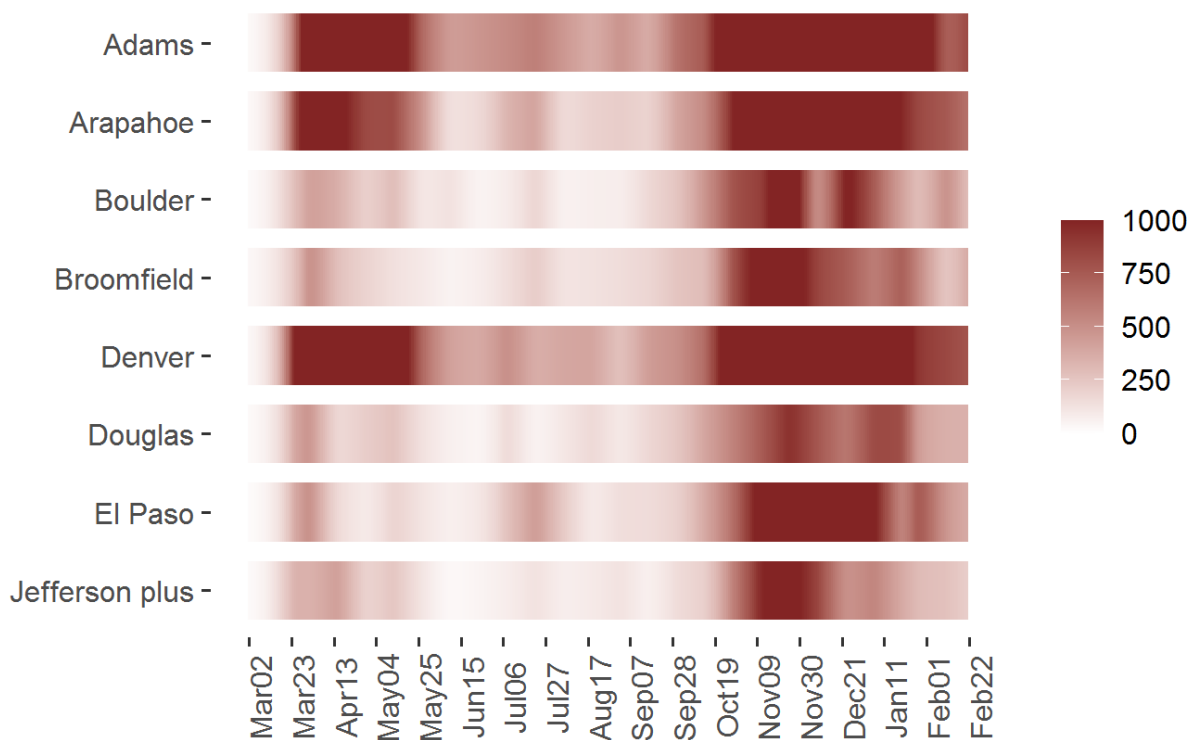
Infection prevalence provides an estimate of the proportion of the population that is currently infected with SARS-CoV-2 and capable of spreading infections. At higher levels of infection prevalence, individuals are more likely to encounter infectious individuals among their contacts. Because many people 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 SEIR models fit separately to each area's reported data.

### Estimated Prevalence per 100,000



### Estimated Prevalence per 100,000



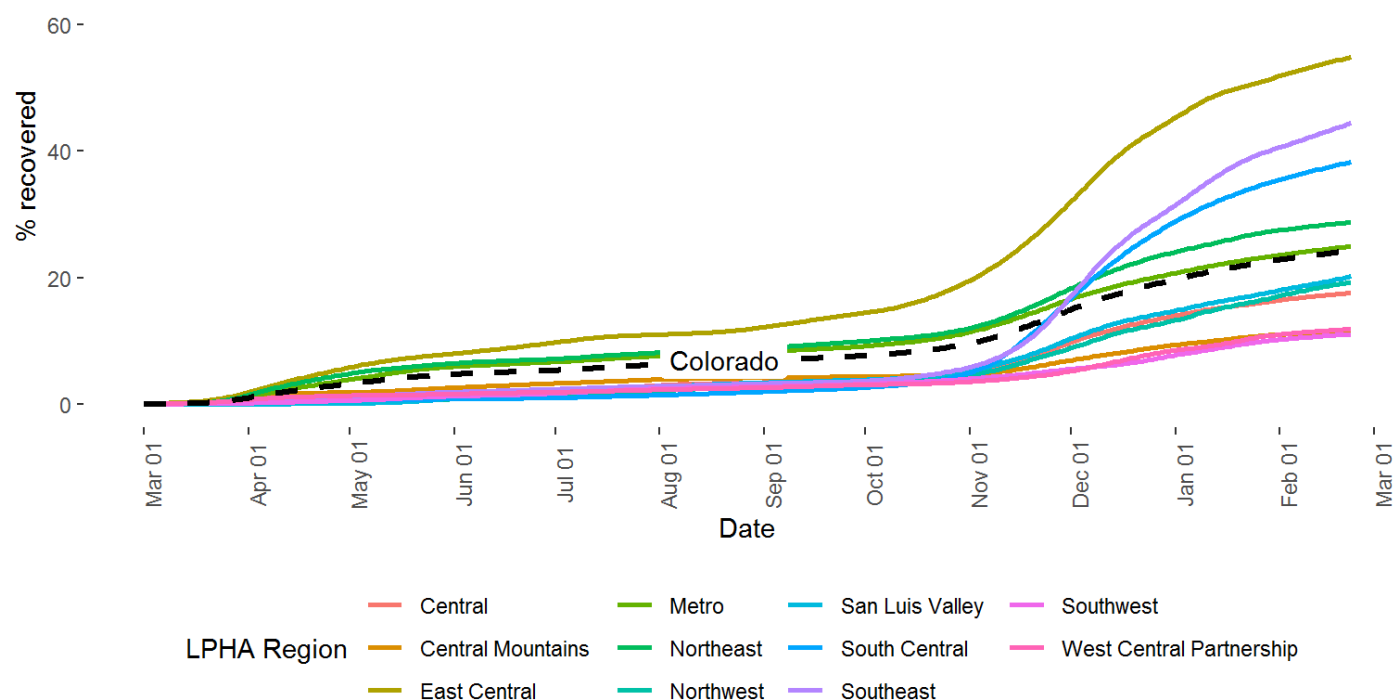
**Figure 4.** Estimated prevalence per 100,000 population for each of the 11 LPHA regions (top), plus the 8 selected counties and county clusters (bottom). All prevalence values over 1,000 per 100,000 are shown in dark red. Prevalence values estimated up to 02/22/2021.

## The percent of the population infected to date

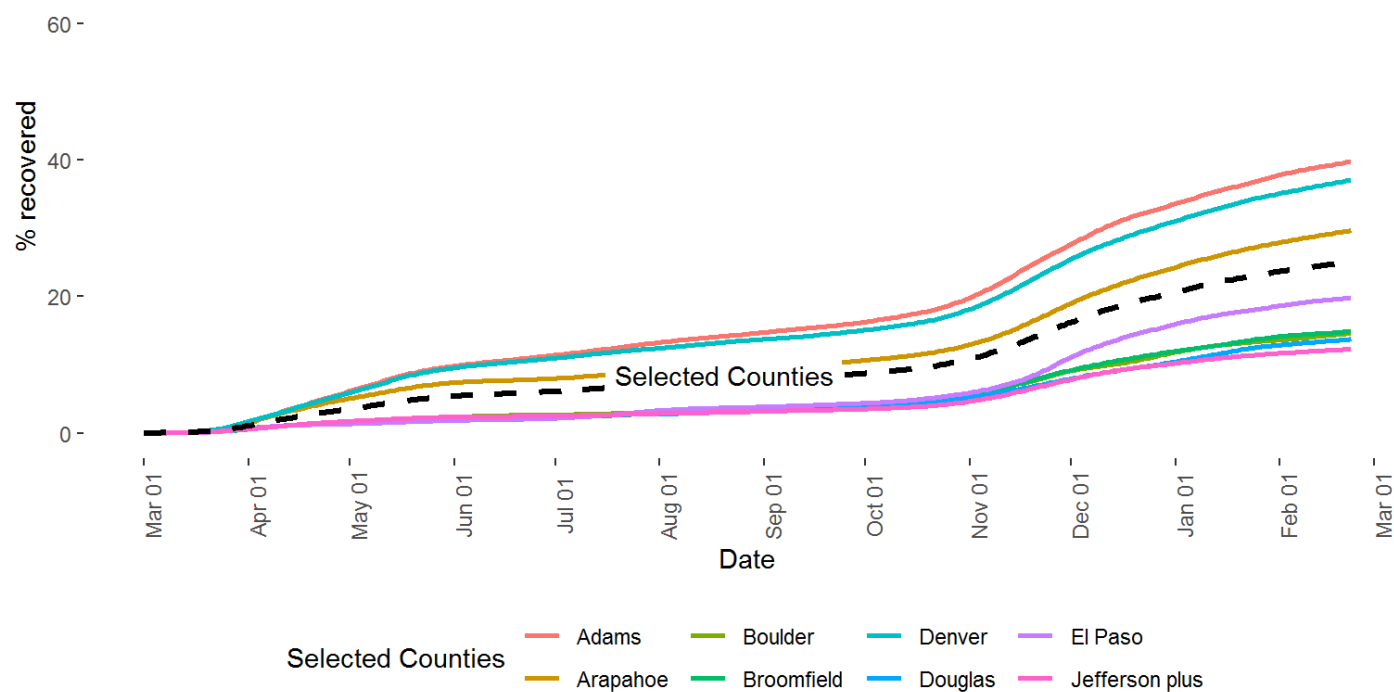
As more people develop immunity, due to vaccination or prior infection, the spread of infections slows because infectious individuals are less likely to encounter individuals that are susceptible to infection.

The figure below shows model-generated estimates of the percent of the population that has been infected to date for each region. This is a partial snapshot of the population currently immune to infection in each region. The roll out of vaccinations throughout Colorado is increasing the size of the immune population which will help to slow the spread of infections. Estimates of the proportion of the population vaccinated to date are provided in Table 1. There is growing evidence that immunity to SARS-CoV-2 following infection wanes over time. This means it is possible that people infected with SARS-CoV-2 early in the pandemic are now susceptible to becoming infected again if they are not vaccinated. We are working to update our estimates to describe the estimated population immune in each region.

## Percent of population infected to date



## Percent of population infected to date



**Figure 5.** Estimated proportion of the population recovered to date for each of the 11 LPHA regions in Colorado (top) and each of the 8 selected counties and county clusters (bottom). Exposed proportion values estimated up to 02/22/2021. Black dashed line indicates mean of Colorado (top) and selected counties (bottom).



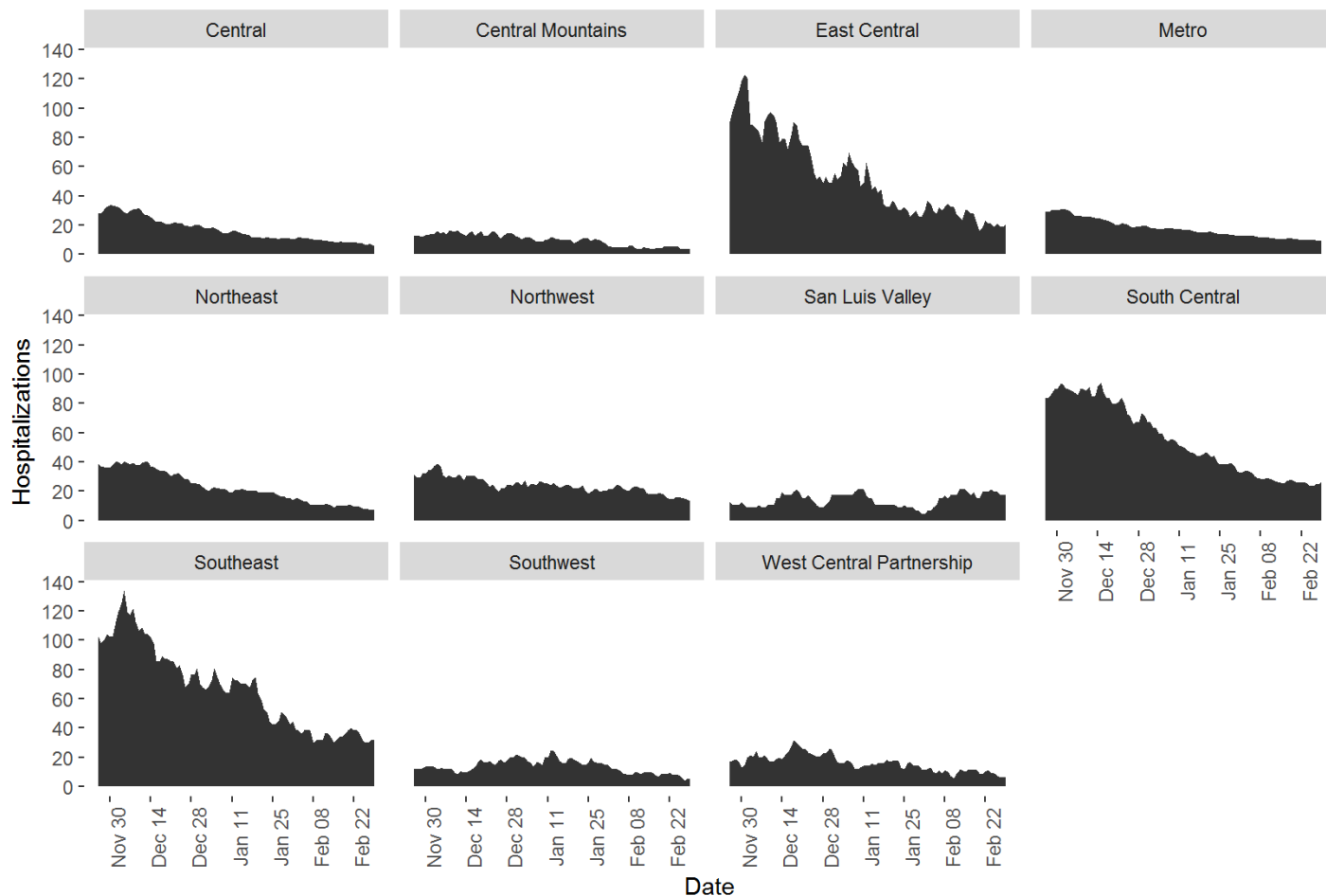
## COVID-19 hospitalizations

The figures below show the daily number of individuals hospitalized with COVID-19 from each region.

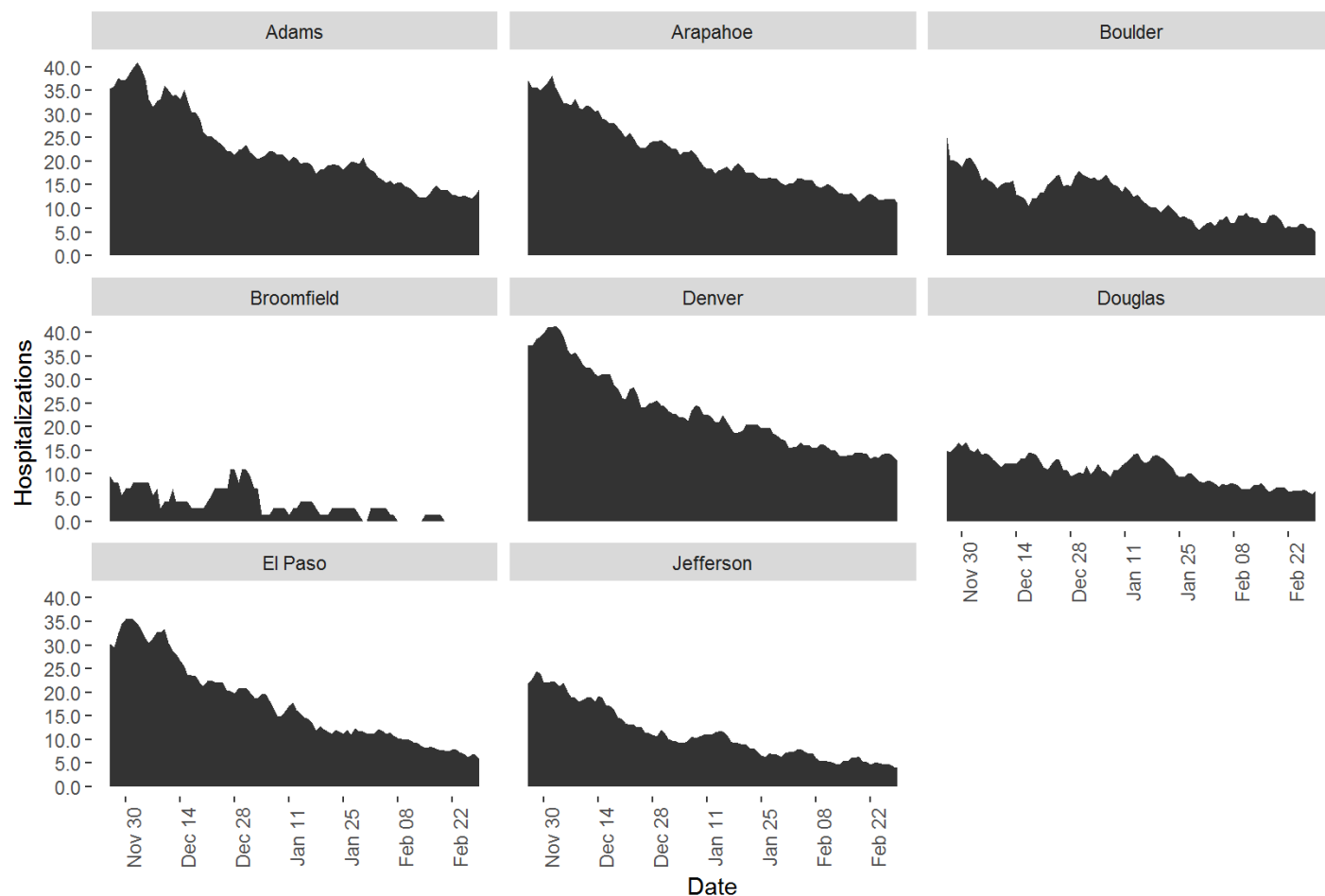
Hospitalization data are from the COVID Patient Hospitalization Surveillance (COPHS) maintained by the Colorado Department of Public Health and the Environment (CDPHE). Each COVID-19 patient is assigned to a region based on their home zip code. COVID-19 hospitalizations are shown per 100,000 population 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

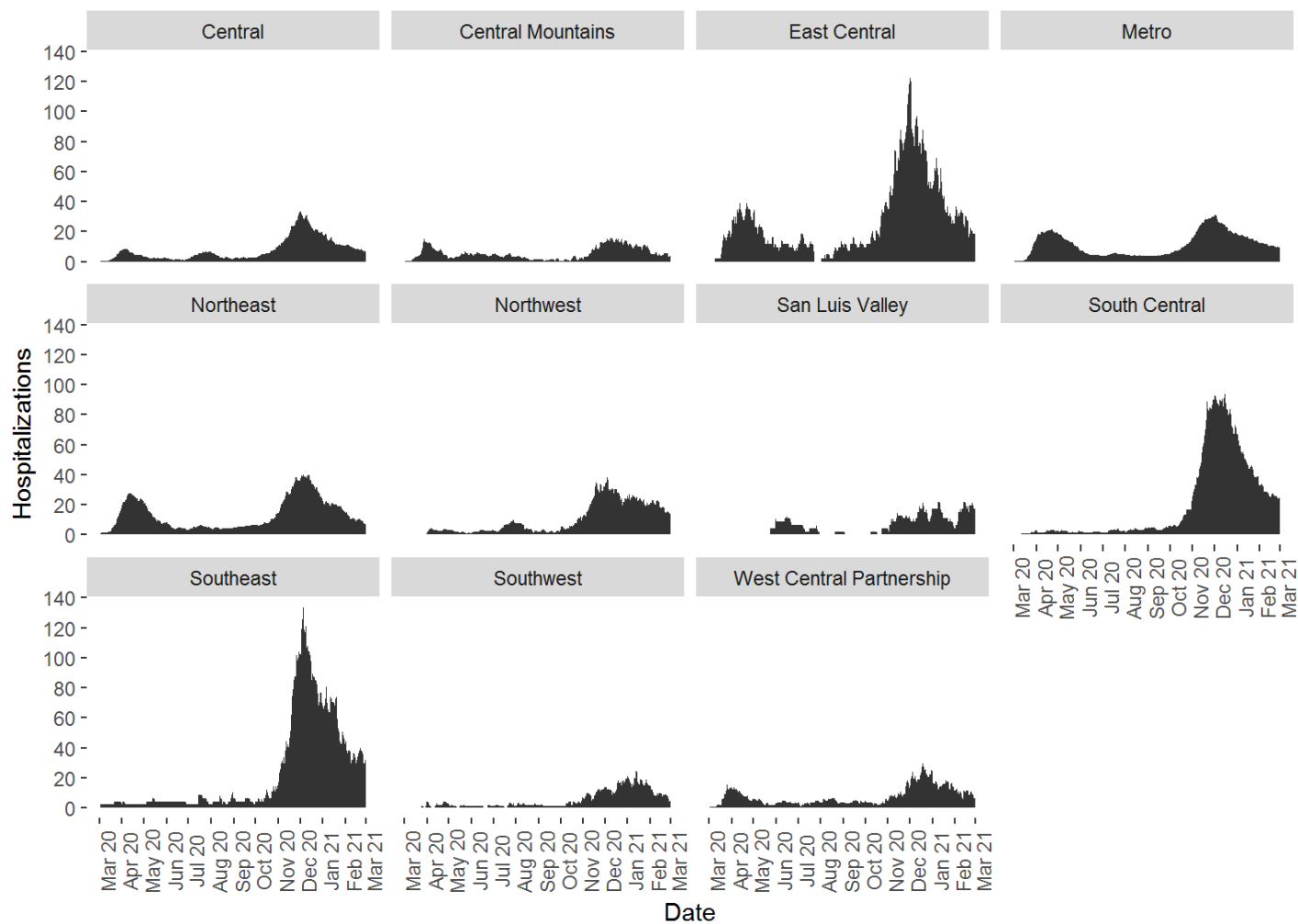


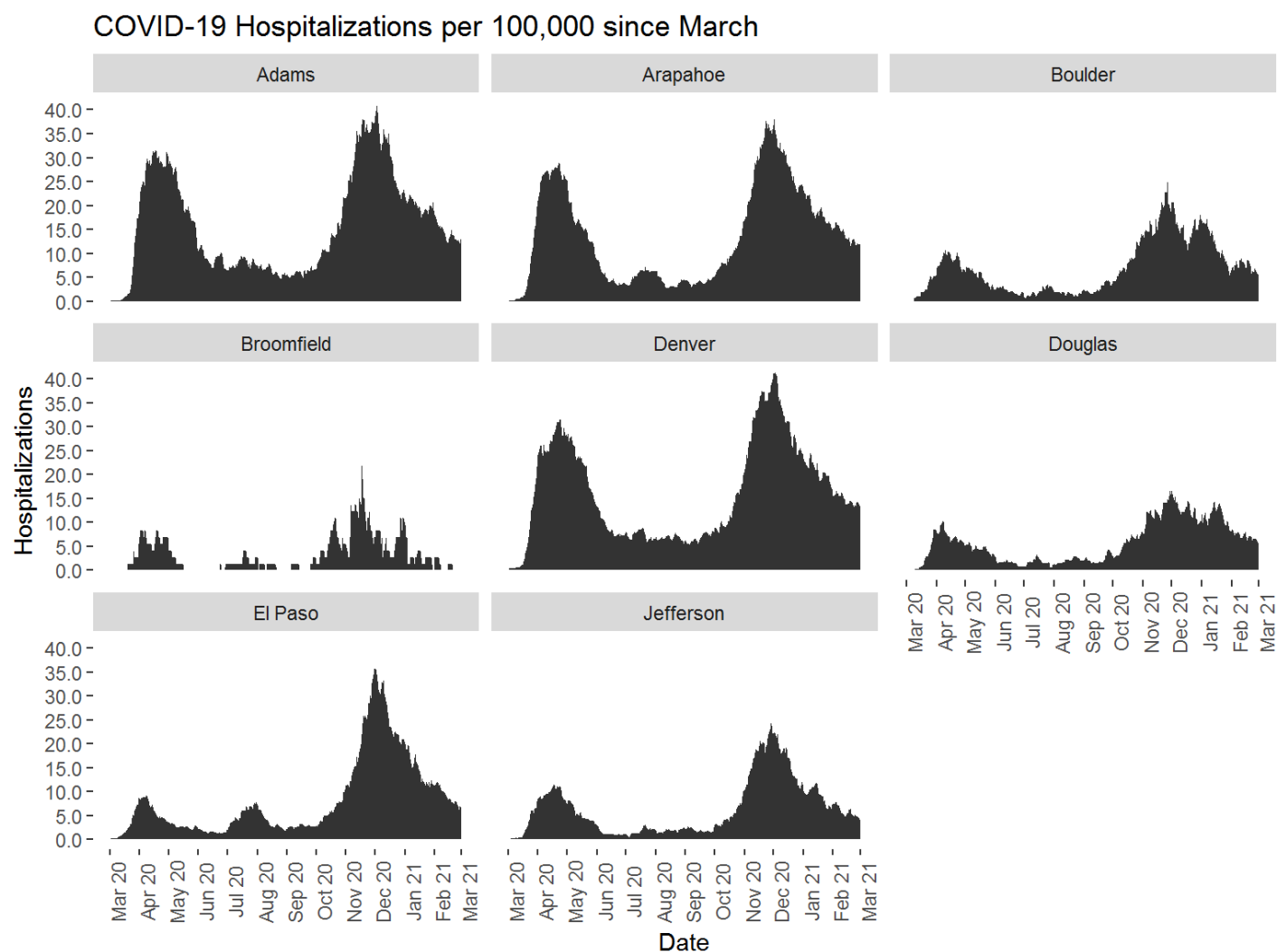
### COVID-19 Hospitalizations per 100,000 over the past 12 weeks



**Figure 6.** 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 03/01/2021.

## COVID-19 Hospitalizations per 100,000 since March





**Figure 7.** 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 03/01/2021.

## 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, and many local public health agencies have asked for model simulations for their jurisdictions.

To provide the needed detail, the Modeling Group has developed regional -level models, using approaches similar to those for the overall Colorado model. The models are generated for the 11 local public health agency (LPHA) regions, which cover the full state and for selected counties. County-level estimation is possible for selected counties due to the large population size. In providing the results for regions within Colorado, 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. Additional details about the methods used to generate regional estimates are described in the Technical Summary, below.

**Methods.** We use data on COVID-19 hospitalizations and reported cases, and a mathematical model of SARS-CoV-2 transmission to estimate the current state of infections in each region. The approach follows that used for the state-wide model, adapted for the smaller population sizes of the LPHA regions and selected counties. 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/>). Briefly, the model is a deterministic age-structured susceptible, exposed, infected, recovered (SEIR) model. It has been parameterized to Colorado-specific data whenever possible - 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. We use model fitting approaches to estimate the level of transmission control for each two-week period of the outbreak. Transmission control is estimated by fitting the model to hospitalization data for each region. In the four regions where population size is small (San Luis Valley, Southeast, Southwest, and West Central Partnership), we fit the model to reported case data, using information from the state-level model to infer the proportion of infections detected by state surveillance systems.

**Data Sources:** COVID-19 hospitalizations are obtained from COPHS reported through 03/05/2021. Due to lags in reporting, these data are cleaved 4 days prior such that hospitalizations through 03/01/2021 are used in modeling and shown in this report.

Case data are based on CEDRS through 03/06/2021. Due to lags in reporting, these data are cleaved ten days prior on 02/24/2021. Both data sources are provided by CDPHE.

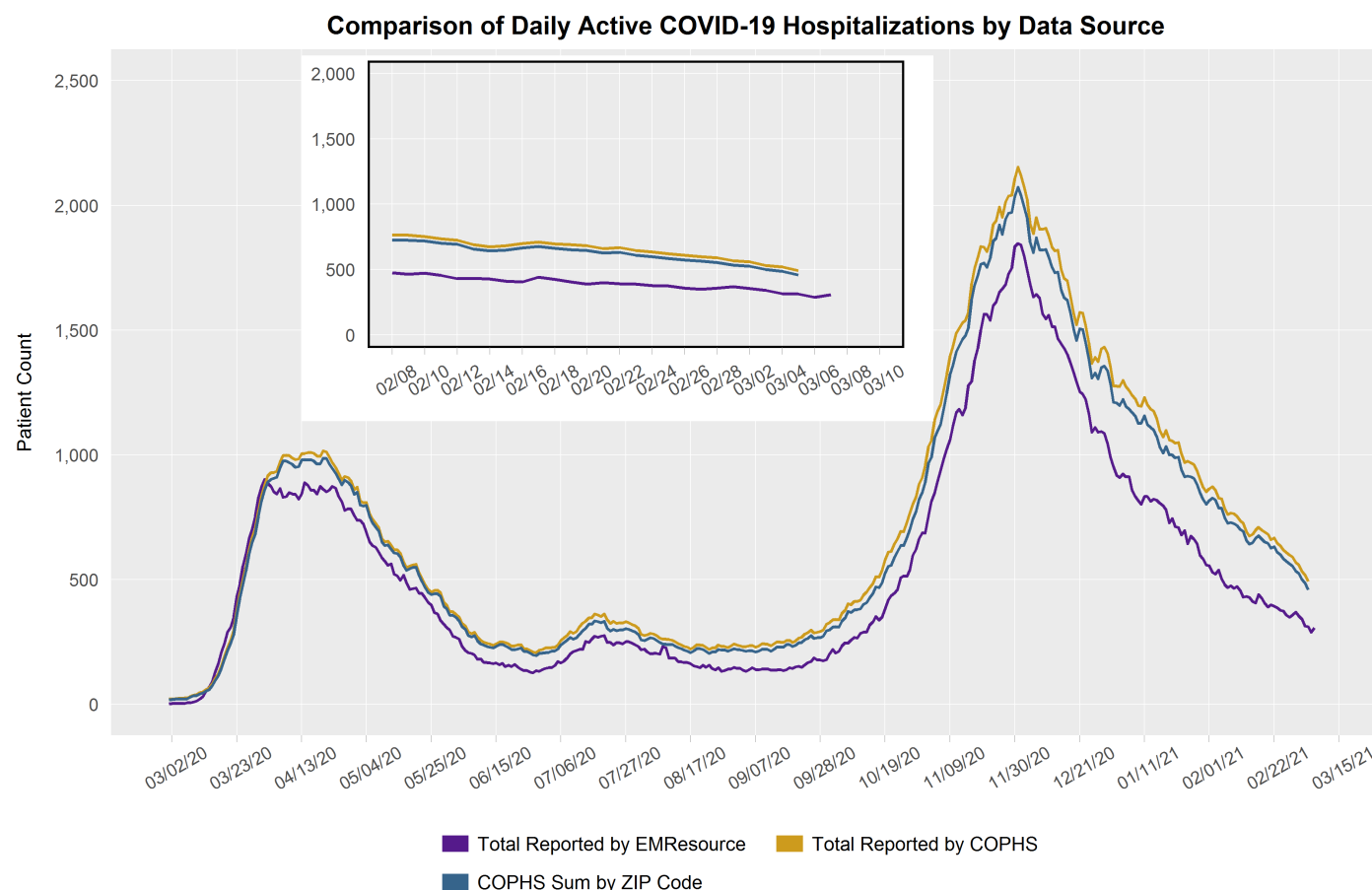
**Limitations:** These estimates are based on the available data and the assumptions in the SEIR model. Assumptions in the model are based on Colorado data when available and the current scientific understanding of SARS-CoV-2, which is evolving rapidly. Estimated prevalence and the percent of the population infected are sensitive to model assumptions, which include: the probability an infected individual will be symptomatic and require hospital care and the estimated length of hospital stay, which varies over time and by age. Estimates for the smallest regions are subject to greater uncertainty than larger regions and may experience greater variation from week to week due to the limited data available in these regions. In contrast to the state-level model, the models used to generate these estimates do not yet explicitly model vaccination or the loss of immunity over time.

Region	Population	Counties
<b>LPHA Regions</b>		
Central	810,420	Chaffee, El Paso, Lake, Park, Teller
Central Mountains	182,689	Eagle, Garfield, Grand, Pitkin, Summit
East Central	43,032	Cheyenne, Elbert, Kit Carson, Lincoln
Metro	3,291,794	Adams, Arapahoe, Boulder, Broomfield, Clear Creek, Denver, Douglas, Gilpin, Jefferson*
Northeast	765,265	Larimer, Logan, Morgan, Phillips, Sedgwick, Washington, Weld, Yuma
Northwest	203,301	Jackson, Mesa, Moffat, Rio Blanco, Routt
San Luis Valley	46,472	Alamosa, Conejos, Costilla, Rio Grande, Saguache
South Central	243,196	Custer, Fremont, Huerfano, Las Animas, Pueblo

Region	Population	Counties
Southeast	46,938	Baca, Bent, Crowley, Kiowa, Otero, Prowers
Southwest	102,154	Archuleta, Dolores, La Plata, Montezuma, San Juan
West Central Partnership	106,839	Delta, Gunnison, Hinsdale, Mineral, Montrose, Ouray, San Miguel
<b>Eight select counties</b>		
Adams	528,857	Adams
Arapahoe	664,988	Arapahoe
Boulder	330,978	Boulder
Broomfield	72,827	Broomfield
Denver	737,854	Denver
Douglas	354,331	Douglas
El Paso	737,354	El Paso
Jefferson plus	601,959	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 8.** Comparison of daily active COVID-19 hospitalizations by data source.

\*EMResource recently began including VA hospitals and other institutions that may not be captured in current COPHS data sources, potentially explaining the under estimation of total hospitalizations from COPHS.

\*The COPHS data were updated in late December to include records that had previously been unreported. At present, the COPHS dataset now estimates more hospitalizations on a given day than EMResources. Because both datasources show the same trend (e.g., both increase and decrease together), this should not impact our estimates of the effective reproductive number. However, the addition of previously unreported records will lead estimates of infection prevalence to be higher in some regions on a given day than they were previously. We have updated the estimates of prevalence since March and these can be viewed in the region and county-specific estimates, allowing apples to apples comparison of changes in prevalence over time.