Summary of Covid-19 Forecasting Models

Prepared by the Fay W. Boozman College of Public in Collaboration with
Others at UAMS and UA-Fayetteville
July 3, 2020

As we all know, Arkansas has experienced a dramatic upsurge in covid-19 cases in the last two weeks. The number of cases reported to the Arkansas Department of Health surpassed even, at the time, the seemingly high numbers forecast by our short-term models for the end of June. In the report prepared for June 19th, we were confident in forecasting the number of covid cases in Arkansas would reach 16,000 by then end of the month. In reality, the number of covid cases on June 30th was over 20,000, doubling the number of covid cases in just over three weeks.

A note about the models before proceeding. Why was there a difference in the number of cumulative cases forecast by the short-term models prepared on June 19th and the actual numbers recorded on June 30th? Models, in addition to being based on empirically derived assumptions, are based on data. If data change, the forecasts will change, too. In almost every forecast we have made, we begin by saying, "if all things remain the same." Obviously, something in the real world changed in the last three weeks of June to greatly enhance the rate at which infections were spreading. And, as a result, we under forecast the number of cumulative cases. The number of new covid cases in Arkansas changed so drastically after June 19th, the short-term models were no longer providing an accurate forecast.

As we go forward, we will also see differences in forecasts using the short-term and long-term models. Short-term forecasts are more sensitive to recent data than are long-term models. Short-term models, which forecast no more than 15 days out, react to and reflect more recent data than long-term models. Recent data in long term models are much less likely to impact predictive growth curves because more recent data are a much smaller proportion of the whole. This is why we caution again looking for changes to an epidemic curve in daily data. For example, an increase of one case in a county having only ten cumulative cases has a much greater impact on percent growth in the county than does one case in a county having more than 100 cases. The principal is the similar in the forecast models.

The short-term forecasts, shown on pages 9 and 21, reflect the rapid growth in covid cases in Arkansas in the last two weeks. As shown on the first graph on page 9, the actual number of daily cases is now higher than would have been forecast using the growth curve first plotted on March 25th. Indeed, growth in recent cases has changed to the point where a third-degree polynomial model fits the data better than the previous second-degree polynomial model. Given the current best-fit model, the short term forecast is for the state to reach about 35,000 cases by July 10th. The time-series short-term models, shown on page 20, provide a more conservative, but nonetheless disturbing forecast. The time-series predicts the number of covid cases will reach 30,000 by July 12th. The time series model of covid deaths forecast 375, also by July 12th.

The long-term forecasts do not show much change from previous models. As shown on page 5, the eSIR model is forecasting active cases in Arkansas will peak in late October at just over 150,000 cases. It is important to note, the model is forecasting active, not total cases. This means that on October 30, if nothing changes, we should expect 150,000 active cases. This model is also forecasting, if all things stay the same, 2,794 hospitalizations, 838 intensive care cases, and 586 ventilations.

The simulations, beginning on page 20, forecasts 20,000 daily new infections by the end of September, if conditions do not change. With modest increases in mitigation, the simulation is showing 12,000 daily new infections. With almost complete compliance with mask wearing in public, the simulation is showing significantly few new daily infections, around 6,000. A similar pattern emerges with respect to daily deaths.

Focusing on the current epidemic in Arkansas, the counties with the highest number of cases per 40,000 are Yell, Sevier, and Lee counties. These are followed by Chicot and Washington counties. The greatest covid disease burden in the state is not in counties having the highest absolute numbers of cases, but in smaller, more rural counties. The map on page 12 shows the percent of a county's caseload diagnosed in the last two weeks. In several rural counties more than 50% of cases have been identified in the last two weeks, suggest increased growth of the epidemic in those counties. This may be due to more widespread testing, but is equally likely to increase spread of the virus. As shown on the map on page 7, counties with the highest increasing case growth are Pulaski, Lee, and Hot Spring counties. Three counties show decreasing growth, Benton, Washington, and Sebastian. All other counties show little change from previous the previous report.

UAMS/UA COVID-19 Research Team
Sean G. Young, Jyotishka Datta, Jackson Cothren, Malcolm Williamson, Geoboo Song, Kristen Gibson.
Data source: ADH

We estimated total infections, hospitalizations, ICU admissions, and ventilators needed for Public Health Regions and the state (see White Paper for details and model assumptions). State results summarized below, PHR results available at http://cvstats.cast.uark.edu, username: cvstatsuser, password: covid19pass. Interactive web maps are also available (PHR Estimates & County-level Changes], user: uacovidview, password: UAcovid19) for easy regional comparisons.

Changes since last report. Since the last report (June 19, 2020), the mean estimate for total active infections at peak decreased by over 20%, with the predicting peak date pushed back to October 29. Similarly, the worst-case estimate at peak came down over 25%, peaking October 24. For the first time since our modeling began, our predictions for the number of beds, ICU beds, and ventilators needed at the state level all fall below the estimates of current supply, however it should be noted that there are still regional variations. While the number of confirmed cases in PHR3 (NWA) continue to increase, the rate of increase has abated somewhat, as can be seen in Map 3. R0 estimates have dropped slightly, with a statewide estimated R0 of 2.41.

Fig 1: Graph of cumulative cases over time by Public Health Region

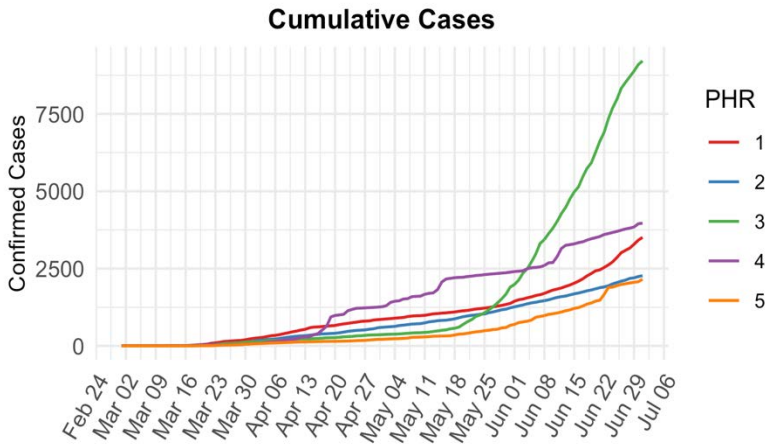


Fig 2: Map of cumulative cases by Public Health Region

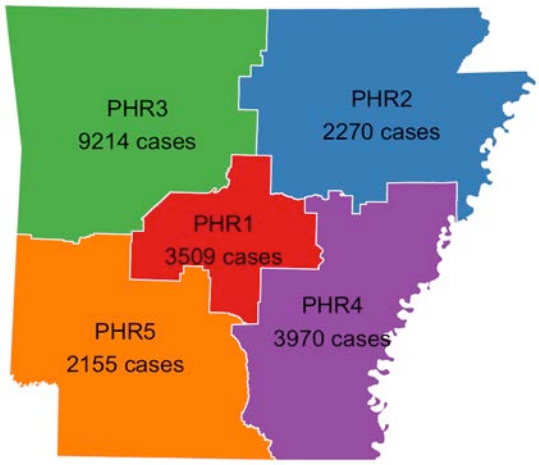


Fig 3: Mean-case estimates of demand for healthcare resources over time (solid lines) compared to estimated capacity (dotted horizontal lines)

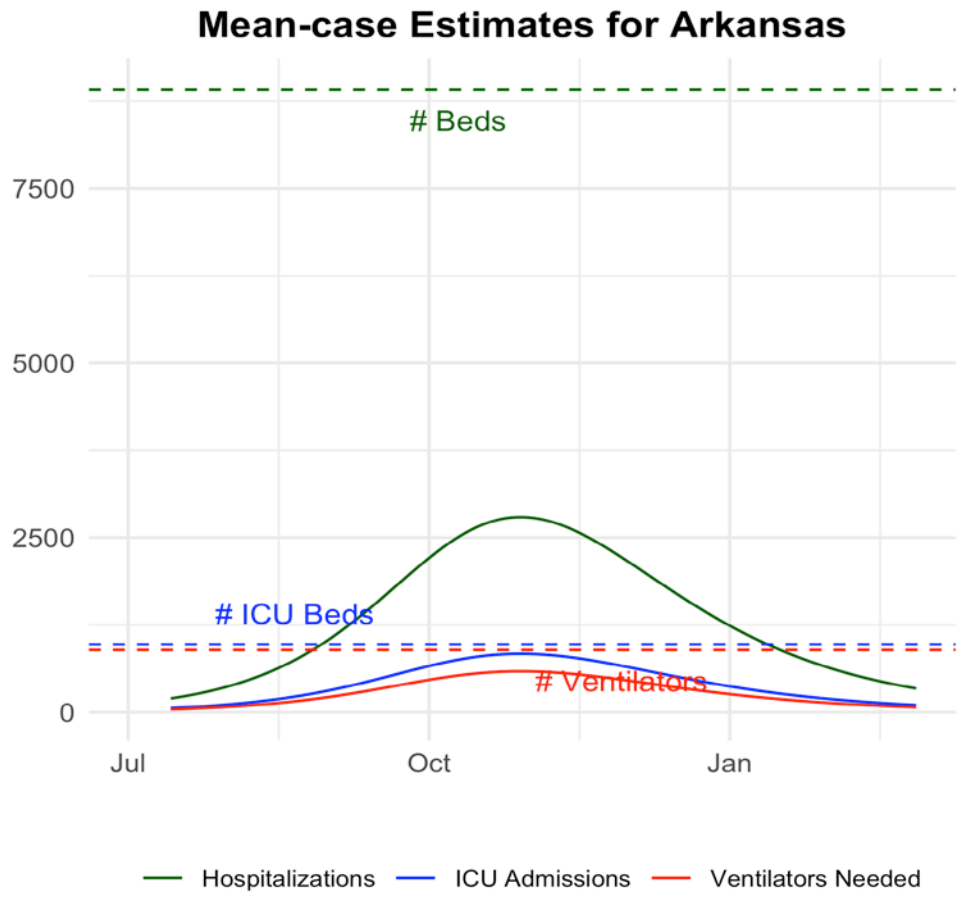


Table 1: Peak number of infections, hospitalizations, ICU admissions, and ventilators needed for Arkansas

Measure	Mean-Case Estimates	Worst-Case Estimates
Predicted Peak Date	10-29-2020	10-24-2020
Total Infections	111,776	186,026
Hospitalizations	2,794	4,650
ICU Admissions	838	1395
Ventilators Needed	586	976

Table 2: Posterior R_0 Calculated for Arkansas (95% CI)

Region	R_0 Estimate
PHR1	2.57 (2.22-3.02)
PHR2	2.15 (1.89-2.46)
PHR3	2.5 (2.24-2.8)
PHR4	1.19 (0.14-2.71)
PHR5	2.7 (2.32-3.2)
Entire State	2.41 (2.12-2.76)

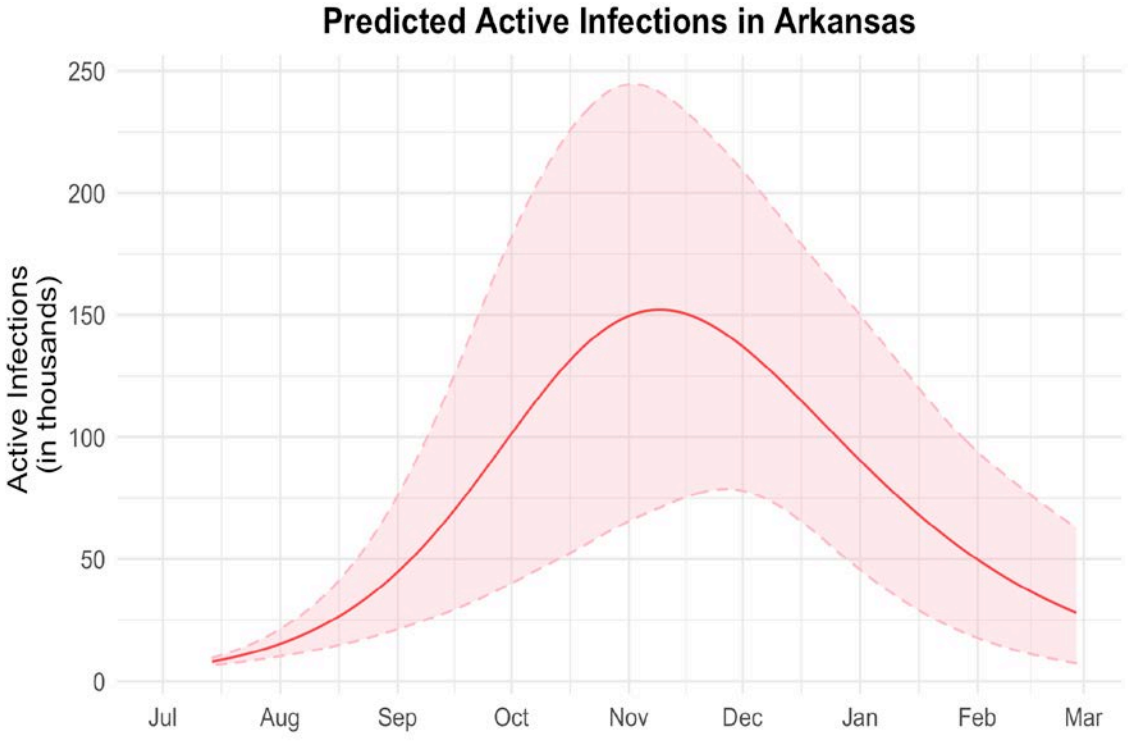
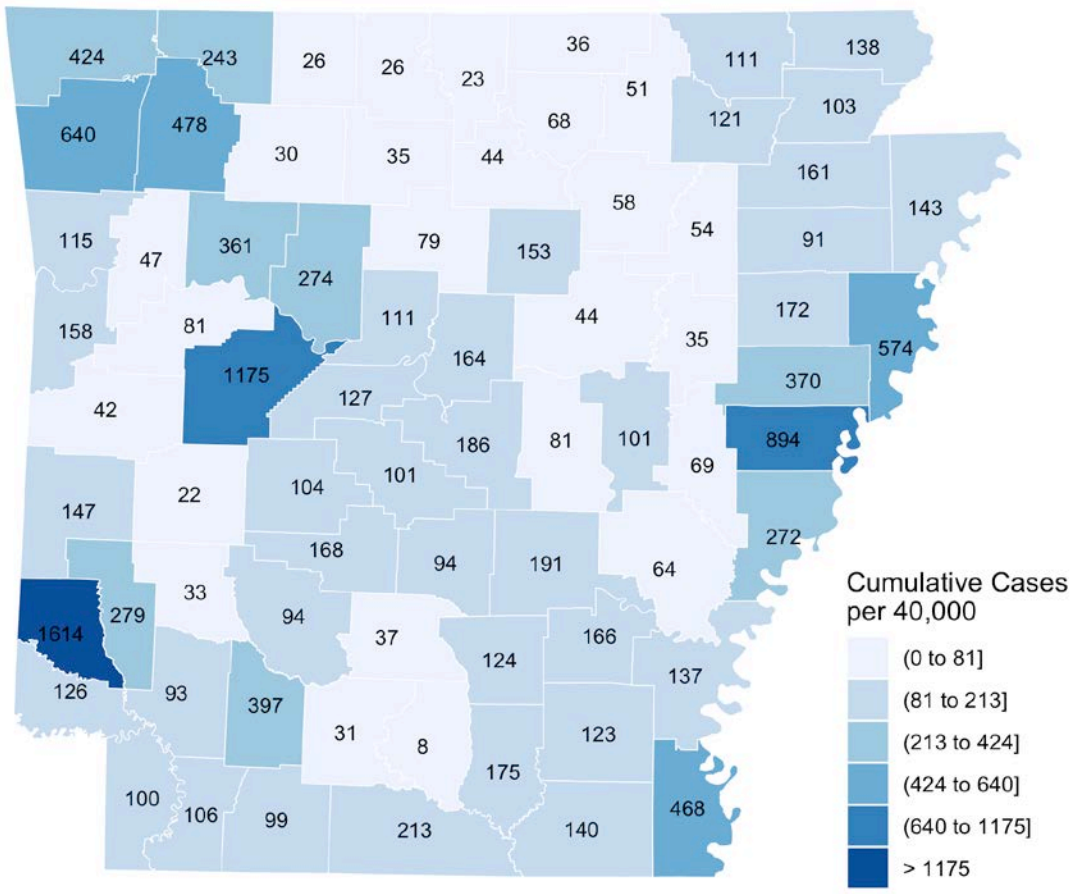
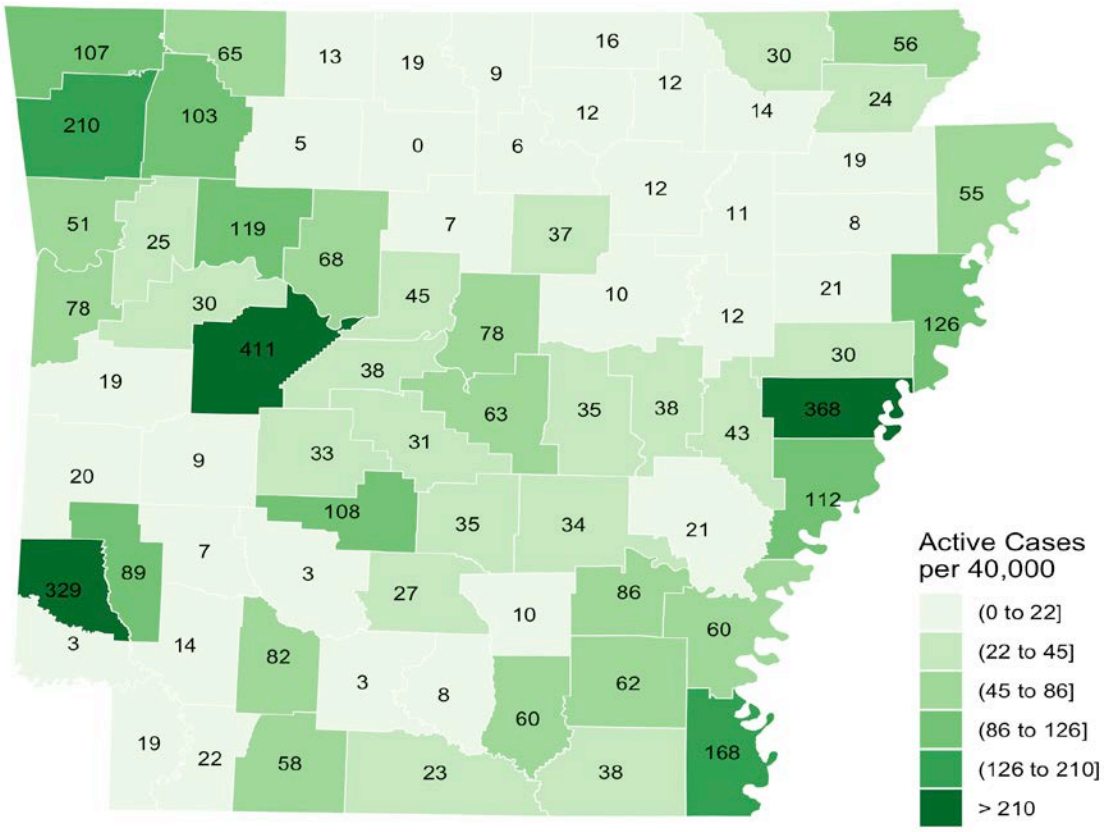


Fig 4: Mean estimate of predicted active infections for the state (solid curve), including asymptomatic infections, with 90% confidence intervals shown (shaded region between dotted lines). Note the date of the peak varies with the magnitude of the peak – more severe estimates peak sooner.

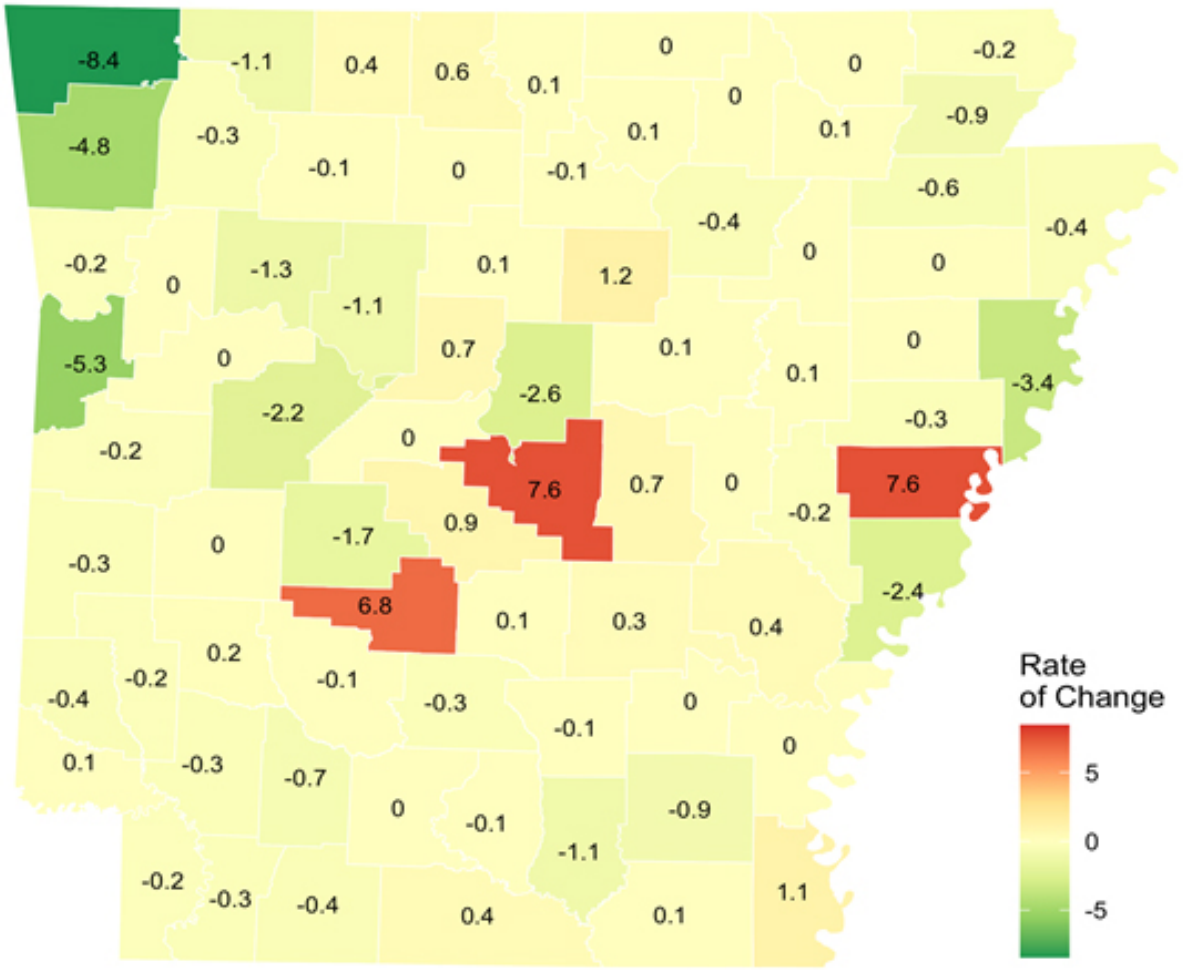
COMMUNITY-ONLY COVID-19 MAPS
Maps below use only COMMUNITY data. Nursing home and prison populations have been removed.



Map 1: Cumulative cases in the community per 40,000. This map shows the total confirmed cases to date in the community, i.e. not including prison or nursing home populations, normalized by county population. The values are calculated by dividing the cumulative total of confirmed cases in the community by county population, multiplying by 40,000 (the approximate mean population per county in Arkansas), and then rounded to nearest integer.



Map 2: Current cases in the community per 40,000 people. This map shows the current "active" cases in the community, i.e. not including prison or nursing home populations, normalized by county population. The values are calculated by subtracting the number of recoveries and deaths from the cumulative total of confirmed cases in the community, dividing by county population, multiplying by 40,000 (the approximate mean population per county in Arkansas), and then rounded to nearest integer.

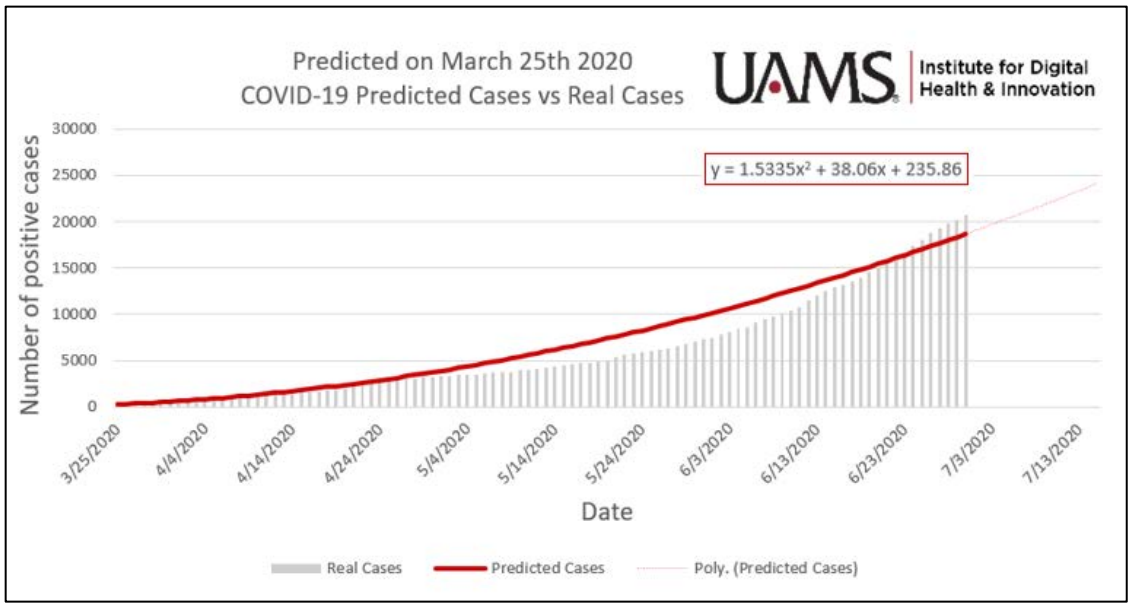


Map 3: Rate of change, confirmed Cases in the community. Is a county gaining new cases faster and faster, or are they managing to "flatten the curve"? This map shows the rate of change over the past seven days, using confirmed cases in the community, i.e. not including prison or nursing home populations. Positive values (red) indicate that the infection rate is increasing more rapidly over time, while negative values (green) indicate that the infection rate is reducing over time.

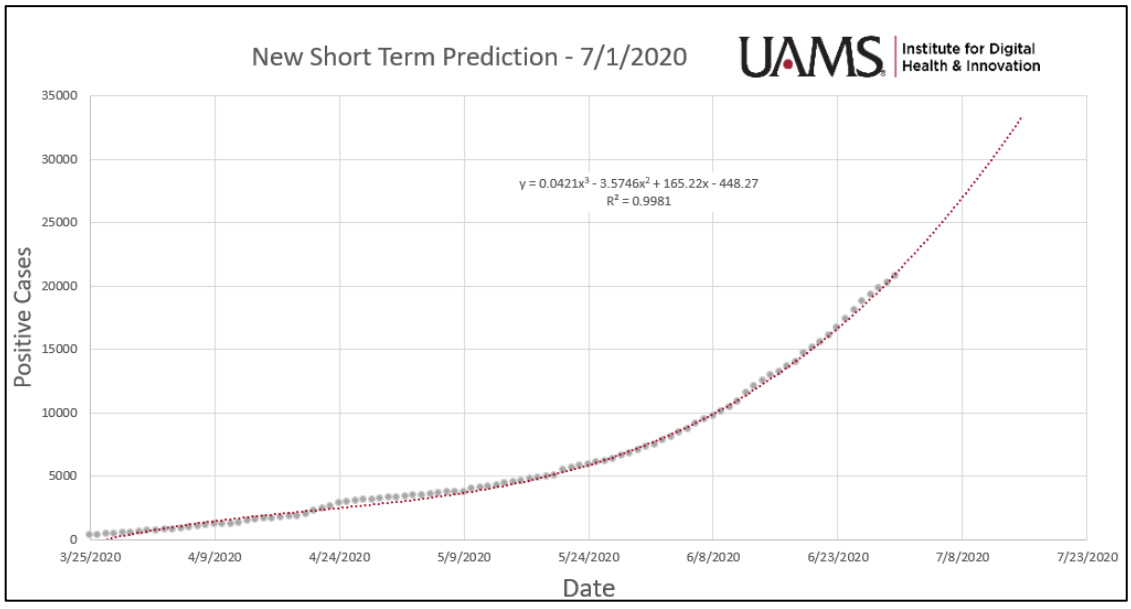
UAMS Research Group
Clare Brown, Adria Abella Villafranca, Kevin Sexton
July 1, 2020

Explanation. The purpose of this work group has largely shifted towards continuous monitoring and assessment of COVID-19 among counties and facilities in Arkansas as well as for UAMS specifically. The focus of the modeling continues to estimate shorter-term needs and disease rates in Arkansas at about 15-days out. Additionally, we provide various descriptive tables and maps of Arkansas to suggest populations and areas of the state that may particularly high risk at present.

Model. The focus of the estimates at this time are to most accurately predict the needs in Arkansas in the short term (i.e., at the daily interval, ~15-days into the future of the date the model is run). The model includes a second-order polynomial trend using the number of Arkansas positive cases per day



The above graph suggests that the current rate of growth as well as the absolute number of covid positive cases has surpassed what was originally projected based on a curve fit on March 25.

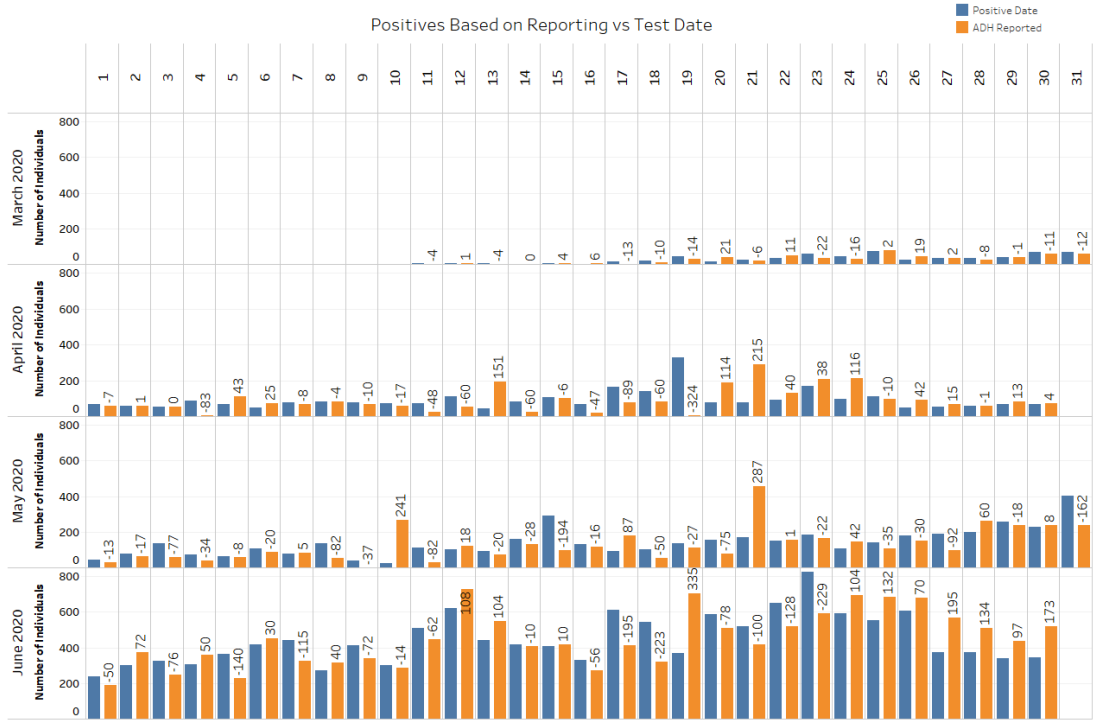


The graph on the previous page is a third-degree polynomial fit on July 1. This model suggests the curve is no longer flatter than the curve fit on March 25th, which was the case for a majority of April, May, and June. The curve now suggests the epidemic in Arkansas is growing at a much faster rate. Of note is that the polynomial terms are significantly larger than in the weekly estimations over the last 2-3 months.

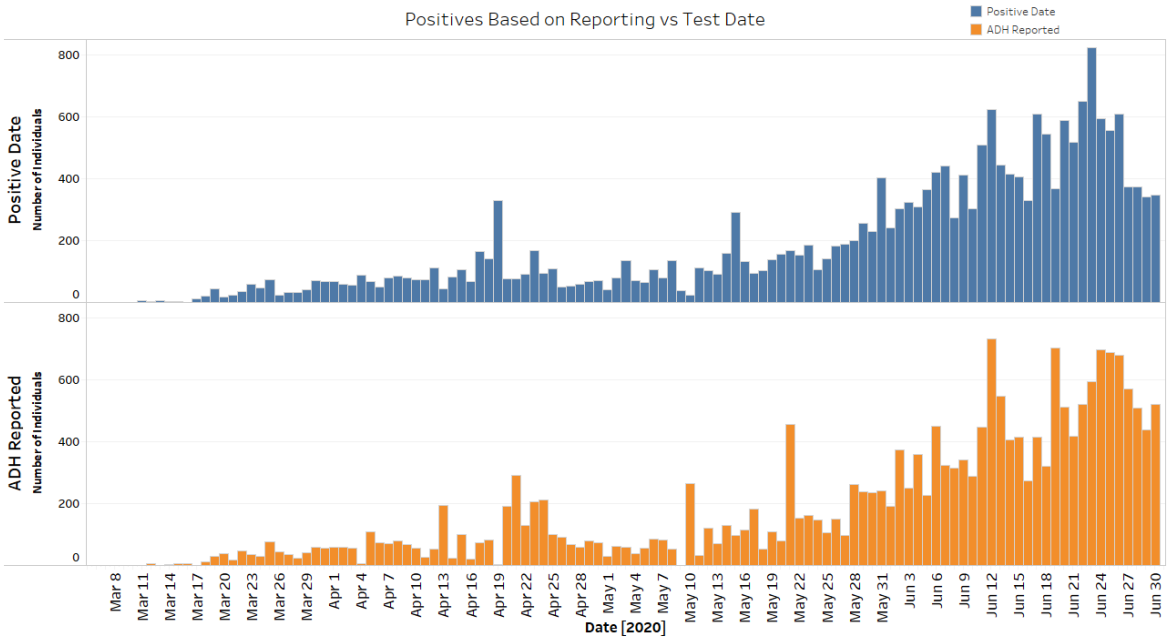
Assumptions:

- Patients who test positive for COVID-19 will be most likely to initially be hospitalized at the nearest hospital. Facility-level probability of treating a given positive patient is impacted through the weights that account for the number of available beds in a given county and in the facility.
- 12% of individuals testing positive for covid-19 will require hospitalization.
- 4.5% of those testing positive for covid-19 will require ventilation.

Considerations Moving Forward. Given the large increase in testing, consideration should be made regarding differences arising from the date to which cases are attributed. Specifically, because it takes time for ADH to receive data from commercial labs, as well to input new data, there are some dates with large differences in the number of tests that were positive on a given date (in orange below) and the number of tests that were "new" and reported by ADH on a given date (in blue below). There are some dates with large differences, which may lead to inaccurate conclusions. For example, the large number of cases reported on May 21 were actually positive cases occurring throughout the entire previous week. The 455 newly reported on May 21 may present a different understanding of the current status of disease, versus the actual 167 positive cases on that date. Of particular importance is that, relative to the number of cases, the lag is shortening.

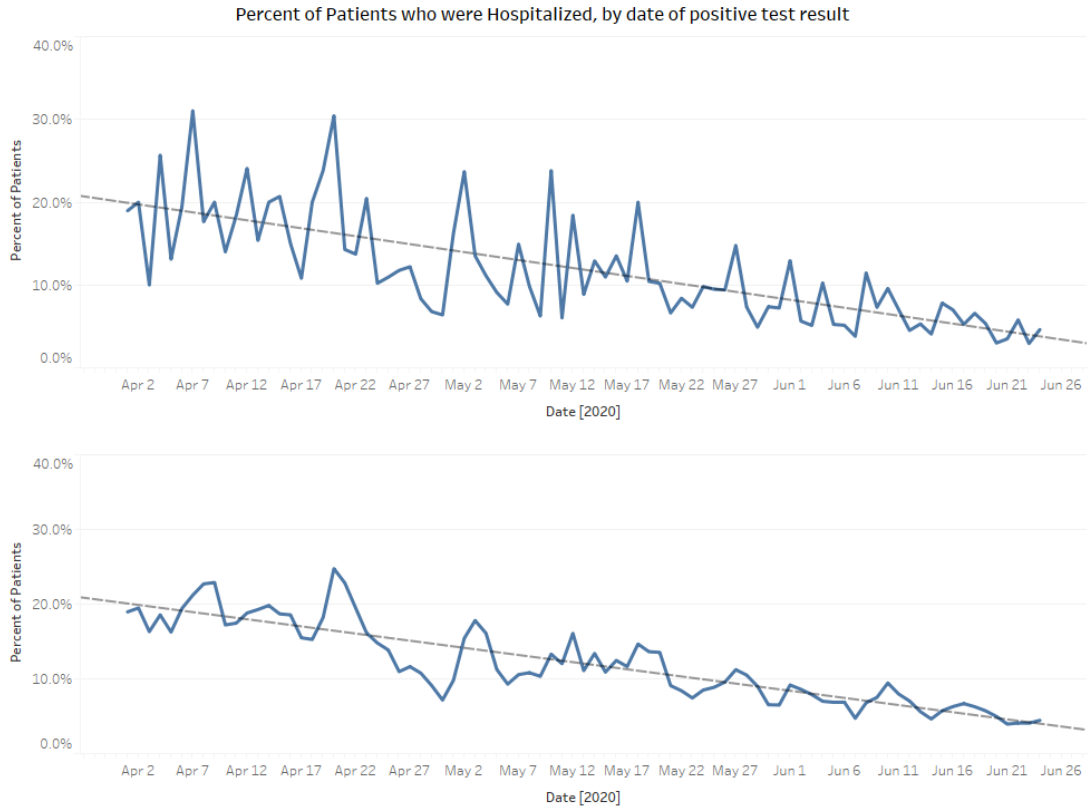


This is the same data shown the previous graph, but structured differently. You can see peaks in reported data are slightly after the actual positive test dates.



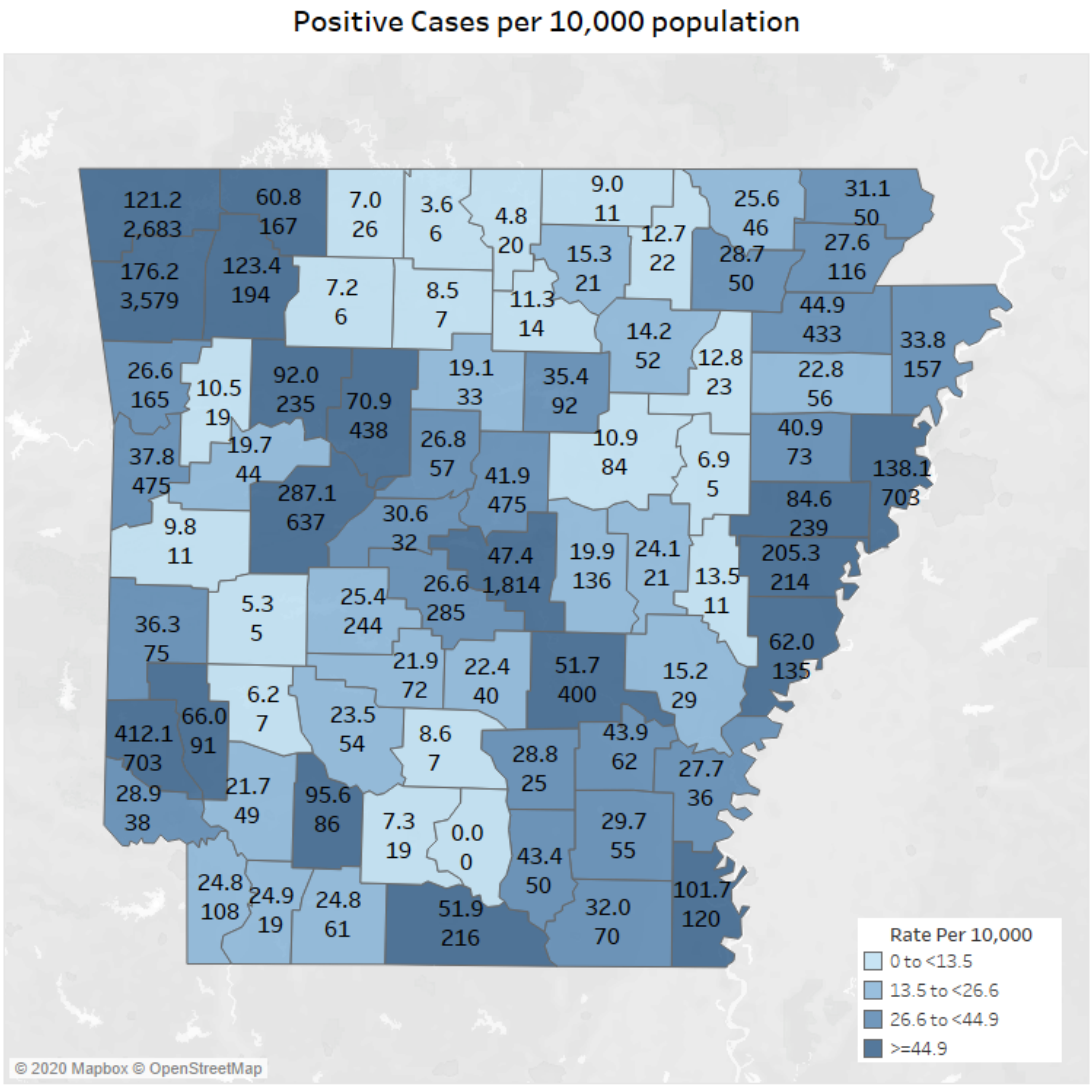
"Positive Date" represents the number of cases on a given date based on the date a test came back positive. "ADH Reported" represents the number of new cases reported by ADH based on ADH acquiring the information of the new case and based on a slight lag in the public reporting. Value on a given date represnts the difference in "ADH Reported" minus "Positive Date". Data from 7/1/2020 at 10:00am.

Another consideration moving forward is hospitalizations rates in terms of the number of positive cases. As seen in the graphs below, hospitalizations are declining. This suggests increased testing is capturing less clinically severe cases of covid-19. Please note that the graph below was limited to dates April 1 (to have enough cases in the denominator) to June 24 (to allow for hospitalization to have occurred). The bottom graphic presents a rolling 3-day average.



Top is raw graphic is raw numbers and bottom graphic is with a 3 day moving average. For stable estimates, data is limited to April 1 to 7 days prior to data pull (i.e., 6/24/2020). Data from 7/1/2020 at 10:00am.

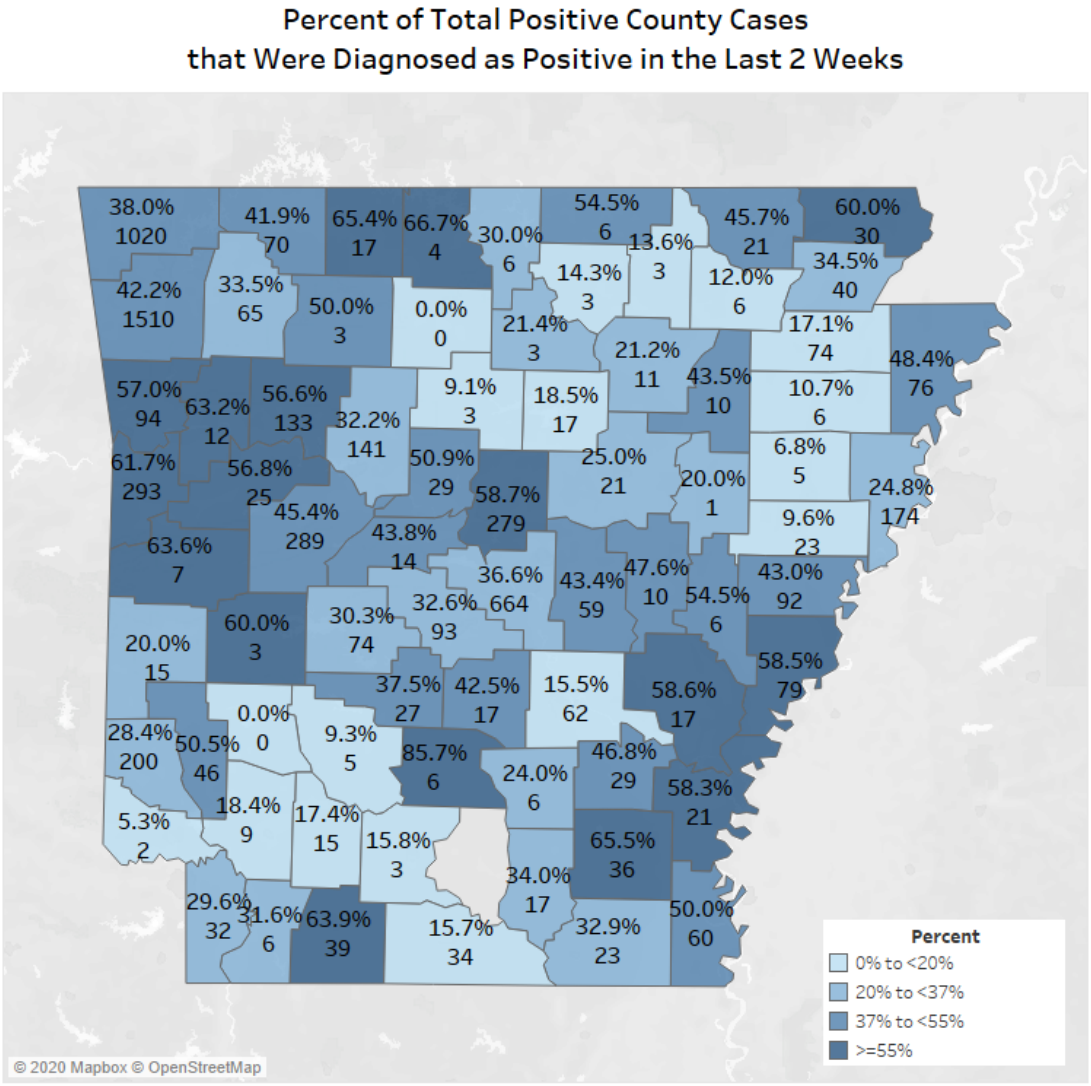
All data presented from this point forward exlcude jails/correctional facilities and nursing homes.



Top number represents total positive county cases per 10,000 residents. Bottom number represents total positive cases.

Data updated 7/1/2020 at 10:00am.

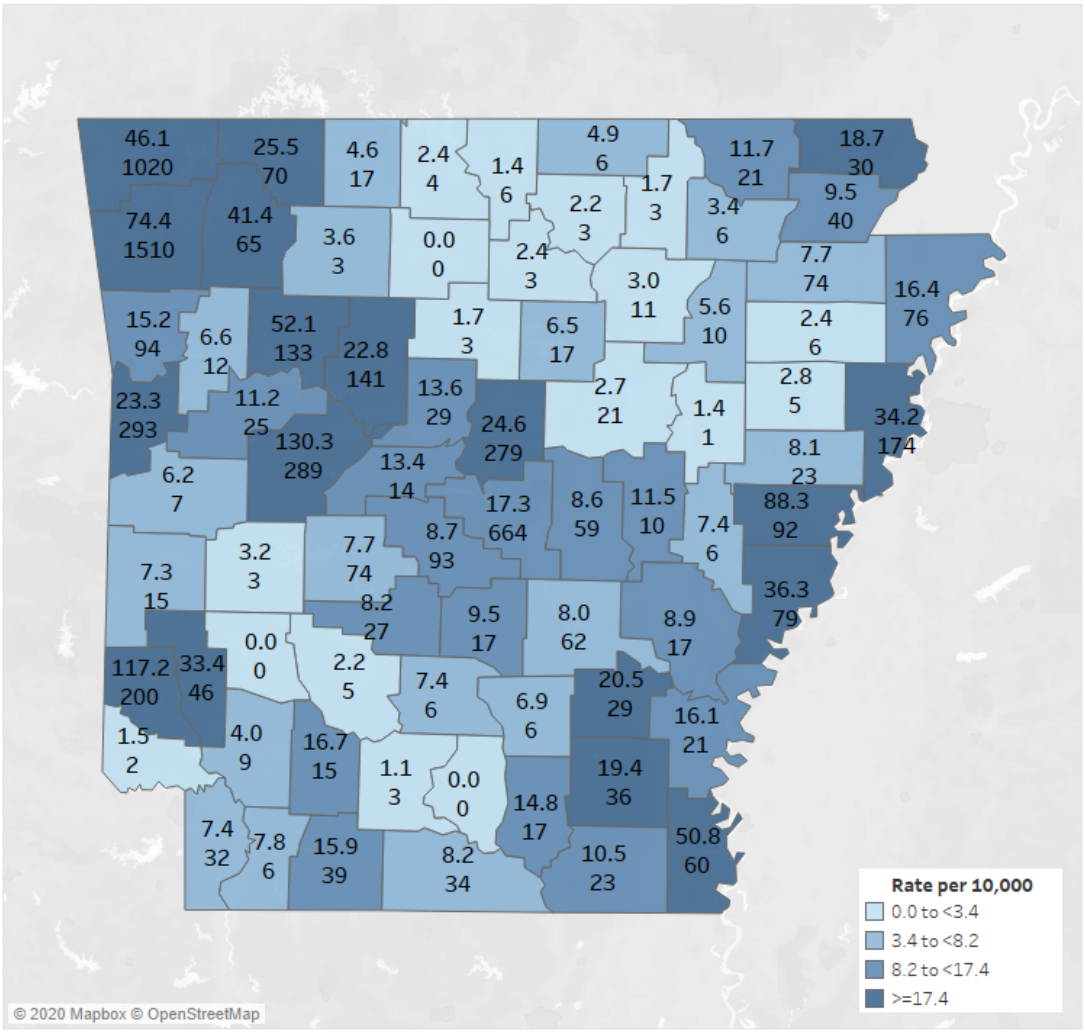
This map shows hotspots in the state; however, rates are not time-dependent. As such, understanding cases in a more recent (such as 2 weeks) timeframe provides more guidance as to current problem areas. However, this graphic highlights that case rates per population is particularly important. For example, Lee County has only 12% of the number of cases as Pulaski County (214 versus 1,8149). However, the rate relative to the population is greater than 400% in Lee County versus Pulaski County. Another example is considering what it means to have 20 new cases in a given county. In Calhoun County, this would mean 3.7 cases per 1,000 residents, compared to 0.05 cases per 1,000 in Pulaski County.



Top number represents percent of total positive county cases that were diagnosed in the last 2 weeks. Bottom number represents total positive cases in last two weeks. Missing counties represent counties with no reported positive cases.
Data updated 7/1/2020 at 10:00am

Using the top and bottom numbers, this map suggests a number of counties that continue to be areas with particularly high rates of cases. Based on counties mentioned in public briefings, Yell, Johnson, and Faulkner counties should potentially be additional areas of concern, particularly in terms of case rates per population (subsequent graphic).

Positive Cases Diagnosed in the Last 2 Weeks by 10,000 Population

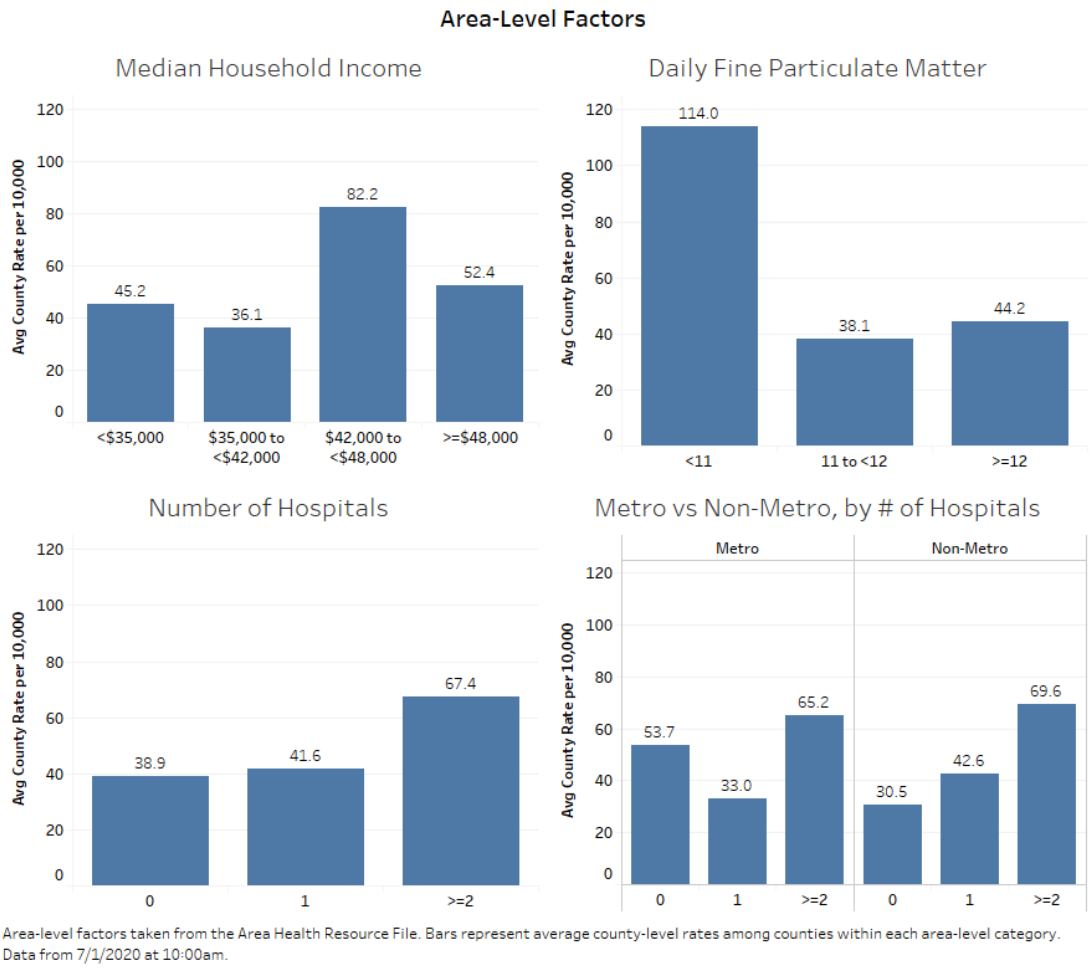


Top number represents total positive county cases diagnosed in last 2 weeks per 10,000 residents. Bottom number represents total positive cases diagnosed in last 2 weeks.

Data updated 7/1/2020 at 10:00apm.

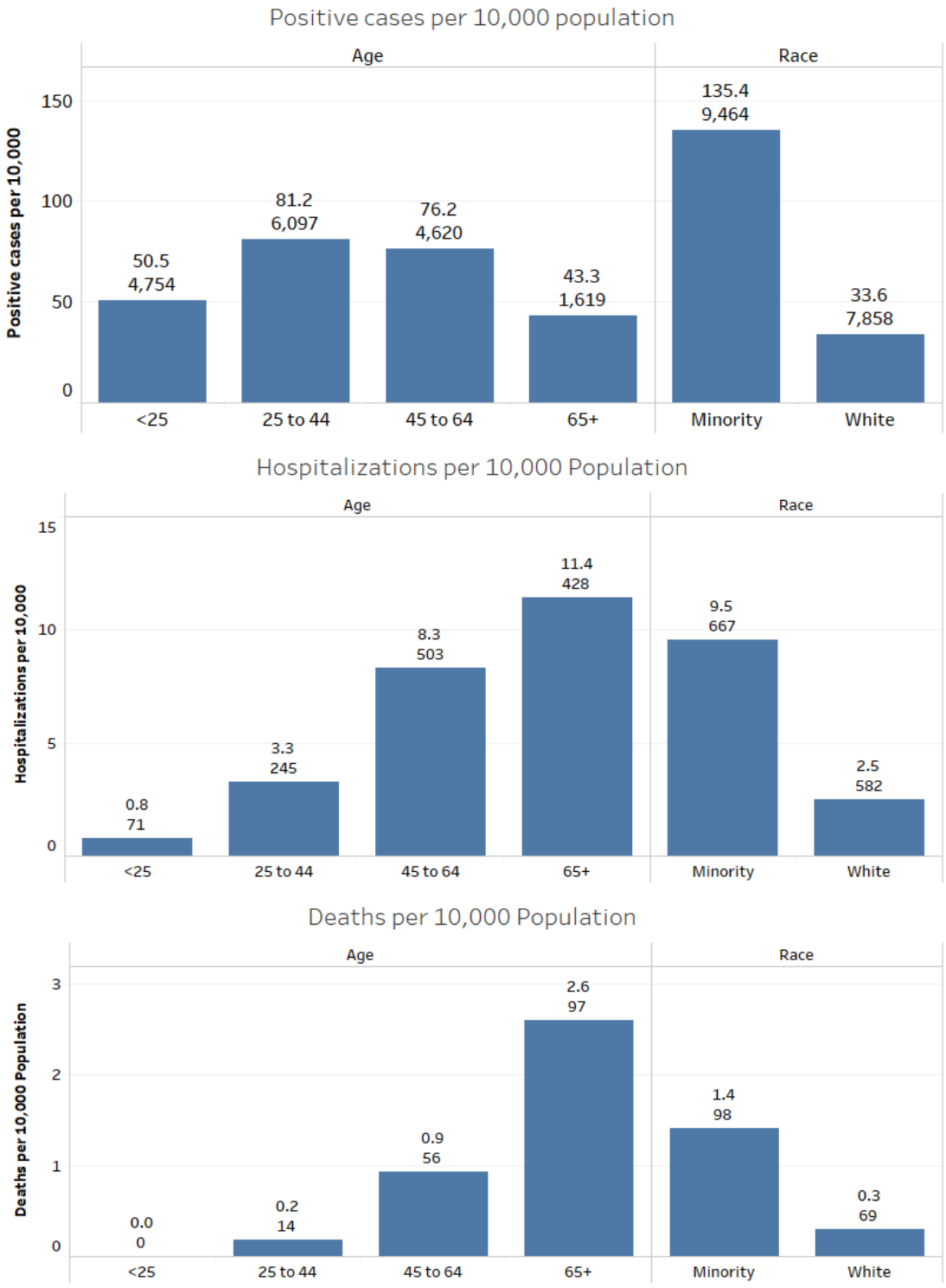
This map, in addition to the map on the previous page, provides an understanding of whether a county has shorter or longer-term high rates of cases. For example, Sevier County has a rate of 117.2 per 10,000 cases in the last 2 weeks, but the number of cases in the last two weeks is a quarter of the county's overall caseload (28%). This suggests more sustained rates of infection compared to, for example Johnson County, which has a rate of 52.1 per 10,000, constituting nearly 60%, and suggesting more recent infection growth.

Another primary takeaway from this map is that, despite the substantial growth in Benton and Washington counties, there are additional counties in Arkansas with equally high or higher rates of new cases when put in perspective of the population size. These counties (Sevier, Yell, and Lee) should also be of concern, although it is recognized that some of these counties have been noted as high rate areas in public briefings.



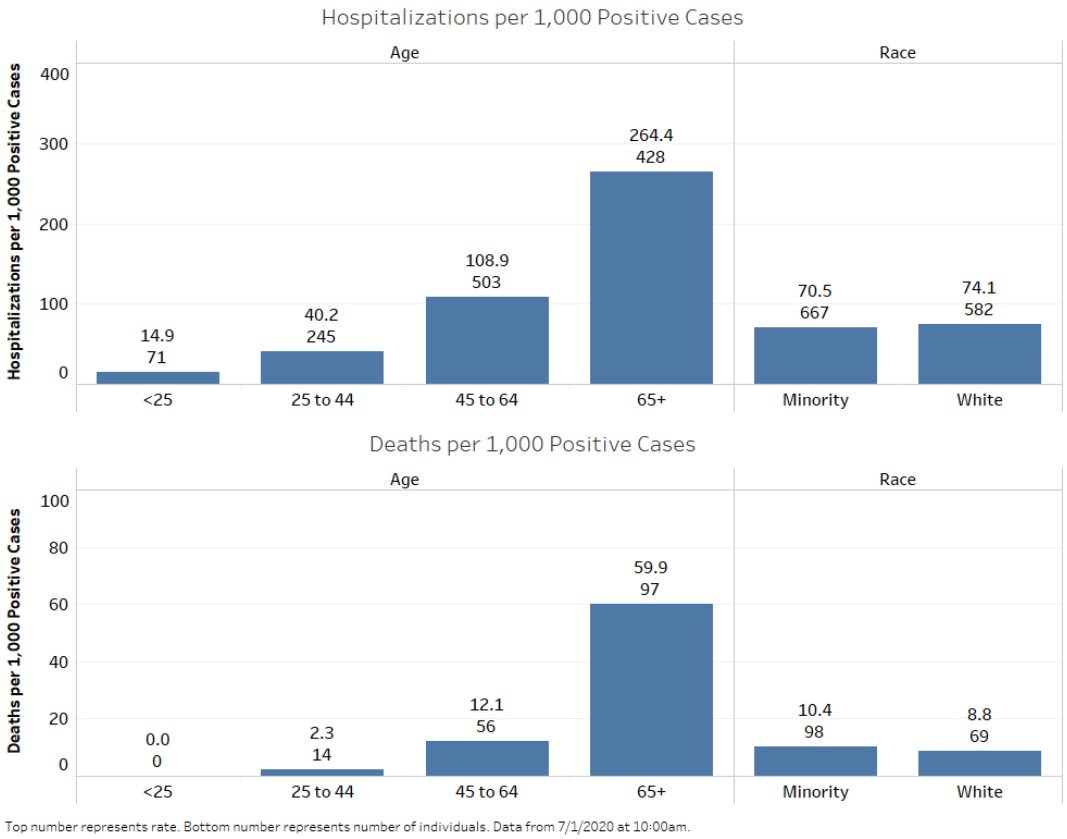
Area-level factors taken from the Area Health Resource File. Bars represent average county-level rates among counties within each area-level category. Data from 7/1/2020 at 10:00am.

The graphics above suggest that, compared to early on in the COVID-19 pandemic, testing in non-urban areas and counties without hospitals has caught up to early testing in urban areas.



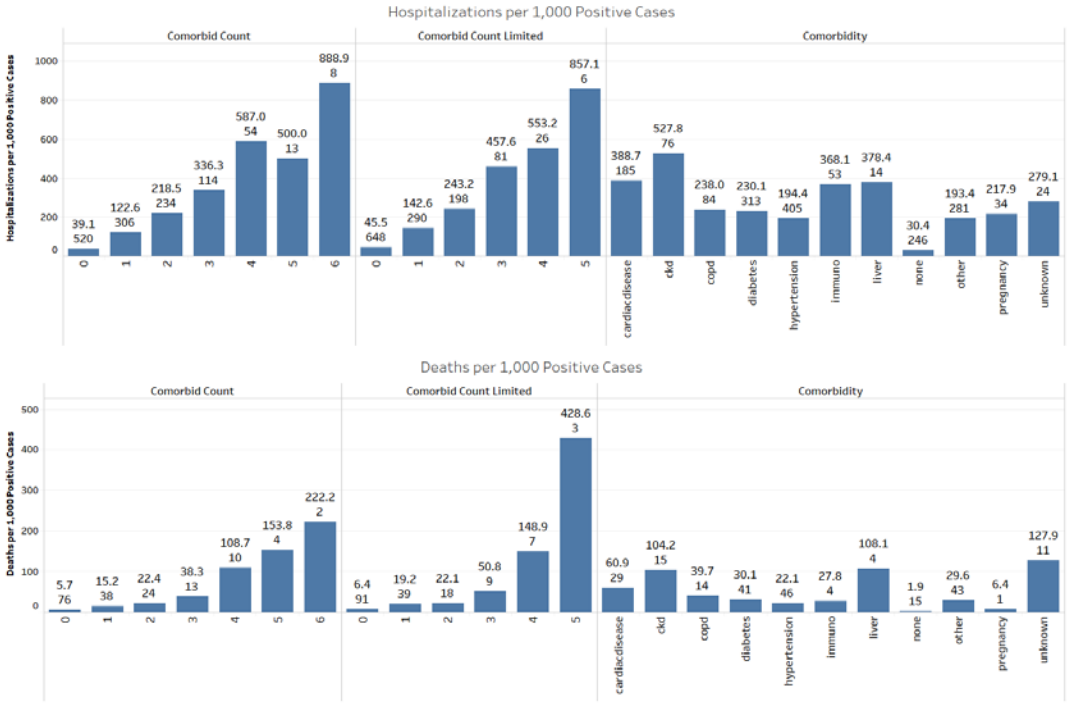
Top number represents rate. Bottom number represents number of individuals. Population denominators taken from 2010 Census data. Data from 7/1/2020 at 10:00am.

This graphic suggests that we have had growth, compared to previous weeks, in terms of cases among the middle-aged population.



Top number represents rate. Bottom number represents number of individuals. Data from 7/1/2020 at 10:00am.

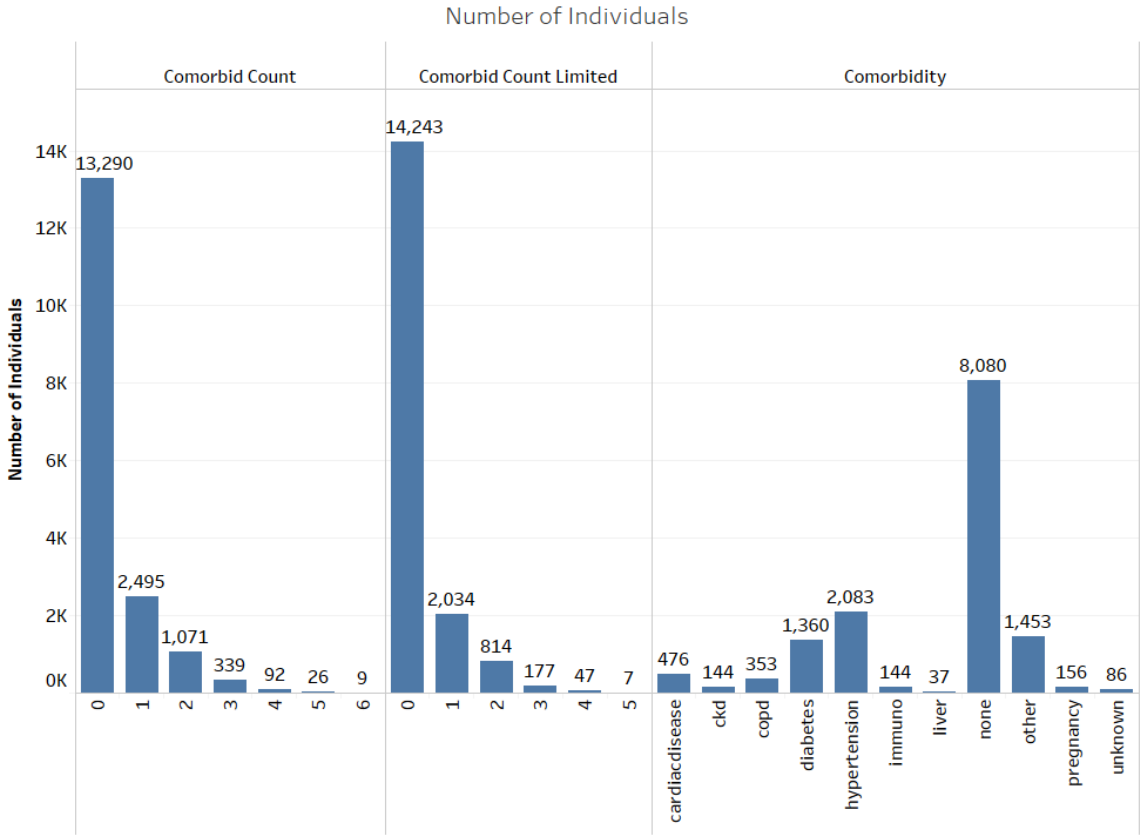
This graph on this page suggests, among those who test positive, older individuals may be most at risk for hospitalization and death. There does not appear to be large racial differences with respect to likelihood of hospitalization or death among positive cases. This ultimately suggests that larger numbers of minority populations will become hospitalized or die simply because of higher rates of disease spread among racial/ethnic groups.



Top number represents rate. Bottom number represents number of individuals. "Comorbid Count" includes pregnancy, diabetes, cardiac disease, hypertension, COPD, Chronic Kidney Disease (CKD), liver disease, and immunocompromised. "Comorbid Count Limited" includes diabetes, cardiac disease, hypertension, COPD, and Chronic Kidney Disease (CKD). Data from 7/1/2020 at 10:00am.

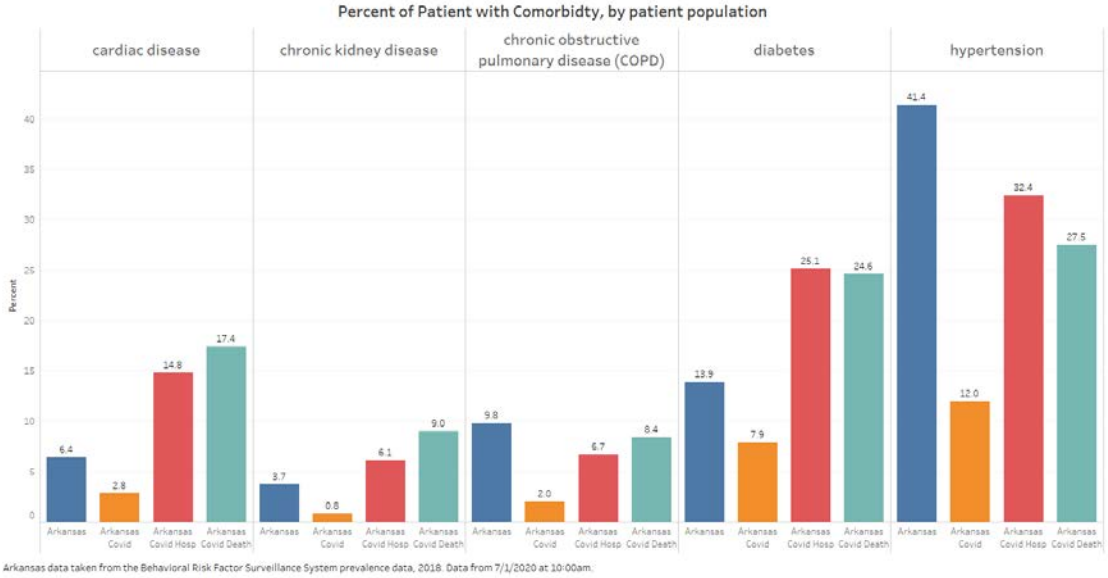
\

This graph on the previous page shows the risk of hospitalization or death associated with specific comorbidities. Chronic kidney disease, cardiac disease, and liver disease are considerable risk factors for hospitalization and death among positive patients. Of greater concern is the association between the number of comorbidities a patient has and hospitalization or death. For example, 75 (this graphic) of the 127 (subsequent graphic) COVID patients presenting with 4 or more comorbid conditions were hospitalized (60%) and 13% died.

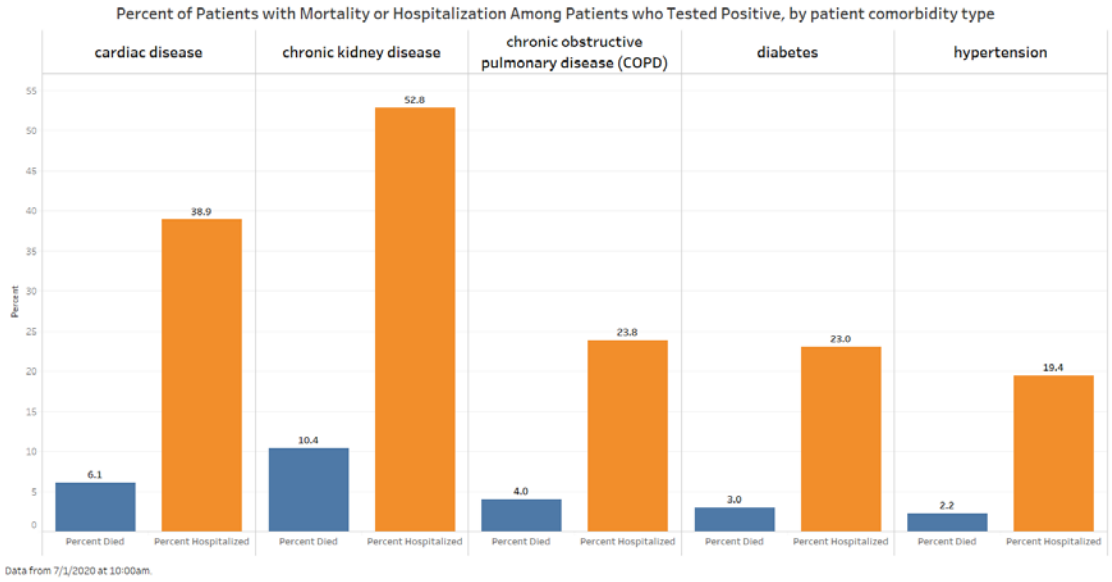


Top number represents rate. Bottom number represents number of individuals. "Comorbid Count" includes pregnancy, diabetes, cardiac disease, hypertension, COPD, Chronic Kidney Disease (CKD), liver disease, and immunocompromised. "Comorbid Count Limited" includes diabetes, cardiac disease, hypertension, COPD, and Chronic Kidney Disease (CKD). Data from 7/1/2020 at 10:00am.

This graphic is primarily to provide a denominator for other graphics.



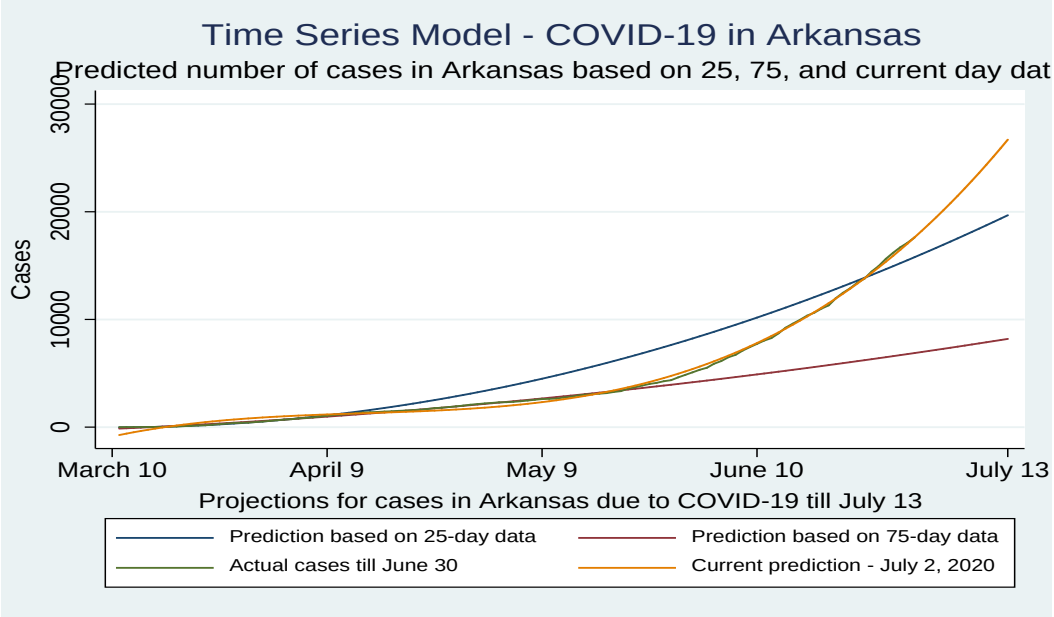
Arkansas data taken from the Behavioral Risk Factor Surveillance System prevalence data, 2018. Data from 7/1/2020 at 10:00am.

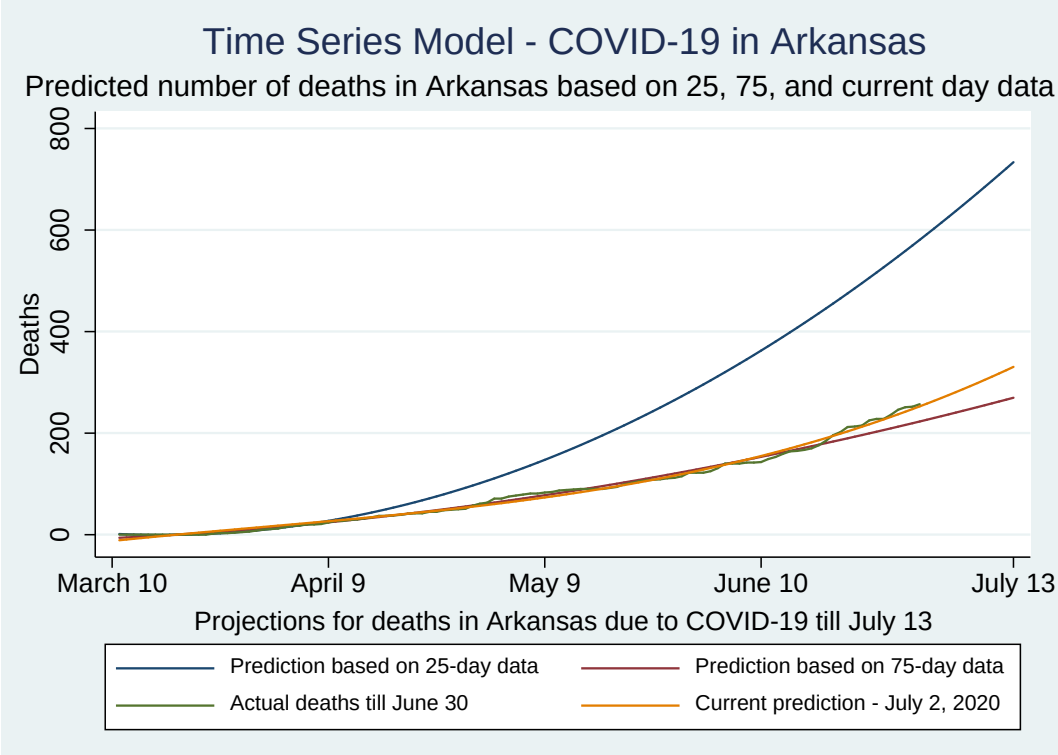


The last two graphs provide another descriptive outlook from which to better understand what population may be most at risk for hospitalization or death. Of note, the chronic condition bar charts show differences compared to those plotted using data from earlier in the epidemic. Specifically, the percentage of covid-19 positive individuals with chronic conditions has continued to decline, likely reflective of the increasing numbers of positive cases in younger adults. Of greater importance is the high rates of chronic conditions among covid-19 positive patients who are hospitalized or die. This suggests that chronic conditions are a greater driver of adverse outcomes among those who contract the disease, rather than a driver of contracting the disease itself.

COVID-19 FORECASTS

COPH Faculty Group
Mick Tilford, Ph.D., Jenil Patel, Ph.D., Suman Maity, Ph.D., & Lori Fischbach, Ph.D.



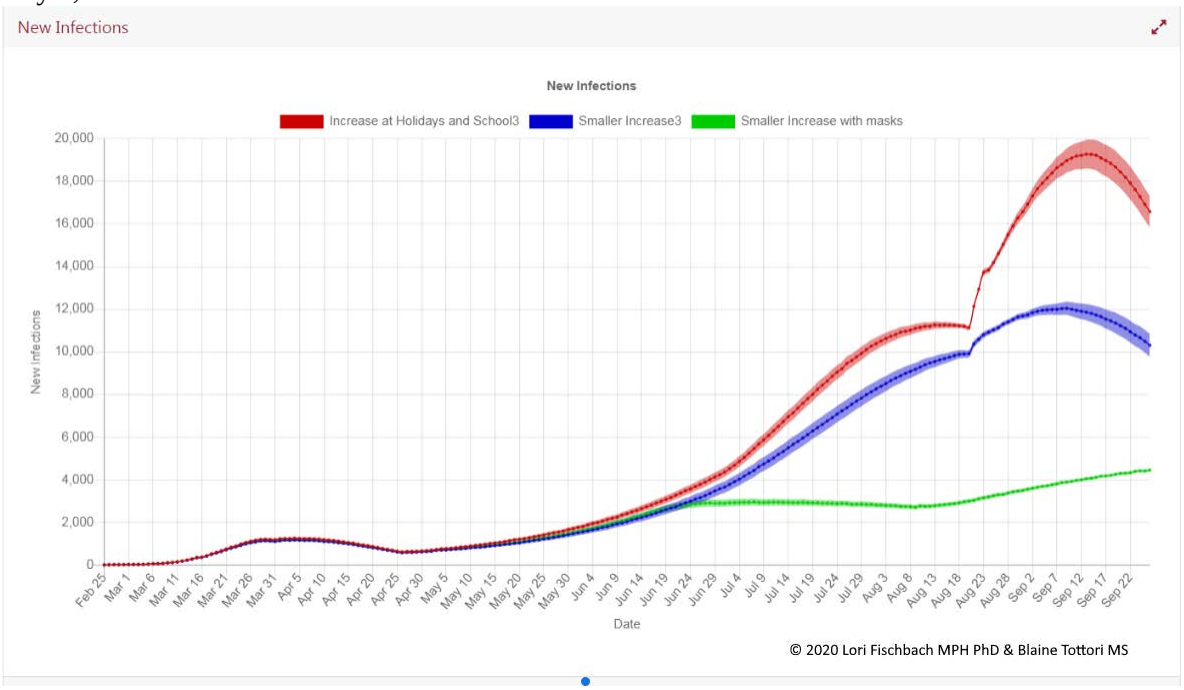


Time series models. As shown above, the times series model is based on community infections, excluding infections occurring in prisons and nursing homes. The model predicts confirmed cases in the state of Arkansas using data through different time periods. Predictions for the number of cases in the state using the first 25 days of data were at approximately 20,000 on July 13th. Predictions for the number of cases based on the 75-day data for the same decreased to around 8,000, consistent with the social distancing measures taken in the state. Following the loosening of social distancing measures, we see a large increase in confirmed cases that deviates significantly from trend. The predicted number of cases are rising and expected to be above 27,000 by July 13.

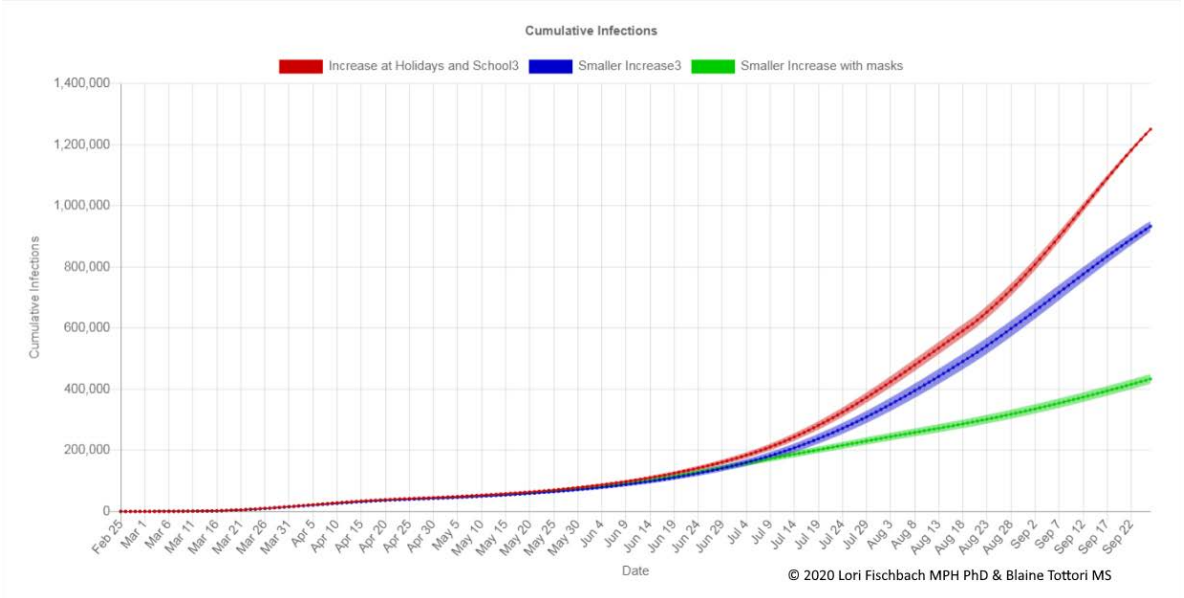
The increase in actual and predicted cases is due to the relaxing of social distancing regulations. Previously, we thought the number of increase cases was associated with increased testing. As shown on the previous page, predicted deaths from covid-19 have increased off trend as of this reporting period, suggesting a real increase in coronavirus infections and resulting deaths.

Simulations. Comparing total (detected and undetected) cases and deaths in Arkansas with 1) increased spread, 2) a smaller increased **spread** on these holiday weekends and at the start of the school year, and 3) a smaller increased spread and most people wearing masks to lower the infectivity and then slightly more infectivity (but still lower than without masks) when colleges/schools resume in-person instruction.

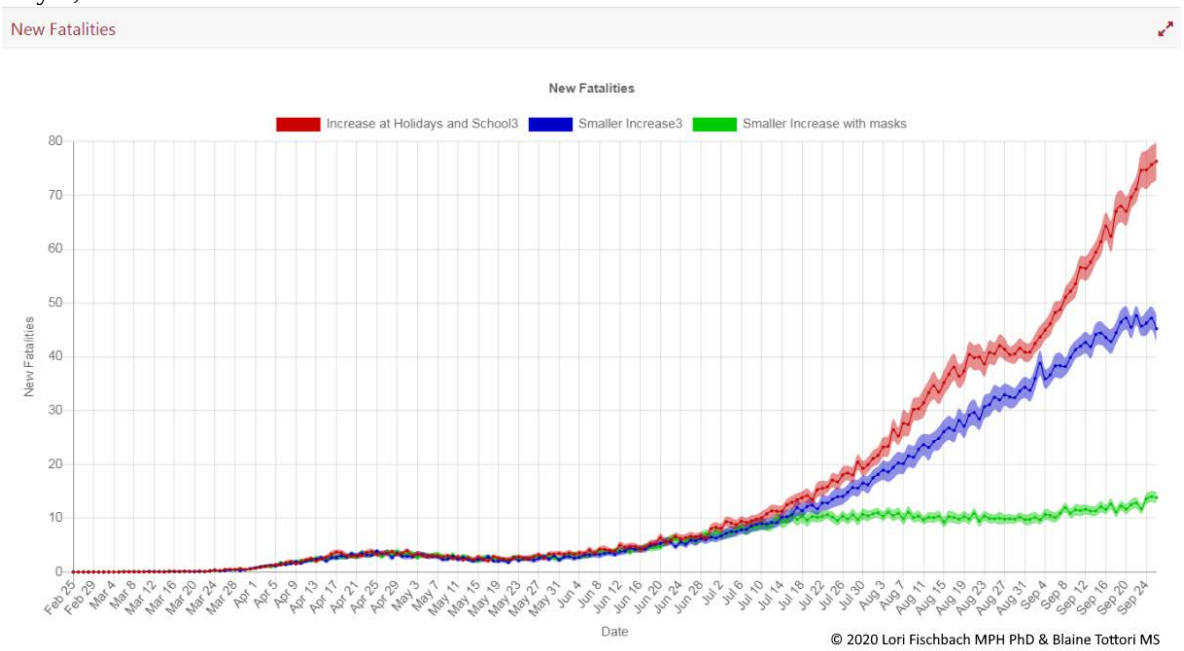
July 2, 2020 Simulation of New Infections:



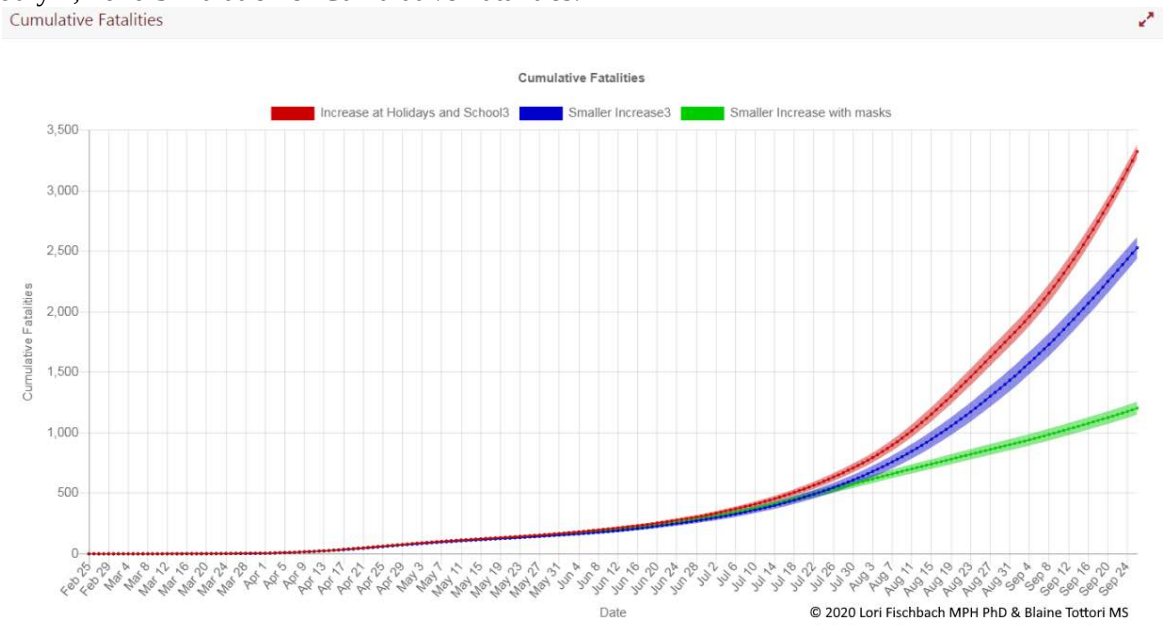
July 2, 2020 Simulation of Cumulative Infections:



July 2, 2020 Simulation of New Fatalities:



July 2, 2020 Simulation of Cumulative Fatalities:



Assumptions used for all models:

(i) February 25 to March 15 - No social distancing.

(ii) March 16 to March 31 – Limited mitigation implemented.

(iii) April 1 to April 27 - Greater mitigation implemented to include little inter-state and international travel, high number of people working at home, masks recommended, and 80% of vulnerable populations shelter-in-place.

(iv) April 27 – May 20 – Phase I re-opening announced

(iv) May 21– May 24 – Graduation parties, other social activities and some travel occur.

(v) May 25 – July 1 & July 10 – August 17 – Some socializing occurs, while others stay home. Some wear masks.

(vi) July 2 – July 9 – 4th of July parties and travel occurs over the weekend.

(vii) August 18 – August 24 - College students return to campuses. Local schools.