When Was West Nile Virus in Contra Costa County? Tracking the 'Hot Zone'

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ABSTRACT: Evidence of West Nile virus (WNV) transmission in Contra Costa County during the 2006 season was detected almost exclusively during periods when the overnight low temperatures stayed at or above 55^0 F. This is close to the developmental threshold of 57.7^0 F identified by Reisen et al. Minimum infection rates in *Culex* species and numbers of positive dead birds peaked during a heat wave in late July and early August, which also coincided with the onset of human cases and sentinel chicken seroconversions. Transmission peaked earlier in the season in the eastern part of the county where average temperatures were somewhat higher. Differences in the spatial and temporal patterns of WNV activity in 2005 and 2006 appear to be associated with microclimate variation.

INTRODUCTION

Since temperature is an important determinant of both mosquito developmental rates and the extrinsic incubation period of West Nile virus (WNV) (Reisen et al. 2006), microclimate may play a significant role in both the geographic and temporal incidence of WNV activity. Contra Costa County's proximity to the San Francisco Bay creates a large microclimate variation across a fairly small geographic span, with eastern inland areas as much as 20^0 F warmer than western coastal areas during July and August, dividing the county roughly into three distinct microclimate regions (Fig. 1). During 2005, the first year in which we saw significant levels of West Nile virus transmission, the majority of human and equine cases occurred in the warmer eastern region of the county. Although the numbers of dead bird reports to the statewide WNV hotline were higher in the more densely populated central area of the county, we found that the incidence of reports per capita was also higher in the east (Schutz et al. 2006). We hypothesized that these differences in intensity of transmission were related to higher summer temperatures in the inland areas of the County.

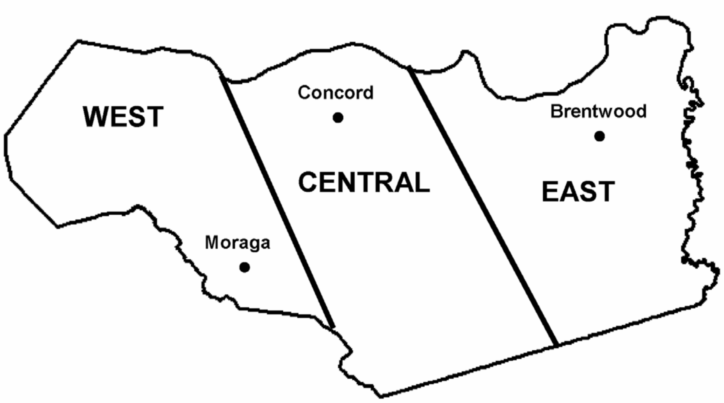

Figure 1. Outline of Contra Costa County showing major microclimate regions

Our objective in the present study was to compare the spatial and temporal distribution of WNV activity in Contra Costa County in 2006 with the distribution observed in 2005, and determine whether any differences could be attributed to changes in microclimate.

MATERIALS AND METHODS

Information on the dates and locations of dead bird and squirrel reports were compiled and reported to us weekly by the staff of the California Department of Health Services West Nile Virus hotline. A subset (approximately 10%) of the dead birds and squirrels reported to the hotline were collected by District personnel and either tested for WNV in-house using the RAMP® rapid test (in the case of corvids), submitted to the California Animal Health and Food Safety Laboratory for necropsy and PCR testing (all other birds), or both (all squirrels and RAMP negative corvids). Mosquitoes for virus testing were collected in dry-ice baited EVS traps; between 40 and 90 of these traps were set weekly at a combination of fixed and non-fixed locations. Pooled mosquitoes from fixed trap locations were submitted to the UC Davis Center for Vectorborne Disease for PCR testing, while samples from non-fixed locations were tested in-house using the RAMP® test. As mosquito populations and workload permitted, we tested a combined total of approximately 20-30 pools per week during the height of the WNV transmission season (July through October). Minimum infection rates by species and week were calculated using the bias-corrected maximum likelihood method (Biggerstaff 2006). Sentinel chicken serum samples were collected biweekly from five flocks of ten chickens each and tested at the CDHS Viral and Rickettsial Disease Laboratory in Richmond, CA. Information on the location of human cases was provided by the Contra Costa County Department of Health Services, and equine case locations by the California Department of Food and Agriculture. Locations of all positive surveillance indicators were mapped with ArcGis® 9.2 (ESRI 2006).

Average monthly high and low temperatures for representative cities from each of three regions of Contra Costa County (Moraga, Concord and Brentwood, representing west, central and east county respectively) were obtained from the California Irrigation

Management Information System (CIMIS) (California Department of Water Resources 2005). Monthly climate maps from the Western Regional Climate Center California Climate Data Archive (2005) were used to identify specific microclimate zones within the county.

RESULTS

The numbers of positive West Nile virus indicators were fairly similar in 2005 and 2006, with the exception of a higher overall minimum infection rate (MIR) in mosquitoes tested in 2006 and a lower number of equine cases (Table 1). However, despite the similarity in numbers, examination of the geographic distribution of virus activity during the two seasons revealed some important differences. In 2005, the majority of human and equine cases and positive mosquito pools occurred in the eastern part of the county (Fig. 2a), whereas in 2006 they were concentrated in the central area (Fig. 2b). The highest density of positive dead birds and squirrels occurred in the central area in both years; however, as the authors have previously noted (Schutz et al. 2006), this is at least in part due to higher human population density in the central county corridor, and hence a higher likelihood of dead birds being reported and submitted for testing.

Although the first indication of WNV transmission in both years was a positive dead bird reported on 29 June, the temporal distribution of virus activity was clearly different. In 2005, the numbers of positive birds reported per week increased gradually, peaking the week of August 19^{th} (Fig. 3a), while in 2006 the increase was much steeper and the peak occurred two weeks earlier (Fig. 3b). In both years, WNV activity commenced and increased as weekly average low temperatures (measured at the district office, located in Concord) exceeded 55^0 F and decreased as low temperatures dropped back below 55^0F. In 2005, low temperatures increased and decreased gradually over the course of the summer, peaking in mid-July and staying below 60^0F. However, there was a pronounced heat wave in late July and early August 2006 where average low temperatures increased sharply and stayed high for several weeks. This coincided with very sharp and almost immediate increases in MIR in *Culex tarsalis* Coquillett and *Cx. pipiens* L., sentinel chicken seroconversions, positive dead birds, and the first onset of human cases. As the heat wave subsided and overnight low temperatures declined, positive surveillance indicators declined as well. In both seasons, we saw little or no evidence of transmission once overnight low temperatures remained below 55^0F, although in 2005 we did continue to sporadically find WNV-positive dead birds until mid-November.

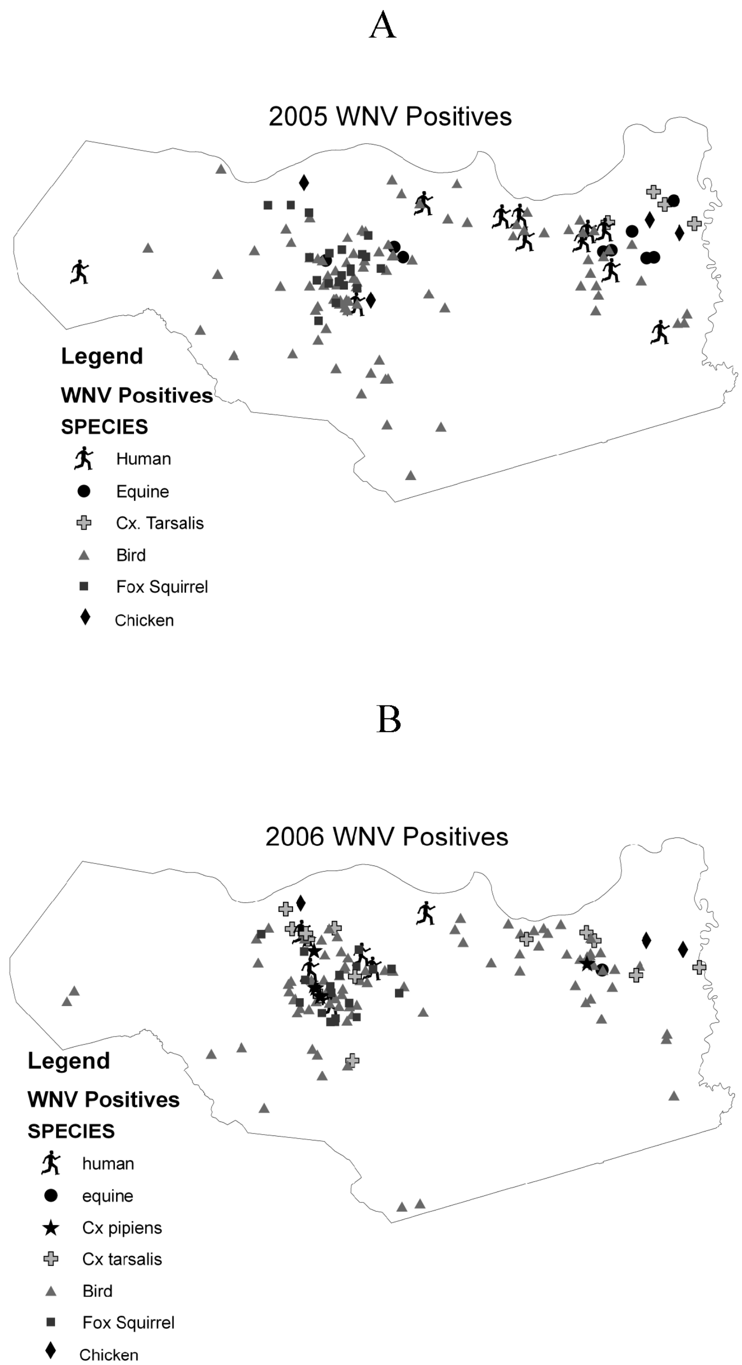

Figure 2. Map of Contra Costa County showing locations of positive West Nile virus indicators in 2005 (a) and 2006 (b).

Table 1. Numbers of WNV positive indicators reported in Contra Costa County in 2005 and 2006. Numbers in parentheses are percent positive of total tested. * indicates county-wide average minimum infection rate (bias-corrected maximum likelihood estimate) per 1,000.

	Dead birds	Squirrels	Mosquito pools	Sentinel chickens	Human	Equine
2006	**92 (24%)**	**19 (46%)**	**20 (0.44*)**	**24 (48%)**	**8**	**1**
2005	**94 (18%)**	**25 (58%)**	**4 (0.14*)**	**18 (36%)**	**11**	**10**

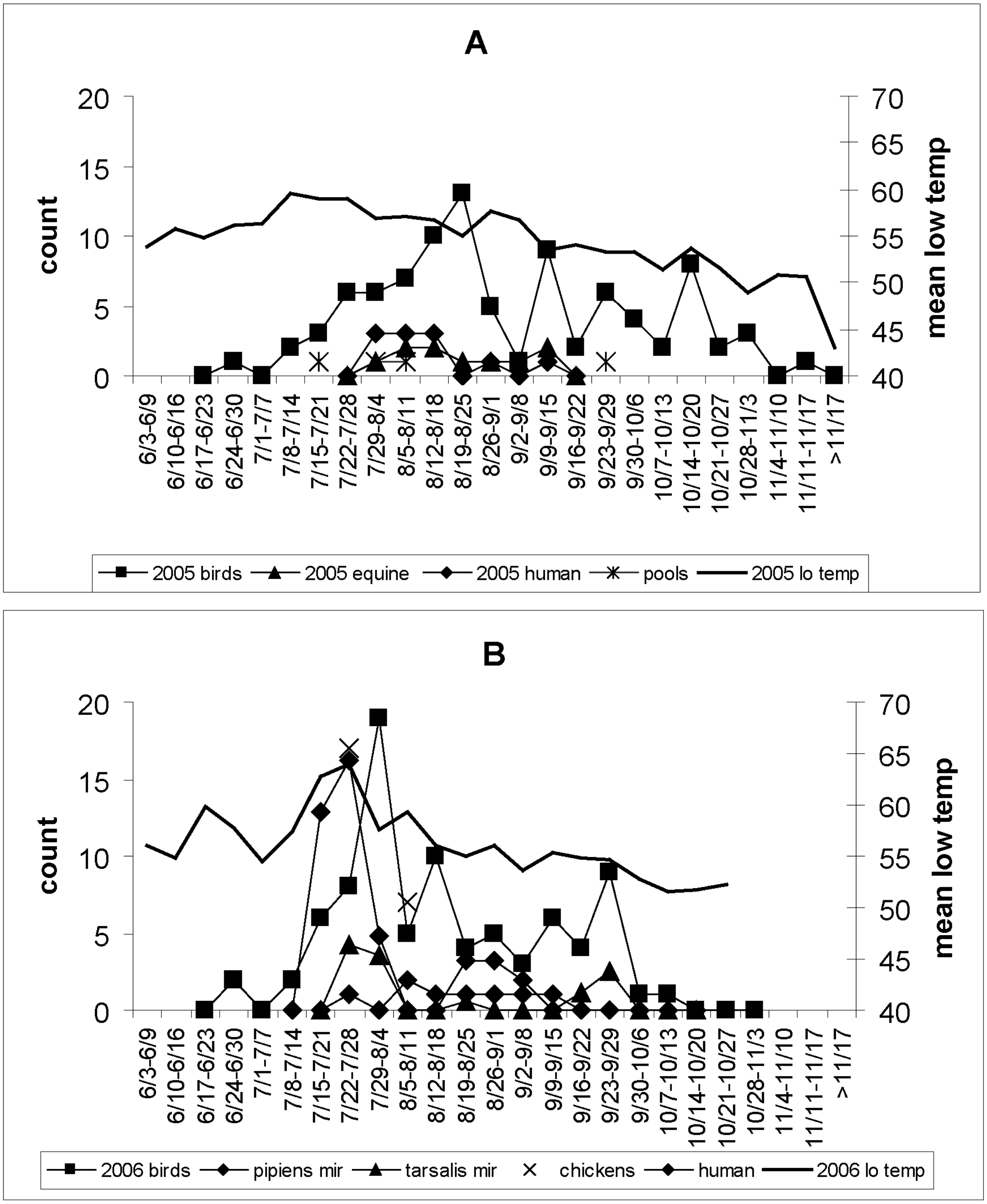

Figure 3. West Nile virus positive indicators (left y axis) and average low temperature (right y axis) by week in 2005 (a) and 2006 (b). Note that sentinel chicken seroconversions were back-dated to probable infection date (estimated as one week prior to blood collection date). Human and equine cases are reported dates of onset. Weekly minimum mosquito infection rates were not calculated for 2005 due to the low number of positive pools (4).

Since it appeared that microclimate was associated with the observed differences in temporal distribution of WNV activity, we also examined its role in spatial distribution by plotting weekly totals dead bird reports and average monthly low temperatures for each of our three microclimate regions (weekly temperature data were not available for all three regions). In 2005, overnight low temperatures were highest in east county, slightly lower in central county, and considerably lower in west county from May through August. In September, however, this pattern changed and central county was warmest (Fig. 4a). An examination of weekly dead bird report totals showed that counts for east and central county ran roughly parallel until September, when they dropped off sharply in east county while declining more gradually in central county. Activity in west county remained very low throughout the season (Fig. 4b). In contrast, during 2006 the 'reversal' in east and central county low temperatures occurred a month earlier and this was concurrent with decreased dead bird reports in east county and an increase in reports from central county (Fig. 5a,b). In both years, average monthly low temperatures barely exceeded 55^0F in west county and we had few dead bird reports or positive indicators of transmission in that region. Linear regression of monthly dead bird report totals vs. monthly average low temperatures for each of the three regions (Fig. 6) showed a strong correlation (r^2= 0.38, p<0.001).

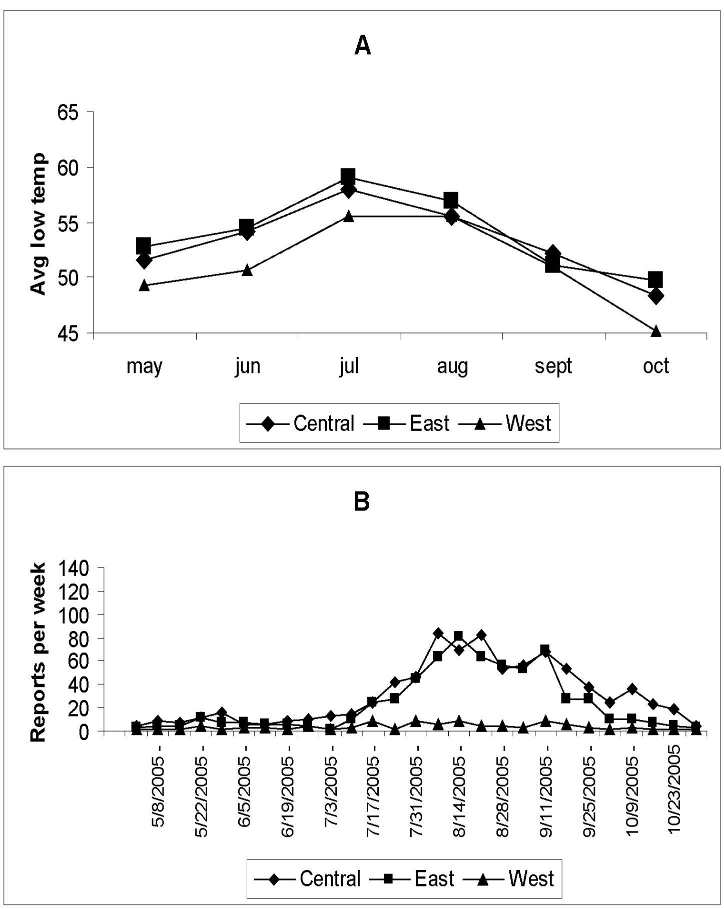

Figure 4. Average monthly minimum temperatures (a) and weekly dead bird report totals (b) for three microclimate regions of Contra Costa County in 2005.

DISCUSSION

Based on our observations during two years of high WNV activity, it appears that microclimate variation can explain both spatial and temporal differences in patterns of virus transmission within Contra Costa County. Specifically, overnight low temperatures above approximately 55^0F appear to trigger and maintain WNV transmission. This temperature is very close to the viral developmental threshold of 57.7^0 F reported by Reisen et al. (2006). Temperatures remaining above this threshold for extended periods may cause significant increases in viral load in vector mosquitoes, driving up transmission rates and 'jump starting' the transmission cycle. A cursory examination of statewide WNV incidence and average low temperatures, as well as discussions with other vector ecologists (T. Su, S. Bearden, pers. comm.) suggest that microclimate may explain larger scale patterns as well.

The authors recognize that this study is largely observational and that factors other than microclimate, such as ongoing mosquito control operations, may also have affected WNV transmission rates. Also, the lack of availability of weekly or daily temperature data from all three microclimate regions of the County made thorough comparisons or statistical analyses difficult. However, the observed patterns do appear to be consistent with observations being made independently by other investigators. We believe that

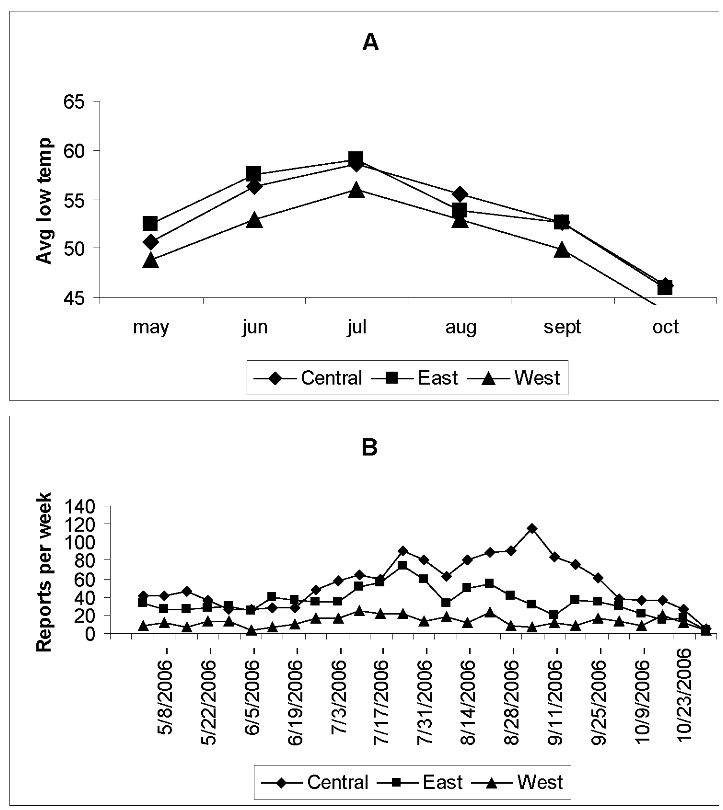

Figure 5. Average monthly minimum temperatures (a) and weekly dead bird report totals (b) for three microclimate regions of Contra Costa County in 2006.

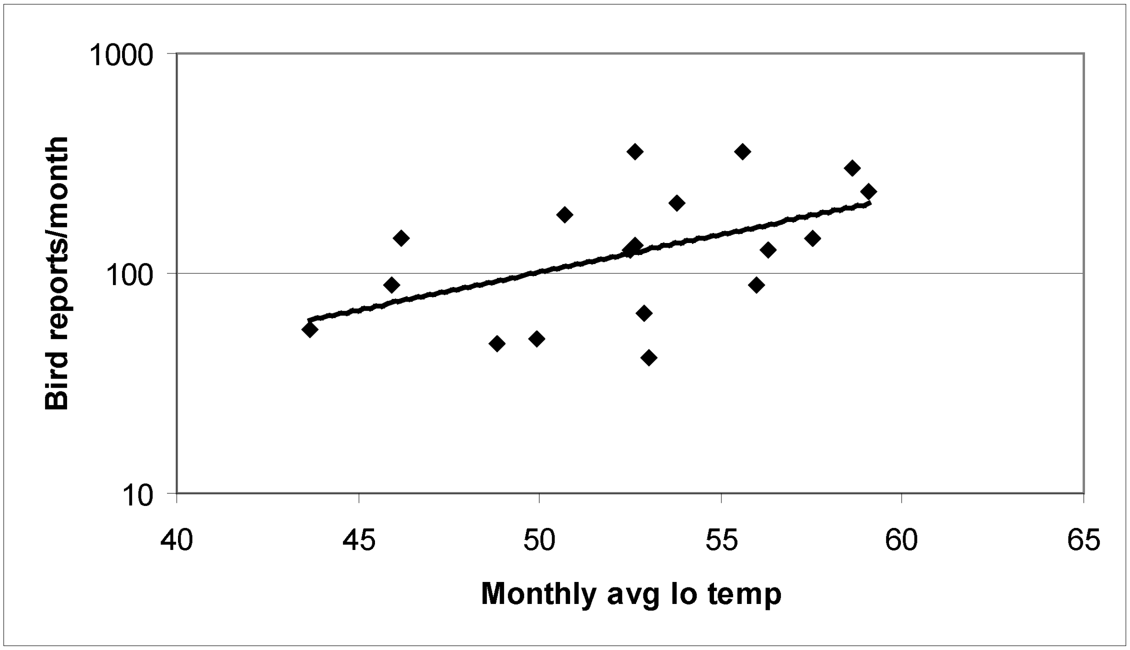

Figure 6. Log (monthly dead bird report totals) vs. average monthly minimum temperatures) for three microclimate regions of Contra Costa County in 2006.

microclimate is a strong determinant of WNV transmission, possibly an important determinant of human case risk, and should be incorporated into existing risk-assessment models to provide both increased spatial and temporal resolution.

Acknowledgments

We wish to acknowledge the staff of the West Nile virus hotline for quickly and efficiently compiling and transmitting dead bird report information, CDFA and Contra Costa Health Services for providing information on equine and human cases, the UC Davis Center for Vectorborne Disease for testing dead birds and mosquito pools and the DHS Viral and Rickettsial Disease laboratory for testing sentinel chicken serum samples. We are also grateful to our dedicated crew of vector control inspectors, technicians and aides for helping to expand and enhance our surveillance program.

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