

**Understanding Patterns of Extraterrestrial Phenomena:
An Exploratory Spatial Analysis of UFO Sightings Throughout the Contiguous
United States from 1910-2014**

by

Hannajane Bull Prichett

MASTER OF SCIENCE
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I thank my family, friends, and professors for all that they have done to support me on this incredible journey.

To my mom and dad, thank you for answering the phone when 9 times out of 10 it was me having a complete mental breakdown.

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ABSTRACT

Are humans alone in the universe? It is one of the most profound existential questions of all time. It is a question that this project regrettably will not answer. We all want to know if UFOs are real because not understanding the unexplained is uncomfortable. Analyses in this project seeks to uncover consistent patterns in the reported sightings of extraterrestrial phenomena in the contiguous United States in the last century. The purpose of this master's project is to analyze data to look for patterns and relationships between UFO sightings and population density, population movement over the last century, and UFO sightings relationships to military installations across the Contiguous United States. To do so, tabular data was geocoded, and a geodatabase was established reflecting sightings between 1910 and 2014. The points were clipped to the Contiguous United States and analysis of the data focused on density and buffer analyses to examine population density relationships, mean center for population movement through time, and buffer analyses to examine sightings relationships to military installations. Results tend to show a relationship between population density and increased sightings of UFOs. No conclusive results showing temporal patterns related to a mean center analysis and mixed results related to military installations were found. GIS based research on UFOs is an important and growing field of study. This Masters Project contributes to helping us better understand UFO data from a spatial science perspective.

Keywords: UFO's, density analysis, buffer analysis, mean center analysis, population density

INTRODUCTION

In June of 2021 the US military declassified data on Unidentified Aerial Phenomena (UAP's). The nine-page report outlines the potential threat that UAP's have and what the Department of Defense is doing to understand and study this threat. The report notes that some patterns emerge: "Although there was a wide variability in the reports and the dataset is currently too limited to allow for detailed trend or pattern analysis there was some clustering of UAP observations regarding shape, size, and, particularly, propulsion. UAP sightings also tended to cluster around U.S. training and testing grounds, but we assess that this may result from a collection bias because of focused attention, greater numbers of latest-generation sensors operating in those areas, unit expectation, and guidance to report anomalies" ("Preliminary Assessment: Unidentified Aerial Phenomena" 2021). The report is vague, but the declassification of information is a step towards transparency between the government and the American people regarding extraterrestrial phenomenon. The Washington Post states: "Both former CIA directors were referring to Air Force and Navy pilot videos that have surfaced in recent years showing unexplained objects on radar traveling at unusual speeds and performing aerial maneuvers that defy logic when compared with what even the most advanced military planes are known to be capable of" (Rosenwald 2021).

Interests by US citizens in documenting and sharing information about UFO sightings is nothing new. There are groups like the National UFO Reporting Center that document sightings going back to 1910. The importance of having open and accessible data about UFO sightings allows people to be better informed, help continue that dialogue on whether we are alone in the universe or not and help us understand the relationship not only that UFO sightings occur but through the use of GIS we can begin to examine where they occur and how it relates to the US population.

There are quite a few organizations who have their data unavailable for nonmembers to download and explore making this topic relatively inaccessible to the public. Many of these organizations require a member fee to access their data which makes it hard to assess all the sighting's data collectively. The National UFO Reporting Center (NUFORC) makes their data public but not in a format that can be easily analyzed. The accessibility of this data is vital for current and future analysis to take place with relative ease.

While some mapping of UFO data has been done showing distribution, and sightings to population per capita further spatial analysis is clearly needed. Maps have an incredible way of presenting a viewer with a question and an answer. Humans are spatial thinkers by nature and maps provide us with ways to think about those questions in a spatial way. UFO sightings phenomena is fascinating because it is spatial with what appears to be a less than random distribution. Understanding why sightings are happening where they are might help us approach the phenomena in a more digestible way. The central thesis of this master's project was to analyze data to look for patterns and relationships between UFO sightings and population density, population movement over the last century and UFO sightings relationships to military installations across the contiguous United States. To achieve this, three separate analyses were performed. The vital piece of this master's project is to contribute to our understanding of the spatial patterns of UFO sightings within the contiguous United States.

To address the objective of the master's project I first turn to a description of the methodology. Following this section, I will then discuss the results of the three analyses in detail and provide a brief discussion on the findings. I will then follow with a conclusion where I speculate the findings and suggest further avenues of research on this topic. With this being an emerging field of study there is so much more to be done but this project hopes to add to the research currently out there and provide ideas for future avenues of analysis going further.

METHODS AND DATA

To begin, we define our study area which was the contiguous United States. This study area was chosen since this phenomenon reaches so far and wide that analysis needed to start somewhere, and the Contiguous United States was the starting point due to the sheer number of sightings within the country alone. There was a total of 80,333 recorded sightings within the original dataset. After the data was clipped to the Contiguous United States there was a total of 64,520 recorded sightings. This means that an overwhelming majority of the recorded sightings, 81.5%-, were in the Contiguous United States alone.

Geographic Information Systems (GIS) analyses were performed using ESRI ArcGIS Pro 2.8.1 and Excel. All data have a common projection: USA Contiguous Albers Equal Area Conic, NAD 1983, EPSG and D North American 1983. USA Contiguous Albers Equal Area Conic was chosen as the projection since it displays density and distribution accurately. The vector data was

obtained multiple different ways. Through data mining online I was able to find an extensive UFO sightings dataset from GitHub. GitHub is a for-profit company where they offer a cloud-based repository hosting service. The original data was taken from the National UFO Reporting Center (NUFORC) and was geocoded by user Sigmong Axel username: @planetsig and then published for public use to the cloud sharing platform, GitHub (Axel, 2014). Military installations data was found through data.gov. The dataset was used was titled: Military Installations, Ranges, and Training Areas and was last updated February 24th, 2021. This dataset was released by the Department of Defense and found on data.gov, the home of the U.S. Government's open data. This data contains both polygon and point data, only point data was utilized. (Military Installations, Ranges, and Training Areas - CKAN 2021). The base maps that were used were from ESRI as well as the 2017 census data that was used. The census data was obtained from Living Atlas through ESRI ArcPro (ESRI 2017).

As previously mentioned, the primary data used in this report was obtained from the National UFO Reporting Center (NUFORC). There were 11 columns in total. Column names were not included so after the data was downloaded, I ensured each column was named and formatted by its correct category in excel. The columns that were given were: Shape, City, State, Country, Shape of Craft, Seconds, Minutes, Description, Date, Longitude, Latitude. Latitude and longitude needed to be reformatted for ArcPro so the software could understand the data format when the data was uploaded. To begin this project, it was vital that I had a volume of data to ask the questions I wanted. With just over 64,000 reports within the Contiguous United States the volume of data was not lacking.

Data acquisition was the first step. Then some simple data editing needed to be done in Excel. The editing included ensuring the fields were formatted correctly with the correct category. After the fields were formatted latitude and longitude needed to be fixed so ArcPro would recognize the points. Once the data was in the correct format, XY to point tool was used to bring the dataset into ArcPro. In ArcPro a frequency table was created to better understand where sightings were occurring. This accounted for all sightings disregarding time and date of sightings and was only considering the exact latitude and longitude of the sightings. It was important to see what exact locations were experiencing higher frequency sightings to further understand what questions needed to be asked. The frequency table was created by first summing latitude and longitude and creating a field called 'geoid.' After creating this column, the

frequency tool was used with inputs 'state' and 'geoid,' and this created the frequency table which was a foundational step in beginning this project. All data were projected in USA Contiguous Albers Equal Area Conic, NAD 1983, EPSG and D North American 1983. Other vector and tabular data were obtained from multiple sources. Census data and base map data was drawn from ESRI, and military data derives from data.gov. These data were combined into a geodatabase which provided the basis for three different analyses.

ANALYSIS

Three analyses were performed in this report. The first focused on a more general understanding of density and distribution of UFO sightings, the second analysis goes into more detail and looks at UFO sightings relationships to population, and the movement of sightings and population over the last century. Where the third and final analysis focuses on military installations to see if there is a spatial relationship between sightings and proximity to military installations. Spatial analyses were performed using ESRI ArcGIS Pro 2.8.1 and Excel. We follow with in-depth descriptions of the three analyses and then move on to discuss the results along with a brief discussion which is then followed with a conclusion.

Analysis 1: Density and Distribution of UFO Sightings

The goal of the first analysis was to gain a general understanding of distribution of density of UFO sightings across the Contiguous United States. To accomplish this goal, four maps were created, one Excel animation, and three ESRI Business Analyst reports and two charts were created. First, a simple distributions of sightings map was made. This map shows all the UFO sightings points on one single map. This was included in the first analysis to plainly show the volume of sightings that existed within the United States. Then, an animation in Excel was made to show the spatial and temporal nature of this data. It is hard to show the temporal aspect of this data in a static map. This animation was difficult to create because the input data needed to be organized in a specific way for Excel to generate the point data accurately. The data needed to be connected to a dataset within the Excel workbook. From Excel, the UFO sightings database was connected. After the connection was made it was vital to ensure that the columns were formatted correctly. The data needed a spatial component for a 3D map to generate, so the latitude and longitude variables included in the dataset were used. The 3D map was generated,

and latitude and longitude were chosen for visualization, and the animation was created. This animation showed all sightings within the contiguous United States from 1910-2014. It was truly incredibly to see how this phenomenon reaches far and wide both spatially and temporally.

Next, a kernel density map of all sightings was created. A kernel density analysis can be defined as one that calculates a magnitude-per-unit area from a polyline or point feature, in this case point feature, using a kernel function to fit a smooth surface to the point (ESRI, 2016). The input feature for the kernel density tool were UFO sightings points and method was planar. This type of analysis was appropriate because this is an effective way to visualize density with point data. Then, a simple overlay map was created. This overlay map was created using the kernel density layer and population density layer. This map was made to see if there was a spatial relationship between the two density surfaces.

A similar density analysis was done on US population data from 2017. This map is showing UFO Sightings per 100,000 people by county. A standard deviation classification scheme was used where sightings were normalized by population. This classification scheme showed below and above average counties where sightings were happening. This analysis looks at sightings normalized by population to understand the spatial relationship between the two variables. Summarize within, in the analysis toolbox was used to achieve this analysis. The input polygon was USA_Counties with input summary features: TotalData_Frequency and summary field as FREQUENCY. From here a Rate per 100,000 field was calculated: $RATE = \frac{!POPULATION!}{100000}$. Then by calculating: $!SUM_FREQUENCY! * !RatePop!$ we were able to get UFO Per 100,000. With this new information the top 10 counties with highest rate of sightings per 100,000 people were selected and a new layer was created.

To wrap up analysis 1, three reports and two charts were generated in Business Analyst: a community report, business report, and a demographic report. The two charts that were created compare income and population size of the 10 counties with the highest rate of sightings per 100,000 people. The reports were run on the 10 counties as well. These reports and charts were created to see if any similarities exist between the 10 counties. To do this, the top 10 counties with the highest rate of sightings per 100,000 people were selected within ArcPro. From here the layer was published to ArcOnline as a web layer. Once published to the online platform I was

able to bring it into Business Analyst and run the reports. Moving away from distribution and density of UFO sightings we move to the second analysis which focuses on the temporal aspect of the UFO sightings data.

Analysis 2: Spatial Temporal Analysis

The second analysis takes a more in depth look at UFO sightings and their relationships to population along with sightings and their relationship to population movement over the last century. This analysis focuses on comparing the mean centers of the two primary datasets, the UFO sightings data and the census population data based on decennial intervals. Sighting's data was separated into nine subgroups of relatively evenly distributed sightings through time due to different volumes of data earlier on in the reporting. This analysis was done to compare and check for spatial and temporal trends in the data. Comparing population shift over time with sightings data shows whether population movement affects the mean center of the sightings data. A mean center analysis can be defined as taking the average x and y values that are stored in the feature centroid and providing an output (Kerski 2011). For example, to understand population movement through the century you take the average x and y values from a 10-year span and the output is a single point generated from that information. Mean centers for UFO sightings were generated using the Mean Center tool within the Spatial Statistics toolbox in ArcPro.

The mean center analysis was done to see if there was a visual spatial relationship between population movement over time and sightings over time. For this analysis I hypothesized that there was a connection between the movement of sightings and population movement over time. From the very beginning of this project, it was noticed that the sightings data that was collected was quite slim between the years of 1910 and 1945. The volume of data collected started growing after the 1950's. This made sense to me for a few reasons: First, the National UFO Reporting Center was not founded until 1974 making it harder to find sightings data reaching further back. The second reason being apprehension against reporting due to negative attitudes or stigma around this topic. It's unclear why sightings started exponentially growing, but they did and because of this I needed to separate the sightings data into groups that

were relatively even to proceed with the analysis. After separating the sightings into nine separate subgroups mean center analysis was run on each temporal range of sightings. The mean centers of population data were from census data that was formatted in an Excel spreadsheet and uploaded to ArcPro. Once uploaded into ArcPro it was symbolized. As the second analysis concludes the final analysis shifts focus from mean centers to examining the relationships between UFO sightings and military installations.

Analysis 3: Multiple Ring Buffer Analysis

The third analysis for this project shifts focus to look at the relationship between UFO sightings and military installations using a multiple ring buffer. A multiple ring buffer creates buffers at specified distances around the input features. The input features were the military installation points. The military installation point data included a total of 762 sites. Three buffers were created around each military installation, a 10-mile, 20-mile, and 30-mile buffer. This analysis was by far the most difficult of all three.

A buffer analysis was tried and was not successful so I proceeded with a multiple ring buffer because the buffers were separated, and this analysis would work best for what I was trying to achieve. Using the multiple ring buffer tool, I was able to use the military installation points as the input and have three buffers created around each of the 762 points. A spatial join was performed to join the UFO sightings frequency data to the buffers they fell into. Then, a process of spatial joins and selecting layers by location needed to be repeated three separate times for each of the three buffers. This ensured that the UFO sightings frequency data was now joined to the correct buffer for further analysis. By repeating this process, we were able to understand the percentages of UFO sightings that fell into each buffer ring. I thought there would be a more efficient way in performing this analysis and dissolving the points into each buffer but that was not the case. It was quite complicated getting the sightings data into the. With this analysis being the most difficult the results were not what originally thought they were going to be.

As we conclude the third and final analysis we will move to the results. In this section I talk about what each analysis shows us and possible avenues for future research. This field of

study is still emerging so there is much more to be explored and analyzed. Following the results, we will have a brief conclusion to wrap up the report.

RESULTS AND DISCUSSION

This section will expand on the findings from each individual analysis. Maps and other infographics that were created within each analysis will be shown and further explained. I will provide a brief discussion on further avenues of research before moving onto the conclusion.

Results of Analysis 1

The first map in this analysis was a distribution of sightings map. This map plainly shows all sightings throughout the Contiguous United States from 1910-2014 (Figure 1). No analysis was done here. This map was included in analysis one to show how this phenomenon reaches far and wide both spatially and temporally. A lot of assumptions can be made from simply looking at the distribution of sightings map. Clustering appears around larger cities such as LA, Houston, Seattle, the entire east coast. The next few maps will help better understand UFO sightings spatial relationship to population.

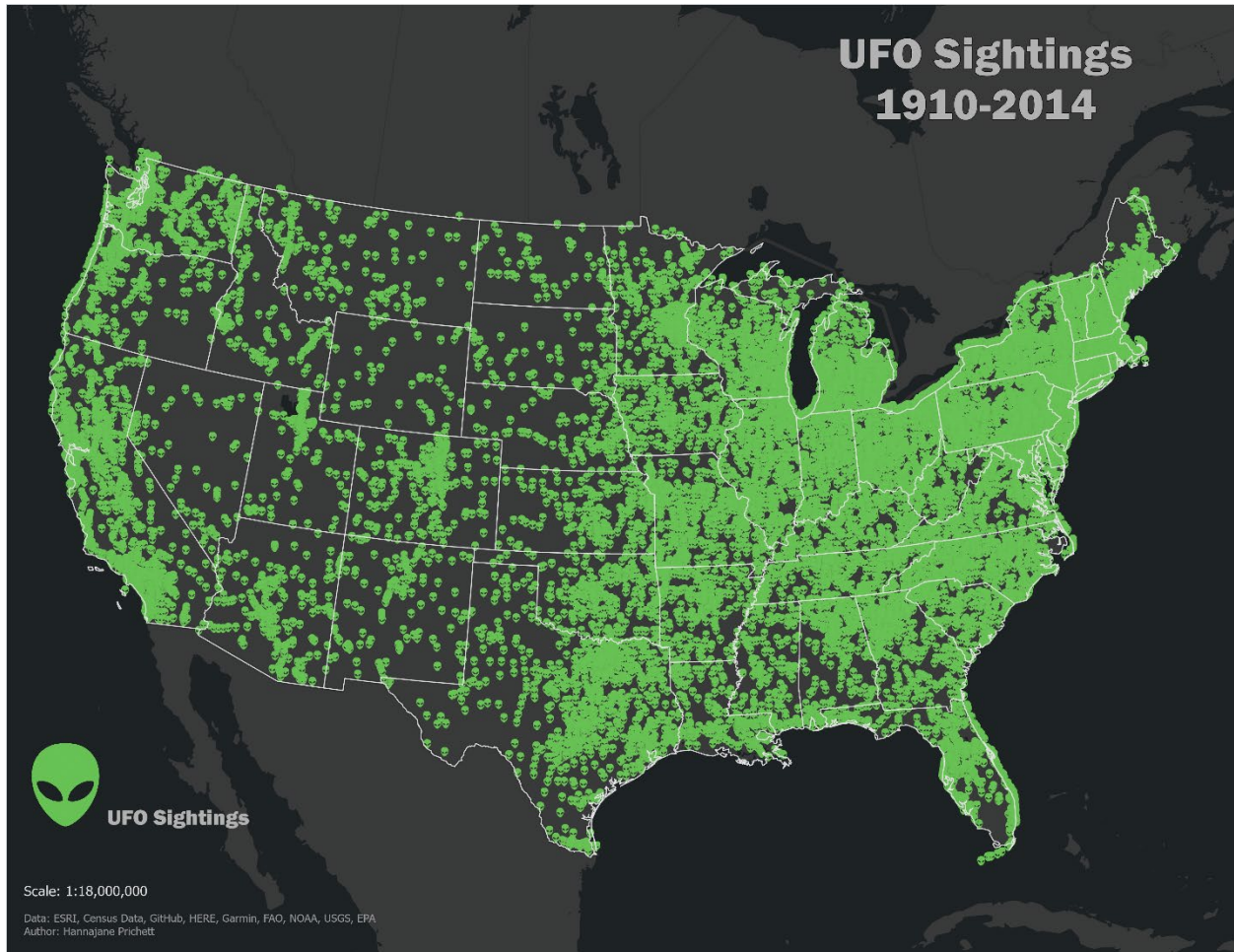


Figure 1: Distribution of sightings map showing all sightings within the contiguous United States from 1910-2014.

After this map was created, we move to the kernel density analysis. Kernel density was used because it calculates a magnitude-per unit area, from a point in this case, using a kernel function to fit a smoothly tapered surface to the point. This analysis was showing density of all UFO sightings for 1910-2014. This analysis revealed that sightings seemed to be occurring in primarily high populated urban areas. The kernel density map shows that sightings were concentrated in New York, Los Angeles, Chicago, and Phoenix. Houston did not show up on that map which was interesting considering it is the fourth largest city in the US (Figure 2). It was important to begin to understand how sightings and population data could be related so another map was created where two density surfaces were overlaid and then spatially related.

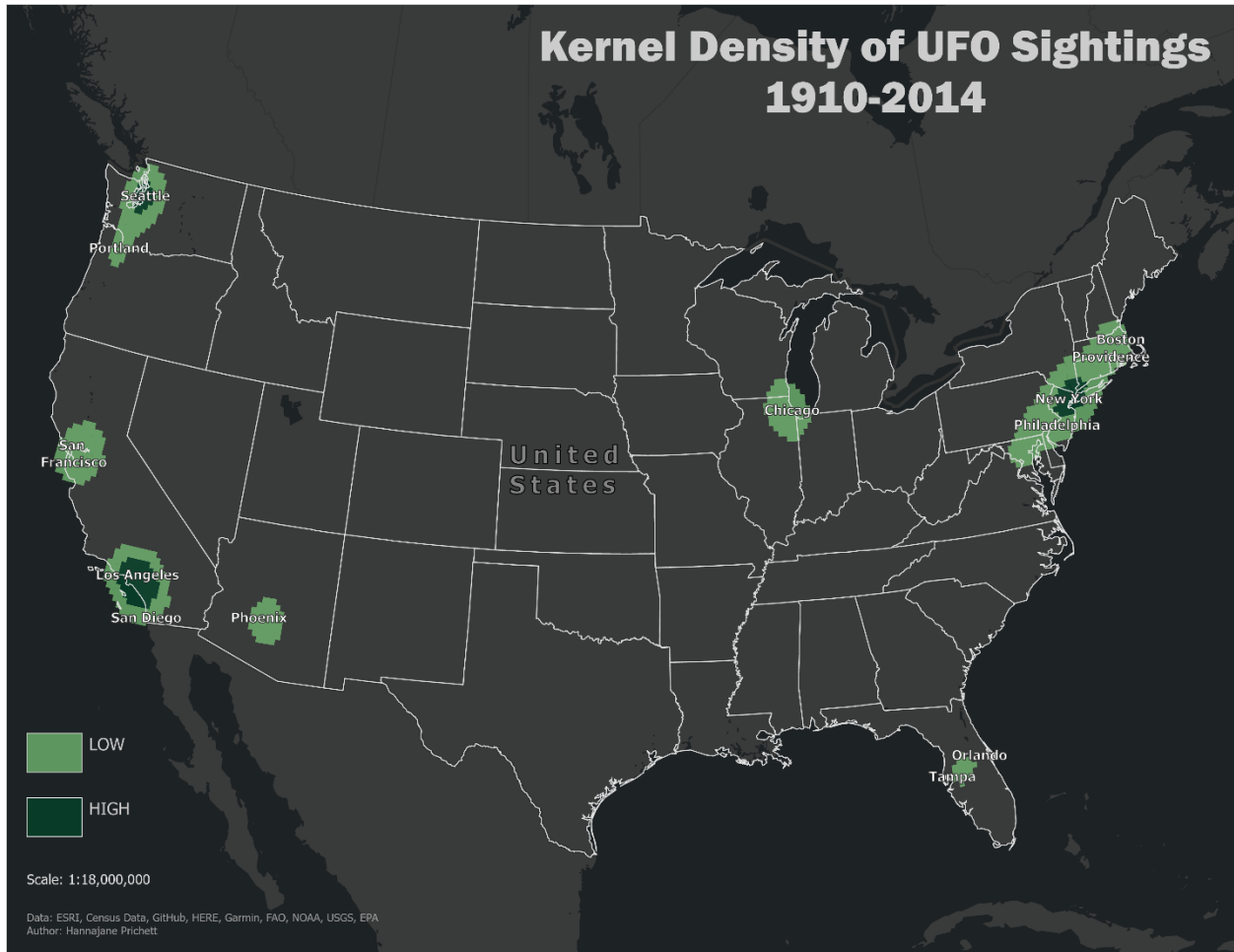


Figure 2: This map is showing density of sightings from low to high using kernel density.

This map shows us how population density by county and density of sightings across the United States are spatially related. We can see that where a higher frequency of sightings is observed are areas with higher population as well (Figure 2). This overlay map reveals sightings occur frequently in the Southwest and Northeast. It's interesting to see these two variables compared visually but further analysis needed to be completed to continue to understand this relationship. To examine how population density and UFO sightings are related we move to the choropleth map which gives us a more in-depth view of the relationship between the two variables.

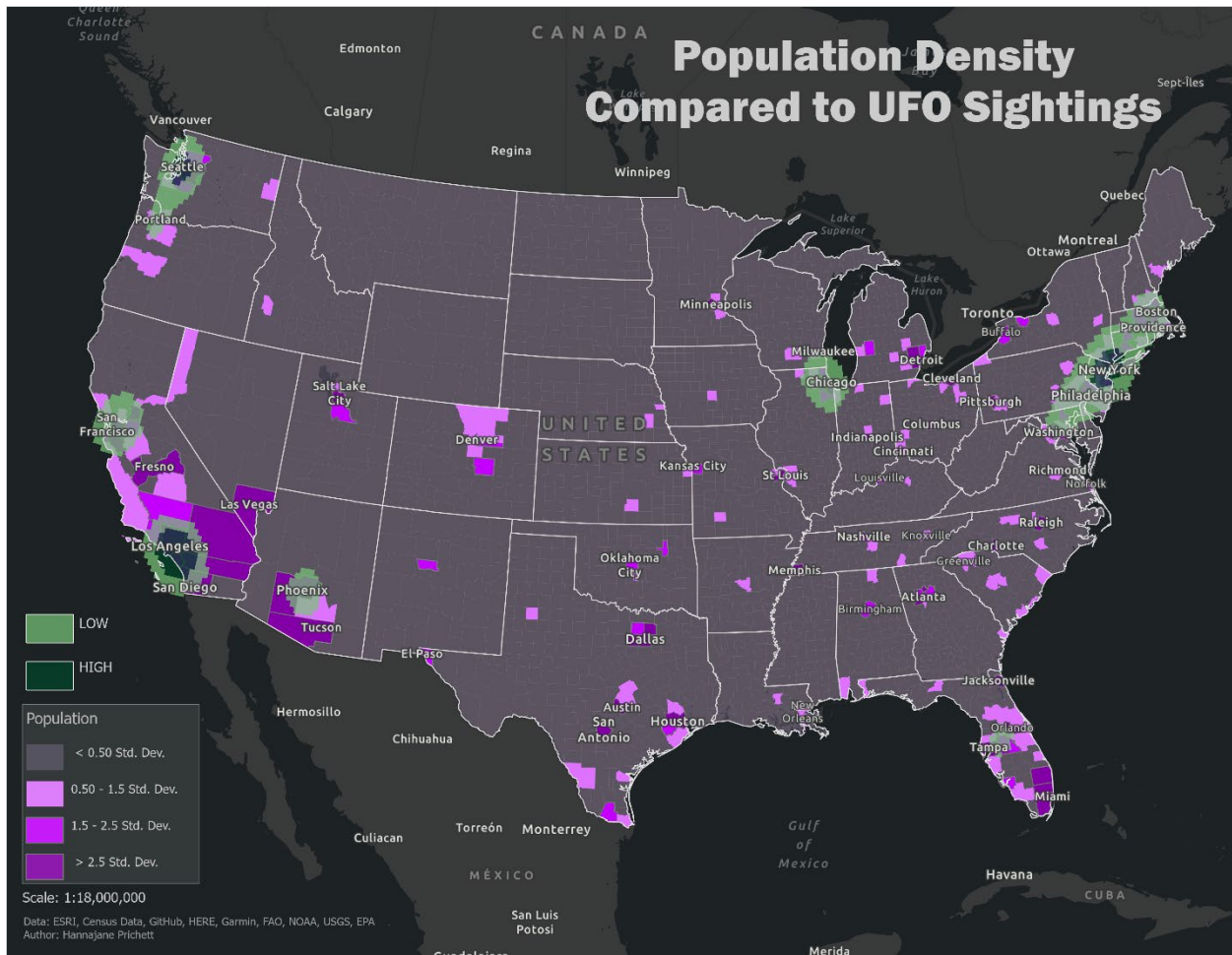


Figure 3: This map is showing population density by county with the kernel density map of UFO sightings overlaid on top.

The choropleth map helped us better understand where sightings were happening above and below average when compared to population. We clearly see that population density seems to follow the kernel density map of sighting but are unable to further speculate without more in-depth analysis. The results that are revealed from this section of the analysis are that there were 11 counties with above 1.5 standard deviations. Only in 11 counties did UFO sightings per 100,000 people exceed the national average. Looking at these counties the ones that are showing higher rates of UFO sightings per 100,000 people are primarily urban, populated areas (Figure 3). There were nine counties with above 2.5 standard deviations. The nine counties included: Clark County, NV, Cook County, IL, King County, WA, Los Angeles County, CA, Maricopa County, AZ, Orange County, CA, Riverside County, CA, San Diego County, CA, and lastly

Snohomish County, WA. The three counties that have the highest frequency of sightings are Los Angeles, Maricopa County in Arizona, and Cook County in Illinois. These counties are twice more likely than average to have a sighting. If seeing a UFO is on your bucket list, then these three counties are where you should be looking.

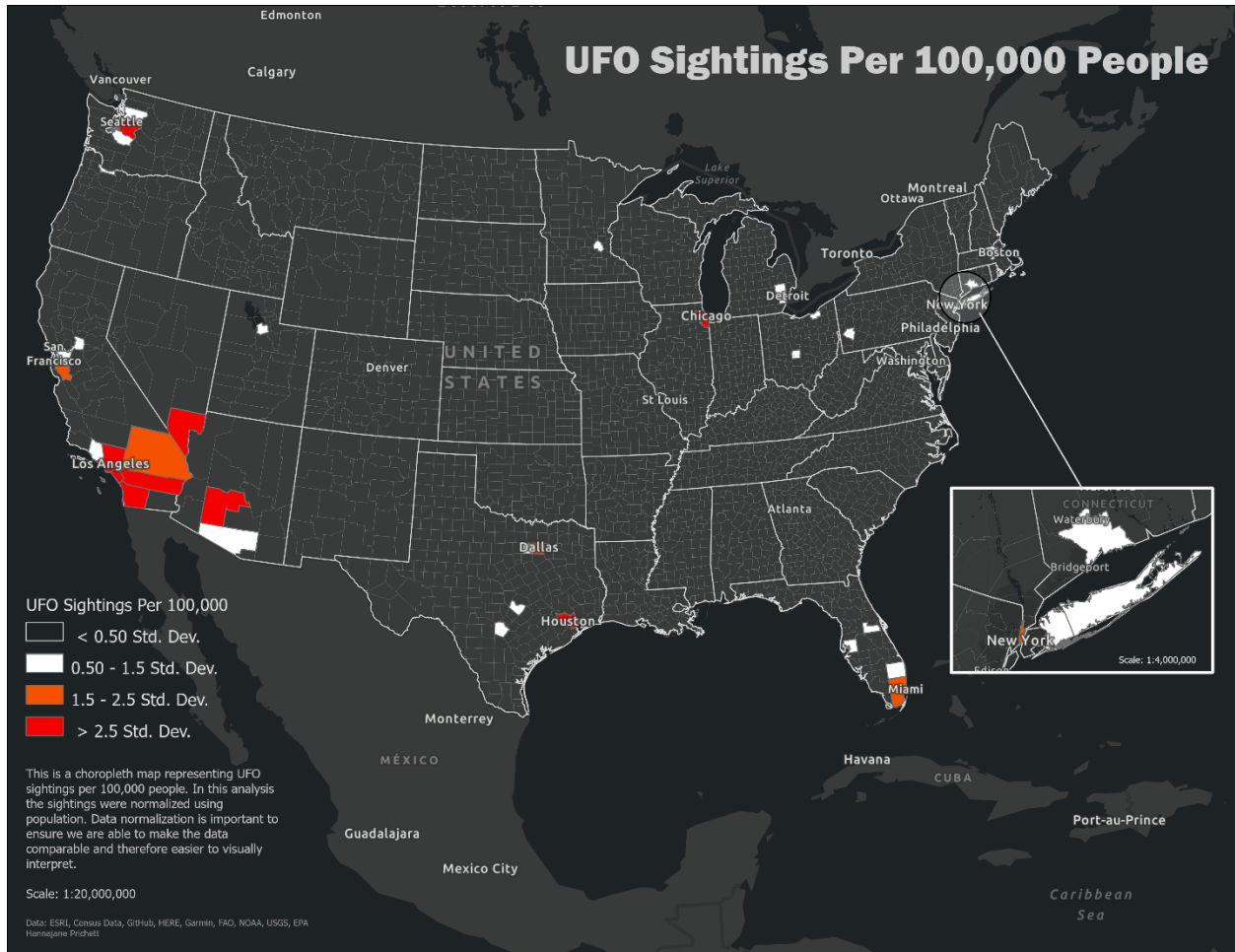


Figure 4: This map is showing UFO Sightings per 100,000 people by county. A standard deviation classification scheme was used where sightings were normalized by population. This classification scheme showed below and above average places where sightings were happening.

To wrap up analysis one we move to Business Analyst which helped us further understand demographic similarities between the counties with the highest rate of sightings per 100,000 people. It was decided that the top 10 counties with the highest rate of sightings per 100,000 people would be looked at. A Business Analyst layer was created in ArcPro and published as a web layer to ArcOnline. This layer was brought into Business Analyst where three separate reports and two charts were created. Business summary reports, community profile reports, and demographic reports for each of the 10 counties with the highest rate of sightings per 100,000 people were

generated to help us understand what similarities between these counties existed, if any. Two charts comparing income and population size were also created. The conclusions that were made from these Business Analyst reports were that the counties with the highest rate of sightings per 100,000 people all had a higher percentage of white-collar workers. I found this interesting and something that should be examined in future research. Looking at the chart of income differences we see that the 2021 median household income is above average when compared to 2019 median household income (Figure 4). The only county that does not meet this criteria is Clark County, NV with a median household income at \$61,830. When looking at population differences for these 10 counties we see that population is above 800,000. Both New York County and Snohomish County in Washington are the least populated out of the 10. New York County at 1,633,977 and Snohomish County at 835,533. Los Angeles County has the highest population at 10,108,711 so it's no surprise that the highest frequency of sightings is occurring here. The other seven counties' populations range between 2.4 million and 5.2 million (Figure 6).

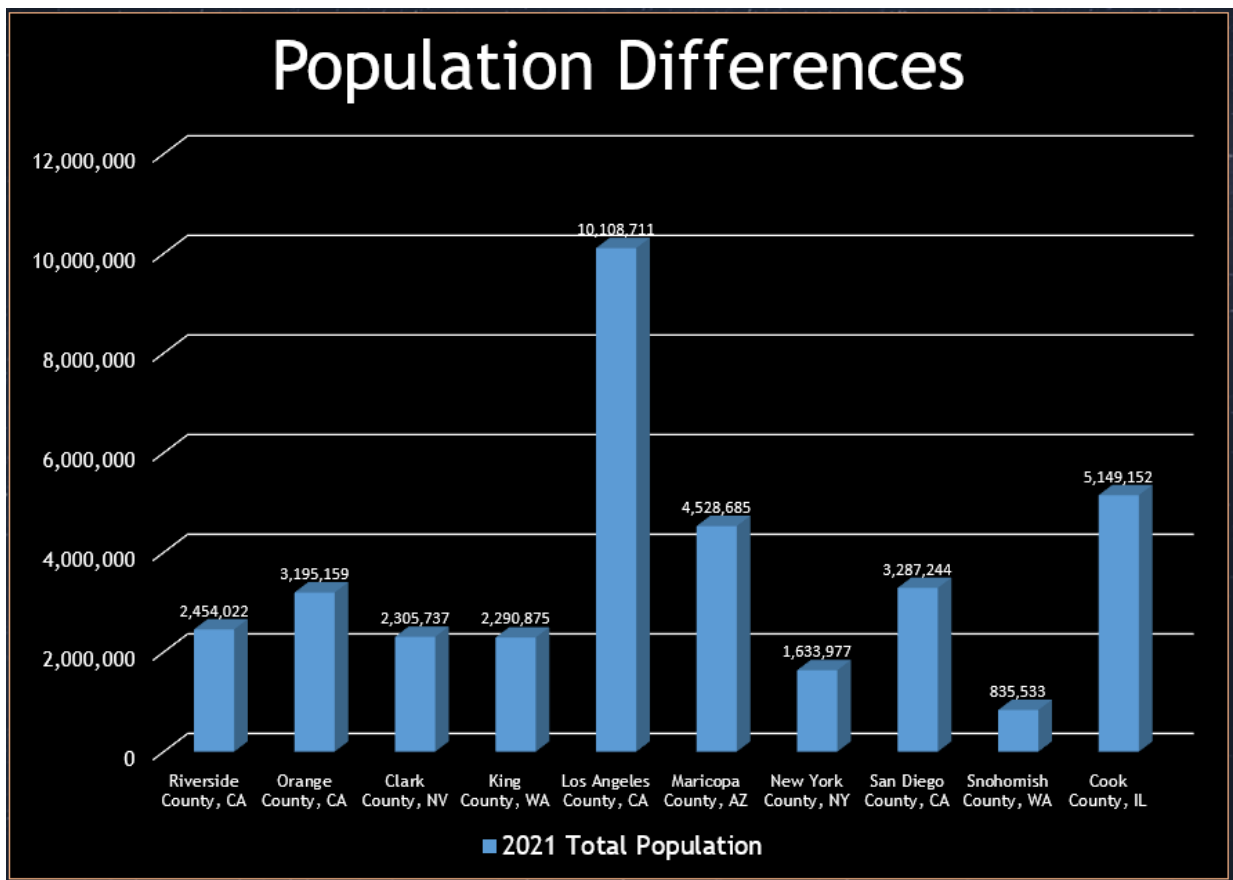


Figure 5: Population differences between top ten counties with the highest rate of UFO sightings per 100,000 people.

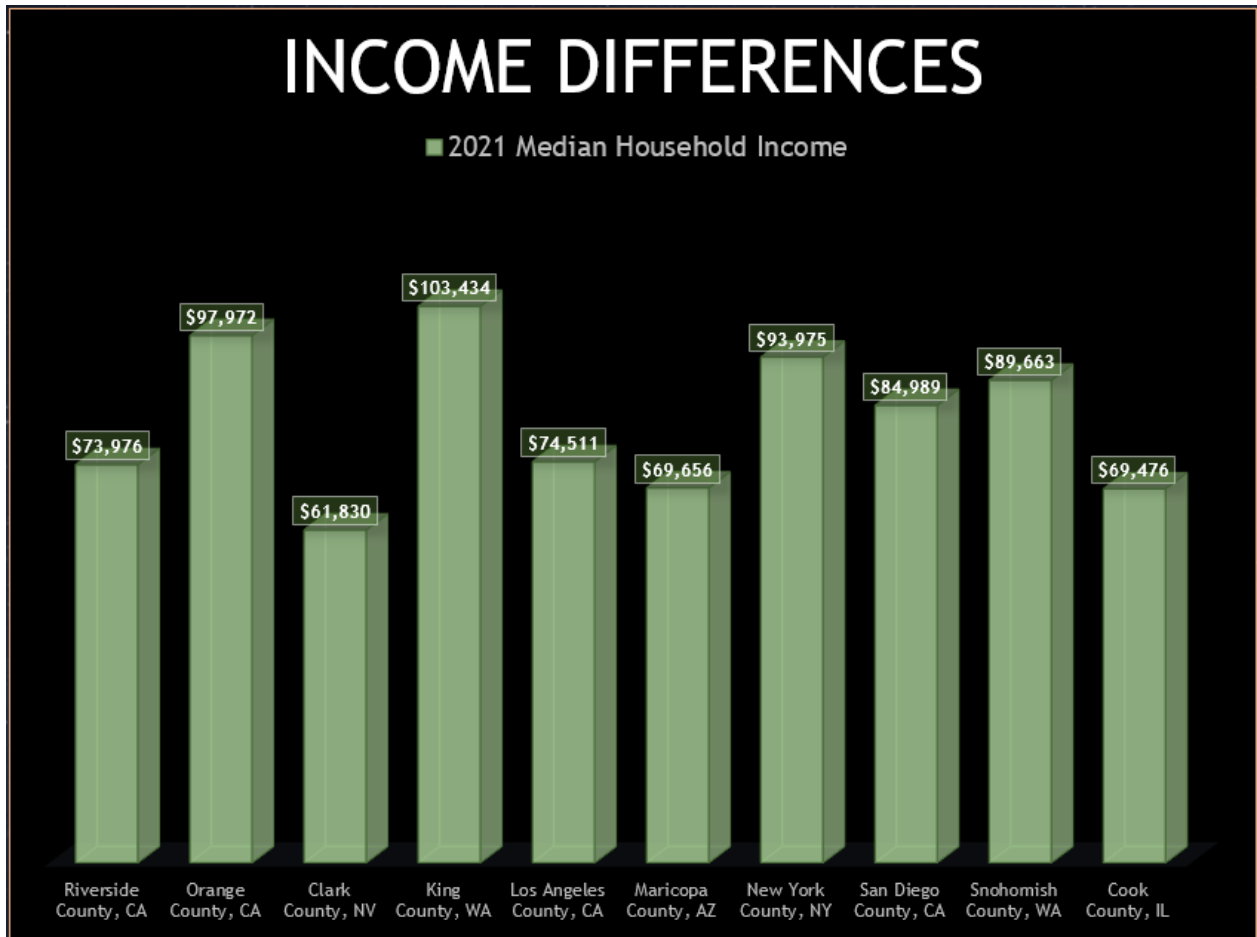


Figure 6: 2021 median household income differences for top 10 counties with highest rate of UFO sightings per 100,000 people.

Results of Analysis 2

The mean center for population shows distinct movement westward over time but after the analysis was completed, I concluded that there was no temporal relationship with the mean center analysis regarding the UFO sightings mean center centroids. This indicates there is no recognizable pattern of UFO sightings moving west in relation to population movement over time. There was an interesting finding with the UFO sightings mean centers, though. Three sightings centroids which covered 1961-1970, 1971-1980, and 1981-1990 were trending west over the 30-year period. I also saw that from 2000-2014, the four mean center centroids within that time span all seem to be trending east (Figure 6). No further conclusions were made but I do think this is something future research should look at. It was also observed in the centroids for the sightings data that sightings through time are occurring on coasts at a higher rate, but I don't have definitive causation as for why this is. We saw this in the first analysis when the kernel

density analysis was overlaid on the population density by county map, so this second analysis seems to follow a pattern. We can hypothesize that this is happening since there are more eyes on the sky in those places, but I cannot state this definitively.

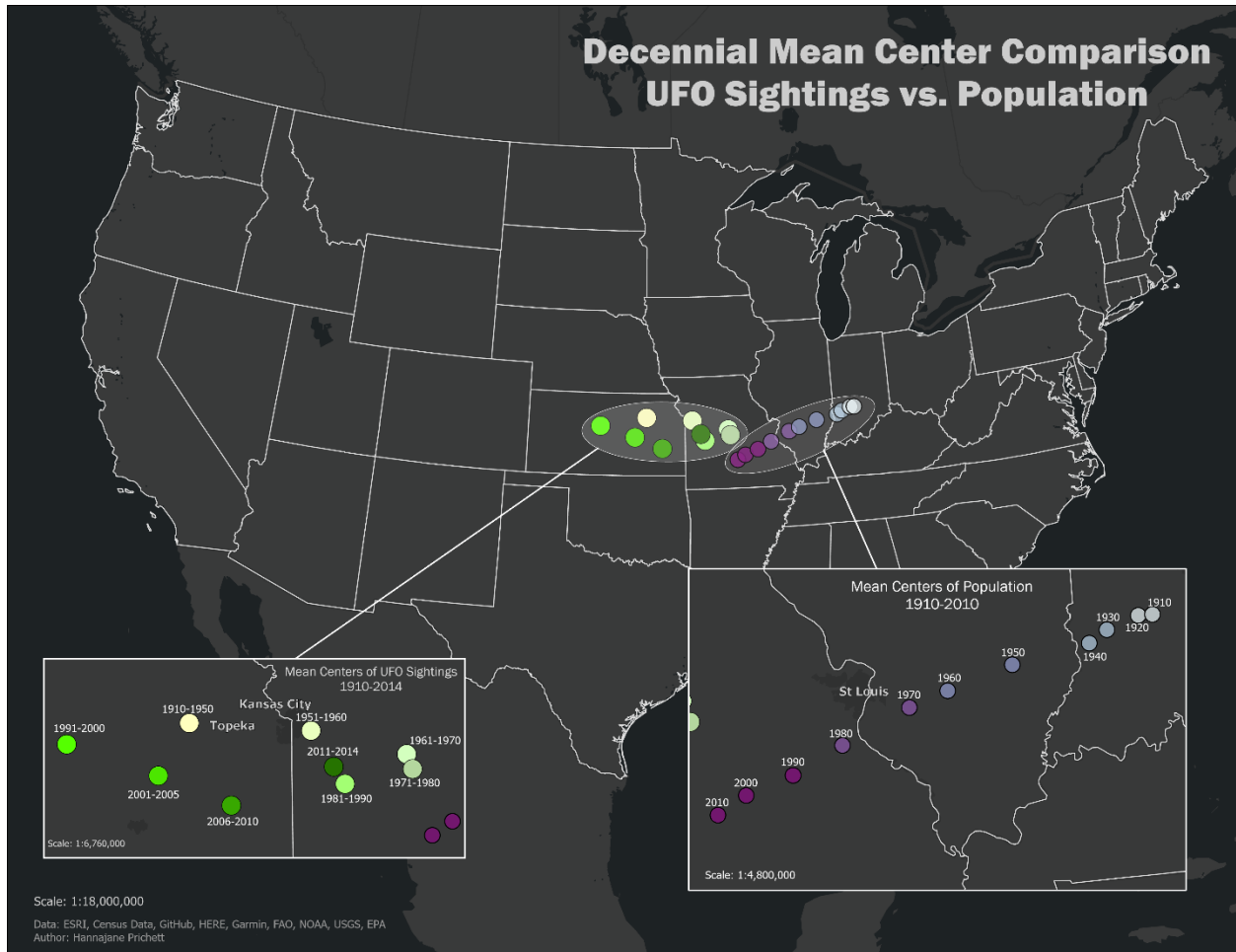


Figure 7: As you can see population is decennial while sightings are split into years according to volume of data within each subgroup. This gave a more accurate representation of the mean centers of sightings over time.

Results of Analysis 3

Analysis three was by far the most difficult analysis, but also provided unexpected results. The US military titled ‘Preliminary Assessment: Unidentified Aerial Phenomena’ reported that “...UAP sightings also tended to cluster around U.S. training and testing grounds, but we asses that this may result from a collection bias because of focused attention, greater numbers of latest-generation sensors operating in those areas, unit expectation, and guidance to

report anomalies” (“Preliminary Assessment: Unidentified Aerial Phenomena” 2021). There was a total of 38,671 UFO sightings within all three buffers combined. There were 3,842 points within the 10-mile buffer, 11,891 points within the 20-mile buffer, and 22,938 points within the 30 miles buffer. This means 59% percent of sightings were within the 30-mile buffer, 30% of the sightings were within the 20-mile buffer, and 10% of the sightings were within the 10-mile buffer. My hypothesis was that sightings would have a higher frequency closer to military installations, but this multiple ring buffer analysis proved that theory incorrect. We can see on the map that there are military installation points in Virginia, Maryland, California, Arizona, New Mexico, and Nebraska that seem to have a higher frequency of sightings within those 10-mile and 20-mile buffer areas. There are several in Oregon and Idaho along with some clustering of points with higher frequency of sightings towards the Southeast of the United States (Figure 7). The locations where the frequency of sightings occur within those 10-mile and 20-mile buffer areas are ones where we saw higher frequency of sightings in our other analyses as well.

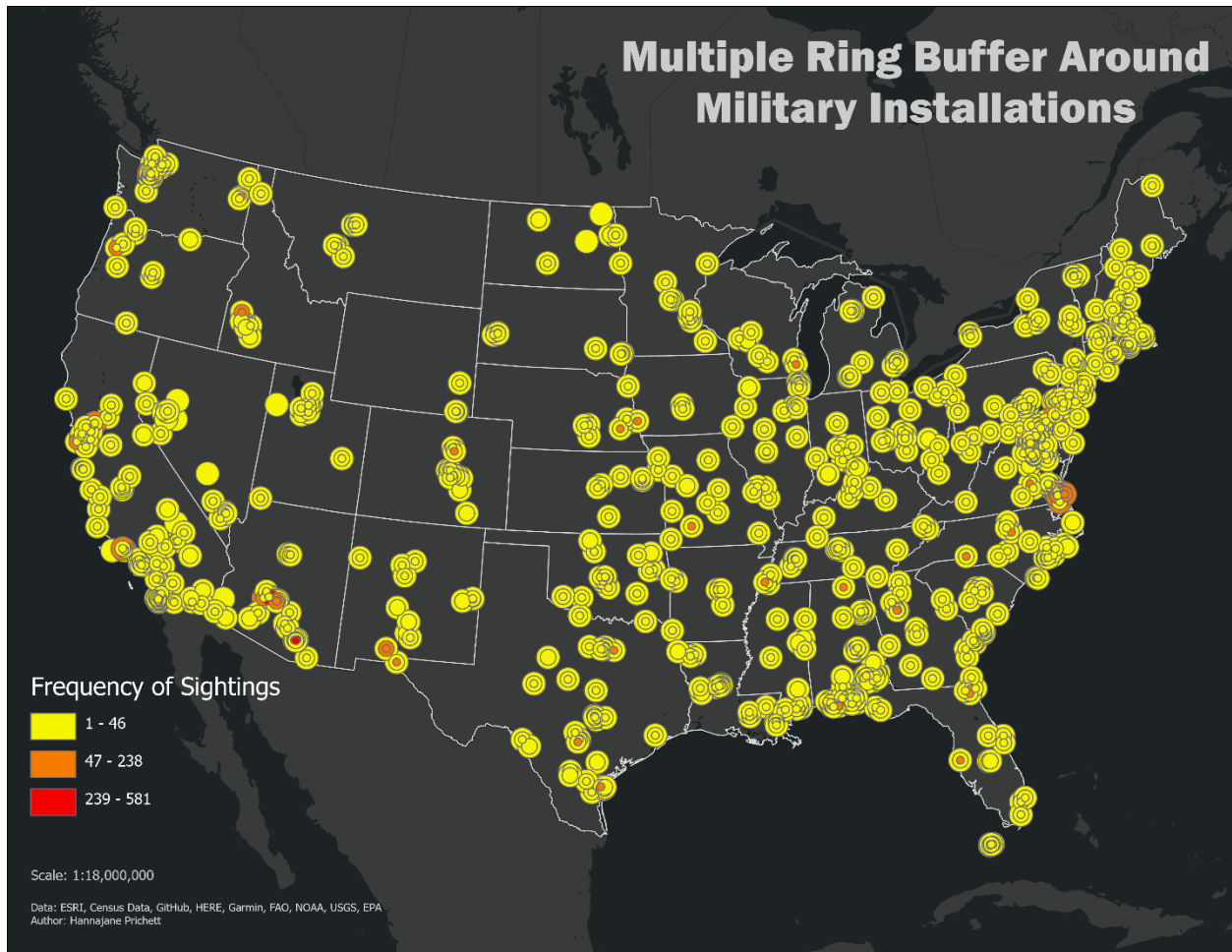


Figure 8: A multiple ring buffer creates buffers at specified distances around the input features. This analysis included a 10-mile, 20-mile, and 30-mile buffer around military installation points.

CONCLUSIONS

To look further into this phenomenon there needs to be a relative consensus of what these sightings mean and how they can be approached in a purely scientific way. The objective of this master's project was to analyze data to look for patterns and relationships between UFO sightings and population density, population movement over the last century and UFO sightings relationships to military installations across the contiguous United States. Analysis one provided a few different density and distribution analyses of UFO Sightings to address UFO sightings relationships to population density. Analysis two provided a mean center analysis to address UFO sightings relationships to population movement over the last century, and Analysis three

provided a multiple ring buffer analysis to understand how UFO sightings were related to military installations.

The findings conclude that there appears to be a strong relationship between population density and UFO sightings. There *are* similarities in the demographic characteristics of the population where UFO sightings were frequently recorded such as a higher percentage of white-collar workers in the counties with the highest rate of UFO sightings per 100,000 people, high population and above average income when compared to US median household income. As well as population moving west in a linear fashion while sightings centroids were more distributed over time, not revealing any clear concrete patterns. Surprisingly, sightings were more frequent further from military installations.

Like all projects there are roadblocks one needs to overcome. I experienced quite a few issues with the third analysis before the outcome was successful. From tools not working, to reworking the original methodology, the third analysis was met with difficulty. Further research into understanding how the multiple ring buffer could work for this analysis was vital to finishing this analysis. Concluding the third analysis wrapped up this project. The three analyses performed serve as a resource for people who would like to go further with this topic.

This project is only the very beginning of what needs to be explored with this phenomenon. There are so many questions to ask and simply not enough time to ask all of them in this paper. I share the excitement with many others as the U.S. government starts showing transparency with their data and findings in the field of UAP's.

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