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Association of Landfall Atlantic Tropical Storms and Human Cases of Locally Acquired West Nile Virus Infection in Florida

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Walden University
2020

Abstract

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MSc, University of Nebraska-Lincoln, 2007

BA, Warner University, 2001

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

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Abstract

West Nile virus (WNv) is the most widely distributed *flavivirus* and considered a vector-borne pathogen of global significance. During the study period from 2002 to 2018, WNv had the highest incidence of locally acquired human cases when compared to any other mosquito borne illness in Florida with 373 cases documented during the study period. The purpose of the study is to determine if there is an association between Florida landfall tropical storms (LTS) and the incidence of locally acquired human WNv cases from 2002 through 2018. The study used a retrospective ecological study design guided by the epidemiological triad model of infectious disease causation. Florida Department of Health provided the data for human cases of WNv, landfall tropical storm information obtained from The National Oceanic and Atmospheric Administration (NOAA) Hurricane Center, and climatic data gathered from Midwestern Regional Climate Center (MRCC) and NOAA National Center for Environmental Information (NECI). The study used a linear regression analysis to determine if an association between landfall tropical storms and local cases of human WNv exists. The results showed LTS precipitation (p = .893) and LTS temperature (p = .128) individually were not significant predictors of locally acquired human cases of WNv. Collectively, LTS precipitation and LTS temperature did not significantly predict incidence of locally acquired human cases of WNv in Florida. The study used multiple linear regression analysis for precipitation and temperature data from areas unaffected by LTS. Results from the regression analysis indicated precipitation (p = .000) and temperature (p = .185) from unaffected areas together were significant predictors of human cases of local acquired WNv.

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Dedication

"It always seems impossible until it's done."

– Nelson Mandela

I am dedicating this PhD dissertation in loving memory to some of the most influential people to enter my life, my parents, the late John Sr. and Katie Mosley, and to my son, the late Jackson Mosley Jr. I feel blessed to have had them in my life and they will live always in my heart.

Acknowledgments

"Hold fast to dreams For when dreams go Life is a barren field Frozen with snow."

– Langston Hughes

I would like to take this opportunity to express my gratitude to my committee chair Dr Talmadge Holmes for accepting me into "Team Holmes". I recall one of his questions during our initial discussion was simply, "are you willing to work hard for this opportunity". His advice throughout my dissertation journey was valuable for my career in public health. In addition to my committee chair, I owe thank you to Dr. Fufaa, my methodology committee member, who remained patiently available throughout my sometimes-arduous dissertation journey. When called upon he provided me with guidance and support.

I am extremely fortunate to have been blessed with an unconditional support from my family and friends. I must first acknowledgement my wife, Dr. Sheryl Mosley, for her patience and support during my dissertation journey. Without her support as a devoted wife, partner, and friend, my journey would have been riddled with even more challenges. My daughter Katrice, son Jackson, and Mason, for they gave me every reason to remain ambitious and a proud father. My siblings are incredible people, brothers John Jr., Michael, Myron Sr., Robert and sisters Suella and Winifred, I appreciate their support and unconditional love through the good times and the difficult periods. In addition, a special thank you to my friend, Teresa Foster. Please forgive me for those I failed to mention but was there for me. This PhD is for all of you.

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Chapter 1: Introduction to the Study

The purpose of this study is to investigate the association between landfall Atlantic tropical storms and the incidence of locally acquired human cases of West Nile viral (WNv) disease in Florida from 2002 through 2018.

WNv is an arthropod-borne zoonotic pathogenic *flavivirus* maintained primarily in an enzootic cycle between viremic avian hosts and *Culex* mosquitoes (Kilpatrick, Kramer, Jones, Marra, & Daszak, 2006). WNv was first isolated in 1937 from a febrile woman in Uganda. During this time, the virus was associated with epidemics that caused flu-like febrile illness and sporadic cases of encephalitis in Africa, Asia, and Europe (DeBiasi & Taylor, 2006; Paz, 2015). In 1999, WNv arrived 1999 in the United States in the New York City area where 62 human cases and 7 deaths were reported (Chen, Huang, Beier, Cantrell, Cosner, Fuller, Zhang and Ruan, 2016). Since the 1999 introduction, WNv is the most common cause of epidemic encephalitis in North America and is responsible for three of the largest mosquito-borne viral neuroinvasive disease outbreaks ever documented in the United States (Sardelis et al, 2002; Turell, Dohm, Sardelis, O’Guinn, Andreadis, & Blow, 2005). Within six years of its introduction in the United States, West Nile virus rapidly spread to the 48 contiguous states, Canada, Mexico, and countries in Central and South America (DeBiasi & Taylor, 2006). In 2016, WNv accounted for 95% of all reported neuroinvasive arboviral disease cases in the United States (Burakoff, Lehman, Fischer, Staples & Lindsey, 2018). Since its introduction in 1999, WNv estimates expect over 40,000 human disease cases and close to 2,000 deaths in the United States (Montecino-Latorre & Barker, 2018).

First evidence of WNv in Florida occurred in 2001 through wild bird death surveillance (Blackmore, Stark, Jeter, Oliveri, Brooks, Conti, & Wiersma, 2003). Since its initial detection in Florida, WNv has spread to all 67 Florida counties (Florida Department of Health [FDOH], 2014). *Culex pipiens* Linnaeus is the most important vector of WNv in the Southeast region of the United States. In much of Florida, *Culex quinquefasciatus* (Say) (Appendix B) has proven to be highly efficient in maintaining WNv cycle with avian host (Vitek, Richards, Mores, Day & Lord, 2008). Southern regions of Florida *Culex nigripalpus* (Theobald) (Appendix C) is a competent vector of WNv (Burakoff et al. 2018). Avian reservoir hosts, especially birds in the family *corvidae* (crows and jays), are effective hosts for disease transmission of WNv. Humans and horses are occasionally infected with WNv but are unable to produce enough viremia to infect a mosquito when it blood feeds. Because of this, humans and horses are dead end host as neither contribute to the WNv life cycle (Bessell, Robinson, Golding, Searle, Handel, Boden, Purse, & Bronsvoort, 2016; George, Harrigan, LaManna, DeSante, Saracco, & Smith, 2015).

According to Clements (2013), 79% of humans infected with WNv are asymptomatic. Approximately 20% are symptomatic and when clinical symptoms of WNv infection are present, typical indications may range from fever or fatigue, to headache and muscle weakness. About 1% of WNv patients may experience serious sequalae in the form of neurological damage, coma and even death in untreated or undiagnosed cases (Levy & Patz, 2015). Following a bite from an infected mosquito, WNv incubation period can vary between 2 to 15 days (FDOH, 2014). Most human WNv infections have shown to occur in the summer months or beginning of the autumn season. WNv illnesses are potentially serious with 1 in 150 infected people becoming seriously ill and those infected may experience symptoms that can last several weeks. Of all encephalitic *flaviviruses*, WNv is the most widely distributed and it is a vector-borne pathogen of global importance (Paz, 2015).

Atlantic tropical storms are low pressure systems that occur annually and produce devastating weather events causing major structural damage, environmental disruptions, potentially displacing people and creating serious public health challenges (Englehart & Douglas, 2001; Morrow, Johnson, Polanco, & Claborn 2010). This disruption can have negative impacts economically for communities and their local governments. Atlantic tropical storm season (commonly called hurricane season) occurs annually from June 1 and lasts through November 30 (National Oceanic Atmospheric Administration [NOAA], 2017). This also coincides with Florida's rainy season and the peak of most mosquito breeding activity. When Atlantic tropical storms make landfall, they produce heavy precipitation that cause flooding, fluctuation in temperature, and humidity (Florida Climate Center, 2017).

Temperature is an important environmental factor in the transmission cycle of WNv and the life cycle of mosquitoes. Higher temperature can impact viral replication rates and transmission of WNv. Increased temperatures affect the length of extrinsic incubation period (EIP), the seasonal phenology of mosquito host populations and the distribution of incidence of human cases. Higher temperatures can cause an increase in the growth rates of mosquito populations and increase their frequency of blood feeding, reduction in EIP, accelerate the virus evolution rate, and increase viral transmission efficiency to avian reservoir hosts. Increasing ambient temperature has shown to augment the life cycle in mosquitoes resulting in quicker development (Dohm, O'Guinn, & Turell, 2002).

Precipitation can be an important factor to consider with WNv and its life cycle. The role of above average precipitation and WNv activity is somewhat controversial. The amount of precipitation may involve complex ecological relationships beyond increased precipitation will result in exponential increase in mosquito populations. It is also important to consider the distribution of precipitation and the ecological requirements of vector mosquito species with WNv (Paz, 2015). The occurrence of above average precipitation has the potential to create new breeding sites for some mosquito species or on the other hand, cause catastrophic conditions and have a negative impact on some mosquito larvae and their habitats (Paz, 2015). Paz (2015) found a positive association with rainfall in the months prior to disease outbreak of human cases of WNv disease.

Below-average precipitation or near drought conditions can influence WNv activity. These conditions can disrupt aquatic food webs that are important for maintaining mosquito larvae populations at a natural level by leaving small isolated pools inaccessible to natural predators when larger reservoirs have receded. These drought conditions can also bring avian host closer to mosquito habitats near dwindling water sources. This can intensify the enzootic phenology of WNv in drought-affected areas (Blackmore et. al, 2003).

There is a need for research beyond individual tropical storms to quantify an association between landfall Atlantic tropical storms and incidence of human cases of WNv. There are few studies that document vector-borne disease outbreaks associated with weather-related disasters, most of the studies cover a few weeks after a weather-related disaster, thus long-term effects have not been assessed (Guzman-Tapia, Ramirez-Sierra, Escobedo-Ortegon, & Dumonteil, 2005).

This chapter includes an introduction to the study, the epidemiology of WNv, its introduction, and its rapid expansion across the United States. The impacts of landfall Atlantic tropical storms, precipitation, and temperature are discussed with emphasis on the state of Florida. The background section will discuss information about the association between landfall Atlantic tropical storms and incidence of human cases of WNv, and background research about landfall Atlantic tropical storms, mosquitoes, and WNv. The problem statement identifies the gap in literature that supports the significance of this study. The chapter proceeds with discussion on the purpose of the study, hypothesis, and research questions that define the study. The basis of the study are clarified in the conceptual foundation section. This chapter will present supporting aspects in the nature of the study, assumptions, scope, delimitations, and limitations of the study. The chapter closes with discussion on the significance of the study and a concise summary.

Background

Public health response to natural disasters is an essential responsibility and critical to saving lives (Harris, Jonathan, Richards, & Anderson, 2014). When responding to areas affected by landfall Atlantic tropical storm systems, emergency personnel may enter areas that have experienced structural devastation exposing them to numerous hazards that can include pestiferous mosquitoes (Caillouët, Michaels, Xiong, Foppa & Wesson, 2008; Waring & Brown, 2008). Urban areas affected by landfall Atlantic tropical storm systems produce mosquito larval habitats in lowland areas, depressions, artificial containers, and abandoned swimming pools not maintained during the recovery efforts and restoration of urban areas (Caillouët et al., 2008). In a study by Caillouët et al. (2008), the researchers found 69% of the swimming pools remained abandoned four months after Hurricane Katrina. Sampling for mosquito larvae found 64% of abandoned swimming pools had mosquito larvae present. In regions affected by Hurricane Katrina, the number of reported cases of WNv neuroinvasive disease transmitted by mosquitoes increased significantly (Caillouët et al., 2008). This may be the result of people living in damaged housing or living outside for extended periods awaiting evacuation (Caillouët et al., 2008).

In 2011, Hurricane Irene recovery efforts were often interrupted by sudden increases in mosquito populations in the hurricane affected regions (Harris et al., 2014). After Hurricane Jeanne made landfall in Gonaïves, Haiti in September 2004, surveillance for mosquito-borne diseases were conducted and researchers reported 3 malaria patients, 2 acute dengue infections, and 116 febrile WNv patients and 2 with acute WNv infections. This was the first observations of human West Nile virus on the island of Hispaniola (Beatty, Hunsperger, Long, Schürch, Jain, Colindres, Lerebours, Bernard, Goodman, Dobbins, Brown, & Clark, 2007).

Problem Statement

Arboviruses are associated with 130 known human diseases; those arboviruses of public health importance belong to one of three virus genera: *Flavivirus*, *Alphavirus*, and *Orthobunyavirus* (Centers for Disease Control and Prevention [CDC], 2018). In 2002 WNv began to spread from the northeast and into Jefferson County, Florida before spreading into every county in the state (Campbell, Marfin, Lanciotti, & Gubler, 2002; FDOH, 2014). During 2002 - 2013 Florida reported 318 cases of WNv illnesses. The highest annual number of reported WNv illnesses occurred during 2002 - 2018 was in 2003 when 94 human cases were reported.

Humans and other mammals are dead-end host and contribute nothing to WNv transmission cycle. Dead-end hosts do not produce enough viremia to infect mosquito vectors but still may suffer disease after infection with WNv (Bessell et al, 2016). The clinical symptoms for humans infected with WNv can be mild illness (fever and headache), aseptic meningitis, and encephalitis that can potentially progress to coma or even death. Less than 1% of humans infected with WNv experience a neuroinvasive form of WNv illness. The economic impacts of WNv neuroinvasive disease may be as much as $225,000 for fatal infections and nonfatal human cases have a calculated cost of $136,839 per case (Florida Dept. of Health Guidebook [FDOH], 2014).

There are more than 80 mosquito species found in Florida. Many species, not all, are competent vectors of arboviruses. The genera *Culex* contain several competent vectors in Florida that are capable of transmitting St. Louis Encephalitis and WNv. *Cx. quinquefasciatus* (Say) and *Cx. nigripalpus* (Theobald) provide statewide distribution of competent West Nile virus vectors that breed in containers, flood pools, and wetland areas (Moore & Mitchell, 1997; Zyzak, Loyless, Cope, Wooster, & Day, 2002; Blackmore et al., 2003).

Atlantic tropical storm are annual occurrences during the summer and fall months. The Atlantic tropical storm that reach land can produce devastating weather-related natural disasters in the form destructive cyclonic winds, frequent and intense periods of precipitation, costal storm surge, flooding conditions and sporadic tornadoes (NOAA: National Hurricane Center, 2017). Atlantic tropical storm systems can cause public health problems with storm-related injuries and mortality, risks of infectious disease exposure, temporary displacement, and homelessness. Healthcare infrastructure impairment by landfall Atlantic tropical storm may lead to potential disruption with public health services for a period. Environmental impacts of landfall Atlantic tropical storm systems can result in substantial alterations to natural ecosystems with fell trees and flooding from precipitation (Harris et al., 2014).

Florida presents a unique situation of competent mosquito vectors found through the state. The climate conditions of Florida are warm and ideal for year around mosquito activity and a destination that is essential for avian migrations. *Culex* mosquitoes and avian reservoir hosts maintain the enzootic cycle of WNv. Florida's warm climate is attractive to humans that move to the state annually and recreate year-round. According the US Census Bureau (2018), "since WNv was introduced to Florida in 2001, the state's population increased almost 30 percent." The warm Florida climate also subjects the state to occasional Atlantic tropical storm annually during the months of June through

November. Atlantic tropical storms that make landfall bring higher precipitation, high winds, and changes in temperature and humidity to the state of Florida. A combination of increasing human populations, annual avian migrations to Florida, presence of ornithophilic and anthropophilic mosquitoes, and warm seasonal weather patterns exacerbated by landfall Atlantic tropical storm systems have the potential of increasing locally acquired human cases of WNv diseases (Rappole, Derrickson, & Hubálek, 2000).

Presently, literature suggest not enough is known about mosquito-borne disease transmission and their association with landfall Atlantic tropical storms beyond individual storm observations that has resulted in conflicting opinions (Guzman-Tapia et al., 2005). In addition, the association between weather variables and West Nile virus is lacking research beyond individual tropical storm events (Caillouët et al., 2008).

Purpose of the Study

The purpose of this retrospective ecological study will be to investigate the association between Atlantic tropical storms that make landfall and the incidence of human cases of locally acquired WNv illnesses in Florida. Guzman-Tapia et al. (2005), recommended research contributions studying the relationship of landfall Atlantic tropical storm systems and mosquito-borne viral diseases and their associations. The findings from the study may provide support with post-Atlantic tropical storm mosquito control response and provide evidence needed to develop improvements for living and working in areas impacted by landfall Atlantic tropical storms. The results of this study may also contribute additional information with predicting outbreaks of mosquito-borne viral diseases. This study can also provide information that may determine if there is an association between landfall Atlantic tropical storms and incidence of local human cases of WNv in Florida.

Research Questions

This study will seek to determine if there is an association between landfall Atlantic tropical storm systems and incidence of local human cases of mosquito borne WNv illnesses in Florida. This study will analyze data from locally acquired human cases of WNv diseases reported to the Florida Department of Health and landfall Atlantic tropical storms from 2002–2018.

Research Question1: Is there an association between Florida landfall Atlantic tropical storm precipitation and human cases of locally acquired mosquito-borne West Nile viral disease occurring from 2002 through 2018?

$H_0$1: There is no association between Florida landfall Atlantic tropical storm precipitation and human cases of locally acquired mosquito-borne West Nile viral disease occurring from 2002 through 2018.

$H_1$1: There is an association between Florida landfall Atlantic tropical storm precipitation and human cases of locally acquired mosquito-borne West Nile viral disease occurring from 2002 through 2018.

Research Question 2: Is there an association between Florida landfall Atlantic tropical storm temperature and human cases of locally acquired mosquito-borne West Nile viral disease occurring from 2002 through 2018?

$H_0$2: There is no association between Florida landfall Atlantic tropical storm temperature and human cases of locally acquired mosquito-borne West Nile viral disease occurring from 2002 through 2018.

$H_1$2: There is an association between Florida landfall Atlantic tropical storm temperature and human cases of locally acquired mosquito-borne West Nile viral disease occurring from 2002 through 2018?

Research Question 3: Is there an association between Florida landfall Atlantic tropical storm precipitation and temperature and the incidence of human cases of mosquito-borne West Nile viral disease from 2002 through 2018?

$H_0$3: There is no association between Florida landfall Atlantic tropical storm precipitation and temperature and the incidence of human cases of mosquito-borne West Nile viral disease from 2002 through 2018.

$H_1$3: There is an association between Florida landfall Atlantic tropical storm precipitation and temperature and the of human cases of mosquito-borne West Nile viral disease from 2002 through 2018

Research Question 4: Is there an association between areas not affected by landfall Atlantic tropical storm occurring from 2002 through 2018 in Florida and human cases of locally acquired mosquito-borne West Nile viral disease?

$H_0$4: There is no association between areas not affected by landfall Atlantic tropical storm occurring from 2002 through 2018 in Florida and human cases of locally acquired mosquito-borne West Nile viral disease.

$H_1 4$: There is an association between areas not affected by landfall Atlantic tropical storm occurring from 2002 through 2018 in Florida and human cases of locally acquired mosquito-borne West Nile viral disease.

The independent variables are weather variables precipitation and temperature associated with landfall Atlantic tropical storms and landfall Atlantic tropical storm, which were continuous variables. The dependent variable is the incidence of locally acquired human cases of WNv in Florida.

Conceptual Foundation

This study uses the epidemiological triad theory that consists of three components: agent, host, and environment. Uzoigwe, Khaitsa & Gibbs (2007), used the epidemiology triad theory in their study and described the agent as a component of causation in conjunction with the host and environment. Moreover, Uzoigwe et al. (2007) implied that all components, agent, host, and environment, are equally important in disease causation. In the event one of the components change, it would cause change in the frequency of disease. According to Egger and Swinburn (1997), the epidemiology triad theory is applicable for infectious or non-infectious diseases. In this study, the epidemiology triad theory is suitable to study the relationship of landfall Atlantic tropical storms and the incidence of human cases of mosquito borne WNv illnesses from 2002 through 2018 in Florida.

Mosquito-borne WNv illnesses will represent (agent), humans the (host), and landfall Atlantic tropical storms ability to affect the environment in various ways as (environment) (Figure 1). In a study by Gage, Burkot, Eisen, and Hayes (2008), researchers studied how the climate variables of precipitation, temperature, and humidity affected vector-borne disease in humans. The researchers compared vector reproduction, development, behavior, and population dynamics. Their study found enough evidence that suggests climate variables can affect all phases of arthropod vector behavior and their ability to transmit pathogens. In this study, a retrospective ecological study approach is based on the epidemiology triad theory.

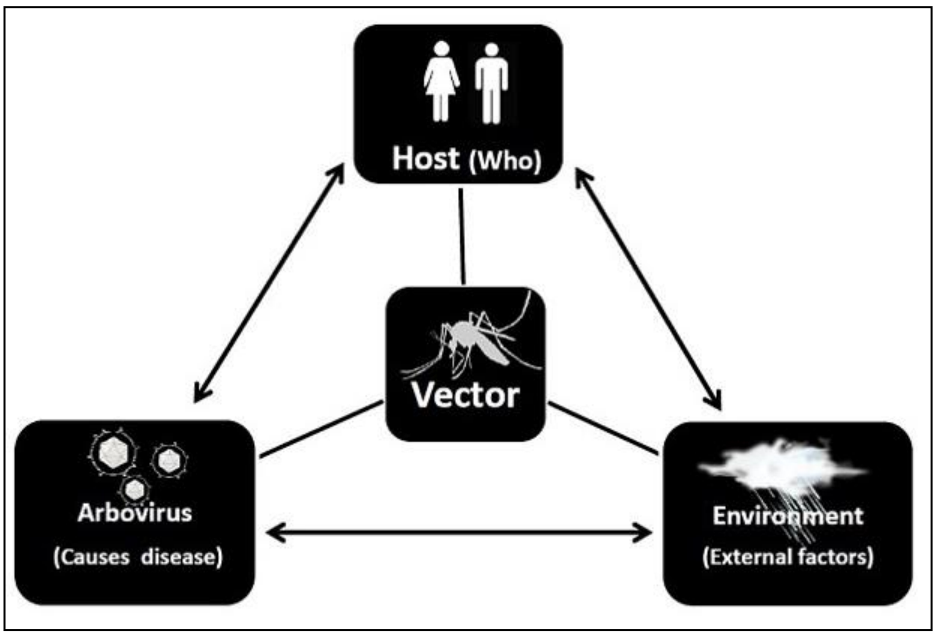

Figure 1. Classical epidemiological triangle. From Epidemiology, Population Health, and Health Impact Assessment by Gulis & Fujino (2015) retrieved May 16, 2018. Diagram created from literature by Jackson Mosley

Nature of Study

This study will be retrospective and will use a quantitative ecological approach to study the association between landfall Atlantic tropical storm, its weather variables precipitation and temperature, and locally acquired human cases of mosquito borne WNv diseases in Florida. Ecological studies are study designs in which at least one variable, either an exposure or the outcome, is measured at the population level. Ecological studies are useful when studying disease patterns and environmental factors (Barr, Taylor-Robinson, Stuckler, Loopstra, Reeves, & Whitehead, 2016).

Operational Definitions

The following operational definitions are important in this study.

Anautogenous: refers to female mosquitoes need to ingest proteinaceous blood from a host to produce eggs (Tsuji, Okazawa, & Yamamura, 1990).

Anthropophilic: describes mosquitoes that exhibit a preference or seek humans as host rather than other animals (Andrianaivolamboa, Olivier, Milijaona, Ratovonjatoa, Le Goffa, Talmana & Vincent, 2010)

Hurricane season: refers to the seasonal period that occurs each year from June 1 through November 30. Most tropical storms are predicted to develop during this time as climate patterns favor tropical disturbance over warm ocean waters (NOAA, 2018).

Dead-end host: refers to a host that is not crucial to the virus life cycle and cannot transmit disease (Weaver & Reisen, 2010).

Extrinsic incubation period (EIP): refers to the time from when a mosquito acquires an infectious agent and its ability to transmit the infectious agent to a susceptible vertebrate host (Tjaden, Thomas, Fischer, & Beierkuhnlein, 2013)

Gonotrophic cycle: a process that begins after mating and involves a female mosquito's search for a host to ingest a blood meal followed by digestion of the blood meal. Maturation of ovaries occurs after when the female mosquito takes a blood meal.

Subsequent search for oviposition sites that leads to laying mature eggs to complete the gonotrophic cycle (Klowden & Briege, 1994).

Hematophagous: refers to arthropod vectors such as mosquitoes and other biting flies and ticks that feed on blood (Weaver and Reisen, 2010).

Locally acquired disease: A disease originating in the place in which it was found; in the study, it refers to as mosquito-borne viral encephalitis diseases acquired in Florida (Venturi, G., Zammarchi, L., Fortuna, C., Remoli, M.E., Benedetti, E., Fiorentini, C., … Bartoloni A, 2016).

Ornithophilic: describes mosquitoes that exhibit a preference to feed on birds rather than other animals (Andrianaivolamboa et al, 2010).

Peridomestic niche: pertains to mosquitoes that have adapted to living near human habitations. (Mendenhall, Moorthy, Lee & Low 2017).

Pestiferous: mosquito species capable of vectoring pathogenic organisms (Rueda, 2008).

Phytotelmata: structures formed by non-aquatic plants that impound water, such as modified leaves, leaf axils, flowers, stem holes or depressions, open fruits and fallen leaves that can be used as part of a mosquito life cycle (University of Florida, 2000).

Precipitation: in this study will refer to rainfall (NOAA, 2017)

The Saffir-Simpson Hurricane Wind Scale: is a numerical rating system that uses categories1 to 5 to classify wind intensity of hurricanes. Hurricanes categorized as two or greater are major hurricanes as the resulting damage is more likely to be significant (NHC- Saffir-Simpson Hurricane Wind Scale, n.d.).

Assumptions

This study will investigate whether there is an association between incidence of locally acquired human cases of mosquito borne WNv and landfall Atlantic tropical storm. The following assumptions were taken into consideration for the study.

Atlantic tropical storm systems data collected by NOAA are accurate and consistent with the weather events occurring from 2002 through 2018. This assumption is significant because the study will use specific information on precipitation, temperature, and landfall track of Atlantic tropical storm.

All human cases of WNv disease data reported to Florida Department of Health are accurately and consistently collected WNv disease information. This assumption is suitable for the study since the incidence of locally acquired human cases of WNv association with landfall Atlantic tropical storm are an important port of the study.

Study populations consist of the residents in the state of Florida. This population will be at risk of exposure to WNv and landfall Atlantic tropical storm systems. This assumption is essential to the citizens of Florida from which the study will draw its conclusions.

Scope and Delimitations

The focus of this research will investigate landfall Atlantic tropical storm systems and their association with incidence of human cases of locally acquired WNv disease in Florida from 2002 through 2018.

The research is limited to Florida residents and does not cover populations outside the state of Florida. The study does not consider thunderstorm or other storm related events that typically occur during Florida's rainy season. Irregular weather events can influence weather patterns in southern United States. El Nino/La Nina typically affect precipitation and temperature patterns in Florida (NOAA: National Ocean Service, 2020). Neither El Nino nor La Nina weather patterns are used in this study. Atlantic tropical storms that do not make landfall in the state of Florida will not be included in this study.

This study is limited to endemic cases of mosquito borne WNv disease acquired in Florida and not all other reportable mosquito-borne diseases data was not included in the study.

Limitations

Tropical storm season starts June 1 and ends November 30 lasting 6 months annually. This study will investigate mosquito borne WNv illnesses association with landfall Atlantic tropical storm systems therefore limiting the observation period to the 6-month Atlantic tropical storm season.

Mosquito borne viruses are present throughout the year in most areas in Florida. A widely used surveillance method by mosquito control programs in Florida are sentinel chickens, which monitor mosquito borne disease activity year-round (FDOH, 2014). Sentinel chicken surveillance may be a useful predictor for WNv activity and predict outbreaks of human cases. This study focused on locally acquired human cases of WNv and did not include positive sentinel chicken surveillance data (Blackmore et al., 2003).

Significance of the Study

By providing knowledge on the association of human cases of mosquito borne WNv illnesses and landfall Atlantic tropical storm in Florida, this study may increase awareness of how this association will affect community health in the aftermath of landfall Atlantic tropical storms. According to Guzman-Tapia et al. (2005), studies of this nature are necessary for building knowledge and evidence of mosquito borne diseases and their association with landfall Atlantic tropical storm systems.

The social change implications of this study will extend beyond adding to the body of knowledge, it will also contribute to a better understanding of the association of human cases of WNv and Atlantic tropical storm that make landfall in Florida. The residents of Florida must contend annually with the potential impacts from Atlantic tropical storm systems, high populations of mosquitoes, and the presence of virulent host capable of transmitting viral diseases to mosquitoes. Results from this study will provide knowledge and support for better preparedness for residents as a protection against mosquito borne WNv diseases following landfall Atlantic tropical storm systems. The information can be applicable to mosquito control agencies, Florida residents, public health officials, and first responders when assisting residents before and after Atlantic tropical storm systems make landfall.

Chapter 2: Literature Review

Introduction

I will discuss in this chapter the search strategies used to conduct the literature review. This section reviews and discusses research on mosquito borne WNv and its association with landfall Atlantic tropical storm systems in Florida. Literature was collected reviewed covering *Culex* mosquito vectors and their role in Mosquito-borne WNv disease transmission in Florida. Landfall Atlantic tropical storm systems and their impact on mosquito ecology in relation to their breeding and vector competence.

In the case of mosquito borne WNv diseases, *Culex* mosquitoes are important vectors whose breeding and vector competence depends on many ecological factors. *Culex* mosquito vectors in Florida and their importance are discussed in this chapter. The Florida Department of Health reportable arboviruses are discussed with respect to their epidemiology and data collected on the incidence of human cases of locally acquired mosquito borne WNv diseases in Florida.

Literature Search Strategy

The search strategy for this literature review involved the strategic identification and use of applicable search terms. Relevant literature and articles for 'mosquito biology' section used the search terms: *Culex, Culex nigripalpus, Culex quinquefasciatus, Culex pipiens, Culex salinarius, and Culex erraticus.* In Florida, *Culex* species are the primary vectors of WNv. To search the literature for the Mosquito borne West Nile viral diseases the search terms included *Flavivirus,* West Nile Virus, West Nile encephalitis, and West Nile encephalomyelitis. Terms that facilitated the search of literature on the association of landfall Atlantic tropical storm system with mosquito-borne viral diseases include 'Florida hurricanes', 'Florida tropical storms' and hurricanes and Mosquito borne viral diseases in Florida. Other key search terms included mosquito vectors in Florida, Florida arboviruses, arboviruses, Florida hurricanes and landfall tropical storms, Florida mosquito species, epidemiology theories, and epidemiological triad theory.

To find relevant literature on the research topics, electronic databases were primarily from the search engines Google Scholar and EBSCO to obtain literature from research journals. Journals reviewed included BioOne, PLoS, PubMed, and Medline. Other online journals accessed for this study include Journal of Medical Entomology, American Journal of Preventive Medicine, CDCs Emerging Infectious Diseases and the journals Insects and Viruses. Additional electronic journals sources included the Journal of Vector Ecology, Journal of the American Mosquito Control Association, Florida Mosquito Control Association and American Journal of Tropical Medical Hygiene. The search strategy also included the criteria for the date of journal publication and targeted date range used was 2000-2020. There were a few exceptions to note, a paper related to information on mosquito gonotrophic cycle, published in 1994. A paper published 1990 by Tsuji, Okazawa, & Yamamura, discussed autogenous and anautogenous mosquito's reproductive strategies. N.A research paper from 1998 focusing on the relationship of Natural Disasters and the vector-borne disease surveillance, Egger and Swinburn (1997) provided supporting information on the epidemiology triad theory and a paper published in 1996 discussing the advantages and disadvantages of secondary data sources. The search strategy provided more than 70 scholarly and academic papers for potential use in the research.

Mosquito Biology

Most species of female mosquitoes in Florida are anautogenous, meaning they require a blood meal for egg production and development. Mosquito life cycle requires complete metamorphosis with four distinct stages, an egg, four stage larva development, pupa and adult (Figure 2). All mosquitoes require water to develop from egg to adult. Aquatic habitats commonly used by mosquitoes are ephemeral pools, edge of lakes and ponds with stagnant vegetation, sluggish swamps and ditches or fields that flood. Some mosquito species breed in containers, tree holes, and phytotelmata (e.g. bromeliads) environments (FMEL, 2017).

Humans haphazardly create ideal environments that provide water sources and a range of receptacles capable of holding water (CDC, 2018). A few species of mosquitoes have evolved a peridomestic niche living close to humans. *Aedes albopictus* (Skuse) and *Aedes aegypti* (L) have expanded their range in North America as peridomestic species. Both *Aedes* species are anthropophilic in their host seeking behavior and adapted to feeding on humans (CDC, 2018). Peridomestic behavior to lesser degree has also been observed with Florida West Nile vectors *Culex nigripalpus* (Theobald) and *Culex quinquefasciatus* (Say), both observed breeding in similar containers as peridomestic *Aedes* species described above (Personal observation).

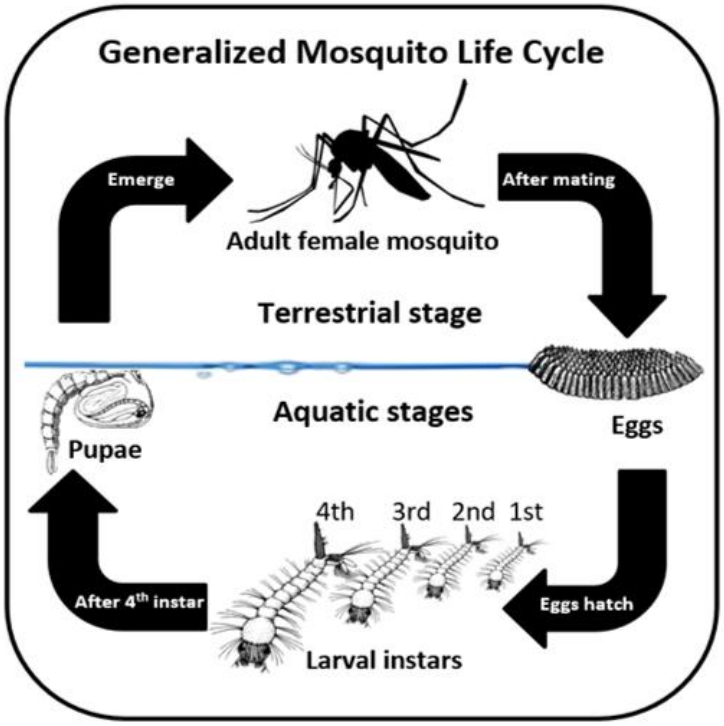

Figure 2. General Mosquito Life Cycle. From "Life Cycle" by American Mosquito Control Assoc. retrieved October 11, 2018. Diagram designed by Jackson Mosley from literature.

Mosquitoes and Weather

Precipitation is the single most important environmental factor affecting arboviral transmission cycles. Rainfall provides the land with surface wetness that supports standing water and directly influence mosquito reproduction with an abundance of suitable oviposition sites. Rainfall and associated surface humidity prevent desiccation and increase the flight range of host seeking mosquitoes requiring a blood source for egg production (Gage et al., 2008).

Temperature can greatly influence arbovirus transmission cycles. Extrinsic incubation period (EIP) is temperature-dependent and small variations in daily ambient temperature can affect the overall EIP of infected female mosquitoes. Reduction of the

EIP may increase the probability that mosquitoes will survive to become infective and transmit a virus while blood feeding on a susceptible host. Environmental temperatures may also benefit nesting behavior of avian species and improve their reproductive success (Ruiz, Chaves, Hamer, Sun, Brown, Walker… & Kitron, 2010).

Collectively precipitation and temperature directly or indirectly affect other factors that impact arbovirus transmission cycles. Humidity and drought conditions are factors related to levels of precipitation and temperature (Appendix 1). Ultimately, these factors can affect landscape features, host behavior, host availability, and vector behavior (J. Day, personal communication, February 6, 2020)

Mosquito borne West Nile virus

Viruses are minute pathogenic organisms that require a host to complete their life cycle (Müller et al., 2010). Mosquito borne viral diseases are arboviruses transmitted specifically by mosquitoes. Some viruses transmitted by mosquitoes can cause epidemic cases of encephalitis, an inflammation of the brain and encephalomyelitis, an inflammation of the brain and spinal cord in susceptible vertebrate host. Epidemics caused by mosquito borne viral diseases can cause financial burden on local economies through healthcare costs associated with human infections (Harris et al., 2014). There are four important factors associated with mosquito borne viral diseases transmission cycles. According to Blackmore et al. (2003) and Moore and Mitchell (1997), the factors that drive mosquito borne viral diseases transmission involve annual occurrence of pathogen cycles, mosquito vectors, amplification reservoir, infected secondary hosts and the biological factors which are driven by environmental influences.

West Nile virus (family *Flaviviridae*, genus *Flavivirus*) is a member of the Japanese encephalitis virus complex (Vitek et al., 2008). WNv is maintained in a bird-mosquito-bird transmission cycle. Despite documenting over 60 different species of mosquitoes capable of being infected with WNv and well over 300 species of birds, effective WNv transmission cycle in nature is attributed to just a few species of *Culex* mosquitoes. Most human cases of WNv infections are caused by the bite of an infected mosquito. Other less common modes of WNv transmission are organ transplant, transfused platelets, red blood cells, or via fresh frozen plasma (Petersen, Brault, & Nasci, 2018).

In Florida per rule 64-D3 (F.S. 381.0031; FAC 64D-3), WNv is a reportable human disease handled by County level Health departments. Reportable cases of human disease are sent to the Florida Department of Health Bureau of Epidemiology for analysis and data distribution (FDOH, 2014).

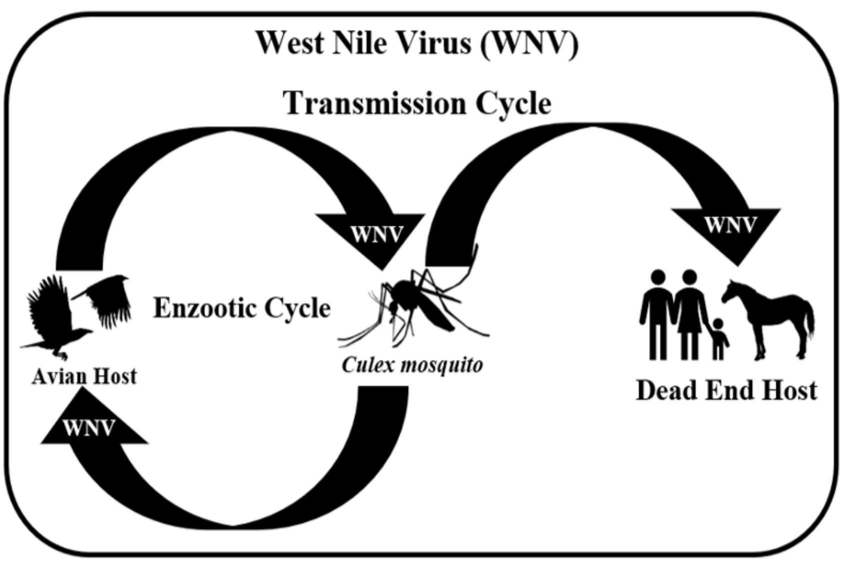

Figure 3. West Nile virus transmission cycle. From "WNV Transmission" by CDC retrieved October 12, 2018. Diagram designed by Jackson Mosley from literature.

Arboviral Surveillance

Florida Department of Health (FDOH) monitors for mosquito-borne virus activity through surveillance with sentinel chickens, mosquito pool testing and veterinary and physician reports (FDOH, 2014).

Sentinel chicken serosurveillance technique uses sentinel chicken flocks distributed throughout Florida in almost half of the 67 counties in Florida. When sentinel chickens receive a bite from an infected mosquito and transmission occurs, sentinel chickens do not become infected; but instead produce antibodies specific to the virus of which they were exposed. The use of sentinel chicken flocks are the most widely used animal surveillance method. Sentinel chicken flocks are tested for St. Louis Encephalitis virus, WNv, and Eastern Equine Encephalitis virus. Florida monitors arbovirus disease activity using sentinel chickens to provide critical information about arbovirus activity (Blackmore et al. 2003). Blackmore et al. (2003) reported that almost all human cases of West Nile virus they studied preceded sentinel chicken seroconversions. This suggest to some degree that sentinel chicken surveillance could be a beneficial predictor of mosquito-borne viral disease activity.

Viral Assay of Mosquito samples (Mosquito pools) are screened in a molecular assay (RT-PCR) for Mosquito-borne viral diseases. Mosquito pool samples are inoculated onto cell cultures to isolate for specific Mosquito-borne viral diseases. Detected isolates can be identified using multiple primer sets and probes (FDOH, 2014).

Atlantic Tropical Storm Systems

Atlantic tropical storm systems occur annually in the North Atlantic Ocean, Caribbean Sea, and Gulf of Mexico. Most Atlantic tropical storm system formation starts from atmospheric easterly African waves that travel westward across the tropical North Atlantic and Caribbean Sea (NOAA, 2018) (figure 4). In Florida, Atlantic tropical storm system season (aka hurricane season) begins annually from June 1 and lasts through November 30 (NOAA, 2018). According to Goldenberg, Landsea, Mestas-Nunez & Gray (2002), the peak period for Atlantic tropical storms is August-September-October when most major hurricanes form. Atlantic tropical storm systems differ significantly in their intensity and wind speed; and based on this, are categorized numerically (Simiu, Vickery, & Kareem, 2007; Englehart & Douglas 2001).

Tropical depressions are Atlantic tropical storm systems with winds less than 61 km (38 mph). Atlantic tropical storm systems with winds of 62 km to 117 km (39 to 73 mph) are classified as tropical storms. Atlantic tropical storm systems with winds 118 km (74 mph) or higher are classified as hurricanes which are then classified based on their wind speed to determine what destruction or property damage the storm will cause should landfall occur (NOAA, 2018).

The Saffir-Simpson Hurricane Wind Scale (Table 1) is a numerical rating system developed in 1969 that uses categories 1 to 5 to classify wind intensity and predict damage potential of hurricanes. Hurricanes greater than a category 2 are classified as major hurricanes and have the potential to cause significant damage (Simiu et al. 2007; NHC- Saffir-Simpson Hurricane Wind Scale, n.d.).

Table 1

Saffir-Simpson Hurricane Wind Scale

Categories	Sustained Winds
Category 1	Winds of 119 km to 153 km
Category 2	Winds of 154 km to 177 km
Category 3	Winds of 178 km to 207 km (Major)
Category 4	Winds of 208 km to 251 km (Major)
Category 5	Winds of 252 km or greater (Major)

Note. From "Saffir-Simpson Hurricane Wind Scale" NOAA Hurricane Center, n.d. Diagram designed by Jackson Mosley from literature.

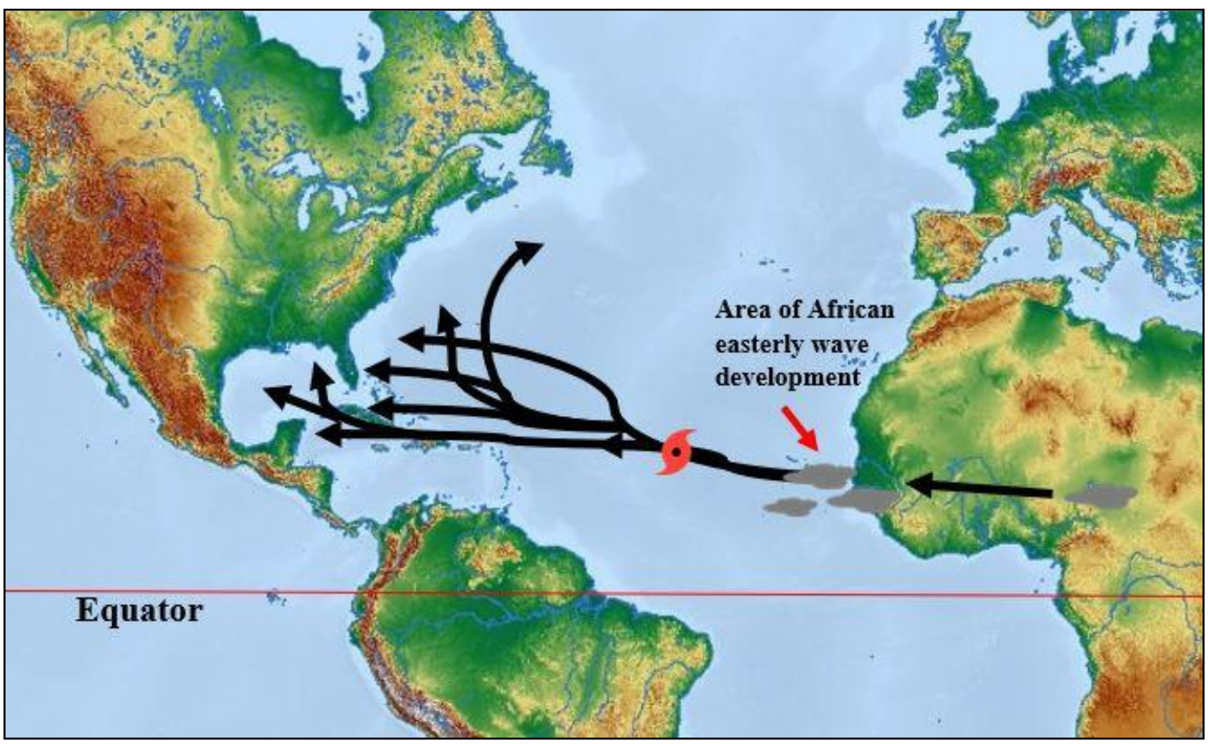

Figure 4. North Atlantic hurricane potential paths after development from African easterly waves. Map created with public domain and free for all to use images and Microsoft Word editing resources. Information from NOAA Hurricane Center (2018).

Summary and Conclusion

In this chapter, the relevant literature reviewed improved knowledge of the topic with more applicable information and scholarly research. The literature review addressed general biological knowledge about vector mosquitoes in Florida. The different diseases caused by West Nile virus was discussed.

The literature reviewed in this chapter-included discussion on the current methods used in arbovirus surveillance, an important part of managing mosquito borne viruses and protecting the public. Thereafter a description of Atlantic tropical storms systems is given with comprehensive information of tropical storm systems and their relationship with mosquito borne WNv disease in Florida.

Chapter 3: Research Method

Introduction

The purpose of this retrospective ecological study is to determine if there is an association with annual landfall Atlantic tropical storms that occur in Florida and their climatic variables (temperature and precipitation) with locally acquired human cases of mosquito borne WNv diseases.

The main segments of this chapter will address the study's research design and rationale, methodology, and threats to validity. A summary of the topics discussed will conclude the chapter. The research design and rationale section will discuss information regarding the study design and both dependent variable and independent variables. The methodology section contains information regarding secondary data, the data analysis plan, target population, sampling procedures, and instrumentation and materials. Ethical considerations of the study provided in the reliability and validity of the data section

Research Design and Rationale

The research design and rationale section will discuss information regarding the study population, sampling procedures, use of secondary data, materials, definition and measure of specific variables, and data analysis plan to be used in the study.

The study used a retrospective ecological study design considering the independent variables are ecological and dependent variable is at the population level. Locally acquired mosquito borne WNv disease data for the study consisted solely of freely available secondary data collected previously by the Florida Department of Health.

Sources for climate data; temperature and precipitation, was obtained from the Midwestern Regional Climate Center (MRCC) and NOAA's National Centers for Environmental Information (NCEI). NECI collects climate data from individual weather stations distributed across Florida. MRCC provides no cost access to NECI weather data.

The study used locally acquired mosquito borne WNv disease data during hurricane seasons (June 1 to November 30) annually, 2002 through 2018 from the Florida Department of Health website for reportable mosquito borne diseases transmitted in Florida.

Methodology

The methodology section will present information regarding the population, sampling and sampling procedures, secondary data, instrumentation, materials, operationalization of variables, and data analysis plan.

Population

The study population for this ecological study are people residing in the state of Florida from which the study will draw its conclusions. The dependent population are from Florida Counties that have confirmed locally acquired human cases of WNv. Florida’s total population during the study period ranges from an estimated 15,982,378 in 2002 census data to over an estimated 21,299,325 people in 2018 (US Census Data, 2018). Florida consist of several major cities and has significant rural populations distributed throughout state.

Secondary Data

This study used secondary climate data obtained from MRCC, a cooperative program between the NOAA's National Centers for Environmental Information (NCEI) headquarters are in Asheville, North Carolina and Regional Climatic Centers. Climate data obtained from MRCC included precipitation and temperature for the period 2002 to 2018. The NCEI records climate data from approximately 1,600 long-term weather stations distributed across the United States. The study used historical precipitation and temperature data from weather stations located in Florida (NCEI, 2018; MRCC, 2018).

The Florida Department of Health collects and maintains reportable arbovirus data and shares this information with CDC ArboNET (FDOH, 2014). Data for human locally acquired mosquito borne WNv disease from Florida Department of Health was used in this study. All data sources used for this study are open access to the public and did not require special permission.

Sampling Procedures

Data used for landfall Atlantic tropical storm systems was acquired from NOAA Hurricane website. The data included the date each Atlantic tropical storm made landfall in Florida and the departure date for each Atlantic tropical storm system. The NOAA Hurricane website provided the official tropical storm system track across Florida. This information was used to differentiate which counties were considered as affected by landfall tropical storms from those counties determined as not affected by tropical storms making landfall.

The official tropical storm system track in Florida obtained from NOAA Hurricane website was applied to a county map of Florida with a 500-km scale bar (Figure 4). The scale bar was centered on the tropical storm system track. I selected all counties within the swath of the scale bar as counties directly affected by the landfall tropical storm as it travels across the state. All counties outside the 500-km swath scale bar, 250 km on each side of the center of the LFTS track, was recorded as not affected by the landfall tropical storm system. I determined the appropriate swath based on a study by Englehart and Douglas (2002) who suggest that rainfall produced from tropical storm systems when making landfall occurs within 600 km from the eye wall. Englehart and Douglas (2002) selected 500km rain field for their study. According to Buckley 2011, scale bars are used to measure the distance on a map. Maps with scale bars can be enlarged or reduced, scale bars that also change in direct proportion to the map will remain applicable for that specific map. Their work provided me with information that supported my study sampling method.

All confirmed locally acquired human cases of mosquito borne WNv diseases were counted starting two weeks and lasting thirty days after the tropical storm system exited Florida. In the unaffected counties, those counties outside the 500km swath all reported human locally acquired mosquito borne WNv diseases cases, were not counted as landfall tropical storm cases.

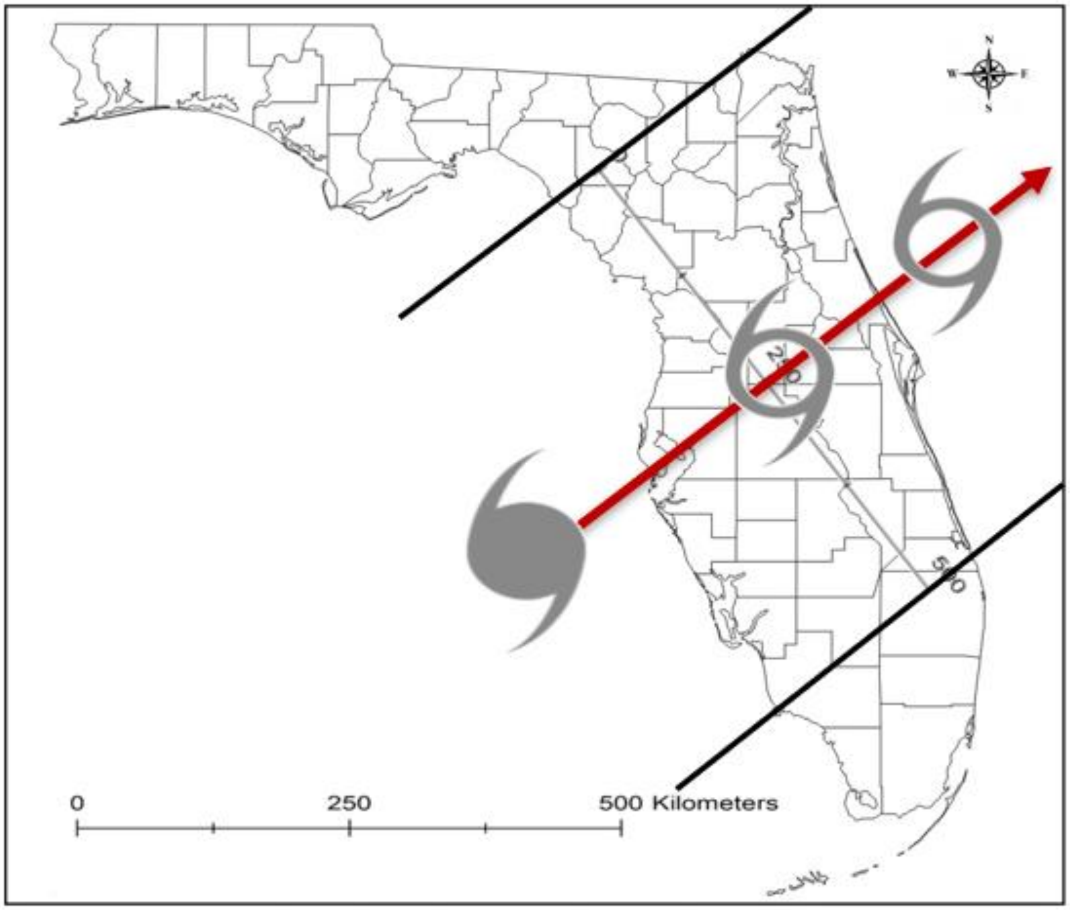

Figure 5. Florida map with 500km determining counties affected by landfall tropical storms.

Instrumentation and Materials

Mosquito borne WNv is a reportable disease in Florida and the United States. Cases of mosquito borne WNv diseases are confirmed by licensed practitioners or physicians and laboratories who are required to notify the Florida Department of Health (Department) of diseases and conditions of public health significance under section 381.0031, Florida Statutes, and Chapter 64D-3, FAC (FDOH, 2018).

NOAA's National Centers for Environmental Information (NECI) was developed from consolidation of three National Data Centers: The National Climate Data Center, the National Geophysical Data Center, and the National Oceanographic Data Center. The Consolidated and Further Continuing Appropriations Act, 2015, Public Law 113-235 was approved to meet the demand for high-value environmental data and information. NCEI objective is transparency to its users and commitment to continuing to provide the geophysical, oceans, coastal, weather and climate data users have come to depend on (NECI, 2016).

NECI land-based weather observations are collected from instruments sited at more than 650 locations across the state of Florida. NECI land-based weather stations monitor temperature, dew point, relative humidity, precipitation, wind speed and direction, visibility, atmospheric pressure, and types of weather occurrences such as hail, fog, and thunder (NECI, 2016).

Reliability and Validity of the Data Compiled by FODH

Merlin system. The Merlin system serves as Florida's repository for reportable diseases and provides automated notification to staff on individual cases of high-priority diseases. Florida's Communicable Disease Frequency Reports can also offer access to the data collected in Merlin. The Merlin system is important to disease management and control in Florida (FDOH, 2014).

All practitioners, hospitals, and laboratories in Florida are required to notify the Florida Department of Health (Department) of diseases and conditions of public health significance under section 381.0031, Florida Statutes, and Chapter 64D-3, Florida Administrative Code effective October 20, 2016 (FDOH, 2014).

Reportable disease and conditions. The Florida Department of Health requires all practitioners to report certain diseases of urgent public health importance upon initial clinical suspicion of the disease prior to confirmatory diagnosis. In cases involving diseases warranting notification upon suspicion (termed suspect immediately) there is a 24 hour a day, seven days a week access for reporting to allow necessary public health response to be initiated in a timely and effective manner. Practitioners are also responsible for providing all necessary information for the laboratories to fulfill laboratory notification requirements (FDOH, 2014).

Reliability and Validity of the Data Compiled by NOAA.

NAO 202-735D: Scientific integrity. Effective December 07, 2011, NAO 202-735 D: Scientific Integrity Administrative Order sets out to promote a continuing culture of scientific excellence and integrity while establishing a policy on the integrity of scientific events conducted by the agency to inform management and impact policy decisions (NOAA, 2011).

In addition, the intent of NAO 202-735 D: Scientific Integrity is to strengthen stakeholder confidence across the spectrum for scientists, decision-makers, and the public on the quality, validity, and reliability of NOAA science. An equal mission of the order is to represent the agency's commitment to a culture of support for excellence of NOAA's principal science asset, its employees (NOAA, 2011).

Study Variables

The study selected variables in this section based on research questions, literature review, and obtainable secondary data sets (Table 3).

Dependent variable. The study dependent variable is the incidence of human cases of locally acquired mosquito borne West Nile viral diseases in Florida. The variable is a continuous variable with the number of human cases of locally acquired mosquito borne WNv disease for each hurricane season, June 1 through November 30 annually from 2002 through 2018. The study did not use data outside the hurricane season.

Independent variables. The study independent variables are precipitation and temperature associated with Atlantic tropical storm systems that make landfall in Florida during each annual hurricane season, June 1 through November 30, from 2002 through 2018.

Precipitation: refers to the rain that falls to the earth's surface, measured by inches. The precipitation dataset will include monthly total precipitation. This variable will be used as a continuous variable and the dataset will include 18 years of monthly values accumulated during annual hurricane seasons from 2002 through 2018.

Temperature: refers to the numerical measure of detection of heat.

Landfall Atlantic tropical storm systems: refers to low-pressure weather systems that rotate counterclockwise and make landfall in Florida. Atlantic tropical storm systems may development in the warm oceanic waters of the Atlantic, Caribbean Sea, and Gulf of Mexico (Shultz, Russell & Espinel, 2005).

Data Analysis

General Information: In this study, descriptive statistics and a linear regression were used in the statistical software IBM SPSS, version 25. A linear regression was applied for dependent variable using the rate of local acquired human cases of WNv per

100,000 population for each landfall tropical storm. Statistical analysis was conducted using a significance level of $p < .05$ and 95% confidence interval.

Precipitation and temperature data were downloaded from NOAA/NECI and Midwestern Regional Climate Center (MRCC) in Microsoft Excel format from land-based weather stations located in Florida. MRCC provided climate division data for Florida. Locally acquired human cases of WNv were retrieved from the Florida Department of Health arbovirus web site.

Research questions and hypotheses. The research questions and hypotheses of the study are the following:

Research Question 1: Is there an association between Florida landfall tropical storm systems precipitation and human cases of locally acquired mosquito-borne West Nile viral disease occurring from 2002 through 2018?

$H_0$1: There is no association between Florida landfall tropical storm system precipitation and human cases of locally acquired mosquito-borne West Nile viral disease occurring from 2002 through 2018.

$H_1$1: There is an association between Florida landfall tropical storm system precipitation and human cases of locally acquired mosquito-borne West Nile viral disease occurring from 2002 through 2018.

Research Question 2: Is there an association between Florida landfall tropical storm temperature and human cases of locally acquired mosquito-borne West Nile viral disease occurring from 2002 through 2018?

$H_0$2: There is no association between Florida landfall tropical storm system temperature and human cases of locally acquired mosquito-borne West Nile viral disease occurring from 2002 through 2018.

$H_1$2: There is an association between Florida landfall tropical storm system temperature and human cases of locally acquired mosquito-borne West Nile viral disease occurring from 2002 through 2018?

Research Question 3: Is there an association between Florida landfall tropical storm precipitation, temperature, and the incidence of human cases of mosquito-borne West Nile viral disease from 2002 through 2018?

$H_0$3: There is no association between Florida landfall Atlantic tropical storm precipitation and temperature and the incidence of human cases of mosquito-borne West Nile viral disease from 2002 through 2018.

$H_1$3: There is an association between Florida landfall Atlantic tropical storm precipitation and temperature and the incidence of human cases of mosquito-borne West Nile viral disease from 2002 through 2018.

Research Question 4: Is there an association between areas not affected by landfall Atlantic tropical storm systems occurring from 2002 through 2018 in Florida and human cases of locally acquired mosquito-borne West Nile viral disease?

$H_0$4: There is no association between areas not affected by landfall tropical storm systems occurring from 2002 through 2018 in Florida and human cases of locally acquired mosquito-borne West Nile viral disease.

$H_1$4: There is an association between areas not affected by landfall tropical storm systems occurring from 2002 through 2018 in Florida and human cases of locally acquired mosquito borne WNv disease.

Table 2

Research Variables

Variable	Variable Type	Measure	Role in Analysis
Precipitation	Independent	Continuous	Predictor
Temperature	Independent	Continuous	Predictor
Human Cases of WNv	Dependent	Rate	Outcome

Threats to Validity

According to Creswell (2009), threats to internal validity can potentially affect the researcher's ability to draw accurate extrapolations from the data about the experimental population.

The study used mosquito borne WNv reportable data from 2002 through 2018. Potential threats to internal validity maybe instrumentation. Over time Florida Department of Health, mosquito borne disease diagnoses and reporting accuracy have improved. In response to landfall Atlantic tropical storms Florida Department of Health and Florida Department of Agriculture and Consumer Service Department of Entomology work closely with local mosquito control agencies to continually develop rapid response to control mosquito populations immediately following a landfall Atlantic tropical storm event. Other form of internal validity threats were not recognized as a concern for this study.

Ethical Procedures

A final version of the research study was submitted for approval from the Institutional Review Board (IRB) of Walden University. Approval was granted and the study was assigned approval number 5-29-15-0183973.

The study used secondary data for landfall tropical storms from NOAA hurricane center, precipitation and temperature data from NOAA/NCEI and MRCC, and local acquired human cases of WNv data from Florida Department of Health. No sensitive information was required from the study.

Chapter 4: Results

Introduction

The purpose of this quantitative ecological study was to identify if there is an association between landfall tropical storms (LTS) climatic variables precipitation and temperature and locally acquired human cases of WNv in Florida. The research questions and hypothesis of the study are as follows:

Research Question 1: Is there an association between Florida landfall tropical storm systems precipitation and human cases of locally acquired mosquito-borne West Nile viral disease occurring from 2002 through 2018?

$H_0$1: There is no association between Florida landfall tropical storm system precipitation and human cases of locally acquired mosquito-borne West Nile viral disease occurring from 2002 through 2018.

$H_1$1: There is an association between Florida landfall tropical storm system precipitation and human cases of locally acquired mosquito-borne West Nile viral disease occurring from 2002 through 2018.

Research Question 2: Is there an association between Florida landfall tropical storm system temperature and human cases of locally acquired mosquito-borne West Nile viral disease occurring from 2002 through 2018?

$H_0$2: There is no association between Florida landfall tropical storm system associated temperature and human cases of locally acquired mosquito-borne West Nile viral disease occurring from 2002 through 2018.

$H_1$2: There is an association between Florida landfall tropical storm system temperature and human cases of locally acquired mosquito-borne West Nile viral disease occurring from 2002 through 2018?

Research Question 3: Is there an association between Florida landfall tropical storm precipitation, temperature, and the incidence of human cases of mosquito-borne West Nile viral disease from 2002 through 2018?

$H_0$3: There is no association between Florida landfall tropical storm precipitation and temperature and the incidence of human cases of mosquito-borne West Nile viral disease from 2002 through 2018.

$H_1$3: There is an association between Florida landfall tropical storm precipitation and temperature and the incidence of human cases of mosquito-borne West Nile viral disease from 2002 through 2018

Research Question 4: Is there an association between areas not affected by landfall tropical storm systems occurring from 2002 through 2018 in Florida and human cases of locally acquired mosquito-borne West Nile viral disease?

$H_0$4: There is no association between areas not affected by landfall tropical storm systems occurring from 2002 through 2018 in Florida and human cases of locally acquired mosquito-borne West Nile viral disease.

$H_1$4: There is an association between areas not affected by landfall tropical storm systems occurring from 2002 through 2018 in Florida and human cases of locally acquired mosquito-borne West Nile viral disease.

This chapter presents information on the data collection process and the results of the study. The chapter includes descriptive analyses of the variables, evaluation of the statistical assumptions, and the findings of the linear regression and multiple linear regression analysis. The findings are described using the appropriate probability values and confidence intervals. The chapter ends with a summary of the findings of the study.

Data Collection

Walden University's Institutional Review Board approved data collection for the study and provided the approval number 06-19-19-0056146 to collect data on human cases of West Nile virus from the Florida Department of Health public accessible website.

The data consists of county level locally acquired human cases of WNv obtained in the State of Florida from 2002 to 2018.

The National Oceanic Atmospheric Administration (NOAA) Hurricane Center website provided official hurricane tracks and data which is accessible to the public. The study extracted tropical storm system dates of landfall in Florida and official tropical storm tracks from 2002 through 2018 hurricane seasons. The data for climate variables used in the study were obtained from the Midwestern Regional Climate Center (MRCC), a cooperative program between the NOAA's National Centers for Environmental Information (NCEI) and Regional Climatic Centers. Climate data obtained from MRCC included averages of precipitation and temperature for the period of 2002 through 2018 for climate divisions.

There are 344 climate divisions in the contiguous United States. Florida has seven climate divisions and each climate division; monthly station temperature and precipitation calculated from the daily observations. The divisional values weighted by area to compute statewide values and the statewide values weighted by area to compute regional values (Guttman & Quayle, 1996). The study will use precipitation, temperature and population data from five Florida climate divisions. Climate divisions six and seven will be combined with climate division five (Figure 5).

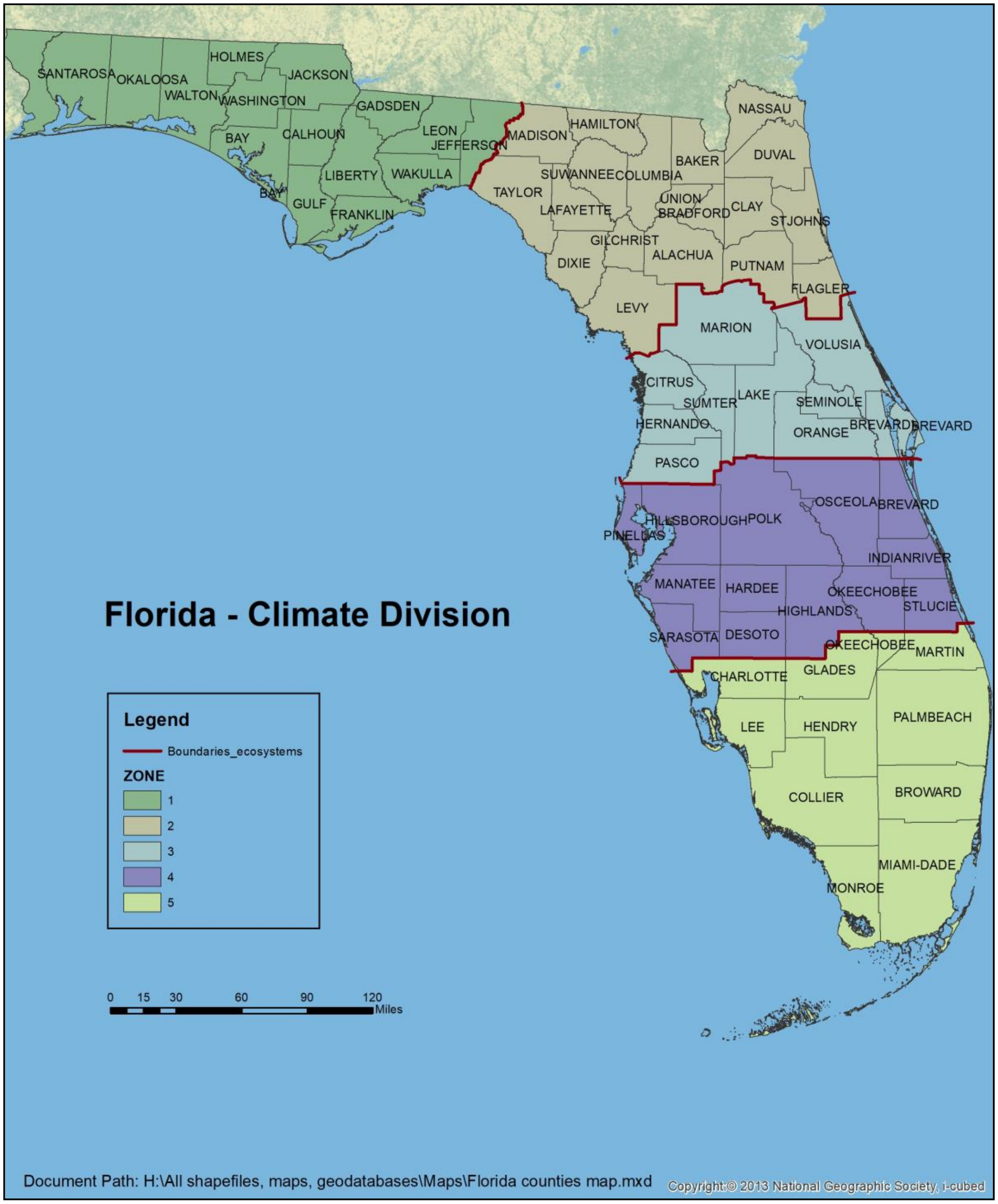

Figure 6. Florida Climate Divisions Map produced by Sabine Moreno using ArcGIS. Use of map with permission. Modification to map combined climate divisions 6&7 into climate division 5. Climate division data retrieved from Midwestern Regional Climate Center.

Results

This section of the study contains the findings starting with the descriptive statistics followed by results of linear regression analysis and multiple linear regression analysis. The study researched the association between landfall Atlantic tropical storms and the incidence of locally acquired human cases of WNv disease in Florida from 2002 through 2018. A linear regression was the analysis selected for the study. Linear regression analysis examines the relationship between the dependent variable and an independent variable. In my study this was selected to analyze research questions 1 and 2. Research questions 3 and 4 were analyzed using multiple linear regression analysis. Multiple linear regression provides analysis the relationship of a dependent variable with two or independent variables (Leard Statistics, 2019).

Descriptive Statistics.

In 1999, WNv was documented in the United States from the New York City area where the viral infections was responsible for seven deaths (Chen et al., 2016). Since the 1999 introduction, WNv is the most common cause of epidemic encephalitis in North America and is responsible for three of the largest mosquito-borne viral neuroinvasive disease outbreaks ever documented in the United States (Sardelis et al., 2002; Turell et al., 2005). The initial evidence of WNv arrival in Florida was documented in 2001 from increasing deaths among wild bird populations (Blackmore et al, 2003). Since its initial detection in Florida, WNv rapidly spread to all 67 Florida counties (Florida Department of Health [FDOH], 2014).

The observations for areas affected by landfall tropical storm precipitation had a monthly average of 6.7 in. (*SD* = 3.6, Min = .2, Max = 18.8). The observations for areas affected by landfall tropical storm temperature had a monthly average of 79.0º F (*SD* = 4.7, Min = 58.2 ºF, Max = 84.4 ºF). Locally acquired human cases of WNV from areas affected by landfall tropical storms had a monthly average of .02 cases per 100,000 population (*SD* = 0.06, Min = 0.00, Max = 0.3). The observations for precipitation from areas not affected by landfall tropical storms had a monthly average of 5.6 in. (*SD* = 3.1, Min = .1, Max = 14.5). Temperature observations from areas not affected by landfall tropical storms had a monthly average of 77.3 ºF (*SD* = 7.0, Min = 53.4ºF, Max = 84.6ºF). Human cases of locally acquired WNV observations from areas not affected by landfall tropical storms had a monthly average of .02 cases per 100,000 population (*SD* = .06, Min = 0.00, Max = 0.60). Table 3 contains the summary descriptive statistics

Table 3.

Descriptive Statistics

	N	Min	Max	Mean	Std. Dev.	Variance
LTS Precipitation	132	.2	18.8	6.7	3.6	12.752
LTS Temperature	132	58.2	84.4	79.0	4.7	22.332
LTS West Nile virus	132	.0	.3	.02	.06	.003
NLTS Precipitation	351	.1	14.5	5.6	3.1	9.495
NLTS Temperature	351	53.4	84.6	77.3	7.0	50.350
NLTS West Nile virus	351	.0	.6	.02	.06	.004
Valid N (listwise)	132					

Note: (LTS) landfall tropical storm areas (NLTS) Non-landfall tropical storm areas

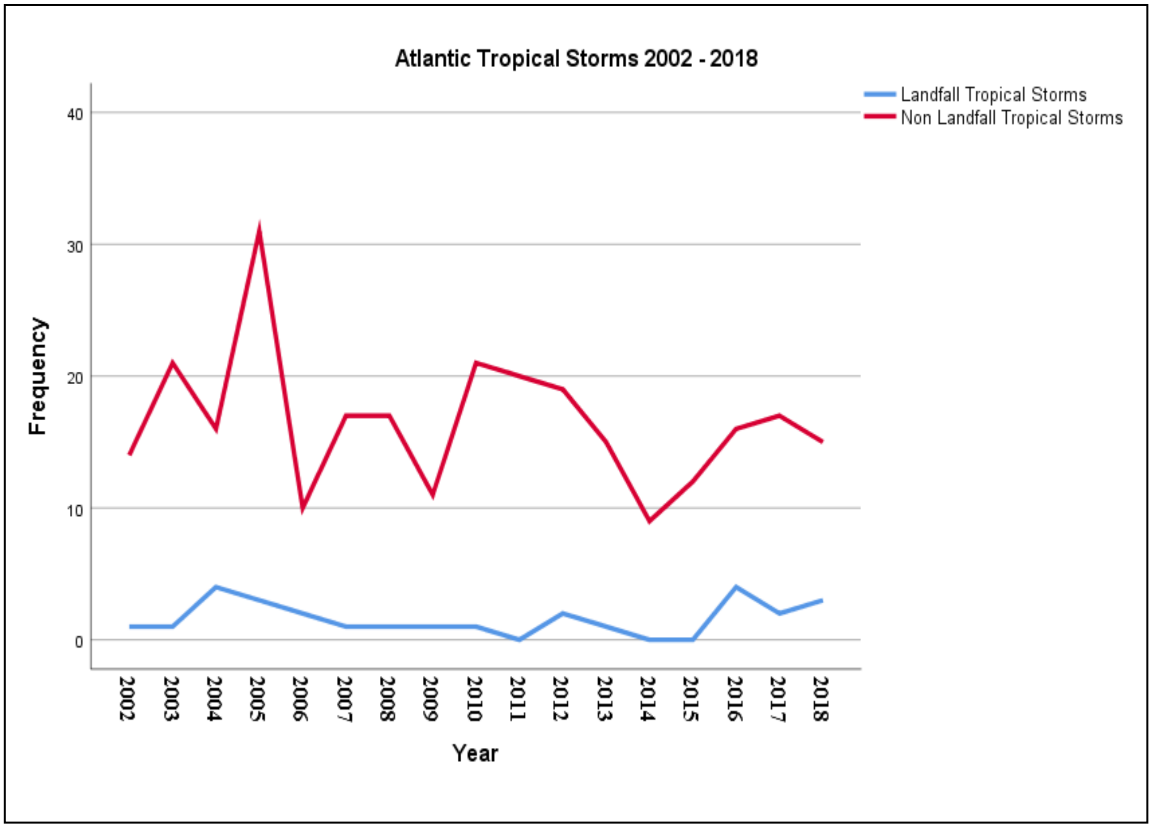

Figure 7. Non-landfall tropical storms and Florida landfall tropical storms 2002 to 2018. From “Atlantic Hurricane Seasons” from NOAA retrieved July 9, 2019

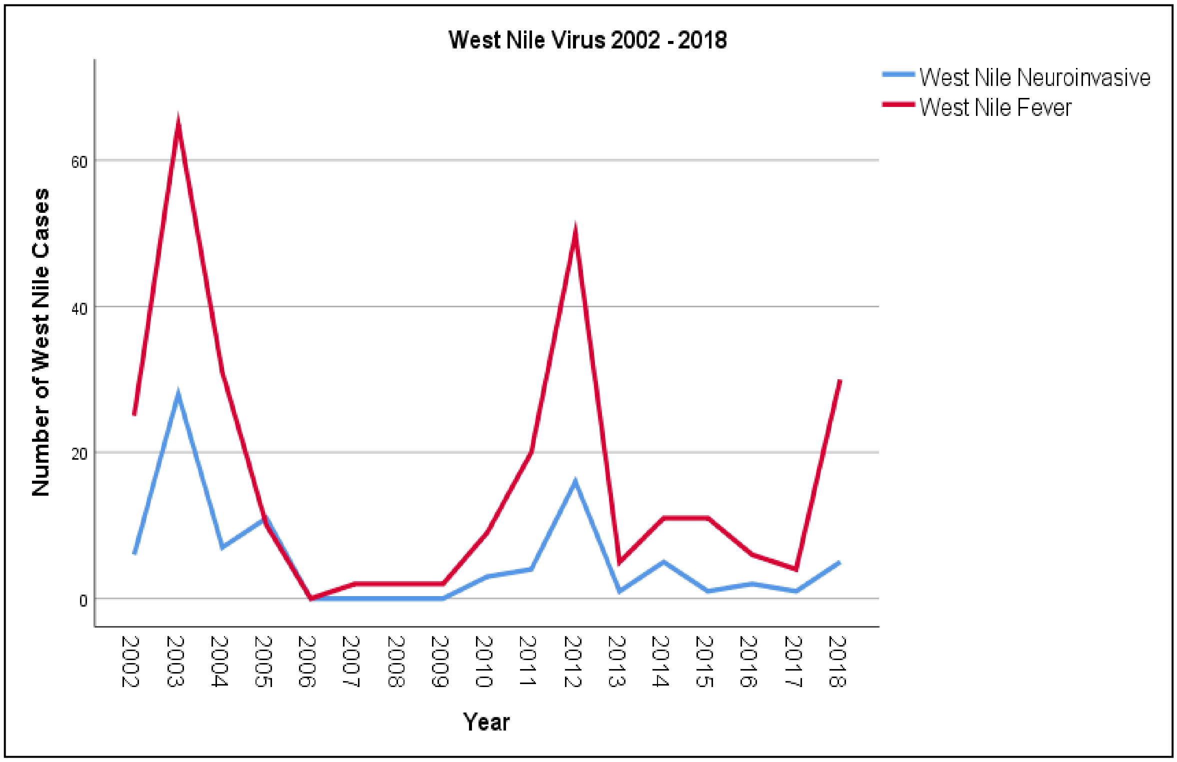

Figure 8. Cases of annual locally acquired human cases of West Nile virus in Florida 2002-2018 data. From "West Nile Virus (WNV)" by Florida Department of Health retrieved July 19, 2019.

Research Question 1

Is there an association between Florida landfall tropical storm systems precipitation and human cases of locally acquired WNv disease occurring from 2002 through 2018?

A linear regression was used investigate this research question as the statistical test to determine the relationship between predictor variable, precipitation from landfall tropical storms and outcome variable, human cases of locally acquired WNv from areas affected by landfall tropical storms.

The results of the linear regression model were not significant, F (1,130) = .018, p =. 893, R^2 = 0.00, indicating precipitation from landfall tropical storms did not explain a significant proportion of variation in human cases of locally acquired WNv. Table 4 summarizes the results of the regression model.

Table 4

Results for Research Question One

	Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
Model	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
1 (Constant)	.021	.010		2.062	.041	.001	.042
LTS Precipitation	.000	.001	.012	.135	.893	-.003	.003

a. Dependent Variable: Landfall Tropical Storm West Nile virus

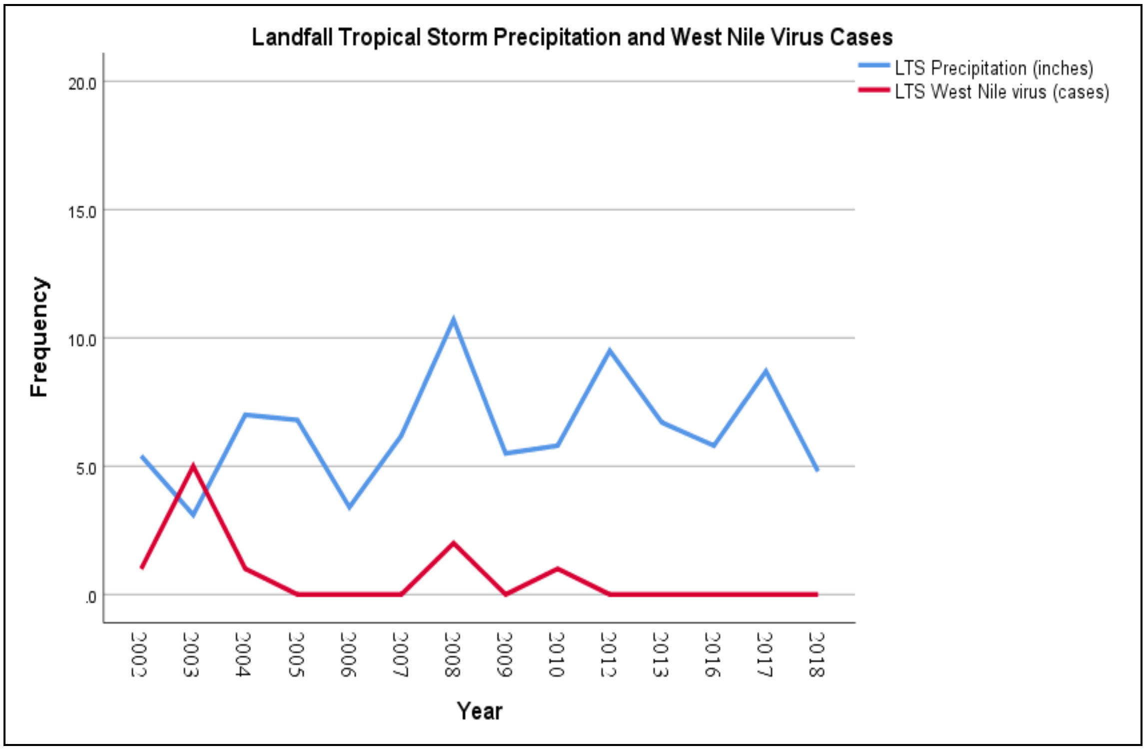

Figure 9. Landfall tropical storm precipitation and cases human of West Nile virus

Research Question 2

Is there an association between Florida landfall Atlantic tropical storm system temperature and human cases of locally acquired mosquito-borne West Nile viral disease occurring from 2002 through 2018?

The first step was to test for the assumptions was to assure the data could be analyzed using the linear regression. A linear regression was used investigate research question 2 as the statistical test to determine the relationship between predictor variable temperature and outcome variable human cases of locally acquired WNv. All required assumption for linear regression were met.

The results of the linear regression model were not significant, F (1,130) = 2.34, p = .128, $R2$ =. 018, indicating temperature from areas affected by landfall tropical storms did not explain a significant proportion of variation in locally acquired human cases of WNv. Regression model summary of results in Table 5.

Table 5

Results for Research Question Two

	Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
Model	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
1 (Constant)	.147	.082		1.807	.073	-.014	.309
LTS Temperature	-.002	.001	-.133	-1.531	.128	-.004	.000

a. Dependent Variable: *Landfall Tropical Storm West Nile virus*

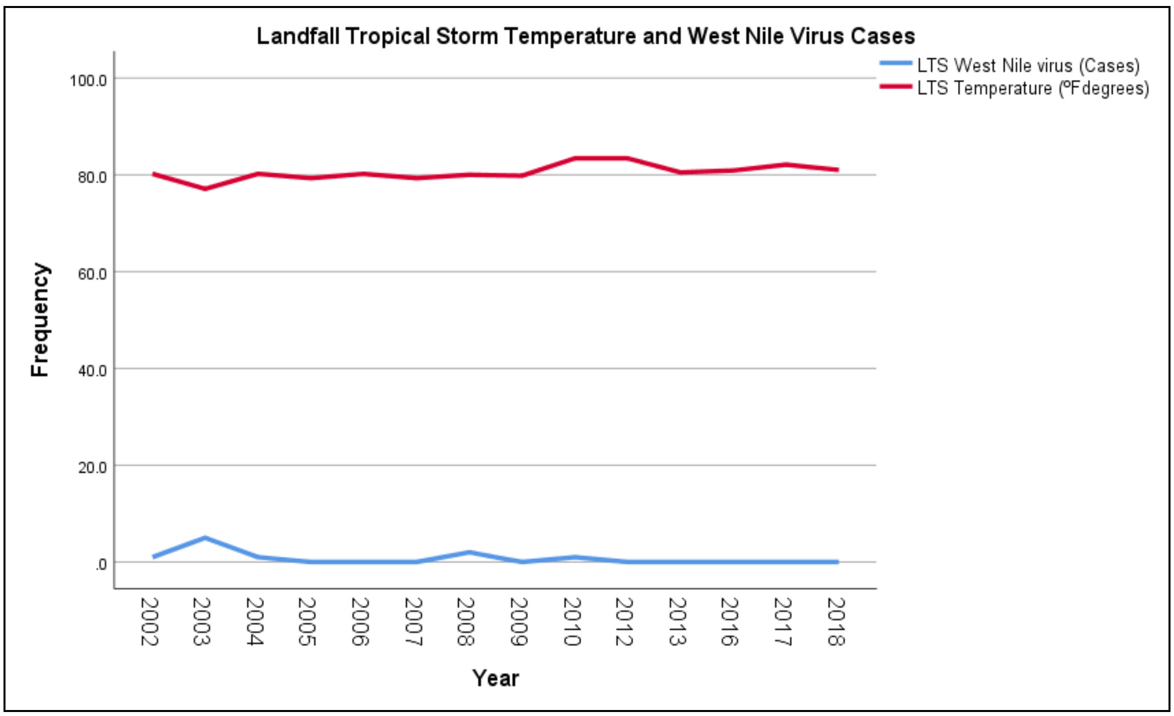

Figure 10. Landfall tropical storm (LTS) temperature and human cases of West Nile virus

Research Question 3

Is there an association between Florida landfall tropical storm precipitation and temperature collectively and the incidence of locally acquired human cases of West Nile viral disease from 2002 through 2018?

To investigate research question 3, a multiply linear regression was used as the statistical test to determine the relationship between independent variables precipitation and temperature from areas affected by landfall tropical storm and the dependent variable locally acquired human cases of WNv. Multiple linear regression assumptions were met for the research question.

The results of the linear regression model were not significant, F (2,129) = 1.58, p =. 209, R^2 = .024. This result indicates temperature and precipitation from areas affected by landfall tropical storms did not explain a significant proportion of variation in locally acquired human cases of WNv. Table 6 summarizes the results of the regression model.

Table 6

Results for Research Question Three

	Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
Model	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
(Constant)	.175	.087		2.0	.047	.003	.347					
LTS Precip	.001	.002	.088	.91	.366	-.002	.004	.012	.080	.08	.804	1.24
LTS Temp	-.002	.001	-.172	-1.77	.078	-.004	.000	-.133	-.154	-.15	.804	1.24

a. Dependent Variable: Landfall Tropical Storm West Nile virus

Research Question 4

Is there an association between areas not affected by landfall Atlantic tropical storm precipitation and temperature occurring from 2002 through 2018 in Florida and human cases of locally acquired mosquito-borne West Nile viral disease?

To investigate research question 4, a multiple linear regression was used as the statistical test to determine the relationship between independent variables precipitation and temperature from areas unaffected by landfall tropical storm and the dependent variable locally acquired human cases of WNv. Multiple linear regression assumptions were met for research question 4. Multiple linear regression was a better fit for the data to analyze the relationship between predictor variables and outcome variable.

The results of the linear regression model were significant, $F(2,153) = 5.34$, $p = .006$, $R^2 = 0.07$, indicating that approximately 7% of the variance in locally acquired human cases of WNv from areas unaffected by landfall tropical storms is explainable collectively by temperature and precipitation. Independently, the predictor variable temperature $p = .185$, from areas unaffected by landfall tropical storm did not significantly predict locally acquired human cases of WNv from areas unaffected by landfall tropical storms. Based on this sample, a one-unit increase in temperature from areas unaffected by landfall tropical storm does not have a significant effect on locally acquired human case of WNv from areas unaffected by landfall tropical storms. Precipitation from areas unaffected by landfall tropical storms significantly predicted cases of locally acquired human cases of WNv transmission in areas unaffected by landfall tropical storms, $p < .005$. This result indicates that on average, a one-unit increase of precipitation will increase the value of locally acquired human cases of WNv by 0.07 units. Table 7 summarizes the results of the regression model.

Table 7

Results for Research Question Four

	Unstandardized Coefficients		Standard Coefficients			95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
Model	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
(Constant)	.05	.043		1.1	.250	-.035	.135					
NLTS Precip	.00	.001	.259	3.9	.000	.003	.008	.207	.208	.207	.638	1.56
NLTS Temp	-.00	.001	-.087	-1.3	.185	-.002	.000	.069	-.071	-.069	.638	1.56

a. Dependent Variable: (NLTS) Non-Landfall Tropical Storm West Nile virus

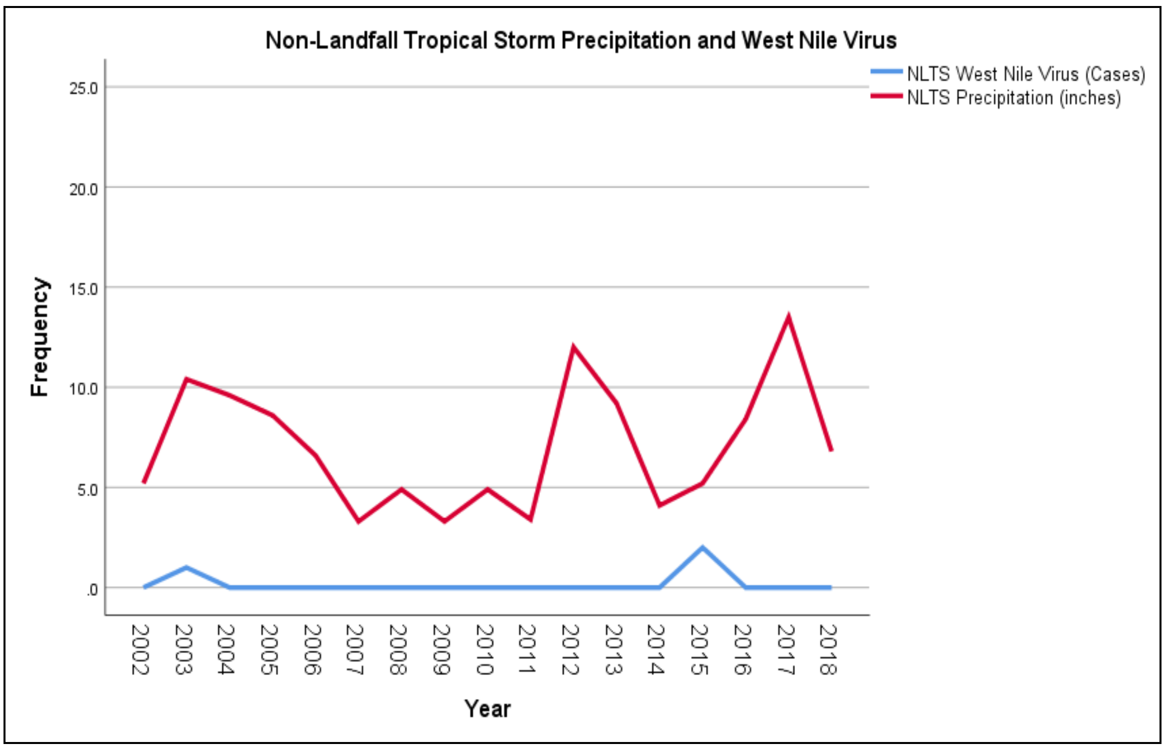

Figure 11. Non-landfall tropical storm precipitation and cases human of West Nile virus

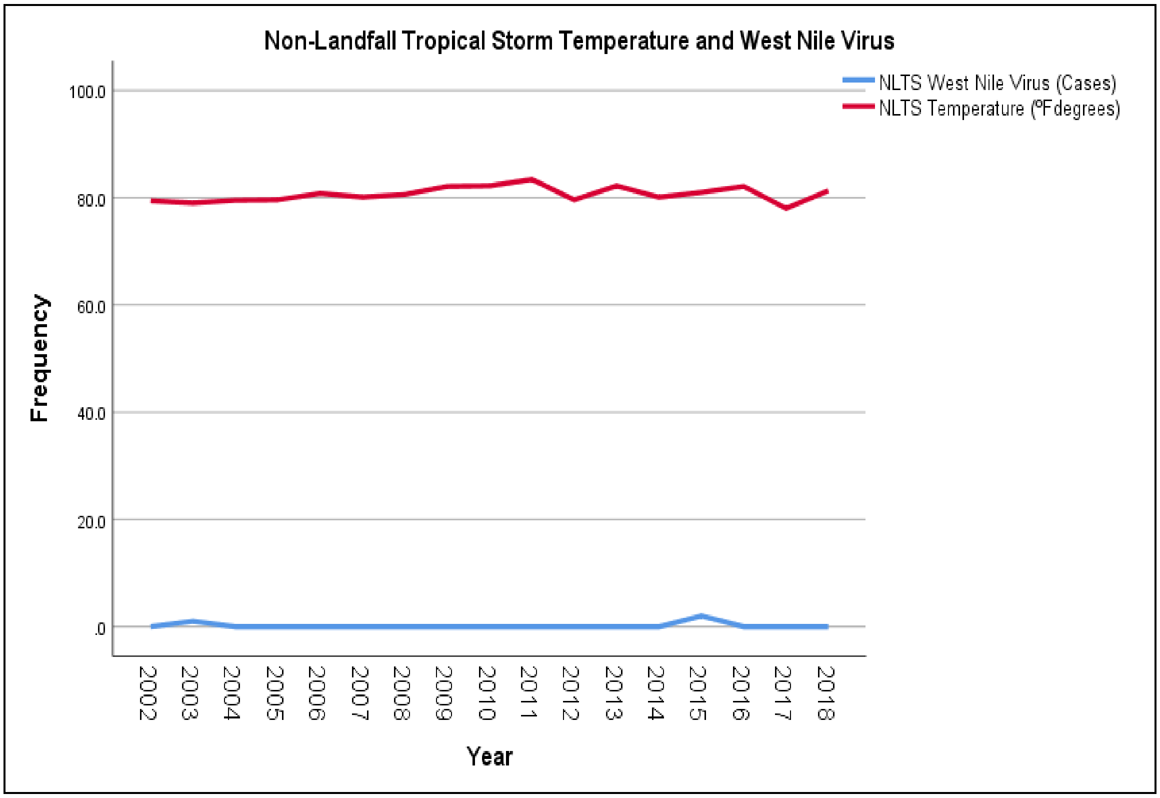

Figure 12. Non-landfall tropical storm temperature and cases human of West Nile virus

Summary

The study was seeking to determine if there was an association between precipitation from landfall tropical storms and the incidence of locally acquired human cases of WNv in Florida. According to the linear regression analyses, there was no association between precipitation and temperature from areas affected by landfall tropical storms and the incidence of locally acquired human cases of WNv in Florida. Precipitation and temperature from areas that had not experienced landfall tropical storms were significant in predicting incidence of local human cases of WNv in Florida (Table 8). An interpretation of the findings for the research questions and the literature reviewed in chapter 2 are discussed in chapter 5. Limitations of the study, positive social change implications, and the recommendations for future work in areas related to the study are discussed and a conclusion is provided at the end of the chapter.

Table 8

Research Questions and Hypothesis Summary

Research Questions	Variable(s)	Null Hypothesis
RQ1	LTS Precipitation	Failed to reject
RQ2	LTS Temperature	Failed to reject
RQ3	LTS Precip & Temp	Failed to reject
RQ4	NLTS Precip & Temp	Rejected

Note. LTS: landfall tropical storm areas, NLTS: Unaffected landfall tropical storm areas

Chapter 5: Discussion, Conclusions, and Recommendations

Introduction

The purpose of this quantitative retrospective ecological study was to determine if there is an association between landfall tropical storm climate variables precipitation and temperature and locally acquired human cases of WNv in Florida. The dependent variable was defined as the incidence of locally acquired human cases of WNv disease; both neuroinvasive and WNv fever, acquired in the state of Florida during the annual hurricane season from 2002 through 2018. The independent variables are temperature and precipitation associated with landfall Atlantic tropical storms.

The study set out to address an area were studies related to how landfall Atlantic tropical storm precipitation and temperature are associated with locally acquired human cases of WNv beyond individual storm events. The literature review I conducted established studies of long-term associations between tropical storms that make landfall in Florida are not available.

Interpretation of Findings

Based on the literature reviewed, this study is the earliest to examine the association between landfall Atlantic tropical storms and the incidence of locally acquired human cases of WNv beyond a single storm event. This study collected and analyzed retrospective precipitation and temperature data from 26 landfall tropical storm systems from 2002 through 2018 and data from the Florida Department of Health confirmed human cases of locally acquired WNv from 2002 through 2018.

WNv diseases are distinguish in two primary groups: neuroinvasive disease and non-neuroinvasive disease. WNv neuroinvasive disease differs from WNV non-invasive disease by the potentially serious ailments such as aseptic meningitis, encephalitis or acute flaccid paralysis. In rare cases, WNv neuroinvasive disease patients' condition can progress to coma or death. WNv neuroinvasive symptoms may range from stiff neck, seizures and limb weakness to altered mental status or cerebrospinal fluid (CSF) pleocytosis and abnormal neuroimaging (FDOH, 2014). WNv fever (non-neuroinvasive) symptoms can cause fever, headaches, myalgias and arthralgias, gastrointestinal symptoms and rash (FDOH, 2014).

During the study period 2002 to 2018, cases of locally acquired human WNv neuroinvasive disease and WNv (non-neuroinvasive form) fever totaled 373 cases collectively. Annual average WNv fever disease was (n=17) cases with the maximum cases of (n=65) reported in 2003 and 0 cases reported in 2006. WNv neuroinvasive averaged (n=5) cases annually with the maximum (n=28) cases reported in 2003 (FDOH, 2014).

The Atlantic basin experienced 281 tropical storm systems from 2002 through 2018. Of the 281 tropical storms systems, 27 (9.6%) of tropical storms made landfall in Florida. The study found a mean of 1.53 annual landfall tropical storms occurred and no year exceeded the maximum of four landfall tropical storms that occurred in 2004 and 2016. There were two consecutive years with no documented landfall tropical storms, 2014 and 2015. WNv local human cases did occur in years without landfall tropical storms, FDOH reported 16 cases in 2014 and 12 cases reported in 2015.

Precipitation is an important environmental factor in the transmission cycle of WNv and an essential ecological requirement for mosquito reproduction. Studies have suggested above average precipitation can create additional larval habitat sites for some mosquito species. Yet, excessive precipitation has the potentially be detrimental and have a negative impact on some mosquito larval habitats (Paz, 2015). A different perspective by Blackmore et al. (2003), found WNv outbreaks are associated with periods of drought prior to WNv human cases. These periodic droughts appear to bring vectors and host species together precipitating arbovirus transmission.

Results from the study using a linear regression model found the association between precipitation from landfall tropical storms and incidence of locally acquired human cases of WNv were not significant. Precipitation from landfall tropical storms had a mean of 6.7 inches and a maximum of 18.8 inches. This suggest that despite the ecological benefit of precipitation for mosquito reproduction, the study found increased precipitation caused from landfall tropical storms alone is not enough to increase or encourage locally acquired human cases of WNv in Florida and supports the research by Paz (2015) suggesting increased precipitation may present difficulty for abundant larval development.

Prior studies have suggested temperature is an important environmental factor in the transmission cycle of WNv and the life cycle of mosquitoes. Higher temperature can affect viral replication rates of transmission of WNv, increase in the growth rates of mosquito populations by increasing their frequency of blood feeding, reduction EIP, accelerating the virus evolution rate, and increasing viral transmission efficiency to avian reservoir hosts (Dohm et al, 2002).

Results from the study using a linear regression model found the association between temperature from landfall tropical storms and the incidence of locally acquired human cases of WNv were not significant. These findings suggest temperature changes due to landfall tropical storms cannot solely be responsible for the incidence of locally acquired human cases of WNv. Temperature during the study period varied from a minimum avg of 58.2 degrees ºF to a maximum of 79 degrees ºF during the study period.

A cumulative analysis of the association between independent variables precipitation and temperature from areas where landfall tropical storms had no impact on the dependent variable human cases of locally acquired WNv.

Precipitation from areas unaffected by landfall tropical storms averaged 5.7 inches from 2002 to 2018. The maximum-recorded precipitation was 14.5 inches for the study period. This is less than the maximum precipitation recorded from areas affected by landfall tropical storms. Temperature for the study period had a minimum of 53.4 degrees and a maximum temperature of 84.6 degrees, slightly warmer than areas affected by landfall tropical storms.

WNv had 163 confirmed local human cases in areas not affected by landfall tropical storms. WNv rate per 100,000 population was .6 cases.

Results of the multiple linear regression analysis model found precipitation and temperature collectively did explain a significant proportion of variation in local human cases of WNv cases in areas not affected by landfall tropical storms.

Limitations of the Study

There were limitations to the study regarding the use of a secondary dataset retrieved from the Florida Department of Health. One of the limitations consisted of the minimal information provided for documented locally acquired human WNv cases. Florida Department of Health provided only the county location and the month an infected individual was confirmed positive with either WNv neuroinvasive or WNv fever. This limitation prevented important information about human cases to be available because of privacy concerns (FDOH, 2019).

Weather station data inconsistency resulting from landfall tropical storms. This study found no data indication reported from some weather stations when tropical storms made landfall. According to the Florida Climate Center (2019), “extremely high winds from landfall tropical storms cause power outages which impact weather station data recording.” However, not all-weather stations experienced interruptions from a tropical storm weather event.

Recommendations

The results of this study will contribute to the limited body of knowledge concerning the association between landfall tropical storms climatic variables and the incidence of locally acquired human cases of WNv in Florida beyond a few storm observations. The results of the study suggest landfall tropical storm precipitation and temperature are not significant predictors of locally acquired human cases of WNv in Florida. This study will create opportunities for future research on the impact of landfall tropical storms and the incidence of mosquito borne viruses. For example, what impact does wind from landfall tropical storm have on mosquito populations and their ability to transmit WNv resulting in human infections.

This study could potentially provide benefits to future research into understanding how precipitation and temperature from landfall tropical storms influence WNv transmission cycle. According to Kramer, Ciota & Kilpatrick (2019), “the abundance of research that focuses on weather-WNv relationship needs more thorough research that covers the complete ecology of WNv transmission cycle and weather events.”

Another consideration for future research may be using data from sentinel animals. WNv activity tracking also use dead-bird reporting maintained by Florida Fish and Wildlife Conservation Commission, and the disease testing performed by Florida Department of Health, which confirms if a dead bird is positive from WNv. It was the observation of dead birds that tested positive for WNv confirming the diseases presences in Florida (Blackmore et al 2003). By far the most relied upon WNv monitoring method in Florida is the sentinel chicken program (FDOH, 2018; Florida Mosquito Control Association, 2018). Sentinel chickens remain asymptomatic when infected with WNv. Following a bite from an infected mosquito, sentinel chickens undergo seroconversion and develop detectable antibodies (fig. 7) which through testing allows Florida Department of Health to determine the presence of WNv activity in a specific area (FDOH, 2018; Hayes, Sejvar, Zaki, Lanciotti, Bode, & Campbell, 2005).

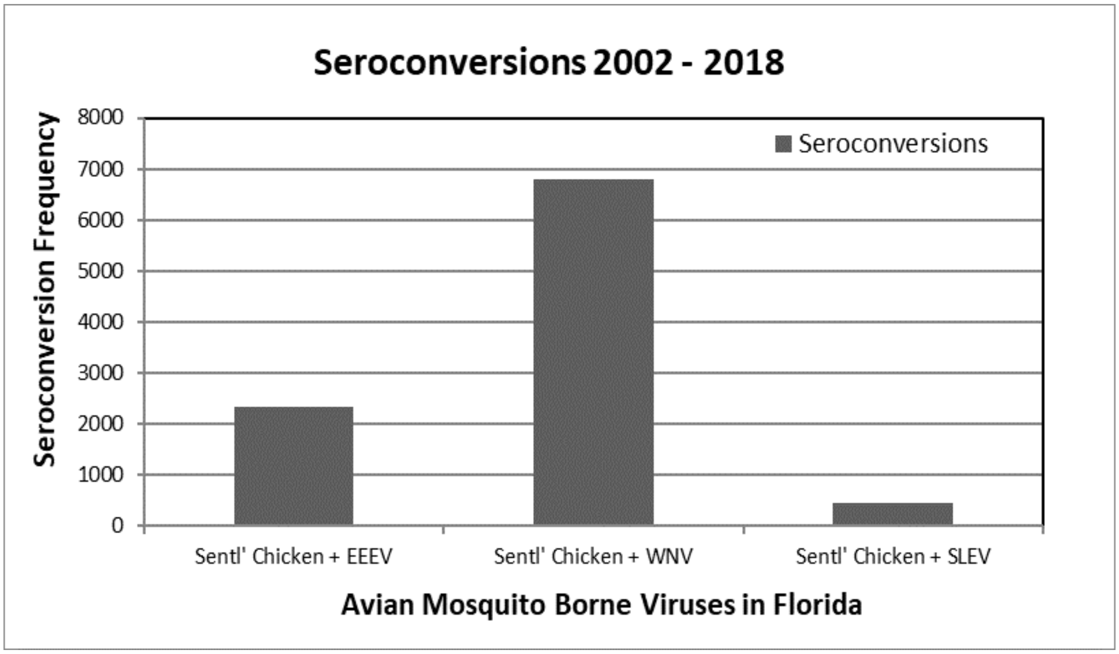

Figure 13, Seroconversion cumulative data 2002 through 2018 from Florida Department of Health

Future research should concentrate on sentinel chicken data. This should include their association with human WNv infections and an understanding of the vector species responsible for transmitting WNv. Rochlin, Faraji, Healy, & Andreadis (2019), in their research of WNv vectors indicate there are primary vectors of WNv in Florida, *Culex quinquefasciatus* (Say) is the primary WNv vector in Florida and parts of the southeastern United States. In Florida, a second WNv vector species, *Culex nigripalpus* (Theobald) is abundant in Florida and have an overlapping range with *Culex quinquefasciatus* (Say).

Moreover, other WNv activity monitoring is necessary as well. For example, Florida Department of Health reporting period for 2018 ended with, 33 positive WNv samples from humans, three WNv blood donors, thirteen horses, one zebra, one redshouldered hawk and five crows positive for WNv. There were 31 positive mosquito pools and 814 positive sentinel chickens reported from 40 counties. The year ended with 19 counties under mosquito-borne illness advisory (FDOH, 2018).

Implications

The social change implications of this study will bring awareness to the importance of tropical storm preparation to include pestiferous mosquitoes and their potential to spread disease. Power outages often occur following landfall tropical storms. Loss of power during hurricane season typically means hot weather and no air condition. These conditions can lead to creative ways to withstand the heat for days or weeks. The choices to mitigate the heat can lead to exposure by open windows, dress with less clothing and time outside the residence for debris cleanup. This social change approach to post landfall tropical storm could have serious implications. According to Florida Medical Entomology Laboratory (2017), expectations in the next five years predicts that a serious threat exist for local human cases of WNv in Florida. FMELs prediction of a dramatic increase expects to cause an epidemic of more than 1000 local human and horse cases of West Nile in Florida (FMEL, 2017).

Conclusions

Based on the literature review conducted, this study is the first to associate and regress the relationship between landfall tropical storms climatic variables and incidence of FDOH confirmed human cases of locally acquired WNv in Florida beyond a single storm event.

The results of this study suggest that landfall tropical storms climatic variables temperature and precipitation are not principal predictors of human cases of WNv acquired in the state of Florida. Contrary to the results of this study, Gage et al, (2008) “consider precipitation as the single most important environmental factor affecting arboviral transmission cycles. Their study also decided precipitation creates additional land surface wetness that supports standing water and directly influence mosquito reproduction with an abundance of suitable oviposition sites.” Studies also suggest temperature can influence arboviral transmission cycles by influencing extrinsic incubation period (Ruiz et al, 2010). Landesman, Allan, Langerhans, Knight, & Chase, (2007) found a strong association in their study with human cases of WNv and preceding year precipitation with above-average rainfall in the eastern United States. Their study was conducted from 2002 through 2004. Their findings are encouraging for future studies similar to my study but analyze more ecology variables.

Finally, my study did not take into consideration all factors associated with landfall tropical storms. High winds from landfall tropical storms are likely to influence bird and mosquito populations to disperse away from areas experiencing high winds. Mosquito larval habitats, which can have some influence on WNv transmission cycle. The study results found areas that did not experience landfall tropical storm provided a stronger ecological relationship with precipitation and temperature with incidence of local human cases of WNv in Florida.

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Appendix A: Factor Associated with Florida Mosquito Borne Virus Transmission

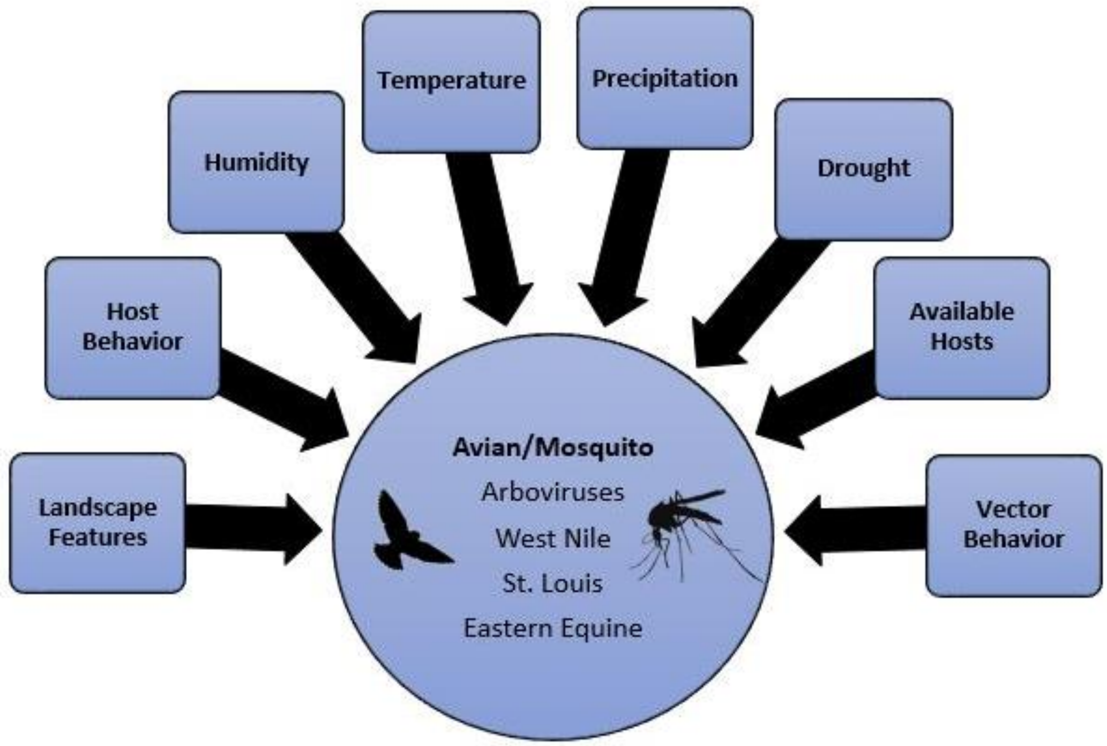
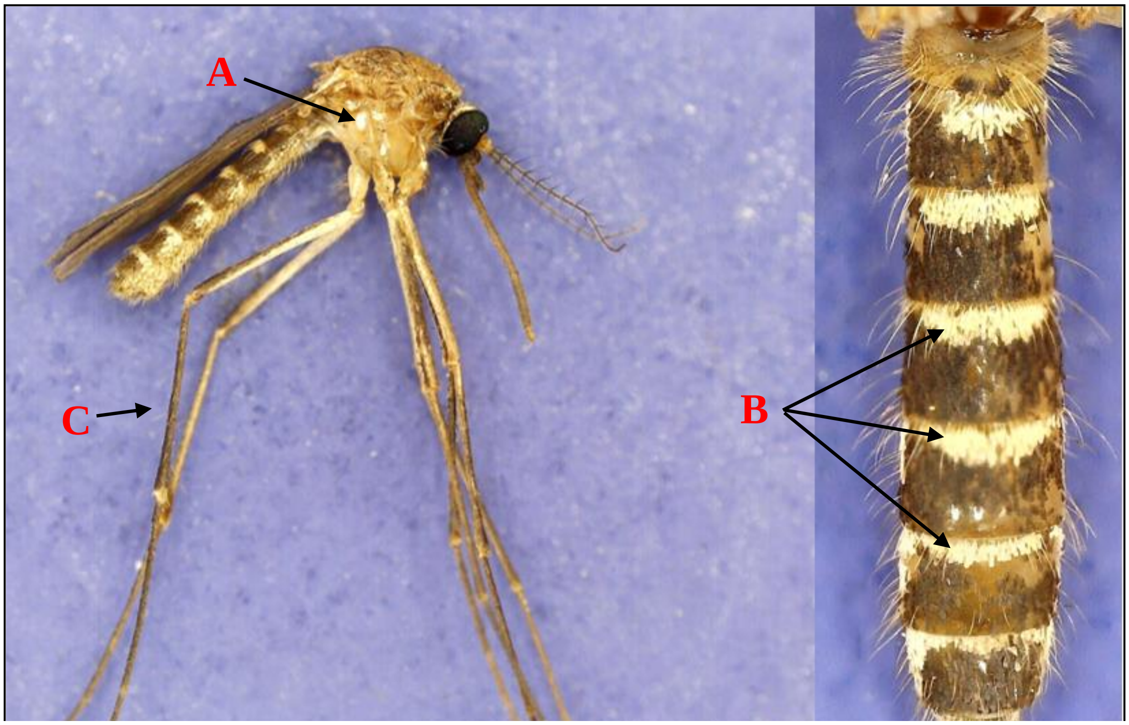
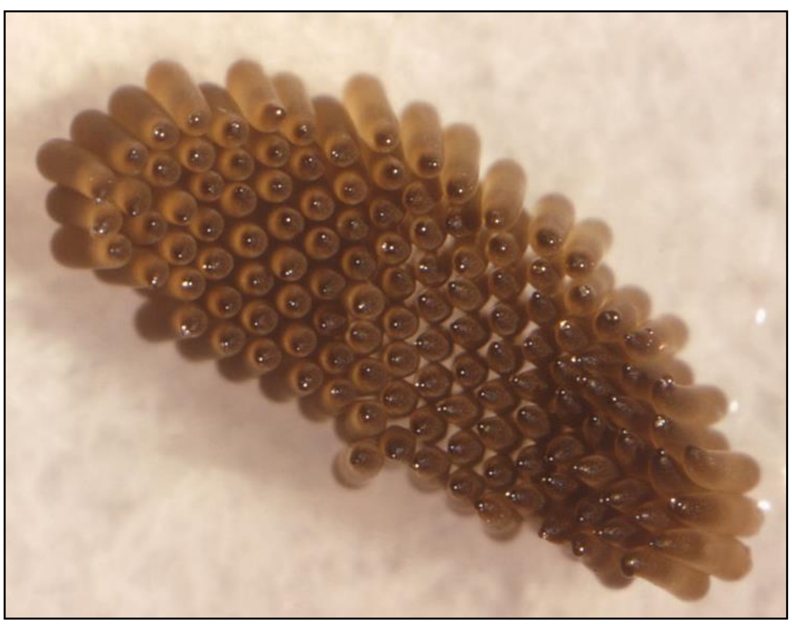


Diagram created from lecture discussion by Johnathan Day

Appendix B: *Culex quinquefasciatus* (Say) and egg raft

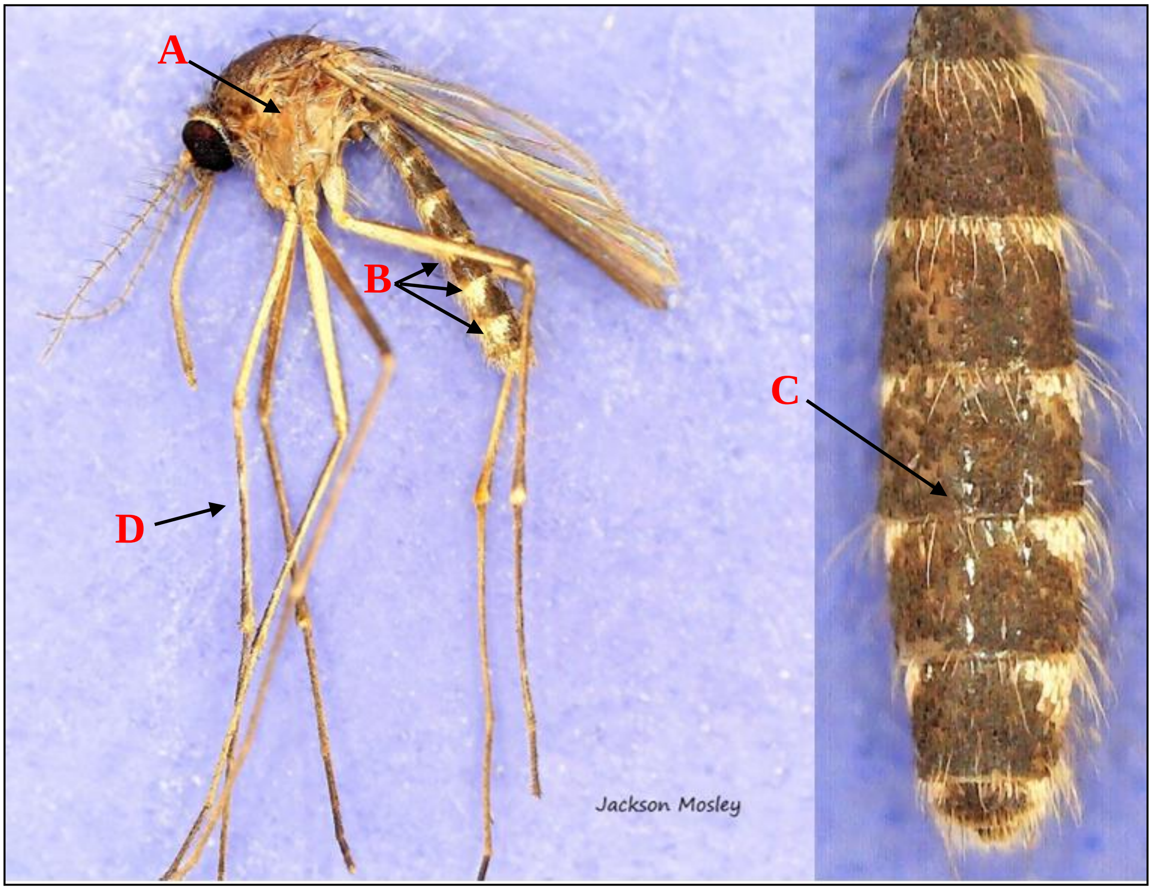


A: lateral thorax with more than three patches of white scales.
B: dorsal abdomen with half-moon shape pale scale commonly on segments III-V.
C: legs mostly dark without bands.
(FMEL, 2017)



Culex quinquefasciatus egg raft

Appendix C: *Culex nigripalpus* (Theobald)



A: lateral thorax with without pale scales fewer than six patches if present.
B: dorsal abdomen with no pale bands.
C: abdomen with lateral triangle shape pale scales well defined on segments V-VII.
D: Legs mostly dark without bands
(FMEL, 2017)

Appendix D: Climate Division map use permission

From: Jackson Mosley <jackson.mosley@waldenu.edu>
Sent: Wednesday, April 1, 2020 9:00 AM
To: Moreno, Sabine <SabineMoreno@polk-county.net>
Subject: [EXTERNAL]: Permission to use Climate Division Map

Good morning,

As I requested during our last discussion, it would be beneficial to my study if you could create a map with Florida climate divisions based on my specifications. For my research, I will need you to design a map with climate divisions 6 and 7 include as part of climate division 5.

I will await your reply and permission to use your map.

Cheers,
Jackson Mosley

MS Moreno, Sabine <SabineMoreno@polk-county.net>
Wed 4/1/2020 11:15 AM
Jackson Mosley

Hello Jackson,

You are welcome to use the attached map ("Florida Climate Division") for your purposes.

Glad to be of service,
Sabine

Sabine Moreno
Environmental Specialist GIS
Polk County Natural Resources – Mosquito Control
Phone: 863-534-7377 ex.208

Appendix E: Public Domain Use Agreement

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