Ecological Factors Influencing the Distribution and Transmission of West Nile Virus in Orange County, California

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Although several studies suggest a close relationship between climatic and biological variables and the emergence and proliferation of infectious diseases, there is little evidence demonstrating the exact relationship between these variables and vector, primary, and secondary host populations of specific viruses. The Center for Tropical Research received a grant from the Orange County Vector Control Division to study the spatial and temporal patterns of West Nile virus in mosquito, avian, and human hosts and to determine how these patterns change with ecological conditions in Orange County, California. West Nile virus is one of many flaviviruses that occur in North America, but it has only recently been introduced to this part of the world. The first reported appearance of this virus was in New York in 1999; since then, it has spread rapidly across North America (Figure 1). California has experienced a dramatic spike in West Nile virus cases in 2008, with a total of 236 human cases reported as of September 23 by the Centers for Disease Control and Prevention (http://www.cdc.gov/ncidod/dvbid/westnile).

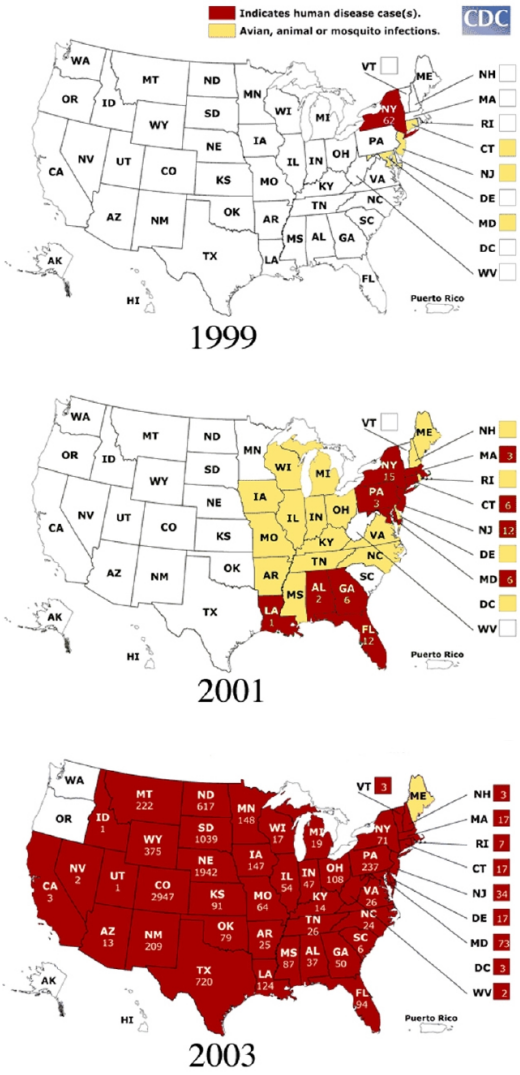

Figure 1. The rapid spread of West Nile virus in the United States during a five-year period, 1999-2003. Maps adapted from CDC website.

West Nile virus must have a vector to transmit to a host, and in Southern California this vector is the Southern House Mosquito, *Culex quinquefasciatus*. Typically, birds are thought to be the primary hosts of this mosquito (and the West Nile virus they carry), and several studies have demonstrated that bird populations can be severely impacted by West Nile virus carried by mosquitoes. Mammals (including humans), on the other hand, are traditionally thought of as secondary hosts. In fact, several researchers have found that there may be host switching that occurs in late summer. As migratory birds leave in the fall, mammals become the “next best thing” for hungry mosquitoes (Figure 2).

By documenting the occurrence of a widespread, recently introduced virus in vector and host populations, and mapping the presence and prevalence of this disease using the most recent and advanced remote sensing and bioclimatic data, I attempted to determine the environmental correlates of West Nile virus infection across Orange County, California. Vector and host populations may play different roles in the spread of a virus during a given season, and assessing the role that both vector and avian hosts have on the transmission of West Nile virus has provided us with a better understanding of how infection spreads to a variety of incidental mammalian hosts, including humans.

The main goals of this study on West Nile virus were to:

1. Assemble multi-year data collected from the Orange County Vector Control Division on the spatial and temporal patterns of West Nile virus mosquito, avian, and human populations.

2. Determine the environmental correlates of infection using bioclimatic and remote sensing data.

3. Explore the effects of anthropogenic stressors on West Nile virus and evaluate their impact on human health.

I used data collected in 2004-2008 by the Orange County Vector Control Division, documenting incidences of mosquito, avian, and human cases of West Nile virus with exact locations where

samples were collected. In addition, I used several environmental variables, such as temperature, precipitation, and amount of vegetation, to capture the ecological conditions at specific locations within the county.

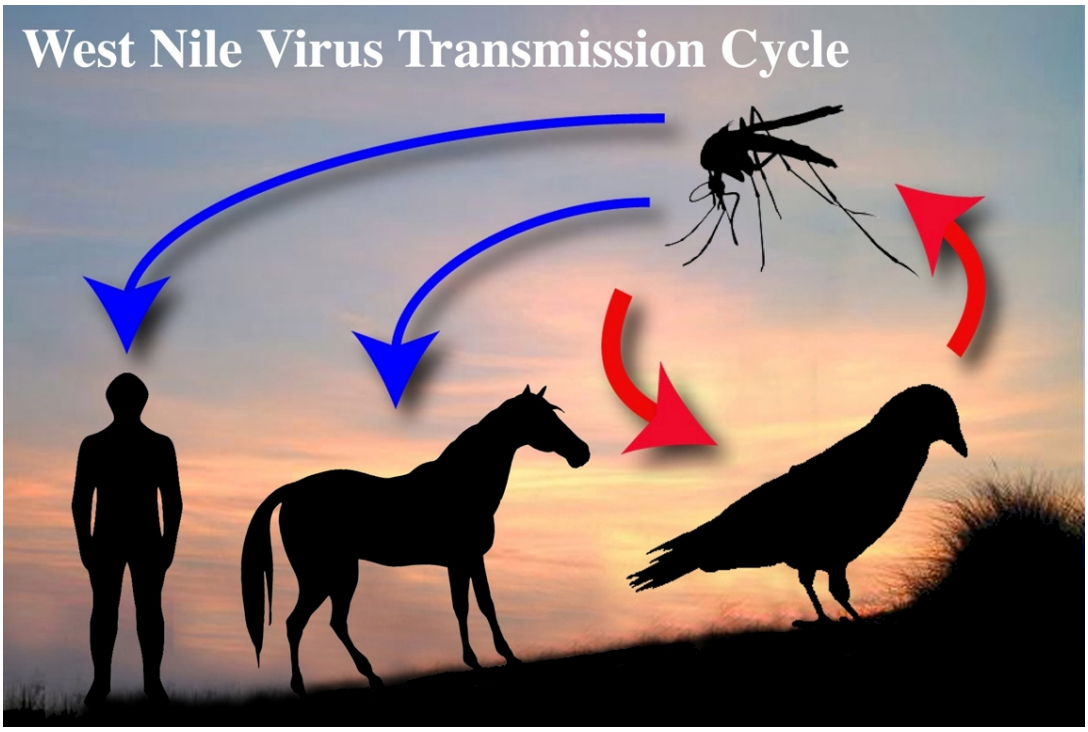

Figure 2. The traditional cycle of West Nile virus in vector and host species. Mosquitoes are the only vector of West Nile virus, but which species of mosquito depends on geographic location. Birds act as the primary host of the virus (red arrows), and mammals, including humans, may act as incidental hosts that are unlikely to spread the virus (blue arrows).

My analyses have found that a strong positive relationship exists between West Nile virus-positive mosquitoes, wild birds, and humans within any single month; in other words, as soon as mosquitoes become infected with West Nile virus, bird and human host populations are immediately at risk. In fact, of all variables examined, these mosquito pools are the best predictors of West Nile virus in humans for a given month. This is a very different result compared to previous studies that suggested that humans and other mammals were not necessarily at risk until later summer months as birds left for migration (Figure 2). In terms of bird species at risk, the impact of West Nile virus on avian populations in this area is still being investigated, but many species in Orange County have been found to carry high prevalence of West Nile virus (Figure 3).

While several environmental variables were investigated, it was precipitation in the previous winter months that best predicted the numbers of West Nile virus positives in the following summer. It is hypothesized that a rainy winter may facilitate the extent to which mosquitoes may survive and reproduce; more mosquitoes may lead to higher West Nile virus prevalence in the following summer months.

Spatial analyses have revealed that much of the valley area in Orange County may serve as good places for West Nile virus to persist. This is in part due to the fact that these valleys (primarily the Santa Ana and Saddleback Valleys) are consistently warm, highly urbanized (with ample man-made water sources such as canals, drainage, and ponds), and highly populated with both primary (bird) and secondary (humans) populations. Recently, Kern County, California has attributed its spike in West Nile virus cases to foreclosed homes that have left abandoned and unchlorinated swimming pools. These artificial pools may act as excellent breeding grounds for mosquitoes.

I am still evaluating the socioeconomic factors that may contribute to the spread of this relatively new disease in Southern California, but my analysis and findings can now serve the Orange County Vector Control Division with a valuable source of baseline data for further monitoring, research, and management.

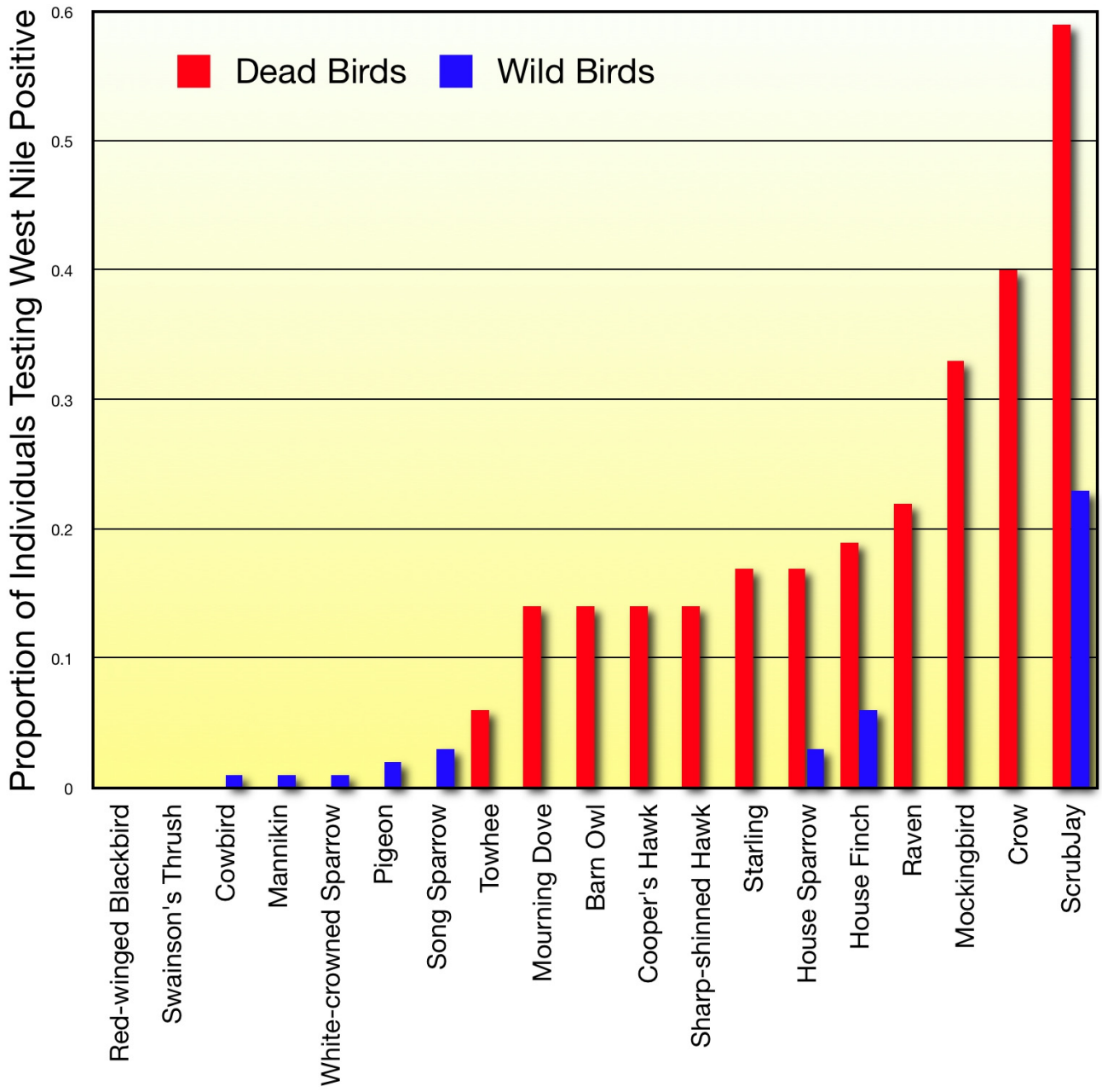

Figure 3. Species of birds that have been found to carry West Nile virus and the proportion of individuals that were positive for years 2004-2008 in Orange County, California. Bars in blue indicate dead birds that were recovered in the field or that citizens reported to Orange County Vector Control. Bars in red indicate those birds that were captured and then released back into the wild. Note the large proportion of positives observed in members of the corvid family (Crows, Scrubjays, Ravens).