The Influence of Humidity, Precipitation, and Temperature on Mosquito-borne Vectors in the United States

Benjamin Folk[1], Dori Stein[2], Mia Obid[3], Sidha Kunada[4]

NASA, Texas Space Grant Consortium, and The University of Texas at Austin Center for Space Research Summer Intern Program

[1] Francis Parker High School, San Diego, California
[2] New Dorp High School, Staten Island, New York
[3] Saint Pius X High School, Houston, Texas
[4] Lafayette High School, Lafayette, Louisiana

Abstract

Mosquitoes are the primary insect vector of dangerous pathogens, specifically dengue fever and the West Nile virus. The potential risk of a mosquito-borne epidemic can be correlated with many environment-specific variables that affect mosquito oviposition, activity, and feeding habitats. We sought to draw connections between environmental variables such as precipitation, humidity, and temperature to the risk of mosquito-borne diseases. Before examining potential data, we hypothesized that the outcome of our study would show a direct positive correlation between mosquito-borne disease transmission and precipitation, temperature, and humidity. This was primarily because the presence of these conditions would create more natural mosquito breeding habitats and make diseases more easily transferable through more suitable conditions. We used data from the Center of Disease Control's (CDC's) National Arbovirus Surveillance System (ArboNET) to analyze the vector transmission of the West Nile virus and dengue fever. The GLOBE Observer Mosquito Project Advanced Data Access Tool (ADAT) was another source of our data that examined submissions from separate institutions in five major cities on the East Coast (Denver, NC, Tallahassee, FL, Hays, KS, Norfork, AR, and Northville, NY). Records from these sites enabled us to evaluate environmental data, including daily air temperature. Additionally, NASA's Prediction of Worldwide Energy Resource (POWER) Data Access Viewer was utilized to obtain the relative humidity percentage statistics at the above sites. Precipitation statistics via rain depth were found using the National Oceanic and Atmospheric Administration's Climate at a Glance County Mapping tool (NOAA). Ultimately, our study found that humidity and the spread of mosquito-borne diseases are not directly related, while increased temperature appears to be directly related to both West Nile virus and dengue fever. Finally, West Nile virus cases were found to positively correlate with precipitation, while dengue fever cases were found to be inversely associated with rainfall levels.

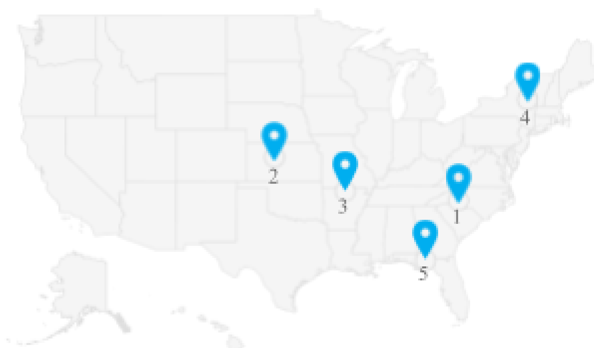
Keywords: Baxter county, CDC, dengue fever, Ellis county, Fulton county, GLOBE, humidity, Leon county, Lincoln county, mosquitoes, NASA, NOAA, precipitation, temperature, West Nile

Contents

Introduction

In our modern world, the ever-changing climate continuously poses new threats and influences the ecosystem around us. The change and development of atmospheric conditions over time engages in a crucial role in how all species live and function together. For example, people who reside in a humid habitat tend to have an increase in dehydration and fatigue. In contrast, people who live in arid habitats tend to have dry skin and little access to produce. Environmental conditions also profoundly affect mosquitoes, influencing their activity, breeding, and feeding habits. In correlation with climate change, the transmission of deadly mosquito-borne diseases such as dengue fever and West Nile virus can increase and pose a serious threat to public health. Since these epidemics contribute to thousands of deaths annually (making mosquitoes the primary cause of animal-related deaths worldwide), scientists have become dedicated to better understanding their behavior. While researching this topic, we formulated a question: How do environmental conditions such as precipitation, temperature, and humidity affect the transmission of mosquito-borne diseases?

To more effectively understand the topic through preliminary data, we analyzed scientific papers, articles, and other sources of information. In general, mosquitoes tend to gravitate towards wet, humid climates, which serve as ideal breeding grounds for cold-blooded females. Consequently, relative humidity in a specified region strongly correlates to mosquito population count; with higher humidities, egg production, larval indices, and mosquito activity are likely to significantly increase (Drakou et al., 2020). Furthermore, mosquito survival rates decrease during dry seasons when relative humidity falls to lower values (Yamana, 2013). While studies published in the National Library of Medicine demonstrate a positive correlation between precipitation and mosquito activity (and therefore mosquito-borne diseases), results are site-dependent. This is primarily because, while an increase in rainfall can create more mosquito breeding habitats, an excess of water can flush out some habitats and lead to an overall decrease in transmission (Drakou et al., 2020; Colón-González et al., 2021). Finally, other sources demonstrated that mosquito activity relies upon temperature, as the insects thrive in a moist and warm environment (Bellone, 25 September 2020). While cold temperatures can decrease population and slow reproduction, high temperatures can quicken mosquito maturity and increase the number of eggs laid in breeding habitats. Because of this, locations with higher temperatures are often at increased risk of mosquito-borne disease.



Map of Studied Locations

1) Denver, North Carolina 2) Hays, Kansas 3) Norfork, Arkansas 4) Northville, New York 5) Tallahassee, Florida

Materials and Methods

In order to effectively analyze the relationship between specific environmental variables (precipitation, humidity, and temperature) and mosquito-borne disease transmission, we compared collected data from specific areas. We examined five separate sites at the county level from 2003-2021, since this choice in scale would present a manageable proportion of data. On the ADAT tool, the Air Quality protocol option was utilized to narrow down the data search to primarily relevant atmospheric conditions. We gathered 9908 temperature samples from East Lincoln High School in Denver, North Carolina, Florida State University Department of Meteorology in Tallahassee, Florida, Hays High School in Hays, Kansas, Norfork Elementary School in Norfork, Arkansas, and Northville Central School in Northville, New York. Data was primarily collected on a daily basis, although weeks and even months were often arbitrarily omitted for unknown reasons (GLOBE n.d.). In addition, humidity reports were obtained through the POWER Data Access Viewer, which tracked the relative humidity percentage by month during the time interval of 2003-2021 (NASA n.d.). Precipitation statistics were found using the NOAA Climate at a Glance County Mapping tool. We organized the data via Google Spreadsheets, where it could easily be compared to and graphed with mosquito-borne disease transmission data.

Our study explored the correlation between dengue fever and West Nile virus cases and the three environmental variables. These specific epidemics were chosen largely because they are a notable public health hazard to the national and international community. In the United States, however, it was found that their impact was not substantial, making sufficient data challenging to find. Because many of the chosen counties either did not survey past cases of each disease or preferred to keep it confidential, data was instead gathered from the ArboNET tool (CDC n.d.).

With this geographical visualization, we could analyze both the annual county and state cases of West Nile virus and dengue fever.[1] While the recorded number of county cases dated back to 2003, the earliest state statistics were obtained from 2010.

Graphs of the acquired data were created to represent the change of specified variables over time. Through the ArboNET tool, the total yearly cases of both West Nile virus and dengue fever at the state and county level for the chosen sites were recorded. Atmospheric condition data was obtained on the GLOBE ADAT tool. From these statistics, the monthly average temperature (in degrees Celsius), rainfall/precipitation (in mm), and humidity (in relative percentage) at the county level were calculated. In order to analyze environmental variables that affected the annual mosquito-borne disease cases, we focused only on temperature figures from late spring to early fall (June to October). This was largely due to mosquito vectors being most active and diseases being most transferable at this time of year (Safe Pro n.d.). Unfortunately, many of the graphs were not continuous, with gaps in years of data when environmental variables were not surveyed. Because of this, only specific county and state annual disease transmission records were compared to environmental data to optimize accuracy in our final assessments. For example, only Leon county, FL and Ellis county, KS annual county West Nile virus cases were graphed and recorded. Furthermore, the annual county dengue fever cases contained only Lincoln county, NC statistics. Kansas and Arkansas data was depicted on the annual state West Nile virus graph, while the annual state dengue fever plot charted Florida and New York's disease cases. In order to further explore the correlation between these factors, the number of disease cases and atmospheric condition data were plotted together in a cohesive graph, with disease statistics as the dependent variable (on the y-axis), and environmental variable records as the independent

[1] The ArboNET tool cataloged dengue fever cases under the categories of local and imported origin, but for the purposes of this study we simply added the total number of cases of each for our analysis.

variable (on the x-axis). These graphs were repeated for each mosquito-borne epidemic on both the county and state level, as well as for every atmospheric condition. Due to insufficient data under the GLOBE ADAT tool, some of the atmospheric conditions had to be graphed by other means. By applying linear regression to these graphs, a line of best fit could be formed to depict the relationship between the two factors. If the line was sloped upward, the two are positively related; the opposite is true if the line is sloped downwards. The coefficient of determination, or r^2 value, was utilized to further quantify this relationship. For every graph, this coefficient is between 0 and 1. As the value of the coefficient approaches 1, the line of best fit more accurately portrays the correlation between disease cases and environmental variables.

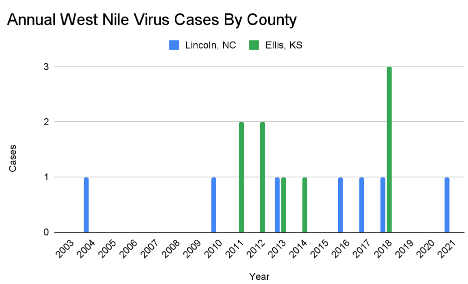


Figure 1. Graphing annual West Nile virus cases at the county level from 2003-2021. Adapted from the CDC. (n.d.). *ArcGIS Web Application*. CDC ArboNET. Retrieved July 25, 2022, from https://wwwn.cdc.gov/arbonet/Maps/ADB_Diseases_Map/index.html

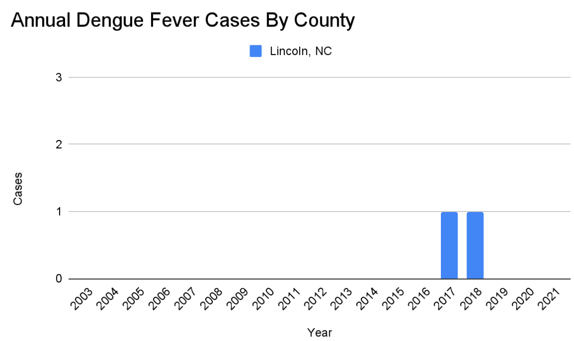


Figure 2. Graphing annual dengue fever cases at the county level from 2003-2021. Adapted from the CDC. (n.d.). *ArcGIS Web Application*. CDC ArboNET. Retrieved July 25, 2022, from https://wwwn.cdc.gov/arbonet/Maps/ADB_Diseases_Map/index.html

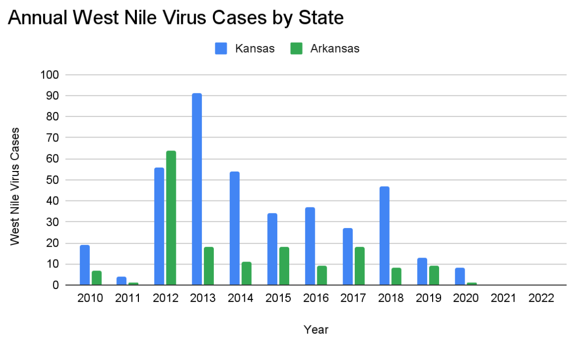


Figure 3. Graphing annual West Nile virus cases at the state level from 2010-2020. Adapted from the CDC. (n.d.). *ArcGIS Web Application*. CDC ArboNET. Retrieved July 25, 2022, from https://wwwn.cdc.gov/arbonet/Maps/ADB_Diseases_Map/index.html

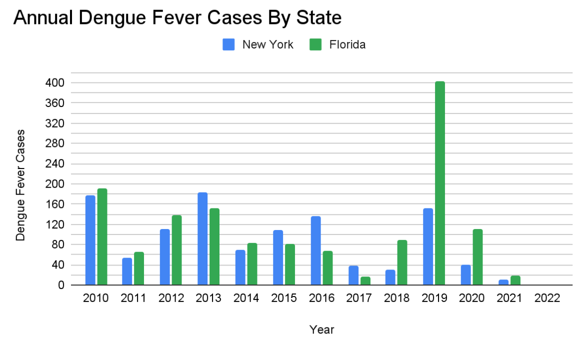


Figure 4. Graphing annual dengue fever cases at the state level from 2010-2021. Adapted from the CDC. (n.d.). *ArcGIS Web Application*. CDC ArboNET. Retrieved July 25, 2022, from https://wwwn.cdc.gov/arbonet/Maps/ADB_Diseases_Map/index.html

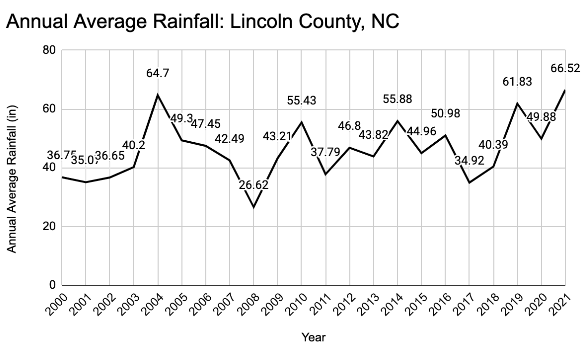


Figure 5. Graphing Lincoln county's annual average rain depth in mm from 2000-2021. Adapted from *Climate at a Glance | National Centers for Environmental Information (NCEI)*. (2022, July). Climate at a Glance. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/

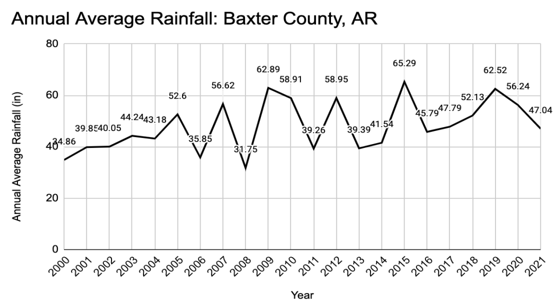


Figure 6. Graphing Baxter county's annual average rain depth in mm from 2000-2021. Adapted from *Climate at a Glance | National Centers for Environmental Information (NCEI)*. (2022, July). Climate at a Glance. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/

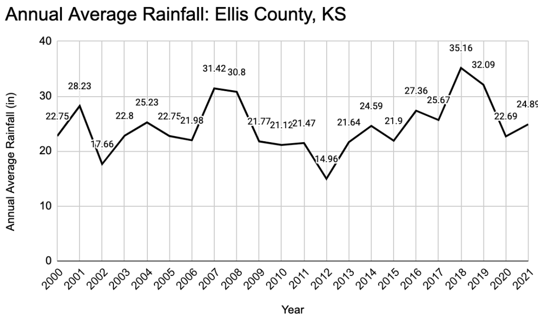


Figure 7. Graphing Ellis county's annual average rain depth in mm from 2000-2021. Adapted from *Climate at a Glance | National Centers for Environmental Information (NCEI)*. (2022, July). Climate at a Glance. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/

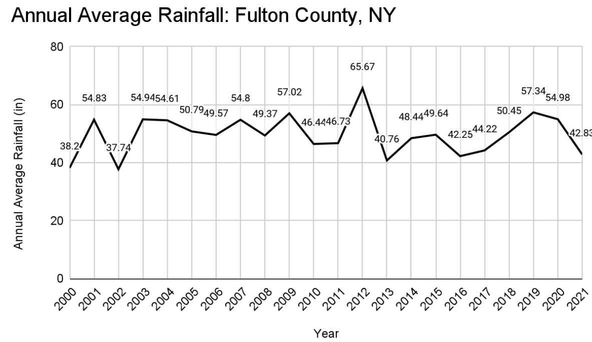


Figure 8. Graphing Fulton county's annual average rain depth in mm from 2000-2021. Adapted from *Climate at a Glance | National Centers for Environmental Information (NCEI)*. (2022, July). Climate at a Glance. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/

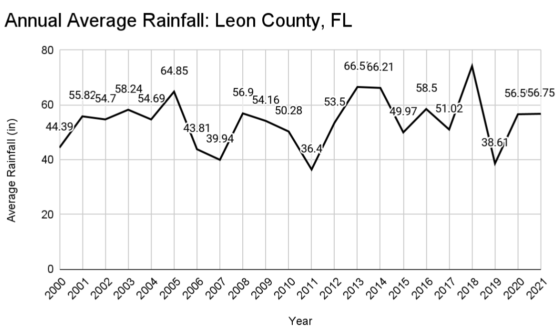


Figure 9. Graphing Leon county's annual average rain depth in mm from 2000-2021. Adapted from *Climate at a Glance | National Centers for Environmental Information (NCEI)*. (2022, July). Climate at a Glance. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance

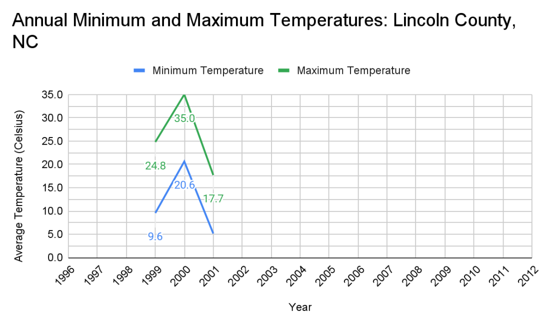
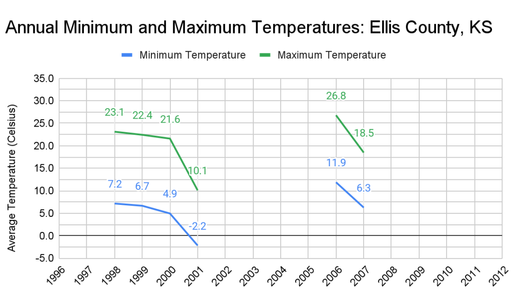


Figure 10. Graphing Denver's annual minimum and maximum daily temperatures in degrees Celsius from 1996-2012. Adapted from the *Advanced Data Access Tool*. (n.d.). GLOBE. Retrieved July 25, 2022, from https://datasearch.globe.gov/



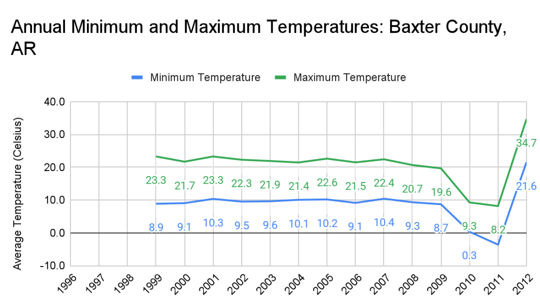


Figure 11. Graphing Hays' annual minimum and maximum daily temperatures in degrees Celsius from 1996-2012. Adapted from the *Advanced Data Access Tool*. (n.d.). GLOBE. Retrieved July 25, 2022, from https://datasearch.globe.gov/

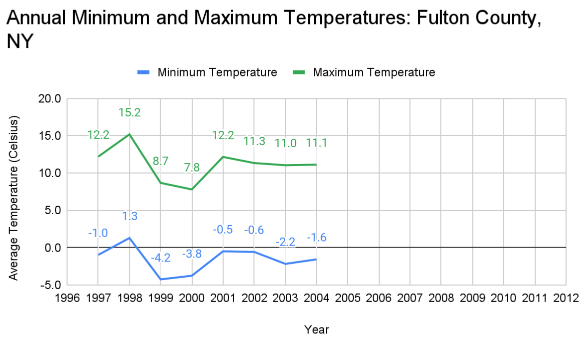


Figure 13. Graphing Northville's annual minimum and maximum daily temperatures in degrees Celsius from 1996-2012. Adapted from the *Advanced Data Access Tool*. (n.d.). GLOBE. Retrieved July 25, 2022, from https://datasearch.globe.gov/

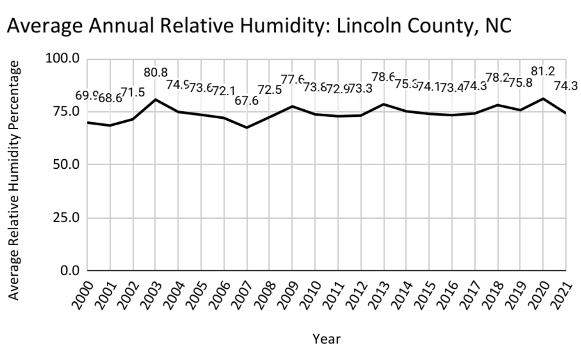


Figure 15. Graphing Lincoln county's annual average relative humidity percentage from 2000-2021. Adapted from Stackhouse, P. (n.d.). *NASA | Data Access Viewer*. POWER Data Access Viewer. Retrieved July 25, 2022, from https://power.larc.nasa.gov/data-access-viewer/

Figure 12. Graphing Norfork's annual minimum and maximum daily temperatures in degrees Celsius from 1996-2012. Adapted from the *Advanced Data Access Tool*. (n.d.). GLOBE. Retrieved July 25, 2022, from https://datasearch.globe.gov/

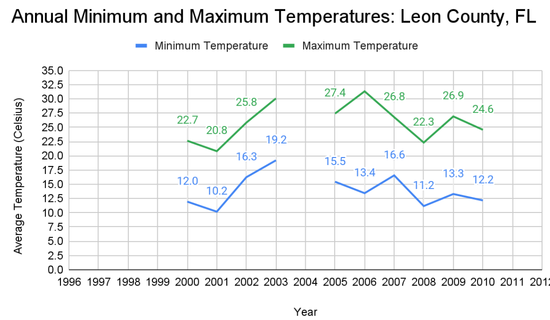


Figure 14. Graphing Tallahassee's annual minimum and maximum daily temperatures in degrees Celsius from 1996-2012. Adapted from the *Advanced Data Access Tool*. (n.d.). GLOBE. Retrieved July 25, 2022, from https://datasearch.globe.gov/

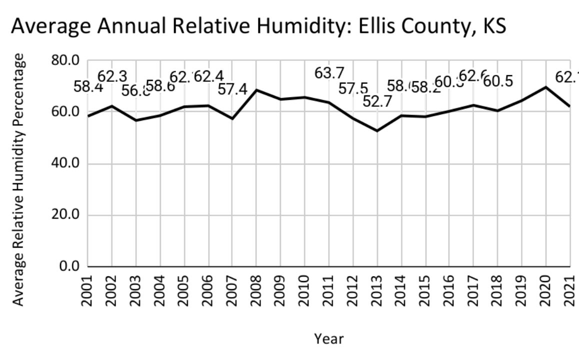


Figure 16. Graphing Ellis county's average annual relative humidity percentage from 2000-2021. Adapted from Stackhouse, P. (n.d.). *NASA | Data Access Viewer*. POWER Data Access Viewer. Retrieved July 25, 2022, from https://power.larc.nasa.gov/data-access-viewer/

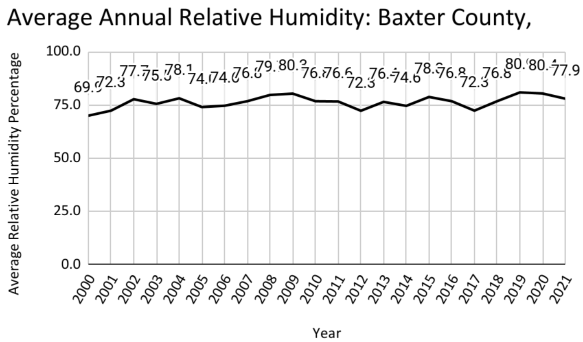


Figure 17. Graphing Baxter county's average annual relative humidity percentage from 2000-2021. Adapted from Stackhouse, P. (n.d.). *NASA | Data Access Viewer*. POWER Data Access Viewer. Retrieved July 25, 2022, from https://power.larc.nasa.gov/data-access-viewer/

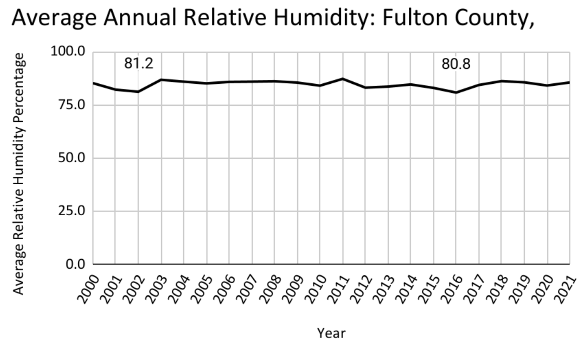


Figure 18. Graphing Fulton county's average annual relative humidity percentage from 2000-2021. Adapted from Stackhouse, P. (n.d.). *NASA | Data Access Viewer*. POWER Data Access Viewer. Retrieved July 25, 2022, from https://power.larc.nasa.gov/data-access-viewer/

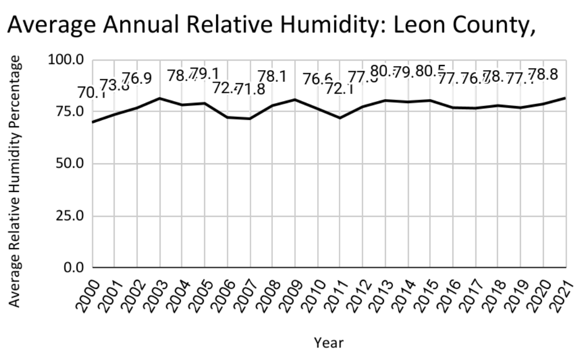


Figure 19. Graphing Leon county's average annual relative humidity percentage from 2000-2021. Adapted from Stackhouse, P. (n.d.). *NASA | Data Access Viewer*. POWER Data Access Viewer. Retrieved July 25, 2022, from https://power.larc.nasa.gov/data-access-viewer/

Results

Humidity

The linear regression of disease cases and relative humidity percentage for Ellis county, KS, and Leon county, FL, were assessed. While the line of best fit in Ellis county demonstrates a slightly positive relationship (where the higher percentage of humidity correlates with a higher number of annual West Nile virus cases) the graph of Leon county's statistics demonstrates the opposite. There, the line of best fit is more sharply angled downward, insinuating that a higher level of humidity is associated with a decrease in West Nile virus cases. Since the coefficient of determination for Leon county is larger than that of Ellis county, Leon's line of best fit is a more accurate model of the disease case to atmospheric condition relationship – at least for that specific location. Meanwhile, the line of best fit between relative humidity percentage and annual county dengue fever cases in Lincoln county demonstrates a directly positive relationship. Lincoln's coefficient of determination is very similar to that of Leon, meaning that both have a similar level of accuracy.

At the state level, similar data is presented. In the state of Kansas, West Nile virus cases positively correlate with higher humidity percentages, as indicated by the line of best fit. Kansas' coefficient of determination (0.385) also shows that the line of best fit depicting correlation has sufficient accuracy. The graphed West Nile virus disease case data for the state of Arkansas demonstrates little correlation through the almost horizontal line of best fit. Additionally, Arkansas' coefficient of determination (0.032) lower than Kansas' higher coefficient of determination suggests that this depiction was less accurate. When the relationship between dengue fever cases and relative humidity is graphed, New York has a near identical line of best fit to Arkansas'.

New York's line of best fit is slightly less accurate, with a coefficient of determination of 0.231. By utilizing linear regression to compare Florida-state dengue fever cases to annual humidity, the graph demonstrated a slightly negative correlation. Furthermore, the low coefficient of determination (0.015) affirmed that this relationship was not very accurate.

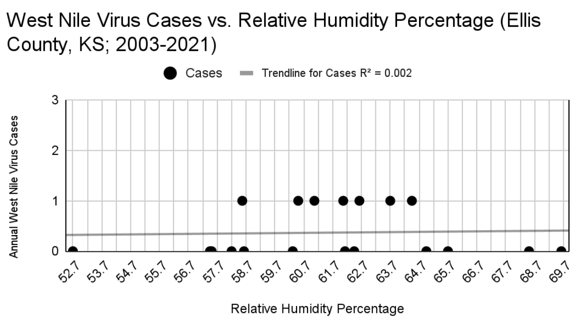


Figure 20. Graphing Ellis county's relative humidity percentage against West Nile virus cases at the county level from 2003-2021. Adapted from Stackhouse, P. (n.d.). *NASA | Data Access Viewer*. POWER Data Access Viewer. Retrieved July 25, 2022, from https://power.larc.nasa.gov/data-access-viewer/ and CDC. (n.d.). *ArcGIS Web Application*. CDC ArboNET. Retrieved July 25, 2022, from https://wwwn.cdc.gov/]arbonet/Maps/ADB_Diseases_Map/index.html

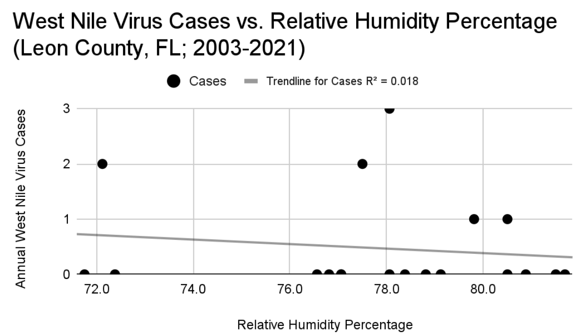


Figure 21. Graphing Leon county's relative humidity percentage against West Nile virus cases at the county level from 2003-2021. Adapted from Stackhouse, P. (n.d.). *NASA | Data Access Viewer*. POWER Data Access Viewer. Retrieved July 25, 2022, from https://power.larc.nasa.gov/data-access-viewer/ and CDC. (n.d.). *ArcGIS Web Application*. CDC ArboNET. Retrieved July 25, 2022, from https://wwwn.cdc.gov/arbonet/Maps/ADB_Diseases_Map/index.html

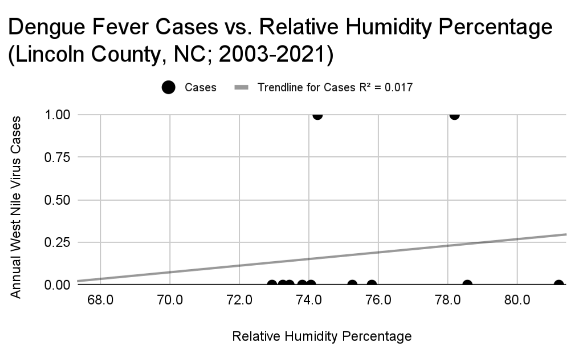


Figure 22. Graphing Lincoln county's relative humidity percentage against dengue fever cases at the county level from 2003-2021. Adapted from Stackhouse, P. (n.d.). *NASA | Data Access Viewer*. POWER Data Access Viewer. Retrieved July 25, 2022, from

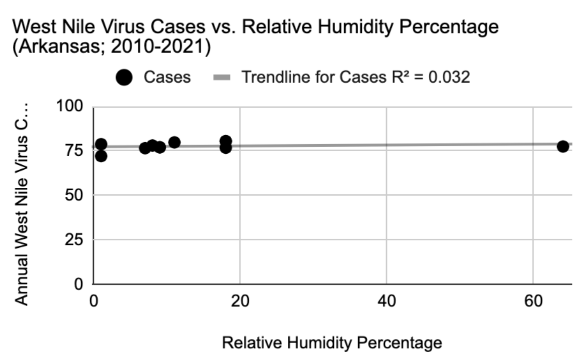


Figure 23. Graphing Ellis county's relative humidity percentage against Arkansas' West Nile virus cases at the state level from 2010-2021. Adapted from Stackhouse, P. (n.d.). *NASA | Data Access Viewer*. POWER Data Access Viewer. Retrieved July 25, 2022, from

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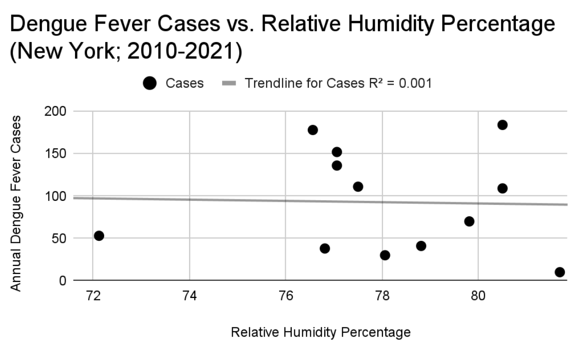

Figure 24. Graphing Fulton county's relative humidity percentage against New York's dengue fever cases at the state level from 2010-2021. Adapted from Stackhouse, P. (n.d.). *NASA | Data Access Viewer*. POWER Data Access Viewer. Retrieved July 25, 2022, from https://power.larc.nasa.gov/data-access-viewer/ and CDC. (n.d.). *ArcGIS Web Application*. CDC ArboNET. Retrieved July 25, 2022, from https://wwwn.cdc.gov/arbonet/Maps/ADB_Diseases_Map/index.html

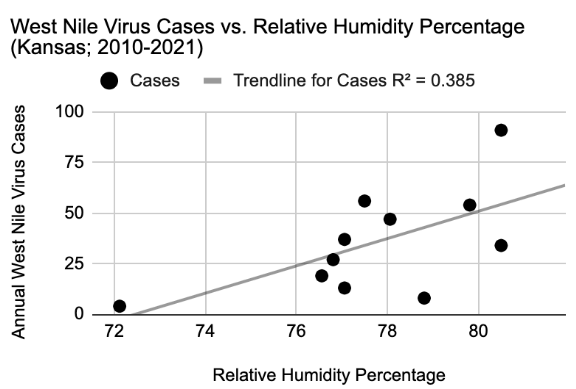

Figure 26. Graphing Baxter county's relative humidity percentage against Arkansas' West Nile virus cases at the state level from 2010-2021. Adapted from Stackhouse, P. (n.d.). *NASA | Data Access Viewer*. POWER Data Access Viewer. Retrieved July 25, 2022, from https://power.larc.nasa.gov/data-access-viewer/ and CDC. (n.d.). *ArcGIS Web Application*. CDC ArboNET. Retrieved July 25, 2022, from https://wwwn.cdc.gov/arbonet/Maps/ADB_Diseases_Map/index.html

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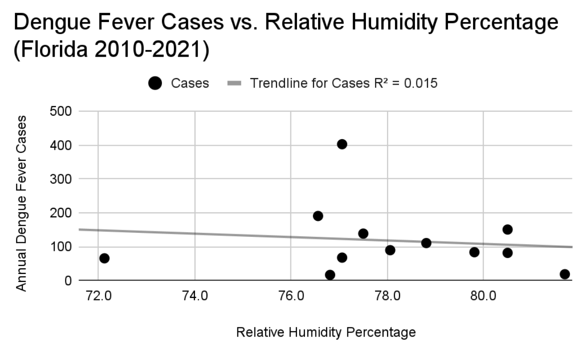


Figure 25. Graphing Leon county's relative humidity percentage against Florida's dengue fever cases at the state level from 2010-2021. Adapted from Stackhouse, P. (n.d.). *NASA | Data Access Viewer*. POWER Data Access Viewer. Retrieved July 25, 2022, from https://power.larc.nasa.gov/data-access-viewer/ and CDC. (n.d.). *ArcGIS Web Application*. CDC ArboNET. Retrieved July 25, 2022, from https://wwwn.cdc.gov/arbonet/Maps/ADB_Diseases_Map/index.html

Temperature

The relationship between average daily temperature and mosquito-borne disease cases could not be sufficiently assessed for many sites due to a lack of temperature data during the year interval of recorded West Nile virus and dengue fever cases (2003-2021 for county-level cases and 2010-2021 for state cases). For example, graphs could not be created for both Kansas and Florida's state-level statistics, as well as Lincoln county, NC's county-level statistics, because the average daily temperature was not recorded at the corresponding time of documented disease cases. While a graph of Ellis county, KS' average daily temperature could be created, there was not a single West Nile virus case during the 18-year period of temperature surveillance. The line of best fit for this graph lies along the horizontal axis and a coefficient of determination could not be assessed. Because of these results, Ellis county's graphed relationship was also inconclusive. However, Leon county, FL records contained both average daily temperature and West Nile virus cases and could successfully be graphed. The line of best fit demonstrated a slightly negative relationship but had a very low coefficient of determination equal to 0.006. Therefore, the line of best fit is likely not sufficiently accurate.

At the state level, the correlation between average daily temperature and mosquito-borne disease cases was successfully graphed for both the states of Arkansas and Florida. However, both of these plots only contained 2 or 3 data points, creating weaker results. The plotted line of best fit for the state of Arkansas maintained a steep angle upwards, with a coefficient of determination equivalent to 1. While this would suggest that the plotted relationship between West Nile virus cases and daily temperature was completely accurate, this is likely not the case due to the above-mentioned lack of data points. Similarly, Florida's graph of dengue fever cases versus average daily temperatures has a coefficient of determination set to 1. The line of best fit for this diagram is even more steeply angled upwards, suggesting an extremely positive correlation between dengue fever cases and high temperatures.

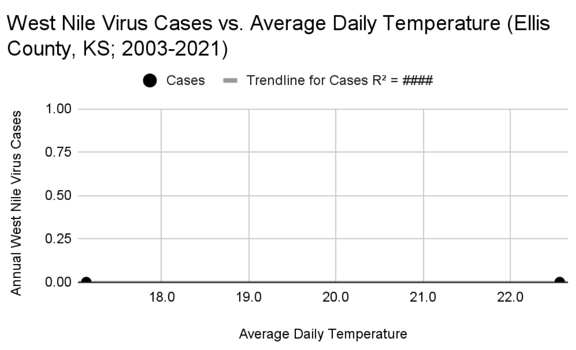


Figure 27. Graphing Ellis county's average daily temperature against West Nile virus cases at the county level from 2003-2021. Adapted from *Advanced Data Access Tool*. (n.d.). GLOBE. Retrieved July 25, 2022, from https://datasearch.globe.gov/ and CDC. (n.d.). *ArcGIS Web Application*. CDC ArboNET. Retrieved July 25, 2022, from https://wwwn.cdc.gov/arbonet/Maps/ADB_Diseases_Map/index.html

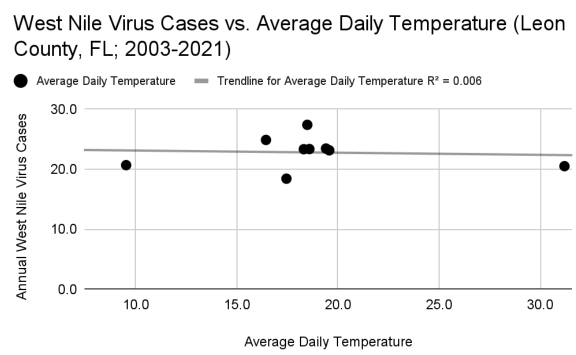


Figure 28. Graphing Leon county's average daily temperature against West Nile virus cases at the county level from 2003-2021. Adapted from *Advanced Data Access Tool*. (n.d.). GLOBE. Retrieved July 25, 2022, from https://datasearch.globe.gov/ and CDC. (n.d.). *ArcGIS Web Application*. CDC ArboNET. Retrieved July 25, 2022, from https://wwwn.cdc.gov/arbonet/Maps/ADB_Diseases_Map/index.html

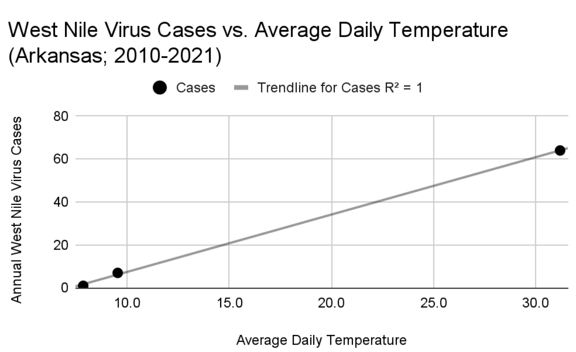


Figure 29. Graphing Baxter county's average daily temperature against Arkansas' West Nile virus cases at the state level from 2010-2021. Adapted from *Advanced Data Access Tool*. (n.d.). GLOBE. Retrieved July 25, 2022, from https://datasearch.globe.gov/ and CDC. (n.d.). *ArcGIS Web Application*. CDC ArboNET. Retrieved July 25, 2022, from https://wwwn.cdc.gov/arbonet/Maps/ADB_Diseases_Map/index.html

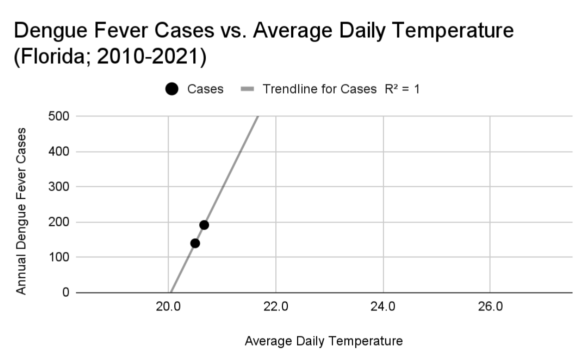


Figure 30. Graphing Leon county's average daily temperature against Florida's dengue fever cases at the state level from 2010-2021. Adapted from *Advanced Data Access Tool*. (n.d.). GLOBE. Retrieved July 25, 2022, from https://datasearch.globe.gov/ and CDC. (n.d.). *ArcGIS Web Application*. CDC ArboNET. Retrieved July 25, 2022, from https://wwwn.cdc.gov/arbonet/Maps/ADB_Diseases_Map/index.html

Precipitation

In contrast to the linear regression graphs of average daily temperature, the average daily rainfall/precipitation was successfully compared to mosquito-borne disease cases. When plotted, Lincoln county, NC's line of best fit suggests a directly negative relationship between local dengue fever cases and levels of rainfall. With an average coefficient of determination (0.35), this approximation matches the data closer than many previous graphs. Meanwhile, the diagrams mapping county-level West Nile virus cases depict the opposite relationship, with higher levels of rainfall correlating with a higher transmission rate. Both the graphs of Ellis county, KS and Leon county, FL's atmospheric and vector prevalence statistics suggest a directly positive interconnection. However, many of the plotted points on each graph do not fall along the line of best fit, giving these counties a lower coefficient of determination and therefore a lower accuracy than Lincoln county (Ellis county has an r squared value of 0.033, while Leon county has an r squared value of 0.083).

The comparison between Ellis county, KS average daily rainfall data and Kansas' recorded West Nile virus numbers at the statewide level delineates a negatively sloped line of best fit. However, with a small coefficient of determination (0.02), this calculation does not strongly predict the data. Similarly, the comparison of Baxter county, AR levels of precipitation to West Nile virus cases produces a coefficient of determination equal to 0.062. The line of best fit for this diagram, which is sloped upwards in this case, also does not fit the data as well. The depiction of Fulton county, NY rainfall records against dengue fever statistics forms an almost horizontal line of best fit, with a coefficient of determination of 0 (meaning the line of best fit does not predict the data at all). Together, this suggests that precipitation levels have little to no effect on dengue fever transmission, at least at the state level. In the graph of Leon county, FL average daily rainfall versus statewide dengue fever cases has a higher coefficient of determination equal to 0.125. This suggests that the negatively sloped line of best fit accurately estimates the correlation between disease transmission and precipitation, at least more so than data from other sites.

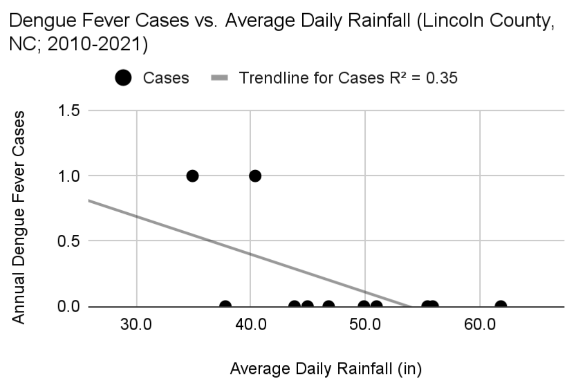


Figure 31. Graphing Lincoln county's average daily rainfall against dengue fever cases at the county level from 2010-2021. Adapted from *Climate at a Glance | National Centers for Environmental Information (NCEI)*. (2022, July). Climate at a Glance. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/ and CDC. (n.d.). *ArcGIS Web Application*. CDC ArboNET. Retrieved July 25, 2022, from https://wwwn.cdc.gov/arbonet/Maps/ADB_Diseases_Map/index.html

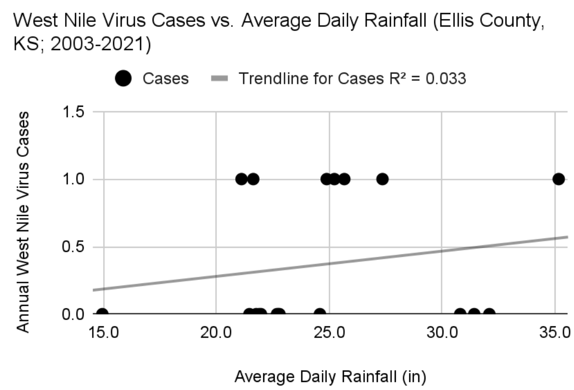
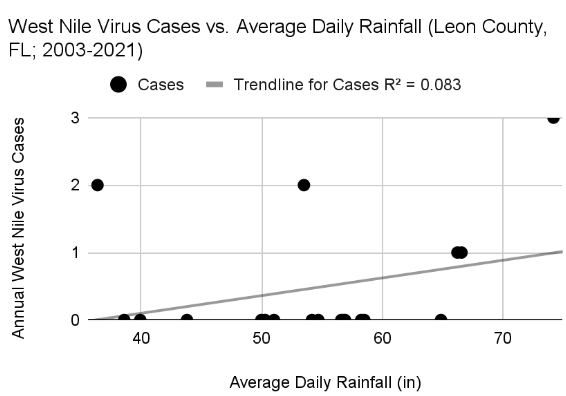


Figure 32. Graphing Ellis county's average daily rainfall against West Nile virus cases at the county level from 2003-2021. Adapted from *Climate at a Glance | National Centers for Environmental Information (NCEI)*. (2022, July). Climate at a Glance. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/ and CDC. (n.d.). *ArcGIS Web Application*. CDC ArboNET. Retrieved July 25, 2022, from https://wwwn.cdc.gov/arbonet/Maps/ADB_Diseases_Map/index.html



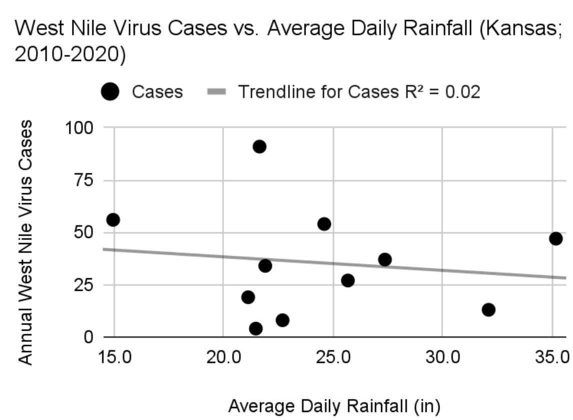
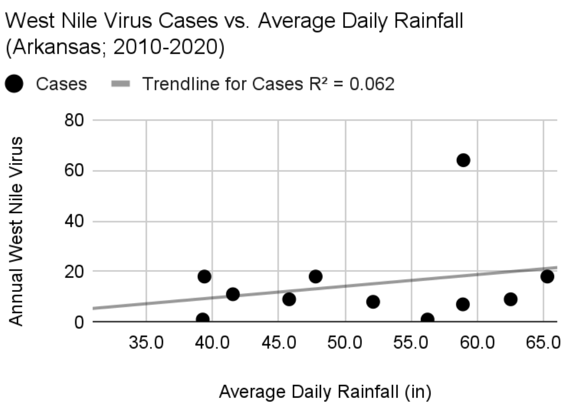


Figure 33. Graphing Leon county's average daily rainfall against West Nile virus cases at the county level from 2003-2021. Adapted from *Climate at a Glance | National Centers for Environmental Information (NCEI)*. (2022, July). Climate at a Glance. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/ and CDC. (n.d.). *ArcGIS Web Application*. CDC ArboNET. Retrieved July 25, 2022, from https://wwwn.cdc.gov/arbonet/Maps/ADB_Diseases_Map/index.html

Figure 34. Graphing Ellis county's average daily rainfall against Kansas' West Nile virus cases at the state level from 2010-2020. Adapted from *Climate at a Glance | National Centers for Environmental Information (NCEI)*. (2022, July). Climate at a Glance. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/ and CDC. (n.d.). *ArcGIS Web Application*. CDC ArboNET. Retrieved July 25, 2022, from https://wwwn.cdc.gov/arbonet/Maps/ADB_Diseases_Map/index.html



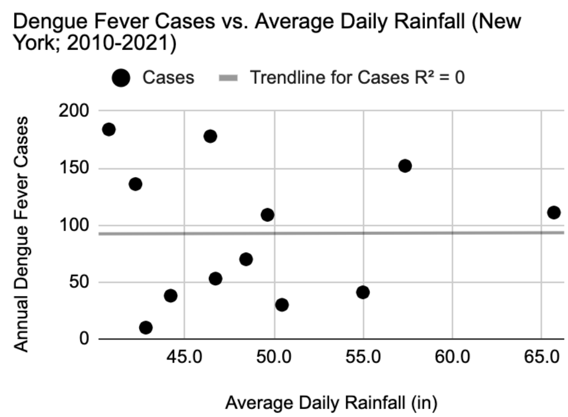


Figure 35. Graphing Baxter county's average daily rainfall against Arkansas' West Nile virus cases at the state level from 2010-2020. Adapted from *Climate at a Glance | National Centers for Environmental Information (NCEI)*. (2022, July). Climate at a Glance. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/ and CDC. (n.d.). *ArcGIS Web Application*. CDC ArboNET. Retrieved July 25, 2022, from https://wwwn.cdc.gov/arbonet/Maps/ADB_Diseases_Map/index.html

Figure 36. Graphing Fulton county's average daily rainfall against New York's dengue fever cases at the state level from 2010-2021. Adapted from *Climate at a Glance | National Centers for Environmental Information (NCEI)*. (2022, July). Climate at a Glance. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/ and CDC. (n.d.). *ArcGIS Web Application*. CDC ArboNET. Retrieved July 25, 2022, from https://wwwn.cdc.gov/arbonet/Maps/ADB_Diseases_Map/index.html

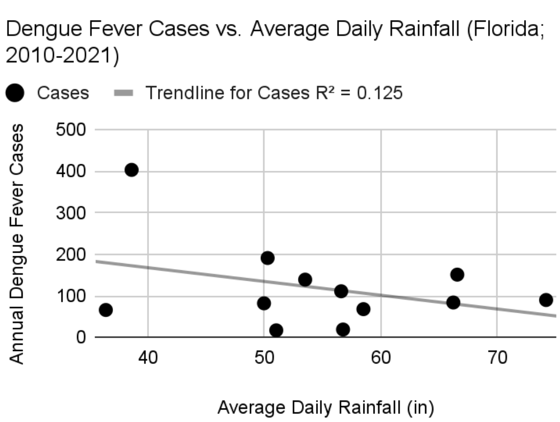


Figure 37. Graphing Leon county's average daily rainfall against Florida's dengue fever cases at the state level from 2010-2021. Adapted from *Climate at a Glance | National Centers for Environmental Information (NCEI)*. (2022, July). Climate at a Glance. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/ and CDC. (n.d.). *ArcGIS Web Application*. CDC ArboNET. Retrieved July 25, 2022, from https://wwwn.cdc.gov/arbonet/Maps/ADB_Diseases_Map/index.html

Discussion

Our study aimed to explore the relationship between precipitation, temperature, humidity, and the vector transmission of dengue fever and West Nile virus. We hypothesized that the spread of mosquito-borne diseases would be positively correlated to the above atmospheric conditions. We utilized various data sources to collect site-specific environmental statistics at the county level before comparing this data to both county and state disease case records. Using linear regression, we were then able to concretely establish a relationship through a graphed line of best fit. We then calculated the coefficient of determination for each comparison in order to numerically quantify the accuracy of the approximations. However, in the process of our analysis, we came across many potential sources of error; when collecting data from GLOBE, we noticed that much of the needed data was missing, causing graphs to be incomplete. This was likely due to the fact that GLOBE is a citizen science program that utilizes limited resources to train observers and obtain statistics. Despite this, the program offered a great potential to pursue other similar studies. Another potential error source was that we did not consider the time of year in which atmospheric data was obtained. As a result, the data of a particular environmental variable could be affected by using information during seasons in which mosquito vectors are not relevant. For example, we could have gathered data from winter when most disease cases occurred during summer. If we pursue the project in the future, we would then attempt to obtain both atmospheric and disease data by month instead of by year – this way, we would maximize efficiency and accuracy in our assessments. An additional method of improvement would be to obtain all of the data before completing any of the write-ups, which would prevent any unnecessary restructuring later down the road.

Humidity

When evaluated at the county level, the relationship between relative humidity percentage and mosquito-borne disease transmission appears to be very inconsistent. While the line of best fit for Ellis county's diagram is primarily horizontal, Leon county's is directed downwards, and Lincoln county's is sloped upwards. None of the county-level coefficients of determination are greater than or equal to 0.02, suggesting a high level of inaccuracy. The graphed lines of best fit could still be applied to predict the risk of West Nile virus and dengue fever. In Ellis county, humidity likely does not significantly affect the number of West Nile virus cases in that location. Leon county should experience slightly fewer West Nile virus incidences when the humidity rises. Dengue fever cases likely increase when the relative humidity percentage rises in Lincoln county. In contrast to the county plots, graphing the state-level data produces slightly more accurate approximations. Both graphs of West Nile virus cases (in Arkansas and Kansas) against relative humidity percentage yield a positive correlation with higher coefficients of determination (0.032 and 0.385) in comparison with other humidity diagrams. This might suggest that the spread of West Nile virus in these states will increase alongside the humidity level. Conversely, both New York and Florida statistics demonstrate a negative correlation between humidity and recorded dengue fever cases. While both of these graphs have an extremely low coefficient of determination (0.015 and 0.001), the lines of best fit are sloped negatively enough that these trends can generally be applied at a state level. In conclusion, while studies such as "Incorporating the effects of humidity in a mechanistic model of … mosquito population dynamics…" predicted a positive relationship between relative humidity percentage and mosquito-borne diseases, we could not reproduce this finding from the data we used (Yamana, 2013). This is likely due to vastly different approximations being formed through the linear regression process. It can be theorized that this discrepancy is likely due to a number of site-specific factors that additionally affect the number of disease cases.

Temperature

Our examination of the effect of temperature on the spread of mosquito-borne diseases was impacted by a lack of sufficient data. Because of this, we were unable to analyze and graph statistics from many sites, including Ellis county, Lincoln county, New York, and Kansas. Graphs of other identified locations were created using limited data and are known to demonstrate inaccurate representations with discrepancies. The average daily temperature was found to have little to no effect on West Nile virus cases in Leon county, but an extremely positive relationship in the state of Arkansas. Similarly, dengue fever in the state of Florida was very steeply correlated with temperature. By these approximations, in most sites even a slight increase in temperature at these locations could drastically propagate the spread of mosquito-borne diseases. While real-life case patterns are likely not as dramatic, these graphs still served as a useful guide to grasp the general effects temperature can have on mosquito vectors. The final relationship produced by these graphs also coincides with the article "How Do Temperature and Weather Affect Mosquitoes?", which predicted a positive correlation between temperature and mosquito-borne disease transmission, since a higher temperature would increase the transfer rate of most fevers, as well as increase the breeding activity of mosquito vectors (Kripena, May 13, 2020).

Precipitation

We were able to successfully visualize and quantify the connection between average daily rainfall and mosquito-borne diseases. At the county level, both Ellis and Leon county statistics produced very similar lines of best fit with a positive slope. While each collection of site data also contained inaccuracies in the approximated relationship (signified by smaller coefficients of determination), the graphs demonstrate that an increase in precipitation directly leads to an increase in West Nile virus cases. In contrast, graphed data from Lincoln County depicts a negative correlation between rainfall and dengue fever cases, suggesting that dengue fever is more susceptible and less effective in wetter environments. This is further supported at the state level by the plot of Florida's statistics. In this diagram, the line of best fit is angled sharply downward, with a higher coefficient of determination (0.125) affirming its accuracy. While dengue fever case records in New York do not agree with this pattern (instead suggesting that precipitation is not related to disease transmission), this is likely because New York isn't a homogenous environment, and has many different habitats and variables that can alter data. The results of state-level graphs of West Nile virus cases against average daily rainfall is not as unanimous. When comparing Kansas' vector transmission to Ellis county's average daily rainfall, a negatively sloped line of best fit is created, insinuating that a rise in precipitation would lead to a decline in West Nile virus cases. However, this disagrees with the prior county-level West Nile virus graphs, along with statistics from the state of Arkansas; with a higher coefficient of determination (0.062) than Kansas' (0.02), Arkansas clearly demonstrates a positive correlation between rainfall and the spread of the West Nile virus. It is likely that West Nile virus cases increase with an increase in precipitation. While this agrees with studies such as "The Effect of Weather Variables on Mosquito Activity," which concluded that precipitation and mosquito-borne disease transmission are positively related, the previously-explored approximation of dengue fever cases disembark from this claim (Drakou et al., 2020). This is most likely because dengue fever was not a disease studied in this paper and may be unique in its environmental weaknesses.

In conclusion, our study found no correlation between humidity and the transmission of mosquito-borne diseases, while increased temperature appears to be directly related to both West Nile virus and dengue fever. Finally, West Nile virus cases were found to increase with an increase in precipitation, while dengue fever cases were found to decrease as rainfall levels increased. While a limited amount of sufficient data hindered our exploration of how mosquito vectors spread, the important factor that environmental conditions play in public health and ecology was highlighted. With the data collected in this study, future steps can be taken towards a better understanding of how exactly atmospheric conditions can influence the world around us.

Acknowledgments

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Mentors: Dr. Rusanne Low, Dr. Erika Podest (NASA JPL), Cassie Soeffing, Andrew Clark, Peder Nelson

For any questions on the research, please contact @benjaminrfolk@gmail.com or @doristein8@gmail.com

Badges

Be a Collaborator

Although we were all separated throughout the country – from California, New York, Texas, to Louisiana – we collaborated efficiently and had fun doing so. In the month we spent working together, we gained problem-solving skills and learned the importance of delegation. We overcame setbacks and worked together in order to improve both our report and our individual data analysis skills. In the process of advancing our project, we each undertook significant responsibilities and roles to contribute to the team. Benjamin Folk (Francis Parker High School, San Diego, California) was the primary author of the scientific paper and poster, as well as the assistant analyzer of data through the creation of graphs. Dori Stein (New Dorp High School, Staten Island, New York) was the supporting author of the scientific paper, gathered data for research and graphs, coordinated the team, and assisted in artistic design (poster and presentation). Mia Obid (SaintPius X High School, Houston, Texas) was the artistic coordinator (poster and presentation) and supporting data analyst. Finally, Sidha Kunada (Lafayette High School, Lafayette, Louisiana) was the primary data analyst, graph creator, and editor of the paper.

Be a STEM Professional

We were privileged to work with many STEM professionals that guided us with our research project. Throughout our weekly Meet Up and Do Science meetings, Peder Nelson's research was very inspiring and provided lots of beneficial advice that helped us when brainstorming a research topic. Dr. Russanna Low offered us many research and data tools that helped us form our research topic. Dr. Low also encouraged us to reach out to Dr. Podest for advice on our research project. Dr. Erika Podest gave us a professional perspective and helped us to format our first professional paper. With her advice, we were able to identify potential issues with our project paper and properly format our data. Finally, Ms. Cassie Soeffing provided us with many useful resources to develop our research paper and assisted us in organizing due dates and tasks.

Be a Data Scientist

Throughout our paper, we gathered data from many sources. For instance, we utilized GLOBE for temperature, NASA for humidity, NOAA for precipitation, and the CDC for disease cases. We organized the gathered data via Google Sheets, in order to compare the correlations via graphing. Although we came across many occurrences where GLOBE'S data was limited, we ultimately found ways to strengthen our paper through other sources. Specifically, we didn't stop searching for data until we got it to match our specific time frame (2000-2020). Throughout this internship, we all gained a lot of knowledge and experience in data organization and research.

Be an Impactor

Due to the impact of epidemiology on public health, it is important to spread awareness of variables that increase mosquito activity in a specified area. By researching conditions such as temperature, precipitation, and humidity-common elements in a region's climate- and their effects on the transmission of mosquito-borne vectors, we have contributed to greater public knowledge surrounding dangerous pathogens. Communities may use our work to better understand how their environment relates to the presence of mosquitoes and their associated diseases.

Be a STEM Storyteller

In order to display our research in an intriguing way, we displayed the most significant parts of our paper on a poster. This way, it is easier to read and understand the depicted results through the usage of graphs, organized titles, and added color. Additionally, we made a slide presentation that included all components of our paper and expanded on what was to be gained from the experience. Through the slides, we made our data very presentable and easy to analyze. Lastly, we filmed a video presentation to share our research study and findings. Together, these various forms of media told the story behind our team's research, making it appealing and accessible to a broader audience.

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