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SCIENTIFIC NOTE

USE OF THE VECTOR INDEX AND GEOGRAPHIC INFORMATION SYSTEM TO PROSPECTIVELY INFORM WEST NILE VIRUS INTERVENTIONS

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ABSTRACT. We sought to estimate West Nile virus (WNV) activity in mosquito populations weekly at the census tract level in Chicago, IL, and to provide this information graphically. Each week we calculated a vector index (VI) for each mosquito trap then generated tract estimates using geographic information systems. During June 29–September 13, 2008, a median of 527 (60%) of 874 possible tracts per week had a VI value. Overall, 94% of the weekly VI tract estimates were 0; among those with a VI estimate greater than 0, the median was 0.33 (range 0.003–3.5). Officials deemed risk levels and weather conditions appropriate for adulticide treatments on 3 occasions, resulting in the treatment of approximately 252 linear kilometers of residential streets and alleys. Our analysis successfully converted complex, raw surveillance data into a format that highlighted areas of elevated WNV activity and facilitated the determination of appropriate response procedures.

KEY WORDS West Nile virus, urban population, *Culex* mosquito, geographic information system

Geographic information system (GIS) technology provides tools for the integrated management, analysis, and visualization of mosquito and arbovirus surveillance data (Gosselin et al. 2005). Numerous studies of West Nile virus (WNV) activity in the Chicago, IL area have retrospectively described patterns in the virus' spatiotemporal activity or tested hypotheses about the association between environmental factors and the occurrence of human cases (Ruiz et al. 2004, 2007, 2010; Gu et al. 2006). However, the methods and findings of these studies are not directly applicable to public health officials who in the midst of a transmission season are faced with the financial and logistical challenge of targeting control measures, including the treatment of areas of a jurisdiction with adulticide.

In Chicago, a city of 2.7 million residents in a 592 km^2 area, the Chicago Department of Public Health (CDPH) leads a municipal task force that conducts WNV surveillance and carries out management and abatement activities. Rather than conduct a retrospective or predictive analysis, our objective was to prospectively estimate WNV activity in mosquito populations in Chicago neighborhoods week by week, using a standardized methodology. This information was then provided graphically to public health officials to inform debates about whether adulticide treatment was needed, and if so, to assist in the delineation of the treatment area's boundaries.

In 2008, adult mosquitoes were routinely sampled from June through September using gravid mosquito traps located throughout the city. The gravid traps were baited with an infusion of mixed fresh grass clippings and water that was replaced each week (Lampman and Novak 1996). Traps were operated 2 nights per week and the collected mosquitoes delivered to the CDPH environmental laboratory for WNV testing using reverse transcriptase polymerase chain reaction (RT-PCR) assay (Lanciotti et al. 2000). The CDPH WNV environmental surveillance and laboratory data were recorded and maintained in the City's Zoonotic Disease Tracker, a web-based application designed and maintained by the Chicago Department of Innovation and Technology. Calculations and formatting of data files for GIS analyses were done by importing data tables from Zoonotic Disease Tracker into SAS (version 9.1, SAS Institute, Cary, NC). Data from Chicago's O'Hare International Airport were excluded because the airport mosquito trap located closest to a Chicago residential area was 2.56 km away and the evaluation criteria used in deciding whether to initiate adulticide treatments within the airport boundaries differed from that in use for residential areas within the city.

We calculated a vector index (VI) for each trap location for each week; the VI provides an estimate of the number of WNV-infected female *Culex* mosquitoes collected from the trap on a given night (Gujral et al. 2007). To arrive at the VI, we

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used the formula described by Nasci et al. (2005).

$$\mathrm{VI} = \sum_{i=\mathrm{species}} \bar{N}_i \hat{P}_i$$

The average density ($\bar{N}$) of each species of female *Culex* mosquitoes was defined as the number of female *Culex* of the species collected from the trap during the week divided by the number of trap collections each week. The estimated infection rate ($\hat{P}$) was defined as the number of female *Culex* mosquito pools from the trap during the week that tested positive divided by the total number of mosquitoes in those pools.

After calculating the VI for each trap-week, the process of estimating and mapping the VI for the city's census tracts involved the following steps in ArcMap software (Version 9.3, Environmental Systems Research Institute, Redlands, CA).

1. We created a circular buffer with a radius of 1.2 km around each trap. This radius represented an estimate of the maximum distance a female *Culex* could be expected to travel in the period of interest in order to reach the trap (Tsuda et al. 2008).
2. We assigned values to each buffer area and converted these areas to raster files: For buffers that overlapped, we calculated the mean VI of the buffers and assigned that value to the overlapping area; for a buffer that did not overlap others, the area was given the VI of the trap around which the buffer was drawn.
3. Using the raster files, we calculated the mean VI value of each census tract, allocated that value to the census tract, and classified it for purposes of visualization using the following scale: no data, 0, <0.5, 0.5 −1, >1.
4. For areas displaying relatively high VI values that were considered candidates for treatment, additional layers were added to the map, such as rivers, highways, and industrial areas. These features assisted officials in delineating exact boundaries of the proposed treatment area, maximizing coverage in residential areas rather than nonresidential areas, and designing routes for the spray trucks to follow.

Given the historical finding that *Culex* female density and WNV positivity in Chicago has sometimes fluctuated significantly from one week to the next, combined with an interest in recognizing persistent or sustained risk, officials opted to review graphical representations of WNV activity covering a 2-wk period in addition to that pertaining to the 1-wk period. To generate the 2-wk outputs, the entire analysis described above was repeated, but VIs were calculated based on the preceding 2 consecutive weeks' data.

During June–September 2008, we sampled 76 unique gravid trap locations. The median number of gravid trap locations sampled per week was 61 (range, 52–69). Through 2,118 trap-nights, these traps yielded 21,193 female *Culex* mosquitoes, which were classified as *Cx. restuans* Theobald, 2,366 (11%); *Cx. pipiens* Linnaeus, 894 (4%); *Cx. pipiens*/*Cx. restuans*, 17,841 (84%); *Cx. territans* Walker, 60 (<1%); *Cx. tarsalis* Coquillett, 21 (<1%); and *Cx. salinarius* Coquillett, 11 (<1%). Eighty-two (4%) of 1,905 mosquito pools (ranging in size from 1 to 50 mosquitoes) tested positive for WNV by RT-PCR. Thirty-seven (49%) of the trap locations yielded at least 1 female *Culex* mosquito pool positive for WNV. Four human cases of WNV disease were reported among Chicago residents, all of whom experienced illness onset in September. One crow, collected in September, tested positive for WNV; a total of 10 dead wild birds were tested during this period.

Chicago residential census tracts range in area from approximately 0.02 km^2 to 21 km^2 (median, 0.5) and in population density from <1 per km^2 to 36,099 per km^2 (median, 5,962) (US Census Bureau 2001, City of Chicago 2005). During June 29–September 13, a median of 527 (60%) of 874 possible census tracts per week had a value for VI obtained (range, 489–548). Overall, 94% of the weekly VI estimates attributed to these census tracts were 0; among those with a VI estimate greater than 0, the median was 0.33 (range 0.003–3.5). For the 2-wk analyses, the median number of tracts for which a value for VI was obtained pertaining to a 2-wk period was again 527 (range, 525–550). Eighty-nine percent of the VI estimates attributed to census tracts for the 2-wk periods were 0; among those with a VI estimate greater than 0, the median was 0.2 (range 0.004–3.0).

Figure 1 displays the weekly mosquito density and infection results, and VI estimate maps for June 29–September 13. No mosquito pools collected from traps in weeks 38 and 39 (September 14–27) were positive for WNV. At the beginning of each week, officials met to review and discuss the graphical representation of the data from the preceding 1-wk and 2-wk periods upon which they were based. In this meeting consensus was sought regarding enhanced entomological surveillance (i.e., where to place additional traps), initiation of door-to-door risk communication campaigns, and evaluation of catch-basin larvicide applications. Moreover, at this time it was also decided whether, when, and where adulticide treatments would take place during the coming week. This decision was based primarily upon the level of human risk in different areas suggested by the mapped VI values and underlying geographies, including residential population density. Also considered were the cost and benefit of adulticide treatments, given the rain and temperature forecasts for the coming week and their implications for *Culex* mosquito activity.

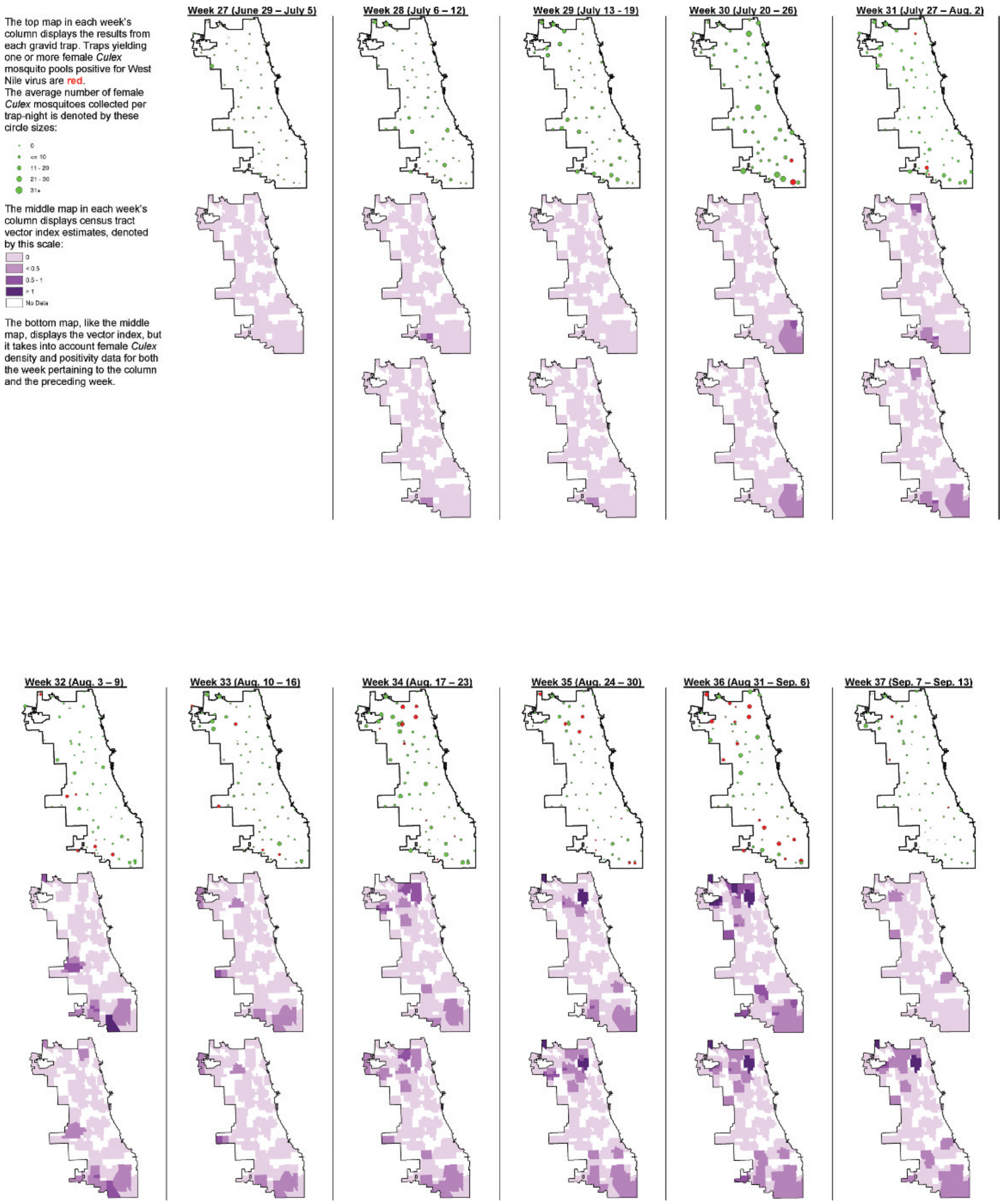

Fig. 1. Weekly female *Culex* mosquito density, West Nile virus positivity, and vector index estimations by census tract for 1- and 2-wk periods in Chicago, June 29–September 13, 2008.

Officials deemed human risk levels and weather conditions appropriate for ultra-low volume insecticide spaying in residential areas on 3 occasions (Fig. 2). On the 14th of August, 127 km of streets and alleys were treated in an 11.6 km^2 area (Fig. 2B); on the 21st of August, 39 km of streets and alleys in a 3.6 km^2 area were treated (Fig. 2C); and on the 28th of August, 86 km of streets and alleys in a 8.1 km^2 area were treated (Fig. 2D).

While formally testing hypotheses regarding the spatiotemporal associations between VI values and other indications of WNV activity (e.g., bird deaths, human cases), ecological attributes, or

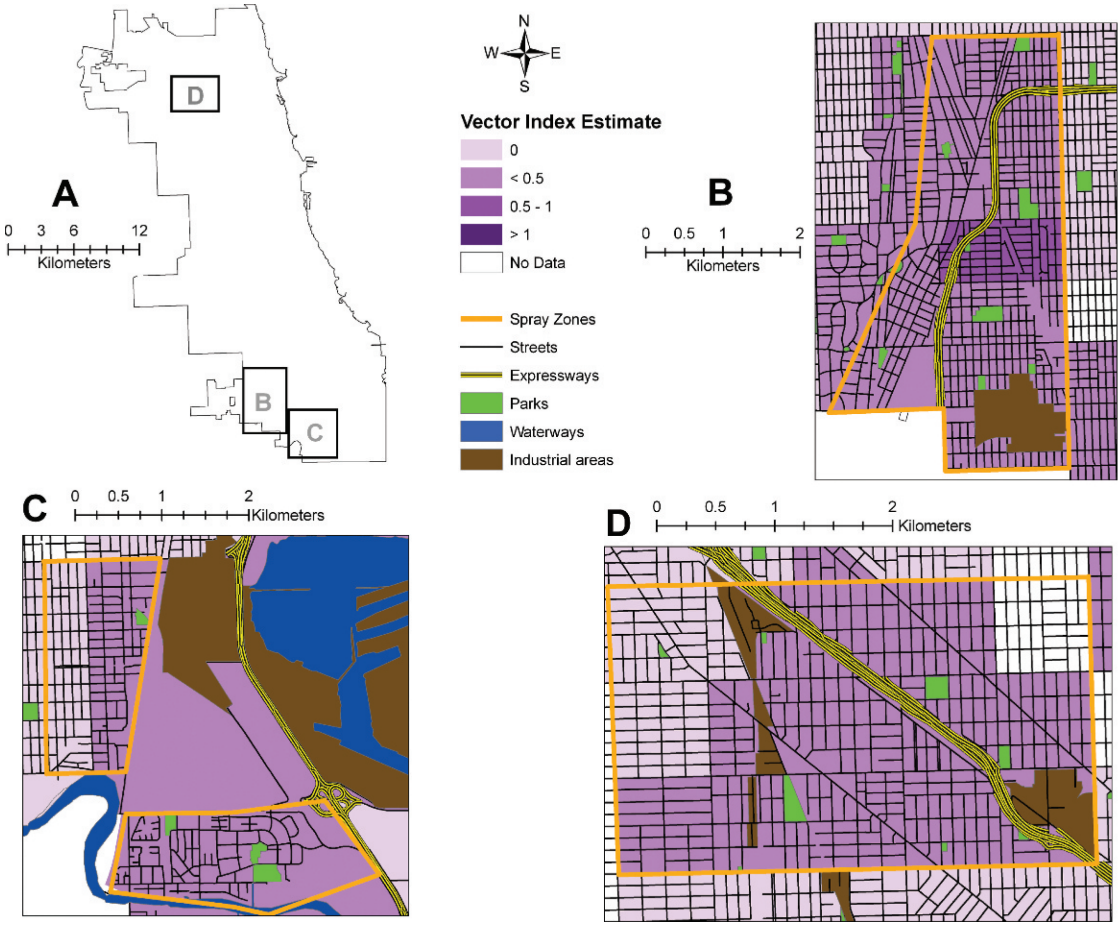

Fig. 2. (A) Chicago areas targeted for ultra-low volume insecticide spaying on (B) August 14, (C) August 21, and (D) August 28, 2008. The vector index values displayed pertain to the 2-wk period that preceded the week of adulticide treatment (i.e., [A] July 27–August 9, [B] August 3–16, and [C] August 10–23).

climate factors are beyond the scope of this report, the method we described could also be applied to research questions related to these associations. Weekly VI values at the county level have been positively associated with the incidence of human cases in the subsequent week (Gujral et al. 2007), but our methodology does not prescribe a formula or threshold for control measures. A predictive model that prospectively incorporates weekly tract-level VI estimates, population density, local weather forecasts, and financial and logistical limitations could validate and ultimately standardize the decision-making process that public health officials take on in the midst of the WNV transmission season. This would incorporate the work of Tachiiri et al. (2006) and Ruiz et al. (2010) while ensuring accessibility and usability for prospective, real-time response at the local level.

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