The Correlation Between Annual Precipitation and West Nile Virus in the United States

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Abstract

Two affairs the United States is currently faced with are the spread of West Nile virus, a vector-borne disease contracted when bitten by an infected mosquito, and increasing precipitation rates. A calculated correlation of the two variables, precipitation and West Nile virus, allows for the acknowledgement of their general relationship and potential applications towards educational outreach, funding, and additional resources in regards to public health and West Nile virus prevention. In order to achieve a numerical value to define the proposed relationship, annual precipitation amounts for each U.S. state were recorded from the National Oceanic and Atmospheric Administration's National Center for Environmental Information and annual West Nile virus case amounts for each U.S. state were recorded from the Centers for Disease Control and Prevention. The data was then analyzed with the Pearson correlation coefficient to reveal a weak and inverse correlation of -0.233. The correlation outcome indicates that precipitation amount alone has little affect on the spread of West Nile virus, and too many external variables could have affected the results, as each U.S. state has very diverse environmental and ecological factors- including surface temperature, biodiversity, population density, and geographic and climatic characteristics. No definite correlation can be concluded by this research, however, it is recommended that additional research and environmental modeling be completed to understand how precipitation affects the spread of West Nile virus within a smaller and more remote study site.

Keywords: West Nile virus, precipitation, correlation, educational outreach, public health

Impact of Precipitation on West Nile Virus Rise and Risk in the United States

Research Questions

Between the years of 2016 and 2020, WNV cases were recorded in nearly all fifty U.S. states, excluding Hawaii (Centers for Disease Control and Prevention, 2021). Additionally, the Mosquito Habitat Mapper (MHM) protocol of the GLOBE Observer Data Visualization System suggests that potential mosquito breeding habitats were present in forty eight U.S. states from 2017 to present day (The GLOBE Program, 2022). With such statistics, it can be considered that mosquito-borne diseases, and the prevention thereof, are of public concern nationwide. Furthermore, understanding how precipitation and WNV relate to each other, especially in a time of rising precipitation rates, will increase knowledge of public education and funding outreach needed for WNV prevention and preparation to promote optimal public health and safety.

The following research addresses two primary research questions (a) '*What is the general relationship between annual precipitation and the number of West Nile virus cases recorded in the United States?'* (b) '*Can this defined correlation be used to designate U.S. states as 'most at risk' vs. 'least at risk' for rising West Nile virus cases in view of the increasing rates of precipitation nationwide?'* The answers to these questions will support the research objectives to (a) understand how precipitation factors as one predictor of West Nile virus case rates and to (b) organize focused educational outreach and funding towards those states predicted to experience a wider spread of West Nile virus as precipitation rates continue to rise globally.

Introduction

Mosquitoes are responsible for the majority of vector-borne diseases in the United States (U.S.), one of these diseases being the West Nile virus (WNV). WNV is a RNA virus that, when contracted, causes the West Nile fever - giving rise to an average of 130 deaths in the U.S. each year (Centers for Disease Control and Prevention, 2022). Unfortunately, mosquitoes breed in a variety of wet environments and containers, making them an insect capable of inhabiting many geographic and climatic conditions of the U.S. Additionally, anthropogenic climate change has accelerated the effects of global warming, one of these effects being an increase in precipitation rates globally. Knowing that mosquitoes thrive and breed in wet environments, the following research addresses the relationship between West Nile virus and precipitation amounts in the U.S. By understanding how the two variables, precipitation and West Nile virus, correlate with one another, environmental and health organizations may apply such knowledge towards West Nile virus prediction and prevention models.

West Nile virus spread is determined by a variety of factors, some including geographical location, climatic characteristics, and population density. The following research will address one of such factors - precipitation. The relationship found between precipitation and WNV may be applied to U.S. WNV prediction models, thus benefiting public health nationwide. This research may also be applied in such a way that it directs focused public outreach towards states ‘most at risk’ of experiencing an increase in WNV cases as precipitation rates continue to rise due to climate change.

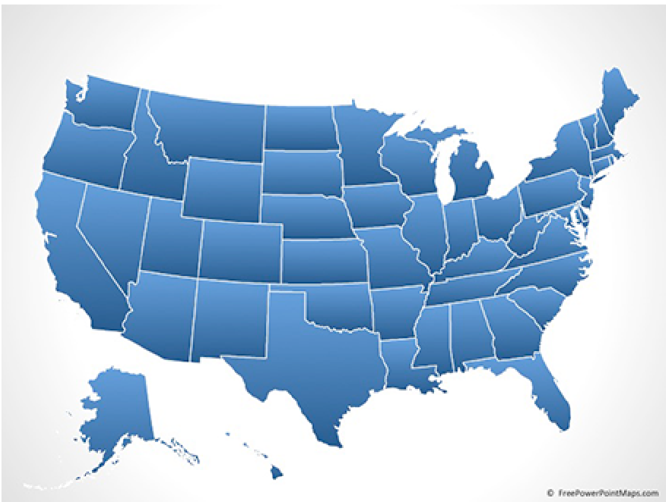
Research Methods

Study Site

Data was collected and interpreted from all fifty states of the United States - a country which contains a diverse array of climatic and geographical characteristics. Covering an area of land of nearly 10 million km^2, the U.S. experiences a broad range of annual precipitation rates due to its numerous climate classifications; including tropical, dry, moist subtropical mid-latitude, moist continental mid-latitude, polar, and highland (National Weather Service, 2022):(The World Bank Group, 2022). Additionally, due to its size, the U.S. withholds a broad range of land coverage characteristics; including coastlines, mountains, forests, plains, valleys, rivers, and lakes.

Figure 1

Map of the United States of America with States



Note: Figure 1 illustrates the following research's study site, the United States of America.

Data Collection

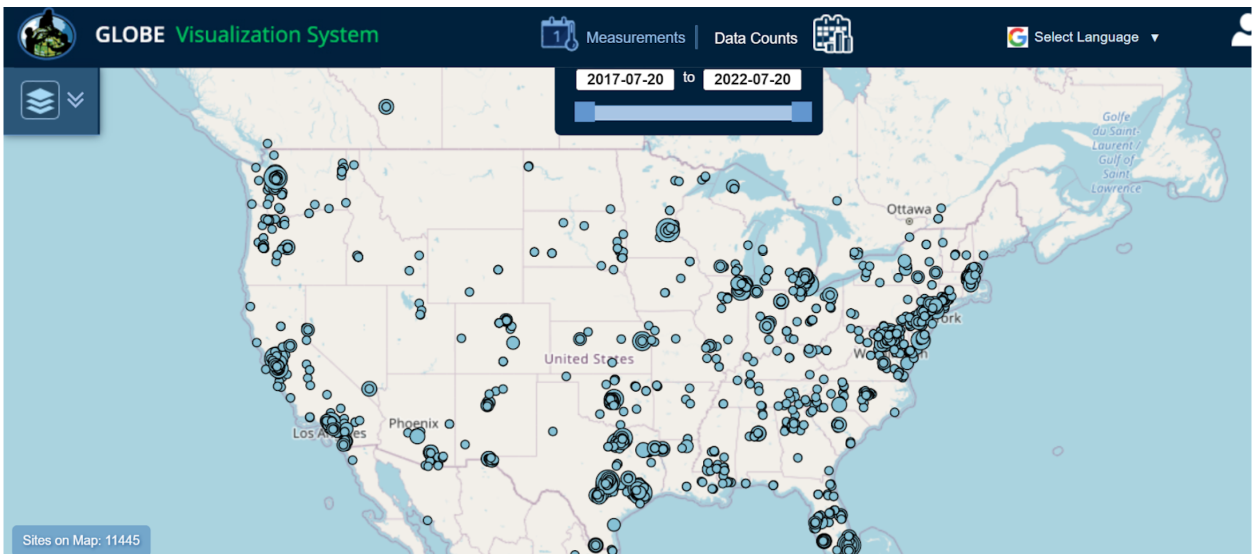
Data from the Centers for Disease Control and Prevention's (CDC) West Nile Virus Final Annual Maps and Data for 1999-2020, the National Oceanic and Atmospheric Administration's (NOAA) National Center for Environmental Information - Climate at a Glance, and the National Aeronautics and Space Administration's (NASA) Global Learning and Observations to Benefit the Environment (GLOBE) Observer Visualization System were used within this research. Annual WNV cases and total annual precipitation, measured in inches, were collected from each of the fifty U.S. states between the years 2016 and 2020 from the CDC and NOAA, respectively.

Data referring to current public knowledge of mosquito breeding sites was collected from the NASA GLOBE Observer Visualization System through the Mosquito Habitat Mapper

(MHM) protocol. When selected, the MHM protocol presented numerous data points within the U.S. in which citizen scientists recorded potential mosquito breeding habitats. Selecting the MHM protocol allowed us to see which locations across the U.S. had the most citizen scientists reporting information regarding the presence of mosquitoes and their breeding sites.

Figure 2

GLOBE Observer Visualization System



Note: Figure 2 Illustrates a total of 11,445 potential mosquito habitats across the fifty United States recorded by citizen scientists through the GLOBE Mosquito Habitat protocol within a five year time period of 2017 to 2022.

Data Analysis

The Pearson correlation coefficient was used to analyze the linear relationship between annual precipitation and annual WNV cases in the U.S. This mathematical equation calculates the direction and strength of the relationship between two variables by providing a value between -1 and 1, with values lower than 0 reciprocating an inverse relationship between the variables and values higher than 0 reciprocating a positive relationship between the variables.

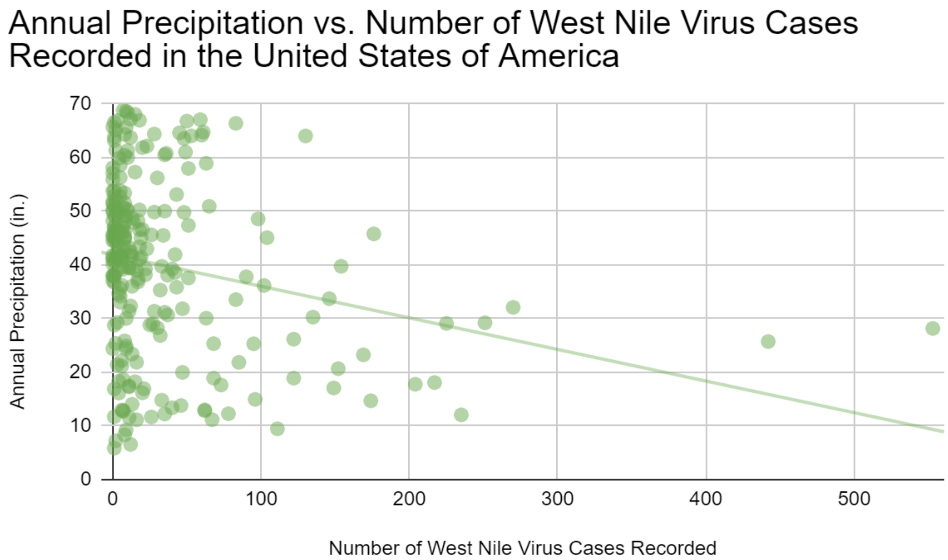
Additionally, the closer the correlation value is to -1 or 1, the stronger the relationship between the two defined variables is. Our research resulted in a correlation coefficient of -0.233 between annual precipitation and annual WNV cases in the U.S. This means that the two variables relate to each other with a generally weak and inverse relationship. To enunciate, according to the correlation coefficient defined within this research, as precipitation increases, the number of WNV cases decreases.

In observing the GLOBE Observer Visualization System data with regards to analyzing current public knowledge of mosquito breeding habitats and vector-borne disease prevention, we found that highly urbanized cities - such as San Francisco, California and San Antonio, Texas - reported large quantities of mosquito breeding habitats. In contrast, rural locations recorded few to no mosquito habitats. The midwestern states Montana and Nebraska withheld no mosquito breeding habitat reports over the five year time period of 2017 to present day.

Results

Figure 3

Annual Precipitation vs. Number of West Nile Virus Cases Recorded in the United States of America



Note: Figure 3 illustrates the general correlation between annual precipitation and the number of West Nile virus cases in the U.S.

Figure 4

Line of Best Fit and Correlation Coefficient of Annual Precipitation and West Nile Virus in the United States

Line of Best Fit	$y = -0.0589x + 41.923$
Correlation Coefficient	$r = -0.2333704374$

Note: Figure 4 presents the Line of Best fit and Correlation Coefficient defined between the two variables, annual precipitation amounts and West Nile virus cases recorded in the United States.

Discussion

The Pearson correlation coefficient provided this research with a weak and inverse relationship, of the value -0.233, between annual precipitation amounts and annual WNV cases recorded in the United States. This outcome has been interpreted to understand that annual precipitation and WNV cases in the U.S. are marginally related to each other in a negative manner. To enunciate, a correlation of -0.233 between the variables suggests that, as precipitation amounts increased, the number of West Nile virus cases recorded decreased. This conclusion does not support the researchers' hypothesis - that more precipitation would result in more WNV cases - and instead procures new questions of interest on the topic.

Because this research was introduced to multiple sources of error, interpretation of the correlation between the two variables should be applied sparsely and only once further environmental modeling and research has been completed. Precipitation amounts across the U.S. vary due to a multitude of climatic factors, including air temperature, humidity, precipitation patterns, and altitude. To assume that any one of these climatic factors does not directly affect WNV spread would be incorrect. Additionally, WNV spread may also be affected by other extraneous factors, including atmospheric pollution, population density, geographic and climatic characteristics, and public awareness. Understanding the connections of WNV cases to these factors, as well as the connections of annual precipitation amounts to these factors, would increase this research's outcome both in credibility and potentiality.

A similar study, published by Mary Anne Liebert Inc. Publishers, presents both results and explanations similar to those found throughout this research. The study collected data on precipitation averages and WNV outbreaks at the county-wide level within the United States. It was then discussed that on average, a year of unusually high precipitation did in fact reciprocate with an increase in WNV cases the following year. However, they also found that a year of unusually low precipitation reciprocated with an increase in WNV cases the following year. These findings, once fully analyzed and interpreted, proposed a hypothesis that emphasizes the impact of ecology and climatic characteristics on both precipitation and its effect on WNV cases (William J. Landesman, 2017). This study provides support towards our conclusion, that further research and environmental modeling within a small-scale study site is needed to accurately calculate the relationship between annual precipitation and WNV cases across the United States.

Conclusion

After collecting extensive data from the CDC, NOAA, and NASA GLOBE Observer, then analyzing said data with the Pearson correlation coefficient and GLOBE Observer Visualization System, this research study concludes that there is no significant relationship found between annual precipitation and the spread of West Nile virus in the United States. When comparing the amount of annual precipitation, in inches, to the number of annual West Nile virus cases for each U.S. state, a correlation coefficient of -0.233 was found - providing a weak and inverse relationship between the two variables. Because of such a low and insignificant correlation, it has been concluded that this research does not withhold enough evidence to define a solid relationship between annual precipitation and WNVcases in the U.S. Additionally, further research and environmental modeling within a small-scale study site will be needed to consider the effects of precipitation as a factor of WNV case rates. With the conclusion that precipitation has little effect on WNV cases across the U.S., it has been reasoned that public awareness and the education of mosquito breeding and vector-borne disease risks should be encouraged and funded for across the entirety of the U.S. - with a focus on those states and locations whom we observed do not currently practice frequent participation in mosquito prevention and tracking through the GLOBE Observer platform.

The above research method may be improved by utilizing a smaller and more remote research site/sample size. We recognize that the diversity in geographical and climatic characteristics across the U.S. introduced a variety of uncontrolled variables to this research - including surface temperature, atmospheric pollution, wildlife and biodiversity, and population density. One possible solution to controlling such extraneous variables, would be to study the effects of precipitation on WNV cases in a specified U.S. state or smaller district/county within a state. The above research method may also produce more viable results by utilizing a larger time period of at least ten years or more. The larger the time period and amount of data points made available, the better established the relationship between annual precipitation amount and annual WNV cases will be.

Research following this study would focus on understanding the other factors of WNV case rates, including surface temperature, atmospheric pollution, population density, and geographic and climate characteristics. Additional GLOBE Observer protocols that may be studied in regards to their relationship to WNV may be the Atmosphere's Aerosols, Surface Ozone, and Surface Temperature protocols, to name a few. It may also be suggested to study the relationship between precipitation and the WNV case rate factors priorly listed, to clearly define how each variable affects not only WNV case rates, but each other variable as well. This additional research will conclude for the science community to what extent the various factors affect WNV cases in the U.S., and will also help to answer one of our originally proposed research questions of identifying those states 'most at risk' versus 'least at risk' for experiencing an increase in WNV cases in the coming years.

Acknowledgments

This research could not have been as thoroughly completed without the assistance and guidance of Dr. Rusty Low, Ms. Cassie Soeffing, Mr. Peder Nelson, and Ms. Sylvie Wurmser. The listed mentors and peer mentor provided insightful knowledge and advice throughout the duration of the above research and have contributed greatly to the success of this project. It is with their help and unwavering support that this research is capable of reaching and informing the science community.

References

Centers for Disease Control and Prevention. (02 June, 2022). *West Nile Virus*. Retrieved on July 16, 2022, from https://www.cdc.gov/westnile/index.html

Centers for Disease Control and Prevention. (17 December, 2021). *West Nile Virus - Final Annual Maps and Data*. Retrieved on July 14, 2022, from https://www.cdc.gov/westnile/statsmaps/finalmapsdata/index.html

National Weather Service. (2022). *Climate Zones*. NWS Jet Stream - Climates. Retrieved on July 21, 2022, from https://www.weather.gov/jetstream/climates&sa=D&source=docs&ust=1658991713369561&usg=AOvVaw0WanLWBOjH6U1a8G8S2QDy

NOAA National Centers for Environmental information. (July 2022). *Climate at a Glance: Statewide Time Series*. Retrieved on July 21, 2022, from https://www.ncei.noaa.gov/cag/

The GLOBE Program. (2022). *Get Data.* GLOBE Observer. Retrieved on July 14, 2022, from https://observer.globe.gov/get-data

The World Bank Group. (2022). *Land area (sq.km)*. The World Bank - Data. Retrieved on July 2022, from https://data.worldbank.org/indicator/AG.LND.TOTL.K2?locations=US

William J. Landesman, Brian F. Allan, R. Brian Langerhans, et.al. (14 September, 2017). *Annual Associations Between Precipitation and Human Incidence of West Nile Virus in the United States*. Mary Anne Liebert Inc. Publishers. Retrieved on July 26, 2022 from, https://www.liebertpub.com/doi/10.1089/vbz.2006.0590

IVSS Virtual Badges

I am a Collaborator

Each team member contributed equally throughout the duration of this research project. Christine Nam (CN) developed the research ideas/plans and worked as a communication liaison between the team and our mentor, Dr. Russanne Low. CN also contributed as a data analyst , supporting author, and a team leader in scheduling daily team meetings to discuss research progression and projections. Julianna Pledgie (JP) contributed as lead paper author and editor, project slideshow and poster curator, and as a supporting data analyst. JP worked diligently to provide the well-developed supporting materials of our research project. Grace Toman (GT) contributed as a supporting data analyst, supporting author, and project video presentation curator. GT developed and edited the project video that will be presented at the 2022 International Virtual Science Symposium.

Each team member thoughtfully contributed towards the research project as a whole. We worked together to develop the research questions and objectives and continued working together daily to collect, analyze, interpret, and discuss data. With CN located along the U.S. West coast and JP and GT located along the U.S. East coast, we each had to make scheduling sacrifices for the better of the project and research. Our differing locations, however, also provided this research with differing viewpoints and opinions which benefited the thoroughness of the project results.

I Make an Impact

This research paper was centered around a research objective of better understanding where educational outreach and funding needed be focused in regards to public safety and West Nile virus prevention. The results of this paper contribute to the overall understanding of how the science community must study the relationship between precipitation and West Nile virus spread.

This research suggests that the science community studies such a relationship with state or district-wide study sites and environmental/ecological modeling. In conclusion, our research paper moved the science community one step closer to fully understanding how precipitation affects West Nile virus spread, how this research should be studied, and how the results should be applied to focused educational outreach and funding for the better of the public.

I am a STEM Professional

This research project was amplified by the advice and contributions of Dr. Russanne Low. Dr. Low helped our team to understand the drawbacks within our research that we may not have originally recognized. Because of Dr. Low's guidance and help as a mentor, we were able to develop a strong conclusion with further insight into how our research methods may be improved and future research initiatives to be studied by the science community. This report acknowledges the support and guidance of Dr. Low under the 'Acknowledgements' header of the paper's 'Conclusion'.