GIS Applications in Modeling for Populations Vulnerable to West Nile Virus: A Pilot Study for Hennepin County, Minnesota

James A. Thompson. *Department of Resource Analysis, Saint Mary's University of Minnesota, Winona, Minnesota, 55987.*

Keywords: West Nile Virus (WNV), Geographic Information System (GIS), ArcGIS 8.3, Spatial Analyst, Hennepin County, Minnesota, *Culex* mosquitoes.

Abstract

West Nile Virus (WNV) is an infectious disease to which humans are susceptible after being bitten by an infected mosquito. Birds, horses, and other mammals are also susceptible and constitute reservoirs of the disease. The disease was first detected in New York State in 1999. By 2002, the disease had spread across the United States to California and Washington State. To date, thousands of people have been infected and hundreds have died from the disease. The populations most at risk are individuals over 50 years of age. In the state of Minnesota, Hennepin County has reported the most cases of WNV. Using a Geographic Information System (GIS), this study combines census data, data on infected animals, and Hennepin County data, to create a model to determine where the most susceptible populations live relative to the location of positive indicators of WNV. This could facilitate educational outreach efforts by health agencies to target those most susceptible as to how they can lower their risk of infection.

Introduction

West Nile Virus (WNV) was first identified in the United States in 1999, in New York City, New York. According to the Minnesota Department of Health (2004), WNV was first reported in Minnesota in 2002. The California West Nile Surveillance Information Center (2004) reported WNV in that state in 2002. In four years, WNV has spread from coast to coast. Humans, especially those over the age of 50, are susceptible to infection with the virus, which can cause West Nile meningitis, West Nile encephalitis, and West Nile Fever. WNV meningitis and WNV encephalitis are neuroviruses that can cause inflammatory problems in all the major organs, including swelling of the brain and spinal cord, and can be fatal. Huhn, et al (2003) report that the 2002 WNV outbreak was the largest epidemic of encephalitis in the history of North America. Fortunately, most people infected with WNV will experience no to mild symptoms.

As of 2003, a total of 14,014 cases and 546 deaths due to the disease have been reported to the United States Center for Disease Control (CDC) from across the U.S. According to CDC records (2004), both the number of reported cases and deaths for 2003 alone nearly equaled those of the previous four years combined. In Minnesota, the MDH (2004) reported the first deaths due to WNV in 2003.

The disease vector for transmission of the virus is primarily through the bite of an infected mosquito of the Family *Culex*. Sampathkumar (2003) has stated that in the New York City area in 2000, it was found that these mosquitoes were able to overwinter, thus surviving to spread the disease in succeeding years.

Dead birds are the primary indicator for the presence of the disease. Members of the Family *Corvidae,* which includes jays and crows, seem to be particularly susceptible and account for the majority of dead birds found infected with WNV. However, WNV has been found in approximately 140 bird species (Sampathkumar 2003). Infected horses are an additional indicator. Human cases are the ultimate concern in the study of WNV.

The USDA Animal and Plant Health Inspection Service (2002) has conditionally approved a vaccine to treat horses infected with WNV. There is no immunization available to treat WNV in humans. In summary, WNV bodes to be a continuing public health issue in Minnesota and the United States for the indefinite future.

Project Scope

The scope of this project was limited to Hennepin County and the study of a single public health issue (WNV) for the years 2002 and 2003. The goal was to prepare a method of screening for populations particularly vulnerable to WNV (those over 50 years of age) in order to facilitate targeting health awareness outreach efforts by public health agencies. The research question was "What is the spatial relationship between WNV indicators and the residences of those most susceptible to infection with WNV?"

Geographic Information Systems (GIS) and GIS Processes

Geographic Information Systems (GIS) combine a database with records that contain spatially specific information and attributes combined with a computerized mapping capability, and hence is a powerful tool for the analysis of spatial data. The GIS software used for this project was ArcGIS 8.3 (with the ArcView level of functionality) and the Spatial Analyst extension. This software provided the capacity for spatial analysis and mapping necessary for a GIS project.

Spatial Analyst is an extension for ArcGIS 8.3 that allows for raster-based analysis. The raster data format is a grid of equal size cells that each contains a single value. Files in this format are referred to as grids. In ArcGIS, both raster and vector data formats can be combined in a single map document. A consistent cell size facilitates analysis between grids. The default cell size used in this project for all grids was 186.4603376 meters.

Traditionally, GIS has largely been used for natural resource study. Cromley and McLafferty (2002) find that the use of GIS for public health is a relatively new application of the software.

The process used in this study to perform GIS analysis had the following steps:

1. Determine project goals and scope
2. Determine the data needed
3. Acquire data
4. Prepare data to be useful for project
5. Perform analysis
6. Present results

Study Area

Hennepin County, Minnesota was chosen for this study. Hennepin is the most populous county in the state, with an estimated population for 2003 of

1,121,035, according to the U.S. Census Bureau (2004). This county reported the highest number of cases in the state for all indicators of WNV for 2003 (MDH 2004). These included 11 human cases, three horse cases, 145 bird cases, and 14 mosquito pools. None of the four deaths from WNV in Minnesota during 2003 occurred in the county. Figure 1 shows the location of Hennepin County in Minnesota.

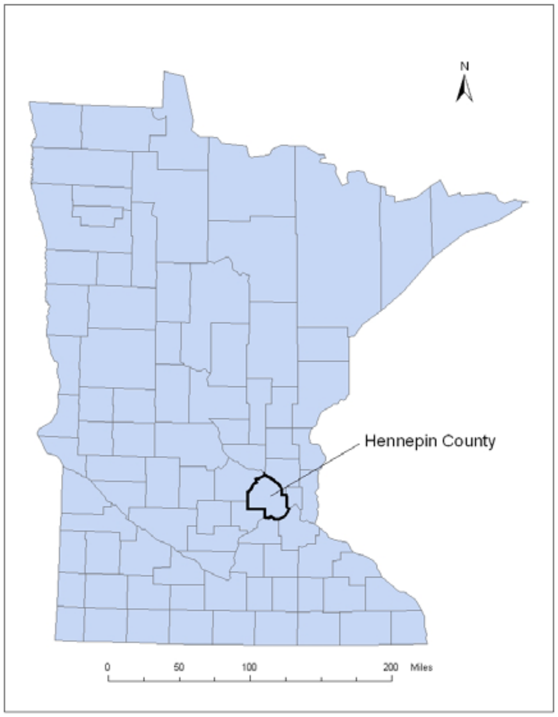

Figure 1. Hennepin County location.

Methods

After determining the goal and scope of this study, it was necessary to determine the data needed for the project. This included census data, information on WNV indicators in Hennepin County, and base data on county boundary, land use and hydrography. GRS83, UTM Zone 15N was chosen to establish a common projection for the project, so that all layers would correspond spatially.

The three main variables to be considered in this study are:

- Census data at the block level
- Wetlands that are *Culex* mosquito breeding sites
- Location of positive indicators of WNV

These three information layers will be analyzed individually for geographic patterns. The final step in analysis will spatially relate the three in order to find the areas where WNV infection is a greater threat for those over 50 years of age. In addition, land use will be considered to determine the relationship between the location of WNV indicators and human activity.

For the study of the population of Hennepin County, two census databases were used. The first, Census Blocks from the 2000 census, contained the geographic location of the census blocks in the county and was obtained from a link to the U.S. Census from the ESRI website (2004). A second census database, SF1, was obtained from the same website. This contained the required information on demographic attributes, including the age of residents in the census blocks.

It was also necessary to obtain data on West Nile Virus in Hennepin County. The Minnesota Department of Health (2004) maintains a webpage with maps showing the number and type of indicators for WNV across the state for 2002 and 2003. The scale of this data shows cases at the county level. This project requires more precise locational data in order to relate the three variables and generate accurate geographic relationships.

Data on the location of infected birds, horses, and mosquitoes was obtained from the Metropolitan Mosquito Control District (MMCD), St. Paul, Minnesota. Mr. Kirk Johnson, Vector Ecologist for the MMCD, provided data on these indicators of WNV in Hennepin County. Without this data, this study would not have been possible.

Data on dead birds was obtained for 2002 and 2003, mosquitoes for 2003, and horses for 2002. It was attempted to obtain data on horses for 2003, but the potential source deemed the data too sensitive as addresses were involved for the location of the infected horses. Data on human cases is not publicly available and was also too sensitive to be obtained by a public researcher.

GIS base data typically includes feature subclass on topography, roads, cities, hydrography, and land use. These layers comprise the foundation of a typical GIS project and provide the "lay of the land" and its major uses. Base data for this project included the boundary of Hennepin County, landuse, scanned USGS topographic quadrangles (DRGs), and hydrography. This data was obtained from the Minnesota DNR Data Deli, the MetroGIS website, and the National Wetlands Inventory website.

A necessary part of any GIS project is the preparation of data for analysis. Some publicly available data is inaccurate and must be corrected. Often data are obtained from several sources for a theme, such as population data. These must be combined to create a database with the required records and spatial attributes. For this project, hydrography data was obtained from several sources. These layers needed to be combined to provide a complete hydrography theme for the county. It was then necessary to edit the theme to clean up discrepancies and errors. DRGs for Hennepin County were downloaded from the DNR Data Deli, and were used as a reference in this process.

Once obtained, it was then necessary to make data specifically useful for Hennepin County. Bird data for 2002 and 2003, horse data for 2002, land use, and hydrography were clipped to the Hennepin County boundary using the Geoprocessing Wizard in ArcGIS.

To make the age data available with the census block locations, the census database SF1 containing population data was joined with the block location layer. A field was added to the table to contain the population totals for residents over 50. With these totals calculated, the blocks were classified according to the raw number of residents over 50. Using the Natural Breaks method, the following four classes were derived:

Class 1: no residents over 50
Class 2: 1-74 residents over 50
Class 3: 75-254 residents over 50
Class 4: 255-868 residents over 50

The first class contained no data relevant to this project and was excluded. These blocks display as white space in all maps. This left only those census blocks with one or more residents over 50, and was renumbered 1-3. These are symbolized in solid colors.

This demographic shapefile was rasterized in Spatial Analyst and reclassified on the total population field with the Raster Calculator. Figure 2 shows the location of census blocks classified on total population.

A new grid was derived based on the highest population class (class 3) alone. The output grid shows only those blocks with a population of 254 to 868

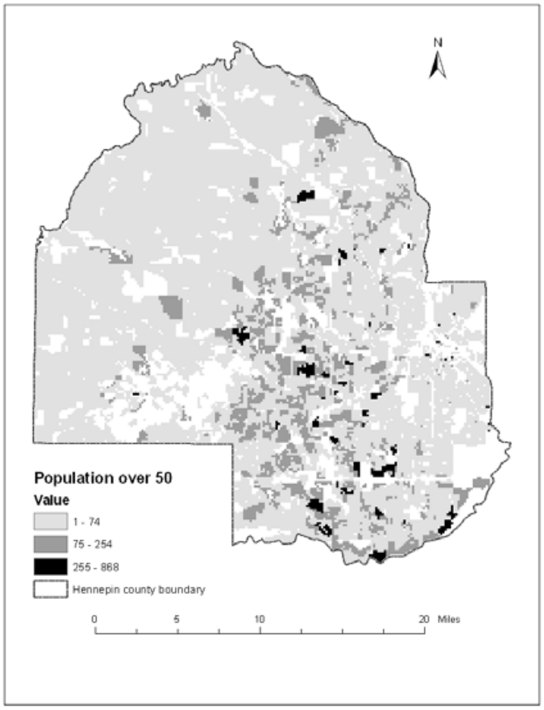

Figure 2. Census blocks with residents over 50. Blocks with none over 50 are white.

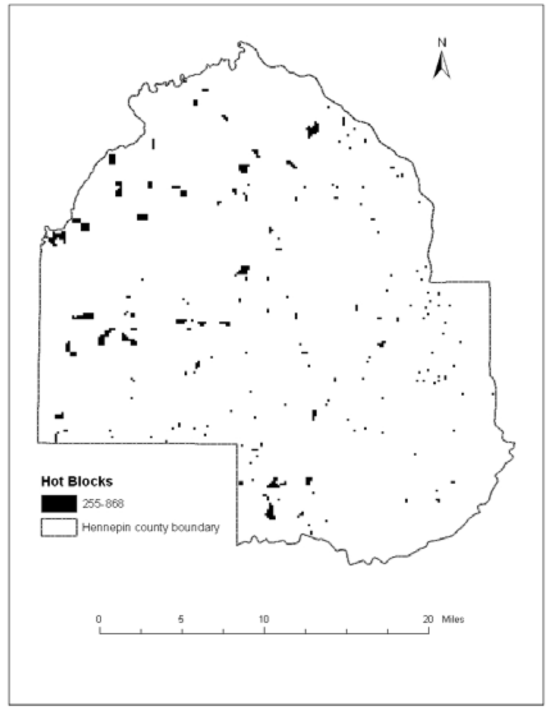

Figure 3. Hot Blocks with most residents over 50.

residents over 50 years of age. These were termed "hot blocks" and are shown in Figure 3.

Four point feature class layers gave the locations of positive indicators for WNV:

- Bird 2002
- Bird 2003
- Horse 2002
- Mosquitoes 2003

Figure 4 shows the spatial clustering of birds positively identified as being infected with WNV in 2002. Figure 5 shows the bird cases in 2003. Figure 6 combines the bird cases for 2002 and 2003. The spatial clustering is consistent over both years in the southeastern part of the county.

Data for horses and mosquitoes was only available for one year each. Figure 7 shows the location of the horse cases

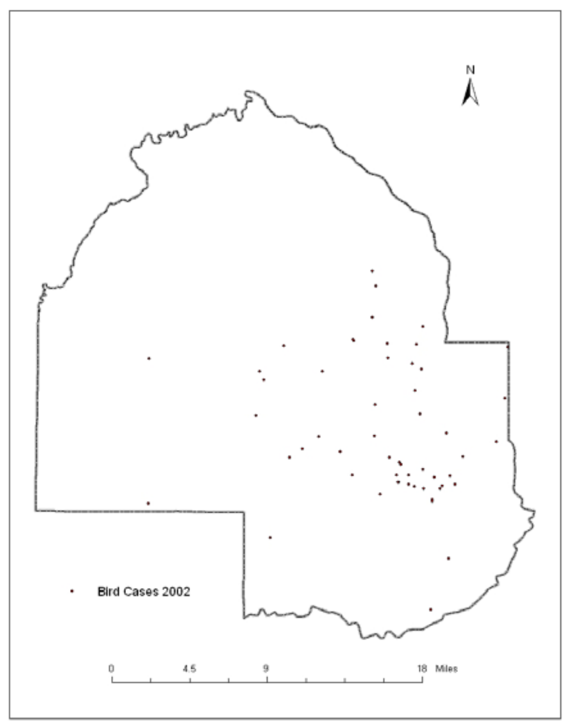

Figure 4. Bird cases for 2002.

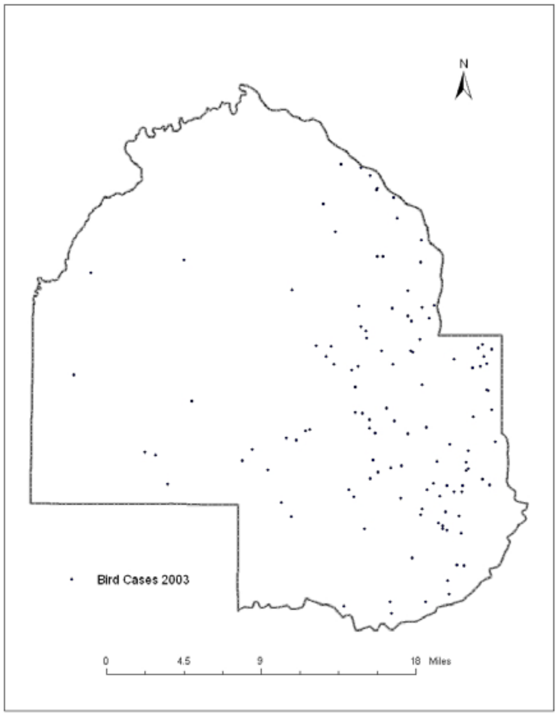

Figure 5. Bird cases in 2003.

positively identified with WNV in 2002. Figure 8 shows the location of mosquito

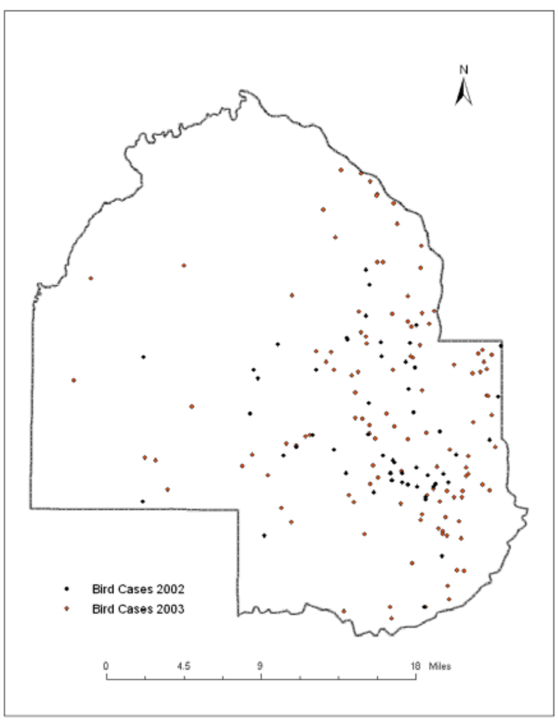

Figure 6. Bird cases for 2002 and 2003.

cases in 2003. These mosquitoes were caught in traps placed on a grid pattern by the Metropolitan Mosquito Control District in St. Louis Park. Consequently, the concentration seen in this map does not necessarily reflect a spatial clustering.

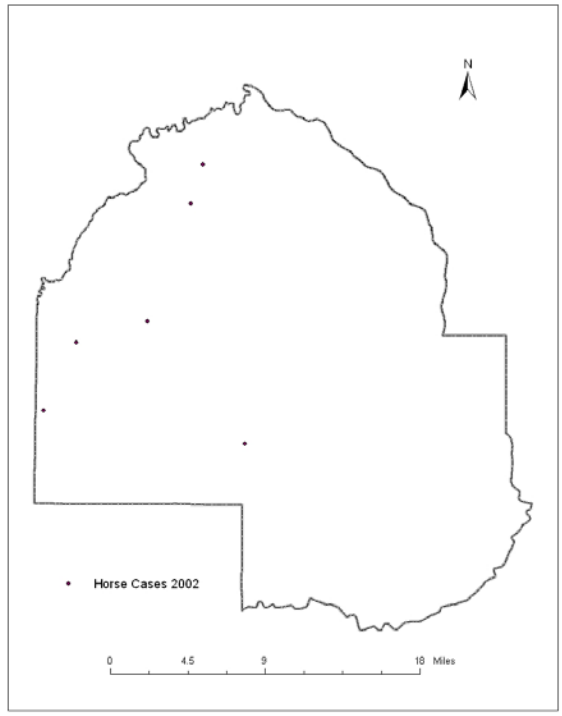

Figure 7. Horse cases for 2002.

All positive indicators for WNV were merged into one shapefile using the Geoprocessing Wizard and converted to raster format in Spatial Analyst. A grid of the straight line distance around positive indicators of WNV was created and reclassified for ten classes. This grid shows a range of values for distance with a radius of one mile. This distance corresponds to studies by Boyd (2002) and Bauer and Gallagher (2003). The output grid is shown below in Figure 9.

A new grid was derived showing only the areas within the first one mile radius. The areas around each positive

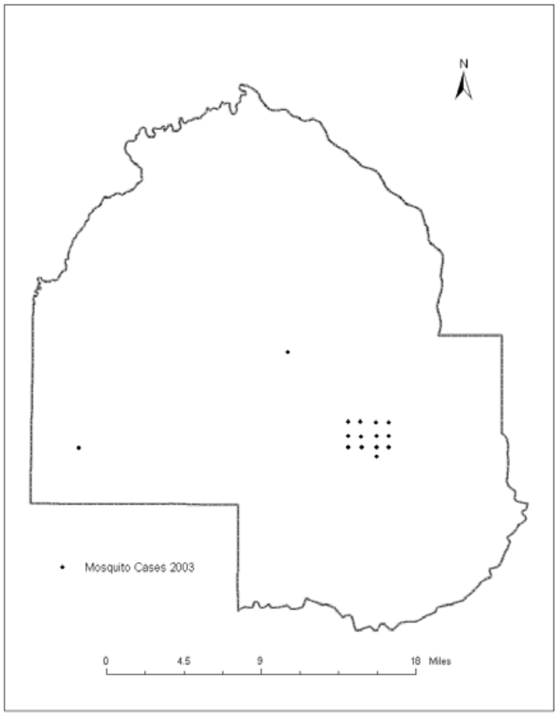

Figure 8. Mosquito traps in St. Louis Park, 2003.

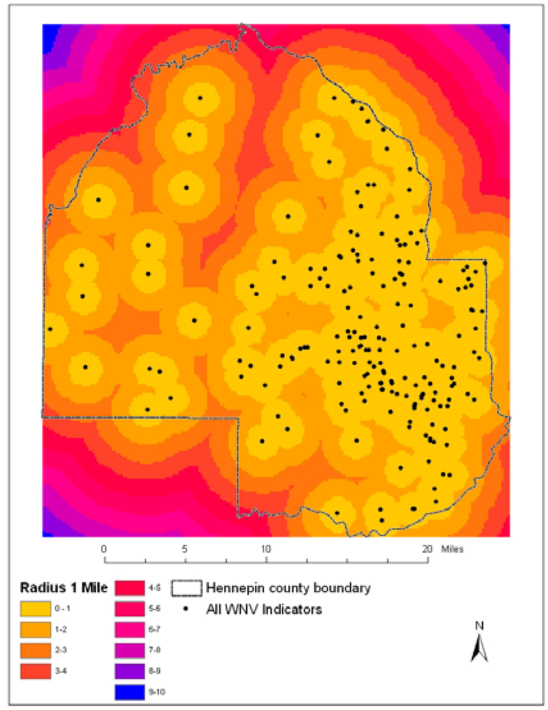

Figure 9. One mile radius around all WNV indicators.

indicator for WNV are termed "hot zones." The "hot zones" represent areas with the greatest danger of infection for residents over 50 years of age. In Figure 10, areas in red represent "hot zones."

The National Wetlands Inventory (NWI) is a program overseen by the U.S. Fish and Wildlife Service (2002) to map wetlands and make this information available to the public. NWI uses a classification scheme organized by system with dozens of subdivisions. Information on wetlands for Hennepin County was downloaded from the NWI website as shapefiles organized by quadrangles at a scale of 1:24000. Where necessary, the quads were clipped to the Hennepin County boundary.

The relevant system classifications for this project were Upland, Palustrine, and Lacustrine. The preferred breeding habitat for the *Culex* mosquito is permanent and semi-permanent wetlands (MMCD 1999). These correspond respectively to the Lacustrine and Palustrine system classes of the NWI. The Lacustrine system is composed of lakes and ponds. The Palustrine system is composed of freshwater marshes. A third system, Upland, is present in Hennepin County and is composed of non-wetland areas. The Lacustrine and Palustrine systems account for the great majority of wetlands in Hennepin County. Of the 201 positive indicators for WNV, 200 were found on the Upland category. The high number of indicators found on the Upland system does not imply that there is a higher risk of infection there, but is only where the indicators were found. The remaining indicator was found on the Palustrine system. Figure 11 shows the location of

WNV indicators in relation to wetland system.

The NWI wetland shapefiles were merged into a single shapefile to aid in processing and to simplify selection of wetland systems. From this merged shapefile, all features that were classified as either Palustrine or Lacustrine were selected and exported to a new shapefile. This permitted the selection by spatial location for positive WNV indicators that are within one mile of these wetland types. Of the 201 WNV indicators, 197 were within this range. The remaining four indicators were all in the city of Minneapolis. The Mississippi River and Minnesota River watersheds contained the great majority of WNV indicators. Figure 12 shows the location of WNV indicators in relation to watershed.

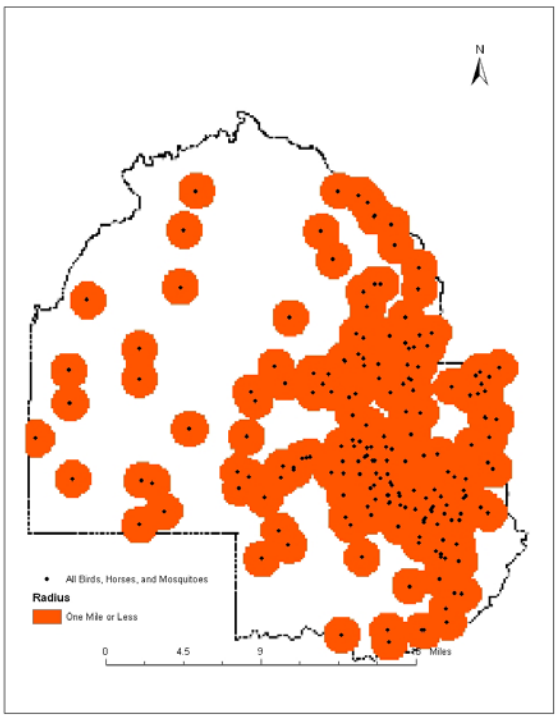

Figure 10. Hot Zones of one mile or less from WNV indicator.

The Palustrine/Lacustrine wetlands shapefile was rasterized to facilitate analysis of wetlands in relation to "hot blocks" and "hot zones" to find the areas where those over 50 would have greater risk of becoming infected with WNV.

These are termed "hot spots" and are the areas where Palustrine or Lacustrine wetlands, census "hot blocks, and WNV "hot zones" overlap spatially. Using the Raster Calculator, a Conditional statement was utilized to obtain a new grid output. The Conditional statement read: hotspots = con((hotblk = = 1 & hotzone = = 1 & wetgrid = = 1), 1, 0).

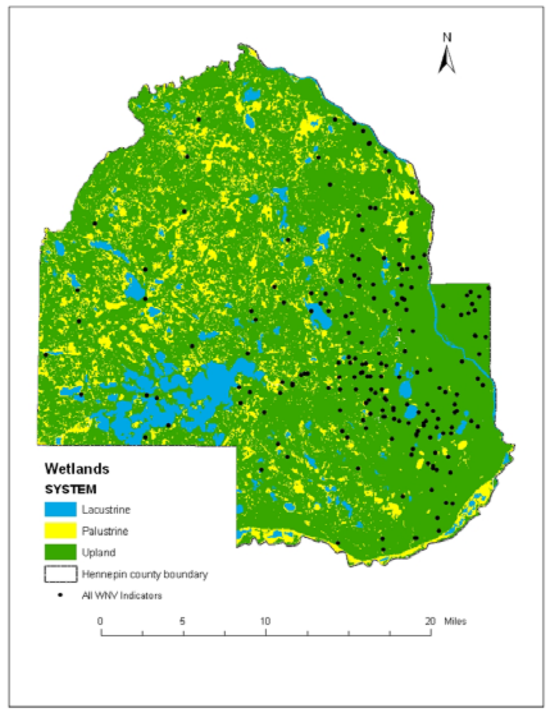

Figure 11: WNV indicators in relation to wetland system

This output met the project goal of finding the spatial relationship between the three variables and is shown in Figure 13.

A second approach to finding "hot spots" did not consider wetlands. Given that wetlands are so extensive throughout Hennepin County, potential

Culex breeding sites are widespread. This second analysis looked only for the relationship between "hot blocks" and "hot zones." The conditional Statement used was: Hotspots2 = con(([hotzone] = = 1 & [hotblk] = = 1), 1, 0). This showed the more extensive distribution of "hot spots" shown in Figure 14. These "hot spots" are spatially concentrated in the southeastern section of the County. This corresponds to the clustering of dead bird indicators in those areas as shown in Figure 5.

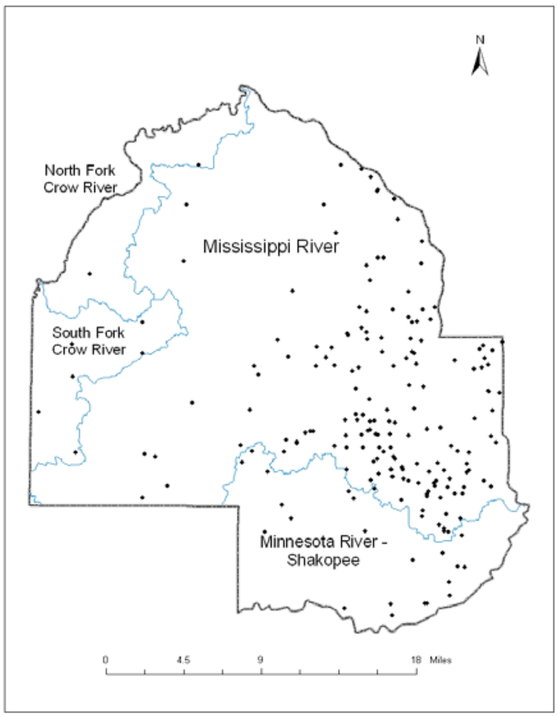

Figure 12. WNV indicators in relation to watershed.

A second approach to the population data was taken to map population density of vulnerable populations in the census blocks. This illustrates how different examinations of the same data can reveal different insights. The first approach used raw numbers of vulnerable populations in the census blocks. From this, the "hot blocks" were derived as described previously and shown in Figure 3.

A different set of "hot blocks" were derived based on population density. This was obtained by dividing the population numbers in each block by its area in acres. This was then rasterized on the density field and reclassified to three classes using the Natural Breaks method. The resulting class breaks were:

Class 1: 0 – 1.35
Class 2: 1.36 – 15.95
Class 3: 15.96 – 86.85

Figure 15 shows the block classification scheme based on population density.

A new grid was derived based on the highest density class (class 3) alone. The output grid shows only those blocks with a population density of 15.96 – 86.85 people per acre, and is shown in Figure 16.

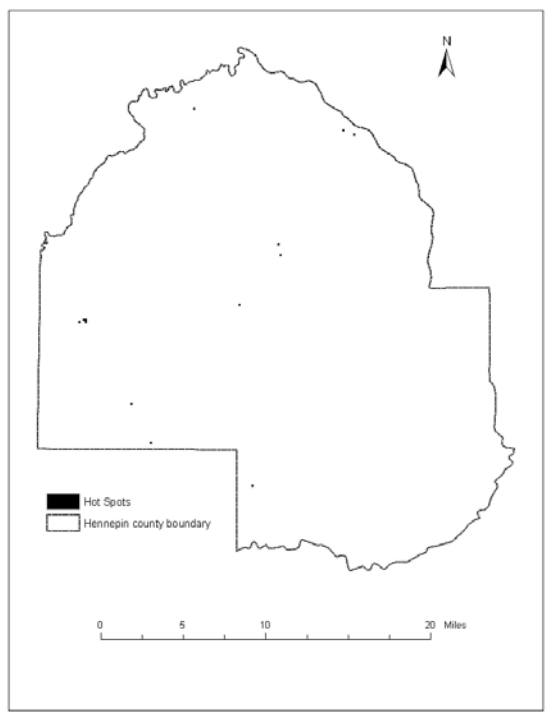

Figure 13. Hot Spots of overlap between wetlands, Hot Blocks, and Hot Zones using first conditional statement.

This gave an interesting perspective of "hot blocks." Without considering the other two variables of this study (wetlands and WNV indicators) there was still a geographic clustering in the southeastern section of the county. This is another indication that WNV infection is greater in this area. Figure 16 shows this clustering.

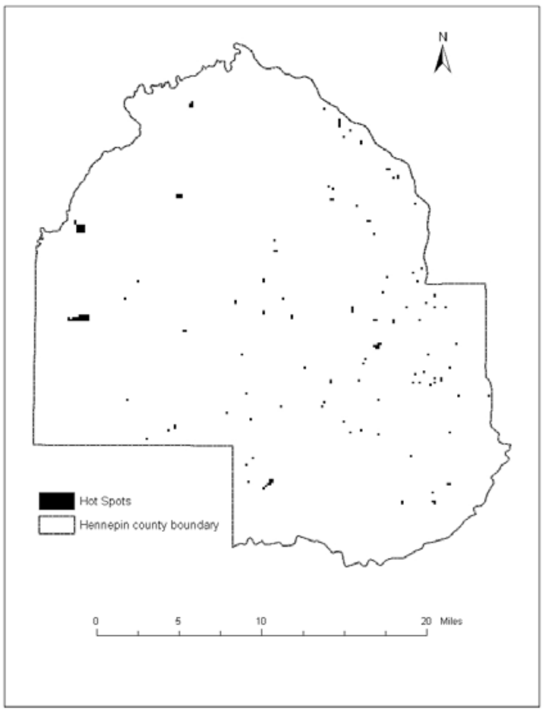

Figure 14. Hot Spots of overlap between hot zones and hot blocks using second conditional statement.

Land use information for Hennepin County was obtained as a shapefile from the MetroGIS website (2004). This contained 21 land use classifications ranging from industrial and commercial sites to golf courses, parklands, and residential areas. These were reclassified into an eight way scheme to simplify analysis. Some areas in the county were unclassified. The classes used were:

1. Agricultural, Golf Course, Park and Undeveloped
2. Airport
3. Industrial and Extractive
4. Highway and Railway
5. Commercial and Retail
6. Residential
7. Water
8. Unclassified

An examination of the location of WNV indicators in relation to land use showed that of the 201 cases, 18 were found in the Agricultural, Golf Course, Park, and Undeveloped class. Four were

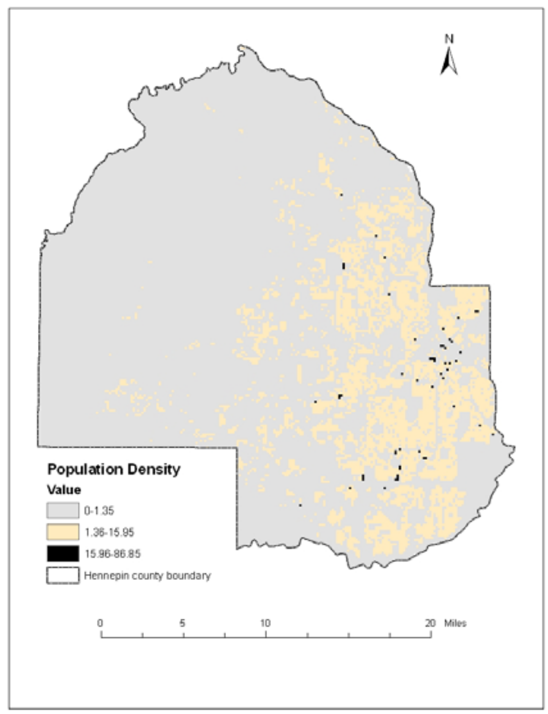

Figure 15: Census blocks classed by population density.

found on Industrial and Extractive sites. One was found on a Highway and Railway site. Five were found on Commercial and Retail sites. The great majority, 165, were found on Residential sites. One was found on Water. Seven were found on unclassified land. Table 1 shows the number of cases found on each land use class in Hennepin County. Figure 17 shows land use in Hennepin County.

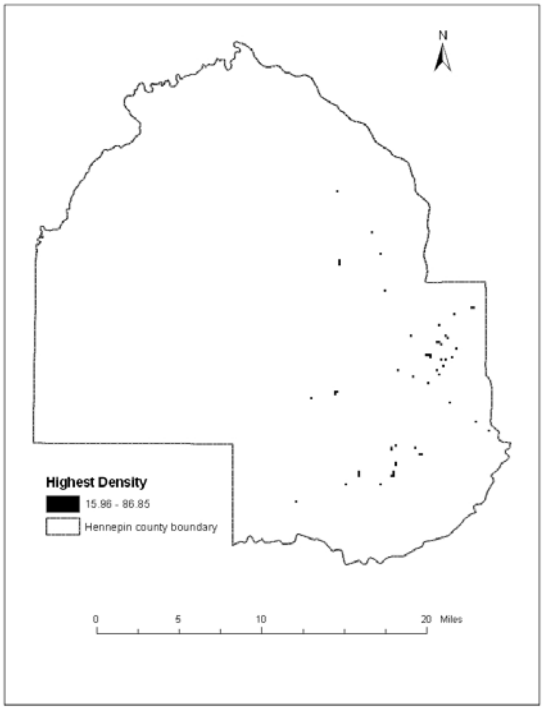

Figure 16. Hot Blocks based on population density.

Table 1. Land Use classes with number of cases per class.

Class	Number of WNV Indicators
1: Ag, Park, etc.	18
2: Airport	0
3: Indust., Extract.	4
4:Hwy,.RR	1
5: Comml,. Retail	5
6: Residential	165
7: Water	1
8: Unclassed	7
Total	201

Results and Discussion

With these steps of collecting, preparing, and deriving data completed, the final goal of the project could be met: the creation of a screening process to determine where the most susceptible

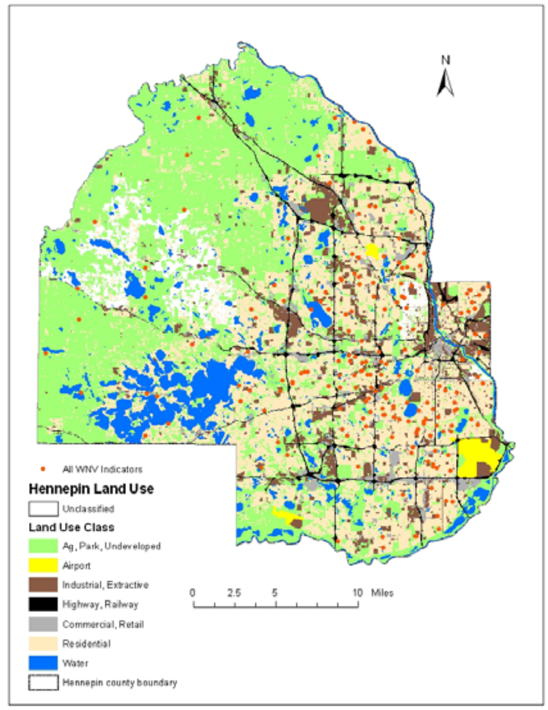

Figure 17. Land use in Hennepin County with WNV indicators.

populations live relative to the location of positive indicators of WNV. Cities with "hot spots" were termed "hot cities." Using the three variables of wetlands, hot blocks, and hot zones to find "hot spots" produced nine "hot cities." The hot cities are listed in Table 2. Figure 18 shows "hot cities" derived from the three variables.

The second method used to find "hotspots" was based on the two

Table 2. Hot cities derived from first conditional statement.

Champlin	Eden prairie
Hassan Township	Independence
Maple Grove	Mound
Plymouth	Robbinsdale
Shorewood	

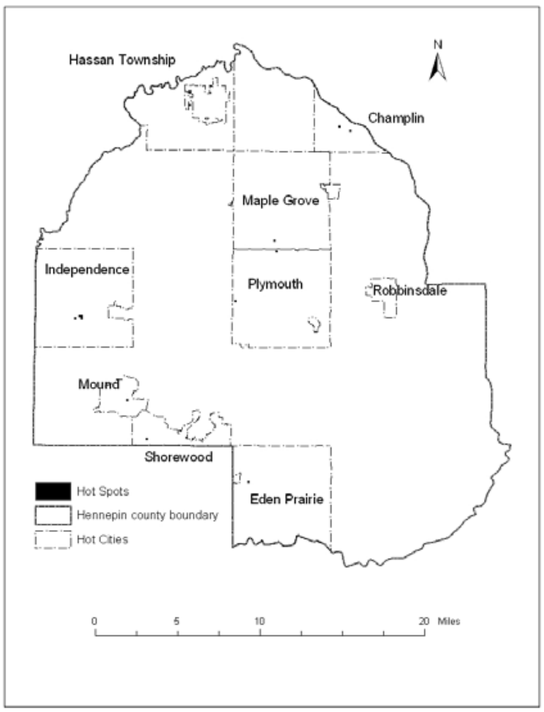

Figure 18. Hot cities derived from first conditional statement.

variables of hot zones and hot blocks. This produced many more "hot cities." The list of hot cities is shown in Table 3. This list does not include every city in Hennepin County, but does include the great majority. Figure 19 shows the hot cities based on hot blocks and hot zones.

The third method used to determine hot spots, and the respective hot cities,

Table 3. Hot Cities derived from second conditional statement.

Bloomington	Brooklyn Center
Brooklyn Park	Champlin
Corcoran	Deep Haven
Eden Prairie	Edina
Golden Valley	Greenfield
Hassan Township	Hopkins
Independence	Maple Grove
Medina	Minneapolis
Minnetonka	Mound
New Hope	Orono
Plymouth	Richfield

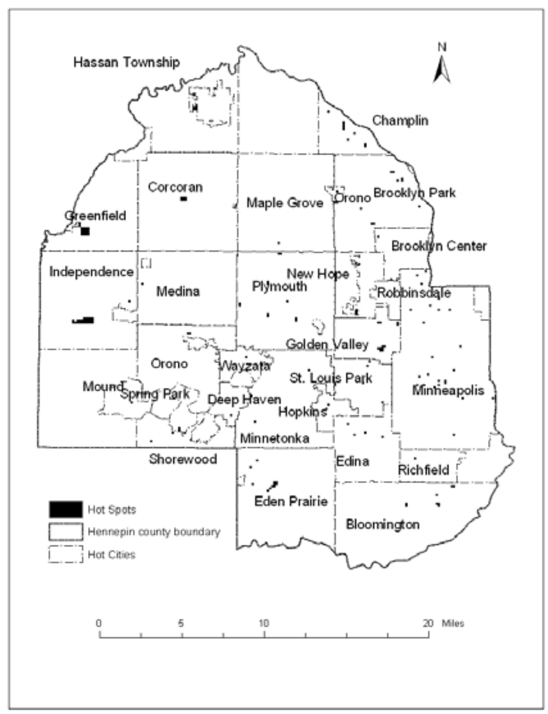

Figure 19. Hot cities derived from second conditional statement.

was based on the hot blocks derived from the population density analysis. For this method the wetlands variable was not used, as in the second conditional statement. The conditional Statement used was: Hotspots3 = con(([hotzone] = = 1 & [hotblkdense] = = 1), 1, 0). This derived the hot blocks shown in Figure 20 and the hot cities listed in Table 4.

Table 4. Hot Cities based on population density

Bloomington	Brooklyn Center
Edina	Minneapolis
Minnetonka	New Hope
Osseo	Plymouth
Richfield	Robbinsdale
St. Louis Park	

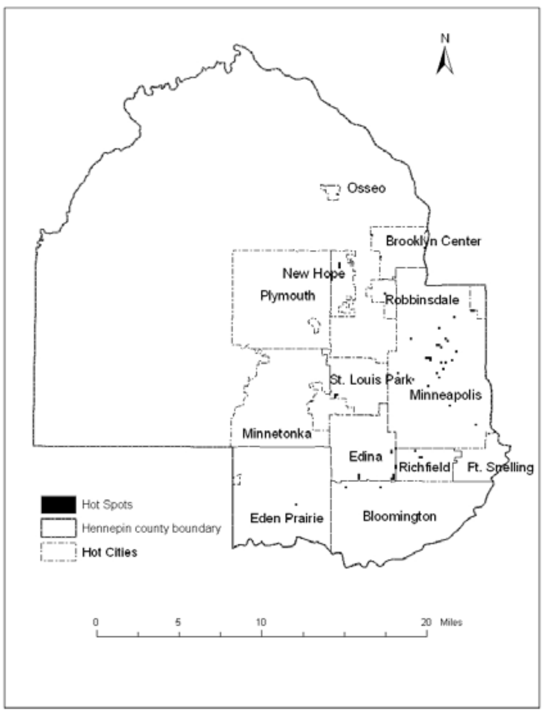

Figure 20: Hot Cities derived from population density analysis

A recent study by the Harvard School of Public Health (2003) found that four in ten U.S. residents in high mosquito areas are not taking adequate precautions against WNV. The procedures outlined in this study provide a foundation for precise outreach efforts that could be taken up by public health agencies. This foundation could allow these agencies to target populations of concern in Hennepin County with greater precision. As West Nile Virus will be a continuing health issue in Minnesota, it can be recommended that the "hot cities" make special efforts to educate those over 50 on the prevention of WNV.

The land use analysis indicates that private citizens are the primary source of information on positive indicators for WNV as they found the great majority (165 of 201) of cases reported to authorities. The Minnesota Department of Health maintains a webpage with an online form for reporting dead birds. This is an important outreach effort by the health agency and is to be commended since the general public is such an important source of information on the presence of WNV.

This study concentrated on the most populous urban county in Minnesota. However, the rural counties of the state often contain a higher percentage of residents over 50 years of age. Even though the overall population in these counties is much less than that of Hennepin County, they may have a higher potential for human WNV cases. Ultimately, an educational outreach program targeting those over 50 could be extended to all counties in the state.

There were some limitations in the scope of this project. First, information on the human cases of WNV was unavailable to the author due to its sensitive status. Health agencies could gain more complete coverage by adding this information. Additionally, information for horse cases for 2003 was unavailable, as it was also deemed sensitive. Again, health agencies could add this information to their database to obtain a more comprehensive understanding of the location of animal cases in the county.

Another consideration is the mobility of birds, mosquitoes, and humans. An infected bird may have become infected in a different location from where it was found deceased. An infected human may have been bitten by an infected mosquito while away from home. The positive indicators for WNV, however, are determined by where the dead bird was found or where the person lives. Such mobility is a complicating factor in the study of West Nile Virus.

The geographic clustering of dead birds for the two years for which data was available does in all likelihood indicate a higher presence of infected mosquitoes in that area. Mapping of this spatial clustering could contribute to mosquito control efforts by the Metropolitan Mosquito Control District (MMCD). This agency could make special efforts to apply larval and adult mosquito controls in that area. In fact, helicopter treatments by the MMCD for 2004 began in May (MMCD 2004). Interestingly, the cities listed for treatment in Hennepin County include nearly all the cities found in this independent study to have both “hot blocks” and “hot zones.”

Conclusion

This study has successfully fulfilled its goal of finding those geographic areas of Hennepin County, Minnesota that have the highest number of vulnerable residents (those over 50 years of age) who are geographically close to areas where the risk of WNV infection is greatest. The criteria used to find these zones of vulnerability were based on the three variables of mosquito breeding habitat, census blocks with residents over 50 years of age, and positive indicators for WNV. Project research applied GIS principles and methodology to spatially analyze the data available and the data derived from that data. This procedure allowed recommendations to be made that would facilitate the efforts of public health agencies to target the vulnerable populations for education on the prevention of WNV. It is hoped that such efforts would ultimately contribute to lowering the number of cases of WNV in the state.

Acknowledgements

I would like to thank the following people for assistance in this project: Kirk Johnson, Vector Ecologist: Minnesota Mosquito Control District; John Ebert and Martha Roldan: Graduate Committee; Jay Meehl, and Dr. David McConville.

References

Bauer, Christopher, and Tim Gallagher. 2003. The incorporation of Geographic Information Systems into a local mosquito control program. Cuyahoga County Board of Health.

Boyd, Keven C. 2002. Integrated GIS solution for mosquito control. http://gis.esri.com/library/userconf/proc02/pap0386/p0386.htm. Accessed 3/31/2004.

California West Nile Virus Surveillance Information Center. 2004. Home Page. http://www.westnile.ca.gov/. Accessed 5/2/2004.

Center for Disease Control, Division of Vector-Borne Infectious Diseases. 2004. West Nile Virus. http://www.

cdc.gov/ncidod/dvbid/westnile/index.htm. Accessed 4/10/2004.
Cromley, Ellen D, and Sara L. McLafferty. 2002. GIS and Public Health. Guilford Press: New York.
Environmental Systems Research Institute, Inc. 2004. Census 2000 Tiger/Line files. http://arcdata.esri.com/data/tiger2000/tiger_county.cfm?sfips=27. Accessed 1/28/2004.
Harvard School of Public Health. July 31, 2003. Four in ten Americans in high-mosquito areas are not yet taking precautions against West Nile/mosquito bites. Ascribe Health News Service.
Huhn, Gregory D., James J. Sejvar, Susan P. Montgomery, and Mark S. Dworkin. 2003. West Nile Virus in the United States: An update on an emerging infectious disease. American Family Physician 68 i4 653-668.
MetroGIS. 2004. Home Page. http://www.metrogis.org/. Accessed 4/2/2004.
Metropolitan Mosquito Control District. 1999. Background, Chapter 1. http://www.auditor.leg.state.mn.us/ped/pedrep/9903ch1.pdf. Accessed 4/2/2004.
Metropolitan Mosquito Control District. 2004. Helicopter Treatments in the Metro Area. http://www.mmcd.org/helicopt.html. Accessed 4/2/2004.
Minnesota Department of Health. 2004. West Nile Virus. http://www.health.state.mn.us/divs/idepc/diseases/westnile/index.html. Accessed 3/31/2004.
Minnesota Department of Natural Resources. 2004. Data Deli. http://deli.dnr.state.mn.us/. Accessed 11/5/2003.
Sampathkumar, Priya, M.D.2003. West Nile Virus: Epidemiology, clinical presentation, diagnosis, and prevention. Mayo Clinic Proceedings 78: 1137-1144.
United States Census Bureau. 2004. Minnesota Quick Facts, Hennepin County. http://quickfacts.census.gov/qfd/states/27/27053.html. Accessed 7/12/2004.
U.S.D.A. Animal and Plant Inspection Service. 2002. Prevention and Control of West Nile Virus Infection in Equine and Other Livestock or Poultry. http://www.aphis.usda.gov/oa/pubs/ada_ahwnv.htm. Accessed 1/31/2004.
U.S. Fish and Wildlife Service. 2002. National Wetlands Inventory: A Strategy for the 21st Century. http://wetlands.fws.gov/Pubs_Reports/NWI121StatFNL.pdf. Accessed 5/2/2004.