Using GLOBE Observations to Analyze the Effect of Hurricanes on Mosquito Population Patterns

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Abstract

Each year, hurricanes hit the United States coastline and disrupt ecosystems in the area. This research aimed to analyze the effect of hurricanes on mosquito population patterns. The scope of this research was the city of Miami, Florida from the time period of 2017 to 2022, in which GLOBE Mosquito Habitat Mapper data was collected. Data from the GLOBE Mosquito Habitat Mapper, local data from Miami-Dade, data from the EM-DAT international disasters database and other data collected from hurricanes that affected Florida from 2017 to 2022 was utilized. This research compiled these datasets and mapped the relationships between them to reveal a trend. Maps of mosquito density and mosquito observations in the five-year time frame were compared to specific hurricane data to determine how mosquito populations react after an extreme weather event. Additionally, through utilizing GLOBE Mosquito Habitat Mapper data, this research determined how frequently citizens of the affected area will observe mosquitos after a disaster. Ultimately, this research analyzed the relationship between the intensity of hurricanes and mosquito population patterns where they hit, as well as how they influence the occurrence of citizen science contributions. The outcomes of this research can be used to predict how future hurricanes can influence mosquito populations and subsequently inform public health policy decisions.

Keywords: hurricanes, flooding, mosquito populations, mosquitoes, GLOBE Observer

Introduction

Mosquitoes are flying insects with over 3,500 types that can be found all around the world. Several of these types of mosquitoes can be vectors, which spread various pathogens to humans and animals alike (CDC, 2020). Diseases that have spread from mosquitoes include Zika virus, West Nile virus, dengue and malaria (CDC, 2016). Across the world, these vector-diseases account for more than 700,000 deaths each year (WHO, 2020). In order to reduce the transmission of vector-diseases by mosquitoes, it is essential to understand the patterns of mosquito populations.

Hurricanes are large storms that form over warm ocean waters. They produce winds of 119 kilometers per hour and higher, which frequently affect the locations they pass through. Additionally, when hurricanes reach land, they push water from the sea up the shore, resulting in what is known as storm surge. Strong wind, heavy rain and storm surge caused by hurricanes can all have detrimental effects (NASA, 2014). Hurricanes tend to result in a variety of long-lasting damages, including infrastructure damage, pollution and contamination, and physical landscape change, all of which can contribute to causing or exacerbating various diseases (Waddell et al, 2021). Such damages and changes have the potential to greatly affect mosquito populations, especially in areas such as Florida. According to the Florida Climate Center, the southeast coast of Florida is “extremely susceptible to a land-falling hurricane”. In particular, Florida is at threat of hurricanes during the Atlantic hurricane season from June 1 to November 30. Historically, the most severe and destructive hurricanes occurred in the months of August, September and October, during which water in the Atlantic Ocean becomes warmer (Florida Climate Center).

The term citizen science is frequently used to describe situations in which the public voluntarily helps to conduct research in any particular field. Through observing the physical environment surrounding them, citizens from around the world are able to contribute to more precise scientific knowledge. Citizen science in the field of mosquito population studies is most seen in the Global Learning and Observations to Benefit the Environment (GLOBE) application, which is an international program that allows citizens and scientists to collaborate in monitoring changes in various Earth systems. Since its creation in 1995, more than 200 million environmental observations have been collected and used to further research in the field (Low et al., 2021).

This research focused on the city of Miami specifically, due to its location on the southeast coast of the state of Florida. Through focusing on this area, more hurricane data and history was available for analysis. Additionally, due to it being an urban area, comparatively more Mosquito Habitat Mapper observations were made on the GLOBE Observer app. Thus, with its high population density and susceptibility to hurricanes, it is important to determine how future hurricanes will impact mosquito population patterns in the area. In addition to this, with analyzing human responses through Mosquito Habitat Mapper observations, this research aimed to target the intersection of hurricanes, mosquitoes and people.

Methods and Materials

This research was conducted by collecting simultaneous field observations from several sources. Firstly, data from all hurricanes that affected the Miami-Dade county of Florida from the years of 2017 to 2022 were gathered from NOAA Historical Hurricane Tracks database, National

Hurricane Center Reports and National Centers for Environmental Information International Best Track Archive for Climate Steward. This data can be found in Figure 1 below.

Hurricane Name	Dates of Occurrence	Date it Affected Miami	Pressure	Maximum Sustained Wind Speed	Storm Speed	Storm Direction	Maximum Rainfall Totals	Category	Direct Fatalities	Total Cost of Damages
Hurricane Sally	9/11/2020-9/19/2020	9/12/2020	1003 mb	30 kt	7 kt	278 degrees	24.88 in	Tropical Depression	4	$7.33 billion
Tropical Depression Three	7/22/2019-7/23/2019	7/23/2019	1013 mb	25 kt	11 kt	331 degrees	3 in	Tropical Depression	0	$0
Hurricane Isaias	7/28/2020-8/5/2020	8/2/2020	996 mb	55 kt	7 kt	324 degrees	3 in	Tropical Storm	0	$0
Tropical Storm Emily	7/30/2017-8/2/2017	8/1/2017	1008 mb	30 kt	8 kt	83 degrees	7.19 in	Tropical Depression	0	$10 million
Tropical Storm Gordon	9/2/2018-9/7/2018	9/3/2018	1006 mb	45 kt	14 kt	310 degrees	12.73 in	Tropical Storm	7	$200-250 million
Hurricane Irma	8/30/2017-9/13/2017	9/10/2017	936 mb	100 kt	6 kt	297 degrees	21.66 in	Hurricane 3	47	$50 billion

Figure 1: Data from all hurricanes that affected Miami from the years of 2017 to 2022

Secondly, mosquito count surveillance data from Miami-Dade County, where Miami is located, was collected from several local sources and research. In their research paper about the community composition and abundance of vector species mosquitoes in Miami-Dade County, Wilke et al. established a mosquito surveillance system in the county. After collecting 2,711,938 mosquitoes in the area from August 2016 to November 2018, they were able to find the prevalence of each mosquito species per season (Wilke et al. 2019). Their results are shown below in Figure 2.

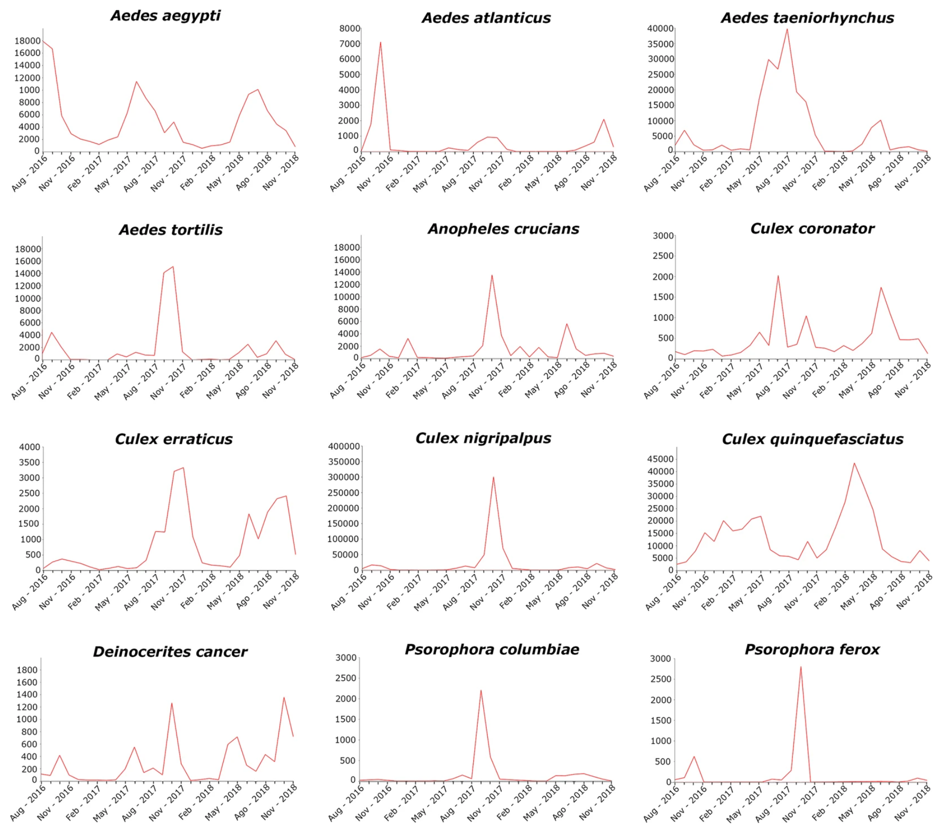

Figure 2: Seasonal mosquito surveillance counts in Miami-Dade County from August 2016 to November 2018. Adapted from "Community Composition and Year-round Abundance of Vector Species of Mosquitoes make Miami-Dade County, Florida a Receptive Gateway for Arbovirus Entry to the United States" by Wilke et al., 2019.

Lastly, research from the GLOBE Mosquito Habitat Mapper database was used to determine how hurricanes also influence mosquito habitat reportings in the affected area. The database is made up of observations made from citizen scientists around the world that identify potential mosquito habitats and the presence of mosquito larvae. Prior to analyzing the data, the data set was cleaned and condensed in order to reduce the amount of memory and time used to parse the dataset. Repetitive data such as copies of when and where the Mosquito Habitat Mapper protocol was followed, data ranges for larvae counts such as '51-100' or 'more than 100', time data within the larvae counts such as ‘25-Jan’, and extreme larvae counts such as ‘100000000’, ‘999999999’, or ‘1.01E+27’ as well as other such data was omitted. The final data set included the latitude, longitude, time the data was collected, and the larvae count that was collected. Data cleaning was performed via Microsoft Excel, utilizing mostly the functions to delete columns and add filters to columns. Once data cleaning was complete, the data was saved as a CSV file for parsing.

After collecting data from these three areas, a python script was written to analyze the differences and similarities between them. The code was written with the Jupyter Notebook computing platform, using the matplotlib and pandas libraries and the OS and datetime modules. The script demonstrates that the data can be analyzed using matplotlib or pandas, with Figure 3 created via matplotlib and Figures 4 and 5 created via pandas. Both methods parse a CSV file that has a table with columns for latitude, longitude, larvae count, and time in that order and drop the data from the file that is not relevant to the location to be analyzed, including only data from the region bounded by latitudes 24.5º N and 31º N and longitudes 80º W and 87º W, and drop data points that include 44586 - the numerical equivalent of the previously mentioned ‘25-Jan’ - as a data point, as the previous data cleaning may not have removed it. Both methods then create graphs of the data, which are then used to analyze the relationship between mosquito populations and hurricanes.

Results and Data

The script written was able to produce several results. The first result can be seen in Figure 3 below, which depicts the dispersion of larvae counts observed through the GLOBE Observer app in Florida from 2017 to 2022. Due to this map demonstrating a relatively high concentration of data in certain locations and the information found about hurricanes that passed through Florida between 2017 and 2022, the Miami-Dade region was chosen to be analyzed.

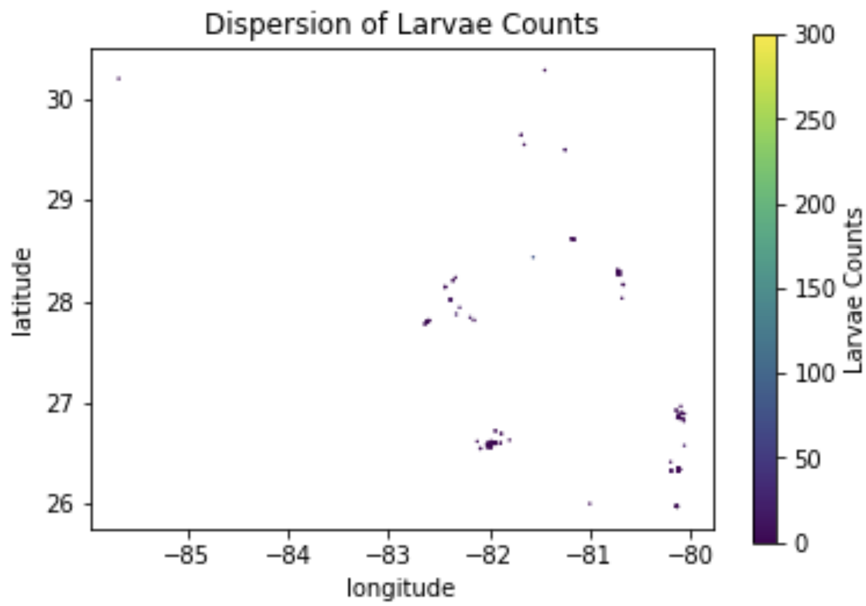

Figure 3: Dispersion of larvae counts observed through the GLOBE Observer App in Florida from 2017 to 2022

Then, this information was demonstrated on a scatter plot and a line graph. Figures 4 and 5 show the relationship between the time of the mosquito habitat observation and the larvae count recorded for the observation as a scatter plot and line graph, respectively.

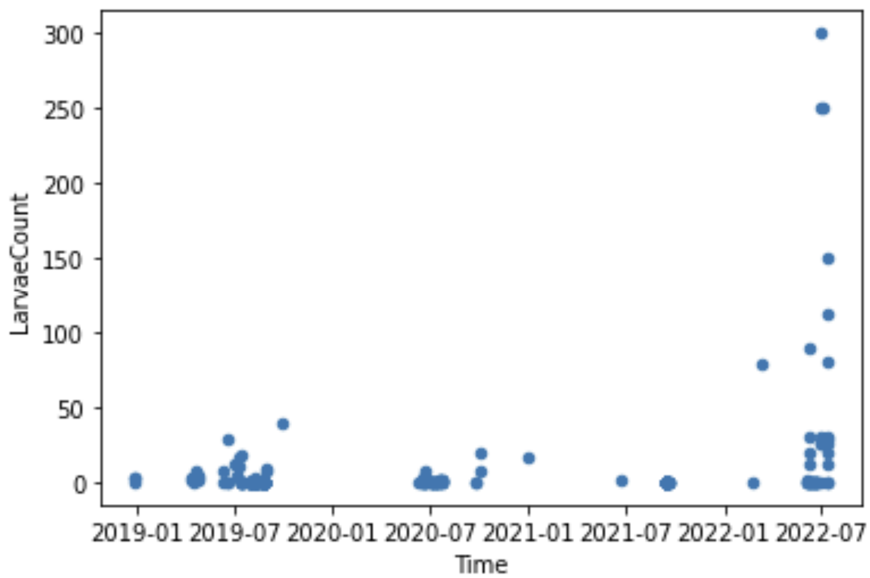

Figure 4: Relationship between the time of a mosquito habitat observation and its recorded larvae count as a scatter plot

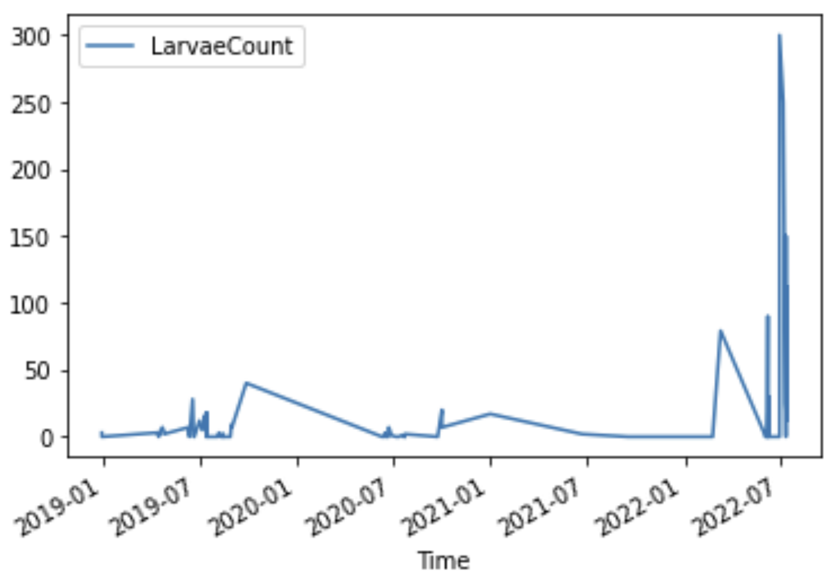

Figure 5: Relationship between the time of a mosquito habitat observation and its recorded larvae count as a line graph

Discussion

Our research revealed a trend connecting mosquito population and citizen mosquito habitat observations with hurricanes. Firstly, the mosquito populations of the most abundant mosquito species in Miami-Dade County appear to experience rapid population growth following intense storms. In Figure 2, during the dates of hurricanes and large storms, many species experienced a local maximum in the following couple months. Secondly, the data on mosquito habitat observations also show bumps in the data near the dates of hurricanes and tropical storms. This reveals an increase in citizen observations during the effects of intense storms.

The increase in mosquito populations due to hurricanes could be the effect of many factors like infrastructure damage or change in physical landscape, but the most notable factor for the population spikes is flooding. Heavy rain and storm surge cause flooding immediately following a hurricane (NASA, 2017). The CDC states that floodwaters give rise to floodwater mosquitoes. Mosquito eggs in the soil placed during previous flooding hatch, resulting in large floodwater mosquito populations (CDC, 2022). Our findings mirror this information, demonstrating how floodwater from intense storms cultivate mosquito populations. Despite our data matching previous studies, the data used is limited. Mosquito data collected from the GLOBE Observer App is opportunistic and can’t be used for population tracking. The storms that appear on the same timeline as Figure 2 also occur at similar times of the year, August and September. With no mosquito data for storms that appeared earlier or later in the year, it is possible that our data coincidently lined up with natural seasonal population growth of mosquitoes. The limited time frame of our mosquito data makes it difficult to prove our claim.

An increase in mosquito habitat observations could be the result of flooding, damaged infrastructure creating breeding sites, and an increased amount of mosquitoes bothering human populations. While the data seems to increase in the occurrence of a hurricane, the data spikes also occur around the same time of every year. In addition, there is a spike in the data without the occurrence of a hurricane. The data spikes around June and July of 2022 with no presence of hurricanes or intense storms. This evidence refutes our claim that mosquito habitat observations increase during the effects of intense storms. The frequency of observations appear to spike annually from June-September, and coincidently lined up with hurricane occurrences. With more data, it would be possible to analyze the effects of more varied hurricanes by comparing trend lines of observation data to hurricanes appearing earlier or later in the year.

Our results show evidence that hurricanes have an effect on mosquito populations and have little effect on mosquito habitat observations. Understanding this mosquito population pattern will increase mosquito control and reduce transmission of vector-diseases carried by mosquitoes. More data on mosquitoes during storms will be necessary to prove our claim and cover the data gap. While the GLOBE Observer data seems to be unrelated to hurricanes, the timeline of our data is also limited. Again, more data will be needed to identify whether or not hurricanes have an effect on mosquito habitat observations. Once data surrounding several more varied hurricanes and tropical storms is gathered, a clearer pattern will be visible.

Should more data be available, a more in-depth analysis could be performed on several levels. Firstly, a bar graph could be created that would display the frequency of GLOBE Mosquito Habitat Mapper observations per month. This would reveal times of high observation counts and be compared to data from Figure 2 to produce more significant results. If there is a high volume of data, a hexagonal bin plot could also be more useful than a scatter plot, since a hexagonal bin plot demonstrates the density of data in a location when there are too many individual data points to plot individually. Creating parallel coordinate or Andrews Plot graphs via the pandas library would greatly aid in visualizing high volumes of data, since both of those can demonstrate high-dimensional data that a scatter plot or line graph simply cannot. Both of those options also open pathways to using high-contrast color maps that would visually demonstrate which periods of time have the highest larvae counts when the time of the mosquito habitat observation is mapped against the other attributes that will be analyzed. Furthermore, once data surrounding several more and more varied hurricanes and tropical storms is analyzed, trend lines for each analysis can be created and graphed against each other in order to discern a clearer pattern - the closer each trendline coincides, the more certainty that the resultant pattern will repeat in the future.

Conclusion

The results of this research show that hurricanes increase mosquito population based on their intensity. Data showed large increases in mosquito population following intense hurricanes, and minor increase in mosquito population following less intense tropical storms. The data is also incomplete. The data only covers a few storms, and there is a lack of seasonal variance between the storms investigated, that the trend seen in the data could be seasonal mosquito population change unrelated to the storms.

This research can be used to inform future research done on mosquito population patterns in any area, in relation to air temperature, wind speed and rainfall levels. Additionally, the methods and materials can be extended to other natural disasters or influential events. The results of this research also contribute to the ability to predict the mosquito population density and frequency of citizen science observations, after a hurricane occurs. In the future, this can be used to create simulations that take data from a hurricane, such as its severity and predicted rainfall levels, and return how many mosquitoes of different species will be present in the months following the event. This can then be used to inform public health policy decisions, such as increased precautions of vector-borne disease spread at certain points throughout hurricane season.

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Citations

Berg, R., & Reinhart, B. (2021). Hurricane Sally. In *Office for Coastal Management*. National Hurricane Center. https://www.nhc.noaa.gov/data/tcr/AL192020_Sally.pdf

Brown, D., Latto, A., & Berg, R. (2019). Tropical Storm Gordon. In *Office for Coastal Management*. National Hurricane Center. https://www.nhc.noaa.gov/data/tcr/AL072018_Gordon.pdf

Cangialosi, J. P., Latto, A. S., & Berg, R. (2021). Hurricane Irma. In *Office for Coastal Management*. National Hurricane Center. https://www.nhc.noaa.gov/data/tcr/AL112017_Irma.pdf

Centers for Disease Control and Prevention. (2020, March 5). *What is a Mosquito?* U.S. Department of Health and Human Services. https://www.cdc.gov/mosquitoes/about/what-is-a-mosquito.html

Centers for Disease Control and Prevention. (2022, July 21). *Mosquitoes, Hurricanes, and Flooding*. U.S. Department of Health and Human Services. https://www.cdc.gov/mosquitoes/mosquito-control/community/mosquitoes-and-hurricanes

Centers for Disease Control and Prevention, & The National Institute for Occupational Safety and Health. (2016, March 21). *Mosquito-Borne Diseases*. U.S. Department of Health and Human Services. https://www.cdc.gov/niosh/topics/outdoor/mosquito-borne/default.html#:~:text=Diseases%20that%20are%20spread%20to

Centre for Research on the Epidemiology of Disasters, World Health Organization, Office of Foreign Disaster Assistance, & US Agency for International Development. (2022, June). *The international disasters database*. EM-DAT; UCLouvain. https://www.emdat.be/

Florida Climate Center. (2020). *Hurricanes*. Florida State University. https://climatecenter.fsu.edu/topics/hurricanes

Florida Department of Health. (2022, July 19). *Mosquito-Borne Disease Surveillance*. Florida Health.

https://www.floridahealth.gov/diseases-and-conditions/mosquito-borne-diseases/surveillance.html

Florida Department of Health in Alachua County. (2018, October 19). *Mosquito Surveillance and Data*. Florida Health. https://alachua.floridahealth.gov/programs-and-services/environmental-health/mosquito-prevention/mosquito-surveillance-and-data.html

Latto, A., Hagen, A., & Berg, R. (2021). Hurricane Isaias. In *Office for Coastal Management*. National Hurricane Center. https://www.nhc.noaa.gov/data/tcr/AL092020_Isaias.pdf

Low, R. D., Nelson, P. V., Soeffing, C., Clark, A., & SEES 2020 Mosquito Mappers Research Team. (2021). Adopt a Pixel 3 km: A Multiscale Data Set Linking Remotely Sensed Land Cover Imagery With Field Based Citizen Science Observation. *Frontiers in Climate*, *3*. https://doi.org/10.3389/fclim.2021.658063

Miami-Dade County. (2022). *Mosquito Inspections and Surveillance*. https://www.miamidade.gov/global/solidwaste/mosquito/inspections-and-surveillance.page

National Aeronautics and Space Administration. (2017, August 7). *What Are Hurricanes?* (S. May, Ed.). https://www.nasa.gov/audience/forstudents/k-4/stories/nasa-knows/what-are-hurricanes-k4.html

Nozzle Nolen. (2022, March 23). *Mosquito Season in Florida: What You Need to Know for 2022*. https://nozzlenolen.com/blog/pest-prevention-control/mosquito-season-in-florida-nn/

Office for Coastal Management, United States Department of Commerce, National Oceanic and Atmospheric Administration, & National Ocean Service. (2022, May 18). *Historical*

Hurricane Tracks. Office for Coastal Management. https://coast.noaa.gov/hurricanes/#map=4.76/27.78/-83.82

Pasch, R., Latto, A., & Cangialosi, J. (2019). Tropical Storm Emily. In *Office for Coastal Management*. National Hurricane Center. https://www.nhc.noaa.gov/data/tcr/AL062017_Emily.pdf

Riles, M. T., & Connelly, C. R. (2020). An Update of the Mosquito Records of Florida Counties, USA. *Journal of the American Mosquito Control Association*, *36*(2), 107–111. https://doi.org/10.2987/20-6923.1

Smith, M. (2018, February 27). *Top 5 Florida Cities Where Mosquitoes Are Most Prevalent*. Sunshine Dad; WordPress. http://sunshinedad.com/top-5-florida-cities-where-mosquitoes-are-most-prevalent/

The GLOBE Program. (2022). *Mosquito Habitats Toolkit*. GLOBE Observer. https://observer.globe.gov/toolkit/mosquito-habitat-mapper-toolkit

Waddell, S. L., Jayaweera, D. T., Mirsaeidi, M., Beier, J. C., & Kumar, N. (2021). Perspectives on the Health Effects of Hurricanes: A Review and Challenges. *International Journal of Environmental Research and Public Health*, *18*(5). https://doi.org/10.3390/ijerph18052756

Wilke, A. B. B., Vasquez, C., Carvajal, A., Moreno, M., Diaz, Y., Belledent, T., Gibson, L., Petrie, W. D., Fuller, D. O., & Beier, J. C. (2020). Cemeteries in Miami-Dade County, Florida are important areas to be targeted in mosquito management and control efforts. *PLoS ONE*, *15*(3), e0230748. https://doi.org/10.1371/journal.pone.0230748

Wilke, A. B. B., Vasquez, C., Carvajal, A., Moreno, M., Petrie, W. D., & Beier, J. C. (2022). Mosquito surveillance in maritime entry ports in Miami-Dade County, Florida to increase preparedness and allow the early detection of invasive mosquito species. *PLoS ONE*, *17*(4), e0267224. https://doi.org/10.1371/journal.pone.0267224

Wilke, A. B. B., Vasquez, C., Medina, J., Carvajal, A., Petrie, W., & Beier, J. C. (2019). Community Composition and Year-round Abundance of Vector Species of Mosquitoes make Miami-Dade County, Florida a Receptive Gateway for Arbovirus entry to the United States. *Scientific Reports*, *9*(1). https://doi.org/10.1038/s41598-019-45337-2

World Health Organization. (2020, March 2). *Vector-borne Diseases*. https://www.who.int/news-room/fact-sheets/detail/vector-borne-diseases

Zelinsky, D. (2019). Tropical Depression Three. In *Office for Coastal Management*. National Hurricane Center. https://www.nhc.noaa.gov/data/tcr/AL032019_Three.pdf

Badge Selection

Data Scientist- We analyzed multiple data sets, comparing them to reveal trend lines. The data was used to investigate and answer our research question. We also pointed out the limitations of the data like limited time frame or limited data volume.