

COVID-19 Regional Models for Colorado

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Prepared by the Colorado COVID-19 Modeling Group

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Introduction

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-levels. Such detail is needed for public health planning and action, and many local public health agencies have asked for model results for their jurisdictions.

To provide the needed detail, the Modeling Group has developed regional- and county-level (for larger counties) models, using approaches similar to those for the overall Colorado model. The model results are for 11 local public health agency (LPHA) regions, which cover the full state and for 7 counties in the Metro Denver area with the largest populations. In providing the results for these smaller populations, when compared with the full state, the model results are subject to greater uncertainty than those for the entire state.

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 the epidemic in each region. The approach follows that used for the state-wide model, adapted for the smaller population sizes of the LPHA regions and Metro counties. A full description of the model is provided at [???](#). Briefly, the model is a deterministic age-structured susceptible, exposed, infected, recovered (SEIR) model. It has been parameterized, i.e., adapted, 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. Transmission control varies from 0% (no control), as before the pandemic, to 100% (full control), as with a complete lockdown. In the three regions where population size is small (Southeast, Southwest, and West Central Partnership), we fit the model to hospitalization and case data, using information from the state-level model to infer the proportion of infections detected by state surveillance systems.

We use the model and available data model to generate five measures for each region. These measures can be used to gauge the current state of transmission in the region.

- ***The hospitalized COVID-19 patients per 100,000 population.*** This is a census of COVID-19 patients, assigned to a region based on home zip code of the hospitalized individuals. These data are provided by the Colorado Department of Public Health and Environment (CDPHE).

- **The effective reproduction number (*Re*)** is a measure of how rapidly infections are spreading or declining in a region. It refers to the number of new cases caused by each infected person.
- **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. It is possible for infection prevalence to be high and the *Re* to be low and vice versa. The two measures should be interpreted together to get a complete picture of risk in a given region.
- **Percent of population infected to date.** This is an approximate measure of the proportion of the population immune to SARS-CoV-2. As this number grows, due to vaccination or immunity, the spread of infections slows. The estimation of this percentage will be updated when a vaccine becomes available.

Caveats. These estimates are based on the available data and the assumptions made in the SEIR model. Key assumptions in the model are based on Colorado data when available and the current scientific understanding of SARS-CoV-2, which is evolving rapidly. 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.

	LPHA Region	Population	Counties
LPHA Regions			
	Central	810,305	Chaffee, El Paso, Lake, Park, Teller
	Central Mountains	182,666	Eagle, Garfield, Grand, Pitkin, Summit
	East Central	43,019	Cheyenne, Elbert, Kit Carson, Lincoln
	Metro	3,291,077	Adams, Arapahoe, Boulder, Broomfield, Clear Creek, Denver, Douglas, Gilpin, Jefferson*
	Northeast	765,075	Larimer, Logan, Morgan, Phillips, Sedgwick, Washington, Weld, Yuma
	Northwest	203,228	Jackson, Mesa, Moffat, Rio Blanco, Routt
	San Luis Valley	46,458	Alamosa, Conejos, Costilla, Rio Grande, Saguache
	South Central	243,125	Custer, Fremont, Huerfano, Las Animas, Pueblo
	Southeast	46,921	Baca, Bent, Crowley, Kiowa, Otero, Prowers
	Southwest	102,122	Archuleta, Dolores, La Plata, Montezuma, San Juan
	West Central Partnership	106,799	Delta, Gunnison, Hinsdale, Mineral, Montrose, Ouray, San Miguel
Metro Denver Counties			
	Adams	522,695	
	Arapahoe	672,640	
	Boulder	341,904	
	Broomfield	68,007	
	Denver	722,337	
	Douglas	342,205	
	Jefferson	608,544	

Table 1: The 11 LPHA Region definitions with counties that are contained in each LPHA region listed. Estimates are also generated for the 7 Denver Metro counties with larger populations. Population estimates are based on 2020 US Census Projections.

*Clear Creek and Gilpin Counties are part of the Denver metro region but are modeled combined with Jefferson County as the populations are too small to allow for stable estimation.

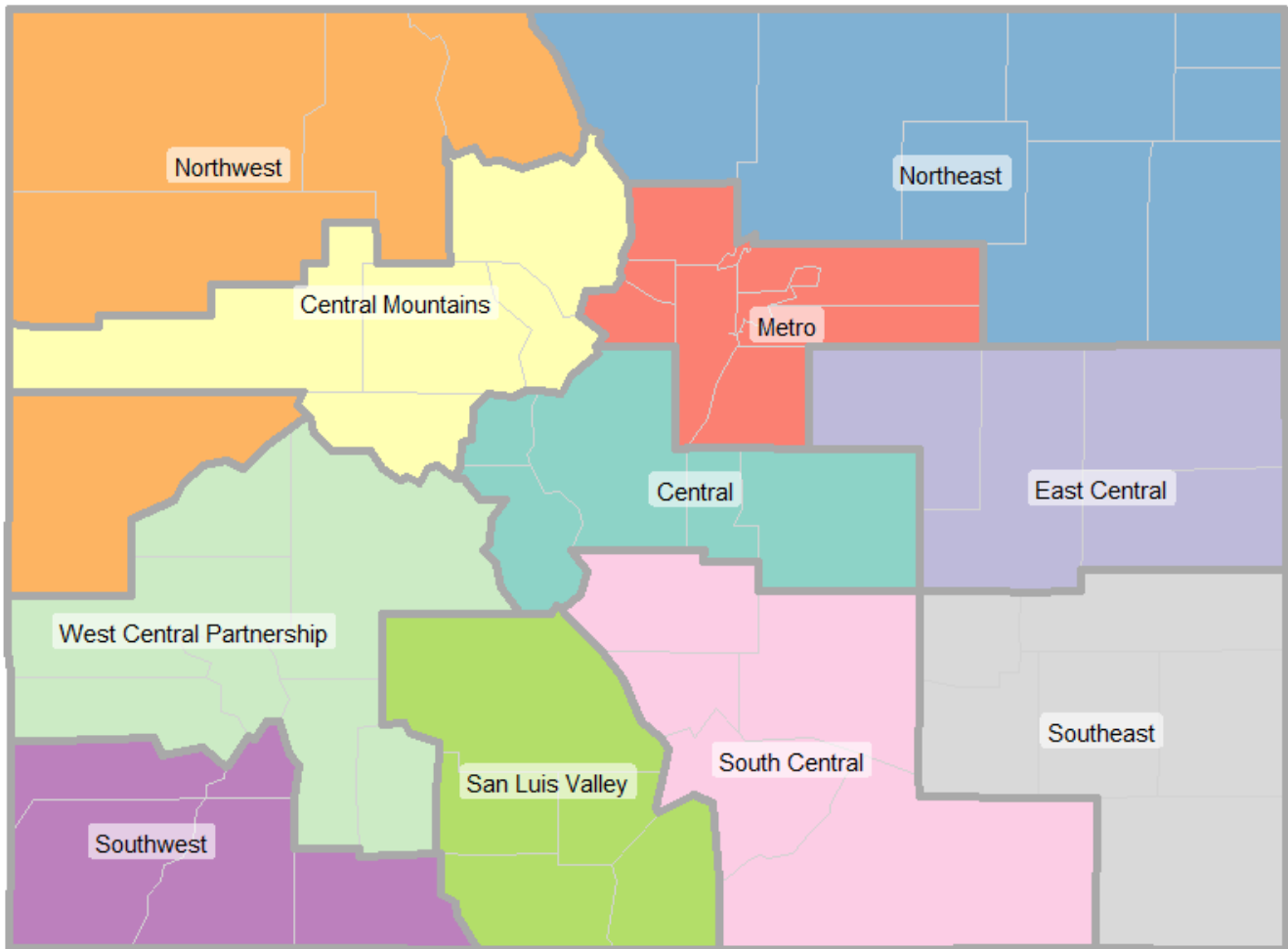


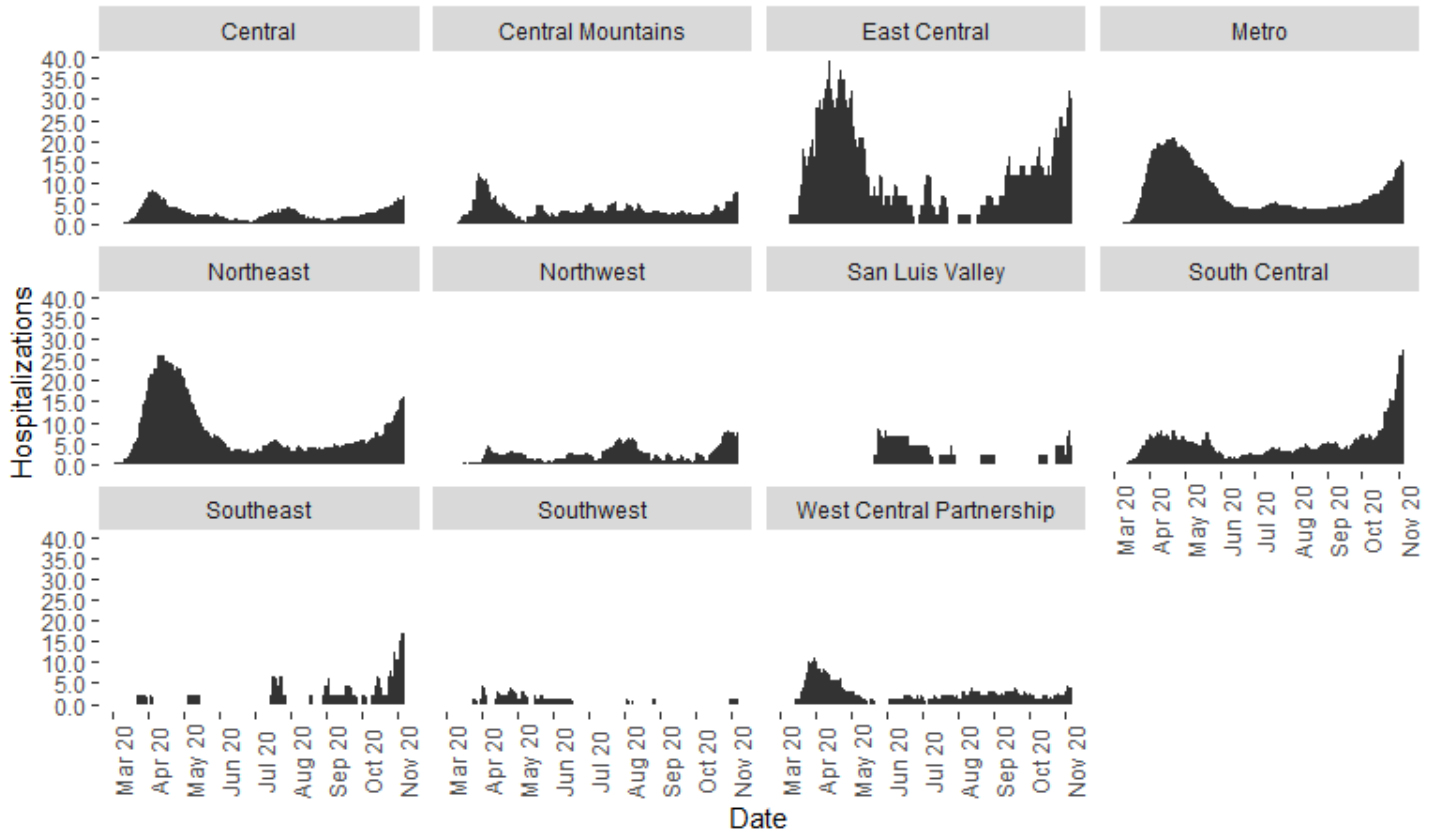
Figure 1. Map showing the 11 LPHA regions and 7 Denver Metro Counties for which estimates were generated.

COVID-19 hospitalizations

The figures below show the daily number of people 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 the 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. 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 since March



Observed Hospitalizations per 100,000

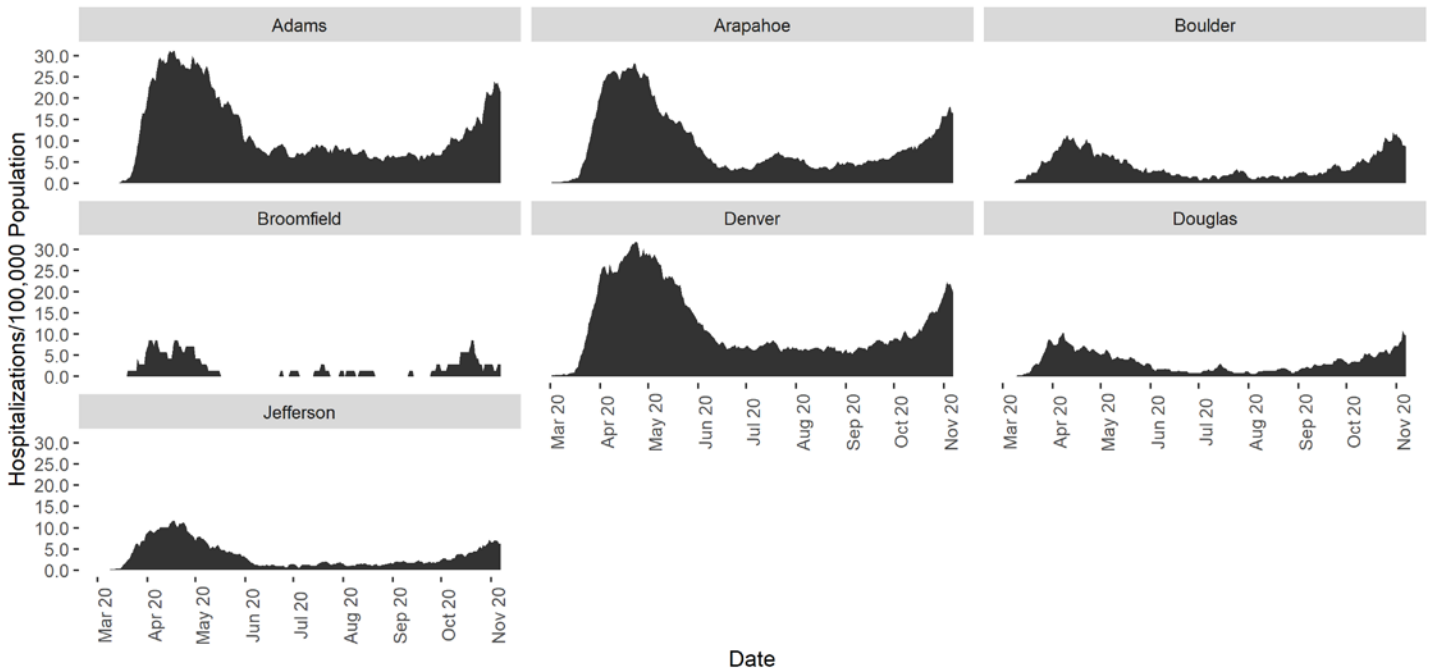
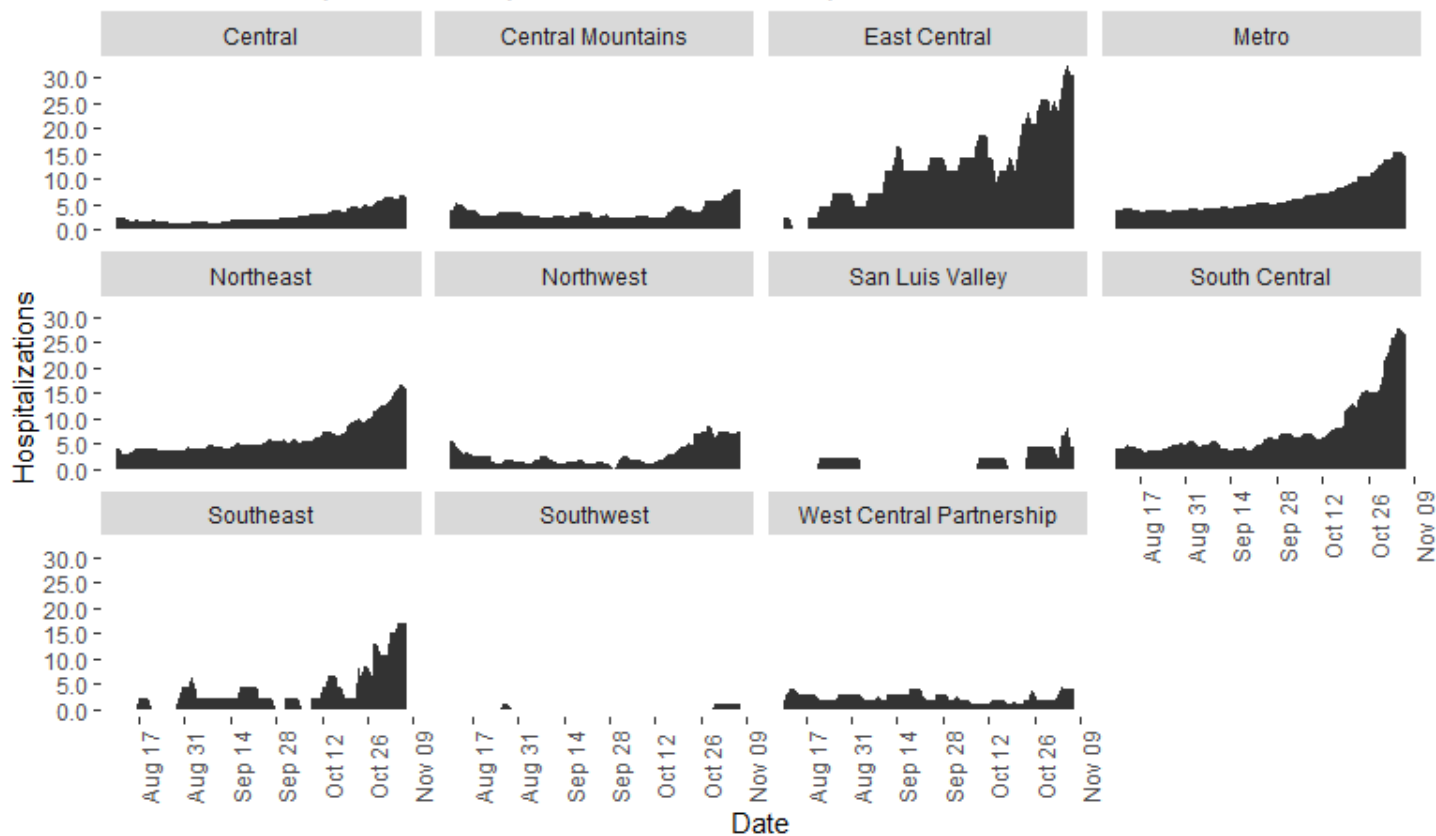


Figure 2. The daily number of people hospitalized with COVID-19 hospitalizations per capita for the 11 LPHA regions and 7 Denver Metro Counties in Colorado since the first case was reported in March 2020. Hospitalization data are from the COPHS hospital census data through 11/02/2020. Hospitalizations are standardized using population estimates from the US Census 2020 projections.

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



Observed Hospitalizations per 100,000

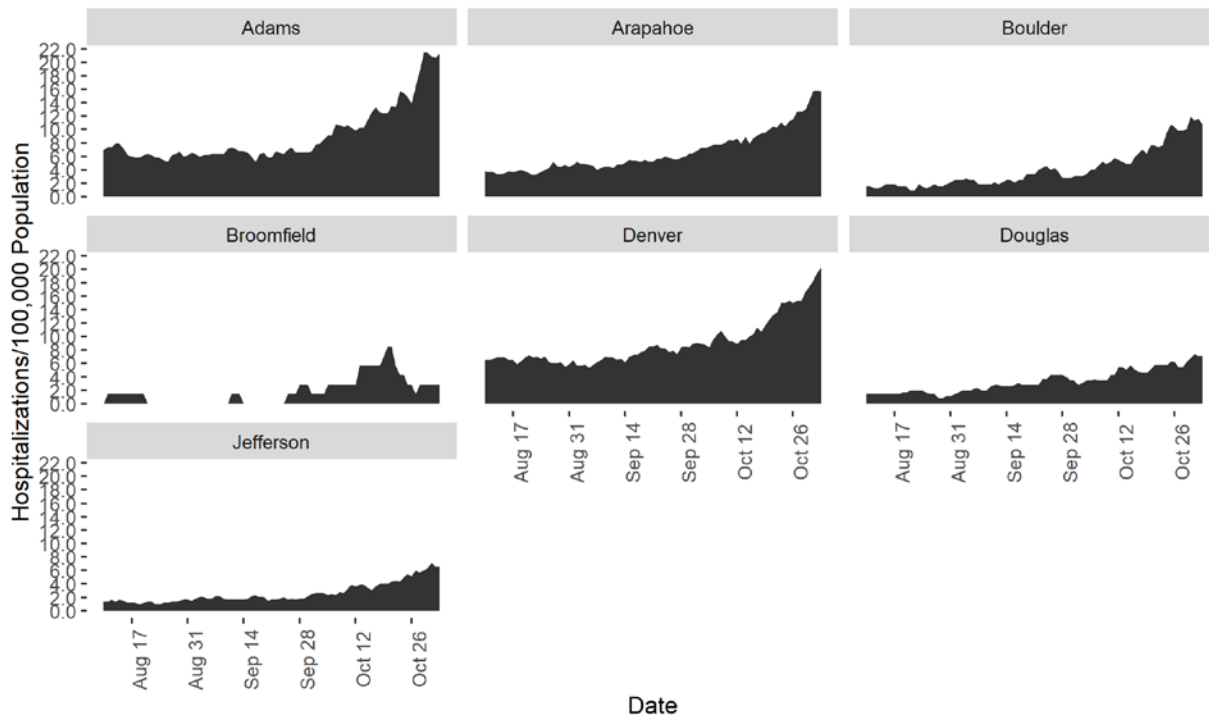


Figure 3. The daily number of people hospitalized with COVID-19 per capita for the 11 LPHA regions and 7 Denver Metro Counties in Colorado over the past 12 weeks. Hospitalization data are from the COPHS hospital census data through 11/02/2020. Hospitalizations in the most recent 4 days may be incomplete due to lags in reporting.

Effective Reproductive Number

The figure below shows the estimated effective reproductive number for each region and Denver Metro Counties 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. When R_e is equal to 1, infections are stable.

The effective reproductive number is estimated using our age-structured SEIR model fit to hospitalization data and, in four LPHA regions with smaller populations, reported SARS-CoV-2 case data. Due to the approximately 13-day lag between infection and hospitalization, we are currently only able to estimate R_e through 10/20/2020.

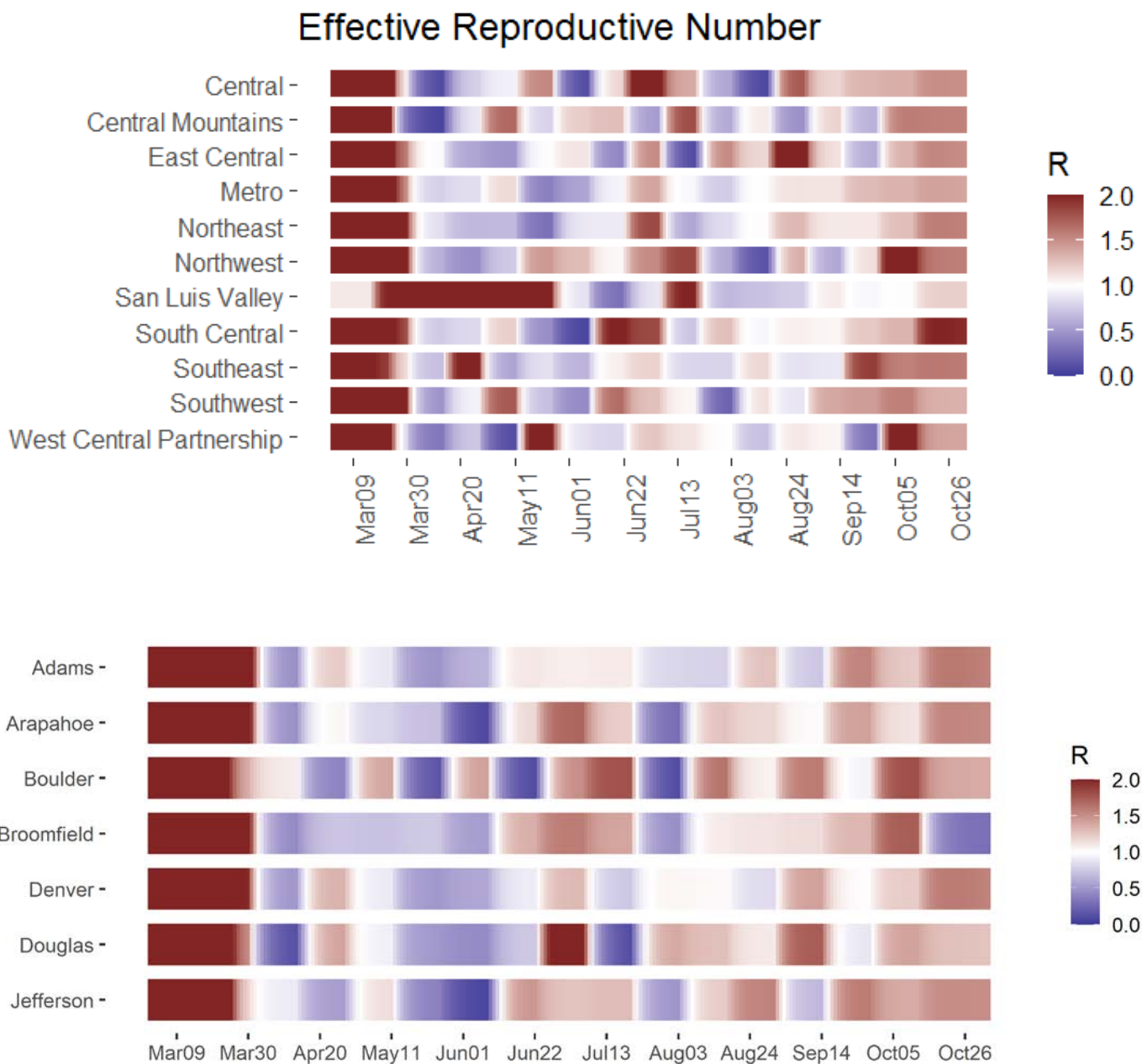
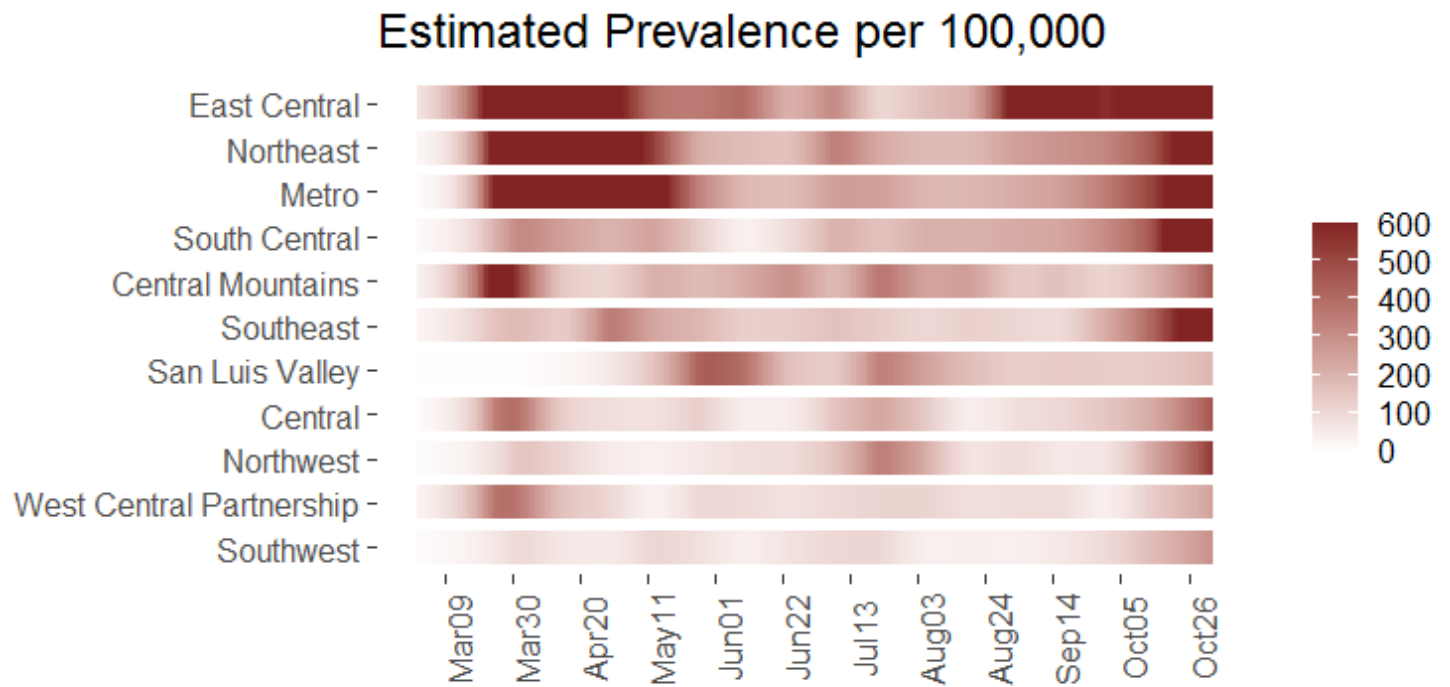


Figure 4. The estimated effective reproductive number over time in the 11 LPHA regions and 7 Denver metro counties. Estimates shown using COVID-19 hospitalization and reported case data through 11/02/2020. Note that, due to 13-day lag between exposure and hospitalization, Re estimates reflect the situation ~13 days earlier on 10/20/2020.

Infection prevalence

Infection prevalence is an estimate of the fraction of the population that is currently infected with SARS-CoV-2 and capable of spreading infections. Infection prevalence is an important tool for gauging SARS-CoV-2 exposure risk – offering an estimate of the riskiness of contacts. At higher levels of infection prevalence, people are more likely to encounter infectious individuals among their contacts. Given the characteristics of SARS-CoV-2 and of COVID-19, many infections are not detected by surveillance systems because infected people may be asymptomatic and COVID-19 may be mild in some – the estimates provided here are intended to provide an approximation of all infections including those not detected by the Colorado surveillance system.

The figure below shows the estimated infection prevalence per 100,000 for each LPHA region and the 7 Denver Metro counties. This is estimated based on the SEIR model. These estimates are sensitive to model assumptions, including assumptions about the probability that an infected individual will be symptomatic and require hospital care, as well as assumptions about length of hospital stay, which has declines over time as clinical care has improved. We also assume that length of stay varies by age.



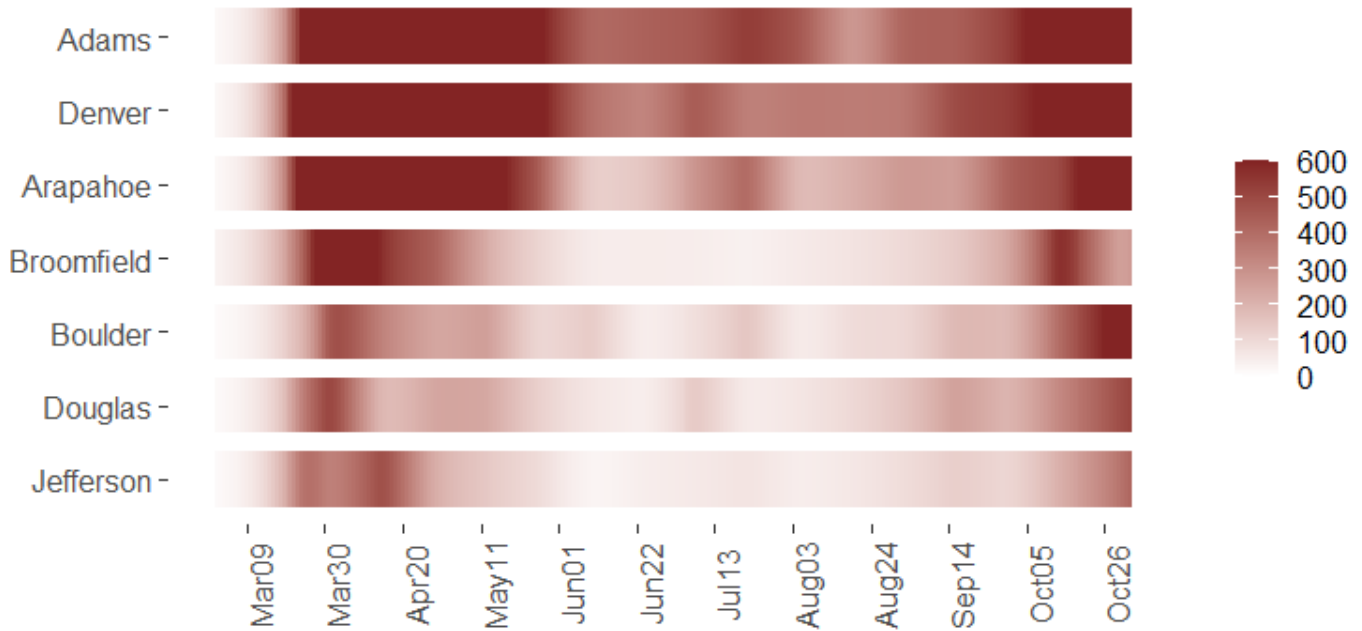


Figure 5. Estimated prevalence per 100,000 population for each of the 11 LPHA regions in Colorado. All prevalence values over 600 per 100,000 are shown in dark red. Prevalence values estimated up to 10/29/2020.

The cumulative number of infections to date

The proportion of the population immune is an important measure of how rapidly infections can spread in a population. As more people develop immunity, due to vaccination or prior infection, the spread of infections slows as infectious individuals are less likely to encounter individuals without immunity. At present, the duration of persistence of immunity to SARS-CoV-2 after infection is incompletely understood. At present, we assume that immunity persists.

The figure below shows model-generated estimates of the percent of the population that has been infected to date for each region. This provides an estimate of the percent of the population that may be immune. As a vaccine becomes available and our understanding of SARS-CoV-2 immunity changes, these estimation methods will be updated. Note the wide range across the seven counties.

Cumulative Proportion of Population Infected to Date

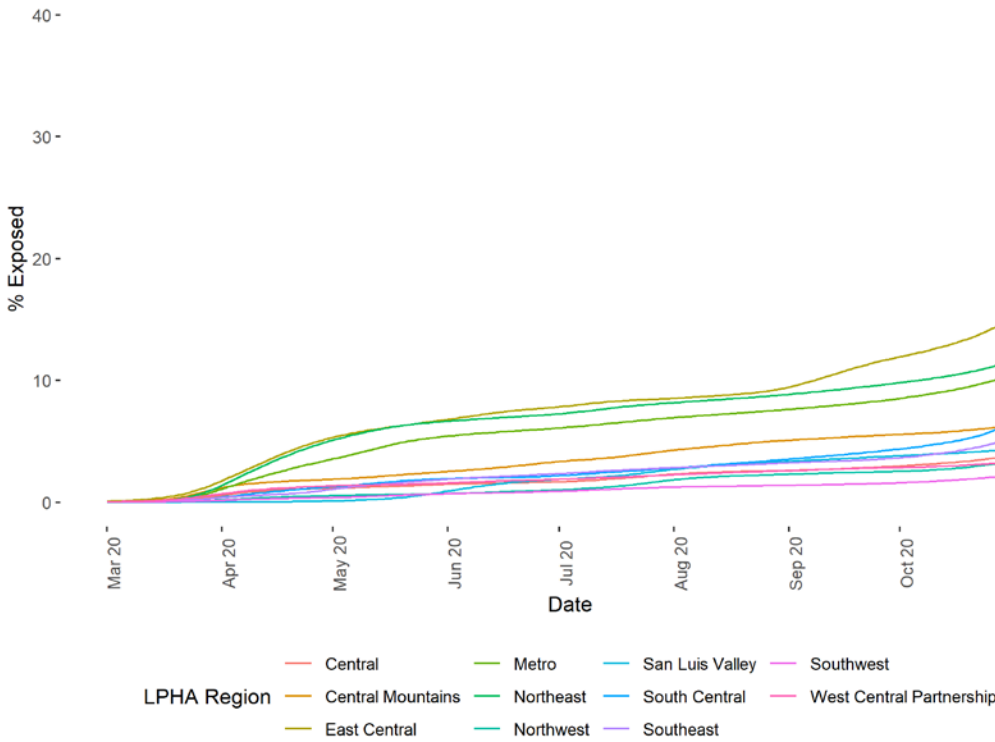
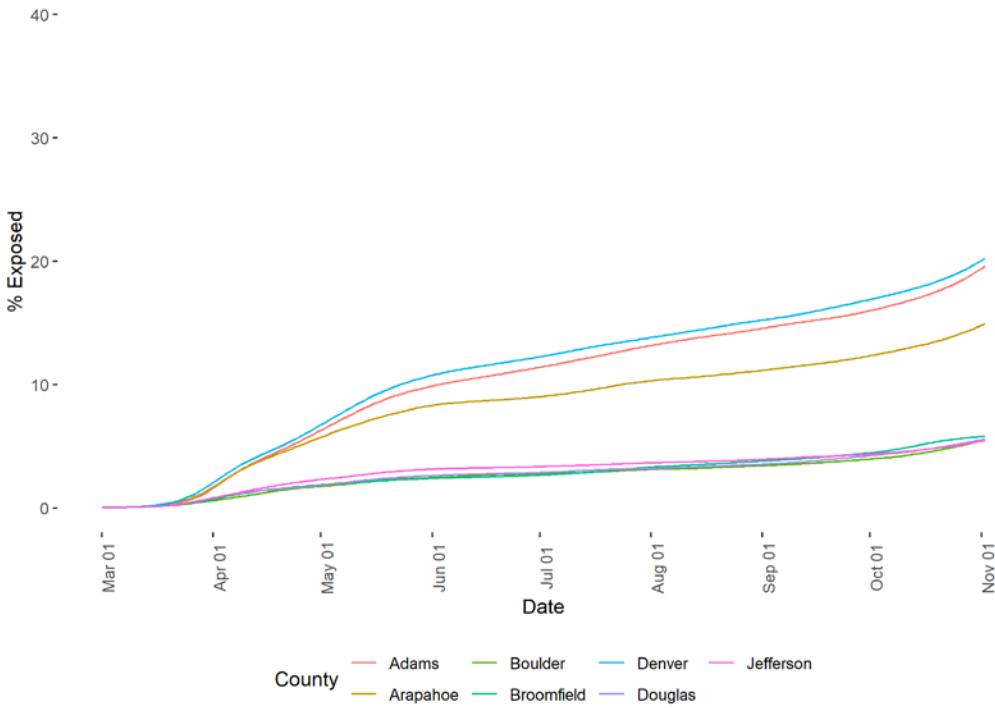


Figure 6. Estimated proportion of the population infected to date for each of the 7 Metro Region Counties (Top) and each of the 11 LPHA regions in Colorado (bottom). Exposed proportion values estimated up to November 2nd.

Summary

The tables below show the most recent estimates of the effective reproductive number, infection prevalence and the proportion of the population infected to date for each LPHA region and 7 Denver metro counties.

LPHA Region	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	Proportion of population infected to date
Central	1.5	Increasing	474	1 in 211	32,200	4.0
Central Mountains	1.6	Increasing	460	1 in 218	11,800	6.5
East Central	1.5	Increasing	1,752	1 in 57	6,700	15.6
Metro	1.4	Increasing	964	1 in 104	353,000	10.7
Northeast	1.6	Increasing	1,052	1 in 95	91,300	11.9
Northwest	1.6	Increasing	555	1 in 80	7,210	3.5
San Luis Valley	1.2	Increasing	190	1 in 526	2,030	4.4
South Central	2.0	Increasing	1,770	1 in 57	17,100	7.1
Southeast	1.6	Increasing	997	1 in 100	2,610	5.6
Southwest	1.3	Increasing	303	1 in 331	2,360	2.3
West Central Partnership	1.4	Increasing	251	1 in 398	3,610	3.4

Metro County	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	Proportion of population infected to date
Adams	1.6	Increasing	1,733	1 in 58	95,000	19.8
Arapahoe	1.5	Increasing	1,198	1 in 83	93,000	15.1
Boulder	1.4	Increasing	712	1 in 140	17,700	5.6
Broomfield	0.7	Decreasing	147	1 in 682	3,600	5.8
Denver	1.6	Increasing	1,568	1 in 64	135,500	20.4
Douglas	1.3	Increasing	466	1 in 215	17,700	5.6
Jefferson	1.5	Increasing	524	1 in 191	31,000	5.5

Table 2. Metrics for evaluating current transmission situation by region. These metrics are evaluated using hospitalization data from COPHS on 11/02/2020. They reflect the proportion of population exposed and the prevalence on approximately 10/29/2020, however the R_e reflects the transmission situation on 10/20/2020.