COVID-19 IN THE AMERICAN SOUTHWEST

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I would like to thank my parents for the encouragement and support they’ve given me over the years.

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Abstract

This paper examines the progress of the COVID-19 virus through the Southwestern United States and the factors that raised or lowered the infection rates with a particular focus on the response of state and county governments. In it, this project shows that preventative measures being implemented only partially changed the rate of infection in the study area and that seasonal trends impacted the spread of the disease as well. This paper will also show that there were two major seasonal spikes in COVID-19, a summer spike and a winter spike, and prove that the temperature fluctuations associated with the changing seasons triggered surges in COVID-19 infections.

Ethics Statement

The principle ethical concerns with GIS practice involve producing complete, accurate, and truthful information that's not misleading or capable of creating a false impression. Joseph Kerski points out that maps still are trusted sources of information and abusing that to mislead others is a violation of GIS ethics. Lying on a map, either by distorting the truth, omitting crucial details, or outright fabricating details is easily done in an era when anyone can be a map producer and, as such, adhering to a solid code of ethics is important for a GIS professional. The ASPRS Code of Ethics on the other hand revolves around the way in which a GIS Professional should conduct themselves in their business affairs. It is a valuable set of guidelines for how an individual working in a GIS related field or position should behave and includes important points such as doing your job faithfully, only doing jobs that you're capable of taking on, giving credit to others for their professional contributions, and promoting equity in the field of GIS by "Encourage[ing] participation without regard to race, religion, gender, disability, age, national origin, political affiliation, sexual orientation, gender identity, or gender expression." (ASPRS Code of Ethics). There are several ethical concerns involved with this capstone project. This project involves sensitive political topics, COVID-19 lockdowns and masking guidelines, and involves an issue that impacted the lives of millions of people around the world, namely the COVID-19 pandemic. Handling this matter maturely, responsibly, and ethically is a significant goal for this project. The information contained in this Capstone Project follows Joseph Kerski's guidelines for Ethics in GIS Technology. All the data and maps in this project are presented accurately and neutrally and none of it is skewed so that it creates a false impression in the viewer.

Introduction

The COVID-19 virus which has plagued the world for the last two years spread rapidly despite all efforts to stop it. Now that the damage is beginning to be clear, it is worthwhile to evaluate whether or not these efforts were worthwhile or effective and to consider what factors lead to the Coronavirus spreading so rapidly.

COVID-19 was first identified from in an outbreak in Wuhan, China in December of 2019 and rapidly spread throughout the nation and soon thereafter to the rest of the world. The first case in the United States was recorded on January 20th, 2020 when a man traveled back from Wuhan, China to his home in Washington state. By the middle of March, every state in America had outbreaks of their own. Many states went into lockdown and many others required masks to be worn in public places in an attempt to fight the spread of the disease. In May, 2020 Operation Warp Speed was launched in an effort to develop a vaccine for COVID-19. This effort would bear fruit in December of that year when vaccines made by Pfizer and Moderna were given emergency authorizations by the FDA and the process of vaccinating the public began.

This study looks at six states in the Southwestern United States and compares several environmental, social, and political factors to see whether any can capably explain why some states and counties had comparatively higher rates of infection than others. These states are California, Arizona, New Mexico, Colorado, Utah, and Nevada. They were selected for being in the same geographic area and thus minimizing geographic differences that might impact the spread of COVID-19.

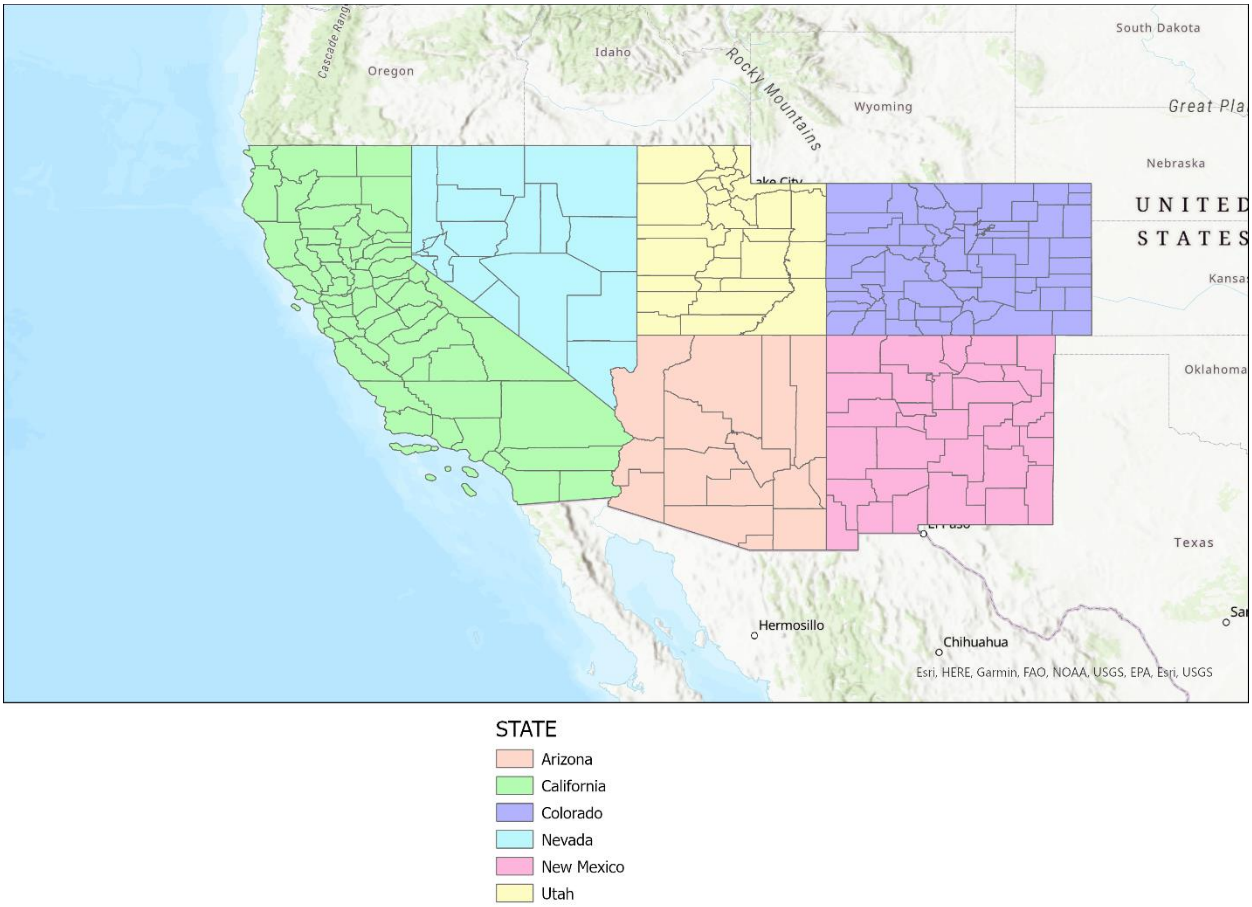

Figure 1 - Study Area

Methods and Data

Methods of Analysis, Techniques, and Justification

In order to measure the rate of infection for COVID-19 and track possible explanatory variables, this analysis isolated six states in the American southwest in order to minimize geographic differences in how the disease spreads. These six states were California, Arizona, New Mexico, Colorado, Utah, and Nevada. To study these states and the COVID-19 infection rates this study pulled information in from many different sources. This analysis also required multiple datasets together to create a massive chart with all the variables needed. The bulk of this work was done in Model Builder to simplify the process and to make sure that it could be easily replicated.

First off, the COVID-19 data itself was required to conduct this analysis. This came from USA Facts and was correlated at the County level. (USAFacts, 2022b) Some calculations were performed in Excel since they would have been too difficult to perform gracefully in Model Builder. These were used to create a chart showing the New Cases each day, calculate the Total Cases by county and by Date, and create separate charts for the six states of the study.

Once the Excel document was ready, the data was pulled into a table in ArcGIS using the Excel to Table tool. From there it was joined to the population data, the Income data, and the County GDP information, using the Join Field tool. These variables were used to test for a relationship between a county's level of wealth and the severity of the rate of infection in that county. While it was still easy and simple to do so the Average Income was calculated using the Income and Population data and the Calculate Field tool. The Calculate Field tool was also used to separate the

COUNTYFP from the FIPS code, which allowed counties to be linked up later in this process. Tangentially to this process the Temperature data was massaged and cleaned up in Excel to isolate the state abbreviations and county codes and then imported into ArcGIS through the Excel to Table feature. This feature was used twice to pull in temperature data from two separate sheets in the document. The last items needed were the county shapefiles themselves. Once all this data was inside ArcGIS it was separated by state. The Select tool and the Table Select tool were used to isolate data for Arizona, California, New Mexico, Colorado, Nevada, and Utah. Once those states were isolated, the Join Field tool was used again to link data together, connecting the infection, income, GDP, and temperature data to the shapefiles for each state. Once these were in place more calculations were conducted to find other values for analysis, population density and the number of COVID-19 infections per capita. The population density value was calculated using the population statistic and the land area that was pulled in from the shapefiles for the County. It exists to help test a hypothesis about population density being a major factor in the spread of COVID-19. A binary value was also set to represent which counties had implemented mask mandates and which did not. For states which had statewide mandates the default value to was set to 1, or TRUE. For Arizona, which didn't have a statewide mandate a Python command was used to fill in the values on the county level:

```
mask_counties = ['Gila', 'Maricopa', 'Pima', 'Santa Cruz', 'Yuma']
def mask_mandate_finder(x):
   for county in x:
      if x in mask_counties:
         return True
      else:
         return False
```

With these in place state level maps were created for visual identification of trends. However, to conduct proper analysis a further step was taken, and the data was merged together again. This was because the primary method of analysis used was the Local Bivariate Relationship tool from ArcGIS which requires a minimum number of features to conduct its analysis. The Local Bivariate Relationship tool is perfect for this study because it isolates the dependent and independent variables, tests for a relationship between the two, and checks how that relationship changes throughout the study area (ESRI, n.d.). This makes it the perfect tool for studying differences in outcomes for a complex subject matter like an infection rate. With these features combined together the data was analyzed for trends to determine why some counties were comparatively hit better or worse than others. The factors looked at were population density, temperature extremes, levels of wealth, and the presence of a mask mandate. A Generalized Linear Regression was also performed on these same features to see if any trends emerged that way. This tool looks for a relationship between the two variables regardless of regional considerations and it allows for the examination of information that was encoded in a binary format such as the presence or absence of a masking mandate. (ESRI, n.d.-a)

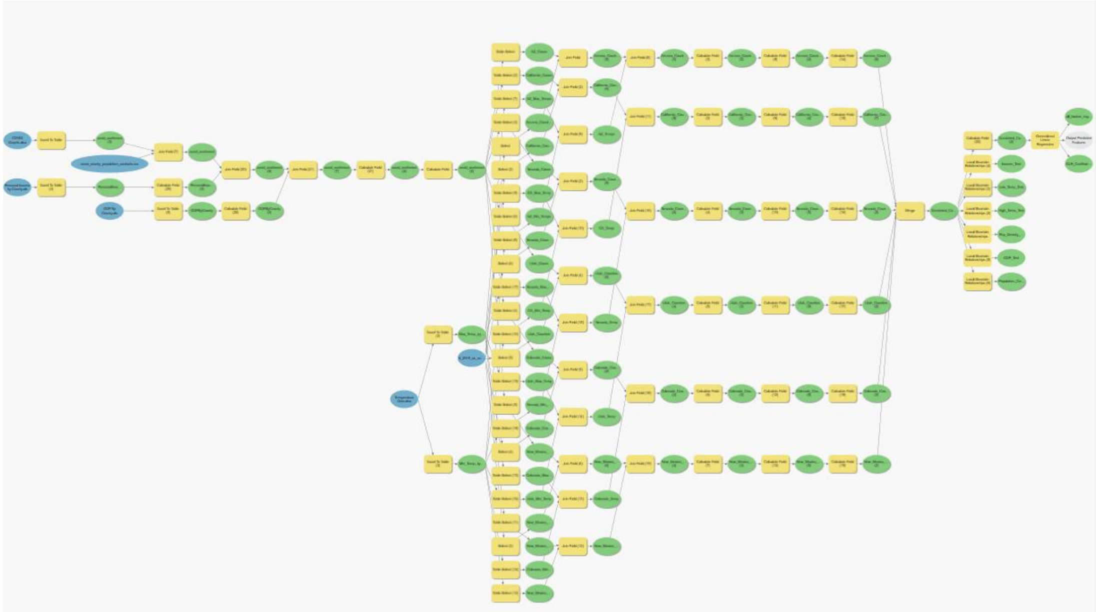

Figure 2 - ArcGIS Model Builder Steps

Finally, outside of ArcGIS, Excel was used to create several tables tracking the new cases of COVID-19 each day, by state, and comparing the exact dates where a Mask Mandate was in place to those where it was not in order to evaluate the effectiveness of these policies. Data sources are summarized in Table 1.

Table 1 - Datasets and Sources

Name	Publication	Owner	URL	Contents	Coordinate System
TIGER/Line Shapefile, 2019, nation, U.S., Current County and Equivalent National	10/12/21	US Census Bureau, Department of Commerce	https://catalog.data.gov/dataset/tiger-line-shapefile-2019-nation-u-s-current-county-and-equivalent-national-shapefile	Shapefile of the Counties and County Equivalents in the United States	NAD 1983

Shapefile					
US COVID-19 cases and deaths by state	06/27/2022	USA Facts	https://usafacts.org/visualizations/coronavirus-covid-19-spread-map	COVID-19 Transmission data by date in the United States	N/A
US County Populations	06/27/2022	USA Facts	https://usafacts.org/visualizations/coronavirus-covid-19-spread-map/	US County Populations	N/A
State Action on Coronavirus (COVID-19)	06/15/2022	National Conference on State Legislatures	https://www.ncsl.org/research/health/state-action-on-coronavirus-covid-19.aspx	Data on legislative actions	N/A
US Coronavirus vaccine tracker	05/15/2022	USA Facts	https://usafacts.org/visualizations/covid-vaccine-tracker-states/	Vaccination rate tracker	N/A
Personal Income by County	11/16/2021	Bureau of Economic Analysis	https://www.bea.gov/data/income-saving/personal-income-county-metro-and-other-areas	Contents on personal income levels by county	N/A
GDP by County	12/08/2021	Bureau of Economic Analysi	https://www.bea.gov/data/gdp/gdp-county-metro-and-other-areas	GDP by county	N/A

		s			
Climate at a Glance	08/2022	NOAA	https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/	Temperature data for the United States by county	N/A

Results

California

Inferences

From the map of California hot spots, Figure 3, it is clear that Southern California is the worst spot for COVID-19 infections. The most severe spot being Los Angeles County, where the disease spread worse than anywhere else in the state, infecting over 2,900,000 people. This is most likely due to the urban environment of the Los Angeles Metropolitan Area that dominates the county.

The safest spots in the state were the rural northern counties such as Alpine County California which suffered a mere 137 cases.

However as Alpine and Los Angelis Counties are also the least and most populous counties in the state respectively, this is not particularly useful for identifying how dangerous the disease was respectively in each state. In fact, when compared to a map of raw population numbers it's soon obvious that the alleged hot spots for COVID-19 were merely the most populous counties in California. To compare the true safety of each county a different map had to be consulted.

A map that shows the expected infections per capita is a better tool for realizing which counties in California were safe and which weren't as it allows the reader to understand the comparative risk of infection for residents of each county. When the total number of infections were compared to the actual population, a clearer picture of which counties were dangerous emerges. As Figure 6 shows, when normalizing the number of infections by each county's population previously benign looking counties can fare much worse.

This time Modoc County in the northeast of California fares the best and Kings County fares the worst. That being said, few places in California really come off well when the infection rate per capita is considered.

The southern end of California still tends to suffer worse than the northern counties do. Even dense urban counties like those found in the Bay Area do not do as badly as some counties in the south.

When the maps for Population Density and Infections per Hundred People, Figures C3 and C4 respectively, are compared there is a mismatch between them. Many of the counties that had a high population density were comparatively well off when it came to their per capita infection rate.

A statewide mask mandate was ordered by Governor Newsom on June 18th, 2020. This would last through until February 5th, 2022. (Romo, 2020) It appears that the mask mandate did reduce the growth in infections that was observed in June of 2020, however the infection rate soon spiked up again as winter began and people began spending more time indoors with each other. A similar bump was seen in the summer of 2021, despite the mask mandate being in place, and another massive spike in the winter. It seems likely that people gathering outdoors in the warm weather lead to the small seasonal spike seen each summer of the infection and people gathering indoors in winter lead to the much larger spike observed during those months. While masks had limited ability to halt the seasonal surges in infections in California, the same can’t be said for vaccines. While prior to the introduction of the vaccine infections were growing each year, after its introduction a massive decrease in the summer spike was seen in 2022. This can be attributed to California managing to get approximately 80%

of its population vaccinated by the time this spike began. (USAFacts, 2022a)

California Total Cases and Population Map

Figure 3 - California Total Cases

Figure 4 - California Population

California Population Density

Figure 5 - California Population Density

California Infections per Hundred People

Figure 6 - California Infections per Hundred People

California Infection Chart

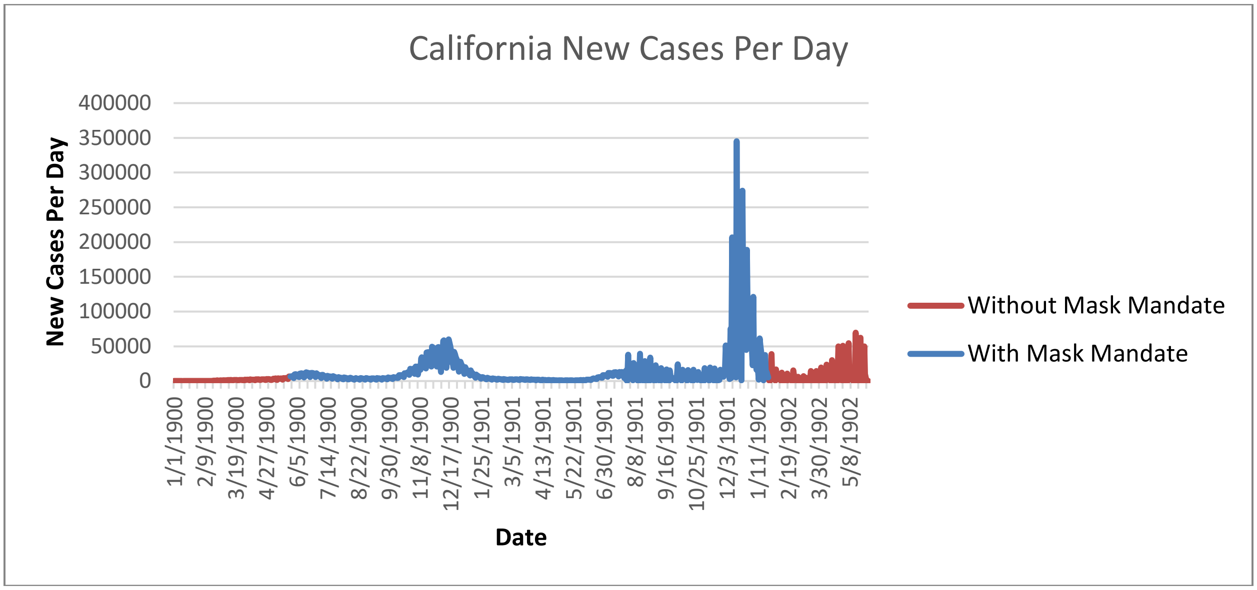

Figure 7 - California New Cases Per Day

Arizona

Inferences

Arizona's maps of the total infected, Figure 8, initially reveals a similar pattern to California where the southern end of the state got the worse end of the infection. That being said, a closer look at the data reveals that the two counties with the highest rates of infection are Maricopa and Pima counties. Those two counties are the homes of Phoenix and Tucson respectively, Arizona's two largest cities. Naturally, a high number of infections would be expected here due to the large population size by itself. Sure enough the population map, Figure 9, confirms that these counties have a high population count.

Looking at the infections when compared to each county's population size in Figure 11 reveals a more complicated picture. Here both Pima and Maricopa Counties start to look better in comparison to other Arizona counties as they both have a fairly low number of infections compared to their population. It is more noteworthy to see what counties did well and which did not. Unlike in California there does not appear to be a major difference between the urban and rural areas. There also does not appear to be any correlation between the Counties that had implemented Mask Mandates (Gila County, Maricopa County, Pima County, etc.) and counties that went without a strict mandate such as Cochise.

Examining the chart reveals that Arizona follows a similar pattern to California with a spike in the summer and a far larger spike in the winter. Interestingly for this study, no statewide mask mandate was ever issued for Arizona. As such to evaluate whether mask mandates had any effect in Arizona evaluation will be done on a county by county level to see if there's any noticeable difference between the infection rates.

Maricopa County is the best case for the mask policy since there was a county wide mask mandate in effect for the county, not just government buildings or other selected regions. Similar to California's policy, Maricopa County's policy was set in June of 2020 and didn't appear to change the summer spike that was occurring in the state at the time.

The most noticeable thing about this infection rate is how neatly it matches up with the overall state's infection rates. It almost looks like the graph scale was just shrunk down slightly to compensate for the smaller region.

Pima County (whose mask policy was set the same day as Maricopa counties) also seems to follow the same trends as the state.

For comparison, some counties that did not implement any masking mandates were examined, such as Cochise County.

While certainly much smaller than Maricopa or Pima Counties, raw numbers alone are not what is being examined here, but rather the infection patterns that emerged. The chart shows that the rises and falls of the infection rate occur regardless of whether or not a mask mandate is in place, suggesting a seasonal factor is the principle driving force in the rise and fall of these surges..

From these it can be concluded that the same seasonal trends observed in California also affect Arizona. The beginning of another summer spike can be seen developing, but it looks to have tapered off, likely due to the fact that 62% of Arizonans have been vaccinated. (USAFacts, 2022a) Once again, vaccines seem to be the key to fighting the infection.

Arizona Total Cases and Population Map

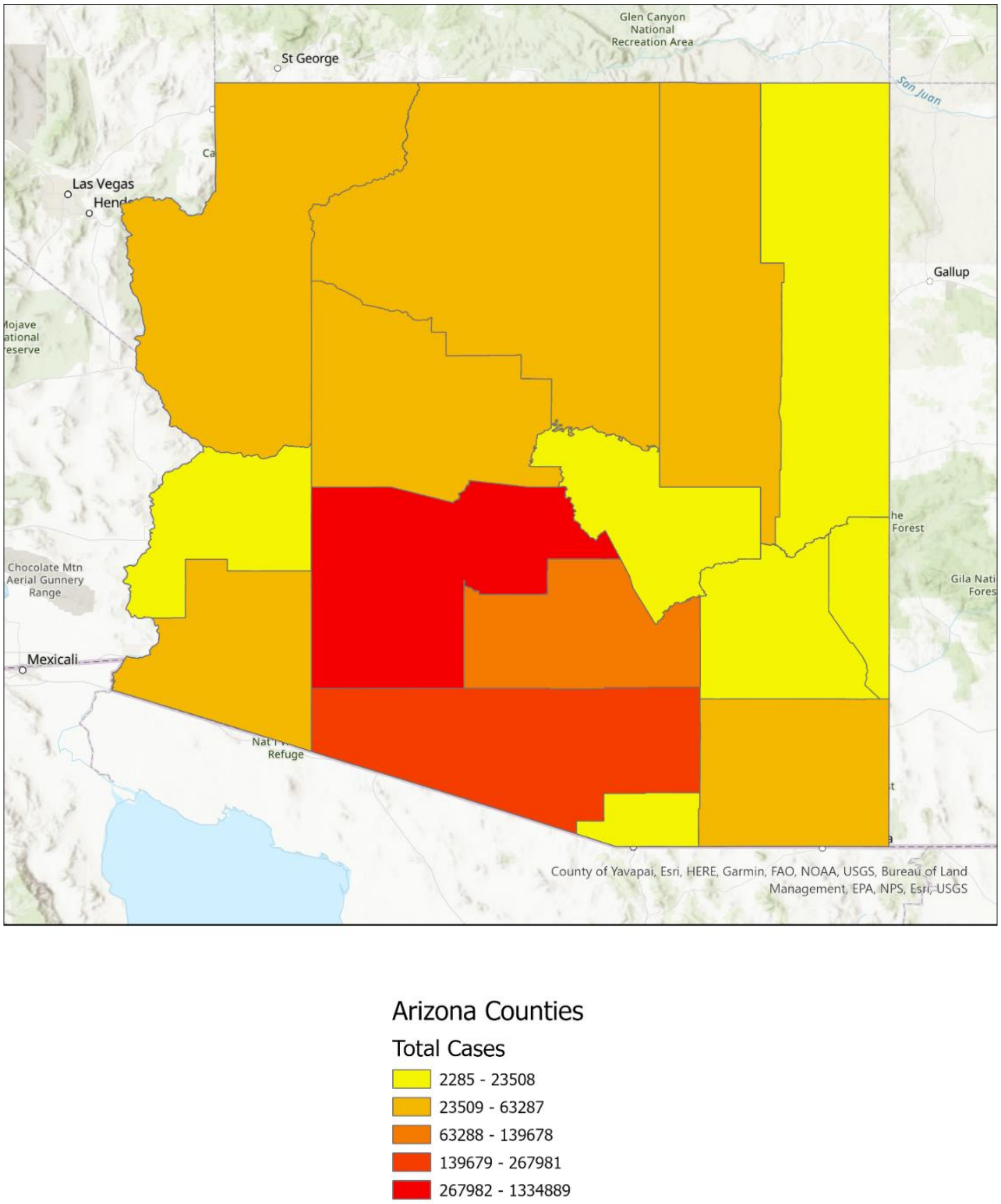

Figure 8 - Arizona Total Cases

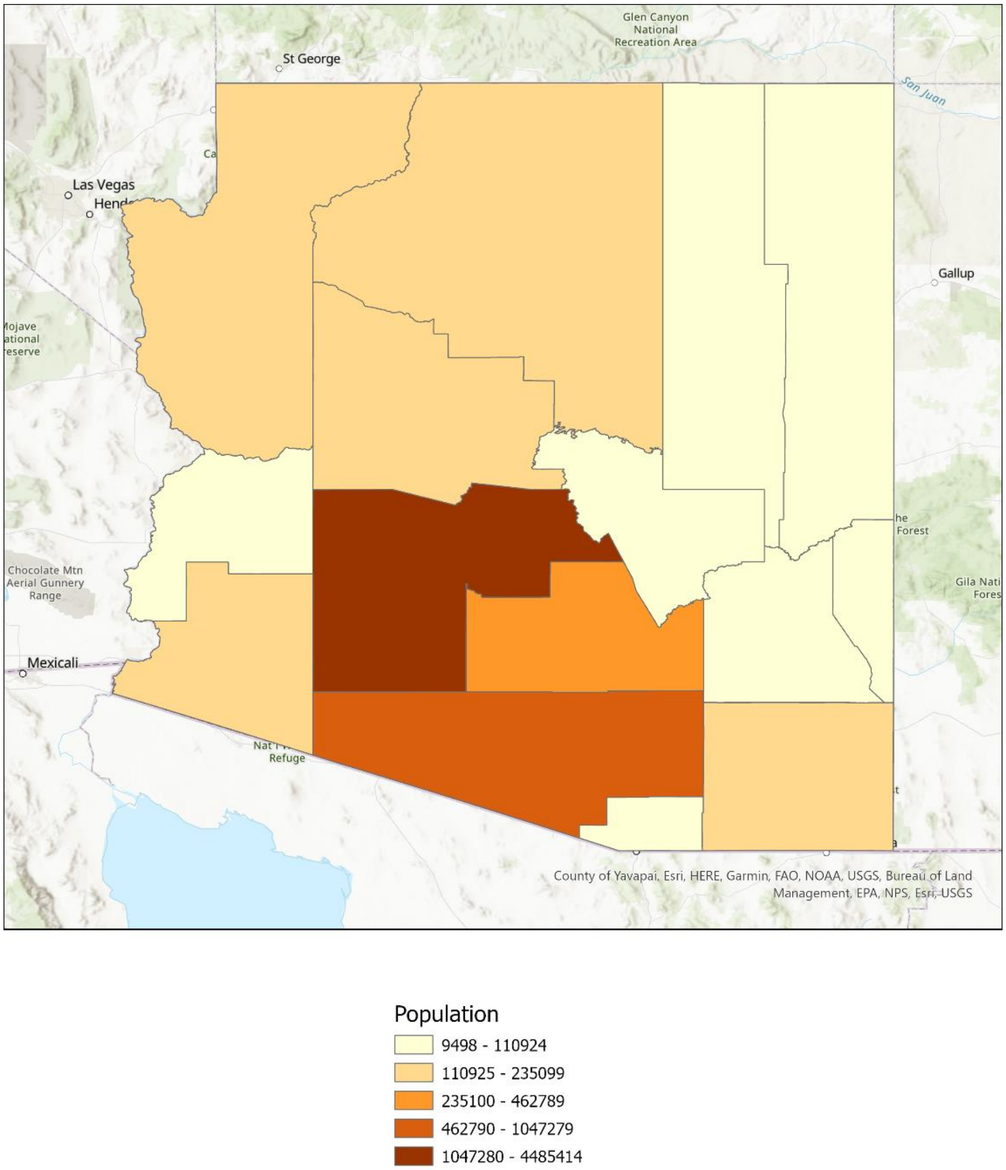

Figure 9 - Arizona Population Map

Arizona Population Density

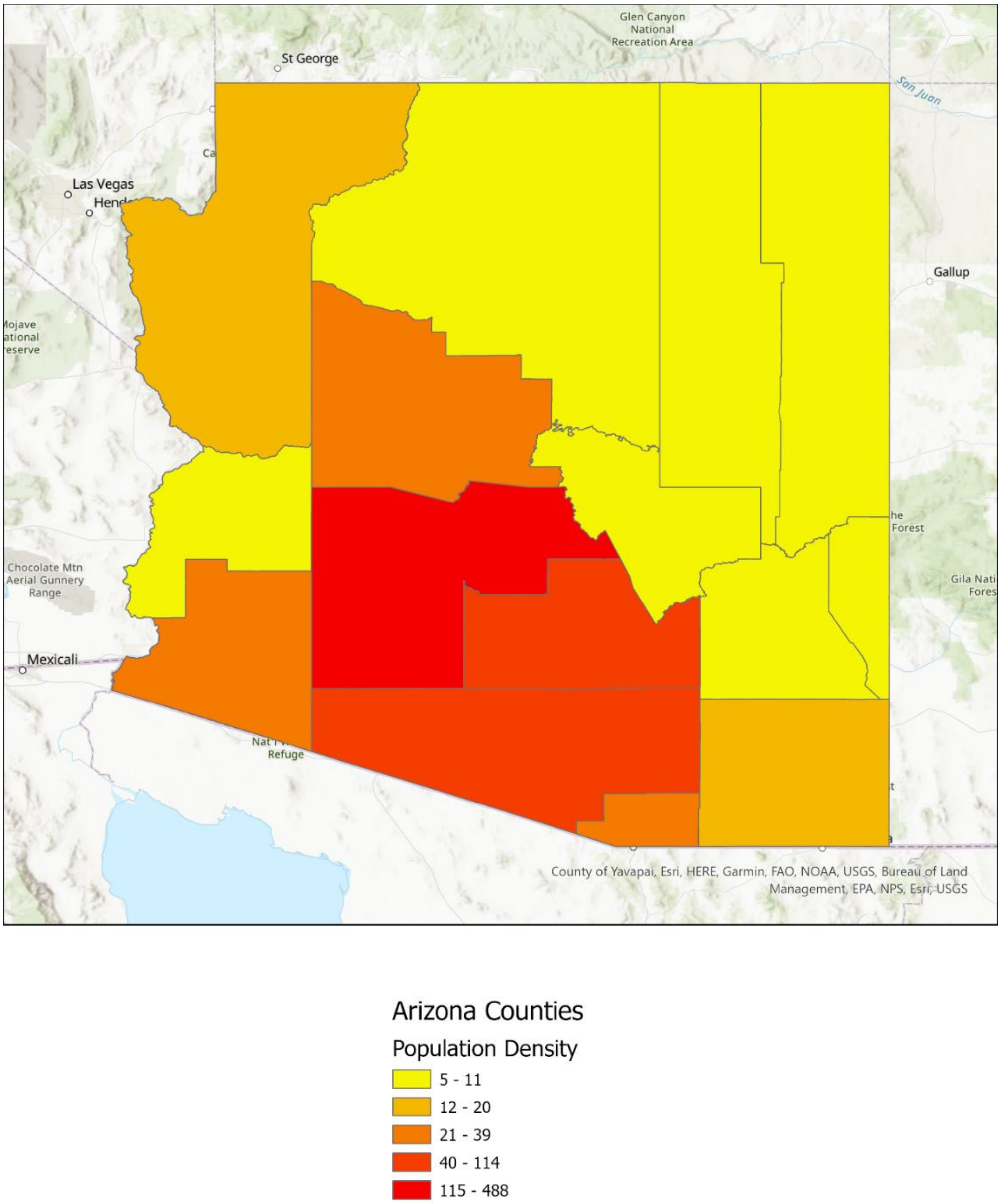

Figure 10 – Arizona Population Density

Arizona Infections per Hundred People

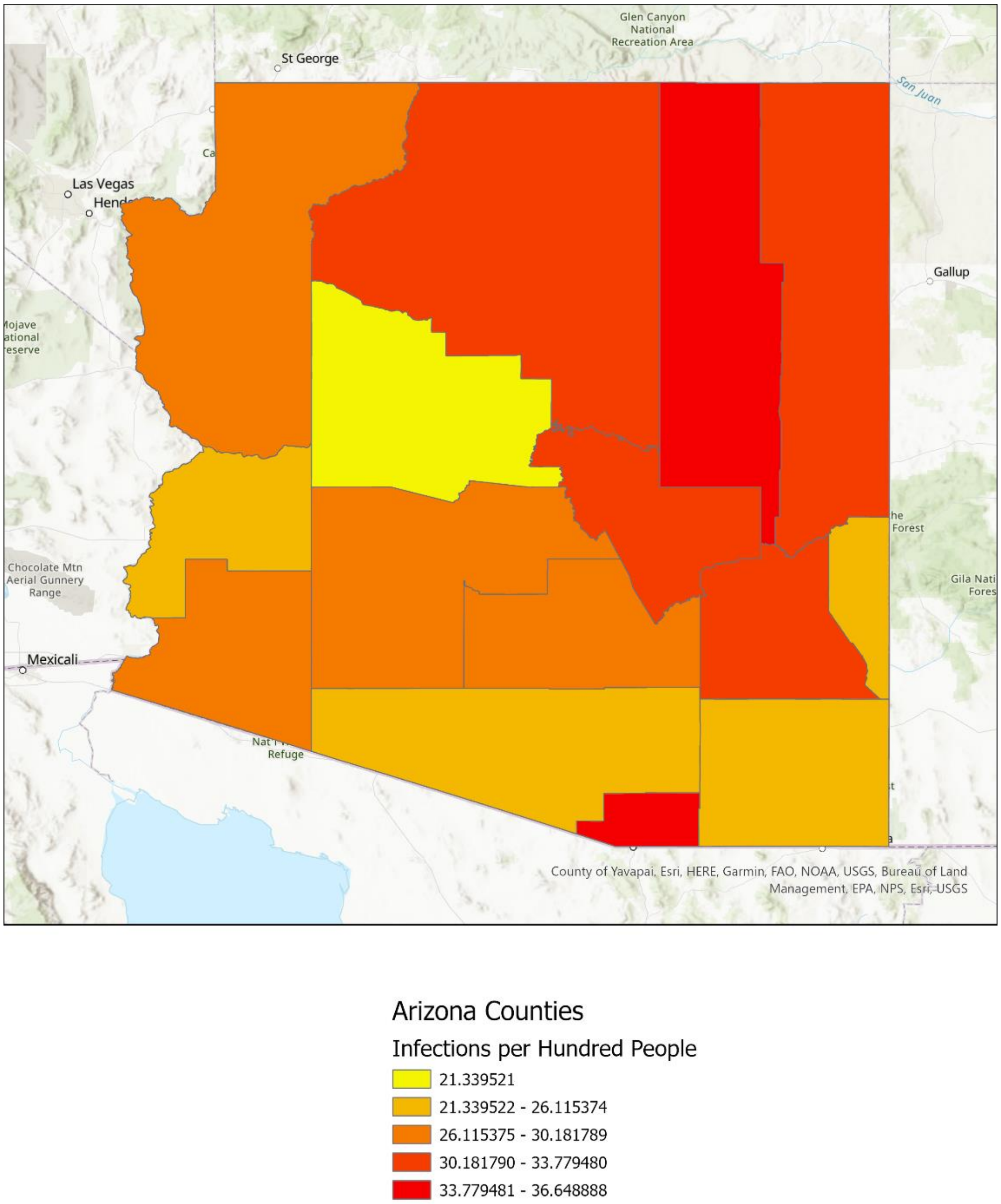

Figure 11 – Arizona Infections per Hundred People

Arizona Infection Chart

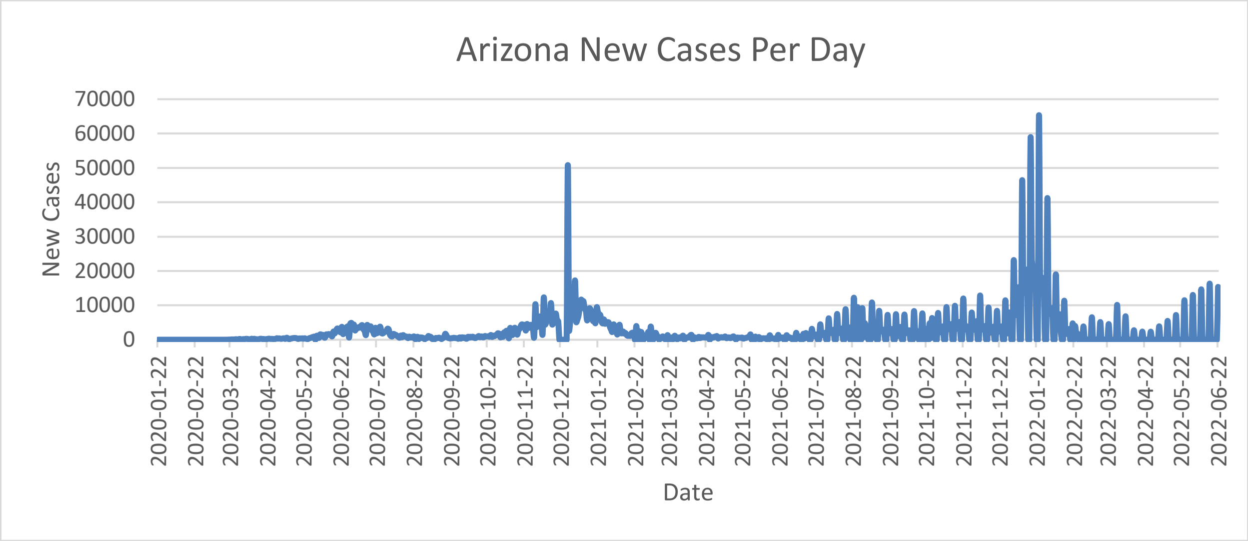

Figure 12 - Arizona Infection Chart

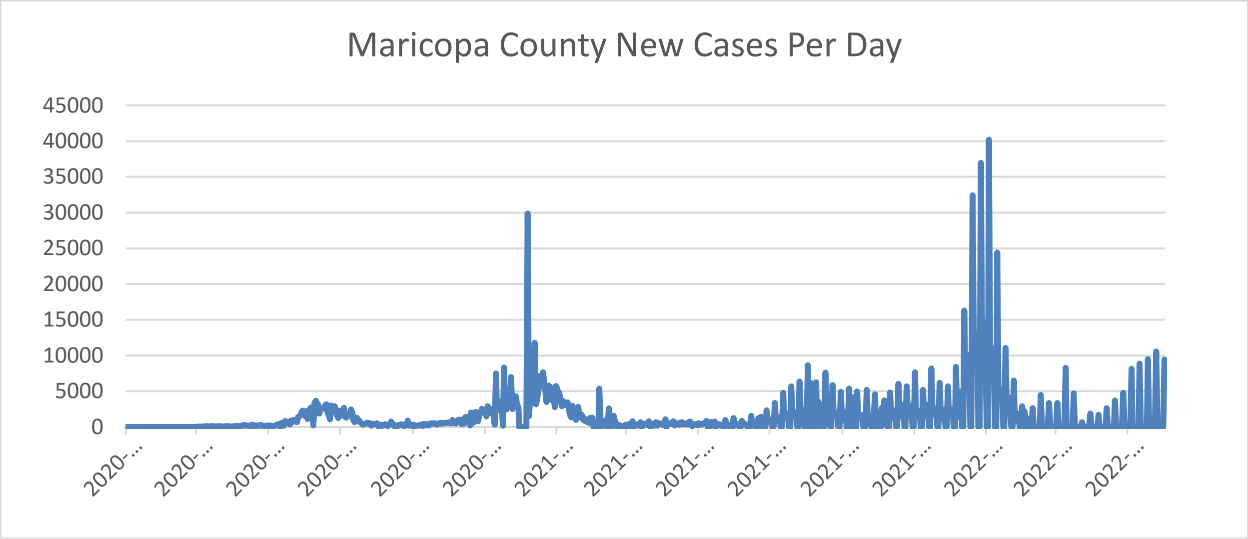

Figure 13 - Maricopa County Infection Chart

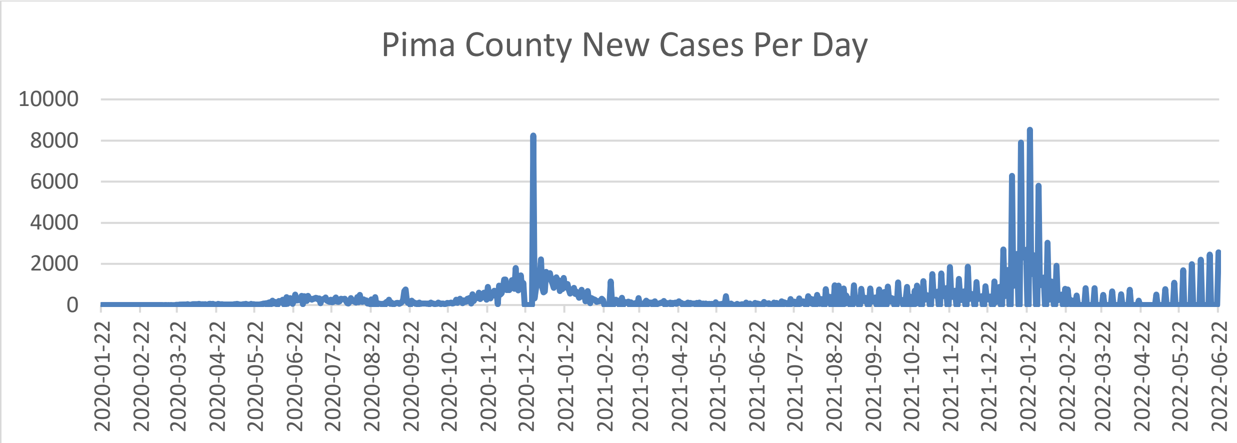

Figure 14 - Pima County Infection Chart

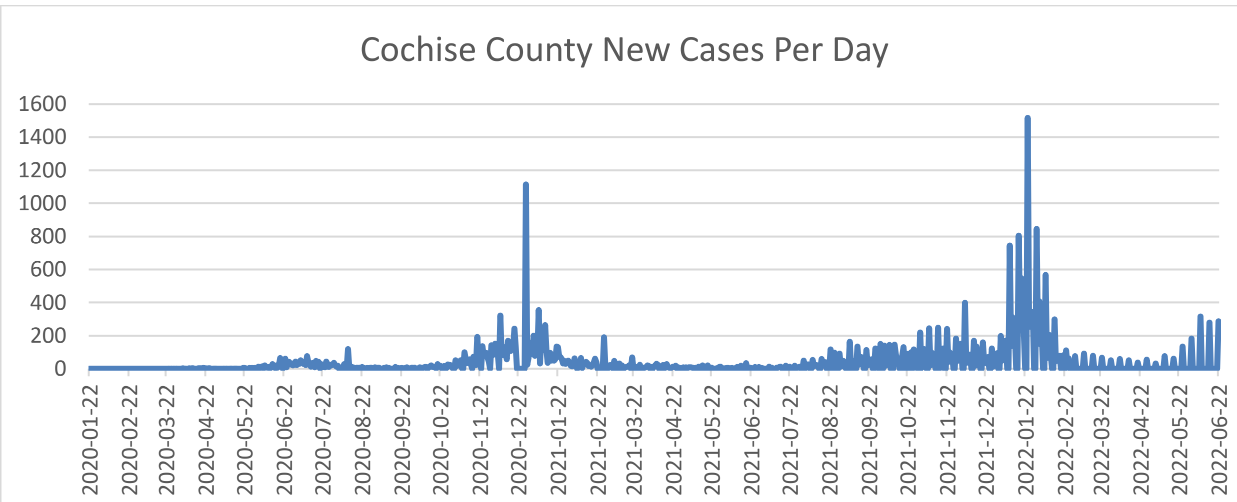

Figure 15 - Cochise County Infection Chart

New Mexico

Inferences

In New Mexico the continued pattern of the raw infection numbers closely following the population in each County continues. As such Bernalillo County, where Albuquerque is located, is the state's most prominent hotspot.

In terms of the infections when adjusted for the population size there is a similar mixed pattern seen in Figures 18 and 19 where the high population density counties have fairly low rates of infection when compared to their more spacious neighbors.

New Mexico implemented their mask mandate in May (New Mexico Department of Health, 2020), early compared to most states and sure enough the initial summer spike is small for New Mexico, however when it comes to winter, the spike in infections came all the same. It was not until after vaccines became available that a reduction in daily cases for the state became evident. It is hard to evaluate how effective the vaccines have been since there was such a small summer spike the first year, but it does appear that the growth has tapered off already.

New Mexico Total Cases and Population Map

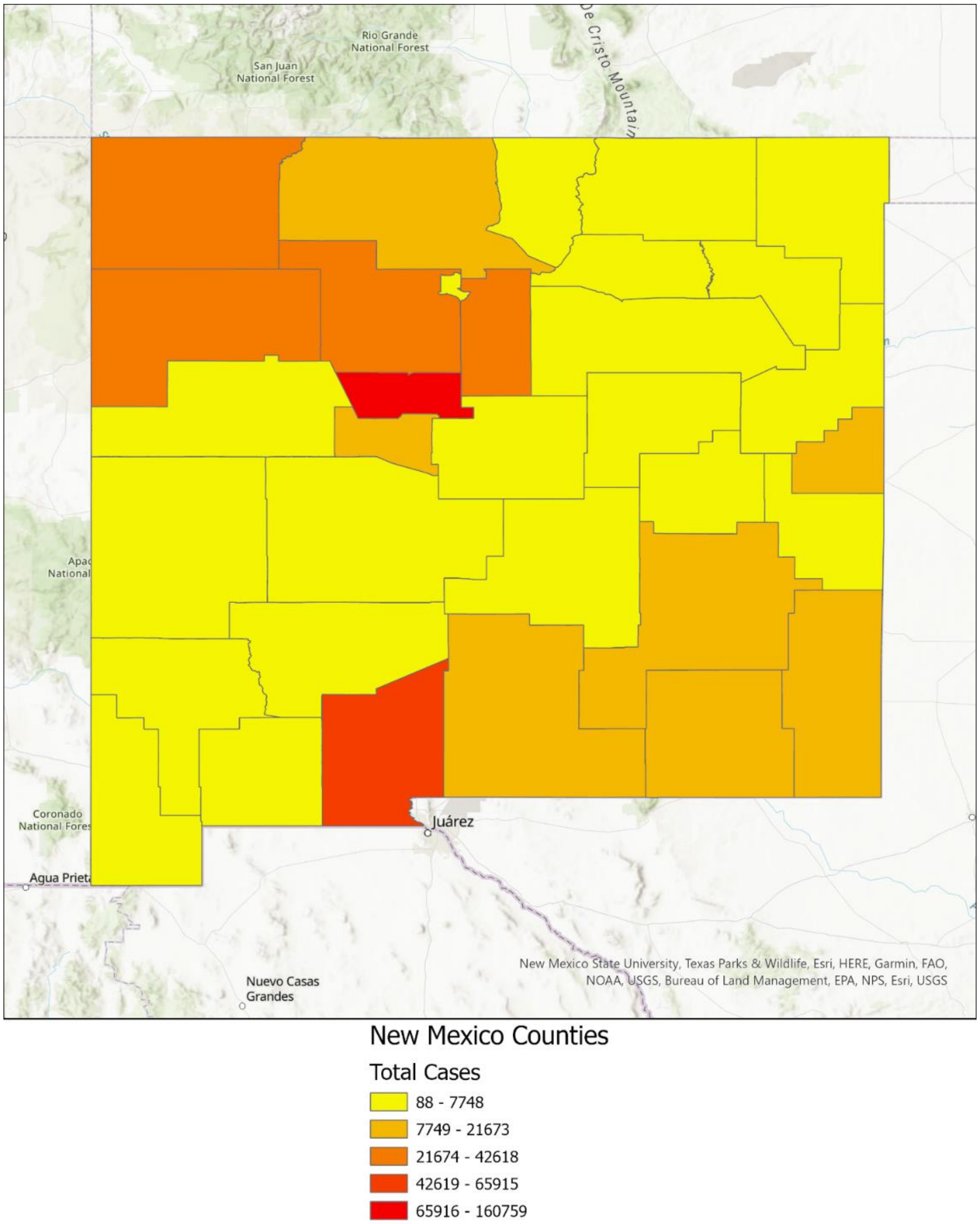

Figure 16 - New Mexico Total Cases

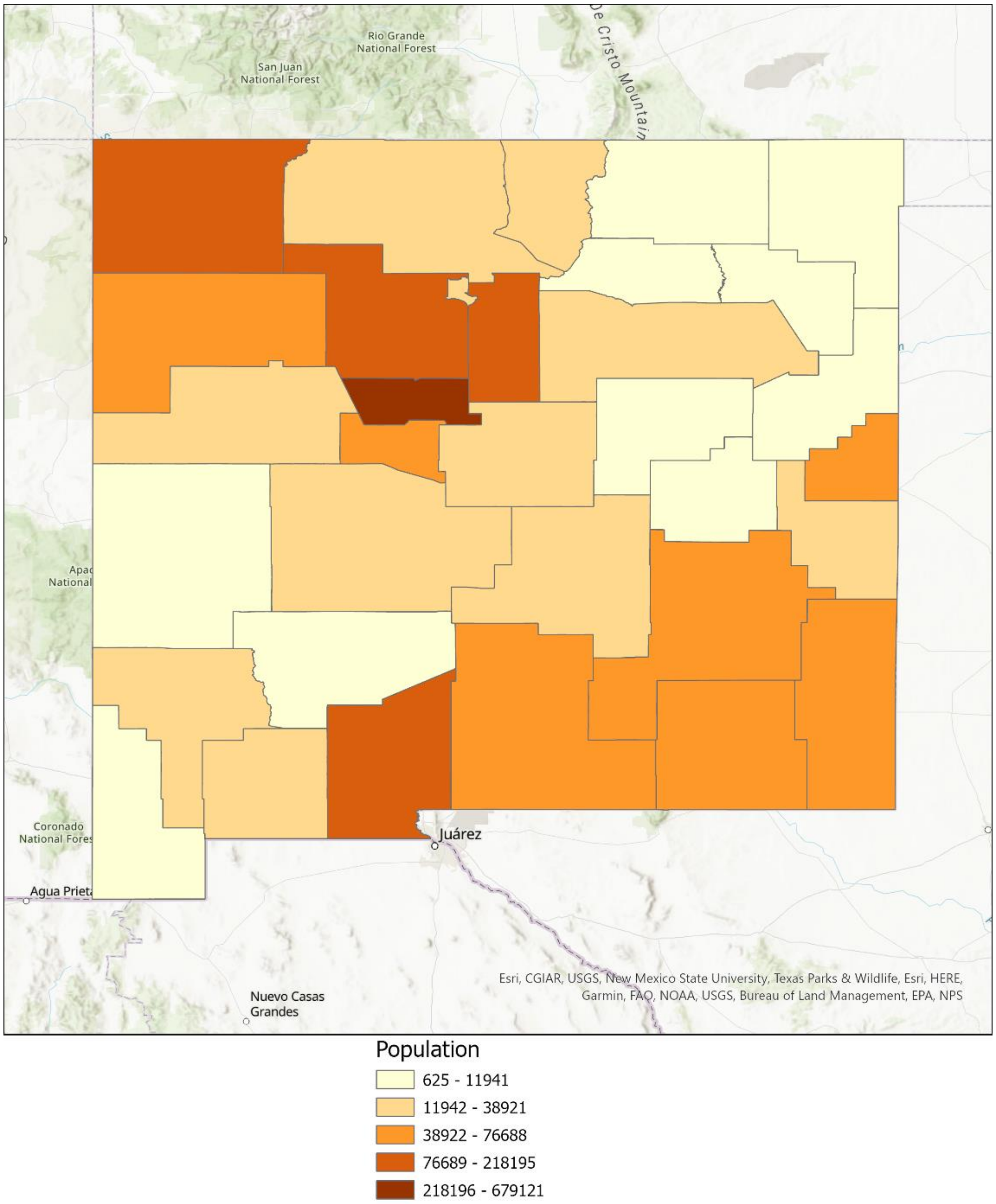

Figure 17 – New Mexico Population Map

New Mexico Population Density

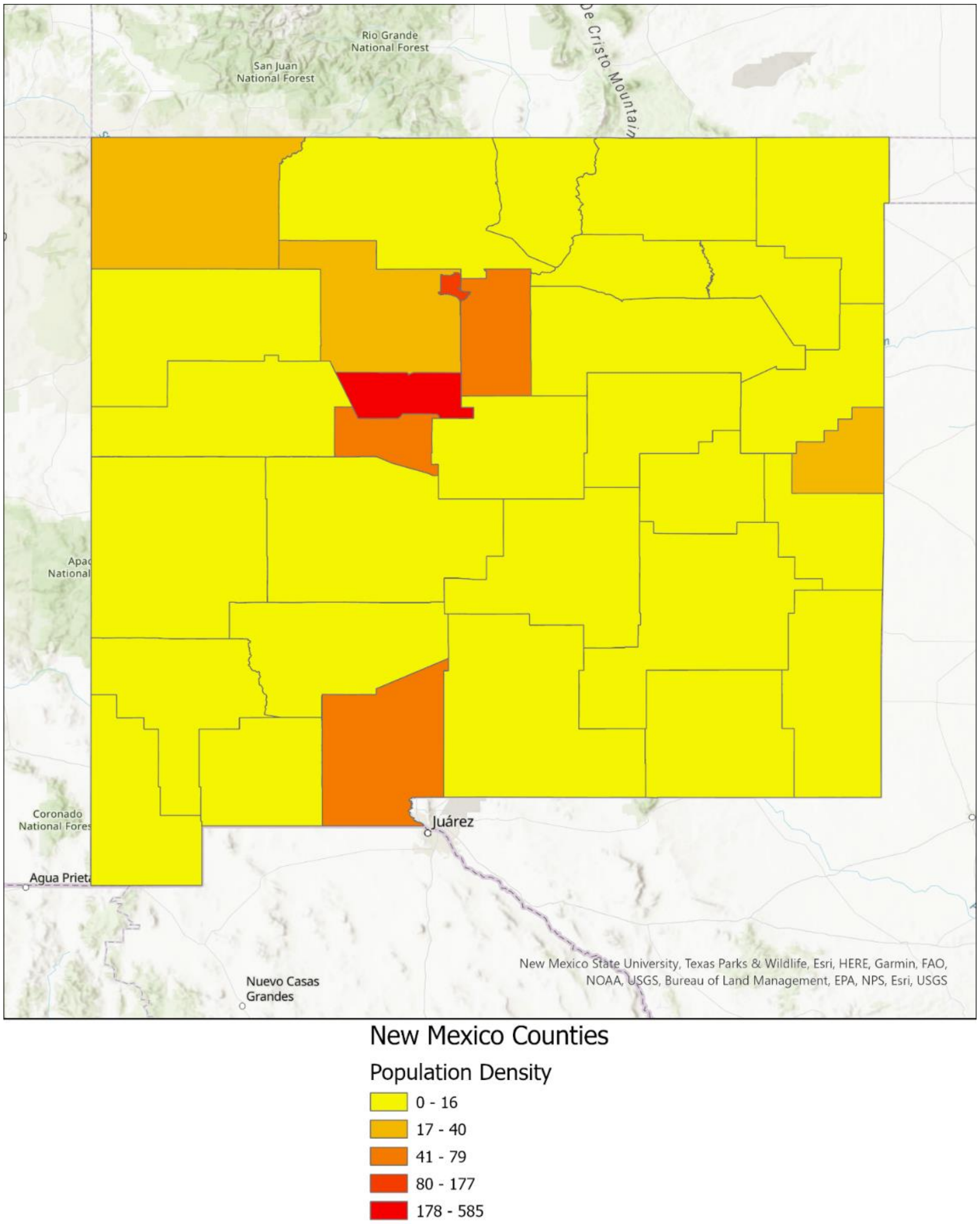

Figure 18 – New Mexico Population Density

New Mexico Infections per Hundred People

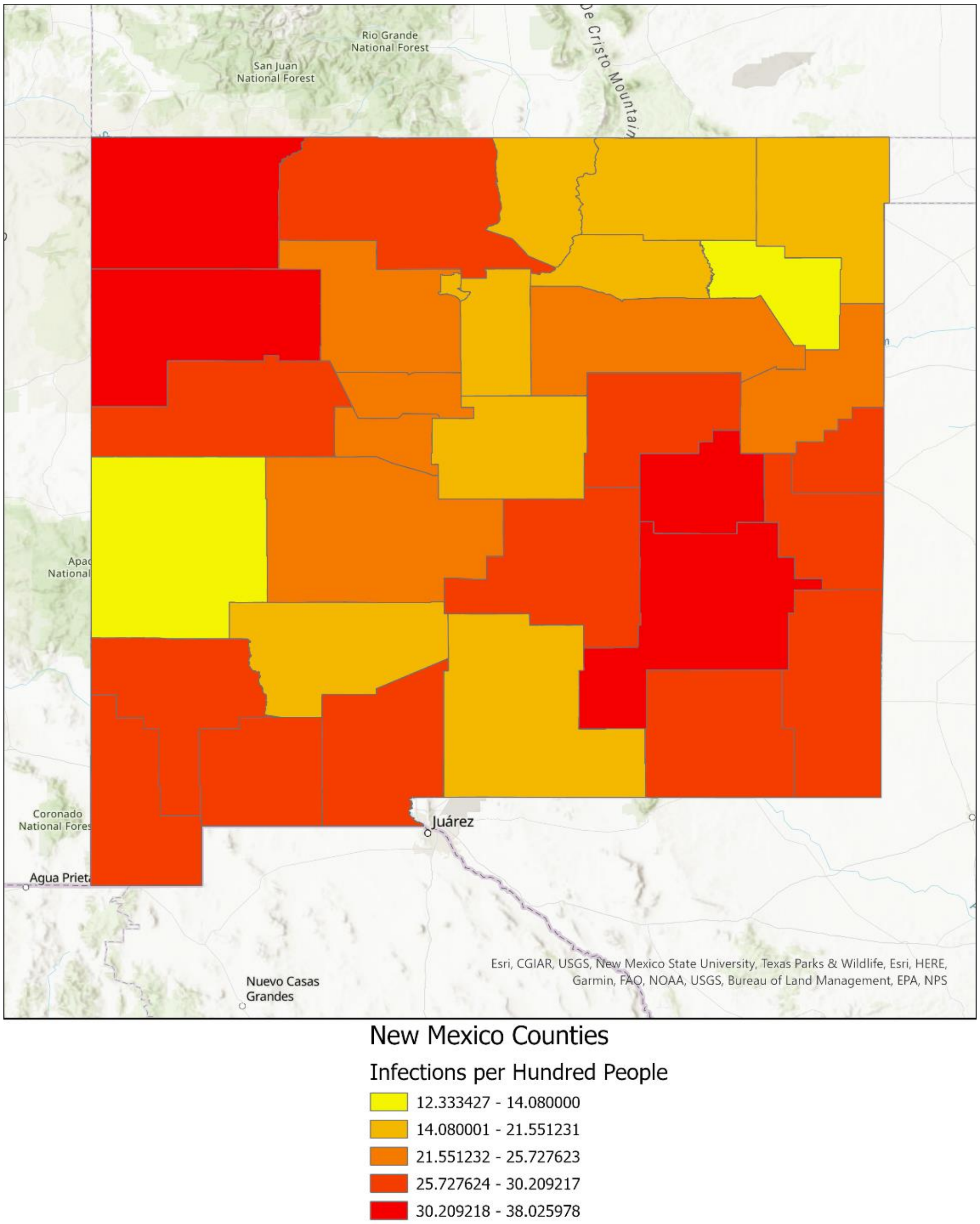

Figure 19 – New Mexico Infections per Hundred People

New Mexico Infection Chart

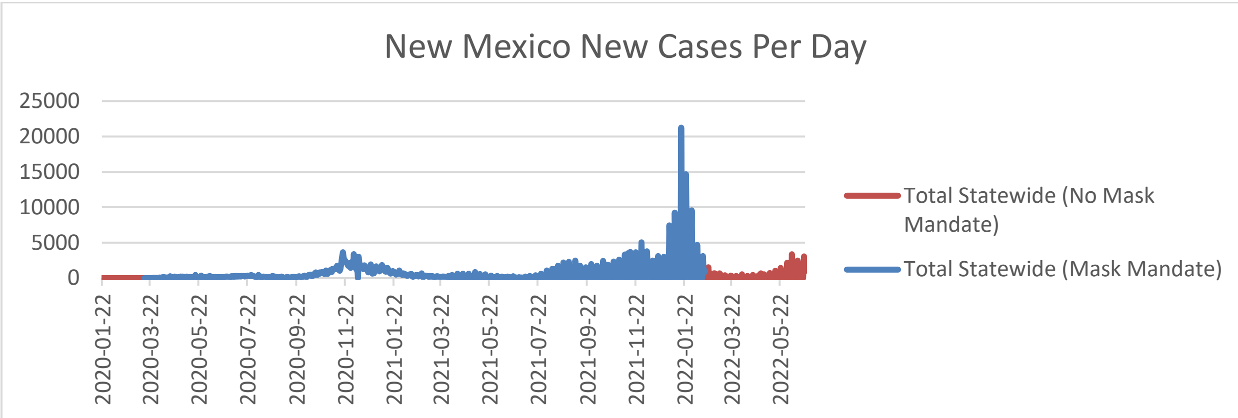

Figure 20 – New Mexico Infection Chart

Colorado

Inferences

The total infection map in Figure 21 and the population map in Figure 22 reveal what should already be expected from seeing similar results in other states, that the bulk of actual infections occur in the populated regions of the state, specifically Denver County and its neighbors.

When compared to the population density the map of Colorado becomes even more of a patchwork than that of other states. While densely populated areas still have moderate rates of infection, many rural ones that were hypothesized to have lower rates of transmission perform even worse.

Colorado was another state with a mask mandate, one that took place in mid-July of 2020 (Wise, 2020) to avoid a surge similar to that observed in other states at the time. As a result, there isn’t much of an initial surge in the Summer of 2020, however by winter the expected surge in infections can be seen still and more typical spikes are seen during the late summer and winter of 2021 similar to other states with or without a mask mandate. An oddly high spike for a few days in summer of 2022 is observed after the vaccine became available, but the rate immediately drops back down so it is possible that those few days were outliers and in general the vaccine is working as intended.

Colorado Total Cases and Population Map

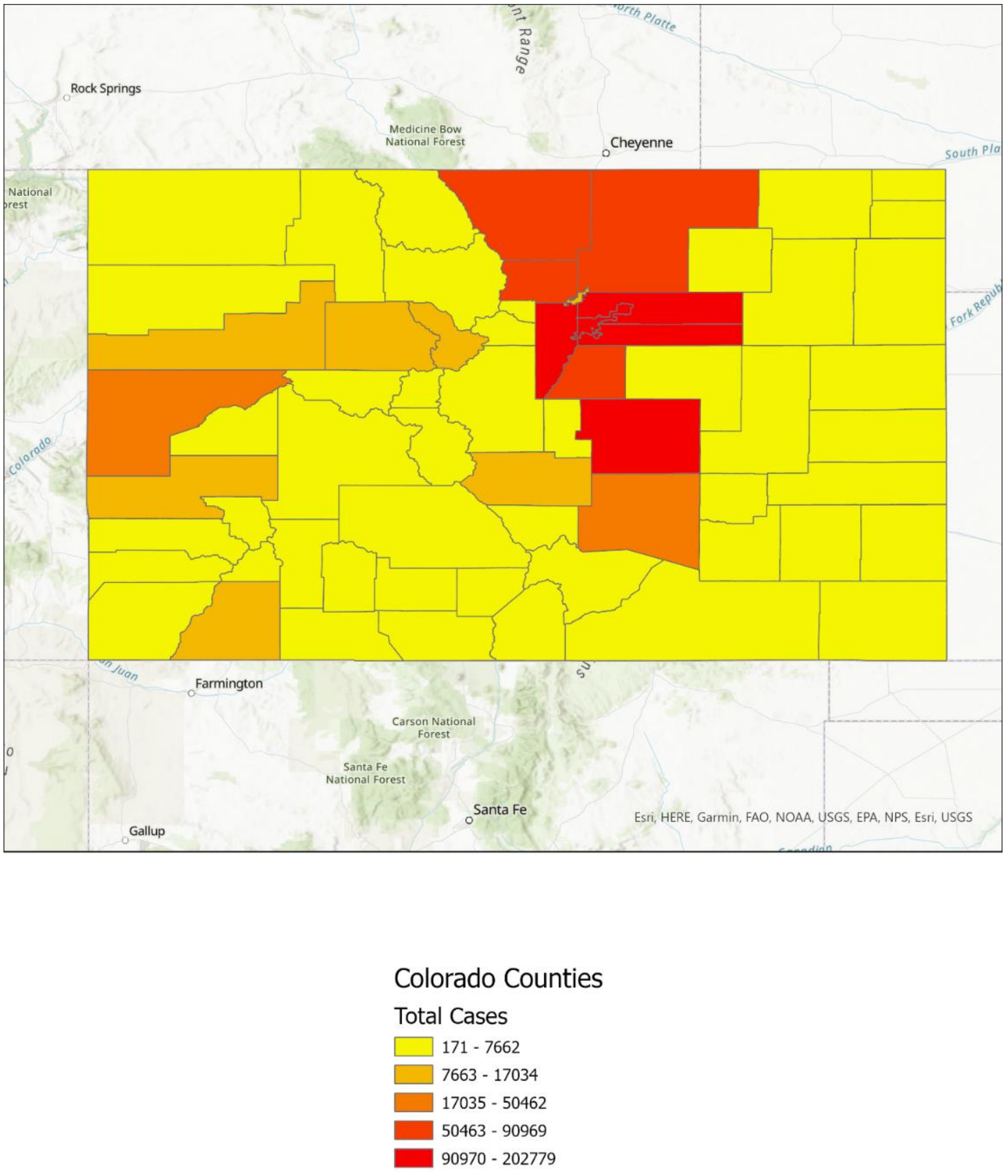

Figure 21 – Colorado Total Cases

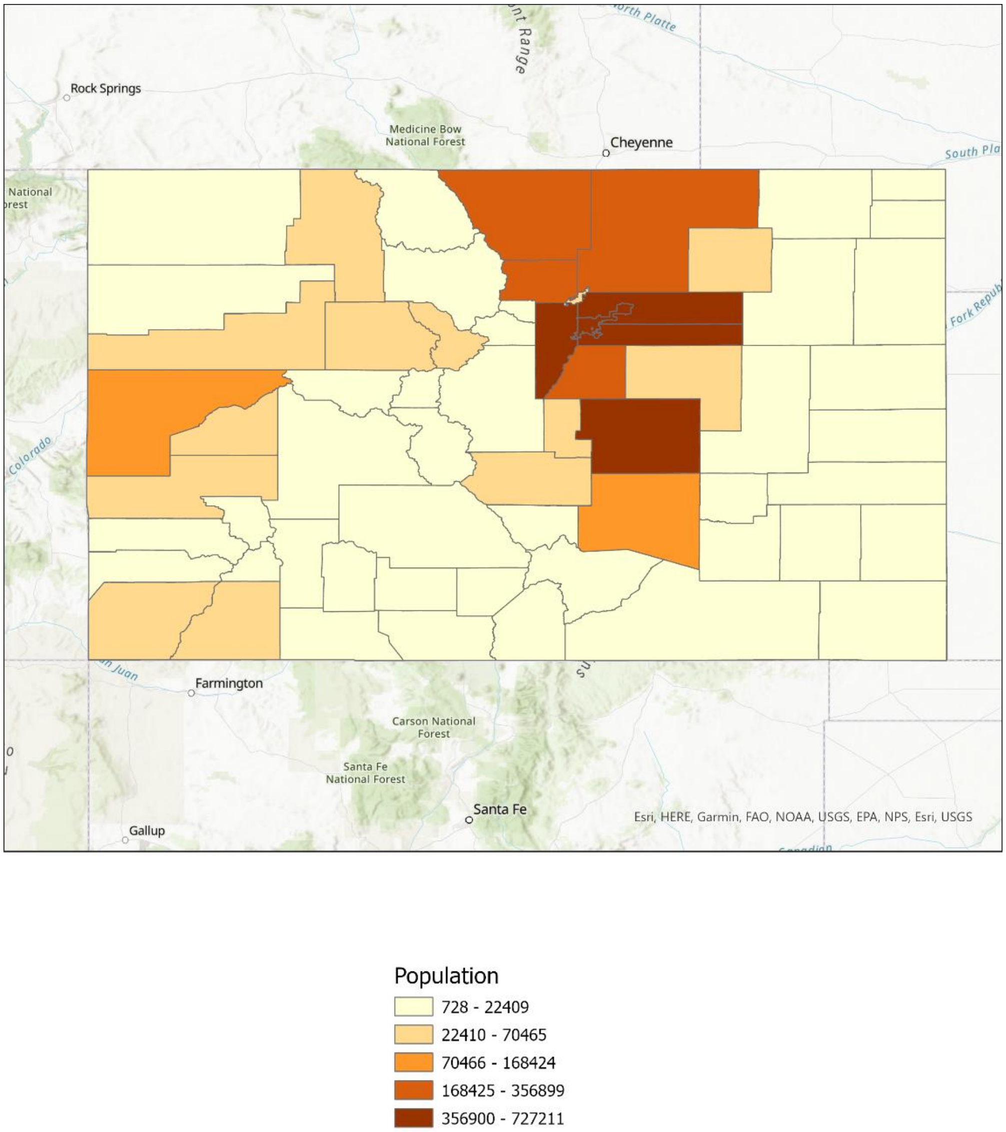

Figure 22 – Colorado Population Map

Colorado Population Density

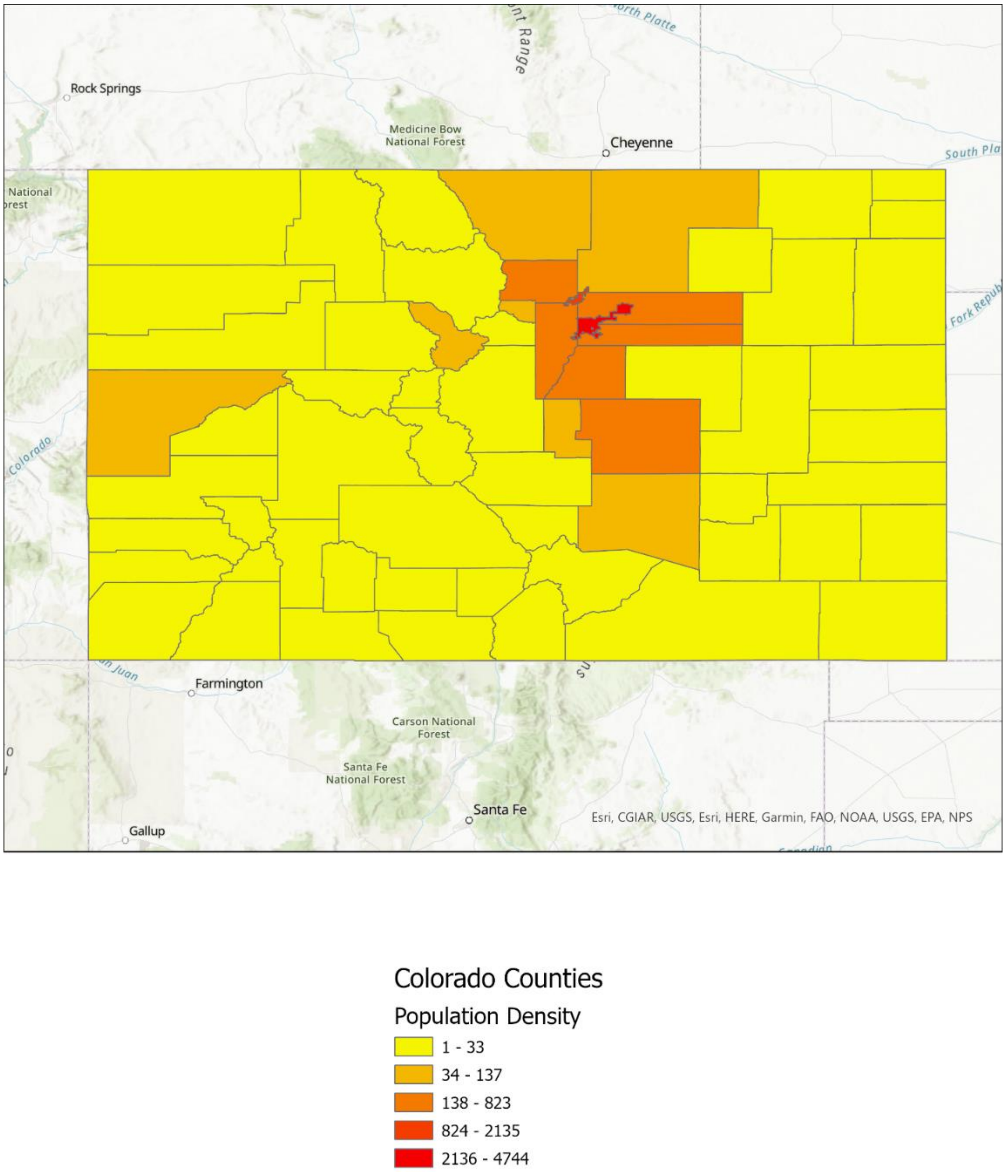

Figure 23 – Colorado Population Density

Colorado Infections per Hundred People

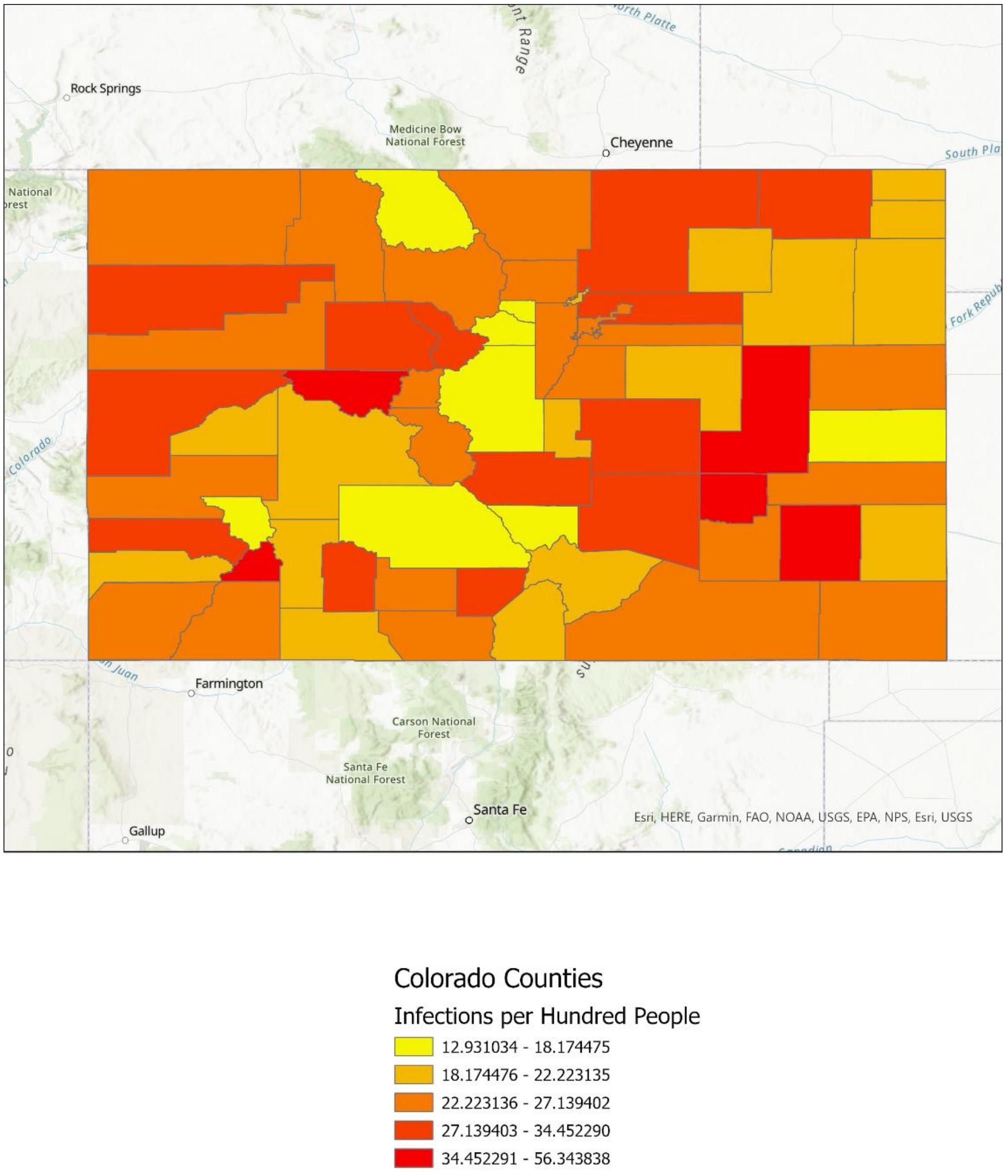

Figure 24 – Colorado Infections per Hundred People

Colorado Infection Chart

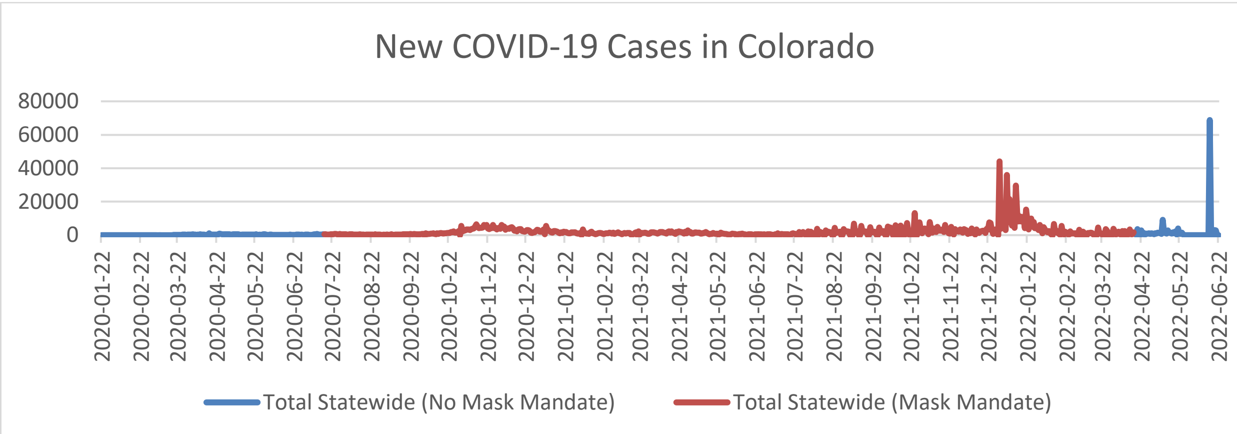

Figure 25 – Colorado Infection Chart

Utah

Inferences

Utah, as with all the other states in this study, has a pattern where the infection's raw numbers follow its population count. This is not anything new, but when adjusted for that population, a small pattern is noticeable here. In Utah it appears that the infection was at its worst in both the high population density counties and the counties directly adjacent to them.

Utah launched its Mask Mandate in late November of 2020 and it did seem to be effective in combating the 2020 winter surge in cases with a minor decrease in cases per day during the month of November. However, by December infections began to increase again and eventually spiked later that month with over 15,000 infections in one day. This was small compared to the surge the following year where the number of infections per day peaked at over 40,000 in the winter.

Utah Total Cases and Population Map

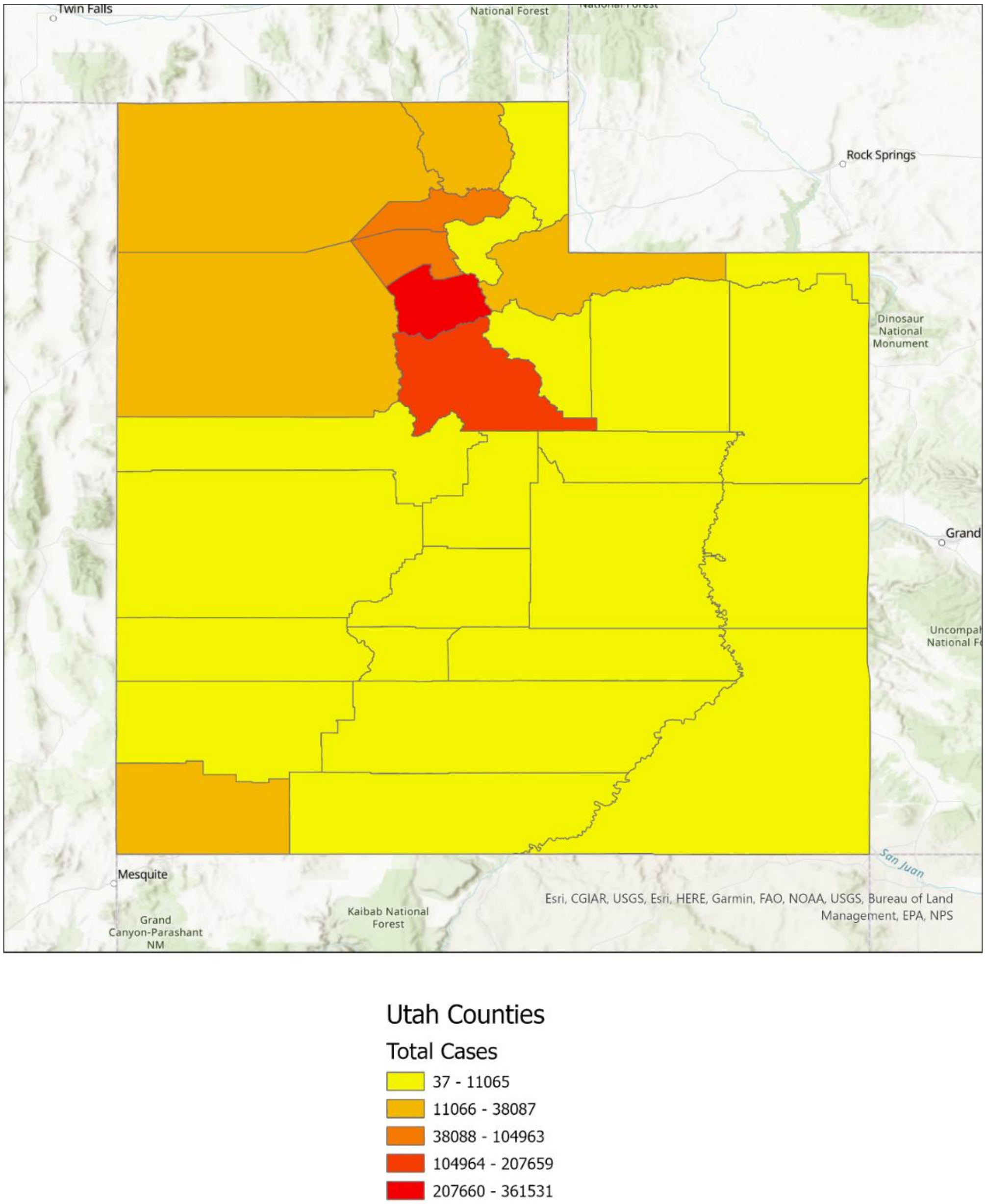

Figure 26 – Utah Total Cases

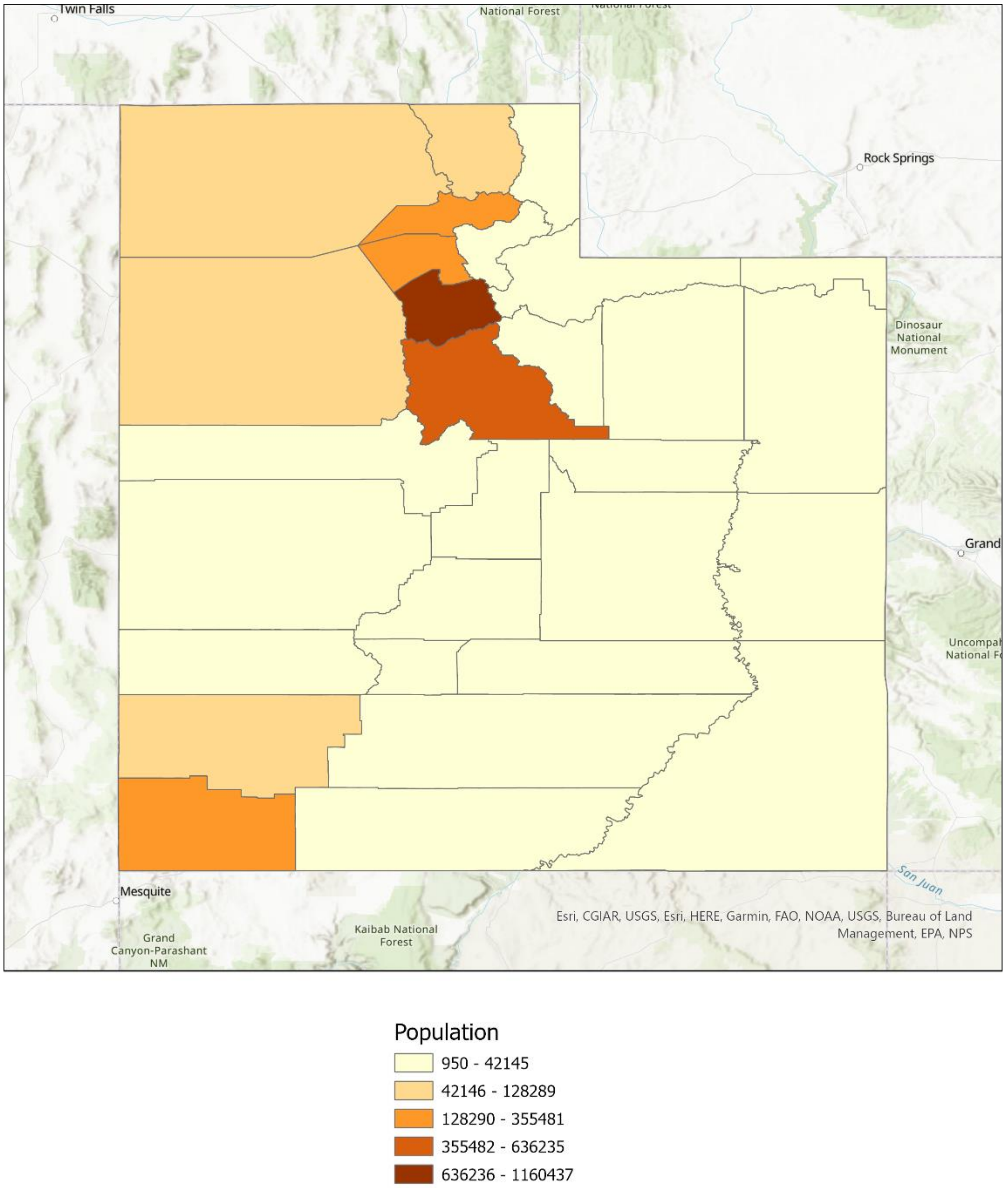

Figure 27 – Utah Population Map

Utah Population Density

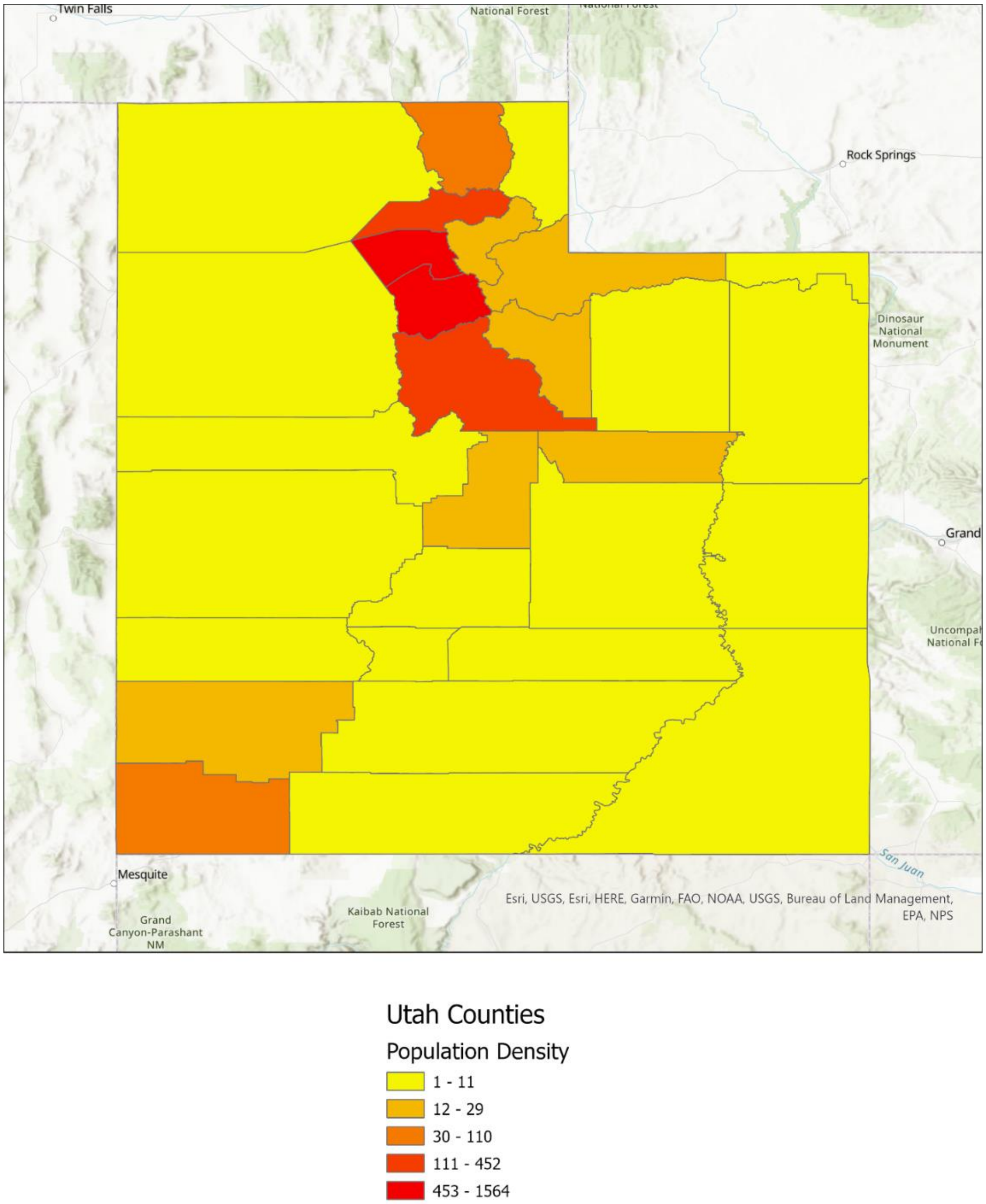

Figure 28 – Utah Population Density

Utah Infections per Hundred People

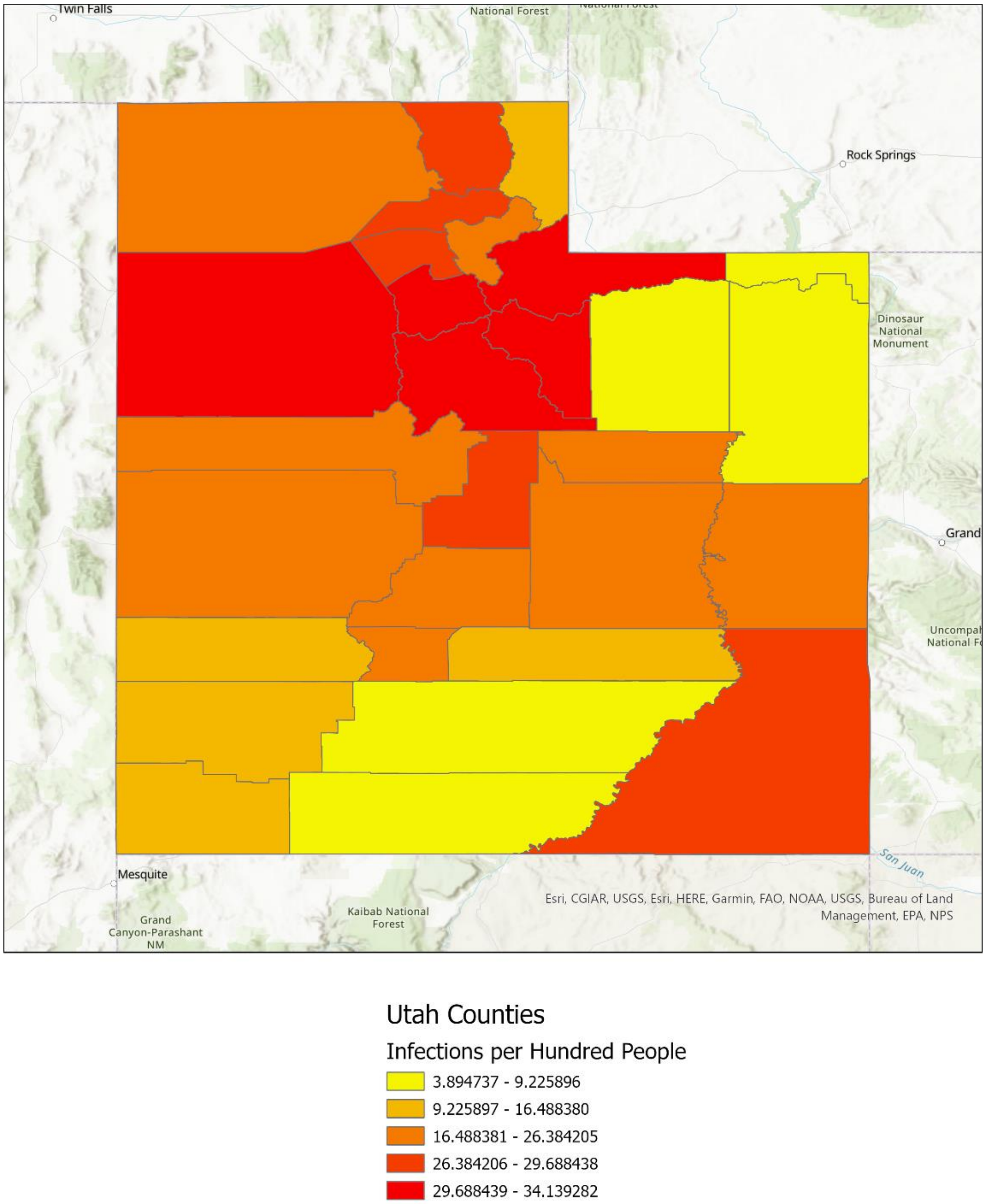

Figure 29 – Utah Infections per Hundred People

Utah Infection Chart

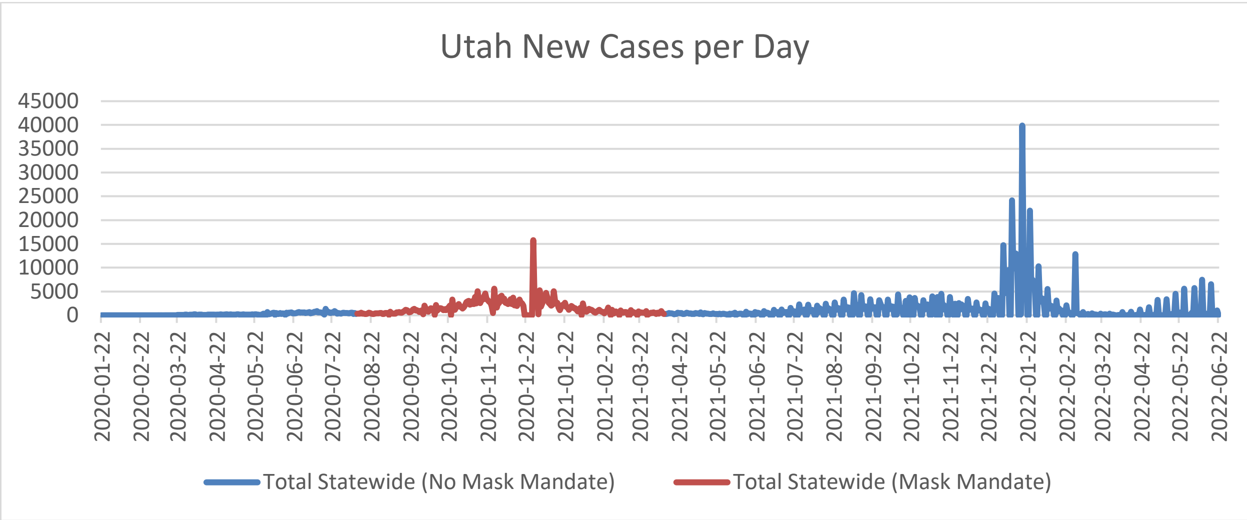

Figure 30 – Utah Infection Chart

Nevada

Inferences

Nevada is a similar case to Utah where the raw numbers of the disease largely follow high population density areas but the population adjusted metrics show that the counties directly adjacent to those high density counties were the ones hit the worst on a per capita basis.

On June 24th, 2020 Nevada enacted its mask mandate, requiring all people to wear masks while in public places. Oddly enough the vaccine program does not seem to be doing much to prevent the summer surge in this state, but a closer look at the data for the state reveals that the bulk of the 2022 surge comes from Clark County, the home of Las Vegas and tourist hotspot, making it a probable outlier in the data.

Nevada Total Cases and Population Map

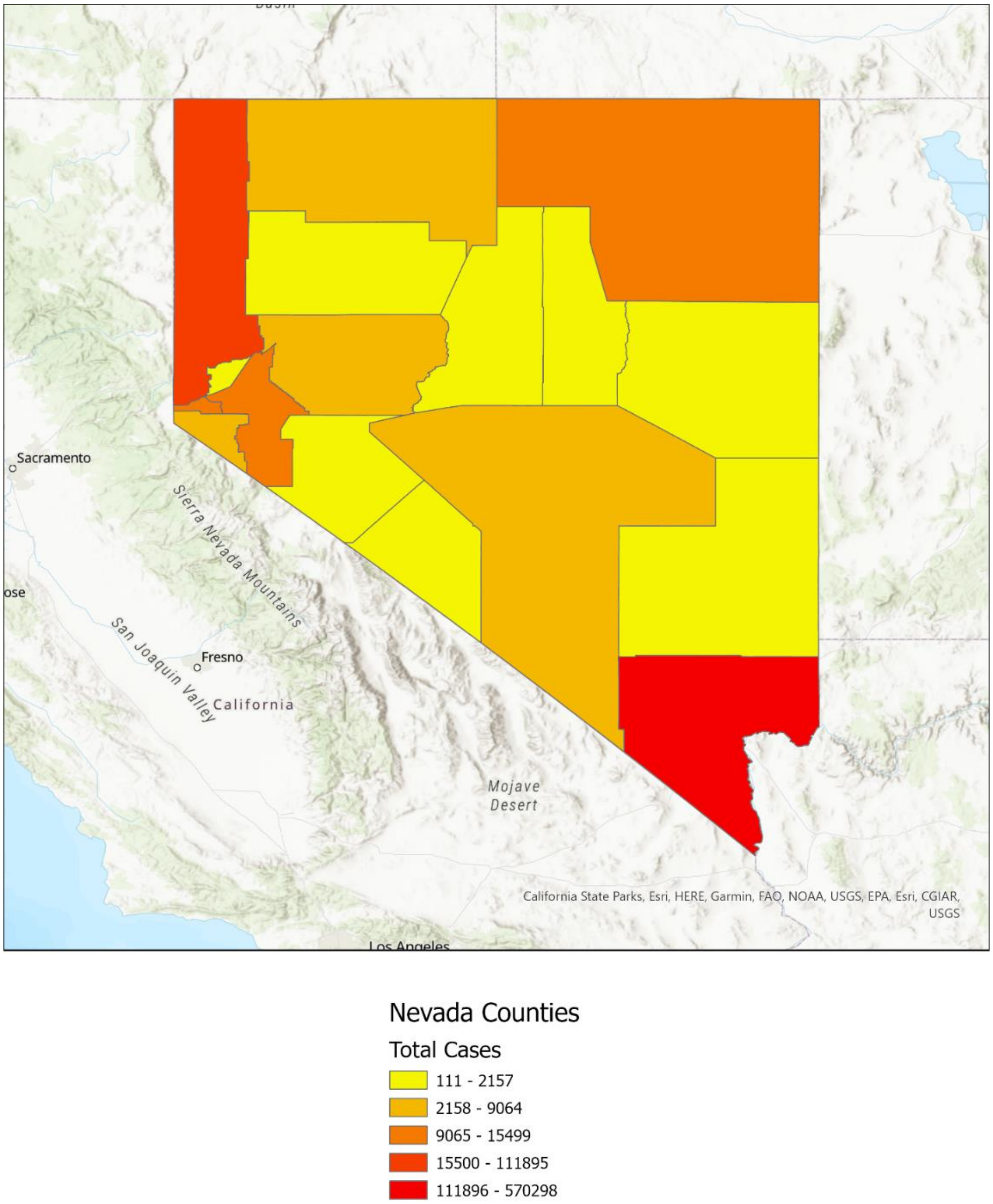

Figure 31 – Nevada Total Cases

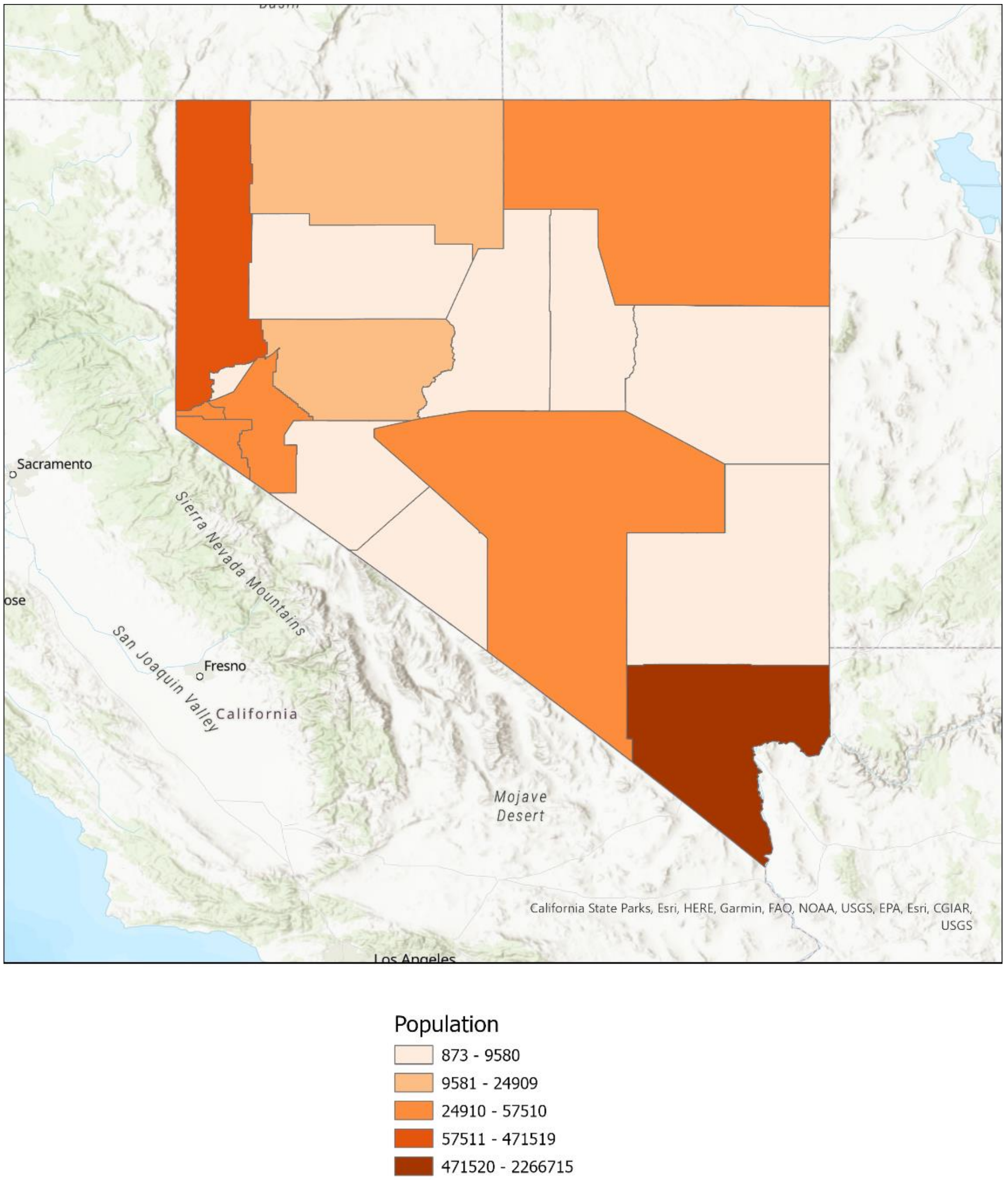

Figure 32 – Nevada Population Map

Nevada Population Density

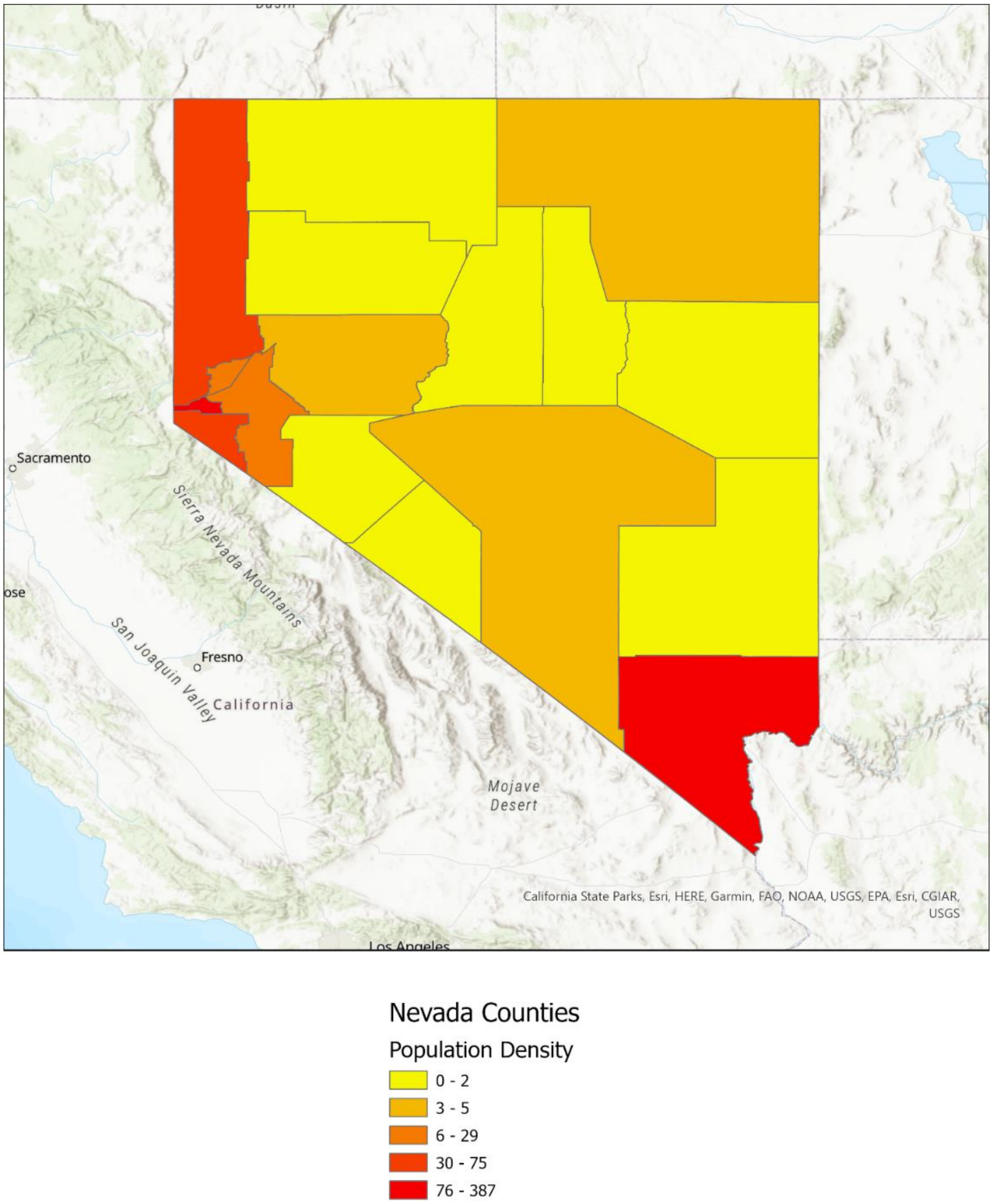

Figure 33 – Nevada Population Density

Nevada Infections per Hundred People

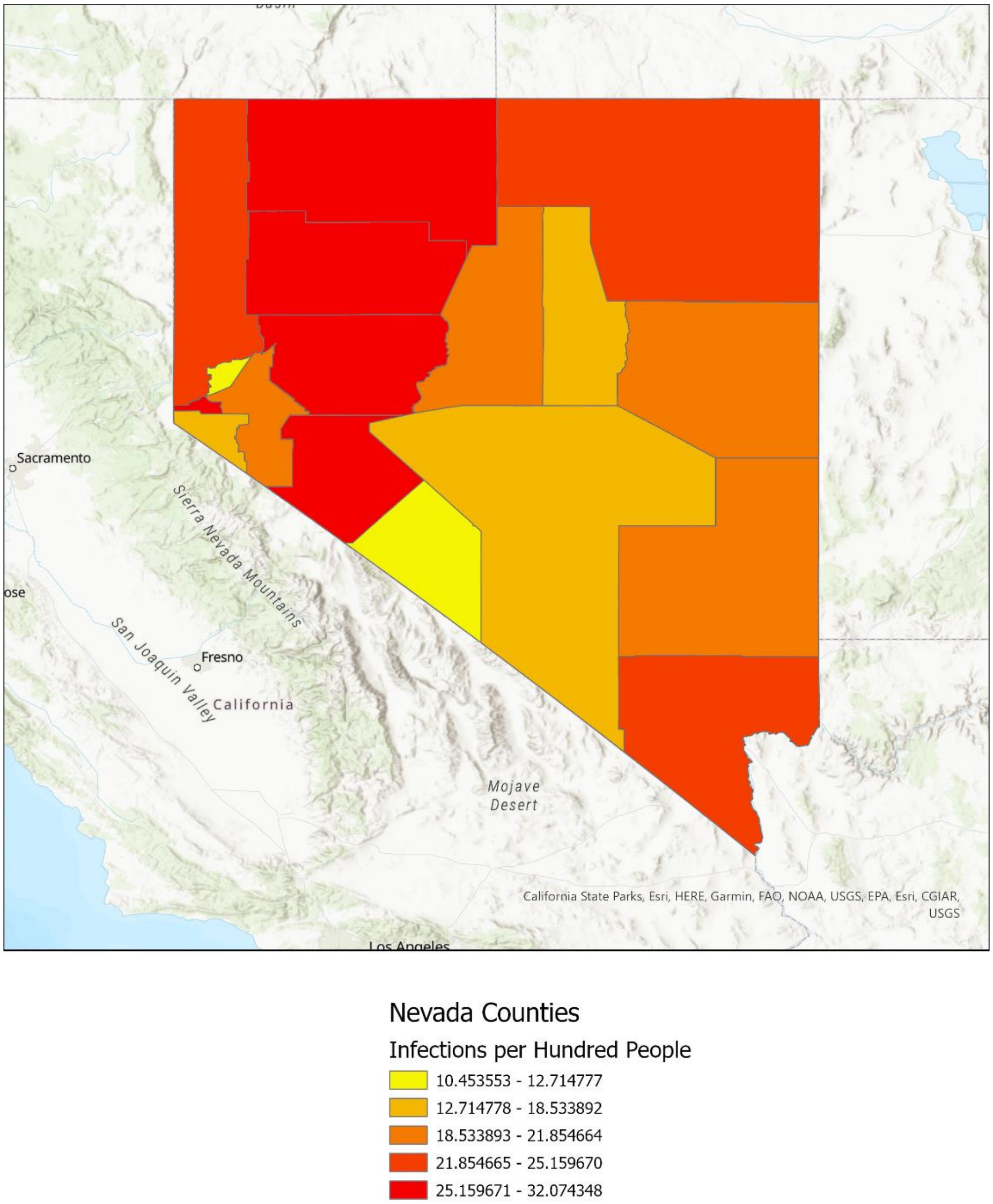

Figure 34 – Nevada Infections per Hundred People

Nevada Infection Chart

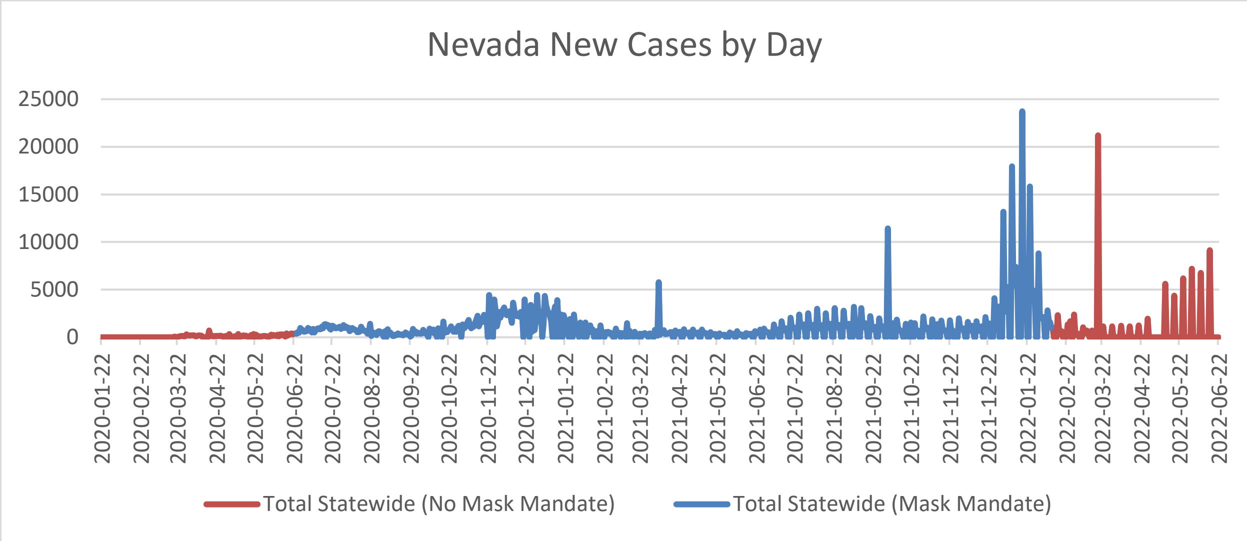

Figure 35 – Nevada Infection Chart

Analysis

Several tests were conducted on the data using the Bivariate Analysis tool that is available in ArcGIS pro. The dependent variable for all these tests was the infections per capita rate, after all, the study was designed to evaluate what factors led to some regions to be relatively safe from COVID-19 and what lead others to be hit heavily. For the analysis, the nearest sixty neighboring counties were selected to be used in the evaluation in order to provide the correlation with sufficient statistical information to find any real relationships between the variables that were being studied.

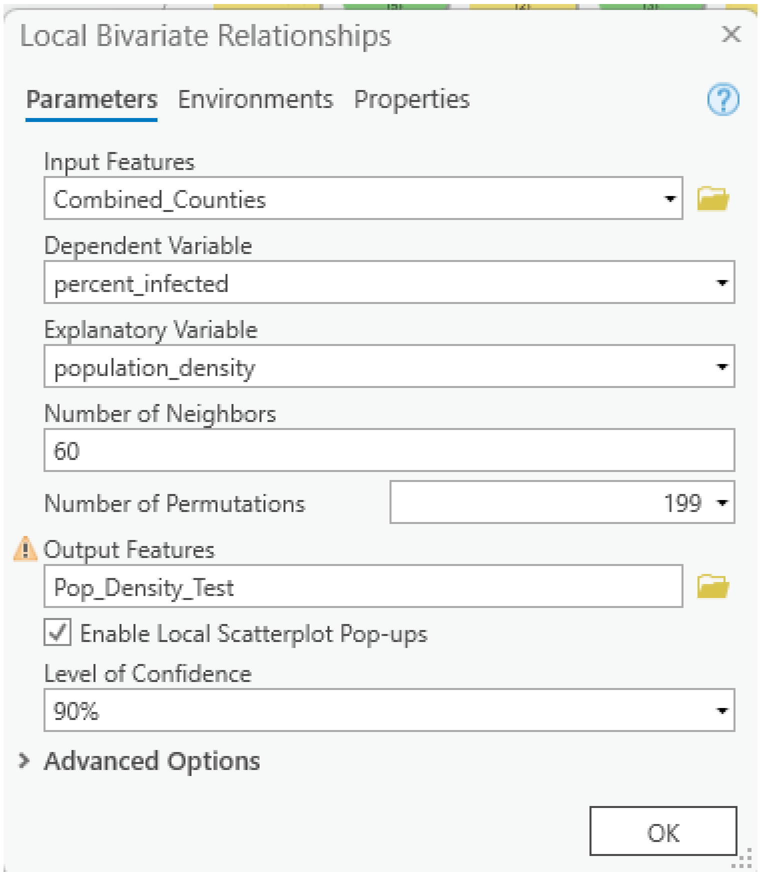

Figure 36 – Bivariate Analysis Input

The first variable to be tested was Population Density. Hypothetically, an airborne disease like COVID-19 would spread faster in heavily developed counties that had large cities and as such a higher average population density. However, when put to a Bivariate Analysis test the results showed there was no significant relationship between either of those factors in any of the counties of the study as can be seen in Figure I2 – Population Density Test Output.

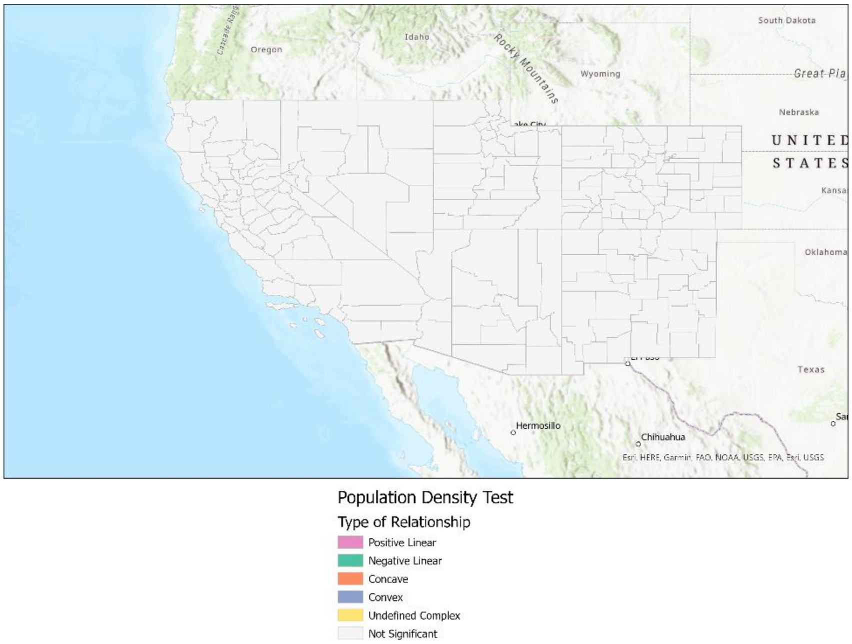

Figure 37 – Population Density Analysis Test

The second test conducted was one based on the temperature. this test was decided on after observing the seasonal trends in the New Infections charts for each state studied. One possible explanation for this pattern was that people congregating indoors and outdoors during the summers and winters was what was causing the significant spikes in infection, and thus areas with a more moderate summer or winter would have a reduced infection rate accordingly. As such the record high and low temperatures for 2020 in each county were tested against the counties infection rate to see if there was a correlation. The high temperature test produced no significant results while the low temperature results produced conflicting results for different counties as can be seen in Figures 38 and 39 respectively.

Figure 38 – High Temperature Analysis Test

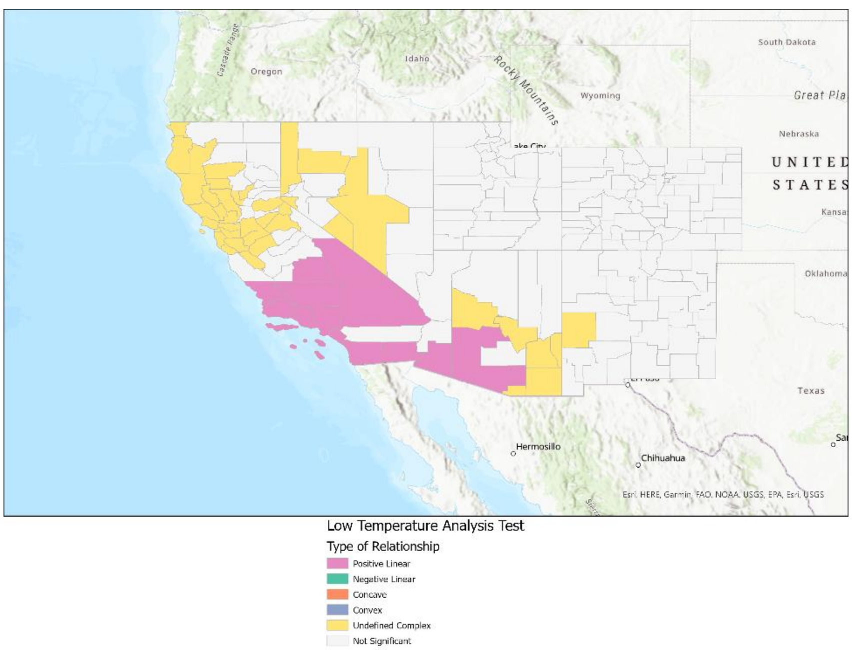

Figure 39 – Low Temperature Analysis Test

For the low temperature testing the Bivariate Analysis found that out of the 216 counties studied only 13 had a positive linear relationship between a low temperature peak and their infection rate whereas 35 had an “undefined complex” relationship between the two variables. The remaining 168 had no significant relationship between the Low Temperature peak and the infection rate. With only a small amount of the studied Counties showing any relationship at all between the two variables and those counties being mixed in how the variable interacted with their infection rates, it can’t be concluded that the Low Temperature point has a meaningful relationship to the spread of COVID-19 from this study alone.

The next analysis conducted was to evaluate whether or not wealth had any impact on COVID-19’s spread throughout a county. This was measured in two ways. The first was through the average income level and the second was through the county GDP.

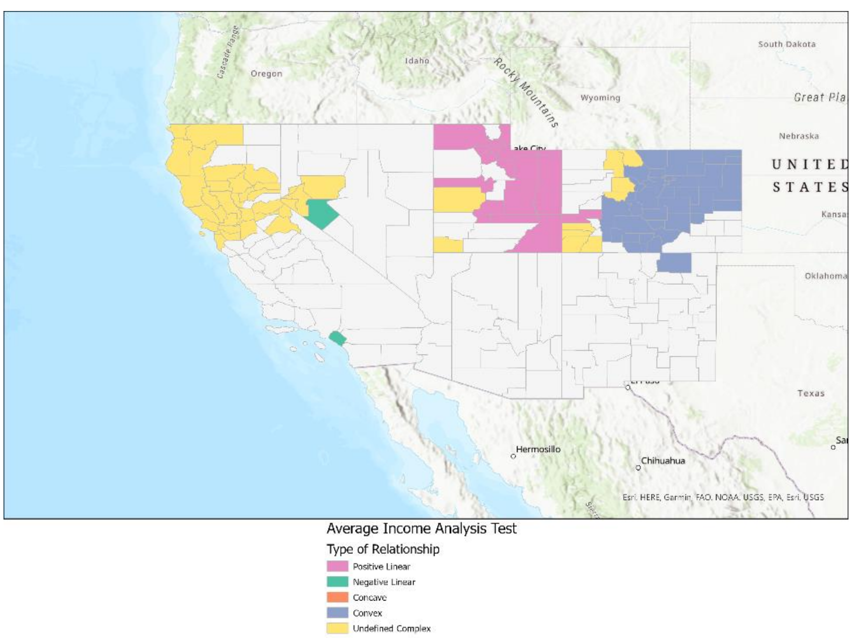

Figure 40 – Average Income Analysis Test

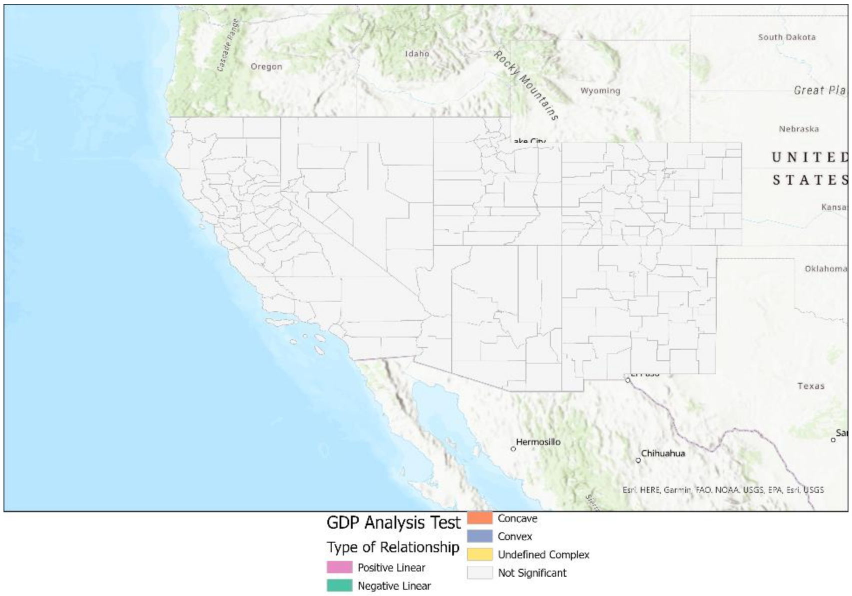

Figure 41 – GDP Analysis Test

While the GDP based analysis produced no results, the Average Income Test produced some unexpected ones. It found that in the northernmost states of this study, the income did have an effect, but not necessarily the negative effect expected. For the most part it seemed that income had a mix of effects on COVID-19 infection rates.

Per Figure 40, out of the 216 counties being studied, 45 had an undefined complex relationship, 42 had a convex relationship, 20 had a positive linear relationship, and only two had a negative linear relationship. The remaining 107 counties had no significant relationship.

These inconsistent results don't seem to point to any solid relationship between a county's average income level and COVID-19 infection rates.

One final test attempted was to perform a Generalized Linear Regression in order to see if any potential relationships between the tested variables existed that were independent of a local region. This test would also allow examination of binary data and allow the evaluation of mask mandates in the studied counties. The guidelines for GLR Regression say to use a Count (Poisson) model type for tracking the rate when the denominator of the rate is a fixed value. (ESRI, n.d.-a) Since the study tracked the per capita rate of COVID-19 infection, this method was used. A Count model requires whole numbers for its Dependent Variable (ESRI, n.d.-a) so the Calculate Field command was used in with a Python line to round the percent_infected field to a whole number. This new percent_infected_rounded field is used as the dependent variable.

The outcomes of this analysis were also interesting. Despite not appearing particularly significant when conducting Bivariate Analysis, the factors for GDP, High Temperature Value, Low Temperature Value, and Mask Mandate presence showed as having significant p-values in this test. This allows the rejection of the null hypothesis that they had no effect and leads to the conclusion that these factors had a statistically significant impact on the resulting infection rate.

Variable	Coefficients	Standard error	t-Statistic	Probability
Average_Income_per_Person	0.0009	0.0009	1.0273	0.3043
GDP	0	0	2.1213	0.0339
High_Value	0.0327	0.0058	5.6322	0
Low_Value	-0.0323	0.006	-5.417	0
population_density	0	0	-0.2186	0.8269
Mask_Mandate	-0.1809	0.0636	-2.8466	0.0044
Intercept	2.3407	0.225	10.4041	0

GLR Diagnostics

Property	Value
Akaike's Information Criterion (AIC)	1526.3616
Akaike's Information Criterion corrected (AICc)	1526.3616

Succeeded at Friday, August 19, 2022 12:34:11 AM (Elapsed Time: 25.29 seconds)

Figure 42 - All Variables Linear Regression Output

As seen in Figure 43 running the four values by themselves doesn't change the p-values for any of the outcomes. They'll have to be tested individually.

Variable	Coefficients	Standard error	t-Statistic	Probability
GDP	0	0	2.4226	0.0154
High_Value	0.0303	0.0052	5.8648	0
Low_Value	-0.0302	0.0054	-5.5597	0
Mask_Mandate	-0.1759	0.0634	-2.7759	0.0055
Intercept	2.4613	0.1892	13.0107	0

GLR Diagnostics

Property	Value
Akaike's Information Criterion (AIC)	1523.4072
Akaike's Information Criterion corrected (AICc)	1523.4072

Figure 43 - Four Variables Linear Regression Output

As shown in Figure 44 below, the GDP is not a statistically significant factor when looked at by itself.

Variable	Coefficients	Standard error	t-Statistic	Probability
GDP	0	0	0.7372	0.461
Intercept	3.1511	0.0146	215.255	0

GLR Diagnostics

Property	Value
Akaike's Information Criterion (AIC)	1564.1034
Akaike's Information Criterion corrected (AICc)	1564.1034

Succeeded at Friday, August 19, 2022 6:04:24 AM (Elapsed Time: 20.83 seconds)

Figure 44 - GDP Linear Regression Output

When looked at as its own variable, Mask Mandates turn out to have a statistically significant impact on COVID-19 infection rates, reducing the infections per capita when they were implemented.

Variable	Coefficients	Standard error	t-Statistic	Probability
Mask_Mandate	-0.2138	0.0608	-3.5184	0.0004
Intercept	3.3569	0.059	56.8694	0

GLR Diagnostics

Property	Value
Akaike's Information Criterion (AIC)	1553.0058
Akaike's Information Criterion corrected (AICc)	1553.0058

Succeeded at Friday, August 19, 2022 6:06:15 AM (Elapsed Time: 20.78 seconds)

Figure 45 - Mask Mandate Linear Regression

One more Linear Regression that limits the variables to the High and Low Temperature Values produces output that confirms the statistical significance of the High and Low Temperature Values as a metric for predicting the infection rate of COVID-19 in a county.

Variable	Coefficients	Standard error	t-Statistic	Probability
High_Value	0.6642	0.1638	4.0552	0.0001
Low_Value	-0.6028	0.1675	-3.5989	0.0004
Intercept	2.6522	5.3446	0.4963	0.6202

GLR Diagnostics

Property	Value
Multiple R-Squared	0.073
Adjusted R-Squared	0.0643
Akaike's Information Criterion (AIC)	1454.7956
Akaike's Information Criterion corrected (AICc)	1454.7956

Succeeded at Friday, August 19, 2022 1:34:12 AM (Elapsed Time: 18.84 seconds)

Figure 46 – Temperature Linear Regression Results

As a result, the study is left with three variables that are statistically significant. These are the High Temperature Value, the Low Temperature Value, and the presence or absence of a Mask Mandate.

Variable	Coefficients	Standard error	t-Statistic	Probability
High_Value	0.0274	0.005	5.4626	0
Low_Value	-0.0258	0.0051	-5.0602	0
Mask_Mandate	-0.1606	0.063	-2.5479	0.0108
Intercept	2.4811	0.1888	13.138	0

GLR Diagnostics

Property	Value
Akaike's Information Criterion (AIC)	1526.8448
Akaike's Information Criterion corrected (AICc)	1526.8448

Figure 47 - Three Variable Linear Regression

Table 2 - Final Linear Regression Output

Variables	Coef	StdError	t_Stat	Prob
High_Value	0.027434	0.005022	5.462596	0
Low_Value	-0.025817	0.005102	-5.060162	0
Mask_Mandate	-0.16064	0.063049	-2.547864	0.010838

Conclusions

Analyzing the course of a disease is not an easy job, especially with COVID-19 still being an ongoing issue for many. While most of the factors that were considered in this study turned out to have negligible effects on the rate of infection, the temperature measurements were determined to be statistically significant through Linear Regression. This, when combined with the seasonal trends observed in the Infection Charts (Figures 7, 12-15, 20, 25, 30, and 35) suggests that human behavioral changes that occur with the changing weather are the principal drivers of high rates of COVID-19 infection. As a logical consequence, counties and regions with more extreme temperatures will suffer greater spikes in their infection rates as people change their habits to suit the seasons.

Another thing that can be concluded is that the mask mandates were an effective method for hindering the spread of the disease with a statistically significant negative correlation that emerged through linear regression.

This has significant implications for public health studies. Mask mandates were heavily favored as a means of preventing the spread of COVID-19 throughout all the states studied, and many medical studies showed that masks prevented infection on the individual level. However, they often became a matter of intense public debate, igniting rancor and causing discord where they were used. Having solid evidence to support the policy’s effectiveness would be important for any policy maker who needs to consider using such measures again.

Much was learned during this analysis and a future study could change several things if it were to be conducted again in the future. First, while the data for COVID-19 infections was handily available at the county level, it was not effective at finding conclusions about what factors caused each county to have a higher or lower rate of infection. A follow up study might wish to use Census Tracts or another smaller unit that might produce more reliable data. Furthermore, a better study with temperature data might expand on the results that were found in this study. A good option would be to track new cases when compared to daily temperatures over time rather than tracking high and low points. A hypothetical future study should also include more states. The initial aim was to evaluate the impact of mask mandates and only one state in the study wound up not having a mandatory mandate, so this became difficult to evaluate. Furthermore, the only clear pattern that did emerge was a seasonal one, seeing if this pattern held up in different regions of the country would have been interesting. Finally, a study in a year to check on the effect of the vaccines on hindering the spread of COVID-19 would be an excellent way to follow up on this research.

LIST OF REFERENCES

Bureau of Economic Analysis. (2021a, November 16). *Personal Income by County, Metro, and Other Areas* | *U.S. Bureau of Economic Analysis (BEA)*. Retrieved August 16, 2022, from https://www.bea.gov/data/income-saving/personal-income-county-metro-and-other-areas

Bureau of Economic Analysis. (2021b, December 8). *GDP by County, Metro, and Other Areas* | *U.S. Bureau of Economic Analysis (BEA)*. Retrieved August 16, 2022, from https://www.bea.gov/data/gdp/gdp-county-metro-and-other-areas

ESRI. (n.d.-a). *Generalized Linear Regression (Spatial Statistics)—ArcGIS Pro* | *Documentation*. Retrieved August 16, 2022, from https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-statistics/generalized-linear-regression.htm

ESRI. (n.d.-b). *Local Bivariate Relationships (Spatial Statistics)—ArcGIS Pro* | *Documentation*. Retrieved August 16, 2022, from https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-statistics/localbivariaterelationships.htm

Fox10 Phoenix. (2020, June 27). *LIST: Arizona cities with face mask requirements*. https://www.fox10phoenix.com/news/list-arizona-cities-with-face-mask-requirements

Garcia, A., & Abdelsayed, A. (2022, February 11). *Mask mandate lifted: Nevada Gov. Steve Sisolak becomes latest to announce end date*. KTNV. https://www.ktnv.com/news/coronavirus/mask-mandate-lifted-nevada-gov-steve-sisolak-becomes-latest-to-announce-end-date

New Mexico Department of Health. (2020, May 15). *Governor signs modified, extended public health order easing some restrictions and requiring face coverings* | *NMDOH - Coronavirus Updates*. https://cv.nmhealth.org/2020/05/15/governor-signs-modified-extended-public-health-order-easing-some-restrictions-and-requiring-face-coverings/

New Mexico Office of the Governor. (2022, February 17). *New Mexico indoor mask mandate lifted | Office of the Governor - Michelle Lujan Grisham*. https://www.governor.state.nm.us/2022/02/17/new-mexico-indoor-mask-mandate-lifted/

NOAA. (2022, August). Climate at a Glance | National Centers for Environmental Information (NCEI). Climate at a Glance. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/

Romo, V. (2020, June 18). *California Gov. Newsom Makes Face Masks Mandatory Amid Rising Coronavirus Cases*. NPR. https://choice.npr.org/index.html?origin=https://www.npr.org/sections/coronavirus-live-updates/2020/06/18/880583357/california-gov-newsom-makes-face-masks-mandatory-amid-rising-coronavirus-cases

Swidler, F. (2021, May 14). *These Colorado Counties No Longer Have A Mask Mandate*. Colorado Public Radio. https://www.cpr.org/2021/04/13/colorado-mask-mandate-where-masks-are-not-required/

US Census Bureau. (2020, October 12). *TIGER/Line Shapefile, 2019, nation, U.S., Current County and Equivalent National Shapefile - Catalog*. Data.Gov. https://catalog.data.gov/dataset/tiger-line-shapefile-2019-nation-u-s-current-county-and-equivalent-national-shapefile

USAFacts. (2022a, June 27). *US Coronavirus vaccine tracker*. Retrieved June 27, 2022, from https://usafacts.org/visualizations/covid-vaccine-tracker-states/

USAFacts. (2022b, June 27). *US COVID-19 cases and deaths by state*. Retrieved June 27, 2022, from https://usafacts.org/visualizations/coronavirus-covid-19-spread-map/

Utah Governor. (2021, April 10). *UTAH'S STATEWIDE MASK MANDATE ENDS TODAY. HERE'S WHAT YOU NEED TO KNOW.* Utah.Gov. https://governor.utah.gov/2021/04/10/utahs-statewide-mask-mandate-ends-today-heres-what-you-need-to-know/

Wise, J. (2020, July 16). *Colorado governor issues statewide mask mandate*. The Hill. https://thehill.com/homenews/state-watch/507711-colorado-governor-issues-statewide-mask-mandate/