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

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Abstract

Mosquitoes are the primary insect vector of dangerous pathogens, specifically dengue fever and West Nile virus. The potential risk of a mosquito-borne epidemic can be correlated with many area-specific variables that affect mosquito oviposition, activity, and feeding habitats. Indicatively, depending on the mosquito's feeding sector, their eating habits can change based on the host's environment. Because of this, we sought to draw connections between environmental variables such as precipitation, humidity, and temperature to the risk of mosquito-borne diseases. Before examining the data, we hypothesized that the outcome of our study would show a direct positive correlation between mosquito-borne disease transmission to 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 CDC's National Arbovirus Surveillance System (ArboNET) to analyze the vector transmission of 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 (East Lincoln High School from Denver, North Carolina, Florida State University Department of Meteorology from Tallahassee, Florida, Hays High School from Hays, Kansas, Norfork Elementary School from Norfork, Arkansas, and Northville Central School from Northville, New York). Records from these sites enabled us to record environmental data such as daily air temperature and precipitation via rain depth. Finally, NASA's Prediction of Worldwide Energy Resource (POWER) Data Access Viewer was utilized to obtain the relative humidity percentage statistics at the above sites.

Introduction

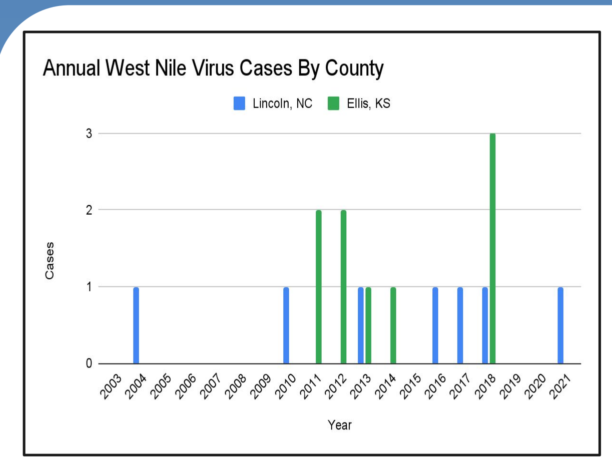
Environmental conditions profoundly affect mosquitoes, influencing their activity, breeding, and feeding habits. In correlation with climate change, the transmission of deadly mosquito-borne diseases such as dengue fever and West Nile virus can increase and pose a serious threat to public health. While researching this topic, we formulated a question: How do environmental conditions such as precipitation, temperature, and humidity affect the transmission of mosquito-borne diseases?

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). While an increase in precipitation 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.

Methods

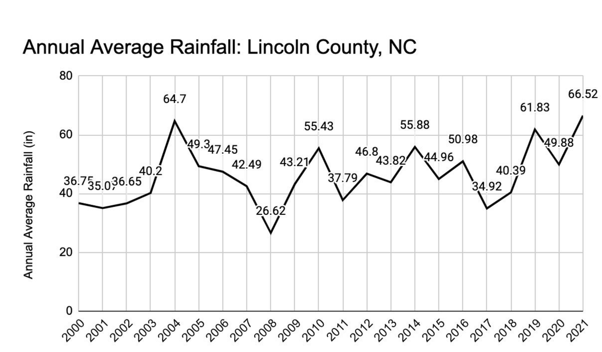
In order to effectively analyze the relationship between precipitation, humidity, and temperature and mosquito-borne disease transmission, we collected data through the GLOBE ADAT tool. We examined five separate counties (Ellis, Leon, Lincoln, Baxter, and Fulton counties) from 2003-2021, since this choice in scale would present a manageable proportion of data. Data was primarily collected on a daily basis (GLOBE n.d.). 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. Finally, disease case records at both the county and state level were gathered from the ArboNET tool (CDC n.d.).

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, before being graphed to represent the change of specified variables over time. 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.). Because many graphs had gaps during years when data was not recorded, only specific county and state annual disease transmission records were compared to environmental data to optimize accuracy in our final assessments. 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 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. By applying linear regression to these graphs, a line of best fit could be formed to depict the relationship between the two factors. The coefficient of determination 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.



Example: This graph records the annual West Nile virus cases at the county level in Lincoln county, NC and Ellis county, KS.

Example: This graph depicts the annual average rainfall data in inches from Lincoln county, NC.



Results

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. 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. In the state of Kansas, West Nile virus cases positively correlate with higher humidity percentages, as indicated by the line of best fit. 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'. By utilizing linear regression to compare Florida-state dengue fever cases to annual humidity, the graph demonstrated a slightly negative correlation, although the low coefficient of determination (0.015) suggests this is inaccurate.

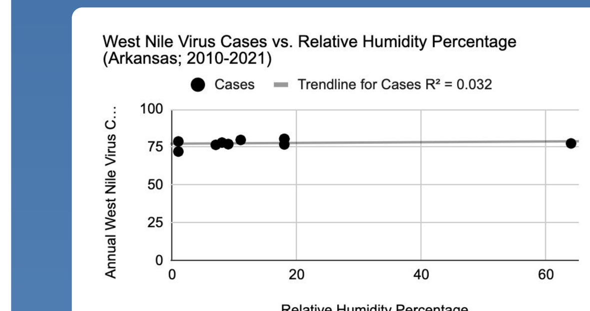
The relationship between average daily temperature and mosquito-borne disease cases could not be sufficiently assessed for many sites due to a lack of temperature data during the year interval of recorded West Nile virus and dengue fever cases (2003-2021 for county-level cases and 2010-2021 for state cases). While a graph of Ellis county, KS' average daily temperature could be created, there was not a single West Nile virus case during the period of temperature surveillance, and the coefficient of determination could not be assessed. Because of these results, Ellis county's graphed relationship was also inconclusive. However, the line of best fit for Leon county, FL average daily temperature and West Nile virus case records demonstrated a slightly negative relationship. The plotted line of best fit for the states of Arkansas and Florida (which each studied either West Nile virus and dengue fever respectively) maintained a steep angle upwards, but it is likely not accurate.

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. 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. The comparison between Ellis county, KS average daily rainfall data and Kansas' recorded West Nile virus numbers at the statewide level delineates a slightly inaccurate negatively sloped line of best fit. Similarly, the comparison of Baxter county, AR levels of precipitation to West Nile virus cases produces a line of best fit for this diagram that sloped upwards in this case and 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, and 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 negatively sloped line of best fit that accurately estimates the correlation between disease transmission and precipitation, at least more so than data from other sites.

Discussion

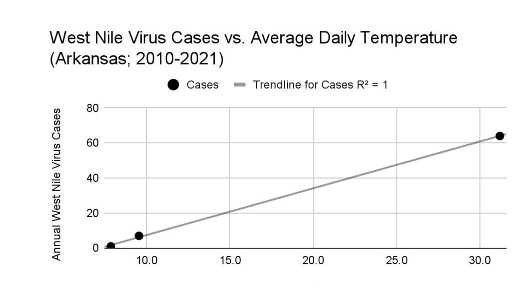
Our study aimed to explore the relationship between precipitation, temperature, humidity, and the vector transmission of dengue fever and West Nile virus. However, in the process of our analysis, we came across many potential sources of error. For example, when collecting data from GLOBE, we noticed that much of the needed data was missing, causing graphs to be incomplete. 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. 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.

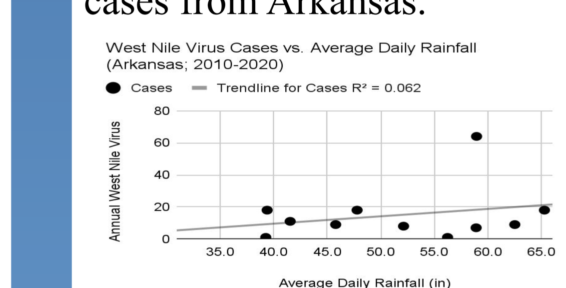
By assessing the most common and accurate relationship represented in our created graphs, we approximated the connection between atmospheric conditions and disease case statistics. Ultimately, our study found no correlation between humidity and the transmission of mosquito-borne diseases, while increased 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 into 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.



Example: This linear regression graph depicts the relationship between relative humidity percentage and statewide West Nile virus cases from Arkansas.

Example: This linear regression graph depicts the relationship between average daily temperature and West Nile virus cases from Arkansas.





Example: This linear regression graph depicts the relationship between average daily rainfall and West Nile virus cases from Arkansas.

Acknowledgements

The authors would like to acknowledge the support of the 2022 Earth Explorers Team, NASA STEM Enhancement in the Earth Sciences (SEES) Virtual High School Internship program.The SEES High School Summer Intern Program is led by the Texas Space Grant Consortium at the University of Texas at Austin (NASA Award NNX16AB89A).
We would also like to give a special thanks to all our **mentors:**
Dr. Rusanne Low, Dr. Erika Podest (NASA JPL), Cassie Soeffing, Andrew Clark, Peder Nelson