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A Spatial Analysis of Demographic Factors of West Nile Virus in Georgia

Sarah Bryant Boos

ABSTRACT

Sarah Boos
 A Spatial Analysis of Demographic Factors of West Nile Virus in Georgia
(Under direction of Sheryl Strasser, PhD)

Background: West Nile Virus (WNV) is a serious mosquito-borne disease that can potentially lead to death.   The purpose of this study is to spatially examine known risk factors for WNV within Georgia at the county level. The study produces maps that relate known WNV cases to high, medium, and low risk factor areas for additional analyses.

Methodology: Cartographic visualization and statistical analysis software was used to examine the relationships between: the geographical distribution of age, race, gender, urbanicity, and population density of Georgians in relation to WNV cases by county. Chi-square analysis and odds rations were calculated to determine whether or not associations of risk and the likelihood of WNV case reports were significant.

Results: Gender was found to be significantly associated with the distribution of reported WNV cases. Identification of high risk areas throughout the state was determined through the use of Geographic Information System software.

Conclusion: Insights into the visual distribution of WNV risk factors throughout the state of Georgia can assist policy makers and public health planners to optimize resources in WNV transmission and prevention abatement and education efforts. This exploratory study provides a critical first glimpse into the distribution of WNV risk factors throughout the state.

INDEX WORDS: encephalitis, socio-demographic, GIS

A Spatial Analysis of Demographic Risk Factors of West Nile Virus in Georgia

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CHAPTER I
INTRODUCTION

1.1 Background

West Nile Virus (WNV) is a serious mosquito-borne disease that can potentially lead to death. The virus is endemic to many countries in Africa, West Asia, and the Middle East and has recently become endemic in the United States, Canada, Mexico, Central America, and the West Indies. The disease poses a public health threat and the most effective means of human WNV case control is through mosquito suppression efforts. Spatial analysis of risk factors through mapping tools can assist public health professionals in their mosquito control efforts. The purpose of this study is to spatially examine known demographic risk factors for WNV within Georgia at the county level. This study will also produce maps that relate known WNV cases to high, medium, and low risk factor areas for additional analysis. Maps of WNV risk factors and cases can hone mosquito targeting strategies and optimize resource management.

This paper will provide an analysis of WNV risk factors by Georgia county census data. The review of literature will highlight research identifying WNV risk factors and the utility of GIS mapping to predict potential areas of high human risk and direct WNV interventions and prevention education. Chapter III will detail the methods and procedures used to analyze WNV risk factors in Georgia through the GIS ArcMap application based on West Nile Virus human cases and census data. Chapter IV will reveal results found in this study, providing tables and maps to display if and where WNV risk factor hotspots are located in the state. The final chapter will discuss details found in this study, answer the previously outlined research questions and make recommendations based on study results.

1.2 Purpose of Study

Environmental and demographic risk factors for WNV have been identified. The purpose of this study is to spatially explore demographic data to determine areas of high potential WNV risk throughout Georgia. Combining cartographic visualization of demographic data with statistical tools can provide valuable insight for detecting areas of concern.

1.3 Research Questions

The purpose of this study is to determine areas of WNV risk throughout Georgia. Determination of areas throughout the state that may have the greatest potential risk will be achieved by answering the following questions:

1) What is the geographic distribution of West Nile Virus cases throughout Georgia?

2) a. What is the geographic distribution of residents aged fifty and over throughout Georgia?

   b. How do age risk levels relate to reported WNV cases?

3) a. What is the geographic distribution of residents of white race throughout Georgia?

   b. How do race risk levels relate to reported WNV cases?

4) a. What is the geographic distribution of male residents throughout Georgia?

   b. How do gender risk levels relate to reported WNV cases?

5) a. What is the geographic distribution of urbanicity throughout Georgia?

   b. How do urbanicity risk levels relate to reported WNV cases?

6) a. Which counties have all four high risk attributes?

   b. Which counties have three high risk attributes?

CHAPTER II
REVIEW OF THE LITERATURE

The purpose of this study is to spatially explore (through the use of Geographic Information Systems mapping software) demographic data which have been identified as risk factors in WNV cases and subsequent infection. The following review of literature presents current knowledge that supports the rationale for data that will be analyzed to answer the study's research questions. Specifically, an overview of WNV disease and transmission, risk factors, prevention, and previous GIS research related to WNV is described.

2.1 West Nile Virus

WNV belongs to the group of viruses known as arboviruses which tend to be mainly transmitted by arthropods. WNV comes from the family of arborviuses called the flaviviruses. The flaviviruses, like the other encephalomyelitis viruses, are transmitted by mosquitoes, and occasionally by other bloodsucking insects, to horses, human beings, and a number of other mammals from avian hosts, which serve as natural reservoirs for these viruses in nature (The American Association of Equine Practitioners [AAEP], 2005). Humans, horses, and other mammals usually serve as dead-end hosts. The principal vectors for WNV in the United States are *Culex* species mosquitoes and many species of wild birds act as vertebrate hosts (Hayes, 1988).

West Nile Virus is an Encephalitis virus which can cause "neuroinvasive disease" which effects a person's nervous system and includes; West Nile encephalitis, West Nile meningitis, West Nile meningoencephalitis, and West Nile Fever. West Nile Virus can be transmitted to humans by being bitten by an infected mosquito or in very rare occasions through blood

transfusion, breast feeding, transplacental, and transplantation. West Nile Virus is found in numerous mosquito species throughout the world. In Georgia the *Culex* mosquito is responsible for human infections (The Center for Disease Control [CDC], 2008).

West Nile Virus symptoms can vary from severe to none at all. Most people who become infected with WNV will never develop symptoms or be aware that they were ever infected. It is estimated that 20% of all people who become infected will develop West Nile Fever, which causes fever, headaches, tiredness, body aches, and occasionally a skin rash and swollen lymph nodes. Symptoms occur two to fifteen days after a mosquito bite and usually last a few days but can last up to several weeks. Research estimates that 1% of all WNV cases end in severe neuroinvasive diseases. The fatality rate for those afflicted ranges from 3 - 15%. Symptoms can include headache, high fever, neck stiffness, stupor, disorientation, coma, tremors, convulsions, muscle weakness, and paralysis. Serious illness can occur in anyone; however, children under the age of 15, adults over the age of fifty, and immunocompromised persons are the most vulnerable (CDC, 2006). Although West Nile neuroinvasive disease is considered to be more serious than West Nile fever, an important 2006 study found that both conditions can cause long-term health complications. The researcher found that more than a year after being diagnosed with WNV, half of patients complained of neurological and psychological symptoms, including fatigue, headaches, depression, memory problems and tremors. Patients who had West Nile fever were just as likely to experience these problems as those who had WNV-associated encephalitis or meningitis (Carson, 2006).

West Nile virus was first isolated from an adult woman in the West Nile District of Uganda in 1937 during research on yellow fever; however, studies conducted on the evolution of the organism suggest that the virus emerged approximately 1000 years earlier. The initial virus developed into two distinct lineages, Lineage 1 and its multiple profiles is the source of the epidemic transmission in Africa and throughout the world, while Lineage 2 remains as an Africa zoonose. WNV has even been hypothesized as one of the possible causes of Alexander the Great's early death, at the age of 32 in 323 BC, based on reports of avian deaths before his illness period (Marr, 2003 & Galli, M 2004). WNV became recognized as a cause of severe human meningoencephalitis in elderly patients during an outbreak in Israel in 1957 (CDC, 2004). WNV has been reported in the Middle East, Africa, Europe, India, Asia, Australia (subtype Kunjin), parts of Central America and the Caribbean and North America (Dauphin, 2004 & Zeller, 2004).

West Nile Virus first appeared in North America in 1999 in New York City. In late August of 1999 two patients in a northern Queens, New York were reported to have encephalitis. The New York Health Department launched an epidemiologic investigation and identified 62 cases of West Nile Virus human cases, including meningitis encephalitis or fever, within New York City hospitals. The WNV outbreak resulted in 7 fatalities (Nash, 2001). Avian, animal and mosquito WNV infections were reported to Center for Disease Control and Prevention (CDC) ArboNET in 1999 from Connecticut, Maryland, New Jersey, and New York (CDC, 2007). Over the next nine years, WNV human cases were detected in all US states except Hawaii and Alaska. Figures 1-10 depict WNV human activity by report year within the US. WNV is now considered endemic in the USA and Canada (CDC, 2003).

Figure 1. Final 1999 West Nile Virus Activity in the Unites States.

Figure 2. Final 2000 West Nile Virus Activity in the United States

Figure 3. Final 2001 West Nile Virus Activity in the United States

Source: U.S. Geological Survey Disease Maps, 2008
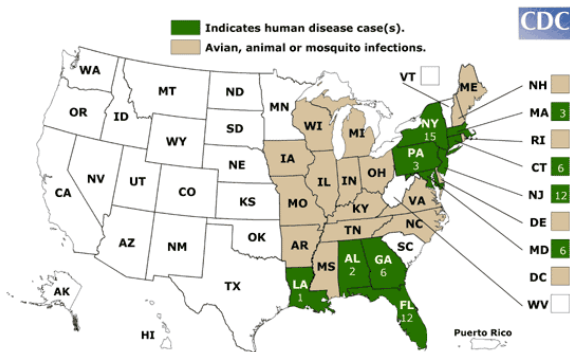
Figure 4. Final 2002 West Nile Virus Activity in the United States
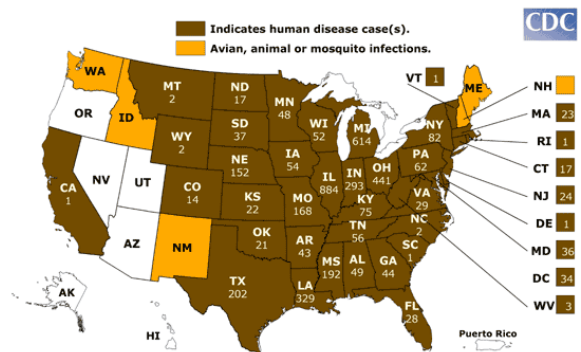
Figure 5. Final 2003 West Nile Virus Activity in the United States
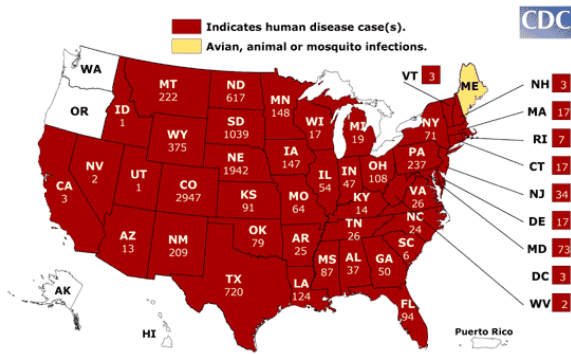
Figure 6. Final 2004 West Nile Virus Activity in the United States
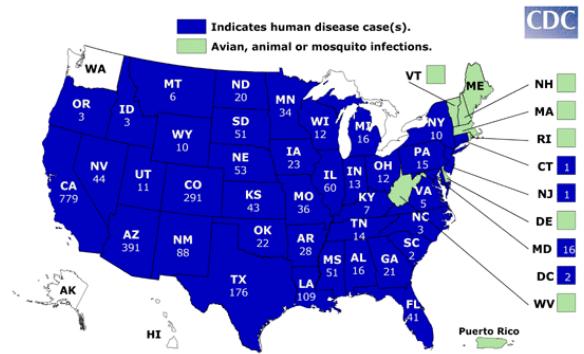
Figure 7. Final 2005 West Nile Virus Activity in the United States
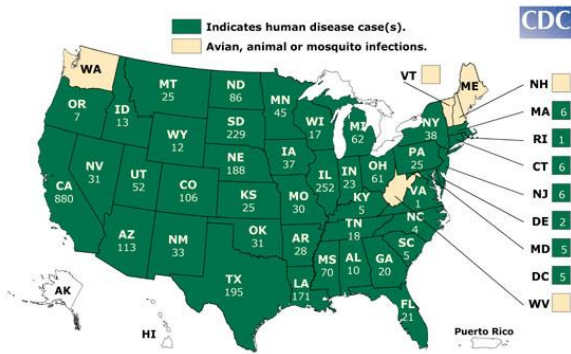
Figure 8. Final 2006 West Nile Virus Activity in the United States
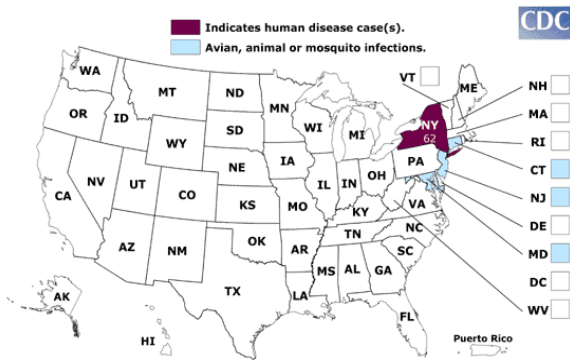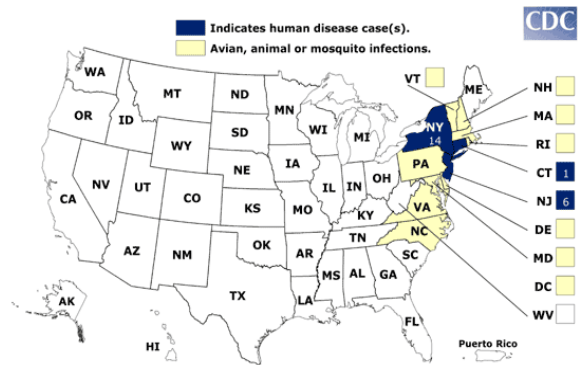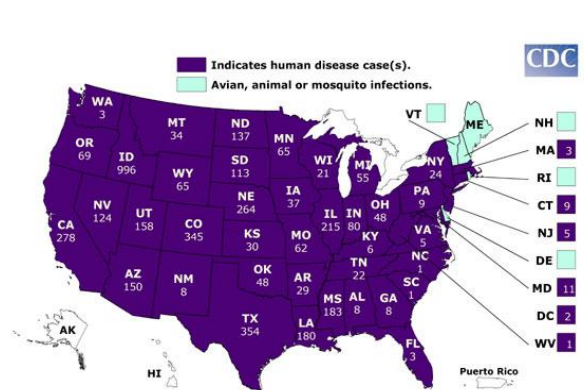

Source: U.S. Geological Survey Disease Maps, 2008

Figure 9. Final 2007 West Nile Virus Activity in the United States
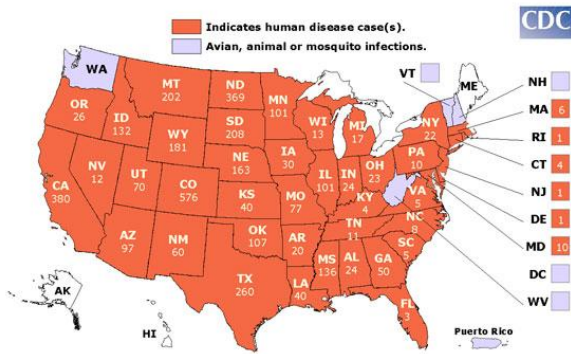
Figure 10. 2008 West Nile Virus Activity in the United States (Reported to CDC as of February 13, 2009)
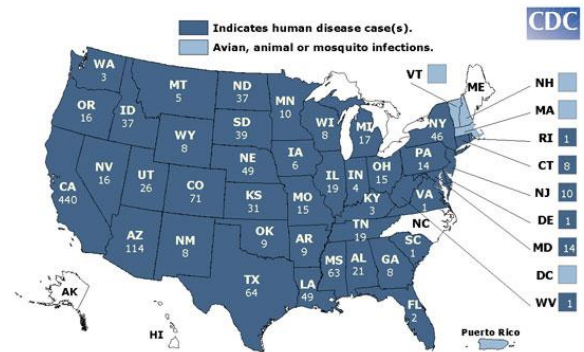
* Source: U.S. Geological Survey Disease Maps, 2008

WNV Transmission

WNV has been shown to infect many species of animals, such as horses, cats, bats, and squirrels, but it is believed that birds serve as primary reservoirs for WNV (Komar, 2003; Rogers, 2002; & Jozan, 2003). Mosquitoes become infected by feeding on an infected bird and then continue spreading WNV to humans and other animals through biting them (Hubalek, 1999; Komar, 2003; & Turell, 2001). Birds are considered one of the most important factors in the WNV transmission cycle. While many avian species have tested positive for WNV, only species that develop sufficiently high levels of viremia, the initial spread of virus in the blood from the first site of infection, will promote transmission of the WNV to mosquitoes. These are called amplifying hosts. The enzootic transmission cycle is essential for the virus to spread, and human proximity to this activity is necessary for transmission to humans. The WNV transmission cycle is shown in Figure 11. Prior efforts to delineate high-risk areas for WNV exposure to humans have focused primarily on the measured presence of WNV-positive bird specimens. A bird that

has tested positive for WNV can be an indication that human cases will occur there, too

(Theophilides, 2003; Guptill, 2003; Mostashari, 2003; & Nasci, 2002).

Figure 11. West Nile Virus Transmission Cycle
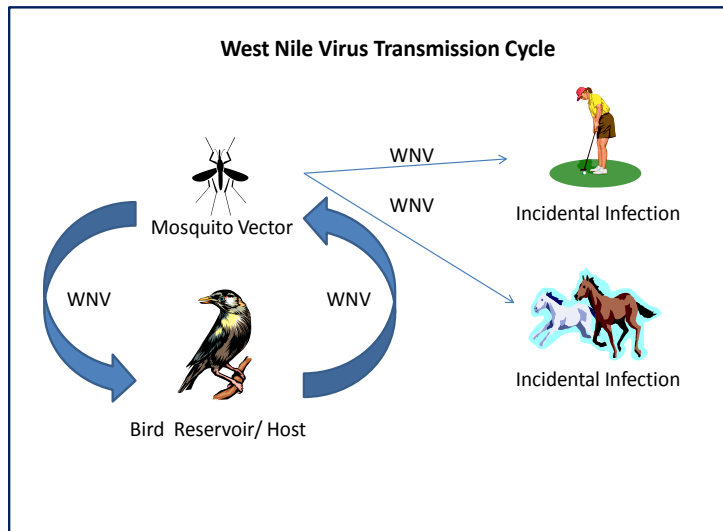
In the U.S., at least 321 avian species, mostly songbirds, have been found to be susceptible to infection. Members of the family Corvidae (crows, jays and magpies) are especially important because they develop severe illness and have a high mortality rate which makes them useful as sentinels for the presence of virus in new endemic areas. Other bird species show few symptoms of infection, but are viremic for several days after exposure and then develop life-long immunity (Reed, 2003).

2.2 Environmental Risk Factors for WNV

Researchers have used environmental factors to investigate WNV disease patterns. These environmental factors include elevation, hydrology, land cover, soil type, and climate (Ruiz, 2004; Tachiiri, 2003; Wontroba, 2003; Mongoh, 2007; Gibbs, 2006; Kunkel, 2006; & Ward, 2008). Several environmental factors have been associated with potential WNV vectors habitats, including close proximity to water and forest cover, distance to livestock and unmanaged pastureland, and proximity to agricultural runoff (Bolling, 2005; Brownstein, 2002; & Hassan, 2004). Standing water has been associated with the greatest concentration of mosquito breeding habitats, while moving water is associated with the least (Kronenwetter-Koepel, 2005). Research conducted in Tennessee found that urban areas with concrete drainage sewers were also breeding grounds for WNV positive mosquitoes capable of spreading the disease to humans (Apperson, 2004).

Climate, including temperature and precipitation, have been shown to play a role in the transmission of WNV. WNV is likely to occur in areas where there is abundant water and during periods of high temperatures, summer through fall. An investigation of the 1998 Italian equine WNV outbreak found that the outbreak peaked in late September and the majority of the cases occurred in wetlands and the flooded areas and marshes of the hill region (Romi, 2004.) A study conducted in Coahuila State, Mexico determined that hot, dry, and arid conditions, temperatures ranging from 18 to 22°C and an average rainfall of 100 to 300 mm per year, were conducive to WNV equine transmission (Blitvich, 2003). Epstein (2001) also concluded that mild winters followed by hot, dry summers favor the transmission of infections (such as WNV) that cycle among birds, mosquitoes, and humans. High temperatures are believed to reduce the incubation

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period of viruses within the infected mosquito vectors, increasing the probability that vectors will transmit the disease to humans or other mammals, and birds (Kilpatrick, 2008).

2.3 Demographic Risk Factors for WNV

Variables surrounding humans on the individual level, such as gender, age, and race have been examined in relationship to WNV infections. Additionally, population density and urbanicity have been recognized as important considerations when examining WNV risk. The evidence surrounding the strength of associated risk between these demographic factors is reported in terms of infection severity and health outcomes.

Age

A person of any age can be infected with WNV; however, U.S. surveillance data indicates that the elderly, over the age of 50, are more susceptible to severe disease and death from WNV infection (CDC, 2003; Tsai, 1998; & O'Leary, 2004). Multiple studies have shown older age to be a risk factor for developing WNV infections. A study conduct in Southern Spain analyzed 504 subjects, selected by random telephone solicitation, using plaque reduction neutralization test to determine the prevalence of past and present WNV infections and possible risk factors. Multivariate analysis using a forward stepwise logistic regression model was performed to assess potential risk factors associated with WNV exposure. Past WNV infections were found to affect mainly older persons with the mean age being 65 and p= 0.018 (Wittel, 2007). A study of the 1999 New York WNV outbreak investigated 59 hospitalized patients with WNV infection. The study results found the median age of the hospitalized patients was 71

years (age range 5 - 90) and 88 % were at least 50 years old. The attack rate of clinical infection increased sharply with age, and the attack rate in persons 50 years old or older was nearly 20 times as high as that in persons younger than 50 years old (RR = 19.6; 95% CI 17.9-21.6) (Nash, 2001). Madalaski (2007) found that the risk for developing severe West Nile Virus disease after infection may be as much as $110\times$ greater in adults 65 and older, as compared to children 5years -15 years (p<0.01). (2005) Jean and colleagues found adults over the age of 64 were at the greatest risk for develop severe West Nile Virus disease (OR = 2.24, 95% CI 1.62–3.11). WNV infection United States WNV statistics for 1999-2001 reveled the median age among the 142 reported West Nile Meningitis or Encephalitis cases was 68 years. In 2002, the median age was 59 years among 2,942 reported cases. People under the age of 50 can also become ill from WNV but they tend to develop only minor symptoms or remain asymptomatic (Hayes, 2001).

Gender

Results from two studies indicate that gender is associated with WNV infection severity. In one study conducted in California, 880 case-patients were identified across 40 counties. Males were found to be at a higher risk than women for developing more virulent symptoms of disease (OR = 1.57, 95% CI 1.18–2.09) (O'Leary, 2004).   In 2002, 39 states and the District of Columbia reported 4,156 human WNV illness cases through the ArboNET reporting system operated by the CDC. Of these, 2,942 (71%) were neuroinvasive illnesses (i.e., meningitis, encephalitis, or meningoencephalitis). Neuroinvasive illness incidence and mortality, respectively, were significantly associated with being 65 or older in age (p = 0.02; p = 0.01) and being male (p < 0.001; p = 0.002) (Jean, 2007).

<u>*Race*</u>

Results from a Chicago study that investigated WNV risk factors during a 2002 outbreak indicates that race, being white, is associated with WNV infection. The study reveals that a census tract is more likely to include at least one WNV case when the tract is comprised of a higher percentage of white residents. The population within the WNV clusters was on average, 82% white, compared to 52% white population outside, while the average for the study area was 54% (Ruiz, 2004).

<u>*Urbanicity*</u>

Urbanicity has been shown to be a risk factor for WNV disease incidence. One study analyzed 977 cases over 8 years (1999–2006) of county-based human WNV disease surveillance data in 8 northeastern states. Analyses demonstrated significant spatial spreading, propagation across the states from east to west, from 1999 through 2004 ($p<0.01$, $r^2 = 0.16$). A significant trend was apparent among increasingly urban counties; county quartiles with the least (<38%) forest cover had 4.4-fold greater odds (95% confidence interval [CI] 1.4–13.2, $p = 0.01$) of having above-median disease incidence (>0.75 cases/100,000 residents) than counties with the most (>70%) forest cover. These results quantify urbanization as a risk factor for WNV disease incidence (Brown, 2008).

2.4 WNV Prevention

Avoiding human exposure to WNV-infected mosquitoes is the basis for preventing WNV disease. One study indicated that clustering of human WNV disease in Chicago varied between mosquito abatement districts, suggesting that mosquito control may have some impact on transmission to humans. Source reduction, application of larvicides, and targeted spraying of pesticides to kill adult mosquitoes can reduce the number of mosquitoes. However, demonstrating the impact of abatement methods on the incidence of human WNV cases is difficult because of all the various determinants of mosquito abundance and human exposure (Ruiz, 2004).

There are several methods of source reduction recommended including the elimination of standing water and vegetation overgrowth. Water plays a key factor in mosquito breeding, without water mosquitoes cannot reproduce. Mosquitoes must lay their eggs in stagnate water in order for the mosquito lifecycle to begin. The mosquito egg hatches into larvae within 48 hours and will continue to live in the water. The larvae will continue to mature and molt until it changes into a pupa. The pupa is the final stage and last approximately two days until the pupal skin splits and the adult mosquito emerges and flies off. This total process, egg to adult, can take anywhere from four to seven days. The best way to prevent mosquito breeding is to rid the property of all standing water. If there is to be standing water on the property it should be changed at least three times a week or in the case of water features, such as yard fountains and Koi ponds, larviciding regularly. An important fact to remember is that mosquitoes rest during the day in locations such as overgrown grass and foliage. To prevent mosquito activity around property, it is important to cut grass regularly and maintain minimal overgrowth (Hayes, 2005).

It is not always possible to completely avoid all contact with mosquitoes but there are several ways to reduce your risk of being bitten. The Centers for Disease Control and Prevention's best practices includes adulticiding, applying chemicals by aerial dispersion to kill adult mosquitoes, as well as several personal protective behaviors. Protective behaviors include; using DEET based repellent on skin and Permethrin-based repellents on clothing, wearing long sleeves and pants when outdoors, and avoiding prolonged outdoors activity from dusk till dawn (CDC, 2006) .

2.5 GIS and WNV Research

GIS data represents real world objects, like roads, land use, and elevation, with digital data. Data is stored in two model types, raster and vector. Raster data represents features as a matrix of cells in continuous space. Raster data consists of rows and columns of cells or pixels, with each pixel storing a single value. Aerial photography is an example of raster data that is used in GIS. Vector data represents each feature as a row in a table, with a defined x, y location in space for each feature shape. Different geographical features are expressed by different types of geometry. Zero-dimensional points are used for geographical features that represent a single point reference or simple location. The locations of wells, peak elevations, features of interest or trailheads are all examples of a point. Points express the least amount of information of any data type. One-dimensional lines or polylines are used to represent linear features such as rivers, roads, and topographic lines. Two-dimensional polygons are used to represent geographical features that cover a particular area of the earth's surface. Lakes, city boundaries, or land uses are examples of polygons. Polygons express the most amount of information of the data types.

Each of these geometries is linked to a row in a database that describes their attributes (ESRI, 2008).

GIS generally perform six major processes or tasks. The first three processes are necessary to allow data to be used properly in GIS' functions. The first data preparation process is the ability to convert geographic data into digital format so that it can be used in GIS analysis. The digitizing process, which converts data from analogue paper maps into computer files, is usually fully automated in GIS. Many types of geographic data already exist in GIS compatible formats, and can be obtained from data suppliers ready to load directly into a GIS. The next process is the ability to manipulate data so it is compatible with the system. It is very important that data is compatible so that it can be overlaid and integrated. GIS can manipulate data permanently or temporary for display purposes. Data manipulation that is routinely performed by GIS includes; projection changes, data aggregation, and generalization to weeding out unnecessary data. The final data preparation process GIS is capable of is data management. GIS uses a database management system to store, organize, and manage data into databases. The most common database design used is the relational design in which data is stored conceptually as a collection of tables. A common field is then used to link different tables together.

The final three processes that GIS is capable of, involve gathering and investigating important information from the data. GIS can perform queries, which is the process of requesting attribute information from various perspectives and combinations of factors located in the databases. GIS can also spatially analyze geographical data using multiple analytical tools. Spatial analysis uses the geographic properties of features to look for patterns and trends, and can analyze different scenarios. Modern GIS have many powerful analytical tools that allow various spatial modeling of data, including topological, network, and cartographic. GIS can also analyze

data using a map overlay technique which combines several spatial datasets (points, lines or polygons) creating a new output vector dataset that can be further analyzed. Geostatistis is another possible analysis. This is a point-pattern analysis that produces field predictions from data points. GIS are also capable of the visualization of large amounts of information interactively. GIS have the capability to produce images including maps, drawings, animations, and other cartographic products (Simon Frasier University, 2008).

GIS has been used in WNV research in numerous ways, from surveillance to risk factor identification and analysis. State and National health and science services use GIS to track, monitor, and develop interventions. Multiple studies have used GIS to spatially analyze WNV case distribution or influencing factors to better understand WNV epidemiology (Brownstein, 2002; The United States Department of Agriculture, 2000; & Ward, 2004). GIS has been used as an early warning system for WNV outbreaks based on dead birds reports. This information is used to predict areas of active virus transmission and served as a basis on which to target mosquito surveillance activities (Mostashari, 2003; Theophilides, 2003; Gosselin, 2005; & Cooke, 2006).

Chapter III

METHODOLOGY

3.1 Data Sources

Three main data sources were combined for use in this study. All data used in this study was secondary data and available to the public via the internet. It was necessary in some cases to calculate additional data from the downloaded data.

Georgia county demographic database construction

The Demographic variables looked at in this study were chosen based on previous West Nile Virus research and demographic variables determined to be risk factors for West Nile Virus infection. The variables were downloaded for each Georgia County from the 2000 Census fact finder website www. Factfinder.census.gov. into an Microsoft Excel file (county_database). The variables downloaded were P1 (total population), P2 (urban or rural [7]), P6 (race [8]) P12 (sex by age [79]), and G001 (area characteristics). These variables where then used to calculate population density, % of total population over 50, % of urban population, % of white population, and % of male population for each Georgia county.

Georgia Human West Nile Virus Cases

County level WNV cases for the years 2003-2008 were obtained from the USGS disease maps website www.diseasemaps.usgs.gov/wnv_us_human.html and are presented in Table 1. This data was also added to the county database.

Table 1. Georgia West Nile Virus Cases by County 2003-2008

Georgia West Nile Cases 2003

County	#of cases
Appling	1
Bartow	1
Ben Hill	1
Bibb	1
Brantley	1
Bryan	1
Bulloch	1
Catoosa	1
Chatham	8
Clayton	1
Coffee	1
Dougherty	2
Fulton	8
Lee	1
Liberty	1
Lowndes	1
McIntosh	1
Muscogee	1
Polk	2
Putnam	1
Seminole	1
Taylor	3
Tift	3
Walker	2
Ware	2
Wayne	1
White	1
Whitfield	1
Total	50

Georgia West Nile Cases 2004

County	#of cases
Chatham	1
Clayton	3
Cobb	2
DeKalb	1
Fulton	8
Gwinnett	1
Lowndes	1
Muscogee	2
Richmond	2
Total	21

Georgia West Nile Cases 2005

County	#of cases
Cobb	3
DeKalb	3
Fulton	8
Muscogee	3
Paulding	1
Richmond	1
Tift	1
Total	20

Georgia West Nile Cases 2006

County	#of cases
Chatham	1
Cobb	1
Dougherty	3
Fulton	2
Muscogee	1

Georgia West Nile Cases 2007

County	#of cases
Bibb	3
Cherokee	1
Clarke	1
Clayton	1
Cobb	5
Columbia	1
Crisp	1
DeKalb	4
Dougherty	1
Fulton	9
Gwinnett	3
Habersham	2
Hall	1
Henry	2
Johnson	1
Miller	2
Mitchell	1
Muscogee	7
Richmond	3
Tift	1
Total	50

Georgia West Nile Cases 2008

County	#of cases
Cobb	1
Dougherty	2
Floyd	2
Fulton	1
Lee	1
Total	7

Data tables were compiled from USGS disease maps WNV data (website www.diseasemaps.usgs.gov)

Georgia Base Map

      The Georgia counties shape file was downloaded from the 2008 TIGER/Line® Shapefiles website (www.census.gov/geo/www/tiger/tgrshp2008/tgrshp2008.html) into ArcGIS 9.0 and named *Counties.shp.* The *Counties.shp* shapefile was then joined with the county_database based on the County Federal Information Processing Standards (FIPS) codes.

3.2 Study Population

      The study population is Georgia residents represented by census data. A total of 8,186,453 people are included in the census data for Georgia.

3.3 Study Measures

      The study measures include the total human WNV cases for 2003-2008 as reported to the CDC. The WNV cases are added together for all five years because WNV is a rare disease and the sample size is small for each year. Risk factor measures included census variables for age, race, gender, urbanicity, and population density.

3.4 Spatial Analysis

      Arc GIS 9.0 was used in the study for all spatial analyses. A preliminary map was created visually showing the geographical distribution of all WNV cases in Georgia from 2003 to 2008. The selection by attributes function was used to select all counties with WNV cases greater than 0 from the counties.shp. The view was saved as a new data layer named *Total_WNV_Cases.lyr* and the label function was then used to label all counties with WNV cases denoting the number of cases in each.

Four maps were created visually showing the geographical distribution of each of the four specified WNV risk factors; aged 50 and over, being white, being male, and living in an urban area. Each risk factor was individually mapped from the *counties.shp* by using the symbology function located in the layer properties menu. Once in the layer properties menu the quantities by graduated color was selected for the value field, *Total_WNV_Cases*. The data was then classified by quantile method into three classes, low risk, medium risk and high risk and saved as separate data layers; *Age_50_over.lyr, Race_white.lyr, Gender_male.lyr, and Urban-_population.lyr*. The *Total_WNV _Cases.shp* was then overlaid with each risk factor shapefile to reveal the number of WNV cases in each risk level for further analysis.

3.5 Secondary Analyses

Additional analyses were performed on the WNV cases that fell into high risk levels using Epi Info version 3.5.1. The odds ratio and 95% confidence intervals were calculated for all WNV cases for each risk factor. The odds ratio is a statistical test of association and was used to determine the association between WNV cases in high risk quantile for each selected WNV risk factor. Chi square was then preformed to determine if the selected risk factors and WNV cases associations were significant using alpha = .05. Lastly, assessment of counties by the number of risk factors associated was conducted using the selection by attribute function in ArcGIS 9.0.

4.1 West Nile Virus Cases in Georgia

1) What is the geographic distribution of West Nile Virus cases throughout Georgia?

Figure 12. Georgia West Nile Virus Cases 2003-2008
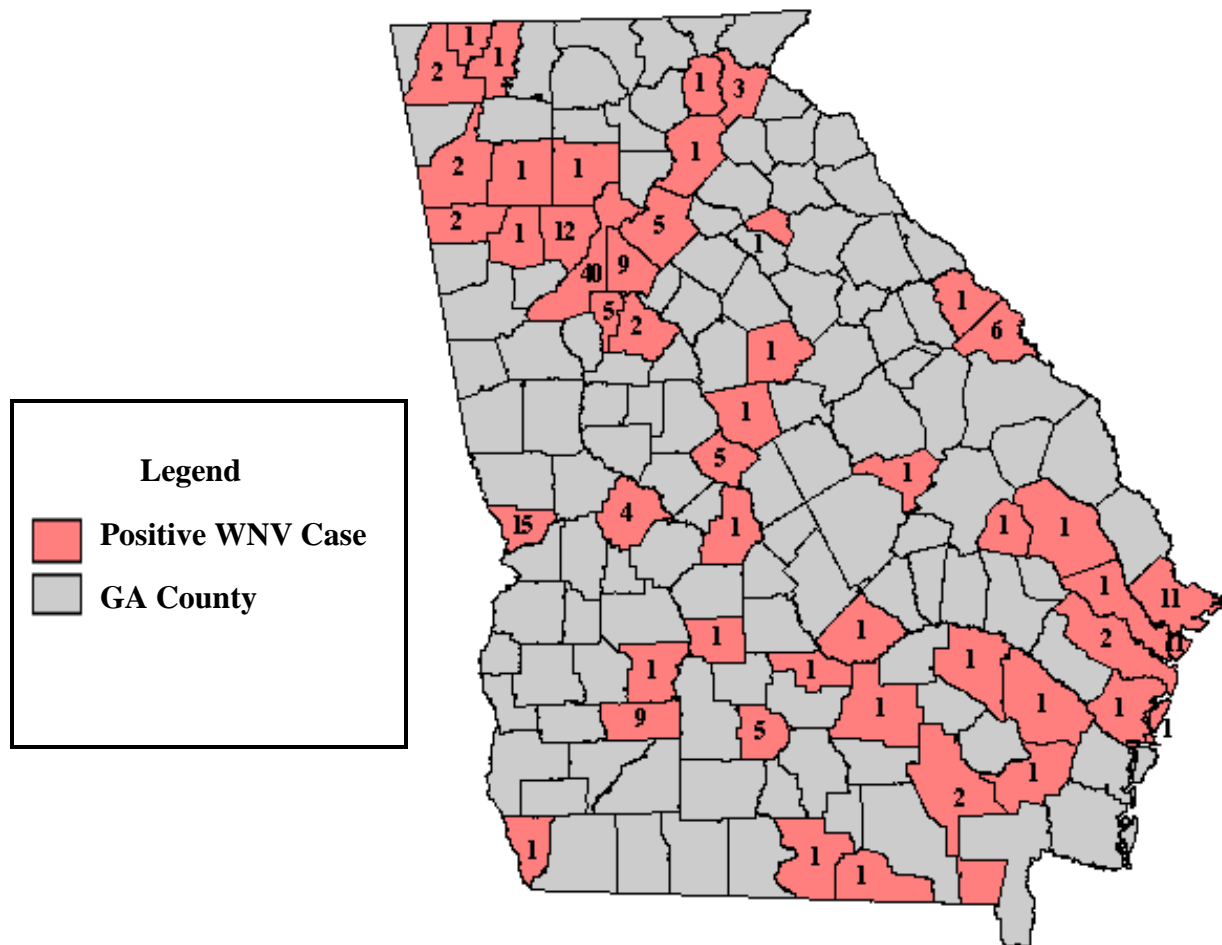
Figure 12 reveals that 47 Counties (29.6%) had a least 1 cases of WNV reported from

2003 to 2008. A total of 6 counties (3.7%) had 9 or more cases of WNV in the same time period.

Fulton County had the highest cases at 40 followed by Muscogee County with 15 cases, Cobb

County with 12 cases, Chatham County with 11 cases, and DeKalb County and Dougherty County both with 9 cases.

4.2 WNV and Age

2) a. What is the geographic distribution of resident age throughout Georgia?

Figure 13. The Geographic Distribution of Residents Aged 50 and Over throughout Georgia
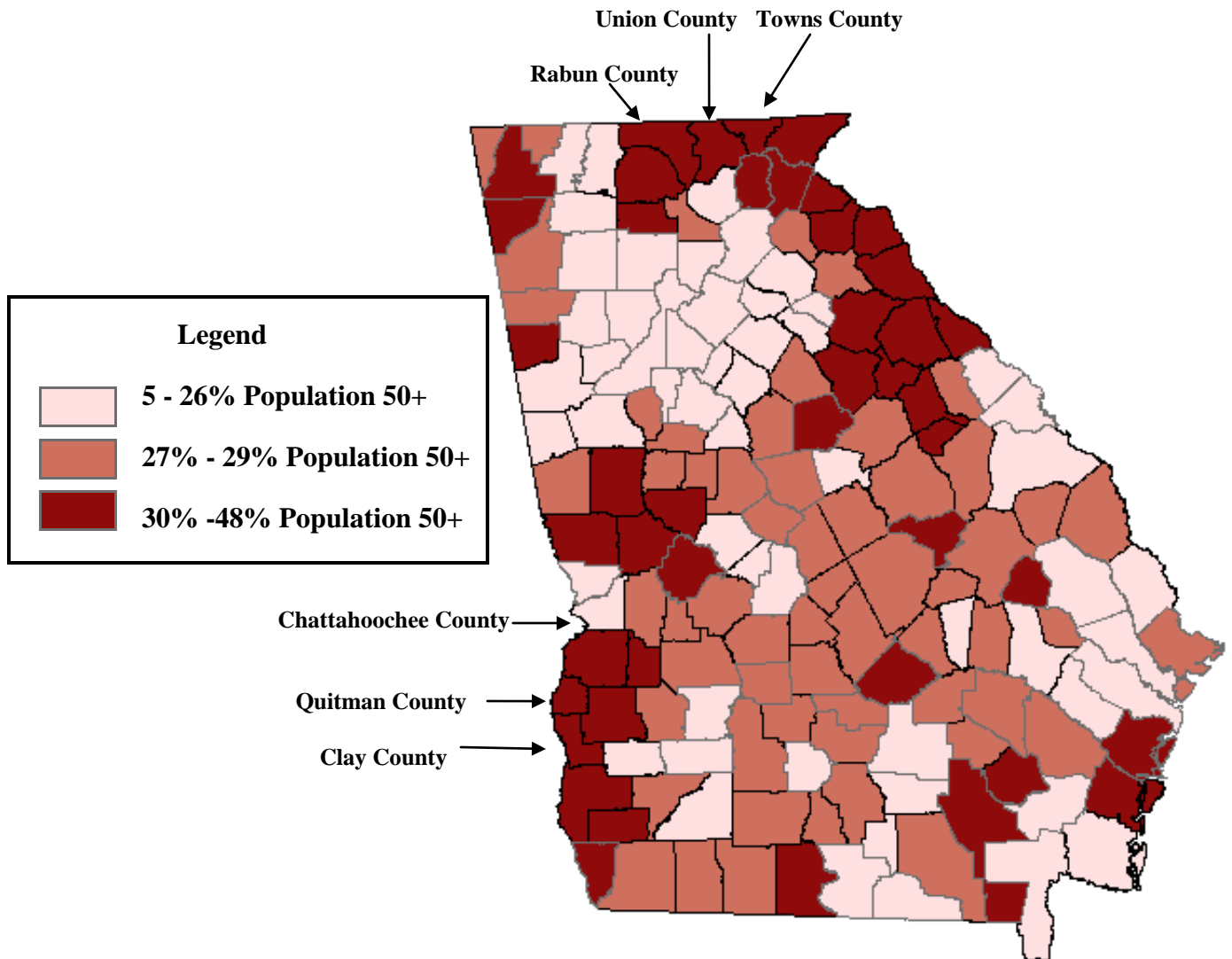
Figure 13 shows the percentage of population 50 and over in Georgia ranges from 5% to 48%. Towns County had the highest percentage of population 50 and over at 48%, followed by

Union County with 43%, Fannin County with 40%, Rabun County with 39%, Quitman County with 39% and Clay County with 38%. Chattahoochee County had the lowest percentage of population 50 and over with 5%.

B. How do age risk levels relate to reported WNV cases?

Figure 14. Overlay of WNV Cases with Distribution of Age over 50
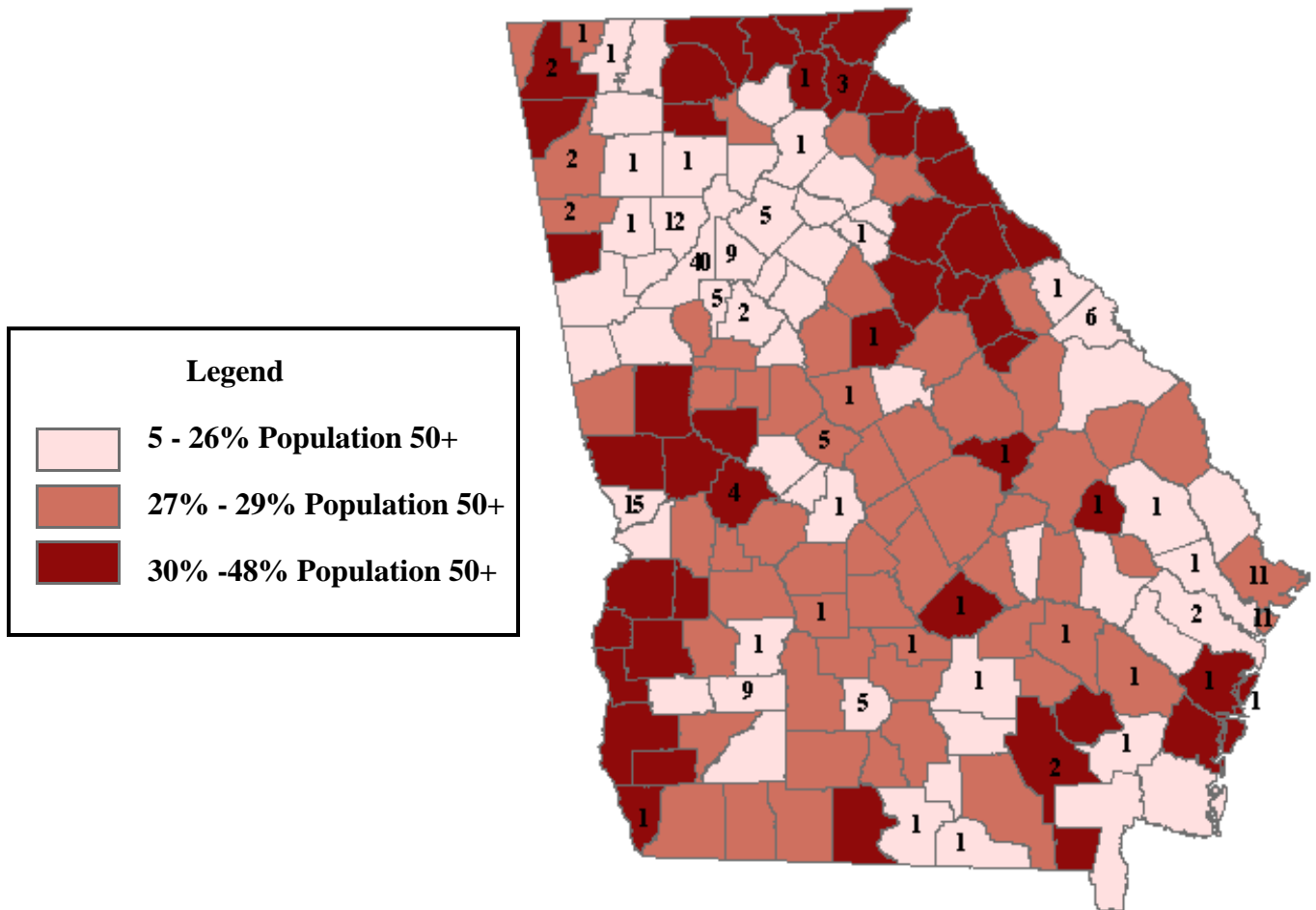
There were 18 cases of WNV reported in counties designated as high risk for the risk factor aged 50 or above (10.7%) and 151 WNV cases reported in counties designated as medium or low risk. The Odds Ratio was found to be 3.86 with the CI (2.29, 6.42), which indicates that

Georgians 50 and over are more likely to contract sever WNV disease than younger Georgians. Similarly, the Chi Square Test statistic was calculated to be 34.07 and $p < 0.05$, which demonstrates that age is significantly associated with WNV cases.

3) A. What is the geographic distribution of resident race throughout Georgia?

4.2 WNV and Race

Figure 15. The Geographic Distribution of White Population throughout Georgia
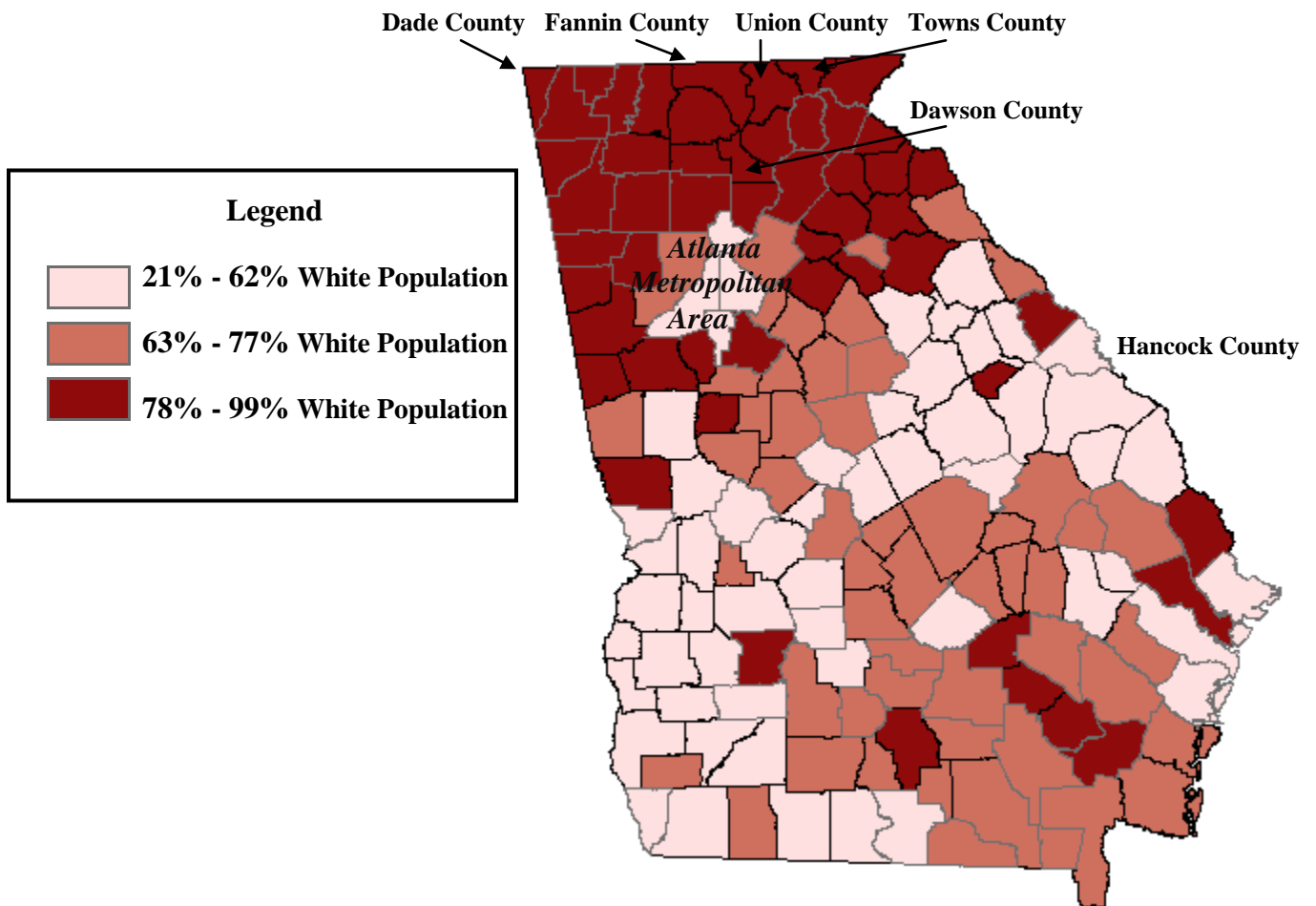
The percentage of white population in Georgia's counties ranges from 21% to 99%. Towns County had the highest percentage of white population with 99%, followed by Fannin

County, Union county, and Dade County all with 98%, then Dawson County with 97%.

Hancock County had the lowest percentage of white population with 21%. A majority of the

Georgia counties with the highest population of white residents are located in the North and the

Northeast of Georgia, excluding the counties that make up the Atlanta Metropolitan area (Fulton,

DeKalb, Gwinnett, Cobb and Clayton Counties).

B. How do race risk levels relate to reported WNV cases?

Figure 16. Overlay WNV Cases with Distribution of White Population
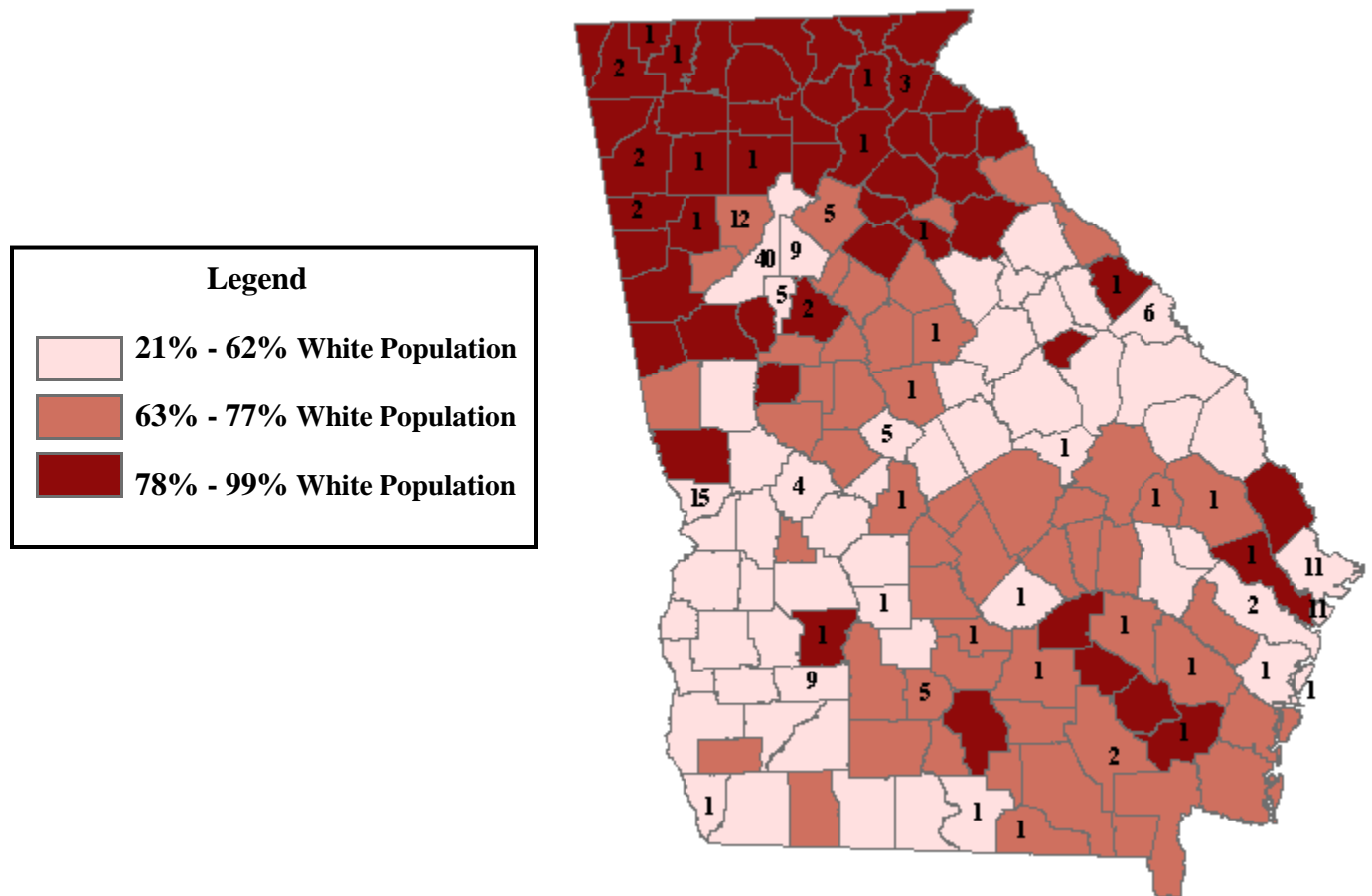
There were 23 cases of WNV reported in counties designated as high risk for the risk

factor of being in the white racial group (%13.6) and 146 WNV cases reported in counties

designated as medium or low risk. The Odds Ratio was found to be .50 with the CI (0.31, .78).

In whites WNV is significantly less likely to occur then in other racial groups. The Chi Square test determined that the association between WNV and race was significant (Chi = 10.19, p < 0.05).

4.3 WNV and Gender

4) A. What is the geographic distribution of resident gender throughout Georgia?

Figure 17. The Geographic Distribution of Male Residents throughout Georgia
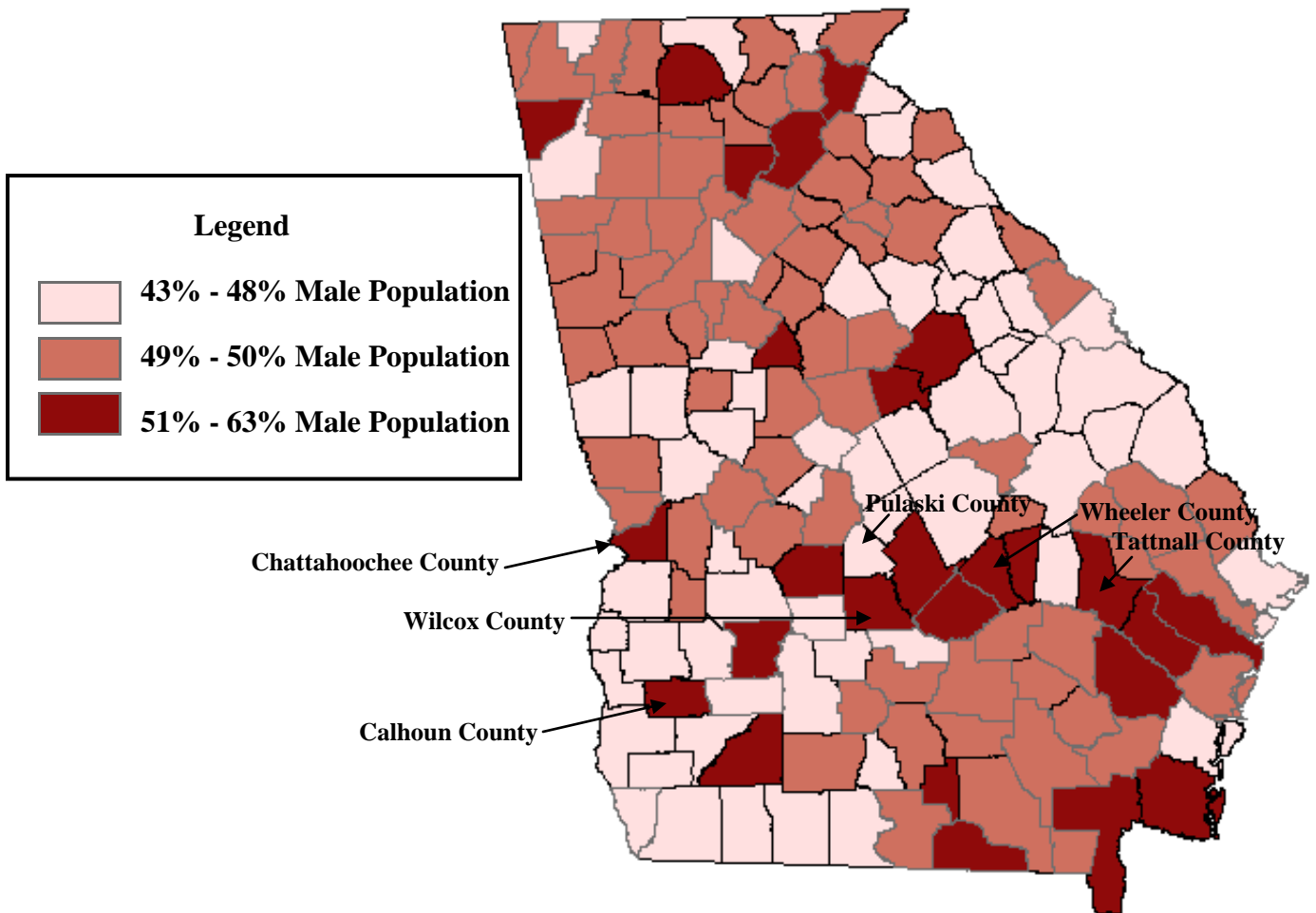
The percentage of male population in Georgia's counties ranges from 43% to 63%. Chattahoochee County had the highest percentage of males at 63%, followed by Tattnall with 58%, Calhoun with 57%, Wheeler with 56%, and Wilcox with 55%. Pulaski County has the lowest percentage of males at 43%.

B. How do gender risk levels relate to reported WNV cases?

Figure 18. Overlay of WNV Cases with Distribution of Male Population
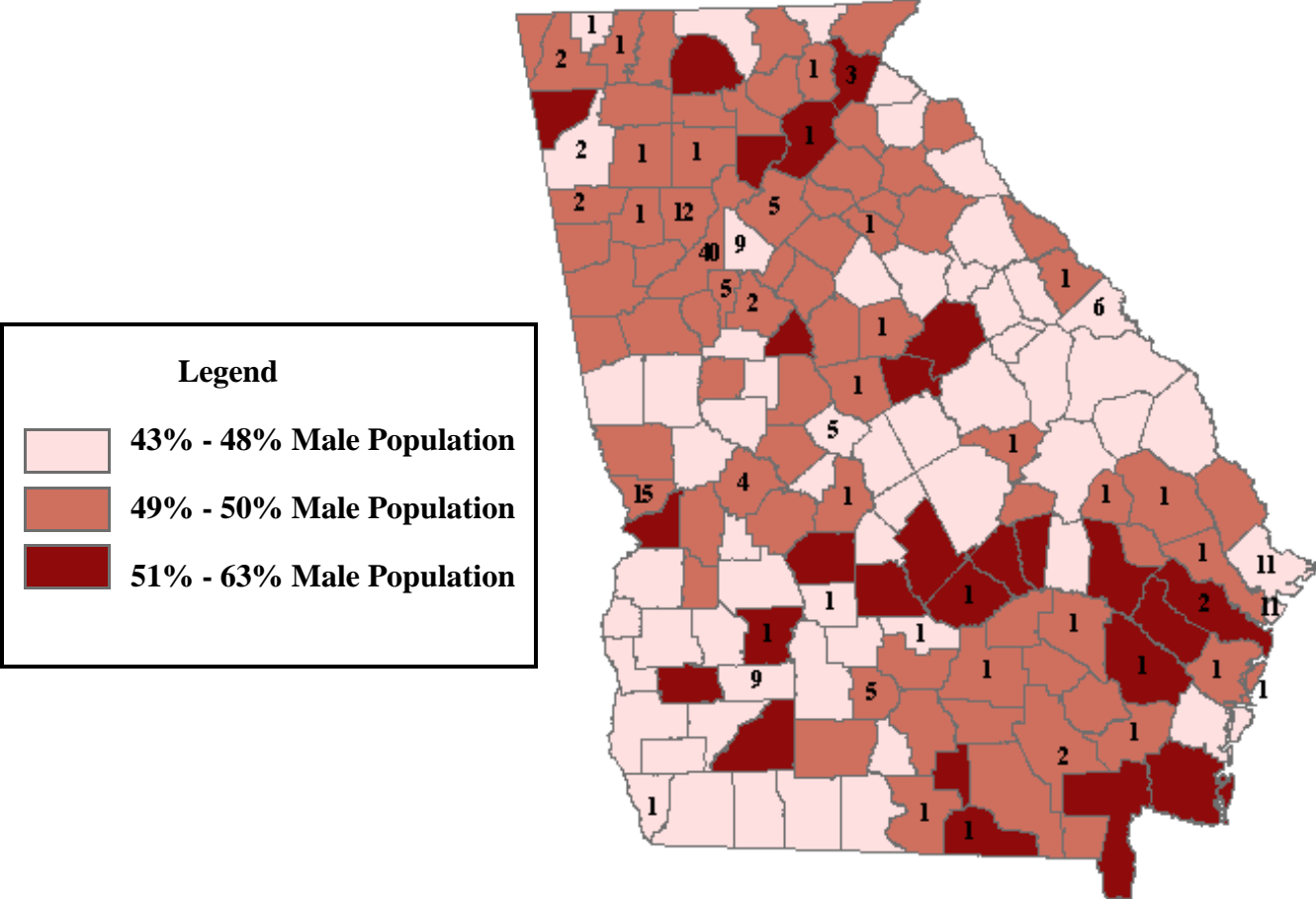
There were 10 cases of WNV reported in counties designated as high risk for the risk factor being male and 159 WNV cases reported in counties designated as medium or low risk. The Odds Ratio was found to be 1.31 with the CI (.65, 2.56), which indicates that males are slightly more likely to get WNV however it is not significant. The Chi Square test determined there was not significant association between WNV and gender (Chi = .07 and p = 0.40).

4.4 WNV and Urbanicity

    5) A. What is the geographic distribution of urbanicity throughout Georgia?

Figure 19. The Geographic Distribution Urbanicity throughout Georgia
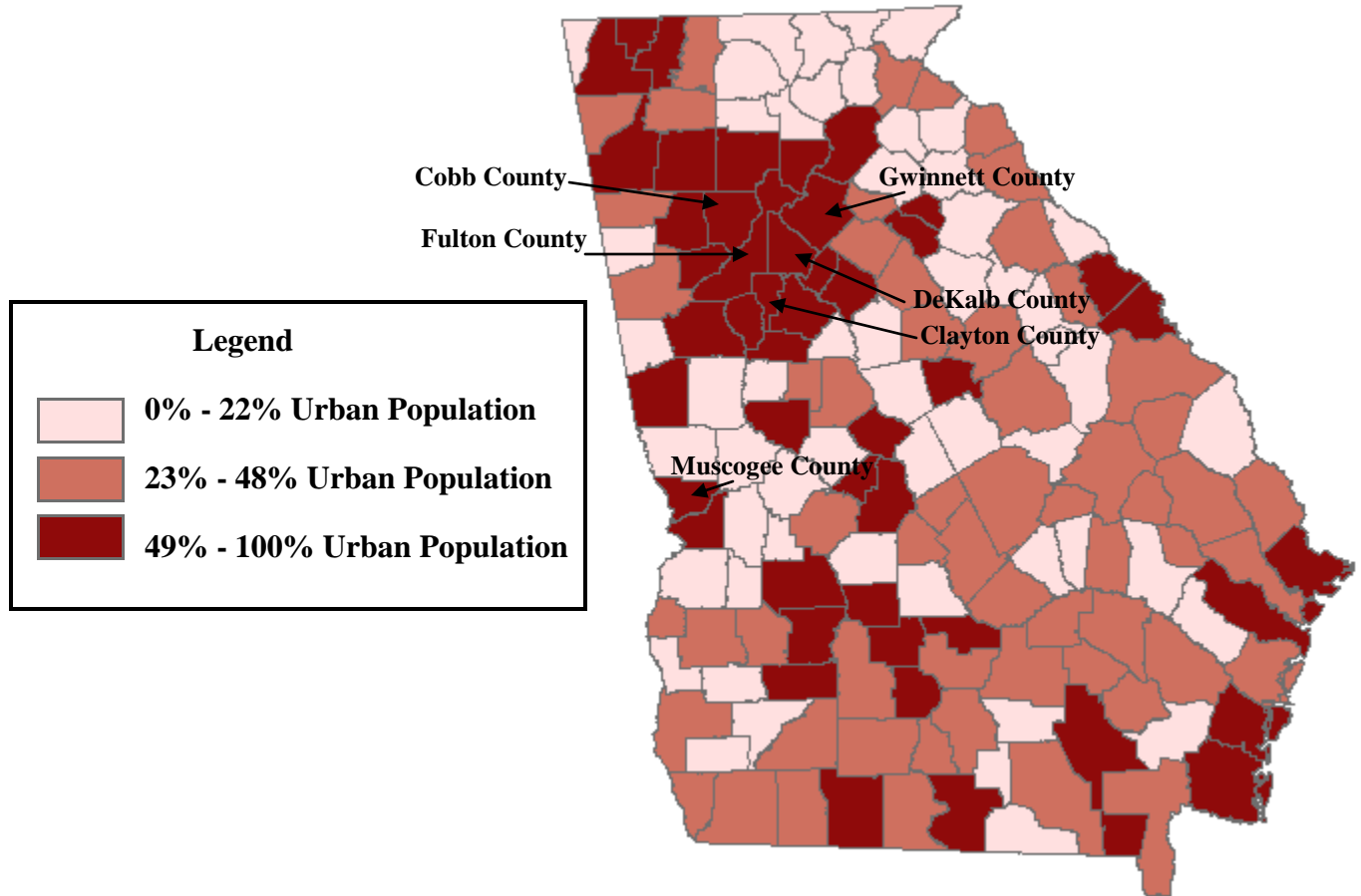
        The percentage of urban population in Georgia counties ranges from 0% to 100%.

DeKalb County had the highest percentage of urban population at 100%, followed by Cobb and

Clayton counties with 99%, Fulton with 98%, Muscogee County with 98%, and Gwinnett

County with 97%. There are 32 counties that have no urban population (20%).

b. How do Urbanicity risk levels relate to reported WNV cases?

Figure 20. Overlay WNV Cases with Distribution of Urbanicity
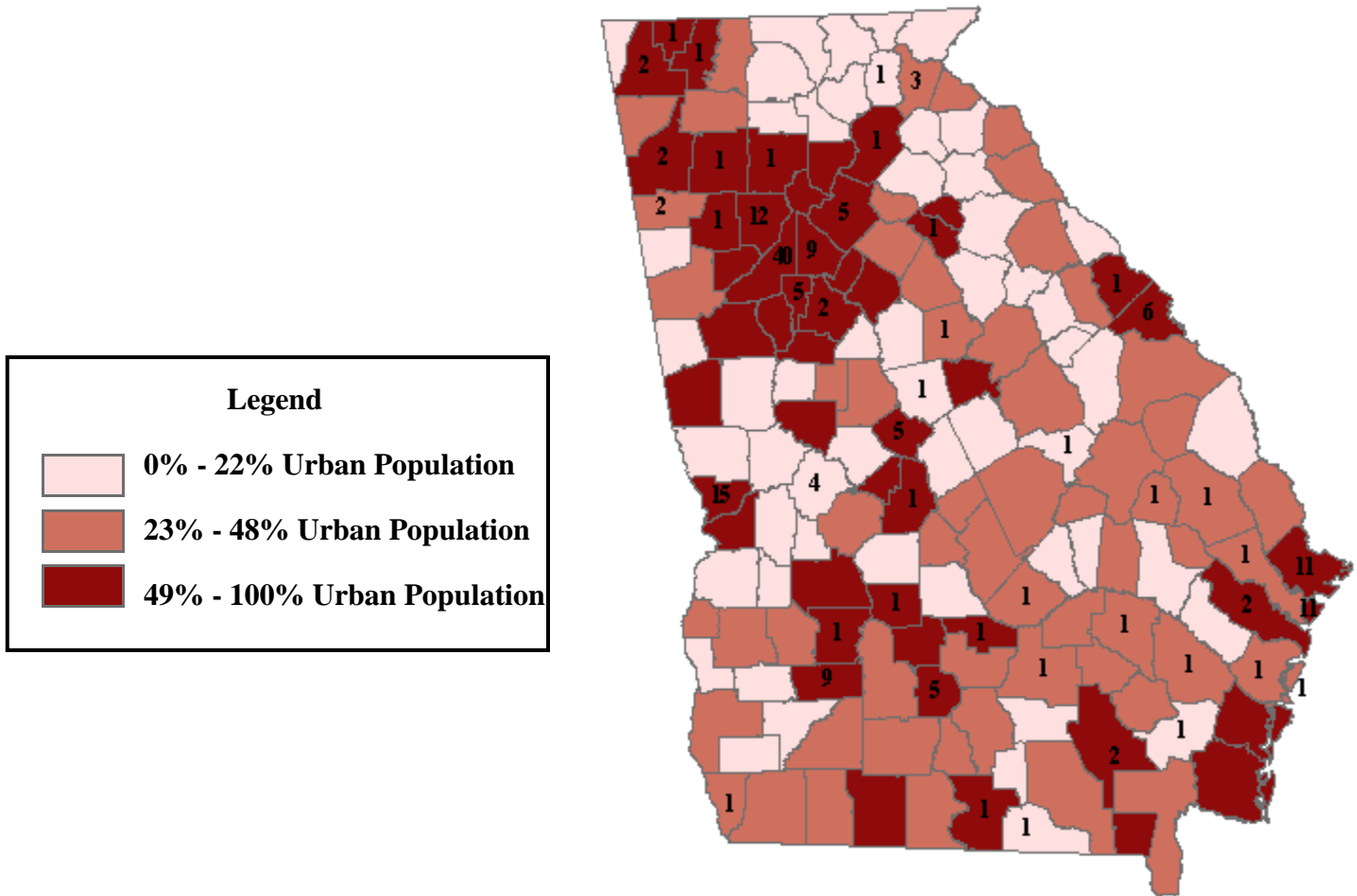
There were 145 cases of WNV reported in counties designated as high risk for the risk factor living in an urban area (85.8%) and 24 WNV cases reported in counties designated as medium or low risk. The Odds Ratio was found to be 3.26 with the CI (2.08, 5.15), which indicates that Georgians living in an urban area three times more likely to get WNV then Georgians living in other areas. The Chi square test statistic determined that there is a significant association between WNV and urbanicity (Chi = 32.1 and $p < .05$).

4.5 County Queries by Number of High Risk Designation

6) a. Which counties are designated high risks for multiple risk factors?

The result from the query ran using Arc GIS9.0 is displayed in Table 2. A total of ten counties; Walker, Upson, Ware, Glynn, Chattooga, Gilmer, Habersham, Forsyth, Lee, and Hall, fell into high risk areas for three attributes. Figure 21 is a map displaying those counties in high risk areas for three risk factors.

Table 2. County Query for High Risk Level for Multiple Risk Factors

High Risk Level Attributes	Counties
1.Male Population > 50% 2.Urban Population > 48% 3.50 and Over Population > 29% 4.White Population > 77%	0
1.Male Population > 50% 2.Urban Population > 48% 3.50 and Over Population > 29%	0
2.Urban Population > 48% 3.50 and Over Population > 29% 4.White Population > 77%	Walker, Upson, Ware, and Glynn
3.50 and Over Population > 29% 4.White Population > 77% 1.Male Population > 50%	Chattooga, Gilmer, and Habersham
1.Male Population > 50% 2.Urban Population > 48% 4.White Population > 77%	Forsyth, Lee, and Hall

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Figure 21. Georgia Counties in High Risk Levels for Three Risk Factors

Chapter V

DISCUSSION AND CONCLUSION

5.1 Discussion

West Nile Virus is a serious public health concern in the United States. In light of the current economic climate of the United States strategic allocation of resources dedicated to the prevention of West Nile Virus transmission is critical. A useful tool that can help health public health decision makers in their planning of WNV prevention efforts is GIS in concert with traditional research methods. This study exemplifies how GIS was used to better understand the spatial location of WNV risk factors throughout the state. GIS was used to explore WNV risk factors in relationship to Georgia's population at the county level. GIS allows the examination of WNV risk data to be visually presented with multiple layers of other data, such as individual risk factors. This allows another dimension of scholarly research.

Human WNV cases are not limited to just one area of Georgia, but as the results from the GIS analysis of WNV distribution shown in figure 4.1, WNV was present in multiple counties across the state. WNV cases were present in 29% of Georgia's counties, from the very north tip of Georgia to the southern coast. The map shows a high number of cases clustered around Atlanta, the state capitol, including Fulton County (40 cases), DeKalb County (9 cases), Cobb County (12 cases), and Gwinnett County (5 cases). Another cluster of WNV cases is located around Savannah and its surrounding counties which include; Chatham County (11 cases), Bryan County (1 case), Liberty County (2 cases), McIntosh County (1 case), and Bulloch County (1 cases). The resultant map that highlights the visual clusters of cases can be used to aid public health and local officials in initiatives to collectively pool resources dedicated to WNV prevention.

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The study reinforced that age [OR 3.86, CI (2.29, 6.42), and p< 0.05], race [OR .50, CI (0.31, .78), and p< 0.05], and urbanicity [OR 3.26, CI (2.08, 5.15), and p< 0.05] are risk factors for WNV illness. In this study Georgia residents aged 50 or above had an almost four times increase odds of contracting severe WNV infection than Georgia residents under fifty. This finding is in agreement with current research indicating that as with many illnesses the elderly are more susceptible to severe disease and death from WNV infection. There could be several factors involved in elderly susceptibility including, compromised immune systems due to age and other illnesses and high risk environmental and socio-demographic factors due to fixed incomes and the inability to keep up homes and properties.

Race was determined to be a risk factor for contracting WNV in this study as well as in past research however in this study being white significantly decreased the likeliness of contracting severe WNV infection from occurring then in other racial groups. The actual reason for this is not clear from this study; however one explanation could be due to socioeconomic factors, such as income and access to healthcare. Another possible explanation could be linked to genetic predisposition. Saint Louis Encephalitis (SLE), another flavivirus, was found to have limited clinical expression among people who had been exposed to another flavivirus. Outbreaks of SLE in Tampa in 1959, 1961, and 1962 resulted in an exposure to one race more than others (McCarthy, 2001). Further exploration using individual case data is required to determine a more accurate picture.

Urbanicity was found to be a risk factor for severe WNV infection in this study. The results determined that Georgians living in an urban area where found to be three times more likely to get WNV then Georgians living in other areas. These findings are not surprising due to the various environmental and socio-demographic factors commonly associated with urban

living. The measure of urbanicity is determined by population density. The census bureau classifies urban as core census block groups or blocks that have a population density of at least 1,000 people per square mile and surrounding census blocks that have an overall density of at least 500 people per square mile. Where there are higher concentrations of people, like in urban areas, the chances of a mosquito coming into contact with a human blood meal is greater than in more rural areas where people are more spread apart.

The risk factor, being male, was not found to be significantly associated with WNV in GA.   The reason for this is not clear from the study however one explanation for the differing results then past research could be due to the fact that the WNV cases data did not specify gender. Without having this specific information it is hard to determine if the study results are different then what is really occurring Georgia.

GIS applications were used in this study to pinpoint counties that were designated high risk for multiple risk factors.   Though no single county fell into high risk level for all four risk factors investigated, Figure 4.8.3 indicate that ten counties did fall into high risk levels for three risk factors. All but one of the ten counties were clustered near or adjacent to counties with high counts of cases. One possible explanation for the lack of cases in high risk counties is that the WNV cases data was not on an individual level therefore the actual physical location of the infected resident was not know. The WNV positive individuals could have lived right on the county line or in close proximity to the high risk county. WNV positive individuals could live in one county that is not high risk but work and play in a high risk county and possibly contracted the virus in a different county. These results help support the use of GIS in locating and predicting high risk areas. This data can then be used to inform WNV education and abatement projects in areas with the greatest potential for success.

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5.2 Study Limitations

A study using GIS and census tract data can present several limitations. The study used US census data from the 2000 census, which on its own has several limitations. Census data is gathered every ten years and therefore can be outdated by the ninth year. Economic and social conditions can impact the population and lead to an inaccurate representation of the current population. The wording of US census questions can be a limitation, for example respondents can select two or more racial categories on the census form which can cause difficulty in accurately calculating racial and ethnic trend in the population. The US census does not provide individual level data which limits the ability to examine relationships among variables more closely. Finally, the U.S. Census can include sampling errors. These errors can occur because data is gathered from a portion of the population rather than the full population as well as the chance of redundant sampling and missing data.

The study used WNV cases data reported to the Center for Disease Control and Prevention. The WNV cases are reported to the CDC by local and state health departments and therefore are representative of severe cases that require hospitalization or doctor visits. Due to the rare occurrence of sever disease outcomes, approxmently 1% of all cases, this data is under representative of the actual WNV cases in Georgia. Due to the rarity of sever outcomes from WNV case numbers were small for each year so five years of WNV cases were pooled together for analysis in this study.

The WNV case data was obtained at the county level which is less powerful then actual geocoded point data or even census tract data. County level data tends to be inadequate for

assessing levels of risk because of the nature of aggregate level data to lose distribution accuracy. In the case of this study it was not feasible to access more specific point data for WNV cases.

One limitation for using GIS is the quantile method used to organize data into classes containing equal numbers of data. Because data is grouped by the number in each class, the resulting map can be misleading. Data with similar values can be placed in adjacent classes, or data with widely different values can be put in the same class.

The ability to generalize findings from this study is limited because only Georgia data were used. If other states would replicate this study, results may not confirm these findings.

5.3 Recommendations

More research examining risk and protective factors of WNV is needed. Further GIS studies using point data would help to improve accuracy in terms of true population variable distribution. Researchers who are interested in pursuing similar research questions are encouraged to seek access to more detailed case data that may be housed in local public health departments. The availability of more specific data would allow for advanced GIS analysis. Advanced GIS statistic methodologies, such as hot spot or cluster analyses are currently being applied in a multitude of disciplines and can be beneficial to WNV research.

Expansion of variables outside of or in conjunction with demographic variables is also suggested. In this study, only demographic variables were considered. While the link of environmental variables and underlying chronic medical conditions, including hypertension, diabetes mellitus, coronary artery disease and immunosuppression, to WNV cases among humans is adequately established, more questions regarding risks among populations remain.

More research in this area may help refine WNV surveillance and reporting systems currently overseen by the CDC.

Another potential avenue for continued research would be to enhance reporting of the disease. This study used WNV case data reported to the CDC, which represents the most severe cases. Therefore, the likelihood that other cases are not officially tracked is high. The WNV cases are reported to the CDC by local and state health departments and therefore are representative of severe cases that require hospitalization or doctor visits. Due to the rare occurrence of sever disease outcomes, approxamently 1% of all cases, this data is under representative of the actual WNV cases in Georgia. Due to the rarity of sever outcomes from WNV case numbers were small for each year so five years of WNV cases were pooled together for analysis in this study.

5.4 Conclusion

WNV is a complex disease with a multitude of factors that influence the distribution and progression of the virus. Demographic, environmental, and medical factors are associated with WNV risk, transmission, and disease severity. This study reinforces the need for greater understanding of the risk factors associated with human and animal infection with WNV in order to develop more effective prevention strategies. While the environmental associations with WNV cases are well known, advanced insight about risk factors inherent among humans is needed. The use of GIS in this area of scientific inquiry will help present a spatial depiction of the epidemiologic data. The resultant maps can help professionals and the public alike in understanding the call for preventive action to help stop WNV transmission.

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