ABSTRACT

Title of Document: **SOCIO-DEMOGRAPHIC VARIABLES AS RISK FACTORS FOR NEUROLOGIC DISEASE DUE TO INFECTION BY WEST NILE VIRUS.**

Lashale D. Pugh, Doctor of Philosophy, 2009

Directed By: Professor Mike Kearney, Ph.D., Department of Geography

The primary question asked by this research was “Can socio-demographic characteristics be considered risk factors for neurological disease due to West Nile Virus?” Based on the results of this research, the answer is yes. Socio-demographic characteristics identified as risk factors are related to educational attainment, income, age of housing and poverty. Socio-economic variables were useful in discriminating between high moderate and low infection rates and showed modest capabilities of estimating actual rates.

One of the most important findings of the research was the public health officials own ideas about the greatest obstacle to preventing the spread of WNV in their jurisdictions. General consensus is that more resources be made available to properly combat this pathogen. More staff and funds to pay workers and provide support for every aspect of surveillance, prevention and control are deemed necessary. Specifically, there is a great need for personnel with specialized training. The support and encouragement of public health organizations is needed to attract individuals into academic fields that will prepare them for infectious disease epidemiology which is crucial to the field.

Local level response may have been dictated by resource availability as opposed to the perceived threat. Surprisingly, length of time in the current position was more closely related to lower infection rates than length of surveillance. This suggests that more experienced public health workers likely have some knowledge or experience which was not made known through the survey. Policy implications suggest increased education for public health officials, especially encouragement of more experienced workers to share their knowledge and experiences with less experienced workers.

SOCIO-DEMOGRAPHIC VARIABLES AS RISK FACTORS FOR NEUROLOGIC DISEASE DUE TO INFECTION BY WEST NILE VIRUS

By

Lashale D. Pugh

Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
2009

Advisory Committee:
Professor Michael Kearney, Chair
Dr. John Townshend
Professor Martha Geores
Professor Joseph Cirrincione
Professor Tony Whitehead

Acknowledgements

I would like to thank my advisor, Dr. Michael Kearney and the rest of my committee, Dr. Martha Geores, Dr. John Townshend, Dr. Joseph Cirrincione and Dr. Tony Whitehead. I am also very grateful to Dr. Charles Christian who began this journey with me, even though our paths took us our separate ways. The guidance and instruction received from my committee has been invaluable in the completion of the dissertation. I am extremely thankful to the department's administrative staff in particular Wilhelmina Johnson and Bob Crossgrove who provided some much need assistance.

The cooperation of the Council of State and Territorial Epidemiologists (CSTE) was invaluable. I would like to thank the organization for allowing me to adopt their questions for my survey and also for providing me with data for comparison. A special thanks as well to the public health officials who responded to my requests for input at every stage of the research process. There are too many to name individually.

I am very grateful to have participated in the many workshops and other developmental opportunities offered by the Graduate School at the University of Maryland. Of particular importance were the workshops and programs offered by PROMISE. Thank you to Dr. Johnetta Davis, Dr. Renetta Tull, and last but not least, Dr. Wendy Carter. The continued support and creative environment fostered by these individuals helped to sustain me and prepare me for life after graduate school. Thank you as well to the fellow graduate students who helped me stay sane and keep things in perspective.

I would also like to acknowledge the following individuals at Youngstown State University for their contributions: Dr. Craig Campbell, chair of the Geography

Department who has been very supportive, Dr. Tom Maraffa and Dr. Dave Stephens who made me believe it was possible, interim provost Ikram Khawaja and Dean Furnish for their patience and understanding, Thanks to John Bralich for making the maps. Dr. Charles Mincey and Dr. Sherri Lovelace-Cameron for the opportunities they gave me. Thank you to Dr. Andy Chang for assistance with the statistics.

As always I also have to thank my family for their continued support and encouragement.

Table of Contents

List of Tables

List of Figures

Acronyms Used

CDC	Centers for Disease Control;
CEE	California Equine Encephalitis
CSTE	Council of State and Territorial Epidemiologists
EEE	Eastern Equine Encephalitis
HHS	Department of Health and Human Services
IRB	Institutional Review Board
SES	Socioeconomic Status
SLE	St. Louis Encephalitis
WEE	Western Equine Encephalitis
WNV	West Nile Virus
USDA	United States Department of Agriculture
USGS	United States Geological Service

Chapter 1: Introduction

In 1999, West Nile Virus (WNV) emerged as a threat to public health in the United States. From 1999 through the end of 2006, 23,975 human cases were reported to the Centers for Disease Control (CDC) (Hayes 2004, USGS 2006, CDC 2007) (see Table 1.1). Of the reported cases, 9,849 required hospitalization with death occurring in 962 of those hospitalized (Marfin 2002, USGS 2006, CDC 2007). In 1999, 62 cases were reported by 6 counties in one state (CDC 2001). Each year since then, the number of counties and states reporting positive human cases has increased. During 2004 alone, 2,539 human cases were reported to the CDC by 505 counties in 40 states and the District of Columbia (DC) (Marfin 2002, USGS 2006, CDC 2007). Of this number, 1,142 exhibited neurological disease with death occurring in 100 of these cases (Marfin 2002, CDC 2007). With respect to these numbers this nation has an epidemic which must be addressed before it becomes large and unmanageable. This research questions whether public health officials have assembled the necessary resources to adequately deal with WNV.

West Nile Virus activity, first reported in New York, has spread across the United States and has now been reported from the 48 conterminous states. The spread has been facilitated by the availability of a variety of competent mosquito vectors. Other factors that contribute to the spread are related to the socio-demographic characteristics of the human populations. Dense population, aging housing stock, poverty and dependency ratio facilitate the spread in urban areas. Analysis of the geography of WNV infection in addition to more traditional epidemiological methods, will be useful in identifying areas at risk of WNV outbreaks.

Table 1.1 *Cumulative total of WNV disease report in humans from 1999-2006*

Reported WNV Disease Cases in Humans, United States 1999-2006				
Year	**Total**	**WNND**	**WNF/other**	**Deaths**
1999	**62**	**59**	**3**	**7**
2000	**21**	**19**	**2**	**2**
2001	**66**	**64**	**2**	**9**
2002	**4,156**	**2,946**	**1,210**	**284**
2003	**9,862**	**2,866**	**6,996**	**264**
2004	**2,539**	**1,142**	**1,397**	**100**
2005	**3,000**	**1,294**	**1,706**	**119**
2006	**4,269**	**1,459**	**2,810**	**177**
Total	**23,975**	**9,849**	**14,126**	**962**

Source: CDC

The Problem

The first cases of WNV in the U.S. were reported in the northern Queens area of New York City (CDC 1999). Although the means of entry into the U.S. has not been determined, genetic studies of the virus itself reveal that the strain in the 1999 New York City outbreak is similar to a strain isolated from a dead goose in Israel in 1998 (Lanciotti et al. 1999, Jordan et al. 2000). Initially thought to be St. Louis Encephalitis (SLE), the disease agent was later confirmed as WNV based on the identification of virus in human, avian and mosquito samples (CDC 1999, Nash et al. 2001). A survey conducted to determine the prevalence of infection in the northern Queens section of New York City found that 19 of the 677 people tested had positive results for WNV (Mostashari et al. 2001). Based on the study results the author estimated that 140 asymptomatic cases occurred for every diagnosed case of meningoencephalitis. The 140:1 ratio was extrapolated to estimate that 8,200 WNV infections occurred throughout the New York City metropolitan area in 1999 (Mostashari et al. 2001).

By 2001 neurological disease in humans had spread outward in all directions from multiple nodes and human infections were detected as far west as Iowa and as far south as Florida. Positive human cases became evident in new locations through unknown means. For example, one positive human case was reported from California in 2002, with the highest concentration of human neurological disease occurring in the midwestern and southern states that year. Of the 9,862 cases reported during 2003, 7,265 (73.7%) occurred in the following five states: Colorado 2,947 (29.9%), Nebraska 1,942 (19.7%), North Dakota 617 (6.3%), South Dakota 1,039 (10.5%) and Texas 720 (7.3%) (CDC 2007).

Canada and Mexico have also reported WNV activity. During 2002, Health Canada reported 340 confirmed human cases of WNV from 3 provinces; 20 cases resulted in death (Health Canada 2003). A year later, 466 confirmed human cases were reported from 9 provinces, 10 cases resulted in death (Health Canada 2004*a*, Health Canada 2004*b*). Twenty-five cases were reported from five provinces during 2004 (Health Canada 2005). The following year the number of cases jumped substantially as five provinces reported a total of 127 cases with 2 cases resulting in deaths (Health Canada 2006). In Mexico, WNV activity was reported in humans, horses and mosquitoes (Blitvich et al. 2003, Mendez-Galvan 2004, Elizondo-Quiroga et al. 2005). Documentation was obtained reporting 6 positive human cases in northern Mexico in 2003 (PAHO 2003) and one positive human case in 2004 (Elizondo-Quiroga et al. 2005). One possible theory regarding the lack of documented cases of WNV in Mexico is the idea that the human population there is exposed to other flaviviruses of the same genus. This may result in developing antibodies which may provide some protection against WNV infection (Oglesby 2005). In North America (excluding Mexico), WNV has resulted in a greater number of reported cases than previous outbreaks (Hayes 2001). There may be variables outside the scope of this dissertation which could account for the low reported numbers in Mexico.

The increased occurrence in humans accounts for the number of cases reported in the U.S. Only four states reported WNV activity (birds, mosquitoes, and other animals in addition to human cases) in 1999 (CDC 2007). From 1999 through 2003, the number of counties and states reporting WNV activity increased yearly. By the end of 2003, 2,289 counties in 46 states and DC reported WNV activity (CDC 2007). During 2004 1,499 counties in 47 states and DC reported WNV activity (CDC 2007). Monitoring virus occurrence in birds and mosquitoes is useful in identifying areas where transmission cycles could occur (CDC 2003).

The WNV transmission cycle exists mainly between birds and mosquitoes. Infected mosquitoes are responsible for transmitting the virus when obtaining a blood meal (CDC 2005). Viral amplification occurs in infected birds, while horses and humans are considered incidental hosts and do not create sufficient amounts of the virus to infect mosquitoes. Although human infections have been reported between late March and early December, occurrence in mosquitoes and birds has been reported earlier in the year (CDC 2007). Several explanations have provided for the early onset of WNV activity in mosquitoes. Such early occurrence has been associated with overwintering mosquitoes which hibernate during the winter and contribute to the maintenance of WNV during the winter season (Nasci et al. 2001). Additionally in states with warm temperatures year round, such as the Gulf States the virus may circulate year-round with cases reported in all 12 months (CDC 2003).

Research on WNV has focused mainly on hosts, vectors (mosquitoes) and their interaction with the environment. More research is needed on the significance of risk factors in the spread of WNV (CDC 2003). Further, explanations regarding the spatial distribution of risk factors for human infection are not readily available. Yet identifying risk factors is significant in mitigating the spread of WNV. Although it is difficult to prevent the spread of the pathogen, one can reduce the risk of being infected by controlling the number of vectors. Vectors can be better controlled once risk factors are identified. Thus far, age (Hochberg et al. 2002, Solomon et al. 2004), flooded basements (Han et al. 1999, Hubalek 2000), proximity to migratory routes of infected birds (Hubalek 2000, Rappole et al. 2000) and weather conditions (Hubalek et al. 2000, Shaman et al. 2002) have been identified as possible risk factors. The role of socioeconomic status has not previously been identified as a significant risk factor in the incidence and spread of WNV. Thus, this research examines the significance of selected socio-demographic characteristics as risk factors in explaining the spatial incidence and distribution of WNV.

This research has the ultimate goal of reducing the number of human cases of WNV by identifying socio-demographic characteristics which may be considered risk factors for infection. Identification of risk factors and those areas at greatest risk of an outbreak can provide the basis for application of arbovirus prevention and control measures. This is important to preventing further spread of WNV disease and presenting a public health risk.

<u>Statement of Research</u>

This dissertation uses disease diffusion models to explain the spread of WNV throughout the northeastern United States. The models used are most suitable for this particular disease. The retrospective study relies on multivariate statistical analysis to predict risk factors associated with WNV infection.

Research Question 1

Can socio-demographic characteristics be identified and related to human cases of WNV infection?

Research Question 2

Is there a particular type of county that is more frequently associated with cases of WNV?

Research Question 3

Is the response by public health officials at the county level appropriate relative to their perception of the threat posed by WNV in their jurisdictions?

Research related to WNV has focused on the host/vector/environment interactions, with little attention to human factors. This research is significant because it identifies risk factors related to population, education, economic well-being and housing characteristics which facilitate the spread of WNV. These results can be useful to local level public health officials in identifying areas at risk for WNV outbreaks.

Study Area

This research focuses on 14 states in the northeast and north central United States (Figure 1.1). These states include Connecticut, Illinois, Indiana, Maine, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont and Wisconsin. The 654 counties in these states were chosen because of the following reasons: (1) number of metropolitan areas; (2) variation in the selected socio-demographic variables by county; (3) similar environmental conditions relative to weather and climate; (4) *Culex pipiens*, is the most common mosquito vector for these counties; and (5) variation in WNV infection rates by county. The diffusion of WNV in these states provided the basis of my analysis of the study area.

Study Approach

This dissertation uses maps as diffusion models to provide an understanding of the geographic diffusion of WNV within the study area from 1999 through 2005 and explain the degree to which WNV occurrence changed at the county level. The use of maps as diffusion models has origins in Hagerstrand’s ideas on the diffusion process (Haggett 2000). Disease maps can be both descriptive and predictive () and have been used by Cliff and Haggett, Gould and Pyle in previous disease studies

(Cliff and Haggett 1986, Gould 1993, Pyle 1979, Haggett 2000, Meade and Earickson 2000).

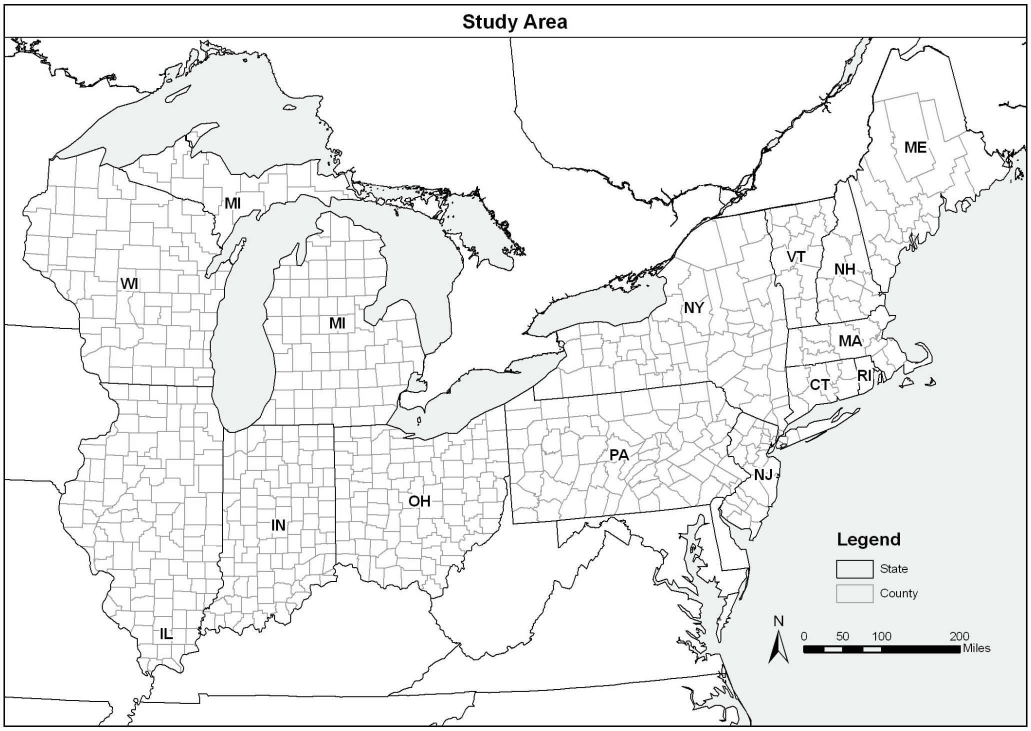


Figure 1.1 *Map of the study area for this research, detailing 654 counties within the 14 state study area*.

Second, the role of socio-demographic characteristics in the diffusion of WNV will also be determined. Those characteristics which act as barriers to the spread or facilitate the spread will be discussed.

Third, there will be a comparison of the degree to which there is a correlation between public health official's perception of WNV as a health issue and their view as to whether resources are appropriate to their perception of WNV as a health problem. The hypotheses which provide the basis for the research are: variation of risk factors by location, specific risk factors can be identified that relate to cases of

WNV, socio-demographic characteristics can be used to produce a classification of counties, public health officials respond to WNV based on their perception of the threat posed by WNV and the socio-demographic characteristics of the survey respondents influences their perception of the risk presented by WNV.

Organization of Dissertation

To help understand the diffusion of WNV Chapter 2 provides an overview of the spread of WNV along with a summary of the current knowledge of West Nile Virus and associated risk factors. It includes a review of the literature on geographic theory in relation to disease diffusion and spatial analysis of disease patterns, studies of a similar disease and risk factors.

Chapter 3 presents a discussion of the data produced, the study methodology and the use of statistical analysis to answer the research questions. Within this chapter is a discussion of the study area selection. This research takes an innovative approach to the study of WNV by attempting to link socio-demographic characteristics to the prevalence of WNV related disease. As a recently emergent disease, it is important to learn as much as possible about WNV in order to prevent future deadly outbreaks. Understanding the spread of WNV will be accomplished by the use of discriminant analysis, factor analysis and regression analysis to analyze socio-demographic characteristics as risk factors for neurological disease. These statistical analyses were performed to organize the data at the county-level and gain a better understanding of the diffusion of WNV.

Chapter 4 contains historical and contemporary geographic perspectives on WNV and describes the diffusion of WNV throughout the U.S. Information regarding positive infection in birds, horses, humans and mosquitoes, is included. Geographic theory and theories on disease diffusion from the literature will be applied to provide explanations for the observed patterns of diffusion associated with WNV in the United States. Knowledge of previous and current patterns of the diffusion of WNV may be useful in determining future patterns allowing public health officials to minimize future impacts of the disease.

Chapter 5 is a discussion of a survey mailed to all 88 county-level public health officials in the state of Ohio and the survey results. It includes a discussion of public health officials and their views on WNV as expressed by their responses to the survey. Furthermore, trends between perspectives on WNV and the number of reported cases of human disease will be discussed. Understanding how public health officials perceive the threat of the disease may be related to how aggressively they respond to the virus.

Chapter 6 contains a summary and interpretation of the findings. Conclusions and policy perspectives will be discussed in this chapter. Also included will be suggestions for further risk factor studies. The results of this research may offer useful suggestions for public policy and future public health directions.

Chapter 2: Literature Review

Introduction

This chapter begins with a review of medical geography, its use in previous research and its relevance to this research on West Nile Virus. Geographic theory on disease diffusion provides the foundation for this research as a means to help understand the spread of WNV throughout the study area. By gaining a better understanding of the mechanisms which facilitated diffusion, it will be possible to reduce the future impacts of WNV including, prevention of the loss of life due to the spread of the disease. A discussion of WNV describes its epidemiology, illnesses associated with the virus and modes of transmission. St. Louis Encephalitis which is genetically similar, is discussed to provide a basis for conclusions regarding the diffusion of WNV. Known risk factors for infection to be discussed will include: age of patients, poverty of individuals, WNV occurrence in birds and mosquitoes and, weather conditions as they relate to diffusion. Selected socio-demographic characteristics of importance to this research will also be discussed.

Medical Geography

Medical geography is the study of disease ecology and focuses on relationships between the natural environment and contagious disease (Pyle 1979). The discipline has a rich history as a basis for this research. Hippocrates was the first scientist to associate environmental factors with health in his 400 BCE treatise, *On Airs, Waters, and Places* where he suggested a link between the humors (internal body fluids) and external forces influencing humoral balance (Valencius 2000).

Thomas Sydenham's 17th century medical investigations continued the Greek tradition of studying the relationship between humans and their environment (Valencius 2000). During a period of intense settlement by Europeans and North Americans, medical geography provided a basis for understanding places and people (Harrison 2000). Allegiance to Hippocratic thought was part of the character of early American medicine. Early 19th century physicians and researchers produced topographies that described illnesses that befell new settlers in the hinterlands of North America (Harrison 2000).

After WWII geographers focused more attention on perfecting techniques in mapping disease and health problems, using cartography to display the distribution of factors related to health (Pyle 1979). Physicians were the early contributors to the field of medical geography; post WWII, geographers contributed spatial analysis to disease ecology and health care delivery (Valencius 2000). Geography's influence is increasingly evident as disease ecology has become more reliant on elaborate techniques of measurement, quantification and visualization, especially through the use of Geographic Information Systems (GIS). These new techniques and technologies allow for timely analysis of spatial data.

During the latter half of the twentieth century the evolution of medical Geography in the United States was influenced by British, French and German Scholars (Pyle 1983). Jacques May, a French medical geographer, is considered the "father" of American medical geography. In 1950, at the request of the American Geographical society, May developed an atlas of disease (Meade and Earickson 2000). May's 1951 article published in the *Geographical Review* set the agenda for the field suggesting the study of relationships between health and environments (Valencius 2000). Current work in the area of disease ecology evolved from May's early influence as patterns of disease distribution are important to the study of disease ecology. Increasingly, scientific knowledge and methods from other disciplines have been adopted in addition to further progress geography (Pyle 1983; Meade and Earickson 2000). As a result, scholars have come to see humans as affecting and being affected by their environment both personally and collectively in health-related ways (Meade and Earickson 2000, McGlashan and Blunden 1983).

New ideas, techniques and technology helped to advance the discipline of medical geography. The argument for more emphasis on understanding culture and behavior relative to persistent disease came from Armstrong (Pyle 1983). In 1963 Howe's national atlas of disease mortality was innovative for its use of statistical data and demographics to produce maps of mortality for numerous causes of death in Britain (Howe and Phillips 1983). Also in the 1960s, Murray applied Howe's techniques to mortality rates in the United States (Pyle 1983). Murray, Howe and Armstrong contributed improvements to disease mapping. Computerization of cartographic and printing methods became more widespread during the 1970s. During this time the United States government released national cancer atlases produced by these new methods (Pyle 1983). By the 1980s medical geographers perfected their disease mapping skills and introduced new techniques after the introduction of microcomputers (Pyle 1983). Geographic Information Systems (GIS) continues to be one of the most innovative technologies available to scholars. This technology combines the use of computers, database, analysis and mapping.

Disease Diffusion

Migration is the most usual explanation of how disease agents or other phenomenon come to be found in a particular location (Meade and Earickson 2000). Understanding the mechanisms that influence the spread of a phenomenon and its spatial pattern are crucial to the geographic study of diffusion (Meade and Earickson 2000). Diffusion is defined as the spread of a phenomenon from one place to another (Haggett 2000, Meade and Earickson 2000). Early work by Torsten Hagerstrand remains the basis of current studies in diffusion (Pyle 1979, Haggett 2000). Hagerstrand described a four-stage model for the passage of diffusion waves, by which an idea or phenomena such as disease spreads from one area to another (Pyle 1979, Haggett 2000). Many researchers suggest that this model of expansion diffusion explains the spread of a disease such as WNV, where it moves to a new place while still remaining in the original location (Haggett 2000, Pyle 1979, Meade and Earickson 2000).

Adaptations to Hagerstrand's ideas on innovation waves have allowed scholars to further knowledge of how diseases spread (Pyle 1979, Haggett 2000). Ideas on barriers and urban hierarchy coupled with increasing computing power have led to the use of better geographic models in the study of disease diffusion (Haggett 2000). One of the early epidemic diseases to be modeled was measles. Measles has been used for epidemic modeling, due to the simplicity of its transmission, as it is spread through direct contact (Haggett 2000). A distinctive wavelike behavior is associated with the diffusion of measles with cycles that vary based on the size of the population under study (Bjornstad et al. 2002). Measles was also ideal for study because it is easily recognized and misdiagnosis is rare (Haggett 2000). As a highly contagious disease agent, measles is associated with high attack rates and epidemic events that are easily identified (Haggett 2000). Measles is globally distributed with spatial variation in temporal patterns. To prevent further deaths, results of measles studies were aimed at aiding the eradication of the disease worldwide (Haggett 2000).

The Hamer-Soper model is a simple mass-action model that has been used to describe the wave-generating mechanism associated with measles (Haggett 2000). People with no immunity are “susceptibles” those with the disease are “infectives.” In contrast, “recovereds” are individuals who have gained immunity as a result of surviving the disease (Haggett 2000, Cliff et al. 1986). As susceptibles and infectives interact, the number of infectives increases and the number of infectives is reduced by recovery or death (Haggett 2000). While this model is useful for predicting the timing of recurrences, it is less accurate in predicting the size of outbreaks (Haggett 2000). This type of model is appropriate for studying non-vectored diseases. WNV is vectored, requiring the mosquito as intermediate host, unlike measles which is spread by direct contact.

In addition to modeling measles, researchers have used epidemic modeling in the study of influenza epidemics. Mapping influenza cases allowed Pyle to identify different patterns of spatial diffusion for influenza (1979). Disease mapping is important in displaying areas at risk of disease epidemics and identifying varying diffusion patterns (Pyle 1979). Mapping the spatial distribution of disease cases can provide clues to the environmental factors which influence disease diffusion. Mapping the distribution of disease cases has been useful in forecasting disease incidence when combined with epidemic modeling. The expanding spatial range of West Nile Virus provides an opportunity to study the factors related to the change in patterns associated with the disease. The model used for this research, is similar to other models insofar as it will be used to determine areas at risk. What makes the model unique is the use of socio-demographic characteristics as risk factors.

Geographic theory on disease diffusion and spatial analysis of disease patterns is important to this research as they provide the foundation for study. Medical geography has three distinct areas of focus: location, ecological relationships, and the unique character of particular places (Haggett 2000). I begin by first identifying the location of cases of neurological disease from WNV, followed by examining the socio-demographic characteristics of counties with and without cases of neurological disease from WNV. Knowledge of similar diseases may be relevant to furthering the study of WNV. Similar diseases that spread in the same manner and by the same agent may provide clues on how to stop the spread. I then look for unique characteristics of the locations where WNV appears. I report the findings and discuss the socio-demographic characteristics or combination of characteristics the data suggests promotes the spread of WNV within the study area.

West Nile Virus

WNV is an arbovirus, "an infectious agent transmitted by an arthropod vector, in which they have the ability to multiply" (Fiennes 1978). WNV is maintained in cycles involving birds and mosquitoes (McLean et al. 2001, Jupp 2001). Mosquitoes that feed on both birds and humans maintain the cycle of transmission when obtaining a bloodmeal. Birds are considered the natural hosts of WNV but antibodies have also been found in other vertebrate species, including: horses, sheep, cattle, pigs, dogs, cats, bats, a chipmunk, a skunk and a domestic rabbit (Fiennes 1978). The virus can live and multiply in mosquitoes and can pass to the next generation by transovarian infection (Jordan et al. 2000).

Epidemiology

WNV was first isolated from a febrile patient in Uganda in 1937 during a study of immunity to yellow fever (Smithburn et al. 1940). Until it first appeared in the Western Hemisphere in 1999, WNV had been found mainly in Africa, the Middle East, the former Soviet Union, India and parts of Europe (Monath and Heinz 1996). Human infections were common in the Nile Delta during the 1950s, an epidemic of mild cases occurred in South Africa in 1974 during which 55% of the population of central and Northern Cape Province were infected (Monath and Heinz 1996). In Asia, infections are common and infection occurs at a very high rate in many areas (Monath and Heinz 1996). From 1996-1999, WNV caused large epidemics in Southern Romania (1996), in the Volgograd region of Russia (1999), and in the northeastern United States (1999) (Hayes 2001). These epidemics occurred in densely populated urban areas as well as nearby suburban/rural areas and were the first reported in large cities (Hayes 2001). The virus continues to be a public health concern in the United States (CDC 2009). When the virus first appears in a new area where the disease is uncommon, diagnosis can be complicated by the fact that many of the symptoms are similar to other illnesses such as flu, or another arbovirus (Monath and Heinz 1996; CDC 2003).

Illness Associated with WNV

Human infection by the virus does not always result in symptoms or illness; most infected people have no clinical symptoms. When symptoms do occur they can range from mild flu-like symptoms to more serious forms of illness (Monath and Heinz 1996). Fever, headache, backache, loss of appetite and generalized muscle pain are the most common symptoms of a mild case (West Nile fever) and may be accompanied by a rash. The illness usually lasts 3 to 6 days, followed by rapid recovery (Monath and Heinz 1996). Diagnosis is made by blood tests that reveal presence of the virus (Monath and Heinz 1996).

There are three categories of severe neurologic illness associated with WNV: meningitis, encephalitis and meningoencephalitis (Sejvar 2003). First, meningitis (swelling of the membranes covering the brain and spinal cord) due to WNV is accompanied by fever, can occasionally be isolated from cerebrospinal fluid. Second, encephalitis (inflammation of brain tissue) due to WNV is accompanied by altered mental status (Sejvar 2003). Meningoencephalitis refers to inflammation of both the brain and the membranes covering the brain and spinal cord. These more severe neurological forms most commonly occur in elderly patients and may result in long-term illness and even death (Sejvar 2003). Occasionally, acute flaccid paralysis and a polio-like illness have also been identified (Sejvar 2003). Supportive care is provided for the symptoms of WNV infection, as there is no cure or specific treatment for WNV (Monath and Heinz 1996). Recent outbreaks in Europe and the United States have resulted in more human cases of severe neurological disease and more deaths than all previously known outbreaks of WNV (Hayes 2001). This increased virulence is a major cause of concern for public health officials.

Modes of Transmission

Mosquito bites are the most common mode of transmission of the virus to human populations (Chamberlain and Sudia 1961, Roehrig and Peterson 2004). Mosquitoes become infected after feeding on a viremic bird and transmit the virus in their saliva when obtaining a blood meal. Whereas WNV is a disease of birds with mammals as terminal hosts, amplification at levels significant to infect mosquitoes does not occur (Dodd and Leiby 2004). Other modes of transmission such as transplacental infection have been identified (CDC 2002*a*) (CDC 2002*e*), but transmission by mosquitoes remains the most significant cause of the disease (Roehrig and Peterson 2004).

Two cases of laboratory acquired infection have been reported (CDC 2002*b*, CDC 2002*a*). Both cases occurred while working with infected specimens (CDC 2002*b*, CDC 2002*a*). At least one case of infection in a newborn has been associated with transplacental infection. Cerebral abnormalities in the infant lead to testing blood samples which tested positive for the virus (CDC 2002*e*). A possible link to breastfeeding was also documented in at least one case in Michigan in 2002 (CDC 2002*b*). The virus has also been transmitted by transplantation of organs from an infected donor. Four cases of WNV infection have been attributed to organ donation. Four organs transplanted from a single organ donor resulted in WNV infection in the organ recipients (CDC 2002*c*, Iwamoto et al. 2003). The source of infection in the organ donor was traced to blood transfusions (Iwamoto et al. 2003).

To reduce the risk of infection by transfusion, blood collection agencies implemented new testing procedures in 2003 by screening all donations for WNV (CDC 2004). Testing of 6 million units from June-December of that year resulted in the removal of 818 units from the blood supply (CDC 2004). As a result of enhanced testing of donated blood only 6 cases of confirmed or probable cases of transfusion-associated transmission of WNV were reported during 2003 (CDC 2004).

St. Louis Encephalitis

Another flavivirus found in the United States is St. Louis Encephalitis (SLE). SLE is also an arbovirus spread by mosquitoes and was first identified as a threat to humans in 1933 after an outbreak in St. Louis, Missouri (Chamberlain 1980). Retrospective studies of similar outbreaks in other locations and serologic testing of residents identified the prevalence of SLE in Paris, Illinois and Toledo, Ohio (Chamberlain 1980). Serologic testing of humans and domestic animals (horses and fowl) along with studies of the environment provided clues that mosquitoes are the likely vector for transmission of the virus (Chamberlain 1980). From 1955 to 1976 SLE was responsible for approximately 71% of vector-borne encephalitis cases in the U. S. (Monath 1980*b*). Living in a low-income household has been identified as one of the social characteristics that increase the risk of contracting SLE and dengue (Monath 1980*a*, Reiter et al. 2003). SLE, dengue and WNV are all flaviviruses and may have similar risk factors.

Risk Factors

It has been suggested that the study of risk factors identifies circumstances favorable for development of an epidemic and possibly to identify circumstances where an epidemic will not develop (Monath 1980, Reeves 1980). Place of risk begins at home where people spend most of their time, so it is appropriate to explore risk factors associated with the home environment.

Buildings in low income neighborhoods may suffer from inadequate maintenance which can result in problems that increase the opportunity to come into contact with competent vectors in and around the home (Han et al. 1999, Meade and Earickson 2000). Meade and Earickson (2000) suggest that “Many diseases seem to occur consistently more often among the poor than among the affluent.” For example, environmental factors such as water quality, sanitation, overcrowding, poor housing and rubbish accumulation contribute to the disproportionate occurrence of disease among the poor (Harpham et al. 1988).

Areas of both low and high SES have been associated with a higher number of cases of SLE due to different factors. Impoverished areas experienced higher numbers of cases of SLE during several outbreaks (Monath 1980). Environmental factors determined the level of SLE transmission in localized geographic areas of affected cities. Exposure to the vector was higher in an area of substandard housing in Greenville, Mississippi in 1975 compared to the non-blighted areas of the same city (Monath 1980*b*). In addition, incidence of SLE in West Central Memphis, (an area of lower-than-average socioeconomic status (SES)) was significantly higher than the rest of Memphis-Shelby County in 1975. Nonetheless, increased vector production has been associated with inadequate outdoor sanitation in impoverished areas during many outbreaks of SLE (Monath 1980*b*). Housing characteristics such as open foundations, absence of or inadequate screening and absence of air conditioning were believed to increase the risk of SLE disease in Houston and Dallas, Texas, and in McLeansboro, Illinois (Monath 1980*b*). However, in Houston in 1964, a greater number of cases of SLE were found in more affluent census tracts as well. Limited indoor exposure to the vector was reported in more affluent areas. While a high incidence of SLE was associated with higher SES in Corpus Christi, Texas in 1966, New Jersey in 1964 and Tampa Bay, Florida (Monath 1980*b*). Individuals in more affluent areas are more likely to be involved in outdoor activities which increase the risk of contact with the mosquito vector. In sum, past research has identified a clear association between the environmental conditions in which people live and risk of infection by SLE. In light of these studies, further study of risk factors is needed to determine if the same is true for WNV.

Age

In the 1950s, Taylor et al. (1956) conducted an intensive study aimed at determining the distribution of WNV antibodies in the human population of Egypt. Specimens were collected from a selective sample of the Egyptian population to describe the geographic extent of antibodies to WNV. Results of the study led the authors to conclude that WNV was a childhood disease with yearly peaks of transmission during mid-summer (Taylor et al. 1956). Adults in the same population were most likely infected as children and had developed immunity to WNV. In contrast to the Egyptian study, studies in the U. S. have identified older age as a risk factor for severe neurological illness and death from WNV infection in the U. S. (Hochberg et al. 2002, Nash et al. 2001). During the outbreak in New York City in 1999, Nash et al. (2001) used active surveillance to identify human cases. This was followed by laboratory testing of serum and cerebrospinal fluids (when available) from hospitalized patients to isolate virus antibodies from serum and cerebrospinal fluids (Taylor et al. 1956). Results of the study identified the median age of patients hospitalized for WNV illness as 71 years; with persons age 50 or older as 20 times more likely to become ill (Taylor et al. 1956). They also identified an age of 75 or older as a risk factor for death from WNV infection (Taylor et al. 1956). Based on results of United States human case surveillance data, the CDC reported the median age of persons with WNV meningoencephalitis as 68 for 2001 (CDC 2002*a*) and 59 in 2002 (CDC 2002*d*). The CDC reported the median age of decedents as 78 for 2002 (CDC 2002*d*). There is great concern in reducing the risk of infection for all individuals. There is a particular interest in reducing the risk of infection in the elderly who are more likely to suffer from more serious complications (Behney et al.). Recent data from the literature reinforces the idea that WNV, once considered a childhood disease is now considered a disease of greatest concern to the elderly. An increase in neuroinvasive disease associated with WNV in elderly patients is evident not only in the United States, but has also been documented in Israel (Weinberger et al. 2001, Tsai et al. 1998).

Poverty

The traditional measure of poverty was determined in 1963 when Mollie Orshansky of the U. S. Department of Agriculture (USDA) determined that food accounted for 33% of a family's budget (Besharov 1995). Using this guideline the poverty level was set at three times "what the USDA called the lowest-cost 'nutritionally adequate' diet" (Besharov 1995), with some modifications, this guideline is still used by the federal government (U. S. Department Of Health & Human Services 2007). Currently, the United States Department of Health and Human Services (HHS) uses poverty thresholds (updated yearly) for statistical purposes, while poverty guidelines are used to determine financial eligibility for certain federal programs (HHS 2009). Direct contributory factors include unemployment, low income and limited education (Harpham et al. 1998).

Researchers have found an association between poverty and vector-borne diseases. Socioeconomic status (SES) was identified as a risk factor for Dengue Fever during a study of two neighboring towns, Laredo, Texas and Neuvo Laredo, Taumalipas, Mexico (Reiter et al. 2003). Seropositive test results were fewer in the more affluent Laredo. In contrast, a greater proportion of seropositive test results were obtained in the less affluent Nuevo Laredo (Reiter et al. 2003). It is possible that the same association exists with WNV and SLE. As these three pathogens are each spread via mosquito bite, it is likely that they may have risk factors in common.

WNV Activity in Birds and Mosquitoes

Scholars have determined that dead birds and mosquito pools that test positive for WNV can be used as early indicators of viral activity (Nasci et al. 2002, Mostashari et al. 2003, Theophilides et al. 2003). This information has been useful in determining where to focus mosquito control efforts. Analysis of dead bird locations, "enabled preemptive measures to reduce mosquito breeding" (Mostashari et al. 2003).

These control measures were used earlier than with laboratory confirmation of WNV activity in vertebrate hosts and arthropod vectors. However, one limitation of using dead birds as an indicator is that someone has to report them (Eidson et al. 2001, Mostashari et al. 2003). As crows and jays (the most likely species to be found dead from the virus) adapt to the pathogen they will develop immunity making them less likely to succumb to the disease (Eidson et al. 2001, Mostashari et al. 2003). Monitoring of WNV activity in birds and mosquitoes is important in determining areas where humans may be exposed to the virus.

Weather Conditions

Weather conditions have been associated with outbreaks of WNV and are related to vector production. For example, flooding of the Moravia River in 1997 caused massive broods of mosquitoes to hatch in association with an outbreak of WNV in the Czech Republic (Hubalek et al. 2000). Warm dry weather after flood conditions was associated with the formation of suitable breeding habitats for mosquitoes in Bucharest (Hubalek 2000). Further, it was found that drought conditions result in a concentration of birds and mosquito vectors near limited water resources in a small area (Shaman et al. 2002, Brinton 2002). Dispersal of avian hosts and mosquito vectors occur when the drought ends, initiating the early transmission phase of the viral cycle (Shaman et al. 2002). The lack of heavy rain to flush sewer systems results in increased mosquito populations in cities (Brinton 2002). Higher temperatures decrease larval development time, leading to the production of a greater number of mosquito vectors in a shorter time period (Alto and Juliano 2001). Research on SLE found that higher temperatures and lack of rain during the summer months resulted in sufficient habitat for *Culex pipiens* to breed (Monath 1980*b*). Although it is important to recognize the connection between weather conditions and WNV, there is also a need to study and identify human interactions with the virus.

Public Health System in the United States

Prior to the mid-1800s, public health officials did not have medical backgrounds, their role served to keep the diseased quarantined to prevent the spread of disease and make sure that economic activities were not disrupted (Fee 1997). At the time, the rapidly growing port cities on the east coast of the United States were susceptible to the threat of epidemic diseases such as, yellow fever. Public health programs were organized at the local level to quarantine ships suspected of carrying disease (Fee 1997). This practice interfered with economic interest and city health departments began to focus more on cleaning up the dirtiest areas of the cities (Fee 1997). As sanitation became more important in preventing the spread of disease, medical practitioners became gained importance in promoting public health.

National Level

The Department of Health and Human Service is the cabinet department most concerned with protecting the health of all Americans (Brandt 1997; HHS 2009). The department has four major operating divisions involved in public health: the Health Care Financing Administration (HCFA), the Administration for Children and Families (ACF), the Administration on Aging (AOA), and the Public Health Service (PHS) (Brandt 1997; Turnock 2004; HHS 2009).

The two agencies within the Public Health Service that provide services relative to WNV are the National Institutes of Health (NIH) and the Centers for Disease Control (CDC) (Brandt 1997). NIH is a medical research agency that investigates disease prevention methods, causes of disease, treatments and even cures. Grant dollars are administered by the NIH to provide financial support and leadership to researchers at the state and national levels. The CDC was established in 1946 as the Communicable Disease Center (Brandt 1997, Turnock 2004). Working in conjunction with states and other partners the CDC provides a health surveillance system to monitor and prevent disease outbreaks, implement disease prevention strategies and maintain national health statistics (Brandt 1997). The CDC mission is “To promote health and quality of life by preventing and controlling disease, injury, and disability.” This is accomplished through partnerships with health organizations both nationally and internationally (CDC website, Accessed 01/22, 2008).

State Level

Each of the 50 states has a health agency primarily responsible for public health within the state (Dandoy 1997). Massachusetts was the first state to create a board of health in 1869 (Dandoy 1997). All states had health departments by 1909, focusing mainly on the recording of births and deaths and the control of communicable diseases (Dandoy 1997). Today, state health departments have expanded their activities with the aim of improving health and services available to all its residents (Dandoy 1997). These activities can be categorized in as follows:

- Health information – collecting and preserving vital records and gathering and analyzing data on the health of the population and health care delivery system

- Disease and disability prevention – controlling communicable disease as well as programs related to prevention and early detection of chronic diseases
- Health protection – oversight of public drinking water, air, food service facilities, sewage systems and sources of radiation and improving access to medical care for underserved populations
- Health promotion – health education programs designed to promote a healthy lifestyle with emphasis on reducing risk factors for cancer and cardiovascular diseases
- Health care delivery – providing healthcare at specialty clinics and primary medical care (Dandoy 1997).

Local Health Department

Local health departments are those entities which have the mission to "protect, promote and maintain the health of the entire population of their jurisdiction" (Rawding and Wasserman 1997). There are approximately 3000 local health departments in the United States. These organizations exist as agencies of towns, cities, counties and in some states are districts of the state level health department (Rawding and Wasserman 1997).

Surveillance

Surveillance plays a critical role in disease control and prevention by quantifying disease activity at a given time and identifying areas where action should be taken to prevent future cases. This is achieved by the collection, orderly consolidation, analysis, and evaluation of data with prompt dissemination to those agencies concerned with disease prevention (Hinman 1997; Heymann 2004).

The CDC collects and reports WNV surveillance data on a weekly basis in five categories: human cases, wild birds, sentinel chicken flocks, mosquitoes, and veterinary cases. Reports from clinicians regarding positive cases are reported by counties; this is an example of passive surveillance. In contrast, active surveillance occurs when investigators go out and collect blood and tissue samples to test for infection. Both active and passive surveillance measures are in place to collect data regarding positive, probable and confirmed cases of WNV.

Human Surveillance

The CDC includes the following goals of surveillance for human cases:

- To assess the local, state and national public health impact of WNV disease and monitor national trends
- demonstrate the need for public health intervention programs
- allocate resources
- identify risk factors for infection and determine high-risk populations
- identify geographic areas in need of targeted interventions
- identify geographic areas in which it may be appropriate to conduct analytic studies of important public health issues (CDC guidelines 2003)

Health care providers report human cases to the local health department classified as probable or confirmed based on the CDC case definition. Confirmed cases of WNV are determined by positive laboratory tests on tissue or body fluid samples (Stephen 2007). A probable case is febrile illness associated with neurologic manifestations the presence of arbovirus antibody, confirmed by laboratory tests (CDC 2003).

In addition to collecting data for human infection, results from tests on blood products are collected to prevent blood products from viremic (producing more of the virus) individuals from entering the blood supply. This measure is in place to reduce the risk of infections resulting from transfusions and organ donation.

Avian Surveillance

Avian surveillance data are collected in the form of dead bird reports, especially corvids (crows and jays), results from sentinel flocks or, wild bird surveillance. Sentinels are the first indicators of viral activity and are used to alert public health officials that the possibility of human infection exists. Because "no single sentinel host species …is effective in all areas" (CDC 1993) sentinel species used varies. In some parts of California captive sentinel chicken flocks are used as sentinels for Western Equine Encephalitis, whereas in west Texas wild house sparrows are used as sentinels to test for Western Equine Encephalitis (CDC 1993, Marin/Sonoma Mosquito and Vector Control District 2008). When reports of large numbers of dead crows were associated with human cases of WNV infection in 1999 dead crows were used as sentinels in those places where sentinels were not already in use. Corvids are highly susceptible and succumb to WNV in large numbers. As a result, in some areas dead crows have been tested for WNV. Dead crows have been the earliest indicator of the presence of WNV. Evidence has been provided which justifies the use of chickens as sentinels for WNV in North America (Langevin et al. 2001). In California, a small amount of blood is drawn bi-weekly to test for antibodies to arthropod-borne viruses (Marin/Sonoma Mosquito and Vector Control District, West Umatilla Vector Control District 2008). Not all jurisdictions maintain sentinel flocks for surveillance. Individuals from wild bird populations are occasionally caught and released after drawing a blood sample for testing (Marin/Sonoma Mosquito and Vector Control District 2008).

Mosquito Surveillance

Mosquito surveillance data is the primary means of quantifying the intensity of virus transmission in an area (CDC 2003). Adult mosquitoes are collected using a variety of trapping techniques to identify the mosquito species, primary vector species present, and the density of mosquitoes. Larval mosquitoes are collected by taking dip samples from a variety of habitats to identify species present in an area and to identify mosquito sources. The data collected are useful in identifying areas where the threat to humans requires application of insecticide or larvicide to reduce the risk of human infection.

Equine Surveillance

In addition to monitoring mosquitoes, equine surveillance data are collected in areas with susceptible horse populations (CDC 1993). Cases of WNV infection in horses have been reported in New York State as well as in Mexico (Blitvich et al. 2003, Trock et al. 2001). In 2002, 660 counties reported the first indicator of WNV as an equine case (CDC 2002*d*). As reported by the CDC, “Bird- and horse-based surveillance are important tools for monitoring the geographic spread of WNV and for signaling WNV activity in an area before the recognition of human illnesses” (CDC 2002*d*).

Chapter 3: Methodology

Introduction

This chapter begins with a discussion of the study area followed by an introduction of the research questions. Next a discussion of the method of data collection and methodologies used to answer the research questions will be presented. A discussion of how the data was analyzed is also included. Diffusion models are used to present a graphic representation of the spread of WNV. Moreover, statistical analysis is used to identify socio-demographic characteristics which may be considered risk factors for WNV infection. Additionally I relate the response by public health officials to their perception of the threat posed by this emerging pathogen.

Study Area

This research focused on 14 central and northeastern states: Connecticut, Illinois, Indiana, Maine, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont and Wisconsin. The 654 counties contained in the fourteen states were chosen for the following reasons: (1) high number of metropolitan areas; (2) variation in the selected socio-demographic variables by county; (3) similar environmental conditions relative to weather and climate; (4) *Culex pipiens*, is the most common mosquito vector for these counties and; (5) variation in WNV infection rates by county. The diffusion of WNV in these states provided the basis of my analysis of the study area. A sample size of 654 total counties were used in this study as a surrogate for conditions in the United States.

This sample provides considerable information to study the spread of WNV across the northeast and north central portion of the United States.

In conjunction with the statistical analysis of diffusion, a concurrent survey was conducted of a sample of counties in the study area. I also selected the state of Ohio to produce a more in depth analysis of diffusion. I surveyed the local level public health officials in Ohio. Research suggests that Ohio and California "have consistently reported the highest prevalence of encephalitis" (Pyle and Cook 1978). Ohio should be representative of the entire study area because of the similar variation in urban and rural areas to the entire region. Other states were excluded from the survey because of a high concentration of urban areas which could result in urban regional proxy instead of variation in cities and towns. Ohio was also chosen for the survey because of the availability of resource support through academic ties with Youngstown State University, Youngstown, Ohio.

The Research Hypotheses

Protecting the public from infectious disease can be achieved by increasing knowledge of risk factors. Risk factors are those characteristics associated with an increased risk of contracting a particular illness. Discerning which risk factors are associated with WNV and ultimately where they occur can be useful in reducing the incidence of infection. The primary question asked is "Can socio-demographic characteristics be considered risk factors for neurological disease due to West Nile Virus?" Several questions were developed to define this research. These are:

- Can socio-demographic characteristics be identified which are related to human cases of WNV infection?

- Is there a particular type of county that is more frequently associated with cases of WNV?
- Is the response by public health officials at the county level related to their perception of the threat posed by WNV in their jurisdictions?

Census Variables

Socio-demographic data taken from the Census Bureau were used as independent variables and categorized as follows: total population, age, education, employment, ethnicity, country of birth, gender, income, housing characteristics and urbanization. These independent variables are shown in Table 3.1.

Previous research on health and environment suggests that socioeconomic status is positively related to the health of individuals and helps to determine where an individual lives (Yen and Syme 1999). In this research socio-demographic variables were used as a surrogate to represent conditions of the social environment within each county. Total population and population density have been associated with a higher prevalence of arbovirus cases (Pyle and Cook 1978). In addition, the literature suggests that old age is a risk factor for severe neurological illness and death from WNV infection in the United States (Hochberg et al. 2002, Nash et al. 2001). The median age of patients hospitalized as 71 years and persons age 50 or older as 20 times more likely to become ill (CDC 2002*a*, CDC 2002*d*, Nash et al. 2001). An increase in neuroinvasive disease associated with WNV in elderly patients is evident not only in the United States, but has also been documented in Israel (Tsai et al. 1998, Weinberger et al. 2001).

Table 3.1 *Socio-demographic variables extracted/created from Census Data*

Population and Age distribution variables

(1) Total population,
(2) Percentage of the population over the age of 65
(3) Percentage of the population under age 18,
(4) Percentage of the population that is white,
(5) Percentage of the population that is foreign born,
(6) Percentage of the population 16 or over in the workforce,
(7) Percentage of the population over age 16 in the workforce that is female,

Education

(8) Percentage of the population over age 25 with a high school diploma (includes equivalency),
(9) Percentage of the population over age 25 with an associates degree,
(10) Percentage of the population over age 25 with a bachelors degree,
(11) Percentage of the population over age 25 with a graduate or professional degree,

Economic well-being and Housing

(12) Percentage of the population living below the poverty level,
(13) Percentage of the population receiving public assistance,
(14) Percentage of the population living in urban areas,
(15) Counties that are urban,
(16) Median household 1999 income,
(17) Median year housing was built,
(18) Percentage of households headed by females,
(19) Average household size,
(20) Percentage of houses that are occupied,
(21) Percentage of houses that are occupied by renters.

Yen and Syme (1999) report that ethnicity, country of birth, urbanization, gender, education and employment have been used in classifying communities as social areas. Indicators of social rank include education and employment (Shevky and Williams 1949). The variables used in this research generally coincide with factor analysis which has been used to analyze North American cities (Price 1942, Berry

1968). For this research, each county was also designated as urban or rural based on the Rural-Urban continuum. As reported by the USDA:

> Rural-urban Continuum Codes form a classification scheme that distinguishes metropolitan counties by size and nonmetropolitan counties by degree of urbanization and proximity to metro areas (USDA 2007).

As designated by the USDA each county is identified by a code from 1 through 9 related to population and proximity to metropolitan areas (Table 3.2). For this study counties were designated as urban when they had an urban continuum code of 1, 2, or 3.

Table 3.2 *2003 Rural –Urban Continuum codes*

Code	Description
Metro counties:	
1	Counties in metro areas of 1 million population or more
2	Counties in metro areas of 250,000 to 1 million population
3	Counties in metro areas of fewer than 250,000 population
Nonmetro counties:	
4	Urban population of 20,000 or more, adjacent to a metro area
5	Urban population of 20,000 or more, not adjacent to a metro area
6	Urban population of 2,500 to 19,999, adjacent to a metro area
7	Urban population of 2,500 to 19,999, not adjacent to a metro area
8	Completely rural or less than 2,500 urban population, adjacent to a metro area
9	Completely rural or less than 2,500 urban population, not adjacent to a metro area

Source: United States Department of Agriculture (2007)

Public Health Variables

The dependent variable was the cumulative infection rate (per 10,000 population) of WNV for each county in 14 states for the years 1999 – 2005. The data used to create this variable were extracted from the CDC and United States Geological Survey (USGS), websites. County-level population data were extracted from the Census Bureau website. The human case data was pooled together with the Census data to create the data set for this dissertation. Infection rate was determined by use of the following formula: infection rate = cumulative positive human infections reported / population / * 10000.

Research Framework

This is a multi-level analysis designed to answer the research questions and test the hypotheses. Due to the complexity of the data it was necessary to conduct the analysis in multiple levels. The first level of analysis examines the diffusion of WNV. Level two involves the statistical analysis of the socio-demographic data, this makes it possible to identify a type of county most often associated with WNV cases. The survey of local level public health officials is the third level of analysis, to make a connection between the county-level public health response and WNV infection rates.

Level One

The CDC county level data of WNV activity in humans, birds, mosquitoes and other animals were collected from the CDC and USGS websites. These data were used to create GIS maps showing the spread of WNV across the 14 states in the study area. This analysis provides a “snapshot” of WNV activity for each year of the study. To examine the process of diffusion a series of maps which show the spread of the disease over time were produced.

Level Two

Level two of the analysis was used to answer the first two research questions. Can socio-demographic characteristics be identified which are related to human cases of WNV infection? Is there a particular type of county that is more frequently associated with cases of WNV? Part one of this second level of analysis provides an understanding of the role socio-demographic characteristics played in the diffusion of WNV. This analysis determines whether WNV neurological disease is found most often in counties with particular socio-demographic characteristics. Although the literature does not associate WNV by county type, such an understanding will add to the body of knowledge about WNV infection.

Research Question 1: Can socio-demographic characteristics be identified and related to human cases of WNV infection?

Hypothesis 1: Risk factors will vary by location.

The goal is to identify risk factors associated with WNV infection resulting in neurological disease in humans. The assumption is that WNV will continue to be a public health issue.

Research Question 2: Is there a particular type of county that is more frequently associated with cases of WNV?

Hypothesis 2: Specific risk factors can be identified that relate to cases of WNV neurological disease.

The goal is to identify a classification of counties. The assumption is that counties with particular socio-demographic characteristics are associated with high or low numbers of reported cases of human WNV neurological disease.

Hypothesis 3: Socio-demographic characteristics can be used to produce a classification of counties.

The third research goal is to describe county types based on selected socio-demographic characteristics to explain the geographic distribution of human cases of WNV resulting in neurological disease. The assumption is that study results will be used to identify areas where prevention and control methods should be employed.

Factor analysis is used to simplify the data and identify underlying factors (Kachigan 1991) associated with the spread of WNV. The principal components factor analysis eliminates redundancies of interdependent variables (Wong 1968). Factor analysis was used on the 21 variables listed in Table 3.1 to produce a classification of counties. This classification is used to determine whether the population of a particular type of county is at a greater risk of infection by WNV. The analysis reduced the number of variables by grouping together those variables which are more closely correlated to at the county level. Once these factors were derived an appropriate description of the structural factors were given. Equally important, were the factor scores. Z scores (mean of 0) for each county in the analysis resulted for each of the derived factors (Kachigan 1991, Warner 2008). While this technique provides an understanding of the effect of selected variables as risk factors for WNV disease, it does not explain variation by county.

Because each factor score represents a standardized factor for each county, it was regressed on the WNV infection rate to further elucidate these variables as risk factors. Mapping the residuals provides a visual representation of the spatial phenomena using a less complex descriptive statistical base that allows for easier interpretation of results (Robinson et al. 1968). The factor analysis identifies statistically significant independent variables and rejects those that are not statistically significant (Thomas 1968, Warner 2008). To further improve our understanding of the geographic distribution of human cases of WNV, stepwise discriminant analysis was used to provide a near-optimal grouping of human case observations into 3 distinct classes (Berry 1968). This technique focused on the 21 socio-demographic characteristics found in literature directly or indirectly related to human cases of WNV. This approach required *a priori* classification of WNV according to infection rate by county. In essence, counties with an infection rate greater than 0, were classified according to WNV infection rate as: high, moderate and low number of cases. See Tables 3.3 and 3.4.

Table 3.3 *Description of A priori Classification of Counties*

A priori classification	Range
H (High)	Infection rate > 2.1
M (Moderate)	Infection rate 1.1-2.1
L (Low)	Infection rate .01 – 1.09

Infection rate = number of cases / 10,000 population

Table 3.4 *County Classification Derived From Discriminant Analysis*

County	Predictor Value	Classification
County A	$L = b_1x_1 + b_2x_2 + \dots b_nx_n$	High
County B	$M = b_1x_1 + b_2x_2 + \dots b_nx_n$	Moderate
County C	$N = b_1x_1 + b_2x_2 + \dots b_nx_n$	Low

On the basis of these discrete groupings it is possible to use them as discriminant variables. According to analysis each variable discriminates among the *a priori* groups based upon the discriminant function (Kachigan 1991). If a variable was related to the high WNV infection rate, it would provide much of the explanation in classifying counties correctly. The same variable would provide less discrimination among counties in moderate, low and high categories and likewise for other variables. On the other hand, variables were most discriminant among all *a priori* groups and classified counties correctly according to *a priori* class. By classifying counties based solely on infection rate they might not be grouped appropriately, because there is no statistical basis for the grouping. The discriminant analysis places each county into appropriate groups based on the statistical analysis.

The factor ratio matrix determines significance of discriminant variables as significant or insignificant. The analysis also provides a classification matrix, a numerical classification of counties in that group (Kachigan 1991). Counties are classed correct or incorrect based upon the discriminant power of variables. At any particular stage of analysis, an understanding of each county among *a priori* groups can be made and determine the number of counties classed correctly and incorrectly. This stepwise discriminant analysis makes it possible to determine individual variables that discriminate among *a priori* groups and identified the number or the combination of variables that were significant discriminators. Level two of the analysis is represented by Figures 3.1 and 3.2. These analyses, factor analytical for which factor scores are regressed on the dependent variable (human WNV infection rate) and stepwise discriminant analysis together, will improve the understanding of the geographic distribution of human cases of WNV in the study area.

Fig 3.1 *Level Two – Part one of analysis*

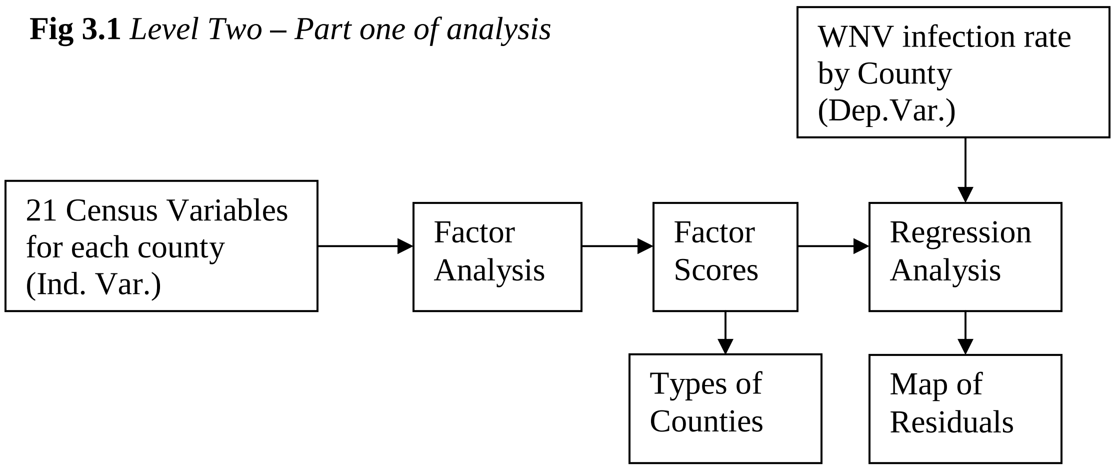
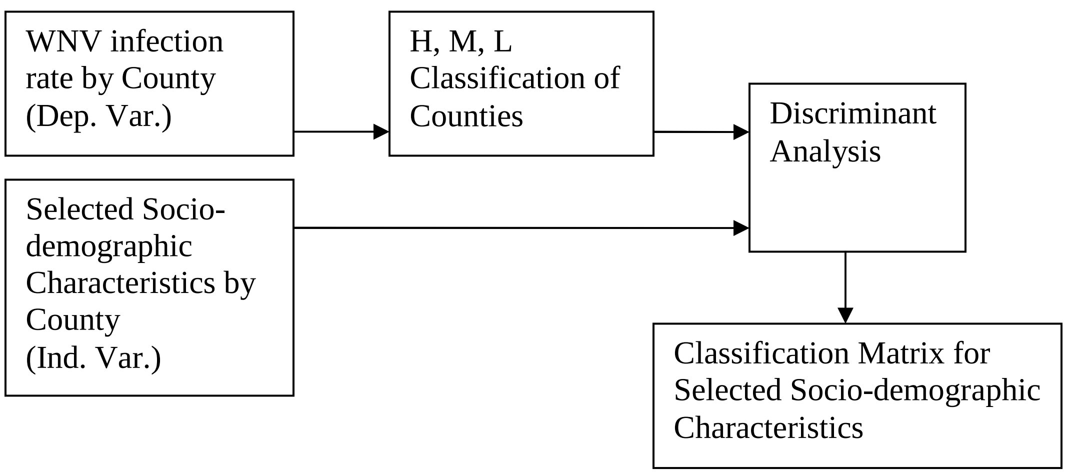


Fig 3.2 *Level Two – Part two of analysis*



Level Three

Research Question 3: Is the response by public health officials at the county level appropriate relative to their perception of the threat posed by WNV in their jurisdictions?

Hypothesis 4: Public health officials are responding to the threat of WNV in accordance with their perception of the disease as a local threat.

The research goal was to relate the response of public health officials to the WNV infection rate within their respective jurisdictions. We assume that public health officials have implemented programs in response to the occurrence of neurological disease.

Hypothesis 5: Socio-demographic characteristics of the survey respondents influenced their perception of the risk presented by WNV.

The assumption is that public health officials with more experience will be more likely to perceive WNV as a greater threat. It is likely that counties with a high infection rate will be associated with a high level of awareness of the disease and the highest level of response.

Examining the diffusion of WNV alone does not provide the total picture, the response by public health officials needs to be examined. To that end, a sample of counties was surveyed. Survey responses help to provide a basis for understanding the relationship between the WNV infection rate in humans and the response by local level public health officials. Data obtained from the survey responses allows the opportunity to determine how local level public health officials in the state of Ohio were able to reduce the risk of infection by their response. The survey is a cost effective measurement tool with the potential to generate substantial data for analysis.

The survey design is modeled after a survey previously administered by the Council of State and Territorial Epidemiologists (CSTE). Their intent was to assess the capacity of state and large city health departments to conduct surveillance, prevention and control activities for WNV infection (CSTE 2005). With approval from the organization, many of their questions were adopted for use in my survey. This was done so that comparison could be made between their state-level responses and my county-level responses.

To achieve the highest possible response rate, county representatives were contacted on several occasions regarding the survey in the following sequence of events. Respondent names were first requested from each county via email. Once respondents' names were gathered I sent a follow-up email to inform each respondent that a survey had been sent via United States Postal Service (USPS). Surveys were mailed to the 88 county-level health departments in the State of Ohio. Due to the length of the questionnaire, it was determined that sending the questionnaires by mail would be preferable to using a web-based survey. A cover letter was attached to the survey as an introduction and to explain the importance of the research. Also included was a consent form with University of Maryland Institutional Review Board (IRB) approval. A self-addressed stamp envelope was included to encourage response. The first mailing was on January 8, 2007, a second survey was mailed on February 19, 2007 to respondents from whom a reply to the initial mailing was not received. I began to receive completed surveys within two weeks of the initial mailing.

Fifty-eight completed surveys were received, representing a 66% response rate. Upon receipt, completed surveys were logged in and assigned a number, based on order received. Responses were entered into a database with the only identifier as the assigned number, to insure anonymity of respondents. The completed surveys and consent forms were then stored in a locked file cabinet in my office. Thank you notices were sent by email to respondents upon receipt of completed survey.

To identify relationships between length of surveillance for WNV and county-level infection rates correlation analysis was used. Correlation analysis is used to analyze the association between seemingly random variables (Kachigan 1991). This analysis measures the strength of a linear relationship between variables. Results of this test refer to the chance that there is no relationship between two variables. Analysis of Variance (ANOVA) is used to identify and measure the source of variation within a dataset (Kachigan 1991). This test analyzes the differences in the mean values associated with a particular variable (Kachigan 1991). ANOVA results will identify differences in responses among the socio-demographic responses of the survey respondents. The use of these statistical analyses will improve the understanding of the diffusion of WNV within the study area and the response to WNV by county-level public health officials in Ohio.

Chapter 4: Diffusion of West Nile Virus Across The Northeastern United States

Introduction

Prior to 1999 WNV was found only in the eastern hemisphere (Brownstein et al. 2004). The means of entry into the United States is unknown, but, surveillance data has made it possible to track the spread of WNV through the study area. This chapter provides an explanation of the surveillance data to define the observed pattern of human cases. Socio-demographic characteristics that both facilitate the spread and act as barriers are determined, and offered here.

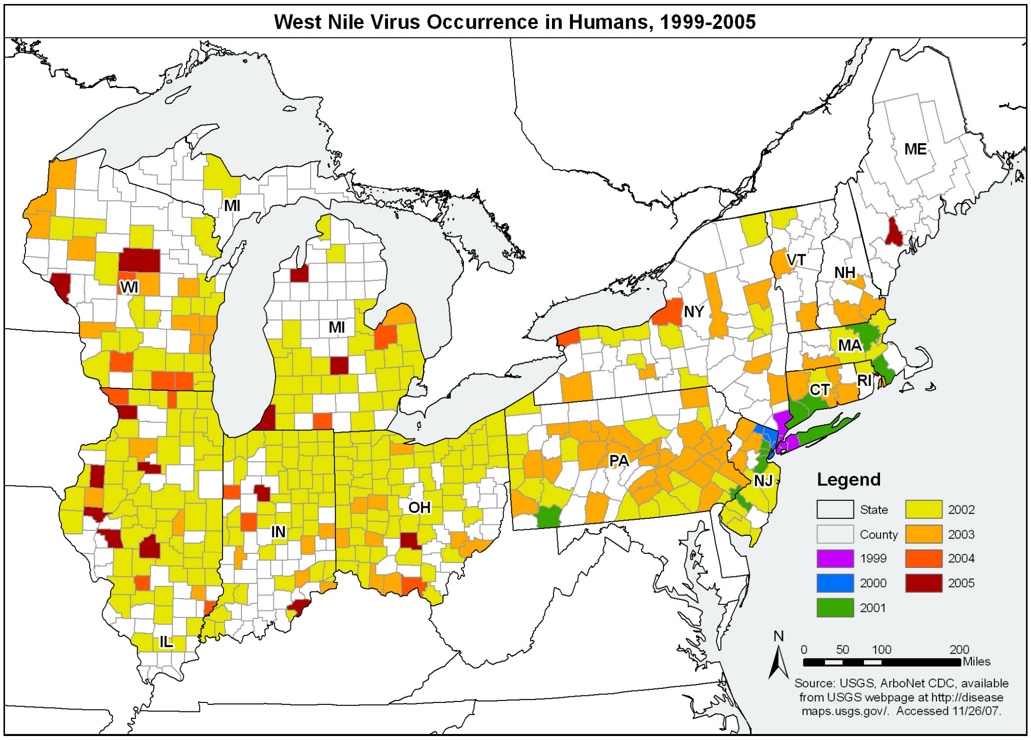
The primary question posed by this research was "Can socio-demographic characteristics be considered risk factors for neurological disease due to West Nile Virus?" In support of this goal it is necessary to identify socio-demographic characteristics associated with human cases of WNV infection. It is also important to determine a type of county more frequently associated with cases of WNV. Finally, the response of public health officials at the county level is related to their perception of the threat posed by WNV in their jurisdictions.

Five hypotheses are addressed in order to answer the research questions. These are: 1) Risk factors will vary by location; 2) specific risk factors can be identified that relate to cases of WNV neurological disease; 3) socio-demographic characteristics can be used to produce a classification of counties; 4) public health officials are responding to the threat of WNV in accordance with their perception of the disease as a local threat and; 5) socio-demographic characteristics of the survey respondents influenced their perception of the risk presented by WNV.

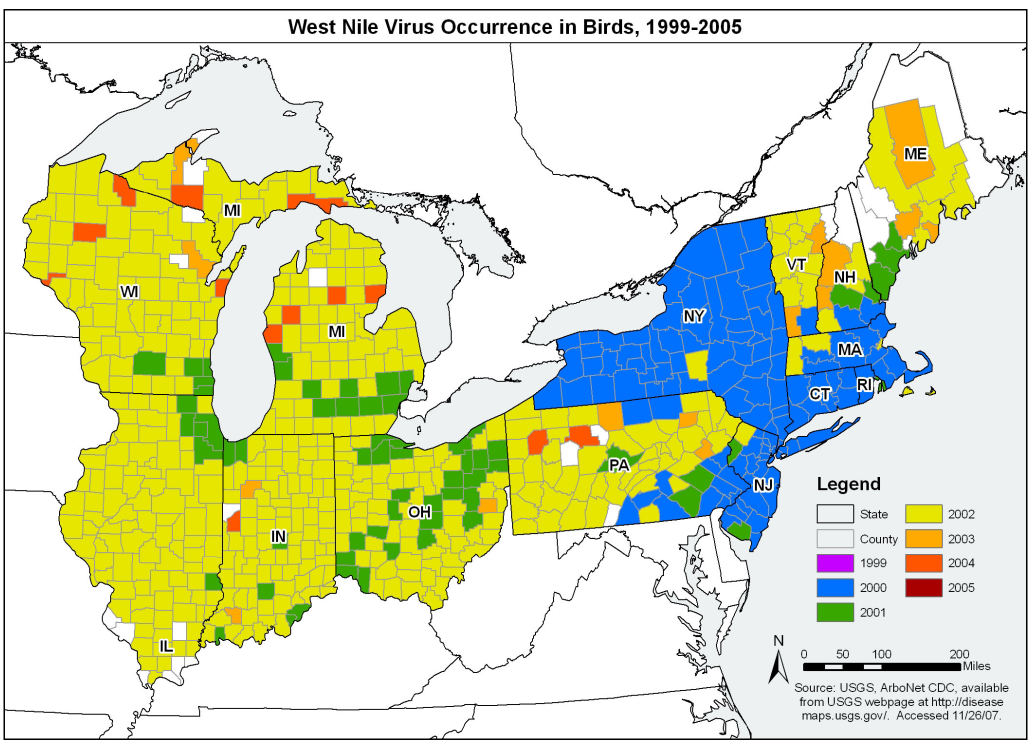
Diffusion of WNV

In 1999 WNV there were 62 documented human cases of WNV which occurred in six counties in the state of New York (Lehman 2008). In 2000 additional cases were reported from 3 counties in New York and three adjacent counties in New Jersey (Lehman 2008). In 2001 counties in 5 states in the study area (CT, MA, NJ, NY, and PA) reported a total of 38 human cases of WNV infection (CDC 2002*a*). During 2002 WNV activity in humans became more widespread and 258 of the 654 counties in the study area reported human cases. The following year 205 counties within the study area reported human cases. Only 80 counties in the study area reported cases of WNV in 2004 compared to 65 counties in 2005. Counties that reported human cases of WNV did not necessarily report cases each year during the focus of this study. Figure 4.1(a) displays the first year that human cases were reported by county within the study area. In 1999 through 2001 human cases are found mainly in northeastern counties of the study area. From 2002 through 2006 human cases were reported from western counties in the study area.

As birds may be used as an early indicator of the presence of the virus it is necessary to illustrate counties where WNV was detected in birds throughout the study area (Figure 4.1(b)). More counties reported infected birds than positive human cases and, prior to 2002, positive birds were reported prior to positive human cases. Surveillance for WNV was begun in 1999 after it was identified as the disease agent.



(a)



(b)

Figure 4.1 *West Nile Virus Occurrence In Humans and Birds, 1999-2005. Choropleth maps of human (a) and avian (b) WNV infection, by first year of detection. Underreporting as a result of mild undetected cases may account for gaps in the human case data. Transportation routes may explain some of the diffusion especially in Ohio and parts of the northeast.*

Over the period assessed the positive infections in birds were reported from a greater number of counties than positive human infections. Further, only a few counties did not report activity in birds in any of the years studied. Beginning in 2001 and 2002 the increase in human cases may have resulted from increased awareness. Prior to this time, the incidence and prevalence of WNV may have been greater than what was documented. Underreporting may explain the disparities between documented human and avian occurrence.

The occurrence of these cases is also presented using a dot map for the years 1999-2005. The dot map illustrates clustering of human cases of WNV infection within the county borders. The earliest reports of avian surveillance data were in 2000 and viral activity in birds was much more widespread than human activity for the same year. Again, a dot map is used to accurately reflect clustering of birds which tested for WNV positive within county boundaries Figure 4.2 (a)). In comparison with the dot map of WNV activity in humans (Figure 4.2 (b)), the clusters exhibit a similar pattern. The clusters are observed near large urban centers located in southeastern New York, southwestern New Jersey, northeastern and southwestern Ohio, northeastern Illinois, southeastern Wisconsin and central Michigan. The pattern of the spread of WNV activity in mosquitoes (Figure 4.3) throughout the study area is similar to that of birds. In 2000 and 2001 positive mosquito reports were concentrated in southern New York, northern New Jersey, western Connecticut, eastern Massachusetts and eastern Pennsylvania. During 2003 through 2005 there was increased reporting of WNV occurrence in mosquitoes in Ohio, Indiana, Michigan, Wisconsin and Illinois, in the western half of the study area.

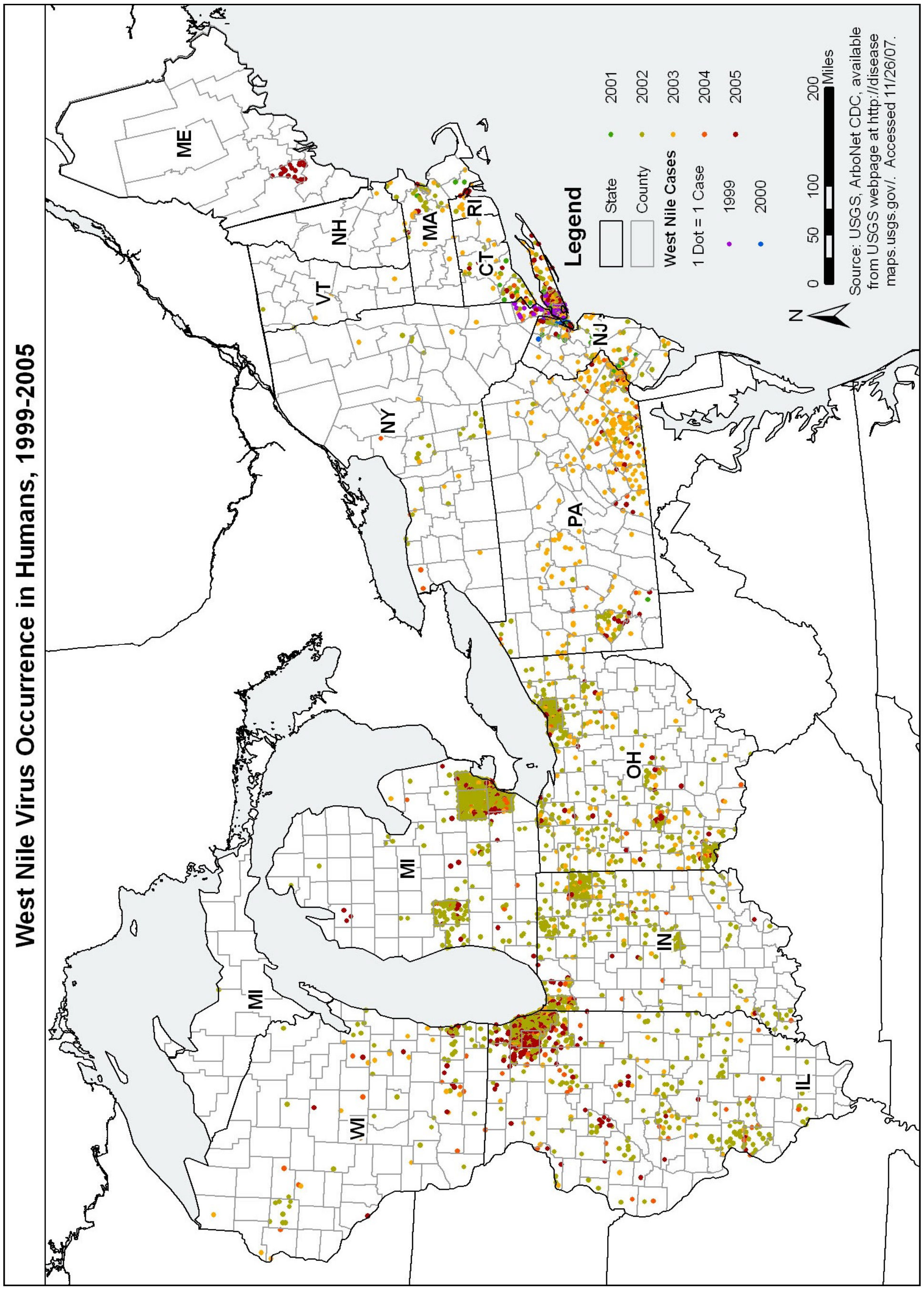

West Nile Virus Occurrence in Humans, 1999-2005
Legend
State
County
West Nile Cases
1 Dot = 1 Case
1999
2000
2001
2002
2003
2004
2005
0
50
100
200
Miles
N
Source: USGS, ArboNet CDC, available from USGS webpage at http://disease maps.usgs.gov/. Accessed 11/26/07.
ME
NH
VT
MA
RI
CT
NY
NJ
PA
OH
MI
IN
IL
WI
MI

Figure 4.2 (a)

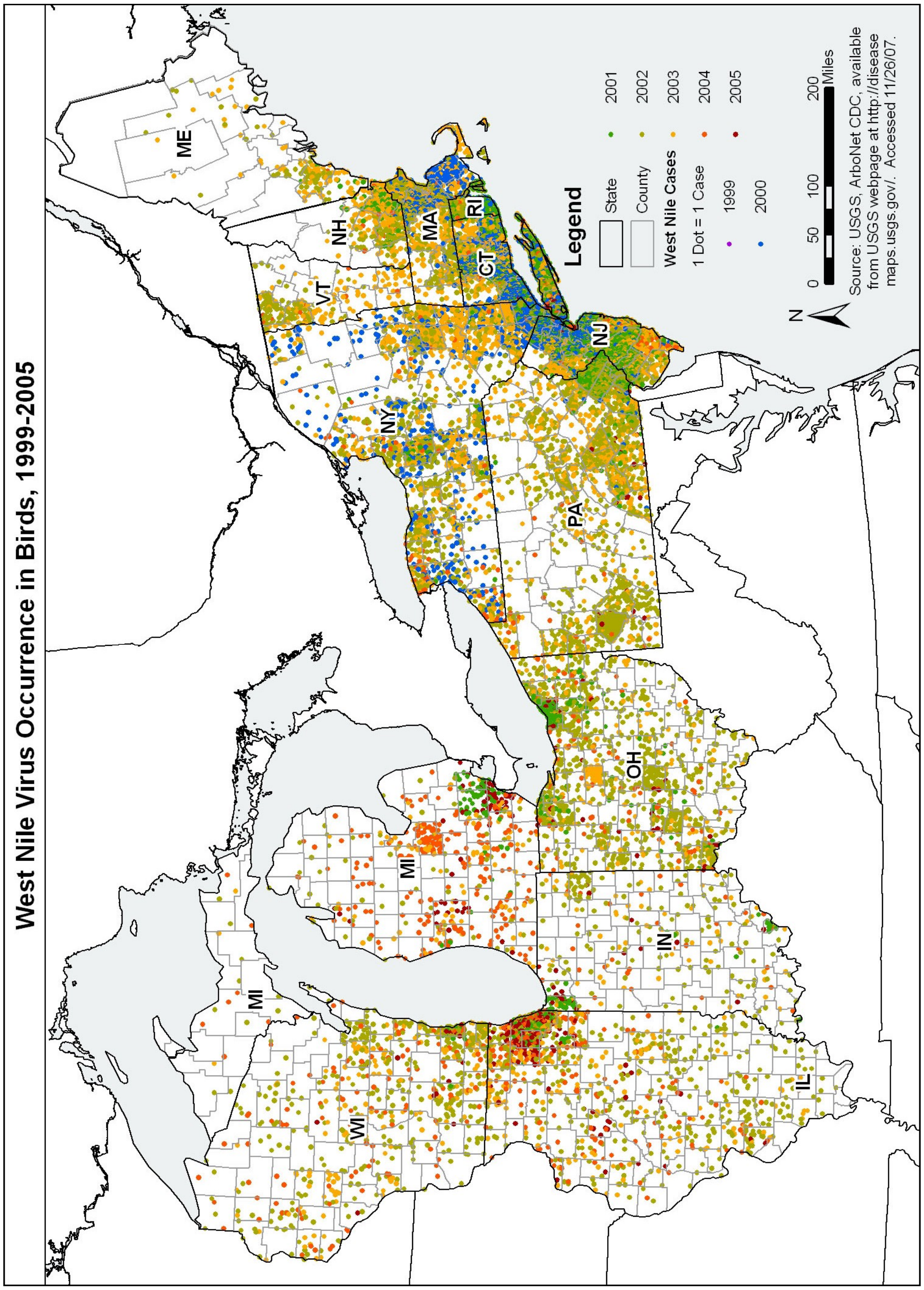


Figure 4.2 (b) *Clusters of West Nile Virus Occurrence in Humans and Birds, 1999-2005. Dot maps of human (a) and avian (b) WNV infection, by first year of detection at the county level within the study area. Clusters of documented human and avian cases are evident where large urban centers are located. The earliest reported cases are clustered in southeastern New York. The pattern of spread represented by the dots appears consistent with major transportation routes throughout the study area. The absence of reported human cases in counties with a large number of reported bird infections is likely related to less dense human populations in those areas; northern Vermont, northwestern New York.*

The most significant wave of viral activity appears in 2002, when viral activity is more widespread, with clusters near large urban centers, especially in New York, New Jersey, Pennsylvania, Illinois and Ohio. Greater awareness and increased reporting of human cases are the most likely reasons for increased reporting of human case data.

WNV activity in animals spread over time at about the same pace as activity in birds and mosquitoes, with the most significant spread occurring in 2002. The same is observed in the human population. Clustering of WNV activity in animals is very similar to the pattern for birds and mosquitoes during the same time period. Fewer positive sentinels were reported than humans and other animals. It is possible that not all areas had surveillance measures in place to detect viral activity in sentinels.

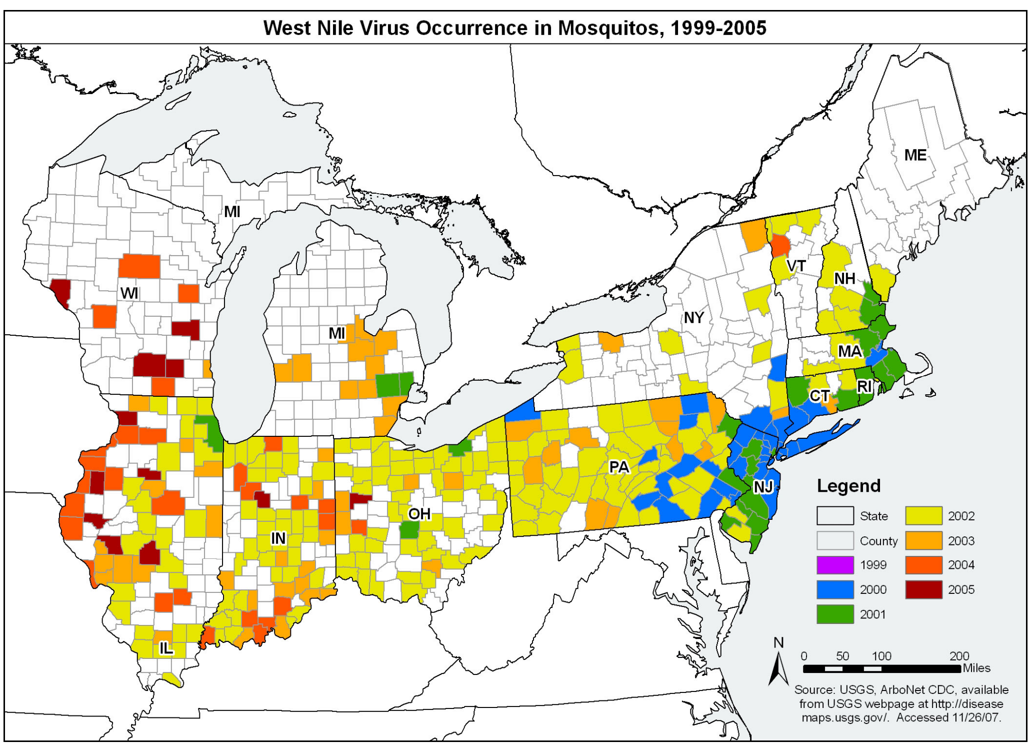


Figure 4.3 *West Nile Virus Occurrence in Mosquitoes, 1999-2005. Choropleth map of WNV infected mosquito pools, by first year of detection at the county level within the study area.*

Discriminant Analysis of County Level Socio-Demographics

Statistical analysis of defined socio-demographics at the county level can improve understanding of the socio-demographic risk factors. Because it is based on observation, *a priori* classification of counties as High (H), Moderate (M), or Low (L) based on WNV infection does not yield the same results as classification based on statistical analysis. Therefore, discriminant analysis was used to determine errors of *a priori* classification, and correctly classify counties. Based on the analysis 11 counties were classified as having a high infection rate, 45 counties had moderate infection rates and 316 counties were classified as having low infection rates. As for predicted membership: 100% of counties were correctly classed as high, 91.11 % were correctly classed as having moderate infection rates and 98.73 % were correctly classed as having low infection rates (Table 4.1). Errors in *a priori* classification of counties were identified in the low and moderate classes.

Table 4.1 *Predicted vs. actual group membership for counties with positive human cases of WNV.*

	Predicted Group			
Actual Group	High	Moderate	Low	Totals
High	11	0	0	11
Moderate	0	41 (91.11%)	4 (error)	45
Low	0	4 (error)	312 (98.73%)	316
				372

Due to the limitations of the analysis only those counties with an infection rate greater than 0 were included in these results.

In an attempt to provide some explanation for the pattern of spread it was necessary to evaluate the socio-demographic characteristics used as variables in the statistical analyses to identify which characteristics can be associated with WNV cases.

Factor Analysis of Socio-demographic Variables

To assess the dimensionality of a set of 21 socio-demographic variables selected from census data, factor analysis was performed using principal components analysis, the default criterion to retain only factors with eigenvalues greater than 1, and varimax rotation was selected. Only five factors had eigenvalues greater than 1; therefore, only Factors 1 through 5 were retained and rotated. Factor 1 (Education and Affluence in Urban Areas) accounted for 33.36% of the variance, factor 2 (Less Affluent Younger Families) accounted for 21.21 % of the variance, factor 3 (Economically Dependent) accounted for 11.17 % of the variance, factor 4 (Older Occupied Households) accounted for 7.00 % of the variance. Together the first four factors accounted for **72.75 %** of the variance in this dataset (Table 4.2). The fifth factor accounted for only 1.2 % of the variance and has been excluded as it was not statistically significant. Thus, the 21 socio-demographic variables have been reduced to only 4 variables, each being some combination of the original 21.

Table 4.2 *Total Variance Explained from Factor Analysis*

Component	Initial Eigenvalues		
	Total Variance	% of Variance	Cumulative %
Education and Affluence in Urban Areas	7.007	33.364	33.364
Less Affluent Younger Families	4.453	21.206	54.571
Economically Dependent	2.347	11.174	65.745
Older Occupied Housing	1.471	7.005	**72.750**
5	1.197	5.701	78.452
6	.890	4.237	82.688
7	.732	3.483	86.172
8	.574	2.731	88.903
9	.410	1.953	90.856
10	.375	1.786	92.642
11	.361	1.717	94.359
12	.268	1.275	95.635
13	.208	.989	96.623
14	.194	.923	97.547
15	.134	.640	98.187
16	.098	.467	98.654
17	.086	.410	99.063
18	.073	.348	99.411
19	.060	.283	99.695
20	.047	.224	99.919
21	.017	.081	100.000

Extraction Method: Principal Component Analysis.

The rotated component matrix indicated that the 21 selected variables formed 4 separate groups or factors. Rotated factor loadings (Table 4.3) were examined to assess the nature of the four retained factors resulting from varimax rotation. A loading was interpreted as large if it exceeded 0.50 in absolute magnitude (Kachigan 1991). Variables with high positive loadings ($\geq$ .50) refer to those county characteristics which are associated with higher WNV infection rates. Variables with negative loadings ($\leq$-.50) have an effect due to their absence at the county-level.

Table 4.3 *Rotated Component Matrix[a] from Factor Analysis*

	Component			
	1	2	3	4
Total Population	**.657**	.106	.264	.227
Percentage of the population that is white	**-.610**	-.174	**-.591**	-.132
Percentage of the population 16 and over in the workforce	.258	**.584**	-.451	.123
Percentage of the population over 25 with a high school diploma	**-.832**	-.019	-.094	.155
Percentage of the population over 25 with an associate degree	.067	-.077	-.006	-.005
Percentage of the population over 25 with a bachelors degree	**.857**	.080	-.237	-.123
Percentage of the population over 25 with a graduate degree	**.858**	-.058	-.095	-.083
Percentage of the population living below the poverty level	-.117	-.279	**.861**	-.060
Percentage of households headed by females	.327	.202	**.775**	.321
Percentage of the population aged 65 or older	-.378	**-.744**	-.005	.047
Percentage of the population under age 18	-.178	**.903**	.004	-.005
Percentage of households that are occupied	.196	.479	-.130	**.673**
Median year housing was built	.086	.368	-.181	**-.782**
Percentage of the population that is urban	**.703**	.140	.035	.496
Percentage of the population that is foreign born	**.789**	.100	.244	.115
Average household size	.090	**.887**	-.095	-.031
Percentage of households receiving public assistance as income	.011	-.110	**.861**	-.045
Median household income in 1999	**.632**	.490	**-.522**	-.019
Percentage of households occupied by renters	**.601**	-.046	.490	.395
Percentage of the population 16 and over and female in the workforce	.360	.482	-.306	.172
Counties designated as Urban	**.561**	.294	-.085	.251

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
[a] Rotation converged in 10 iterations.

Factor One: Education and Affluence in Urban Areas

Eight variables had high positive loadings on the first factor. These eight include: total population; percentage of the population over age 25 with a bachelors degree; percentage of the population over age 25 with a graduate degree; percentage of the population that is urban; percentage of the population that is foreign born; median 1999 income; percentage of houses that are occupied by renters; and counties that are urban. Factor one has been labeled as ‘Education and Affluence in Urban

Areas', based on the variables with positive loadings associated with education, income, urbanicity. Within the study area counties fitting that description correspond with Chicago, Detroit, Indianapolis, Cleveland, Columbus and Cincinnati metropolitan areas. Megalopolis, on the easternmost part of the study area has the greatest concentration of counties fitting this description. As a result of the analysis the counties at greatest risk of infection correspond with the red areas shown in Figure 4.4.

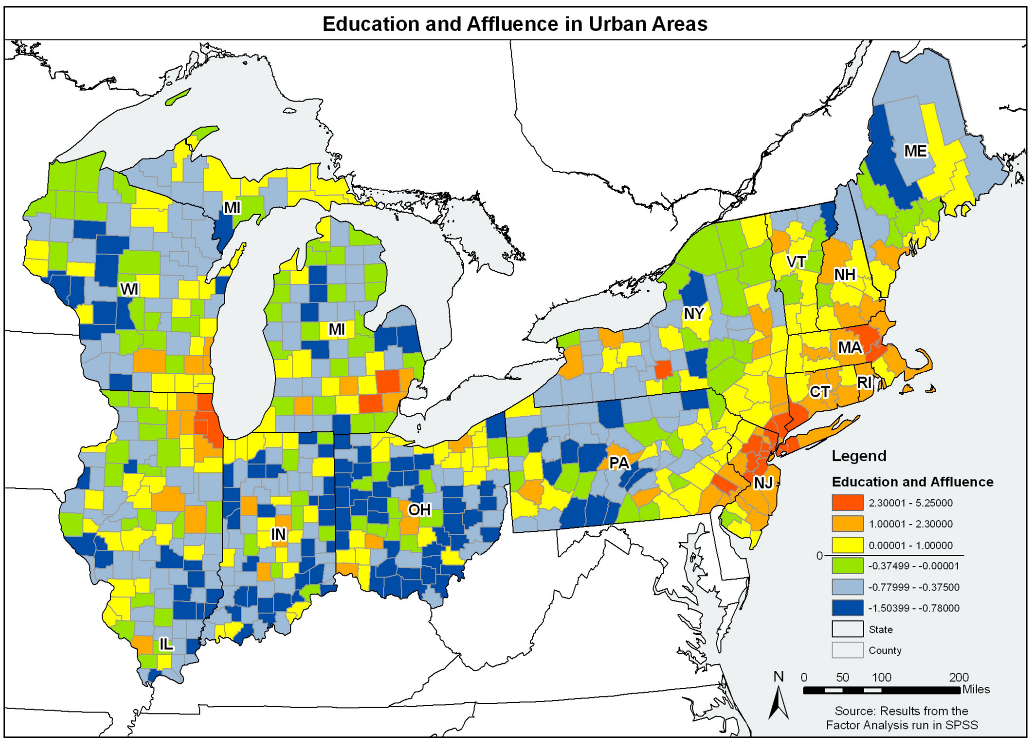


Figure 4.4 *Choropleth Map of county-level factor scores. Counties with higher factor scores (red areas) considered to have the highest risk of WNV infection, based on the analysis. This is most notable in counties located in the eastern half of the study area.*

Population levels are varied throughout the study area, with heavily populated areas located in each of the 14 states. The most populated areas are located along the east coast, from Massachusetts to New Jersey, eastern and western Pennsylvania, western New York, northeastern and central Ohio, northwest Indiana, northeast

Illinois, southeast Wisconsin and the southern portion of Michigan. When comparing population demographics to the counties identified at risk by this first factor, they correspond highly with the most populated areas.

Percentage of the population over 25 with a graduate degree had the highest loading on the first factor. The eastern half of the study area contains the largest concentration of counties with a high percentage of the population that has earned a graduate degree (Figure 4.5).

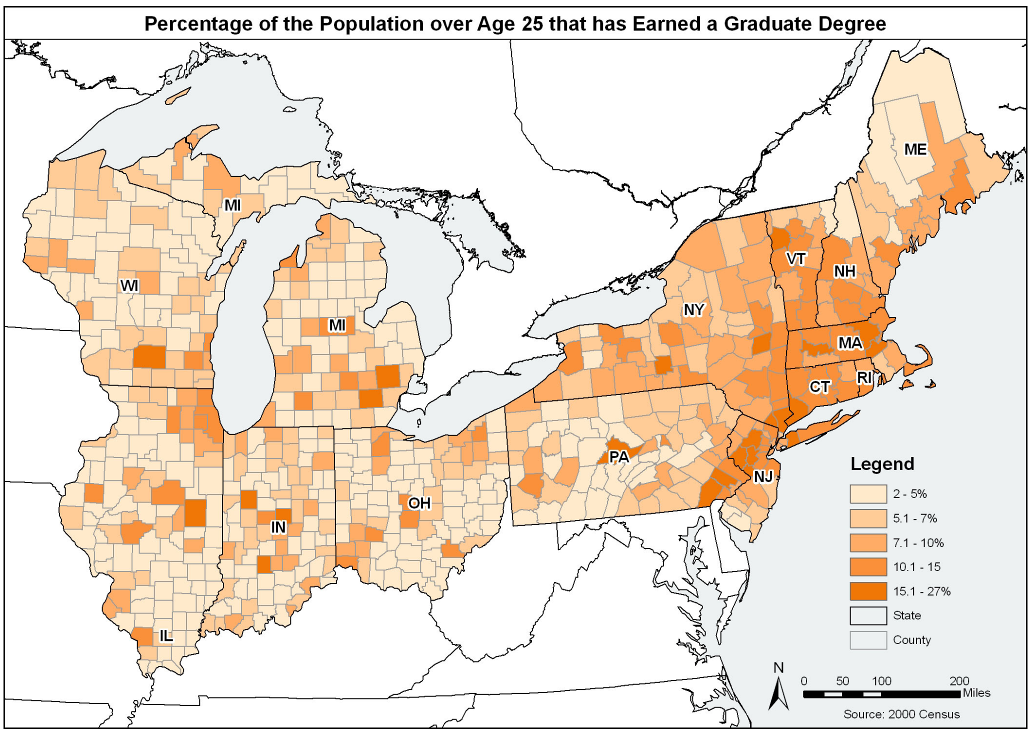


Figure 4.5 *Choropleth Map showing percentage of the population over age 25 with a graduate degree. Counties that have a high percentage of the population with graduate degree are more likely to have higher WNV infection rates, based on the analysis. There is a large concentration of these counties found in the eastern half of the study area.*

The percentage of population that has earned a Bachelors degree is highest in those states closest to the east coast. New York, Vermont, New Hampshire, Massachusetts, Connecticut and Rhode Island have the highest percentage of individuals over age 25 with an associates degree. In Ohio, Indiana and Pennsylvania, the percentages are much lower in comparison to those individuals with a high school diploma. In the states west of Pennsylvania the percentage with bachelors and graduate degrees are highest mainly near large metropolitan areas. Risk factors based on this county type include high educational attainment, high population and urbanicity.

Factor Two: Less Affluent Young Families

Three variables had high loadings on factor two. These three variables are: percentage of the population 16 or over in the workforce; percentage of the population under age 18; and average household size. Factor two has been labeled 'Less Affluent Young Families' based on the variables with high positive loadings associated with the number of young workers, household size and a high number of children in the population. The counties with the greatest risk of WNV infection based on this description correspond with the suburban and outlying areas adjacent to those identified as 'Education and Affluence in Urban Areas' (factor 1). Figure 4.6 highlights areas identified at greatest risk by the analysis, counties located in Illinois, Indiana, Michigan, Ohio, and Wisconsin and along the east coast. The percentage of the population age 16 and over in the workforce is greatest in more populous areas where the population is more diverse (Figure 4.7). Much of the eastern and western portions of the study area indicate the incidence of the highest percentages of the population 16 and over in the workforce. The central portion of the study area exhibits the lowest percentages.

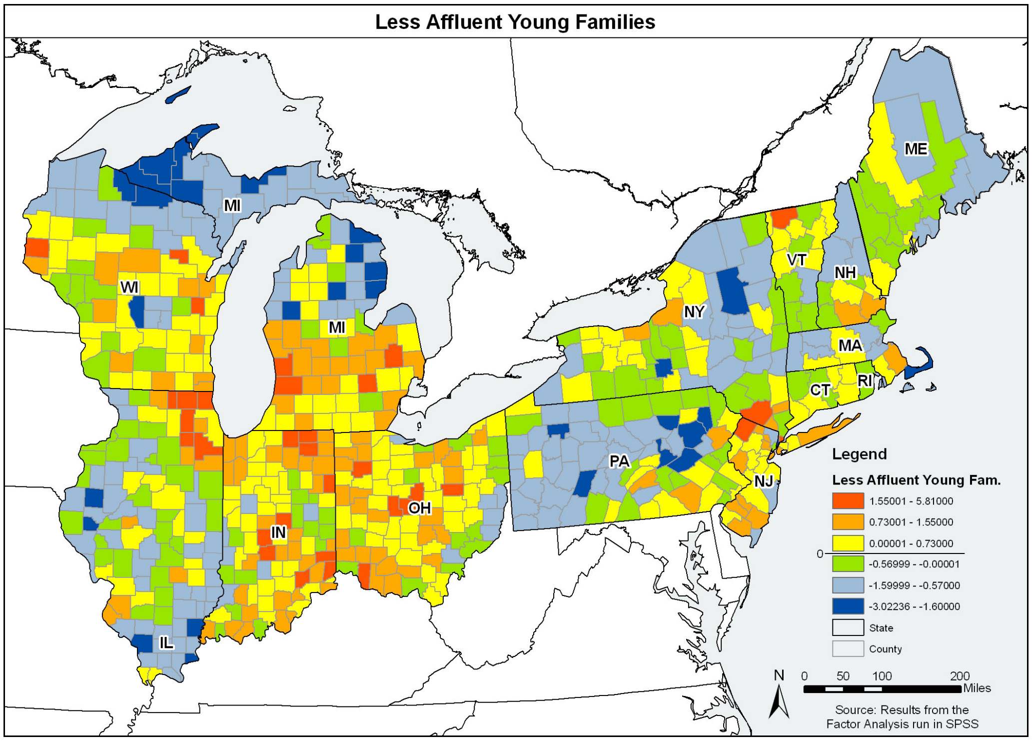


Figure 4.6 *Choropleth Map of county-level factor scores for counties labeled Less Affluent Young Families based on the analysis. The greatest concentration of these counties is in the western half of the study area.*

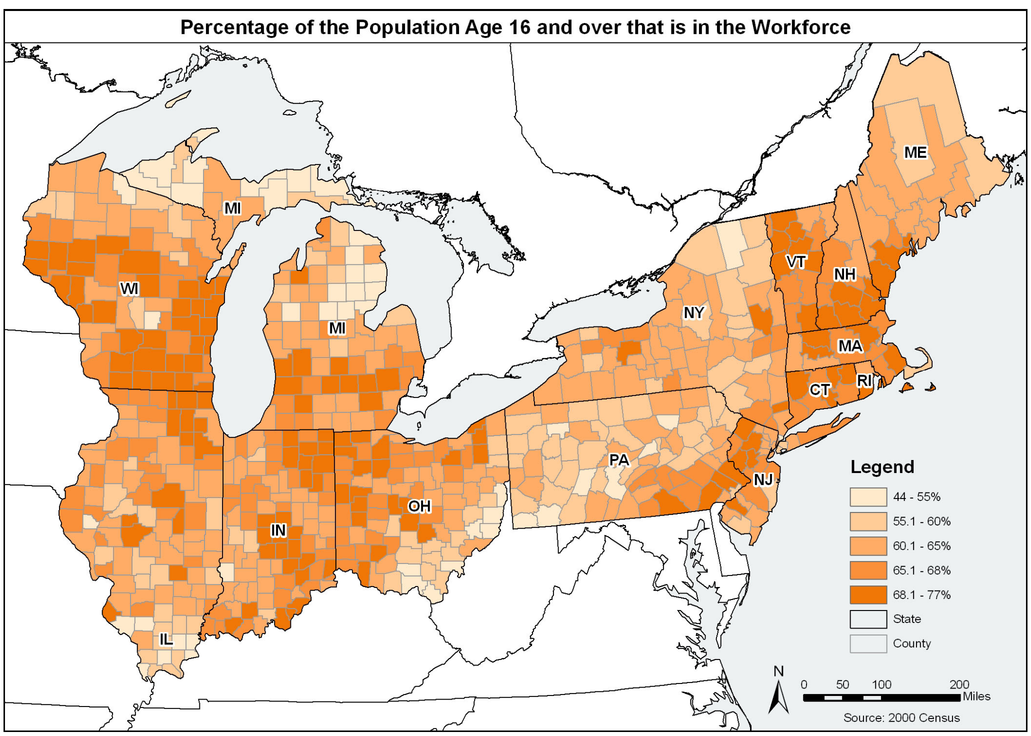


Figure 4.7 *Choropleth Map showing percentage of the population 16 and over in the workforce at the county level. These percentages are highest percentages in most of the western half and far eastern portion of the study area.*

The distribution of the population over age 65 is varied throughout the study area, with the lowest percentages found in Ohio, Indiana, most of the lower peninsula of Michigan, in Illinois and Wisconsin, many of the counties surrounding Chicago and extending up into Wisconsin. The highest percentage of the population over age 65 is concentrated in counties in the southern and western parts of Illinois, northern Wisconsin, northern Michigan, eastern Pennsylvania into northern New York, eastern New Hampshire and most of Maine. Much of Wisconsin, Michigan, northeastern Illinois, Indiana, Ohio and western New York contain the counties where the percentage of the population under age 18 is highest (Figure 4.8). These counties correspond closely with counties where the population over 65 is lowest. Based on these results, higher average household size and high percentage of the population under the age of 18 are considered risk factors for WNV infection.

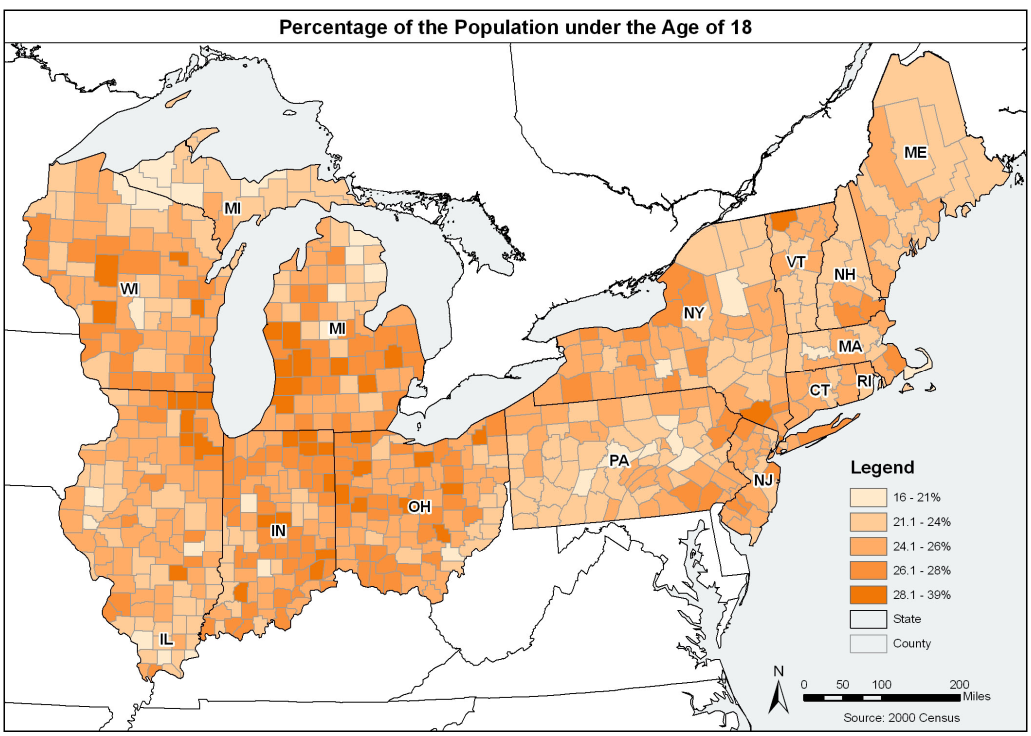


Figure 4.8 *Choropleth Map showing percentage of the population under age 18 at the county level. The greatest concentration of these counties is located in the western half of the study area.*

Factor Three: Economically Dependent

Three variables had high loading on factor three. These three include: percentage of the population living below the poverty level; percentage of households receiving public assistance; and percentage of households headed by females. Factor three has been labeled ‘Economically Dependent’ based on the variables with high loadings. Counties at greatest risk based on this factor are located in northern Wisconsin, southern and northeastern Illinois, central Michigan, southern Ohio, southeastern Pennsylvania, northeastern New Jersey, Maine and southeastern New York (Figure 4.9). In these counties a high percentage of individuals living below poverty and a high percentage of households receiving public assistance increase the risk of WNV infection.

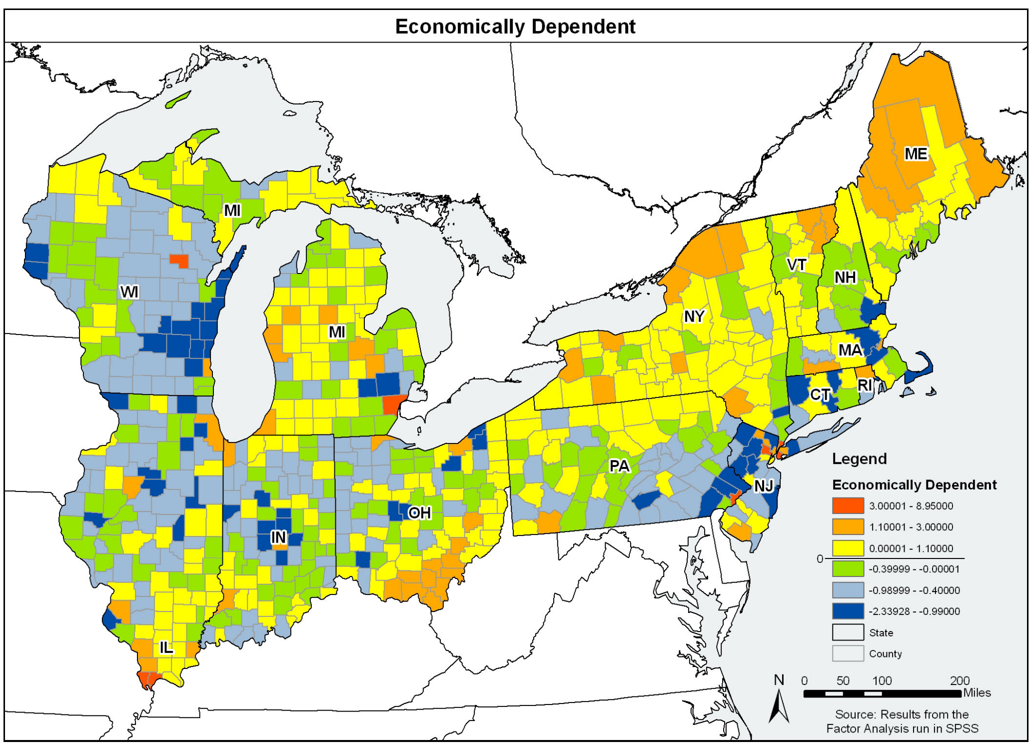


Figure 4.9 *Choropleth Map of county-level factor scores for Economically Dependent. Northern New York, Vermont and Maine in addition to southern Ohio, northeastern and southern Illinois and central Michigan are areas at greatest risk of infection for this county type.*

Those areas of the study area where the percentage of female headed households is greatest mainly occur in densely populated urban areas (Figure 4.10). Many of these counties also have high percentages of the population living below the poverty level. The percentage of the population living below the poverty level shows some variation with the highest percentages evident throughout most of Maine and located in the area that extends from southern Ohio and extends northeastward through Pennsylvania and into New York (Figure 4.11). The highest concentration of households receiving public assistance is in Michigan, northern Maine, New Hampshire and Vermont (Figure 4.12). The area extending from southern Ohio and northeastward through southwestern Pennsylvania and into New York also has a high percentage of households receiving public assistance.

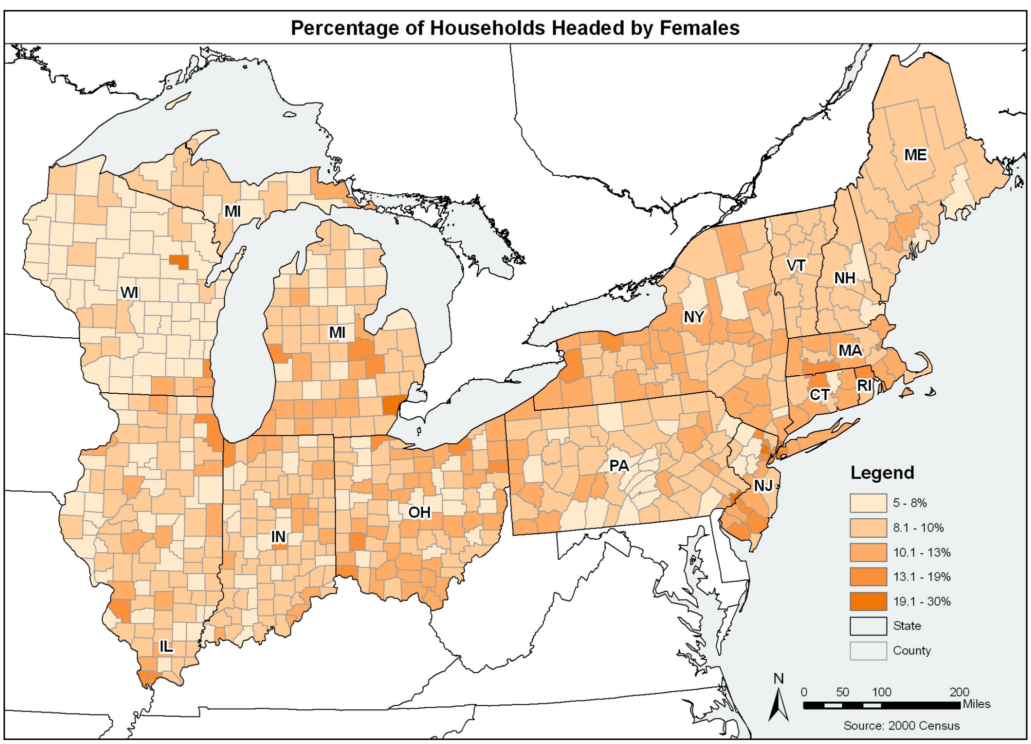


Figure 4.10 *Choropleth Map showing percentage of households headed by females. The highest percentages occur in eastern counties, while Wisconsin has the lowest percentages overall..*

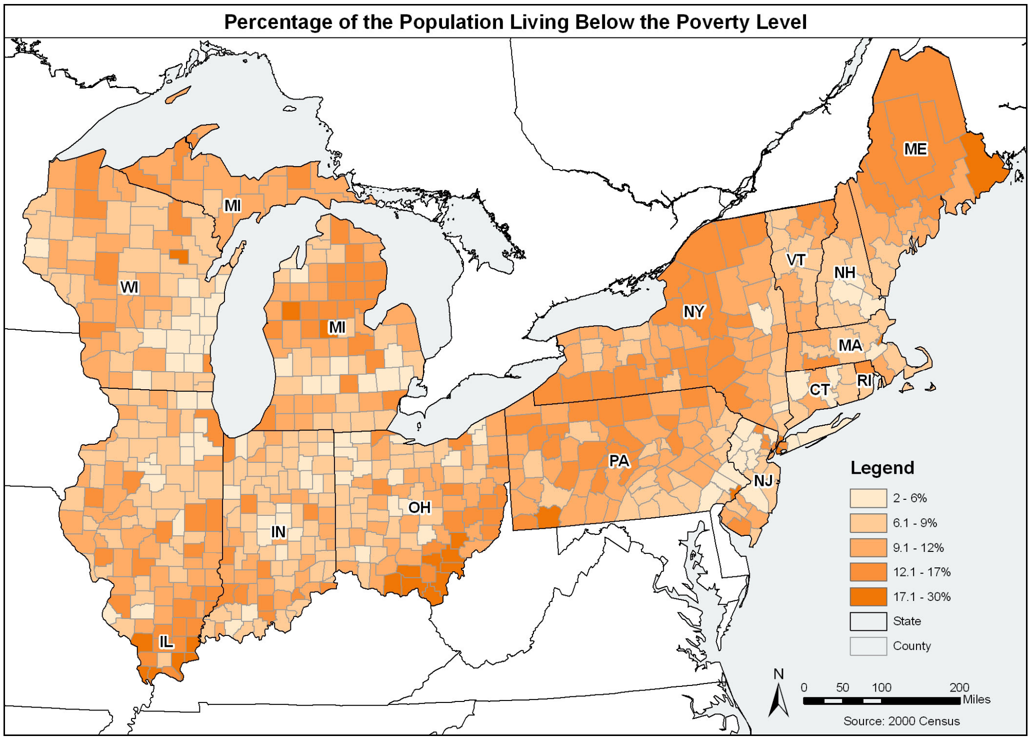


Figure 4.11 *Choropleth Map showing percentage of the population living below the poverty level by county. The highest percentages occur in much of the central and north east of the study area.*

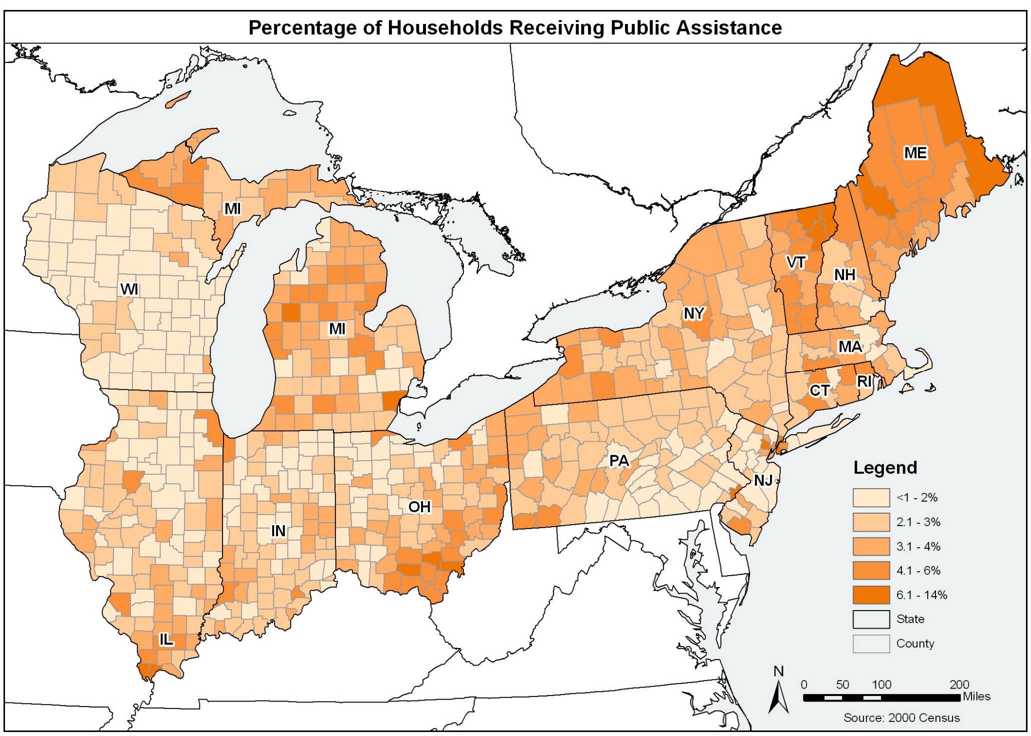


Figure 4.12 *Choropleth Map showing percentage of households receiving public assistance at the county-level. The greatest concentration is shown in the northeastern counties.*

Based on these results the combination a high percentage of female headed households, high poverty levels and a high percentage of households receiving public assistance increases the risk of WNV infection.

Factor Four: Older Occupied Households

Two variables had high loading on factor four. These are: percentage of households that are occupied and median year built. Factor four has been labeled 'Older Occupied Households,' based on the high loadings associated with older residences. Results show that areas of increased risk for WNV infection are located in central and western Illinois, central Indiana and Pennsylvania, western New York and Massachusetts (Figure 4.13).

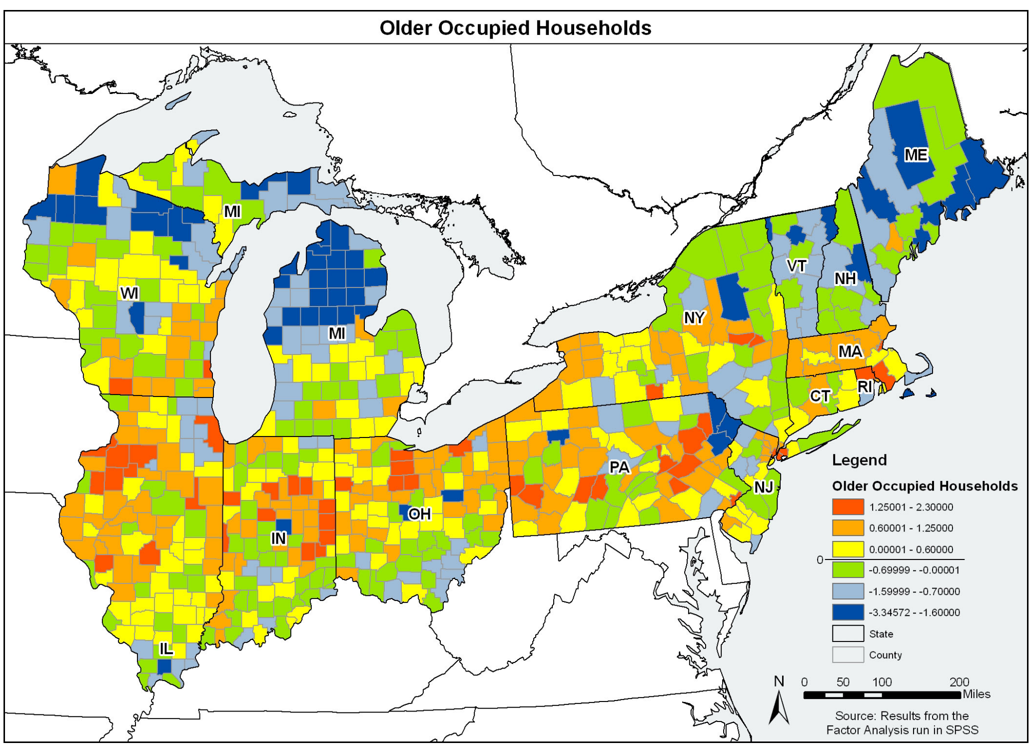


Figure 4.13 *Choropleth Map of county-level factor scores for counties with Older Occupied housing. Across the southern half of the study area are counties where most of the older occupied housing is located and have increased risk of WNV infection.*

The pattern is similar to that of the location of counties containing the oldest housing stock (Figure 4.14). The newest housing stock is found throughout Michigan, Wisconsin, Maine, Vermont and New Hampshire. Additionally there are pockets of newer homes in Eastern Pennsylvania, as well as northeastern Illinois, northwestern and southern Indiana and southern Ohio.

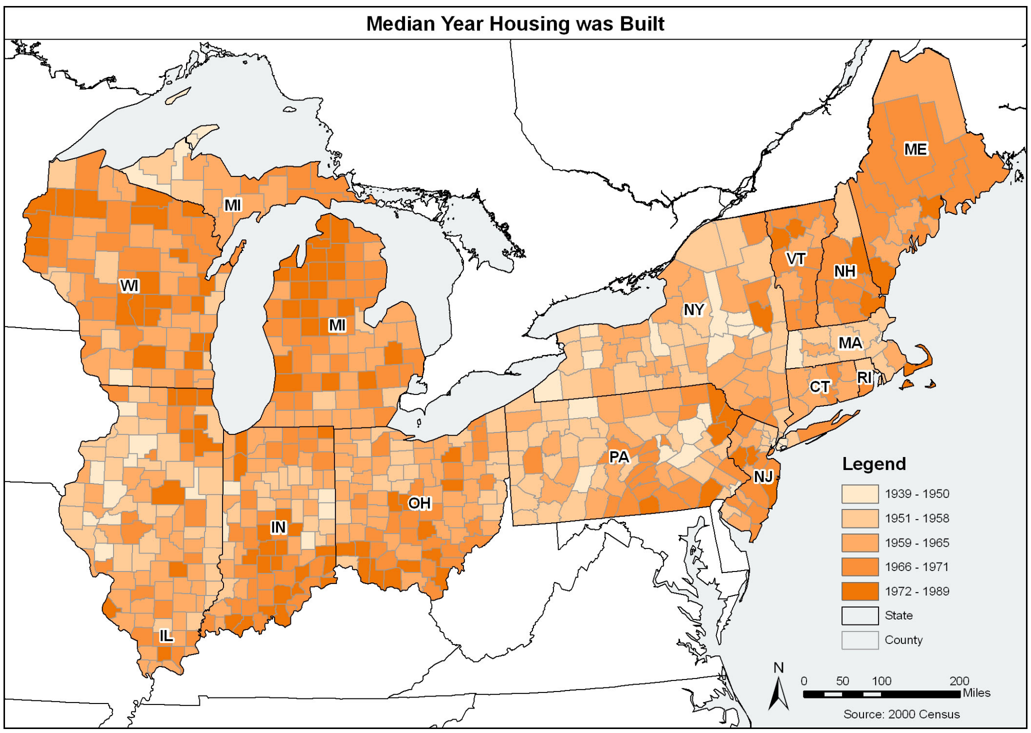


Figure 4.14 *Choropleth Map showing median age of housing at the county level. The older housing stock is concentrated in western Illinois, central Indiana, northwest and eastern Ohio, western Pennsylvania and western New York.*

<u>Public Health Variables</u>

The highest infection rates occur in the western part of the study area (which is less populated than the eastern portion), in comparison to the eastern portion where the virus was first detected (Figure 4.15). Infection rates were highest in western and southern Illinois, eastern Indiana/western Ohio, western and southeastern

Pennsylvania, western Wisconsin, eastern Michigan and southwestern Maine. The highest infection rates were not always associated with the most heavily populated counties.

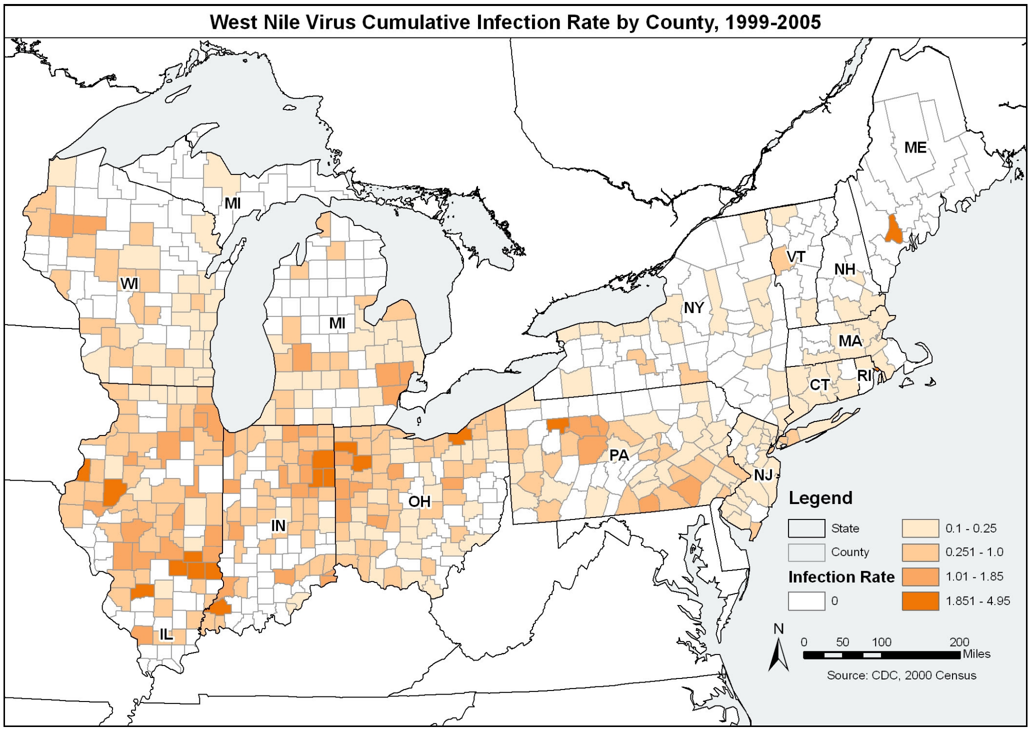


Figure 4.15 *Choropleth Map showing cumulative infection rate at the county level from 1999-2005. Infection rates are highest in the western half of the study area, with the exception of one county in western Maine. Over reporting of mild cases due to increased awareness on some years may explain the pattern seen here.*

Percentage of the population living in urban areas is highest from southeastern Pennsylvania into New Jersey, along the east coast northeast into Southeastern Maine, in central and northeast Illinois, eastern Wisconsin, southern Michigan, and northeast Ohio, central Indiana and southwestern Ohio (Figure 4.16). The pattern of counties that are urban is similar to that of the percentage of the population living in urban areas. Counties were considered urban when they had a urban continuum code of 1, 2 or 3 (USDA 2007). Of the 654 counties in the study area 296 (45.26%) were designated as urban for this research.

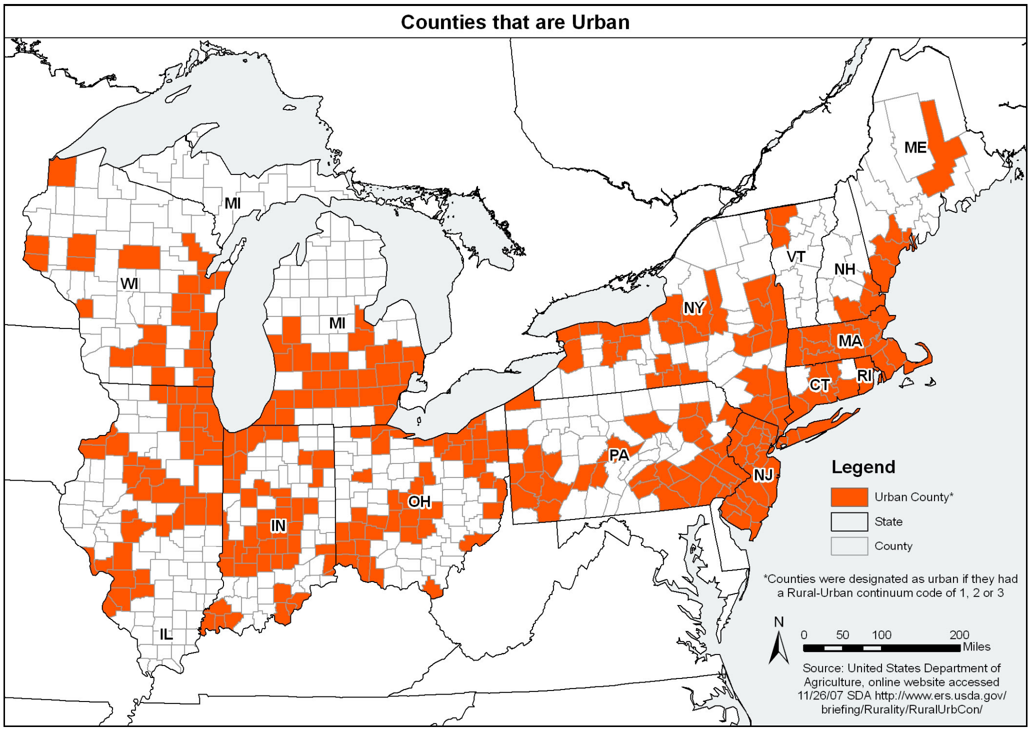


Figure 4.16 *Choropleth Map showing counties designated as urban. 45.26% of the counties in the study area have been designated as urban.*

In order to account for more of the variance among variables the factor scores for the four factors were regressed against the WNV infection rate by county. This use of the model attempts to predict infection rates based on the factor scores. County-level WNV infection rates were predicted from factor scores resulting from the factor analysis of 21 selected socio-demographic variables. The total N for this sample was 654. Standard multiple regression was performed; that is all predictor variables were entered in one step. The overall regression was not statistically significant based on the results: R = 0.28, R^2 = 0.08, adjusted R^2 = 0.07, F (4, 649) =

14.014, $p < .001$. The model was not particularly effective at predicting infection rates as only 7% of the variance in infection rates was accounted for by the regression.

In order to account for more of the variance among variables the values of the 21 socio-demographic variables were regressed against the WNV infection rate by county. This was done as a means of determining statistical significance of the individual variables. County-level WNV infection rates were predicted using the 21 selected socio-demographic variables. The total N for this sample was 372 (counties with an infection rate greater than zero). Standard multiple regression was performed; that is all predictor variables were entered in one step. The overall regression was somewhat statistically significant based on the results: $R = 0.44$, $R^2 = 0.20$, adjusted $R^2 = 0.15$, $F (21, 350) = 4.04$, $p < .001$. This use of the model was more effective at predicting infection rates and explained 15% of the variance in infection rates.

The map of residuals (Figure 4.17) shows those counties having values which are either above or below the expected values, where the ‘expected’ values are infection rates predicted by the regression equations. Mapping residual values provides a visual explanation how well the model did at predicting county-level infection rates. The red areas represent counties with low predicted infection rates and high actual infection rates (positive residuals). Of all counties reporting human cases 20% are colored shades of red on the residuals map. Counties with positive residuals are concentrated mainly in the southwestern portion of the study area encompassing Wisconsin, Illinois, Indiana, Michigan, Ohio and Pennsylvania. These states also show the most variation in residuals. Blue areas represent counties with lower infection rates than those predicted by the model (negative residuals). Of counties that reported positive human WNV infections 30% are had negative residuals. Over prediction of infection rates by the model occurred in more counties than under prediction. The grey areas represent counties where predicted infection rates were within one standard deviation of the mean. Fifty percent of counties that reported positive human infections are shaded grey on the map of residuals. In these counties the model achieved greater accuracy of prediction.

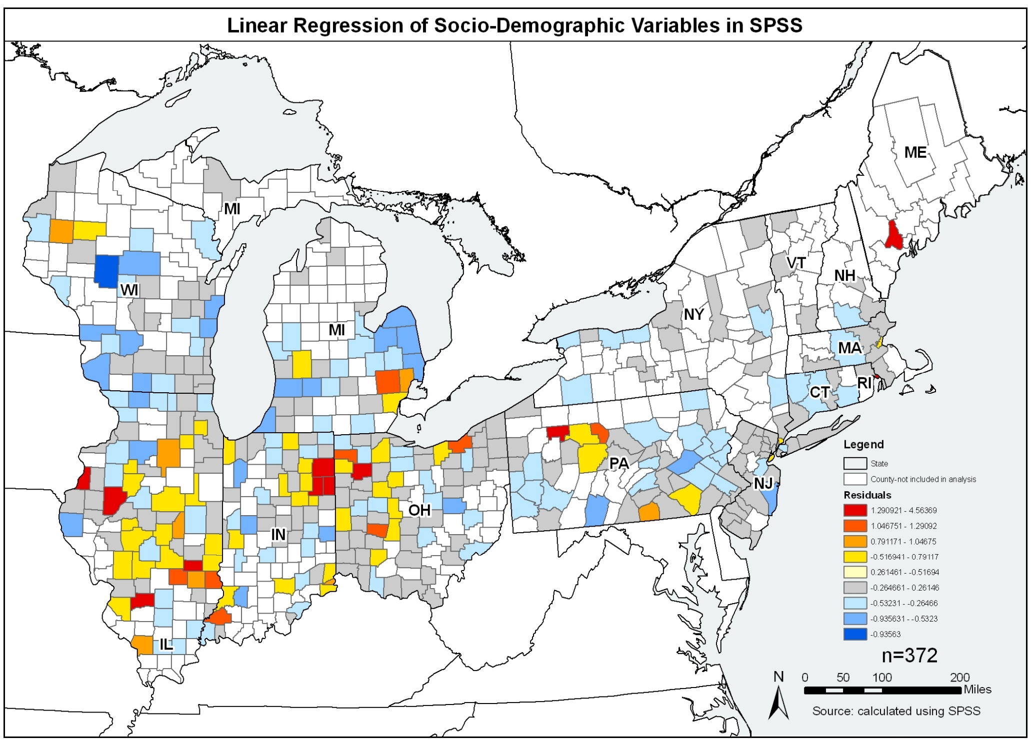


Figure 4.17 *Choropleth Map of residuals from regression of factor analysis. The pattern represented highlights the Midland cultural region influenced by the mobility of the human population. Major interstate transportation routes also seem to influence the geographic pattern.*

There is a high concentration of counties with negative residuals in southern and western Indiana which extends northeast up into Maine. Positive residuals are associated with values higher than the mean, while negative residuals are associated with values less than the mean. Less variation in either direction from the predicted values represents a greater fit of the model.

<u>Summary</u>

From 1999-2005 WNV was detected in humans, birds, mosquitoes and animals in counties throughout the study area. Factor analysis of selected socio-demographic characteristics resulted in the identification of four county types associated with high WNV infection rates. These are: 1) Education and Affluence in Urban Areas, 2) Less Affluent Young Families, 3) Economically Dependent, and 4) Poverty Indicators. Different socio-demographic characteristics are associated with each county type, the factor names are reflective of variables with high positive loadings. Linear regression and subsequent mapping of residuals supports the idea of using socio-demographic variables as a means of predicting areas at increased risk of WNV infection.

Chapter 5: Survey Results: Local Level Findings

Introduction

To analyze the response of county-level public health officials in the state of Ohio and to relate that response to the infection rate a survey of public health officials was conducted. A copy of the questionnaire administered is included in Appendix B. Aggregate responses are included in Appendix C.

In determining the possible response of public health officials to the threat of WNV, the number of WNV surveillance staff members was analyzed. The number of staff available to respond to WNV concerns may reflect the ability to respond aggressively at the local level. The number of WNV surveillance staff varied by county with clusters of personnel with clinical degrees in the south, west and east. Staff members with degrees in epidemiology are mainly in southern counties. Clusters of counties with PhD or Masters degrees in related sciences exist in the southwestern area of the state. Clusters of clerical and administrative staff were found mainly in the northeast, southwest and western states. Some explanation for this pattern may be provided by the location of state-level offices in the southern part of Ohio.

Surveillance is a most important activity as it allows public health officials to become aware when positive cases of the virus are presented within the county. Surveillance activities include the reporting of WNV case data by county and state level health departments via the Arbovirus Surveillance Network (ArboNET) (O'Leary 2004). "ArboNET is a national reporting and information system managed by CDC's Division of Vector-borne Infectious Diseases in Fort Collins, Colorado" (Garvey 2006). Positive case data is reported for humans, birds, mosquitoes, and non-human animals (horses). The USGS produces maps from this data which are made available for public use via the internet. This information can be used to begin prevention and control methods where needed.

Control activities are those with the aim of reducing the number of mosquito vectors. Mosquito surveillance data is used to determine where to concentrate activities related to reducing mosquito populations in a given area. Application of pesticides to control the vectors can begin when the location of positive mosquitoes is known. Larvicide is used to prevent larvae from maturing into adults. Adulticides are used to treat areas where mature mosquitoes exist and are capable of spreading disease.

Prevention methods include educating the public as to how they can reduce or minimize their risk of infection. These activities include educational materials or messages regarding the use of DEET, and protective clothing to reduce the risk of being bitten by the vector. Other messages may promote the idea of avoiding the outdoors at dusk and dawn, when most mosquitoes are active. Prevention messages are also likely to include information regarding the elimination of containers which collect water and promote vector breeding in and around the home environment.

Results

The results indicate that local level public health officials have begun surveillance activities for WNV in humans, horses, birds, and mosquitoes (Table 5.1). Mosquito control in addition to prevention activities in the form of radio and TV

Public Service Announcements (PSA's) have also begun. Responses from most counties indicate that surveillance activities are widespread. Sixty-four percent of respondents indicated human surveillance has been implemented. Equine surveillance was reported by 31% of respondents. Avian surveillance is in place in 81% of participating counties, and 71% of respondents indicated that mosquito surveillance has been implemented for WNV. Mosquito control and radio or TV PSA's have been begun in 40% of responding counties.

Table 5.1 *WNV Activities Implemented by Local Level Public Health Officials*

Activity	N	%
Human surveillance	37	64
Equine surveillance	28	31
Avian surveillance	47	81
Mosquito surveillance	41	71
Mosquito control	24	40
Radio or TV PSA	22	40

Source: Survey of Local Level Public Health Officials in the State of Ohio

Prevention messages have also been widely used (See Table 5.2). The most commonly promoted messages are those suggesting the use of DEET based products (83%), peri-residential source reduction (67%) and personal prevention methods (88%). This pattern is consistent throughout the state. Those counties that have modified messages for lower literacy and non-English speaking audiences are mainly located in the southern portion of the state (9%). Radio and TV PSA's were implemented mainly in the northern and western portions of the state (31%).

Table 5.2 *WNV Prevention Messages Used and Promoted by Local Level Public Health Officials*

Prevention Message	N	%
Use of DEET-based repellents	48	83
Peri-residential source reduction	39	67
Personal protective measures	51	88
Notification of adulticiding activities	17	29
Modification of messages for lower literacy and non-English speaking audiences	5	9
Radio PSA	18	31

Source: Survey of Local Level Public Health Officials in the State of Ohio

Where surveillance is in place there is variation of the duration among counties (Table 5.3). With respect to human disease counties those counties collecting surveillance data for 6 months or less are concentrated in the northern part of the state. Counties which collect human surveillance data for 7-9 months are found mainly in the southwest part of the state. Counties collecting human surveillance data for 10 – 12 months are found mainly in the northern and western parts of the state. The few counties that reported surveillance for equine disease for 5 months or less were mainly in the north, counties collecting equine data for 6-9 months are mainly in the west, while counties collecting the same data for 10 -12 months are clustered in the north and south. The majority of counties collected avian surveillance data for at least six months while only 2 counties collected data for 10-12 months. There is a cluster of counties in the south collecting avian data for 7-9 months. A majority of counties in the sample (69%) collect mosquito surveillance data; these counties are spread around the state with no apparent pattern. Mosquito surveillance data are collected for 1-6 months in about three-fourths of the responding counties. The counties that reported collecting mosquito data for 7-9 months were clustered in the southern part of the state.

Table 5.3 *Duration of WNV Surveillance measured in months*

Type of Surveillance	Number of months surveillance	
	N	Average
Human disease	44	9
Equine disease	32	8
Avian mortality	50	6
Mosquito	43	5

Source: Survey of Local Level Public Health Officials in the State of Ohio

Only five counties reported are using active surveillance for human cases. This involves collecting blood samples to test individuals for WNV. Most are collecting primarily passive data (information regarding positive cases that have been reported). In most Ohio counties, a combination of active and passive data are being collected. Passive surveillance is most common for equine surveillance among counties. Several counties use a combination of active and passive methods. Only four counties use primarily active surveillance methods for equine disease. Active surveillance is much more common for avian mortality.

When comparing the length of avian surveillance to infection rates correlation analysis resulted in a pearson coefficient of 0.130. Comparing the length of mosquito surveillance to human infection correlation analysis resulted in a pearson coefficient of 0.204. Comparing the length of human surveillance to human infection rates correlation analysis resulted in a pearson coefficient of -0.065. The lack of a significant positive correlation between length of surveillance and infection rates suggests that surveillance has no impact on infection rates. With no appropriate surveillance system in place in 1999 and 2000, it is likely that underreporting of positive human WNV infections occurred. Beginning in 2001 increasing arbovirus surveillance throughout the study area and greater awareness of WNV among clinicians is likely for overreporting of human WNV infection, especially in 2002. This sequence of events may have an affect on the results which are based on a cumulative infection rate for 1999-2005.

Based on the survey results there does seem to be some collaboration between jurisdictions. For the areas of surveillance, prevention and control 38% of respondents indicated they collaborate with a particular city or county.

To examine the response of public health officials it was necessary to divide counties into to groups: those counties with an infection rate greater than zero and those counties with an infection rate equal to zero. Twenty-four counties had an infection rate greater than zero, with an average of 2.8 WNV activities implemented and 2.5 WNV prevention messages per county. Three counties with an infection rate greater than zero did not implement WNV activities and three did not promote WNV prevention methods. Thirty-three counties had an infection rate equal to zero, with an average of 3.5 WNV activities implemented and 2.8 WNV prevention messages per county. Two counties with an infection rate greater than zero did not implement WNV activities and three did not promote WNV prevention methods. These results were also compared to the demographic responses of the respondents. For counties where the respondent was employed for more than fifteen years in the present job the infection rates ranged from 0.04 – 0.35. The highest infection rates were associated with counties where respondents were in the current position for fifteen years or less.

With respect to length of employment in the present position there is a cluster of counties where the respondent has more than twenty years in the northern part of the state, with a few counties in the western part of the state. Counties where the respondent was employed between fifteen and twenty years were mainly concentrated in the western part of the state. Those employed between ten and fifteen years are mainly in the western part of the state. In the southern part of the state is the highest concentration of those employed between five and ten years in the current position, While those employed for 5 years or less are located throughout the entire state. ANOVA was used to determine the relationship between experience of survey respondents and infection rates. Comparing infection rates to the demographics of survey respondents with ANOVA yielded the following F values: Years in current position 2.28, gender 0.03, education 0.24, and age 0.55. Of these results, only years in current position yielded an F value greater than 1. This suggests a significant relationship between years in current position and the WNV infection rate. For demographics with F values less than 1, there are no significant relationships between these variables and county-level infection rates. More experienced public health officials have knowledge which makes them effective in obtaining lower WNV infection rates. Accessing the knowledge of experienced public officials and using that information to train less experienced public health officials can help to further reduce WNV infection rates. What is it that they do know that people with less experience do not?

Summary

A survey of local level public health officials in the State of Ohio was administered by mail to all 88 counties. The purpose of the survey was to measure the response of public health officials to WNV. Sixty-six percent of the surveys were returned. The number of staff members employed by each county to respond to WNV varied by county. Surveillance activities have been implemented in the majority of counties to detect WNV occurrence in humans, horses, birds and mosquitoes. Counties implemented mosquito control measures to reduce the number of mosquitoes. Counties also implemented PSA's to educate the public in ways to reduce their risk of WNV infection. The most commonly used prevention messages were related to the use of DEET-based products and personal protective measures. Collaboration between jurisdictions for surveillance/prevention/control was reported by 38% of respondents. The 24 counties with infection rates greater than zero implemented an average of 2.8 WNV activities and 2.5 prevention messages per county. An average of 3.5 WNV activities and 2.8 prevention messages were implemented in counties with infection rates equal to zero. Infection rates were lowest in counties where respondents were employed for more than fifteen years. Analysis did not identify a significant relationship between county-level infection rates and type of surveillance, or between the length of avian or mosquito surveillance. However, some correlation between human surveillance and county-level infection rates has been identified.

Chapter 6: Discussion of Research Findings

Introduction

Results of the Survey of Public Health Officials in the state of Ohio were presented in the previous chapter. In this chapter I will discuss the meaning and implications of the findings. Three questions guided this research, they are: 1) Can socio-demographic characteristics be identified and related to human cases of WNV infection? 2) Is there a particular type of county that is more frequently associated with cases of WNV? 3) Is the response by public health officials at the county level appropriate relative to their perception of the threat posed by WNV in their jurisdictions?

Can socio-demographic characteristics be identified and related to human cases of WNV infection?

Earlier research suggests that a relationship exists between several demographic variables and the spread of WNV (Han et al. 1999, Ruiz et al. 2004, Ruiz et al. 2007). This research confirmed earlier findings with respect to the United States. In particular, I found the following socio-demographic characteristics to be positively linked to higher WNV infection rates: educational attainment, age of the population, poverty levels, and age of housing. Socio-economic variables were useful in discriminating between high moderate and low infection rates and showed modest capabilities of estimating actual rates.

Is there a particular type of county that is more frequently associated with cases of WNV?

Earlier research identified a positive relationship between impoverished areas and higher disease rates during studies of dengue fever along the United States/Mexico border (Reiter et al. 2003) and St. Louis Encephalitis in the United States (Chamberlain 1980). Similarly research on WNV in Romania (Han et al. 1999) and Russia (Hubalek 2000) report a relationship between impoverished areas and disease rates. Very little data have been published regarding WNV and socio-demographic characteristics. However, a recent report comparing environmental conditions and socio-demographic characteristics identified three county types associated with WNV infections related to housing age, income and race in Chicago (Ruiz et al. 2007). The study here included an analysis of 21 socio-demographic variables and identified a relationship between socio-demographic variables and WNV infection rates. It also identified four county types which are positively linked to higher infection rates: 1) educated and affluent urban counties, 2) counties with less affluent young families, 3) economically dependent counties and 4) counties with older occupied housing.

Is the response by public health officials at the county level appropriate relative to their perception of the threat posed by WNV in their jurisdictions?

Previous research found public health officials have well developed surveillance and control programs (CSTE 2005). This research found that local level public health officials have in Ohio responded to WNV by implementing programs related to surveillance, control and prevention. Based on the results, the new activities and programs have been implemented by the majority of responding counties. The implication is that county-level public health officials perceive WNV as a threat to local populations.

Contributions of This Research

An earlier report by the CDC suggested the identification of disease risk factors as a means of preventing future infections (CDC 2003). After 10 years of experience with WNV in the United States future risk factor studies are still considered a priority by the CDC (Nasci 2009). As WNV is now considered endemic in the United States periodic outbreaks are to be expected (Komar 2009). Risk factors have been analyzed to identify four county types with an increased risk for WNV outbreaks.

More importantly, a relationship between experienced public health officials and lower WNV infection rates has been identified. The important information gathered by disease surveillance alerts public health officials of the presence of disease agents. This knowledge is necessary in order to minimize the effect on human populations. Safeguarding the health of human populations is the objective of this research. The most important means of achieving that objective is to retain experienced public health workers. Policy implications of these results, suggest increased education for public health officials, especially encouragement of more experienced workers to share their knowledge and experiences with less experienced workers.

Three levels of analysis were necessary to answer the research questions.

Level one: Diffusion of WNV across the Northeastern United States

The first level of analysis used CDC and USGS data to create county-level GIS maps which show the spread of WNV across the 14 states in the study area. WNV infection in birds is more widespread than in humans. Some similarity in clustering of avian infection and human cases is also observed.

Level Two: Analysis of County-level Socio-demographic Variables

This level of analysis answered the first two research questions. Part one of this level identifies county types associated with higher WNV infection rates within the study area. Part two of this level identifies errors in a priori classification of counties based on infection rates with discriminant analysis.

Research Question 1: Can socio-demographic characteristics be identified and related to human cases of WNV infection?

Hypothesis 1: Risk factors will vary by location.

It is possible to identify socio-demographic characteristics that are related to human cases of WNV infection. This was achieved by using factor analysis. By using selected variables taken from census data, it was possible to identify characteristics which are associated with WNV infection. Socio-demographic characteristics can be used as risk factors as a means of predicting areas where future outbreaks could occur. Analysis of 21 socio-demographic variables selected from census data were reduced to five factors. These five factors accounted for 78.45% of variance in the dataset. Urban (factor 1, accounted for 33.36% of the variance, Economically Dependent (factor 2) accounted for 21.21% of the variance, Poverty Indicators (factor

3) accounted for 11.17% of the variance, Older Occupied Households (factor 4) accounted for 7.00% of the variance. The descriptive names for the four factors are associated with particular counties in the study area. In essence, the analysis has identified socio-demographic characteristics which facilitate the spread of WNV and may be considered risk factors for WNV infection.

Research Question 2: Is there a particular type of county that is more frequently associated with cases of WNV?

Hypothesis 2: Specific risk factors can be identified that relate to cases of WNV neurological disease.

Hypothesis 3: Socio-demographic characteristics can be used to produce a classification of counties.

This analysis identified four types of counties associated with WNV infection. Counties with a population that is educated and affluent, less affluent with young families, having high levels of poverty, low percentages of white residents and consisting of older housing stock facilitate the spread of WNV. Therefore, communities with large numbers of elderly, areas with low dependency ratios, and high percentages of white residents in the population contribute less to the diffusion of WNV. Age of housing, percentage of residents that were "White", and low income have previously been included in variables accounting for much of the variance in an earlier study which also used factor analysis (Ruiz et al. 2007).

Level Three: Survey of Local Level Public Health Officials in the State of Ohio

Research Question 3: Is the response by public health officials at the county level appropriate relative to their perception of the threat posed by WNV in their jurisdictions?

Hypothesis 4: Public health officials are responding to the threat of WNV in accordance with their perception of the disease as a local threat.

County-level public health officials have implemented a variety of prevention and control measures to reduce the public's risk of WNV infection. Surveillance has been implemented at the county-level to identify the presence of WNV. Surveillance measures are now in place to detect WNV occurrence in humans, birds and mosquitoes by 64%, 81% and 71% of responding counties respectively. Mosquito control activities and radio or TV PSAs have also been implemented at the county level. This suggests that public health officials perceive WNV as a threat to local populations.

Hypothesis 5: Socio-demographic characteristics of the survey respondents influenced their perception of the risk presented by WNV.

One of the most important findings of the research was the public health officials own ideas about the greatest obstacle to preventing the spread of WNV in their jurisdictions. General consensus is that more resources be made available to properly combat this pathogen. More staff and funds to pay workers and provide support for every aspect of surveillance, prevention and control are deemed necessary. Specifically, there is a great need for personnel with specialized training.

The support and encouragement of public health organizations is needed to attract individuals into academic fields that will prepare them for infectious disease epidemiology which is crucial to the field.

Summary of Findings

The primary question asked by this research was “Can socio-demographic characteristics be considered risk factors for neurological disease due to West Nile Virus?” Based on the results of this research, the answer is yes. Socio-demographic characteristics identified as risk factors include: high average household size, a high percentage of the population under the age of 18, high percentage of the population living in poverty, high percentage of households receiving public assistance, older housing stock and a high percentage of the population over age 25 with associate degrees. In response to the question “Is there a particular type of county that is more frequently associated with cases of WNV?” analysis yielded 4 county types. The counties have been designated as: Education and Affluence in Urban Areas, Less Affluent Young Families, Economically Dependent and Older Occupied Housing.

Questions regarding the public health response were also addressed. Fifty-eight completed surveys were returned of the eighty-eight mailed, representing a 66% response rate. The high response rate could be attributed to the fact that the topic was of importance to the respondents. Survey responses were analyzed to answer the question “Have public health officials implemented programs in response to the occurrence of neurological disease due to WNV?” The answer was yes, public health officials did implement new programs in response to WNV.

Socio-demographic characteristics of the respondents did not seem to influence their perception of the risk presented by WNV. This is likely due to the fact that the survey respondents may not have been the individuals responsible for the initial response to the disease agent. Additionally, local level response may have been dictated by resource availability as opposed to the perceived threat. Surprisingly, length of time in the current position was more closely related to lower infection rates than length of surveillance. This suggests that more experienced public health workers likely have some knowledge or experience which was not made known through the survey.

The model used in this research does not take into account environmental factors which could have an effect on the arthropod vector and avian hosts. Arthropod numbers can fluctuate due to weather conditions. Dispersal of avian hosts may also be related to environmental conditions. A sufficient number of competent vectors and a number of viremic avian hosts avian hosts when found in areas with the socio-demographic characteristics associated with the four types of counties identified here will facilitate the spread of WNV among human populations.

Future Research

Conducting analysis using the same 21 variables using for all United States counties would provide a more conclusive analysis regarding the role of socio-demographic variables. The identification of socio-demographic characteristics or combinations of characteristics not included in this analysis as risk factors for WNV infection could also be addressed in further research. Such information would add another dimension to identifying areas to focus prevention methods. Other potential research could also examine census data in conjunction with environmental factors. Comparing rural areas to urban areas was outside the scope of this dissertation. This type of comparison would identify characteristics specific to either urban or rural communities also provide data useful to public health officials in the prevention of human WNV disease. A similar study could be conducted in response to newly emergent diseases.

Personal growth in intellect addition to growth within the discipline has increased my own understanding of the limitations of this research. The survey tool may not adequately address the hypotheses. Therefore, refinement of the survey instrument to more directly relate to the hypotheses would likely yield more specific results. This would allow the opportunity to address the smaller questions that lead us to the bigger one. Future research could ask more open-ended questions administered in person or by phone, to more accurately assess the perceptions of public health officials.

Appendix A

Variable	**How Variable Was Calculated**
INFRATE	Number of human cases reported / Total population * 10000
TOTPOP	Total population
%≥65	Population 65 years and over/Total population
%UND18	(Under 18: Male + Under 18: Female) / Total Population
%WHITE	Total white population/Total population
%FORBORN	Total population foreign born / Total population
%≥16WORK	Workers 16 years and over/Total population
%WORK≥16FEM	Female workers 16 years and over/Total population
%>25HS	[Population 25 years and over: Male; High school graduate (includes equivalency) + Population 25 years and over: Female; High school graduate (includes equivalency)] / (Population 25 years and over: Male + Population 25 years and over: Female)
% >25 ASSOCDEG	[Population 25 years and over: Male; Associate degree + Population 25 years and over: Female; Associate degree] / (Population 25 years and over: Male + Population 25 years and over: Female)
%>25 BACHDEG	[Population 25 years and over: Male; Bachelors degree + Population 25 years and over: Female; Bachelors degree] / (Population 25 years and over: Male + Population 25 years and over: Female)
% >25 GRADDEG	[Population 25 years and over: Male; Graduate degree + Population 25 years and over: Female; Graduate degree] / (Population 25 years and over: Male + Population 25 years and over: Female)
%BELPOV	Population for whom poverty status is determined: Income in 1999 below poverty level / Total Population
%HHPUBAS	Households with public assistance as income / Total number of households
%POPURB	Total population urban / Total population
URBAN	Urban rural continuum code of 1, 2 or 3
MED99INC	Median household income in 1999
MEDYRBLT	Median Year Housing Built
%FEMHH	Female Householder: No husband present / Total Households
AVGHHSZ	Total population in households / Total number of households
%OCCHH	Housing Units Occupied: Total / Housing Units Total
%RENTOCC	Occupied Units; Renter occupied / Occupied housing units

Appendix B

Survey of Local Level Public Health Officials in the State of Ohio

Please respond for activities, data and cases that occurred in calendar year 2005 unless otherwise noted.

Definitions:	'Your jurisdiction'	= your county (or city, as applicable)
	'Your agency'	= the county (or city health dept.)
	'Your program'	= the county (or city) WNV or infectious disease program
	'WNV Surveillance program'	= the program within your agency
	'Prevention'	= public education, elimination of mosquito breeding sites, etc.
	'Control'	= application of adulticide and larvicide to reduce number of adult and larval mosquitoes

State: ______________________ County or City: ____________________________

Respondent's Title: ____

1) Indicate below the number of (West Nile Virus (WNV) surveillance staff during 2005 – both epidemiology and laboratory – from all funding sources based on highest professional degree. These are mutually exclusive categories so place each staff person in only one column:

Health Dept. Employees	# with DVM, MD/DO, RN or other clinical degrees	# with PhD, DrPH, MSPH, MPH degrees in epidemiology	# with PhD or Masters degree in related sciences	# of all other clerical, administrative and programmatic staff
1.0 FTE				
0.50-0.99 FTE				
<0.50 FTE				
Contractors				
1.0 FTE				
0.50-0.99 FTE				
<0.50 FTE				

2) Does the county/city health department have adequate access to medical entomologist(s):
   - within the public health agency ______YES ______NO

     -If yes, did your agency also have this access in 1999? ______YES ______NO

   - through contract or other formal arrangement with a local college or university? ______YES ______NO

     -If yes, did your agency also have this access in 1999? ______YES ______NO

3) Does the county health department have adequate access to expertise in wildlife biology within a county (city) agency? ______YES ______NO

   -If yes, did your agency also have this access in 1999? ______YES ______NO

4) Does the county/city health department have a designated public health veterinarian within your agency? ______YES ______NO

   -If yes, did your agency also have this access in 1999? ______YES ______NO

5) Has WNV activity been detected in your jurisdiction (human, equine, avian, mosquito)? ______YES ______NO

6) Please enter the number of human cases reported in your jurisdiction by year.

Number of Human Cases By Year						
1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**

7) How would you characterize the number of human cases of infection for your jurisdiction by year after it was first detected?

	1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
“HIGH”							
“MODERATE”							
“LOW”							

8) a. Please complete the following table concerning the duration of surveillance during the year:

Type of Surveillance	Indicate # of months of surveillance
Human disease	
Equine disease	
Avian mortality	
Mosquito	

b. What type of surveillance is used in your jurisdiction for (check most applicable box):

Type of Surveillance	Primarily Active	Combination of Active and Passive	Primarily Passive
Human disease			
Equine disease			
Avian mortality			

---

9) **For human West Nile neuroinvasive disease surveillance in 2005:**

a. Did your agency require reporting of:

- Hospitalized encephalitis cases of unknown etiology?

______YES ______NO

- Hospitalized meningitis cases of unknown etiology?

______YES ______NO

b. Did your agency implement a laboratory-based surveillance system to report CSF specimens positive for arboviral infection?

______YES ______NO

10) Did your program use the CDC/CSTE National Public Health Surveillance System (NPHSS) case definition for neuroinvasive disease to classify cases as confirmed or probable *or* did you use another case definition in your jurisdiction?

______CDC/CSTE NPHSS case definition used exclusively

______ A modified case definition specific to your jurisdiction

---

11) **For equine West Nile disease surveillance in 2005:**

a. Did your agency have a system in place for reporting cases of equine neurologic disease to the state health department from veterinarians, veterinary diagnostic labs or other agency labs?

______YES ______NO ______DON'T KNOW

b. If yes, were specimens submitted for diagnostic testing for:

WNV?	______YES	______NO	______DON'T KNOW
Other arboviruses?	______YES	______NO	______DON'T KNOW
Rabies?	______YES	______NO	______DON'T KNOW

c. How many equine specimens were tested in the public health laboratory for:

WNV?	______YES	______NO	______DON'T KNOW
Other arboviruses?	______YES	______NO	______DON'T KNOW
Rabies?	______YES	______NO	______DON'T KNOW

d. Were temporal-geographic clusters (2 or more cases) of equine neurologic disease reported to your agency? ______YES ______NO

e. If yes, how many clusters were reported? __________

f. If yes to (d), did your program or any county agency investigate the clusters to determine the cause of the illness? ______YES ______NO

g. If yes to (d), what was the median interval in days from the date the cluster was defines as such and reported to your program (or another within your agency or another state agency) until the investigation began (same day=0 days; next day=1 day, etc.) ________

---

12) **For *avian* West Nile Virus infection surveillance in 2005:**

a. Did your agency establish and maintain a database of dead bird sightings?
______YES ______NO

b. If yes, were specimens submitted for diagnostic testing for WNV?
______YES ______NO

c. If yes to (b), did your agency have a policy in place for determining which avian specimens and how many avian specimens to test?

---

13) **For mosquito-based West Nile Virus surveillance in 2005:**

a. Does your agency collect information about mosquito surveillance?
______YES ______NO

If no to question 13a, please skip to question 14

b. Approximately what percentage of the human population in your jurisdiction is covered by mosquito surveillance?
______% ______ DON'T KNOW

c. Does your agency or any other agency within your jurisdiction conduct
Adult mosquito surveillance? ______YES ______NO
Larval mosquito surveillance? ______YES ______NO

d. For how many trap-nights were adult mosquitoes collected in **2005?**
__________ # TRAP-NIGHTS __________ DON'T KNOW

e. Concerning mosquito speciation when testing for WNV, does your agency receive reports from local laboratories and/or does your public health laboratory identify the species? ______YES ______NO

f. Does your agency either calculate minimum infection rates with your mosquito data or receive such data? ______YES ______NO

g. Does your agency map larval breeding sites? ______YES ______NO

h. does your agency evaluate adult mosquito control using caged mosquitoes to measure kill rates in sprayed areas? ______YES ______NO

i. Does your agency monitor for pesticide resistance? ______YES ______NO

---

14) Which of the following WNV activities have been implemented in your jurisdiction? (check all that apply) Please include the year the activity was implemented:
- □ Human Surveillance YEAR __________
- □ Equine Surveillance YEAR __________
- □ Avian Surveillance YEAR __________
- □ Mosquito Surveillance YEAR __________
- □ Mosquito Control YEAR __________
- □ Radio or TV PSA YEAR __________

15) Which of the following WNV prevention messages does your program use and promote? (check all that apply)
- □ Use of DEET-based repellents
- □ Peri-residential source reduction
- □ Personal protective measures
- □ Notification of adulticiding activities
- □ Modification of messages for lower literacy and non-English speaking audiences
- □ Radio PSA

16) Do you collaborate with adjacent counties/cities for the following activities related to mosquito vectors of WNV?

Activity	Adjacent Cities YES	Adjacent Cities NO	Adjacent Counties YES	Adjacent Counties NO
Surveillance				
Prevention				
Control				

a. Is there a particular city or county where you collaborate most in regard to WNV? If so, please name it ____.

17) Has WNV funding enhanced your agency's capacity to conduct surveillance for other vector-borne diseases?

a. Other mosquito-borne ______YES ______NO
b. Other tick-borne ______YES ______NO
c. Other flea-borne ______YES ______NO

18) What has been the total agency budget by year for WNV related activities?

Year	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Budget							

19) What was the percentage of your budget spent for the following WNV related activities within your jurisdiction?

Year / **Activity**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Surveillance	%	%	%	%	%	%	%
Prevention	%	%	%	%	%	%	%
Control	%	%	%	%	%	%	%
Total							

20) In **2005** what was the median interval in days between the date that a WNV-positive dead bird was collected and the date that positive laboratory results on that bird were reported to the WNV surveillance program? __________ DAYS

21) In **2005** what was the median interval in days between the date that a WNV-positive human specimen was collected and the date that positive laboratory results were reported to the WNV surveillance program? __________ DAYS

22) In **2005** for cases of human disease that were ultimately determined to be probable/confirmed, what was the median interval in days between the date of onset of the case and the date that the case was reported on ArboNET? _________ DAYS

23) In **2005** in order to count a case as confirmed or probable, did your agency require confirmation of commercial-lab-positive specimens by your public health laboratory or a diagnostic reference laboratory?

Human specimens ______YES ______NO
Bird specimens ______YES ______NO
Mosquito specimens ______YES ______NO

24) Were out-of state laboratories required to report positive WNV tests on specimens collected within your jurisdiction?

Human specimens ______YES ______NO
Bird specimens ______YES ______NO
Mosquito specimens ______YES ______NO

25) What is the capacity of the public health laboratory in your jurisdiction? (check all that apply):

______ BSL 2
______ BSL 3
______ Animal BSL 3

26) Which agency or organization is responsible for mosquito control in your county?

27) Do you collaborate with adjacent counties/cities for the following activities related to mosquito vectors of WNV?

	Adjacent Cities		**Adjacent Counties**	
Activity	**YES**	**NO**	**YES**	**NO**
Surveillance				
Prevention				
Control				

28) What has been the biggest obstacle in responding to WNV in your jurisdiction?

Please circle the socio-demographic characteristics that best fit your description:

How many years have you been employed in your present job?

1 5yrs or less
2 5-10 yrs
3 10-15 yrs
4 15-20
5 More than 20 years

What is your gender?

1 MALE
2 FEMALE

Highest level of education you have attained?

1 NO FORMAL EDUCATION
2 HIGH SCHOOL
3 SOME COLLEGE
4 GRADUATE/PROF DEGREE

Current age?

1 18-24
2 25-34
3 35-44
4 45-54
5 55-64
6 65 OR OLDER

That completes the survey, thank you for your time and cooperation.

Appendix C

State: ______________________ County or City: ____________________________

Respondent's Title: ____

N=58 (100%)
Sanitarian 8 (13.8%)
Administrator 1 (1.7%)
Director Env. Health 36 (62.1%)
Emergency Preparedness Coordinator 2 (3.4%)
Assistant Health Commissioner 2 (3.4%)
Program Mgr. 2 (3.4%)
Director 1 (1.7%)
Director of Nursing 3 (5.2%)
Disease Surveillance Specialist 1 (1.7%)
Epidemiologist 1 (1.7%)
Mosquito Program Coordinator 1 (1.7%)

1) Indicate below the number of (West Nile Virus (WNV) surveillance staff during 2005 – both epidemiology and laboratory – from all funding sources based on highest professional degree. These are mutually exclusive categories so place each staff person in only one column:

Health Dept. Employees	# with DVM, MD/DO, RN or other clinical degrees		# with PhD, DrPH, MSPH, MPH degrees in epidemiology		# with PhD or Masters degree in related sciences		# of all other clerical, administrative and programmatic staff	
	N	Median and range	N	Median and range	N	Median and range	N	Median and range
1.0 FTE	13	2 (1-5)	5	1 (1-3)	8	1 (1-4)	28	2 (1-32)
0.50-0.99 FTE	3	2 (2-3)	0	NA	1	1 (NA)	6	1.5 (7-7)
<0.50 FTE	8	1 (NA)	6	1 (NA)	4	1 (NA)	17	1 (1-5)
Contractors								
1.0 FTE	0	NA	0	NA	0	NA	0	NA
0.50-0.99 FTE	0	NA	0	NA	0	NA	0	NA
<0.50 FTE	0	NA	2	1(NA)	0	NA	3	1 (NA)

2) Does the county/city health department have adequate access to medical entomologist(s):
   - within the public health agency ______YES ______NO
   - N=58, Y=20 (30%)

     -If yes, did your agency also have this access in 1999? _____YES ____NO

     - N=26, Y=12 (50%)

   - through contract or other formal arrangement with a local college or university? ______YES ______NO
   - N=52, Y=6 (10%)

     -If yes, did your agency also have this access in 1999? _____YES ____NO

     - N=13, Y=4 (30%)

3) Does the county health department have adequate access to expertise in wildlife biology within a county (city) agency? ______YES ______NO

N=58, Y=34 (60%)

-If yes, did your agency also have this access in 1999? _____YES ____NO

- N=35, Y=27 (80%)

4) Does the county/city health department have a designated public health veterinarian within your agency? ______YES ______NO

N=58, Y=12 (20%)

-If yes, did your agency also have this access in 1999? _____YES ____NO

- N=20, Y=10 (50%)

5) Has WNV activity been detected in your jurisdiction (human, equine, avian, mosquito)? ______YES ______NO
   N=56, Y=53 (90%)

6) Please enter the number of human cases reported in your jurisdiction by year.

Number of Human Cases By Year						
1999	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
N=16 range 0	N=16 range 0-1	N=20 range 0-1	N=34 range 0-441	N=38 range 0-108	N=27 range 0-12	N=114 range 0-12

7) How would you characterize the number of human cases of infection for your jurisdiction by year after it was first detected?

	1999	2000	2001	2002	2003	2004	2005
"HIGH"				9(30%)	2(10%)		
"MODERATE"			1(10%)	4(10%)	8(20%)		5(10%)
"LOW"	17(100%)	17(100%)	18(90%)	18(60%)	27(70%)	32(100%)	31(90%)

8) a. Please complete the following table concerning the duration of surveillance during the year:

Type of Surveillance	Indicate # of months of surveillance
Human disease	N= 44 Avg=9
Equine disease	N= 32 Avg=8
Avian mortality	N= 50 Avg=6
Mosquito	N= 43 Avg=5

b. What type of surveillance is used in your jurisdiction for (check most applicable box):

Type of Surveillance	Primarily Active N=22	Combination of Active and Passive N=51	Primarily Passive N=86
Human disease	N=5 (9%)	N=17 (32%)	N=31 (58%)
Equine disease	N=4 (8%)	N=8 (16%)	N=38 (76%)
Avian mortality	N=13 (23%)	N=26 (46%)	N=17 (30%)

---

9) **For human West Nile neuroinvasive disease surveillance in 2005:**

a. Did your agency require reporting of:

- Hospitalized encephalitis cases of unknown etiology? ___YES ___NO
-N=53, Y=42 (79%)

- Hospitalized meningitis cases of unknown etiology? ____YES ___NO
- N=53, Y=43 (81%)

b. Did your agency implement a laboratory-based surveillance system to report CSF specimens positive for arboviral infection? ____YES ____NO
N=54, Y=21 (40%)

10) Did your program use the CDC/CSTE National Public Health Surveillance System (NPHSS) case definition for neuroinvasive disease to classify cases as confirmed or probable *or* did you use another case definition in your jurisdiction?
N=40

__36(90%)____CDC/CSTE NPHSS case definition used exclusively
__4 (10%)____ A modified case definition specific to your jurisdiction

---

11) **For equine West Nile disease surveillance in 2005:**

a. Did your agency have a system in place for reporting cases of equine neurologic disease to the state health department from veterinarians, veterinary diagnostic labs or other agency labs?
N=56 _24 (40%)___YES _20 (40%)___NO ___12 (20%)__DON'T KNOW

b. If yes, were specimens submitted for diagnostic testing for:
WNV? N=22 _16 (73%)__YES _4 (18%)_NO _2 (9%)_DON'T KNOW
Other arboviruses? N=20 _7(35%)_YES _5 (25%)_NO _8 (40%)_DON'T KNOW
Rabies? N=20 _12 (60%)_YES _4 (20%)__NO _4 (20%)___DON'T KNOW

c. How many equine specimens were tested in the public health laboratory for:
WNV? ______YES ______NO ______DON'T KNOW
N=6, 27 specimens, avg=4.5, range 1-11

Other arboviruses? ______YES ______NO ______DON'T KNOW
N=2, avg=2, range=NA

Rabies? ______YES ______NO ______DON'T KNOW
N=3, avg=9, range=3-20

d. Were temporal-geographic clusters (2 or more cases) of equine neurologic disease reported to your agency? N=48 _5(10%)__YES _43 (90%)__NO

e. If yes, how many clusters were reported? __N=4, Avg=1, range=(0)1-3 ____

f. If yes to (d), did your program or any county agency investigate the clusters to determine the cause of the illness? N=5 __1(20)__YES ______NO

g. If yes to (d), what was the median interval in days from the date the cluster was defines as such and reported to your program (or another within your agency or another state agency) until the investigation began (same day=0 days; next day=1 day, etc.) N=0________

---

12) **For *avian* West Nile Virus infection surveillance in 2005:**

a. Did your agency establish and maintain a database of dead bird sightings?
N=58 _52 (90%)_____YES ______NO

b. If yes, were specimens submitted for diagnostic testing for WNV?
N=52 _49(94%)_____YES ______NO

c. If yes to (b), did your agency have a policy in place for determining which avian specimens and how many avian specimens to test?
N=40, Y=39 (98%)

---

13) **For mosquito-based West Nile Virus surveillance in 2005:**

a. Does your agency collect information about mosquito surveillance?
N=58 __40 (69%)____YES ______NO

<u>If no to question 13a, please skip to question 14</u>

b. Approximately what percentage of the human population in your jurisdiction is covered by mosquito surveillance?
N=40 _66.4% mean_____% _19 (48)_____ DON'T KNOW

c. Does your agency or any other agency within your jurisdiction conduct
Adult mosquito surveillance? N=49 _ 39 (80)_____YES ______NO
Larval mosquito surveillance? N=47 _18 (38%)____YES _____NO

d. For how many trap-nights were adult mosquitoes collected in **2005?**
N=43 _Mean=1988_ # TRAP-NIGHTS Range=0-54579 _14 (33%)_ DON'T KNOW

e. Concerning mosquito speciation when testing for WNV, does your agency receive reports from local laboratories and/or does your public health laboratory identify the species? N=45 _38 (84%)_YES _7 (16%)__NO

f. Does your agency either calculate minimum infection rates with your mosquito data or receive such data? N=47 _10(21%)_YES _37(79%)_NO

g. Does your agency map larval breeding sites? N=47 _18(38%)_YES _37(79%)_NO

h. does your agency evaluate adult mosquito control using caged mosquitoes to measure kill rates in sprayed areas? N=47 _4 (9%)_YES _43 (91%)_NO

i. Does your agency monitor for pesticide resistance? N=47 _1 (2%)_YES _46 (98%)_NO

---

14) Which of the following WNV activities have been implemented in your jurisdiction? (check all that apply) Please include the year the activity was implemented:

- □ Human Surveillance N=37 (64%) YEAR _N=31 Median=2000__
- □ Equine Surveillance N=18 (31%) YEAR _N=14 Median=2002__
- □ Avian Surveillance N=47 (81%) YEAR _N=43 Median=2001__
- □ Mosquito Surveillance N=41 (71%) YEAR _N=38 Median=2001__
- □ Mosquito Control N=23 (40%) YEAR _N=19 Median=1999__
- □ Radio or TV PSA N=22 (40%) YEAR _N=19 Median=2000__

15) Which of the following WNV prevention messages does your program use and promote? (check all that apply)

- □ Use of DEET-based repellents N=48 (83%)
- □ Peri-residential source reduction N=39 (67%)
- □ Personal protective measures N=51 (88%)
- □ Notification of adulticiding activities N=17 (29%)
- □ Modification of messages for lower literacy and non-English speaking audiences N=5 (9%)
- □ Radio PSA N=18 (31%)

16) Do you collaborate with adjacent counties/cities for the following activities related to mosquito vectors of WNV?

Activity	**Adjacent Cities** **YES**	**NO**	**Adjacent Counties** **YES**	**NO**
	N=53		**N=55**	
Surveillance	16 (30%)		12 (22%)	
Prevention	18 (34%)		9 (16%)	
Control	14 (26%)		9 (16%)	

a. Is there a particular city or county where you collaborate most in regard to WNV?

If so, please name it __N=22 (38%)___________________________________.

17) Has WNV funding enhanced your agency's capacity to conduct surveillance for other vector-borne diseases?

a. Other mosquito-borne N=49 _7 (14%)___YES ______NO

b. Other tick-borne N=49 _4 (8%)_____YES ______NO

c. Other flea-borne N=49 _2 (4%)_____YES ______NO

18) What has been the total agency budget by year for WNV related activities?

Year	**1999 N=18**	**2000 N=21**	**2001 N=21**	**2002 N=27**	**2003 N=29**	**2004 N=30**	**2005 N=31**
Budget							

19) What was the percentage of your budget spent for the following WNV related activities within your jurisdiction?

Year / **Activity**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Surveillance	%	%	%	%	%	%	%
Prevention	%	%	%	%	%	%	%
Control	%	%	%	%	%	%	%
Total	N=17	N=18	N=22	N=23	N=25	N=25	N=27

20) In **2005** what was the median interval in days between the date that a WNV-positive dead bird was collected and the date that positive laboratory results on that bird were reported to the WNV surveillance program? ___________ DAYS
N=34, Mean=17.5, Med=14, Min=2, Max=90

21) In **2005** what was the median interval in days between the date that a WNV-positive human specimen was collected and the date that positive laboratory results were reported to the WNV surveillance program? ___________ DAYS
N=16, Mean=7.08, Med=0, Min=0, Max=18

22) In **2005** for cases of human disease that were ultimately determined to be probable/confirmed, what was the median interval in days between the date of onset of the case and the date that the case was reported on ArboNET? __________ DAYS
N=5, Mean=8.8, Med=0, Min=0, Max=28

23) In **2005** in order to count a case as confirmed or probable, did your agency require confirmation of commercial-lab-positive specimens by your public health laboratory or a diagnostic reference laboratory?
Human specimens N=40 __28 (70%)____YES ______NO
Bird specimens N=44 __33(75%)____YES ______NO
Mosquito specimens N=39 __27(69%)____YES ______NO

24) Were out-of state laboratories required to report positive WNV tests on specimens collected within your jurisdiction?
Human specimens N=38 __17(45%)____YES ______NO
Bird specimens N=36 __9 (25%)____YES ______NO
Mosquito specimens N=35 __9 (26%)____YES ______NO

25) What is the capacity of the public health laboratory in your jurisdiction? (check all that apply): N=7
__6 (86%)_____ BSL 2
______ BSL 3
__1 (14%)____ Animal BSL 3

26) Which agency or organization is responsible for mosquito control in your county?
N=51 (88%)

27) Do you collaborate with adjacent counties/cities for the following activities related to mosquito vectors of WNV?

Activity	**Adjacent Cities** **YES**	**NO** N=39	**Adjacent Counties** **YES**	**NO** N=41
Surveillance	16 (41%)		9 (22%)	
Prevention	14 (36%)		6 (15%)	
Control	12 (32%)		4 (10%)	

28) What has been the biggest obstacle in responding to WNV in your jurisdiction?
N=51 (88%)

Please circle the socio-demographic characteristics that best fit your description:

How many years have you been employed in your present job?

1 5yrs or less
2 5-10 yrs
3 10-15 yrs
4 15-20
5 More than 20 years

What is your gender?

1 MALE
2 FEMALE

Highest level of education you have attained?

1 NO FORMAL EDUCATION
2 HIGH SCHOOL
3 SOME COLLEGE
4 GRADUATE/PROF DEGREE

Current age?

1 18-24
2 25-34
3 35-44
4 45-54
5 55-64
6 65 OR OLDER

That completes the survey, thank you for your time and cooperation.

Glossary

A priori – Classification made without examining the variables.

Active surveillance – Collection of blood and tissue samples to test for viral infection.

Arbovirus (Arthropod Borne Virus) – viruses which require an intermediate arthropod host to spread to susceptible vertebrate hosts.

Arthropod – Segmented, invertebrate animals that have exoskeletons belonging to the phylum Arthropoda. This includes mosquitoes and other insects which act as intermediate hosts and spread viral diseases.

Culex pipiens – The most common mosquito vector for WNV in the northeastern US. This species normally feeds on birds, but some urban strains feed readily on humans.

Epidemic – The occurrence of an illness in a given area, in excess of what is normally expected.

Encephalitis – Brain inflammation resulting from viral infection.

Febrile – Fever, usually associated with encephalitis due to WNV infection.

Meningitis – Inflammation of the, caused by a viral infection.

Meningoencephalitis – Inflammation of the membranes covering the brain and spinal cord, as well as the brain due to viral infection.

Passive surveillance – Collection of data from clinicians, regarding positive cases of WNV.

Peri-residential – In or around the home environment.

Rural – Areas (counties) having an urban continuum code greater than 3.

Sentinel – The first indicator of viral activity used to alert public health officials that the possibility of human infection exists. Captive fowl or horses, or wild populations of birds are used for the purpose of drawing blood at specific intervals for viral testing.

Surveillance – The collection, orderly consolidation, analysis, and evaluation of data with prompt dissemination to those agencies concerned with disease prevention.

Transovarian – Transmission of a WNV by mosquitoes to their offspring, by infection of eggs in their ovary.

Urban – Areas (counties) having an urban continuum code of 1, 2 or 3.

Viremic – Presence of virus in the blood.

Virus – An infectious particle dependent on host cells to reproduce and capable of causing a number of diseases.

References

Alto, B. W. & S. A. Juliano. 2001. Temperature Effects on the Dynamics of Aedes Albopictus (Diiptera: Culicidea) Populations in the Laboratory. *Journal of Medical Entomology*. **38**: 548-556.

Behney, C., A. Burns & H. Banta. 1983. The City and Disability. eds. A. Greer & S. Greer, 179-210. Beverly Hills: Sage Publications.

Berry, B. J. L. 1968. A Synthesis of Formal and Functional Regions Using a General Field Theory of Spatial Behavior. In *Spatial Analysis: A Reader in Statistical Geography*, eds. B. J. L. Berry & D. F. Marble, 419-428. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Besharov, D. 1995. Poverty, Welfare Dependency, and the Underclass. In *Reducing Poverty in America: Views and Approaches*, ed. M. Darby, 13-56. Thousand Oaks: Sage Publications.

Bjornstad, O., B. Finkenstadt and B. Grenfell. 2002. Dynamics of measles epidemics: estimating scaling of transmission rates using a time series SIR model. Ecological Monographs **76**(2): 169-184.

Blitvich, B. J., I. Fernandez-Salas, J. F. Contreras-Cordero, N. L. Marlenee, J. I. Gonzalez-Rojas, N. Komar, D. J. Gubler, C. H. Calisher & B. J. Beaty. 2003. Serologic Evidence of West Nile Virus Infection in Horses, Coahuila State, Mexico. *Emerging Infectious Diseases*. **9**: 853-858.

Brandt, E. 1997. The federal contribution to public health. *In* Principles of Public Health Practice. Eds. Scutchfield and Keck, 57-67. Albany, Delmar Publishers.

Brinton, M. A. 2002. The molecular biology of West Nile Virus: A New Invader of the Western Hemisphere. *Annual Review of Microbiology*, **56**: 371-402.

Brownstein, J., T. Holford, D. Fish. 2004. Enhancing West Nile Virus Sureillance, United States. *Emerging Infectious Diseases.* **10**(6): 1129-1133.

CDC. 1993. Guidelines For Arbovirus Surveillance Programs In The United States. Fort Collins.

--- 1999. Outbreak of West Nile-Like Viral Encephalitis. *Morbidity and Mortality Weekly Report*. **48**: 845 - 848.

---. 2001. Human West Nile Virus surveillance - Connecticut, New Jersey, and New York, 2000. *Morbidity and Mortality Weekly Report.* **51**: 498-501.

---. 2002*a*. Laboratory-acquired West Nile Virus infections - United States, 2002. *Morbidity and Mortality Weekly Report.* **51**: 1133-1135.

---. 2002*b*. Update: investigations of West Nile virus infections in recipients of organ transplantation and blood transfusion - Michigan, 2002. *Morbidity and Mortality Weekly Report.* **51**: 879 single page.

---. 2002*c*. West Nile virus Activity - United States, 2001. *Morbidity and Mortality Weekly Report.* **51**: 498-501.

---. 2002*d*. Provisional surveillance summary of the West Nile Virus epidemic - United States January-November 2002. *Morbidity and Mortality Weekly Report.* **51**: 1129-1133.

---. 2002*e*. Intrauterine West Nile virus Infection – New York 2002. *Morbidity and Mortality Weekly Report.* **51**(50): 1135-1136.

.

---. 2003. Epidemic/Epizootic West Nile Virus in the United States: Guidelines for Surveillance, Prevention, and Control. 3rd Revision. Fort Collins.

---. 2004. Update: West Nile Virus screeining of blood donations and transfusion-associated transmission – United States, 2003. *Morbidity and Mortality Weekly Report.* **53**(13): 282-284.

---. 2005. WNV Fact Sheet. Date accessed September 27, 2005.

---. 2007. West Nile Virus Activity - United States, 2006. *Morbidity and Mortality Weekly Report.* **56**(22): 556-559.

Chamberlain, R. W. 1980. History of St. Louis Encephalitis. In *St. Louis Encephalitis*, ed. T. P. Monath, 3-61. Washington D. C.: American Public Health Association.

Chamberlain, R. W. & W. D. Sudia. 1961. Mechanism of transmission of viruses by mosquitoes. *Annual Review of Entomology.* **6:** 371-390.

Cliff, A., P. Haggett, K. Ord. 1986. *Spatial Aspects of Influenza Epidemics*. London: Pion Limited.

CSTE. 2005. Assessing Capacity for the Surveillance, Prevention, and Control of West Nile Virus Infection in State and Large City/County Health Departments.

Dandoy, S. 1997. The State Public Health Department. *In* Principles of Public Health Practice. Eds. Scutchfield and Keck, 68-86. Albany, Delmar Publishers.

Dodd, R. Y. & D. A. Leiby. 2004. Emerging Infectious Threats to the Blood Supply. *Annual Review of Medicine.* **55**: 191-207.

Eidson, M., N. Komar, F. Sorhage, R. Nelson, T. Talbot, F. Mostashari, R. McLean, The West Nile Virus Avian Mortality Surveillance Group. 2001. Crow Deaths as a Sentinel Surveillance System for West Nile Virus in the Northeastern United States, 1999. *Emerging Infectious Diseases.* **7**(4)**:** 615-620.

Elizondo-Quiroga, D., C. Davis, I. Fernandez-Salas, R. Escobar-Lopez, D. Olmos, L. Gastalum, M. Acosta, A. Elizonda-Quiroga, J. Gonzalez-Rojas, J. Cordero, J. Guzman, A. Travassos da Rosa, B. Blitvich, A. Barrett, B. Beaty and R. Tesh. 2005. West Nile Virus Isolation In Human And Mosquitoes, Mexico. *Emerging Infectious Diseases.* **11:** 1449-1452.

Fee, E. 1997. History and Development of Public Health. *In* Principles of Public Health Practice. Eds. Scutchfield and Keck, 10-30. Albany, Delmar Publishers.

Fiennes, R. N. 1978. *Zoonoses and the Origins and Ecology of Human Disease*. New York: Academic Press.

Garvey, K. 2006. UC Davis Mosquito Research Rising to New Heights. Retrieved March 24, 2009 from http://www.vetmed.ucdavis.edu/ucmrp/news/archive/2006/reisennasagrant.html.

Haggett, P. 2000. *The Geographical Structure of Epidemics*. New York: Oxford University Press Inc.

Han, L. L., F. Popovici, P. Alexander, V. Laurentia, L. Tengelsen, C. Cernescu, J. Gary, Jr., N. Ion-Nedelcu, G. Campbell, t. Tsai. 1999. Risk Factors For West Nile Virus Infection And Meningoencephalitis, Romania. *Journal of Infectious Diseases.* **179:** 230-233

Harpham, T., T. Lusty and P. Vaughan. 1988. *In the shadow of the city. Community health and the urban poor*. New York, NY: Oxford University Press.

Harrison, M. 2000. Differences of degree: Representations of India in British medical topography, 1820 - *c.* 1870. In *Medical Geography in Historical Perspective*, ed. N. A. Rupke, 51-69. London: The Wellcome Trust Centre for the History of Medicine at UCL.

Hayes, C. G. 2001. West Nile Virus: Uganda, 1937, to New York City, 1999. *West Nile Virus: Detection, Surveillance, and Control.* **951**: 25-37.

Hayes, N. 2004. Summary of West Nile Virus Activity. *Fifth National Conference on West Nile Virus in the United States*. Denver, CO.

Health Canada. 2003. Results of 2002 Surveillance Program.

---. 2004a. Human Surveillance: Results of 2003 Program.

---. 2004b. Results of 2003 Surveillance Program.

---. 2005. Results of 2004 Surveillance Program.

---. 2006. West Nile Virus National Surveillance Report.

Heymann, D. 2004. Control of Communicable Diseases Manual. 18th ed. Washington D.C. American Public Health Association.

Hinman, A. 1998. Global Progress in Infectious Disease Control. Vaccine **16**(11/12): 1116-1121.

Hochberg, L. R., J. Sims, B. Davis. 2002. West Nile encephalitis in Massachusetts. *New England Journal of Medicine.* **346**: 1030-1031.

Howe, G. M. and D. R. Phillips. 1983. Medical Geography in the United Kingdom, 1945-1982. *In Geographical Aspects of Health*. Eds. N. D. McGlashan and J. R. Blunden. London, Academic Press: 33-52.

Hubalek, Z. 2000. European Experience With The West Nile Virus Ecology And Epidemiology: Could It Be Relevant For The New World? *Viral Immunology*. **13**: 415-426.

Hubalek, Z., H. M. Savage, J. Halouzka, Z. Juricova, Y. O. Sanogo and S. Lusk. 2000. West Nile Virus Investigations in South Moravia, Czechland. *Viral Immunology*. **13**: 427-433.

Iwamoto, M., D. Hernigan, A. Gausch, M. Trepka, C. Blackmore, W. Hellinger, S. Pham, S. Zaki, R. Lanciotti, S. Lance-Parker, C. DiazGranados, A. Winquist, C. Perlino, S. Wiersma, K. Hillyer, J. Goodman, A. Marfin, M. Chamberland,

L. Petersen. 2003. Transmission of West Nile Virus from an organ donor to four transplant recipients. *New England Journal of Medicine.* **348**: 2196-2203.

Jordan, I., T. Briese & W. I. Lipkin. 2000. Discovery And Molecular Characterization Of West Nile Virus NY 1999. *Viral Immunology.* **13**: 435-446.

Jupp, P. G. 2001. The Ecology of West Nile Virus in South Africa and the Occurrence of Outbreaks in Humans. *Annals of the New York Academy of Sciences.* **951:** 143-152.

Kachigan, S. 1991. *Multivariate Statistical Analysis: A Conceptual Introduction*. New York, NY: Radius Press.

Komar, N. 2009. Environmental Surveillance - Avian Mortality. *Tenth National Conference on West Nile Virus in the United States*. Savannah, Georgia.

Lanciotti, R. S., J. Roehrig, V. Deubel, J. Smith, M. Parker, K. Steele, B. Crise, K. Volpe, M. Crabtree, J. Scherret, R. Hall, J. Mackenzie, C. Cropp, B. Panigrahy, E. Ostlund, B. Schmitt, M. Malkinson, C. Banet, J. Weissman, N. Komar, H. Savage, W. Stone, T. McNamara, D. Gubler. 1999. Origin of the West Nile Virus Responsible for an Outbreak of Encephalitis in the Northern United States. *Science.* **286:** 2333-2337.

Langevin, S. M. Bunning, B. Davis and N. Komar. 2001. Experimental infection of chickens as candidate sentinels for West Nile Virus. *Emerging Infectious Diseases.* **7**(4): 726-729.

Lehmann, J. 2008. Personal communication.

Marfin, A. 2002. West Nile Virus, 2001: Southern and Western Expansion. *Third National West Nile Virus Planning Meeting*. Atlanta, GA.

Marin/Sonoma Mosquito and Vector Control District, West Umatilla Vector Control District. 2008. Disease Surveillance.

McGlashan, N. D. & J. R. Blunden. 1983. Introduction. In *Geographical Aspects of Health*, eds. McGlashan & Blunden, 1-11. London: Academic Press.

McLean, R. G., S. Ubico, D. Docherty, W. Hansen, L. Sileo and T. McNamara. 2001. West Nile Virus Transmission and Ecology in Birds. *Annals of the New York Academy of Sciences.* **951:** 54-57.

Meade, M. S. & R. J. Earickson. 2000. *Medical Geography*. New York: The Guilford Press.

Mendez-Galvan, J. 2004. West Nile Virus in Latin America. *Fifth National Conference on West Nile Virus in the United States*. Denver, CO.

Monath, T. P. 1980*a*. Epidemiology. In *St. Louis Encephalitis*, ed. T. P. Monath, 239-312. Washington, D.C.: American Public Health Association.

---. 1980*b*. *St. Louis Encephalitis*. Washington, D.C.: American Public Health Association.

Monath, T. P. & F. X. Heinz. 1996. Flaviviruses. In *Fields Virology, Third Edition,* eds. B. N. Fields, D. M. Knipe, P. M. Howley, R. Chanock, T. P. Monath, J. Melnick, B. Roizman and S. Straus 961-1034. Philadelphia, PA: Lippincott-Raven.

Mostashari, F., M. Bunning, P. Kitsutani, d. Singer, D. Nash, M. Cooper, N. Katz, K. Liljebjelke, B. Biggerstaff, A. Fine, M. Layton, S. Mullin, A. Johnson, D. Martin, E. Hayes, G. Campbell. 2001. Epidemic West Nile Encephalitis, New York, 1999: Results of a Household-Based Seroepidemiological Survey. *The Lancet*, **358**: 261-264.

Mostashari, F., M. Kulldorff, J. Hartman, J. Miller, V. Kulasekera. 2003.Dead bird clusters as an early warning system for West Nile Virus Activity. *Emerging Infectious Diseases.* **9**: 641-646.

Nasci, R. 2009. 10 years of WNV in the U.S.: A Historical Perspective. *Tenth National Conference on West Nile Virus in the United States*. Savannah, Georgia.

Nasci, R., H. Savage, D. White, J. Miller, B. Cropp, M. Godsey, A. Kerst, P. Bennett, K. Gottfried and R. Lanciotti. 2001. West Nile Virus in overwintering *Culex* mosquitoes, New York City, 2000. *Emerging Infectious Diseases.* **7**(4): 1-3.

Nasci, R., N. Komar, A. Marfin, g. Ludwig, L. Kramer, T. Daniels, R. Falco, S. Campbell, K. Brookes, K. Gottfried, K. Burkhalter, S. Aspen, a. Kerst, R. Lanciotti and C. Moore. 2002. Detection of West Nile Virus-infected mosquitoes and seropositive juvenile birds in the vicinity of virus-positive dead birds. *American Journal of Tropical Medicine and Hygiene.* **67:** 492-496.

Nash, D., F. Mostashari, A. Fine, J. Miller, D. O'Leary, K. Murray, A. Huang, A. Rosenberg, A. Greenberg, M. Sherman, S. Wong and M. Layton. 2001. The Outbreak of West Nile Virus Infection in the New York City Area in 1999. *New England Journal of Medicine.* **344:** 1807-1814.

Stephen, J. A. 2007. State of New Hampshire avboviral illness surveillance, prevention and response plan 2007 season. State of New Hampshire Department of Health and Human Services.

Oglesby, C. 2005. West Nile virus a North American fixture. CNN.com. Date accessed March 27, 2009.

O'Leary, D. 2004. ArboNET Update, 2004. Retrieved March 24, 2009 from http://www.cdc.gov/ncidod/dvbid/westnile/conf/pdf/OLeary_WS1_04.pdf

PAHO. 2003. Update on West Nile Virus in Mexico.

Price, D. O. 1942. Factor Analysis in the study of metropolitan centers. *Social Forces.* **20:** 449-455.

Pyle, G. F. 1979. *Applied Medical Geography*. Washington, DC: V. H. Winston & Sons.

Pyle, G. F. & R. M. Cook. 1978. Environmental Risk Factors of California Encephalitis in Man. *Geographical Review.* **68**: 157-170.

Pyle, G. F. 1983. Three Decades of Medical Geography in the United States. Geographical Aspects of Health. N. D. McGlashan and J. R. Blunden. London, Academic Press: 81-101.

Rappole, J. H., S. R. Derrickson, Z. Hubalek. 2000. Migratory birds and spread of West Nile Virus in the Western Hemisphere. *Emerging Infectious Diseases.* **6**: 319-328.

Rawding, N and M. Wasserman. 1997. The Local Health Department. Principles of Public Health Practice. Eds. Scutchfield and Keck, 87-100. Albany, Delmar Publishers.

Reeves, W. C. 1980. Foreword. St. Louis Encephalitis. T. P. Monath ed. Washington, D. C., American Public Health association: xi-xvii.

Reiter, P., S. Lathrop, M. Bunning, B. Biggerstaff, D. Singer, T. Tiwari, L. Baber, M. Amador, J. Thirion, J. Hayes, C. Seca, J. Mendez, B. Ramirez, J. Robinson, J. Rawlings, V. Vorndam, S. Waterman, D. Gubler, G. Clark and E. Hayes. 2003. Texas lifestyle limits transmission of Dengue Virus. *Emerging Infectious Diseases.* **9:** 86-89.

Robinson, A. H., J. Lindberg and L. Brinkman. 1968. A Correlation and Regression Analysis Applied to Rural Farm Population Densities in the Great Plains. Spatial Analysis: A Reader in Statistical Geography, eds. B. J. L. Berry & D. F. Marble, 290-300. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Roehrig, J. T. & L. Peterson. 2004. Meeting Summary. *Fifth National Conference on West Nile Virus in the United States*. Denver, CO.

Ruiz, M. O., C. Tedesco, T. McTighe and C. Austin. 2004. Environmental and social determinants of human risk during a West Nile virus outbreak in the greater Chicago area, 2002. *International Journal of Health Geographics.* **3:** 8

Ruiz, M. O., E. Walker, E. Foster, L. Haramis and U. Kitron. 2007. Association of West Nile virus illness and urban landscapes in Chicago and Detroit. *International Journal of Health Geographics.* **6:** 10.

Scutchfield, F. & C. Keck. 1997. Concepts and Definitions of Public Health Practice. *In* Principles of Public Health Practice. Eds. Scutchfield and Keck, 3-9. Albany, Delmar Publishers.

Sejvar, J. J. 2003. New or emerging clinical syndromes in humans. *Fourth National Conference on West Nile Virus in the United States*. New Orleans.

Shaman, J., J. F. Day & M. Stieglitz. 2002. Drought-Induced Amplification Of Saint Louis Encephalitis Virus, Florida. *Emerging Infectious Diseases.* **8:** 575-580.

Shevky, E. and M. Williams. 1949. The Social Areas of Los Angeles: Analysis and Typology. University of California Press, Berkeley.

Smithburn, K. C., T. Hughes, A. Burke and J. Paul. 1940. A Nuerotropic Virus Isolated From The Blood Of A Native Of Uganda. *American Journal Tropical Medical Hygiene.* **20:** 471 – 472.

Solomon, T., M. Ooi, D. Beasley and M. Mallewa. 2004. West Nile Encephalitis. *British Medical Journal.* **326:** 865-869.

Taylor, R. M., t. Work, H. Hurlbut and F. Rizk. 1956. A study of the ecology of West Nile virus in Egypt. *American Journal of Tropical Medical Hygiene.* **5**: 579-620.

Theophilides, C. N., S. Ahearn, S. Grady and M. Merlino. 2003. Identifying West Nile Risk Areas: The Dynamic Continous-Area Space-Time. *American Journal of Epidemiology.* 157**:** 843-854.

Thomas, E. N. 1968. Maps of Residuals from Regression. In *Spatial Analysis: A Reader in Statistical Geography*, eds. B. J. L. Berry & D. F. Marble, 326-352. Englewood Cliffs, N. J.: Prentice-Hall.

Trock, S. C., B. Meade, A. glaser, E. Ostlund, R. Lanciotti, B. Cropp, V. Kulasekera, L. Kramer and N. Komar. 2001. West Nile Virus Outbreak Among Horses In New York State, 1999 and 2000. *Emerging Infectious Diseases.* **7:** 745-747.

Tsai, T. F., F. Popovici, C. Cernescu and G. Campbell. 1998. West Nile encephalitis epidemic in southeastern Romania. *The Lancet.* **352:** 767-771.

Turnock, B. J. 2004. *Public Health: What It Is and How It Works*. Sudbury: Jones and Barlett Publishers, Inc.

U. S. Department of Health & Human Services. 2009. HHS What We Do.

USDA. 2007. Measuring Rurality: Rural-Urban Continuum Codes.

USGS. 2006. West Nile Virus Disease Maps.

Valencius, C. B. 2000. Histories of Medical Geography. In *Medical Geography in Historical Perspective,* ed. N. A. Rupke, 3-28 . London: The Wellcome Trust Centre for the History of Medicine at UCL.

Warner, R. M. 2008. *Applied Statistics: From Bivariate Through Multivariate Techniques*. Los Angeles: Sage Publications.

Weinberger, M., S. D. Pitlik, D. Gandacu, R. Lang, F. Nassar, D. David, E. Rubinstein, A. Izthaki, J. Mishal, R. Kitzes, Y. Siegman-Igra, M. Giladi, N. Pick, E. Mendelson, H. Bin, T. Shohat, and M. Chowers. 2001. West Nile Fever Outbreak, Israel, 2000: Epidemiologic Aspects. *Emerging Infectious Diseases.* **7:** 686-691.

Wong, S. T. 1968. A Multivariate Statistical Model for Predicting Mean Annual Flood in New England. In *Spatial Analysis: A Reader in Statistical Geography,* eds. B. J. L. Berry & D. F. Marble. 353-367. Englewood Cliffs, N. J.: Prentice-Hall.

Yen, I. H. & S. L. Syme 1999. The Social Environment And Health: A Discussion Of The Epidemiologic Literature. *Annual Review Public Health.* **20:** 287 - 308.