Continuing Impacts of West Nile Virus on Birds of California's Central Valley

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ABSTRACT

West Nile virus activity has continued in California's Central Valley since the first outbreaks in 2004 and 2005 and, based on rates of human infections, activity increased again in 2012. I used data from Central Valley Christmas Bird Counts and reports of human cases of West Nile virus infection to look for correlations between virus activity and bird abundance from 2004 through 2016. Declines in Yellow-billed Magpie (*Pica nattali*) observations were strongly correlated with the number of human infections. Magpie numbers declined to nearly half their pre-West Nile levels in the winter following the summer (2005) with the highest number of human infections and remained relatively stable through the winter of 2011-12. Following the increase in virus activity in 2012, magpie numbers declined steadily through 2016. During the years of stable Yellow -billed Magpie numbers, numbers of human cases were also stable with annual cases at around one-seventh of the peak in 2005. California Scrub-Jay (*Aphelocoma californica)* and American Crow (*Corvus brachyrhynchos)* numbers were also correlated with virus activity, but, correlations were weaker suggesting apparent impact of the 2012 outbreak was less than for the magpie. The Oak Titmouse (*Baeolophus inornatus)* appeared relatively unaffected by the new outbreak. These observations are consistent with the hypothesis that a significant subset of the Central Valley's scrub-jays, crows, and titmice have developed resistance to West Nile virus, while resistance has yet to develop in Yellow-billed Magpies.

INTRODUCTION

Declines in Yellow-billed Magpie (*Pica nuttalli*) numbers following the first outbreaks of West Nile virus (WNV) in the Central Valley (CV) and elsewhere in California in 2004-05 have been well-documented (Airola et al. 2007, Koenig et al. 2007, Pandolfino 2007, Crosbie et al. 2008, Pandolfino 2008a, Wheeler et al. 2009, Smallwood and Nakamoto 2009). As of 2010, numbers had shown no signs of recovery (Pandolfino 2013). Declines in populations of the California Scrub-Jay (*Aphelocoma californica*), American Crow (*Corvus* *brachyrhynchos*), and Oak Titmouse (*Baeolophus inornatus*) were also documented following the 2005 outbreak (Airola et al. 2007, Smallwood and Nakamoto 2009). However, these three species showed evidence of recovery after 2005 (Pandolfino 2008b, 2009, 2010).

Data from the summer of 2012 revealed an increase in the number of infected birds and human infection cases (Center for Disease Control [CDC] 2012, Foss et al. 2015), which prompted me to examine Christmas Bird Count (CBC) data to determine if this increased level of virus activity had affected CV magpies or other species. Crosbie et al. (2008) found little evidence of immunity among the magpies that survived the 2004-05 virus outbreaks, raising the possibility that continued exposure to WNV could result in further population declines or continued population depression (Wheeler et al. 2009, Ernest et al. 2010, Pandolfino 2013). These results suggest the possibility that, while WNV-resistance may have developed in populations of the scrub-jay, crow, and titmouse, no resistance may exist among the magpies. By examining abundance changes during the recent resurgence of the virus I hoped to test this hypothesis.

METHODS

I obtained CBC data from National Audubon Society (2010) and data on WNV infections from the California Department of Public Health (http://westnile.ca.gov/). I used data from the 17 CV CBC circles that reported data consistently during the period covered by my analyses (Figure 1). Of those 17 CBCs, only the Red Bluff count failed to report data for each year, (i.e. 2006-07 through 2009-2010). All CBC data were normalized for relative effort using the number of birds observed per party hour for each circle. I used the total number WNV human infection cases reported from the following counties: Butte, Colusa, Fresno, Glenn, Kern, Kings, Madera, Merced, Placer, Sacramento, Shasta, Solano, Stanislaus, Sutter, Tehama, Tulare, Yolo, and Yuba.

The number of human WNV cases used is the total for each calendar year, with nearly all of those cases occurring during summer months. The yearly bird species abundance from CBC data is based on the numbers from the following winter.

I used Pearson correlation coefficient (r) to determine strength of associations between virus activity and bird numbers. The number of human infection cases in a given year was the effect and the change in bird abundance from CV CBCs from the previous year was the response variable. Correlations were considered significant when the probability of non-correlation was <5% ($p < 0.05$). I used the period starting with the year of first human cases, 2004, through 2016 for these analyses. I tested correlations for the four species that have been shown to be WNV-sensitive (Yellow-billed Magpie, California Scrub-Jay, American Crow, and Oak Titmouse) as well as 10 species known to be resistant to WNV. The resistant species were selected based on the risk assessment (lowest risk) of Wheeler et al. (2009) as well as their presence in the CV year-round.

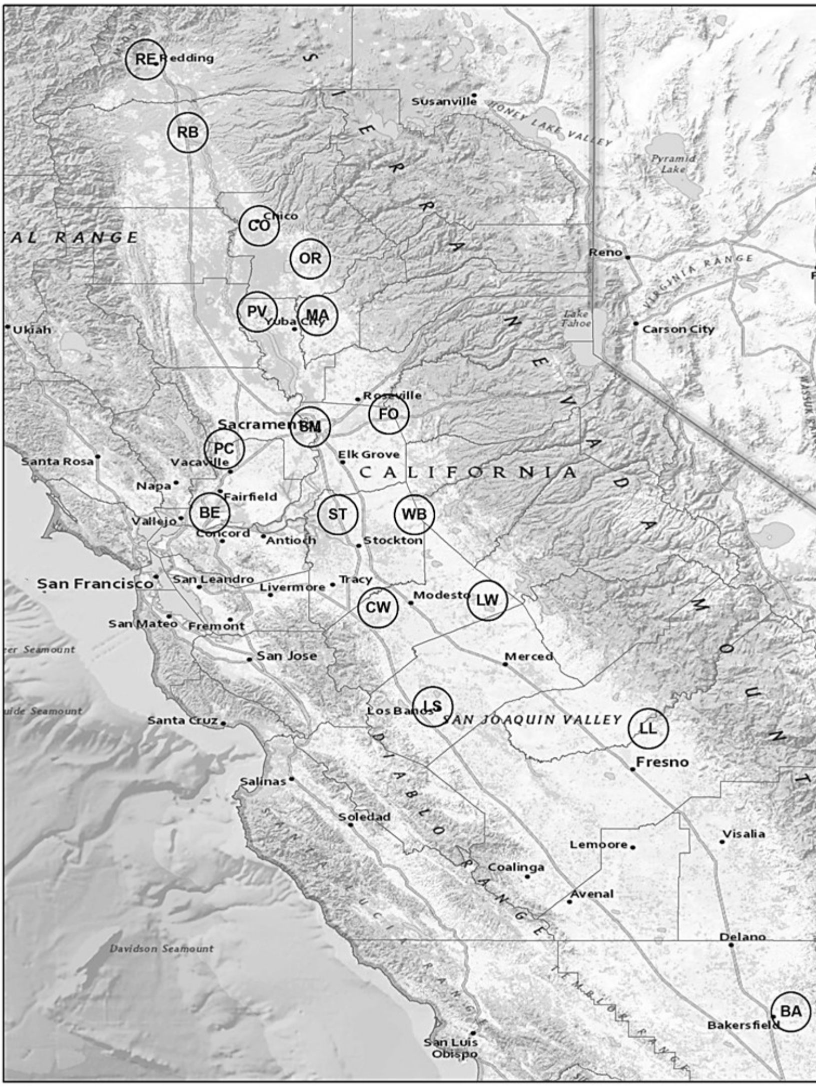

Figure 1. Location of the 17 Christmas Bird Count circles in the Central Valley, California, used for analyses. From north to south they are: RE = Redding; RB = Red Bluff; CO = Chico; OR = Oroville; PV = Peace Valley; MA = Marysville; FO = Folsom; SM = Sacramento; PC = Putah Creek; BE = Benicia; ST = Stockton; WB = Wallace-Bellota; CW = Caswell-Westley; LW = LaGrange-Waterford; LS = Los Banos; LL = Lost Lake; BA = Bakersfield.

RESULTS

Abundance of the Yellow-billed Magpie based on CBC data from 2000-16 (Figure 2) shows the previously documented decreases following the 2005 WNV peak, relatively steady numbers at lower abundance from 2006-11, and renewed declines coincident with the resurgence of WNV infections in 2012. California Scrub-Jay numbers (Figure 3) showed a sharp decline in 2005, followed by a rapid recovery, with much less dramatic declines starting in 2012. Abundance data for the American Crow (Figure 4) suggest declines pre-dating WNV, continuing with some fluctuation through 2007, with rebounding numbers during 2008-2011, and additional declines beginning in 2012. The pattern for the Oak Titmouse (Figure 5) showed the declines of 2004-05 rapidly reversed and relatively steady numbers through 2016. Comparing average abundance during the lowest period of WNV activity (2008-2011) to the period of renewed activity (2012-16) showed that magpie abundance declined by 45%, scrub-jay by 7%, crow by 35%, and titmouse by 11%. Interpreting these data for the American Crow may be more difficult as the CV wintering population may consist of significant numbers of birds breeding elsewhere (Verbeek and Caffrey 2002).

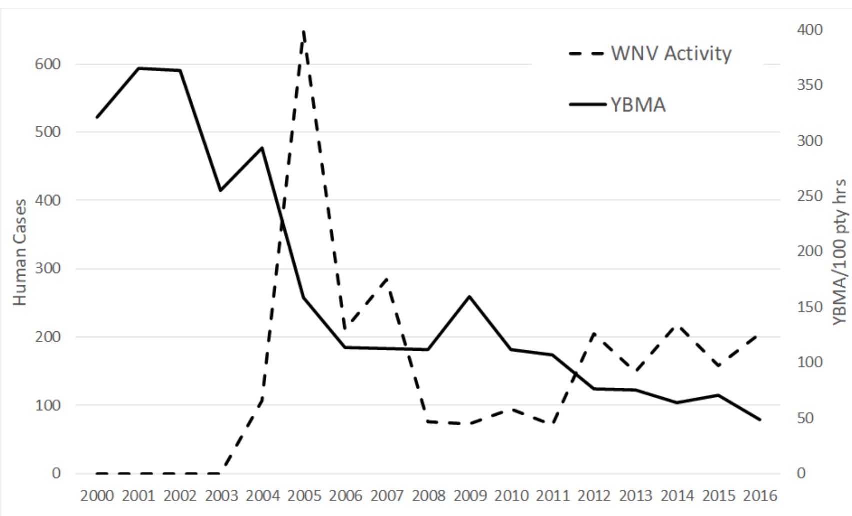

Figure 2. Yellow-billed Magpie (YBMA) abundance (birds/100 party hours) from CBC data and total human cases of WNV reported in the Central Valley counties for that calendar year. For CBC data, the years correspond to the winter at the end of each calendar year (e.g. 2005 is the winter of 2005-06).

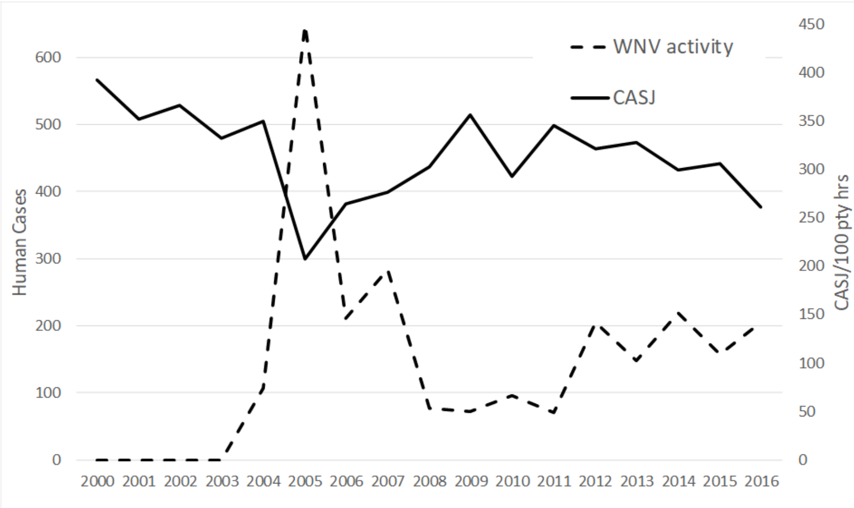

Figure 3. California Scrub-Jay (CSJA) abundance (birds/100 party hours) from CBC data and total human cases of WNV reported in the Central Valley counties for that calendar year. For CBC data, the years correspond to the winter at the end of each calendar year (e.g. 2005 is the winter of 2005-06).

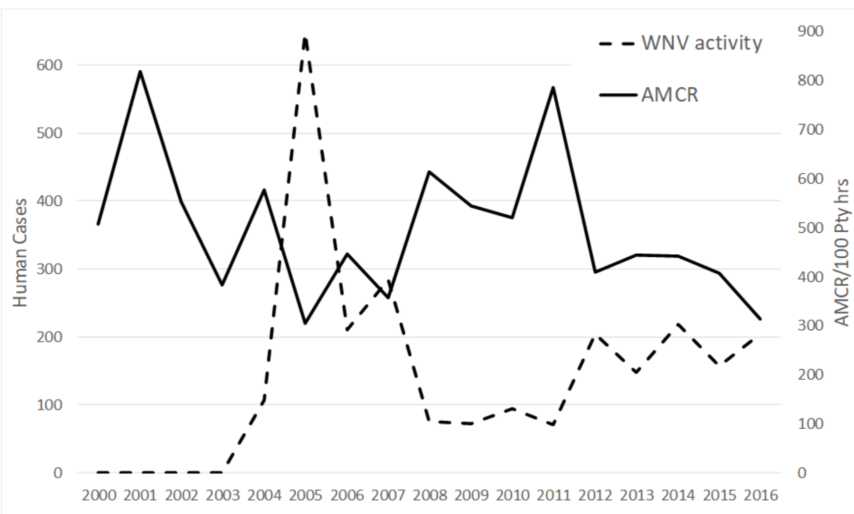

Figure 4. American Crow (AMCR) abundance (birds/100 party hours) from CBC data and total human cases of WNV reported in the Central Valley counties for that calendar year. For CBC data, the years correspond to the winter at the end of each calendar year (e.g. 2005 is the winter of 2005-06).

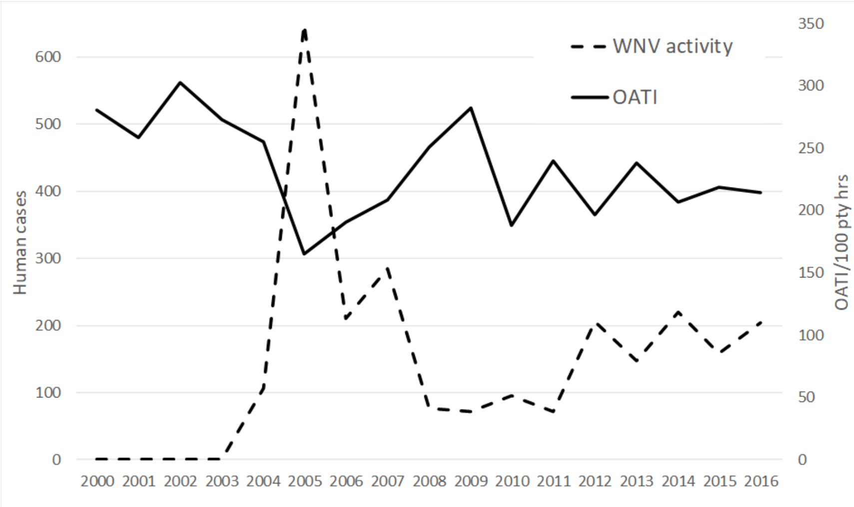

Figure 5. Oak Titmouse (OATI) abundance (birds/100 party hours) from CBC data and total human cases of WNV reported in the Central Valley counties for that calendar year. For CBC data, the years correspond to the winter at the end of each calendar year (e.g. 2005 is the winter of 2005-06).

Table 1 shows the correlations between the numbers of WNV human infections in CV counties and year-to-year declines in the CBC abundance for the four WNV-sensitive species and the 10 WNV-resistant species. Only the magpie, scrub-jay, and crow showed significant correlations, with the magpie showing the strongest correlation and the crow the weakest. Correlation for the Oak Titmouse approached significance. None of the 10 WNV-resistant species showed significant correlations with WNV activity, and only the Nuttall's Woodpecker approached significance.

DISCUSSION

The fact that some WNV-sensitive species were able to recover following the initial outbreak in the CV, in spite of the continued (though lower) level of virus activity, suggests that a significant subset of those species may have survived exposure and developed (or are developing) immunity. In contrast, the Yellow-billed Magpie did not appear to recover to pre-WNV numbers. Further, the observation that the species that recovered after 2005 also declined less than the magpie after the 2012 resurgence also indicates a relative dearth of resistant individuals within the magpie population. All of this, coupled with the observation of Crosbie et al. (2008) that very few magpies showed immunity after 2005, and the rapid onset of mortality following infection inferred by Ernest et al. (2010), supports the hypothesis that the Yellow-billed Magpie has yet to develop a significant WNV-resistant

Table 1. Correlations (r) and statistical significance (p) between bird species abundances and human cases of West Nile virus for species considered sensitive to and resistant to the virus. Significant negative correlations (indicating significant population declines when human cases were more abundant) are shown in **bold.**

WNV-Sensitive Species	**Scientific name**	**r**	**p**
Yellow-billed Magpie	*Pica nuttalli*	**-0.81**	**<0.001**
California Scrub-Jay	*Aphelocoma californica*	**-0.74**	**<0.01**
American Crow	*Corvus brachyrhynchos*	**-0.58**	**<0.04**
Oak Titmouse	*Baeolophus inornatus*	**-0.53**	**0.07**
WNV-Resistant Species	**Scientific name**	**r**	**p**
California Quail	*Callipepla californica*	-0.17	0.57
Rock Pigeon	*Columba livia*	-0.12	0.70
Mourning Dove	*Zenaida macroura*	0.30	0.31
Anna's Hummingbird	*Calypte anna*	-0.15	0.61
Nuttall's Woodpecker	*Picoides nuttallii*	-0.50	0.08
Black Phoebe	*Sayornis nigricans*	0.03	0.91
European Starling	*Sturnus vulgaris*	0.01	0.98
American Goldfinch	*Spinus tristis*	-0.22	0.48
Song Sparrow	*Melospiza melodia*	0.25	0.41
Red-winged Blackbird	*Agelaius phoeniceus*	0.28	0.35

population. Therefore, ongoing activity of the virus is likely to continue to produce declines in the magpie population, or, at minimum, hold the population below pre-WNV levels. This hypothesis could be further tested by trapping and assessing large numbers of WNV-sensitive species to see if they show the presence of anti-WNV antibodies.

This lack of a resistance in the magpie population could be a result of the extremely high mortality rate among the magpies (Ernest et al. 2010), such that very few, if any, birds are surviving exposure. Alternatively, it is possible that this species displays immune tolerance to WNV (i.e., an inability of an organism to mount any immune response to a given antigen; Benacerraf and

Unanue 1979). In that case, even if some birds survive infection, they are still sensitive to re-infection upon subsequent exposure to the virus. In any case, the survival of a viable population of this California endemic rests on the hope that the very strong selective pressure of this virus will enable a WNV-resistant population to ultimately develop. The fact that a substantial amount of good quality habitat for this species remains (Pandolfino 2013) is also reason for some optimism.

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Vermilion Flycatcher
(Pyeocephalus rubinus)
1 January 2017
Maxwell Cemetery,
Colusa Co.

Photo © Chris Conard