

Paper 3018

Comprehensive GIS Application for West Nile Virus Surveillance

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Abstract

ArcView and geographic cluster analysis could be used together for early detection of West Nile Virus (WNV) presence and targeted response.

Learning from past experiences, in 2004 the Chicago Department of Public Health combined traditional mosquito abatement and spatial analysis to detect WNV activity. Traditional approaches involve testing mosquitoes and birds for WNV presence. Mosquito traps are located using GPS and test results are mapped to show positive locations. The second approach involves encouraging citizens to report dead birds in their neighborhood through a non-emergency hotline. Spatial analysis performed on dead bird calls using Kulldorff Method identifies statistically significant locations. These data, combined with traditional test results, are mapped in ArcView to show potential WNV hotspots by each day or week.

The solution, which could be modified to detect other communicable diseases, involves an Oracle database with Access front-end, a Java API for batch geocoding, and Visual Basic to dynamically generate maps.

Introduction

In 2002 the City of Chicago's Department of Public Health (CDPH) conducted a retrospective spatial analysis of an epidemic and epizootic of WNV infections occurring in Chicago (1). The study demonstrated that age-adjusted human case rates were three times higher in geographic areas with a high density of early-season crow deaths.

Noting other studies (2, 3), which link early season crow and other avian deaths to eventual human cases of WNV, the Chicago Department of Public Health began development of a real-time WNV spatial data repository and surveillance system. This system acts as a data entry point, warehouse, geographic analysis tool, and a complete surveillance and reporting system.

The goal of this system is to gather information in real-time from disparate data sources, process and summarize geographic data, and report results in a consistent and standardized format. The GIS solution allows policy makers, field and lab staff to view, analyze and further geo-process all relevant WNV data sources necessary for identifying places in the city that need more focused surveillance and/or mosquito control measures.

Data Sources

A multi-disciplinary approach to WNV surveillance required the Chicago Department of Public Health to develop a WNV data repository. WNV Surveillance requires several CDPH units share data outside of traditional roles and coordinate efforts with other City of Chicago departments to collect and process data. Once complete, the

integrated data repository allowed for standardized geographic reporting and analysis, which had previously been performed manually and replicated in each office.

The CDPH's Office of Environmental Health operates the Mosquito Abatement program, which is the primary source of mosquito surveillance information. Every spring over 100 mosquito traps are selectively placed throughout Chicago and their locations collected by a full time entomologist using a geographic positioning device (GPS). Ten seasonal field workers gather mosquito collections from these traps two times each week. Bi-weekly collections of adult mosquitoes from these traps are returned to CDPH's laboratory for classification by sex and species and tested for presence of WNV. Results of these collections and tests are entered into the data repository daily.

The Mosquito Abatement program also administers a citywide larvicide program targeting publicly operated rainwater catch basins and standing water locations each spring. The larvicide program is conducted by the City of Chicago's Department of Water Management and Department of Streets and Sanitation, which apply methoprene, an insect growth regulator, to over 200,000 locations. Throughout the WNV season CDPH's entomologist samples catch basins in areas of significant bird deaths or positive mosquito populations for evidence of "breakthrough" mosquitoes in treated catch basins.

Human Cases of WNV are reported to CDPH by local hospitals via facsimile and entered into the Department's Communicable Disease Access database. Human WNV reports are investigated and verified for accuracy by case investigators in the Communicable Disease office. The patient's home address or known place of infection is used as the geographic identifier.

Citizens are encouraged to report dead birds to the City of Chicago's award-winning Chicago Service Request non-emergency hotline commonly known as 311. These calls (averaging approximately 40/day) record date of call, type, location, and condition of bird. The Department of Streets and Sanitation dispatches field units by aldermanic ward to collect dead birds, which are reported in a condition acceptable for laboratory testing. To reduce cost and ensure laboratory capacity, samples from a ward are tested until two positive bird results are found in the same ward.

Solution

Leveraging the existing processes and available hardware and software, we developed a zero-cost application solution for the WNV program in 2004. The solution consists of 16 different software components serving from five physical locations and on two separate networks all brought together to produce a comprehensive WNV Surveillance system. The principal achievements of the Chicago WNV application are its simplicity, the convergence of independent data sources, and the integration of processes from disparate technology components. The components of the WNV application operate on both Windows and UNIX operating systems, consist of Oracle and MS Access databases, use Java and Visual Basic, and employ statistical tools and ESRI ArcView 8.3. While a single application platform is quite possible and perhaps more stable, we adopted this methodology to save considerable time and cost.

Components

A high-end workstation running Windows XP was converted to be the dedicated WNV Server. This machine hosted the Oracle 9i database as well as the MS Access front-end for the WNV application. ESRI ArcView 8.3 and Visual Basic 6.0 (Dynamic Link Libraries) DLLs for ArcView automation was loaded on the Server and each client PC (Windows 2000). In addition the Server PC housed, an Access 2000 database facilitates the automation of tasks, an FTP client, Java clients for geocoding addresses, and SatScan (v4.0.3) statistical program for spatial analysis.

Components outside of the WNV Server includes:

- City of Chicago Non-Emergency hotline, also known as 311 or Chicago Service Request (CSR) System.
- Business Objects Server
- FTP Server
- Intelligence Dispatcher geocoding engine
- Communicable Diseases (CD) Database
- WNV Client workstations.

Automated Mapping and Reporting Process

Nightly, the Business Objects server queries the 311 Oracle database and collects all the dead bird calls from the previous day. That information is placed on an FTP server. Soon after that the WNV Server starts an FTP client program to gather the data from the FTP Server. The FTP process is employed because the 311 System and WNV Servers are physically located on different networks.

Also occurring nightly, human cases are queried and copied from the Communicable Disease database to the WNV Server using database links. Database links is possible as the CD database is on the same network as the WNV Server.

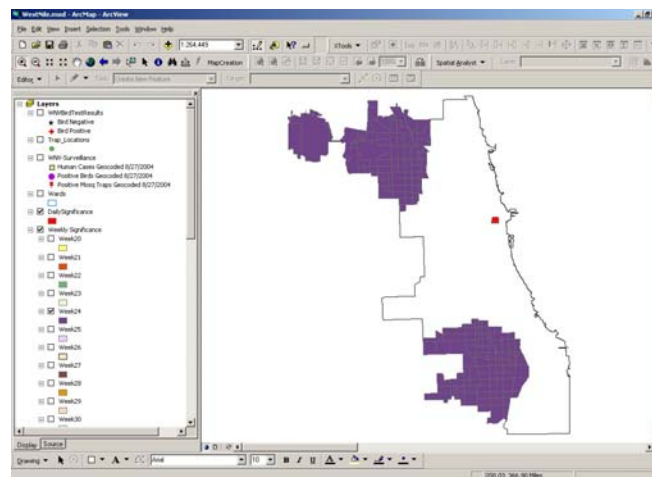
Java client programs in the WNV Server application are evoked next to geocode the dead birds and human case addresses collected in the previous steps. The Java programs will take each address and run it against the City of Chicago's Department of Business and Information Services' Intelligence Dispatcher. The Intelligent Dispatcher is a geocoding engine used to identify the addresses' associated geography. Ward, census, and X and Y coordinates are populated using this procedure. Accurately geocoded address attributes are then appended into the WNV Oracle database. Addresses that fail the geocoding process are logged on the WNV Server. Automated email notifications are sent to the system administrators and Communicable Disease staff in the event of a human case or 311 call geocoding failure.

Visual Basic functions within the supplementary Access database of the WNV application will then generate the data for the SatScan statistical analysis. This includes creating a control file and a case file. The control file consists of dead bird calls from April 1st thru 21 days prior to the current date or the date of first confirmed WNV Positive dead bird case, whichever comes first (4). The case file consists of de-duplicated dead bird calls for the past seven days. For de-duplication purposes, calls from same city

block within seven days are treated as one case. The SatScan process is then run in batch mode automatically using the control and case file. The output is saved on the WNV Server as dBase (.dbf) file. SatScan generates a file of census tracts*, from which statistically significant numbers of dead bird calls were received during the previous day. These census tracts are identified by calculating the deviation from the expected number of calls based on the control file data. The significant census tract table is joined to census tract geography in ArcView and displayed to show geographic WNV hotspots for the previous day.

In order to maintain a history of the WNV hotspots and also identify any WNV movement over time, dBase files are maintained for each week for the WNV season (week 20 thru 45). The dBase file for that particular week is updated after each day's SatScan run. The weekly data is then plotted in ArcView to show census tract hotspots for each week. ArcView users can select any one of the weeks and view the WNV hotspot for that week. This helps summarize movement of WNV epizootic activity over time. The daily significance map identifies areas of most recent activity necessary for immediate intervention. Weekly significance analysis facilitates the identification of trends over time, assists with larvicide program evaluation, and aids in development of strategic plans.

WNV application users launch ArcView by selecting a button on the application interface. Visual Basic DLLs registered on each client PC query the WNV database and dynamically generate geographic data in ArcView. The various map layers display mosquito trap locations, mosquito trap results, 311 dead bird locations, tested bird results, catch basin/standing water test results and human positive cases. These data are then layered over the geographically significant census tracts to generate a comprehensive picture of the WNV activity in Chicago for that day or for any of the previous weeks.



Daily and weekly (historical) significance views available on the WNV ArcView map.

* Census tracts summarize local area populations and are used to calculate case rates within statistically significant areas.

Analysis & Response

WNV maps are used to target mosquito abatement and evaluate the larvicide program. Census tracts identified as having significant spatial clustering of bird deaths received intensified surveillance efforts. These census tracts, according to previous studies, Kulldorff et al, (4), might have an increased likelihood of developing human cases of WNV within weeks of identifying them as significant. Intensified efforts in significant census tracts not only reduce the risk to humans but also help leverage the limited resources. To date, five of the six WNV positive human cases in 2004 fell near or within a significant area (Appendix B).

Conclusion

While there was a strong correlation bird mortality and human risk in Chicago in 2002 (1), it is not certain that this will be the case every year due to changes in the population of susceptible birds, public enthusiasm for calling in bird locations, and mosquito populations. Therefore the spatial analysis of dead bird sightings is used as one of several tools in identifying areas of potential increased human risk.

Nonetheless CDPH experience shows that the geographic hotspots identified with SatScan do serve as a potential indicator of increased WNV activity. Focusing mosquito monitoring and abatement activities around these geographic locations is practical and efficient. By modifying the SatScan parameters in the coming years, CDPH hopes to pinpoint significant areas to smaller geographic units so that a more focused surveillance and abatement program is possible.

The methodology adopted by CDPH could be used for a quick and simple set-up of other types of disease surveillance systems. Since time is critical in emergency situations a comprehensive model like the Chicago WNV system is ideal and effective.

Acknowledgements

Dr. Bill Paul, Deputy Commissioner of Epidemiology and Disease Control at Chicago Department of Public Health is the sponsor behind the WNV application.

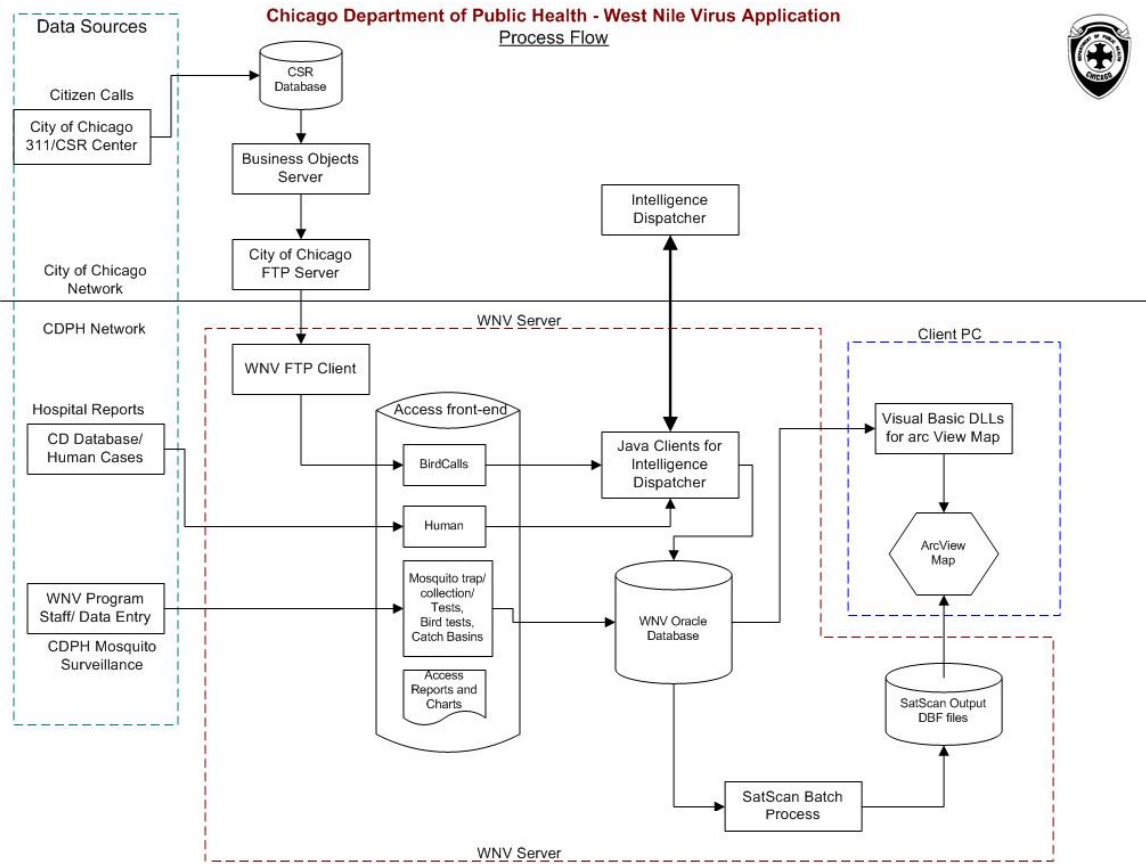
Dr. John Paul Mutebi is a medical entomologist and is the WNV Program Director at CDPH. He and his staff are responsible for the data and business logic behind the WNV application.

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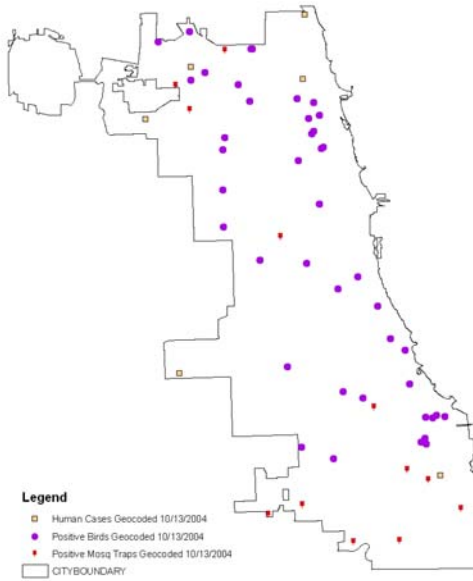
Molly Mangan, Director of Geographic Information Systems, Chicago Department of Business and Information Services for technical support and initial design of the WNV Application.

Appendix A

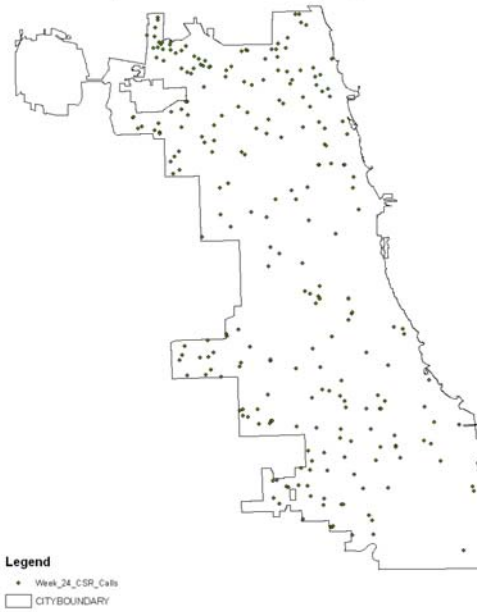


Appendix B

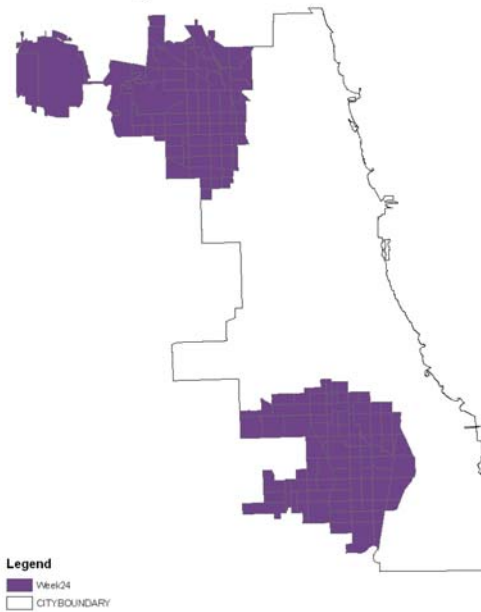
Traditional Sources of WNV Surveillance



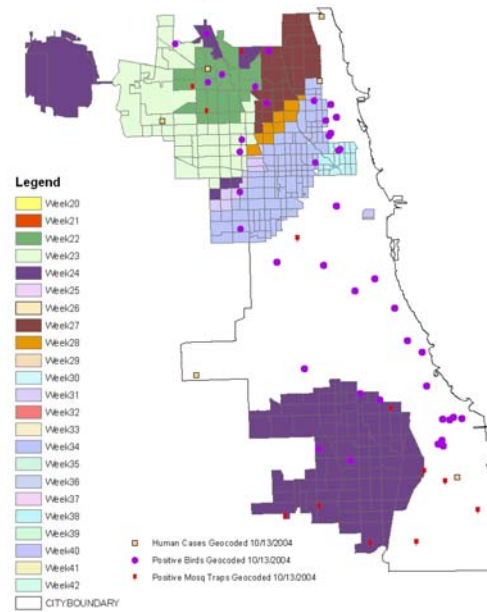
Citizen Reported Dead Bird Calls (311) in Week 24



SatScan Significant Census Tracts in Week 24



Season End Comprehensive WNV Surveillance



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