



Cochise Health  
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## *The Reproductive Number of SARS-CoV-2 in Cochise County AZ:*

### *A Stratified Review*

Mark Wager, December 2020

COVID-19 has affected many people's lives around the globe in 2020, but the rate at which the virus is spread varies depending on many factors including geographic location and social distancing policies. Understanding the basic reproductive number ( $R_0$ ) for COVID-19 can help locate hot spots where viral transmission is most high, helping public health leaders to know the extent of an epidemic in their community and where to focus intervention efforts. Data reported to the Arizona Department of Health Services on COVID-19 case numbers in Cochise County from March through November 2020 were analyzed to determine the  $R_0$  on a county level and individual city level.  $R_0$  was also calculated for pre-Arizona economic shutdown orders, during the Arizona shutdown, over the summer, while schools were reopening, and during the fall season. On a county level, the mean  $R_0$  for Cochise County was 1.04, ranging from a max  $R_0$  of 2.00 on some days to a min of 0.47 on other days. Sierra Vista had the highest individual city mean  $R_0$  of 1.14, ranging from a max of 2.20 to a min of 1.00 during the year.

### **Introduction**

COVID-19 (Coronavirus Disease 2019) is an illness caused by the severe acute respiratory coronavirus 2 (SARS-CoV-2). First discovered in Wuhan City, China in December 2019, it has caused the fifth worldwide pandemic since the flu pandemic of 1918 (Liu et al., 2020). One important metric for understanding the transmissibility or contagiousness of viruses is  $R_0$ , the basic reproductive number (Delamater et al., 2019). Essentially, the  $R_0$  value equates to the additional cases that will arise in a susceptible population after contact with one infectious case (Dietz, 1993). If  $R_0 > 1$ , the virus is expected to spread. If  $R_0 < 1$ , the virus is expected to eventually disappear (Delamater et al., 2019).

$R_0$  can vary though if pathogen transmission is affected by social, behavioral, environmental, or biological factors; it can vary over time and location (Delamater et al., 2019). For this reason, although it may be beneficial to get an overall mean of  $R_0$  across large geographical areas, it is also important to focus in on specific communities to locate hot spots where intervention efforts should be centered. Furthermore, it would also prove beneficial to look at how  $R_0$  changes by month or timespan. Doing so will help to understand what interventions may work to prevent the continued spread of the infectious agent.

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There have been many statistical models generated to predict  $R_0$ , though each have their benefit and limitations. The gold standard for calculating  $R_0$  is an individual-level model through effective contact tracing where close contacts of an infectious individual are recorded (Pandit, 2020). The number of the number of secondary (tertiary, etc.) cases are then averaged. However, this method has its limitations where contact tracing fails to record information on all close contacts either due to interviewer limitations, forgetfulness of the infected case, or inability to contact the case. For this reason, the calculations provided in this paper will follow a population-level model.

## **Methods**

A population-level model is the ratio of the infection rate of a population to the population's recovery rate (Breban et al, 2007). It is an average of the change in infected members of the population from day to day across the timespan of the presence of the virus (Pandit, 2020). In Arizona, COVID-19 cases are first diagnosed by physicians or pharmacists through a series of PCR or antigen tests, which are then reported to the Arizona Department of Health Services (ADHS) and local county health departments. Members of the county health department COVID-19 Case Investigations Team then contact these diagnosed cases to provide information, conduct contact tracing, and note final disposition status of the case (e.g., survived or died). Information is logged into the ADHS Medical Electronic Disease Surveillance Intelligence System (MEDSIS) for later follow-up or analysis.

This analysis aimed to quantify  $R_0$  based on month and city of Cochise County, Arizona. Furthermore, to gauge the transmission spread during different times of the year,  $R_0$  was also calculated over five different timespan events of the year 2020: from time of first case to March 30<sup>th</sup>, 2020 (the time of the AZ economic shutdown), the span of the AZ economic shutdown (April 1<sup>st</sup> – May 15<sup>th</sup>, 2020), the summer wave of COVID cases (May 16<sup>th</sup> – July 31<sup>st</sup>, 2020), the approximate reopening time of Cochise County schools (August – September, 2020), and the fall wave of COVID cases (October – November, 2020). The total  $R_0$  for all of Cochise County was then averaged.

Statistical software used for this analysis was SAS University Edition. COVID-19 case data was exported from MEDSIS and de-identified. Since the data analyzed was de-identified and had no personal information included, no IRB approval was needed for this review. Patients that were listed as “not a case” or “suspect” were excluded to promote a confident  $R_0$  value based only on confirmed PCR or probable antigen cases. Test date for confirmed cases were then grouped by month and timeframe of events listed above. Cases were also organized by city of residence, and cases that lived in cities outside of Cochise County were excluded. Frequencies of case diagnosis were then exported to Excel, where rate of infection and rate of recovery were then calculated. The Centers for Disease Control (CDC, 2020) have defined that cases with moderate COVID-19 symptoms may remain infectious for up to 10 days since onset of symptoms. For this analysis, all cases were presumed to be infectious for at least 10 days after



symptom onset. Equation 1 illustrates the daily basic  $R_0$  calculation, where  $\beta$  = infection rate and  $\mu$  = recovery rate.  $R_0$  was then averaged over the course of each month, event, city, and the entire county.

$$\text{Equation 1: } R_0 = \frac{\beta}{\mu}$$

## Results

Table 1 presents the total number of confirmed COVID-19 cases in each respective city of Cochise County. For simplicity, analysis of  $R_0$  by city was only analyzed for cities which had 50 or more cases during the timeframe of March 12<sup>th</sup>, 2020 (date of the first confirmed COVID-19 case in Cochise County) through November 30<sup>th</sup>, 2020. Table 2 presents the calculated  $R_0$  for Cochise County AZ. Table 3 presents  $R_0$  for Benson, Bisbee, and Douglas AZ, Table 4 presents  $R_0$  for Fort Huachuca, Hereford, and Huachuca City AZ, Table 5 presents  $R_0$  for Naco, Pirtleville, and Sierra Vista AZ, and Table 6 presents  $R_0$  for Willcox AZ. Each table is stratified by month, event, and the year leading up to November 30<sup>th</sup>. The mean  $R_0$  over these timeframes is presented along with the median, minimum, and maximum daily  $R_0$  values within those corresponding timeframes.

Table 1: Number of COVID-19 cases for each city of Cochise County from March 12<sup>th</sup> – November 30<sup>th</sup>, 2020, and their corresponding % of Cochise County cases.

City	Number of COVID-19 Cases	% of all Cochise County Cases
Benson	141	3.43
Bisbee	159	3.87
Bowie	14	0.34
Cochise	17	0.41
Douglas	1992	48.48
Dragoon	5	0.12
Elfrida	29	0.71
Fort Huachuca	65	1.58
Hereford	119	2.90
Huachuca City	51	1.24
McNeal	18	0.44
Naco	92	2.24
Pearce	29	0.71
Pirtleville	93	2.26
Pomerene	3	0.07
Saint David	43	1.05
San Simon	23	0.56
Sierra Vista	738	17.96
Sunsites	2	0.05
Tombstone	21	0.51
Willcox	451	10.98
Winchester Mountains	1	0.02
Unknown City	3	0.07

Table 2: Mean  $R_0$  and median, min, and max daily  $R_0$  for COVID-19 in Cochise County AZ, stratified by year total through November 30<sup>th</sup>, 2020, month, and event.

	Mean $R_0$ (SD)	Median $R_0$	Min $R_0$	Max $R_0$
<i>Cochise County</i>				
March 12 <sup>th</sup> – Nov. 30 <sup>th</sup>	1.04 (0.17)	1.01	0.47	2.00
Month				
March	1.15 (0.32)	1.00	1.00	2.00
April	1.00 (0.23)	1.00	0.71	1.86
May	1.11 (0.23)	1.08	0.75	2.00
June	1.05 (0.05)	1.05	0.96	1.14
July	0.98 (0.07)	0.98	0.85	1.17
August	0.97 (0.19)	0.98	0.47	1.74
September	1.02 (0.11)	1.01	0.79	1.27
October	1.05 (0.09)	1.04	0.90	1.34



Event	November	1.05 (0.08)	1.05	0.91	1.27
	Pre-AZ Shutdown	1.15 (0.32)	1.00	1.00	2.00
	AZ Shutdown	1.03 (0.25)	1.00	0.71	2.00
	1 <sup>st</sup> Wave (Post-AZ Shutdown)	1.04 (0.11)	1.03	0.85	1.70
	Back-to-School	1.00 (0.16)	1.00	0.47	1.74
	2 <sup>nd</sup> Wave (Fall)	1.05 (0.09)	1.04	0.90	1.34

Abbreviations: (SD) Standard Deviation

Table 3: Mean R0 and median, min, and max daily R0 for COVID-19 in Benson, Bisbee, and Douglas AZ, stratified by year total through November 30<sup>th</sup>, 2020, month, and event.

		Mean R0 (SD)	Median R0	Min R0	Max R0
<i>Benson</i>					
	March 12 <sup>th</sup> – Nov. 30 <sup>th</sup>	1.03 (0.27)	1.00	0.00	3.00
	Month				
	March	0.00 (0.00)	0.00	0.00	0.00
	April	0.98 (0.28)	1.00	0.00	2.00
	May	1.04 (0.21)	1.00	0.67	2.00
	June	1.10 (0.23)	1.00	0.80	2.00
	July	0.95 (0.15)	0.95	0.70	1.33
	August	0.97 (0.32)	1.00	0.00	2.00
	September	1.07 (0.42)	1.00	0.50	3.00
	October	1.03 (0.30)	1.00	0.00	2.00
	November	1.08 (0.25)	1.00	0.75	2.00
	Event				
	Pre-AZ Shutdown	1.00 (0.00)	1.00	1.00	1.00
	AZ Shutdown	0.99 (0.23)	1.00	0.00	2.00
	1 <sup>st</sup> Wave (Post-AZ Shutdown)	1.03 (0.22)	1.00	0.67	2.00
	Back-to-School	1.02 (0.38)	1.00	0.00	3.00
	2 <sup>nd</sup> Wave (Fall)	1.06 (0.27)	1.00	0.00	2.00
<i>Bisbee</i>					
	March 12 <sup>th</sup> – Nov. 30 <sup>th</sup>	1.02 (0.29)	1.00	0.00	3.00
	Month				
	March	1.00 (0.00)	1.00	1.00	1.00
	April	0.97 (0.18)	1.00	0.00	1.00
	May	1.07 (0.21)	1.00	1.00	2.00
	June	1.06 (0.46)	1.00	0.00	3.00
	July	0.97 (0.16)	0.95	0.57	1.25
	August	0.90 (0.28)	1.00	0.00	1.25
	September	1.08 (0.26)	1.00	0.80	2.00
	October	1.03 (0.48)	1.00	0.00	3.00
	November	1.08 (0.21)	1.07	0.75	1.63
	Event				
	Pre-AZ Shutdown	1.00 (0.00)	1.00	1.00	1.00
	AZ Shutdown	0.98 (0.15)	1.00	0.00	1.00
	1 <sup>st</sup> Wave (Post-AZ Shutdown)	1.04 (0.33)	1.00	0.00	3.00
	Back-to-School	0.99 (0.28)	1.00	0.00	2.00
	2 <sup>nd</sup> Wave (Fall)	1.06 (0.37)	1.00	0.00	3.00
<i>Douglas</i>					
	March 12 <sup>th</sup> – Nov. 30 <sup>th</sup>	1.04 (0.27)	1.00	0.00	3.00
	Month				
	March	1.13 (0.35)	1.00	1.00	2.00
	April	1.05 (0.47)	1.00	0.50	3.00
	May	1.10 (0.32)	1.00	0.00	2.00



	June	1.06 (0.11)	1.04	0.93	1.46
	July	0.98 (0.09)	0.98	0.81	1.26
	August	0.97 (0.32)	0.99	0.35	2.44
	September	1.05 (0.29)	1.00	0.46	1.75
	October	1.08 (0.14)	1.05	0.79	1.50
	November	1.05 (0.10)	1.03	0.89	1.40
Event	Pre-AZ Shutdown	1.13 (0.35)	1.00	1.00	2.00
	AZ Shutdown	1.05 (0.45)	1.00	0.00	3.00
	1 <sup>st</sup> Wave (Post-AZ Shutdown)	1.04 (0.14)	1.02	0.81	1.75
	Back-to-School	1.01 (0.30)	1.00	0.35	2.44
	2 <sup>nd</sup> Wave (Fall)	1.06 (0.12)	1.04	0.79	1.50

Abbreviations: (SD) Standard Deviation

Table 4: Mean R0 and median, min, and max daily R0 for COVID-19 in Fort Huachuca, Hereford, and Huachuca City AZ, stratified by year total through November 30<sup>th</sup>, 2020, month, and event.

		Mean R0 (SD)	Median R0	Min R0	Max R0
<i>Fort Huachuca</i>					
	March 12 <sup>th</sup> – Nov. 30 <sup>th</sup>	1.01 (0.29)	1.00	0.00	3.00
	Month				
	March	0.00 (0.00)	0.00	0.00	0.00
	April	0.00 (0.00)	0.00	0.00	0.00
	May	0.96 (0.23)	1.00	0.00	1.50
	June	1.09 (0.27)	1.00	0.75	2.00
	July	0.96 (0.21)	1.00	0.50	1.50
	August	1.02 (0.44)	1.00	0.00	3.00
	September	0.93 (0.30)	1.00	0.00	1.50
	October	1.01 (0.36)	1.00	0.00	2.00
	November	1.13 (0.35)	1.00	0.50	2.33
	Event				
	Pre-AZ Shutdown	0.00 (0.00)	0.00	0.00	0.00
	AZ Shutdown	0.00 (0.00)	0.00	0.00	0.00
	1 <sup>st</sup> Wave (Post-AZ Shutdown)	1.01 (0.27)	1.00	0.00	2.00
	Back-to-School	0.97 (0.38)	1.00	0.00	3.00
	2 <sup>nd</sup> Wave (Fall)	1.07 (0.35)	1.00	0.00	2.33
<i>Hereford</i>					
	March 12 <sup>th</sup> – Nov. 30 <sup>th</sup>	1.03 (0.34)	1.00	0.00	3.50
	Month				
	March	1.00 (0.00)	1.00	1.00	1.00
	April	0.98 (0.28)	1.00	0.00	2.00
	May	0.97 (0.18)	1.00	0.00	1.00
	June	1.09 (0.38)	1.00	0.75	3.00
	July	1.00 (0.26)	1.00	0.63	2.00
	August	0.97 (0.22)	1.00	0.00	1.50
	September	1.07 (0.40)	1.00	0.33	2.00
	October	1.07 (0.48)	1.00	0.33	3.00
	November	1.15 (0.47)	1.10	0.57	3.50
	Event				
	Pre-AZ Shutdown	1.00 (0.00)	1.00	1.00	1.00
	AZ Shutdown	0.99 (0.23)	1.00	0.00	2.00
	1 <sup>st</sup> Wave (Post-AZ Shutdown)	1.02 (0.31)	1.00	0.00	3.00
	Back-to-School	1.02 (0.32)	1.00	0.00	2.00
	2 <sup>nd</sup> Wave (Fall)	1.11 (0.47)	1.00	0.33	3.50



<i>Huachuca City</i>						
Month	March 12 <sup>th</sup> – Nov. 30 <sup>th</sup>	1.02 (0.41)	1.00	0.00	6.00	
	March	0.00 (0.00)	0.00	0.00	0.00	
	April	1.00 (0.00)	1.00	1.00	1.00	
	May	0.97 (0.18)	1.00	0.00	1.00	
	June	1.04 (0.37)	1.00	0.00	2.00	
	July	1.04 (0.33)	1.00	0.50	2.33	
	August	0.94 (0.20)	1.00	0.00	1.00	
	September	1.02 (0.35)	1.00	0.00	2.00	
	October	0.95 (0.20)	1.00	0.00	1.00	
	November	1.25 (0.98)	1.00	0.40	6.00	
	Event	Pre-AZ Shutdown	1.00 (0.00)	1.00	1.00	1.00
		AZ Shutdown	0.98 (0.15)	1.00	0.00	1.00
		1 <sup>st</sup> Wave (Post-AZ Shutdown)	1.03 (0.31)	1.00	0.00	2.33
Back-to-School		0.98 (0.29)	1.00	0.00	2.00	
2 <sup>nd</sup> Wave (Fall)		1.10 (0.71)	1.00	0.00	6.00	

Abbreviations: (SD) Standard Deviation

Table 5: Mean R0 and median, min, and max daily R0 for COVID-19 in Naco, Pirtleville, and Sierra Vista AZ, stratified by year total through November 30<sup>th</sup>, 2020, month, and event.

		Mean R0 (SD)	Median R0	Min R0	Max R0	
<i>Naco</i>						
Month	March 12 <sup>th</sup> – Nov. 30 <sup>th</sup>	1.02 (0.23)	1.00	0.00	2.33	
	March	0.00 (0.00)	0.00	0.00	0.00	
	April	0.00 (0.00)	0.00	0.00	0.00	
	May	0.00 (0.00)	0.00	0.00	0.00	
	June	1.07 (0.15)	1.00	0.90	1.50	
	July	0.98 (0.23)	1.00	0.33	1.50	
	August	0.93 (0.36)	1.00	0.00	2.00	
	September	1.00 (0.00)	1.00	1.00	1.00	
	October	1.02 (0.40)	1.00	0.00	2.33	
	November	1.13 (0.29)	1.00	0.75	2.00	
	Event	Pre-AZ Shutdown	0.00 (0.00)	0.00	0.00	0.00
		AZ Shutdown	0.00 (0.00)	0.00	0.00	0.00
		1 <sup>st</sup> Wave (Post-AZ Shutdown)	1.02 (0.17)	1.00	0.33	1.50
Back-to-School		0.96 (0.25)	1.00	0.00	2.00	
2 <sup>nd</sup> Wave (Fall)		1.08 (0.35)	1.00	0.00	2.33	
<i>Pirtleville</i>						
Month	March 12 <sup>th</sup> – Nov. 30 <sup>th</sup>	1.01 (0.26)	1.00	0.00	2.00	
	March	0.00 (0.00)	0.00	0.00	0.00	
	April	0.00 (0.00)	0.00	0.00	0.00	
	May	0.98 (0.27)	1.00	0.00	2.00	
	June	1.12 (0.38)	1.00	0.40	2.00	
	July	0.99 (0.22)	1.00	0.50	1.83	
	August	0.92 (0.26)	1.00	0.00	1.00	
	September	0.97 (0.18)	1.00	0.00	1.00	
	October	1.07 (0.41)	1.00	0.00	2.00	
	November	1.04 (0.11)	1.00	0.88	1.33	
	Event	Pre-AZ Shutdown	0.00 (0.00)	0.00	0.00	0.00
		AZ Shutdown	1.02 (0.15)	1.00	1.00	2.00
		1 <sup>st</sup> Wave (Post-AZ Shutdown)	1.02 (0.31)	1.00	0.00	2.00



	Back-to-School	0.94 (0.23)	1.00	0.00	1.00
	2 <sup>nd</sup> Wave (Fall)	1.06 (0.30)	1.00	0.00	2.00
<i>Sierra Vista</i>					
	March 12 <sup>th</sup> – Nov. 30 <sup>th</sup>	1.14 (0.20)	1.09	1.00	2.20
	Month				
	March	1.18 (0.37)	1.00	1.00	2.00
	April	1.13 (0.22)	1.00	1.00	2.00
	May	1.19 (0.31)	1.00	1.00	2.00
	June	1.14 (0.08)	1.13	1.00	1.30
	July	1.10 (0.07)	1.08	1.00	1.26
	August	1.11 (0.11)	1.09	1.00	1.36
	September	1.12 (0.24)	1.00	1.00	2.20
	October	1.13 (0.09)	1.11	1.00	1.31
	November	1.17 (0.12)	1.13	1.02	1.50
	Event				
	Pre-AZ Shutdown	1.18 (0.37)	1.00	1.00	2.00
	AZ Shutdown	1.14 (0.27)	1.00	1.00	2.00
	1 <sup>st</sup> Wave (Post-AZ Shutdown)	1.14 (0.14)	1.11	1.00	2.00
	Back-to-School	1.12 (0.18)	1.08	1.00	2.20
	2 <sup>nd</sup> Wave (Fall)	1.15 (0.11)	1.13	1.00	1.50

Abbreviations: (SD) Standard Deviation

Table 6: Mean R0 and median, min, and max daily R0 for COVID-19 in Willcox AZ, stratified by year total through November 30<sup>th</sup>, 2020, month, and event.

	Mean R0 (SD)	Median R0	Min R0	Max R0	
<i>Willcox</i>					
	March 12 <sup>th</sup> – Nov. 30 <sup>th</sup>	1.03 (0.25)	1.00	0.00	3.00
	Month				
	March	0.00 (0.00)	0.00	0.00	0.00
	April	1.00 (0.00)	1.00	1.00	1.00
	May	1.09 (0.38)	1.00	0.00	2.33
	June	1.03 (0.14)	1.04	0.60	1.30
	July	1.00 (0.14)	0.96	0.81	1.46
	August	0.95 (0.44)	1.00	0.00	3.00
	September	1.03 (0.24)	1.00	0.50	1.50
	October	1.11 (0.26)	1.00	0.67	2.00
	November	1.04 (0.14)	1.05	0.80	1.49
	Event				
	Pre-AZ Shutdown	0.00 (0.00)	0.00	0.00	0.00
	AZ Shutdown	0.98 (0.15)	1.00	0.00	1.00
	1 <sup>st</sup> Wave (Post-AZ Shutdown)	1.06 (0.24)	1.00	0.60	2.33
	Back-to-School	0.99 (0.36)	1.00	0.00	3.00
	2 <sup>nd</sup> Wave (Fall)	1.08 (0.21)	1.02	0.67	2.00

Abbreviations: (SD) Standard Deviation

## Discussion

Nine cities and one military base in Cochise County had 50 or more COVID-19 cases confirmed between March 12<sup>th</sup> and November 30<sup>th</sup>, 2020. The first confirmed case occurred on March 12<sup>th</sup>, 2020 in Sierra Vista, though Benson, Huachuca City, and Willcox did not experience



their first cases until April. Fort Huachuca and Pirtleville did not have their first cases until May, and Naco did not have its first case until June. Bisbee did have cases in March but not in April, Naco did not have any cases during September, and Huachuca City did not have any cases during the months of August and October. This indicates that in the months following when they again had confirmed cases of COVID-19, SARS-CoV-2 was once again re-introduced to these cities after being successfully eliminated or individuals with the virus were not tested for COVID-19. It is interesting to note that almost 49 percent of all COVID-19 cases in Cochise County were based out of the city of Douglas.

Other studies have shown the mean  $R_0$  for the United States around 1.61, and other countries to possibly be up to 2.79 (Al-Reei, 2020). Despite the fast spread of COVID-19, however, mean  $R_0$  for Cochise County was calculated at 1.04. Nevertheless, other  $R_0$  models have found the mean reproductive number for COVID-19 to also range around 1.00 (Virol, 2020, Elkenberry et al., 2020). Prior to the April 1<sup>st</sup> Arizona economic shutdown, the mean  $R_0$  for Cochise County was calculated to be 1.15, and the mean  $R_0$  of during the AZ shutdown was calculated at 1.03, illustrating the effectiveness of stay-at-home orders. During the time of school re-openings between August and September 2020 the county-wide mean  $R_0$  was figured at 1.00, which suggests the virus was not spreading fast among individuals but spread was not slowing towards eradication either. The Fall season wave of COVID-19 cases did bring  $R_0 > 1$  again due to a quickened spread. These trends are similar throughout each individual city of Cochise County.

As noted previously, the value of  $R_0$  represents the number of secondary cases that can arise after contact with one infectious case. To put this in perspective, an  $R_0$  of 1.05 could be interpreted as the equivalent of each infected case only infecting one other person during their period of infectivity, and after 20 cases have been infected, two people were then infected by the 21<sup>st</sup> case. This number is an average across all cases, for where one case may infect two other people another case may not infect any. These calculated values may be an underestimate for several reasons. This analysis only included confirmed and probable cases, not suspect cases. This may of course have excluded positive cases that did not have a confirmed diagnosis. Furthermore, untested/undiagnosed cases would not have been reported to the County Health Department and therefore would not have been included in the calculation. For this analysis, an infectious period of 10 days was assumed for all patients, but other more severe cases are expected to have an infectious period of up to 20 days (CDC, 2020). This could have extended the  $R_0$  to be higher due to a longer time of infectivity.

The purpose for including the minimum and maximum  $R_0$  value was to identify whether there were days when spread of COVID-19 may have been higher than others. For Cochise County as a whole,  $R_0$  was found to be as low as 0.47 on certain days, while ranging up to as high as 2.00 on other days. These of course were means over the whole county, and while some cities as mentioned above had experienced an  $R_0$  of zero on certain days, four cities experienced an  $R_0$  of 3.00 on at least one day during various months: Douglas (April), Fort Huachuca



(August), Benson (September), and Bisbee (June and October). In the month of November, Hereford had a daily max  $R_0$  of 3.50 and Huachuca City had a daily max  $R_0$  of 6.00. If caught in a timely manner, these dates are important for identifying hot spots of COVID-19 spread in these cities and thus areas in need of intervention or more extreme quarantine precautions. Dates when the  $R_0$  is higher than average could be viewed as dates when COVID-19 is spread to more contacts than usual and therefore more secondary cases can be expected to appear in subsequent days. This will of course extend the length of time SARS-CoV-2 will be actively circulating in the population.

Limitations of the population-level model include limits on the amount of information provided. If individuals infected with COVID-19 are not tested or diagnosed (e.g., they believe their symptoms are the result of a cold, allergies, etc.), the data is not as likely to be accurate. This model also assumes that exposure to COVID-19 for all members of Cochise County occurred within the boundaries of the county, which we know to not be true since many cases commonly reported visiting friends or family in other locations within Arizona (e.g., Tucson and Phoenix). Douglas, a border town with Mexico, also had residents reporting often visiting friends or family members in the neighboring Mexico border town of Agua Prieta. Furthermore, many cases were lost to follow-up, and the final disposition of each of these cases are assumed to be “survived” unless medical records reported through MEDSIS list them as deceased.



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