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West Nile Virus Activity in Kern County and the Factors Leading to the 2007 Outbreak

Brian Carroll[1], **Richard Takahashi**[2], and **William Reisen**[3]

[1]Arbovirus Field Station, Center for Vectorborne Diseases, School of Veterinary Medicine, 4705 Allen Rd, Bakersfield, CA 93314

[2]Kern Mosquito and Vector Control District, 4705 Allen Rd, Bakersfield, CA 93314

[3]Center for Vectorborne Diseases, School of Veterinary Medicine, University of California, Davis, CA 95616

Abstract

West Nile virus (WNV) reappeared in Kern County in late-May 2007, amplified rapidly and was detected concurrently by all surveillance methods. Enzootic activity during 2007 had some similarities to that of the previous three years, with 77 seropositive sentinel chickens in 9 flocks, 207 positive mosquito pools, 124 dead birds that tested positive, and 168 seropositive wild birds. WNV disease in equines remained infrequent, with only 4 cases reported. In contrast, Kern County had a significant increase in human disease, with 138 laboratory confirmed fever and neuroinvasive cases, combined incidence = 17.8 per 100,000 population. The standard surveillance indicators, sentinel chickens and mosquito pools, indicated that WNV enzootic activity was on the decline, yet there were epidemic numbers of human cases. During this fourth year of virus activity, WNV was found throughout Kern County on the floor of the Central Valley.

INTRODUCTION

West Nile virus (WNV) activity in California began in 2003 and was limited to six counties south of the Tehachapi Mountains (Hom et al. 2004). By June 2004 WNV activity had spread north of the Tehachapi Mountain range and into the Bakersfield area of Kern County in the southern San Joaquin Valley (Takahashi et al. 2005). WNV quickly spread from there and by the end of the year was detected in every county of the state (Hom et al. 2005). During 2005 WNV activity was focused primarily within the city of Bakersfield (Carroll et al. 2006), while activity in 2006 was widespread throughout Kern County on the valley floor (Carroll et al. 2007). The current paper discusses the reappearance of WNV in Kern County in 2007 and describes detection by various surveillance methods, its spread through the county, differences between 2007 and the previous three years, and factors that possibly led to the human epidemic.

Address correspondence: William K. Reisen, Center for Vectorborne Diseases, University of California, Old Davis Rd, Davis, CA 95616, Ph: 530-752-0124, Fax: 530-754-6360, Email: arbo123@pacbell.net.

MATERIALS AND METHODS

Background

Surveillance information was gathered by multiple agencies including five separate mosquito control agencies, the Kern County Department of Public Health, Edwards Air Force Base and the Arbovirus Field Station (AFS) of University of California, Davis (UCD). All of the data presented in this report were collected within the boundaries of the Kern Mosquito and Vector Control District (KMVCD), the largest district in the county covering 1,650 square miles. Other districts include the Delano Mosquito Abatement District, South Fork Mosquito Abatement District, West Side MVCD, and Antelope Valley MVCD. Sampling locations are shown in Fig. 1.

Dead Birds

Dead birds were reported by the public to the CDHS-VBDS hotline who forwarded pertinent information to the KMVCD for bird pickup. Birds were submitted to the California Animal Health and Food Safety (CAHFS) Central Laboratory at UCD for necropsy. Oral swabs and/or kidney tissue were sent to the UCD Center for Vector-borne Diseases (CVEC) laboratory for testing by reverse transcriptase-polymerase chain reaction (RT-PCR).

Mosquitoes

Mosquitoes were collected biweekly by dry ice baited CDC traps (Sudia and Chamberlain 1962) and by Reiter/Cummings gravid traps (Cummings 1992). Collections were identified by species and pooled into groups of ≤50 females each and then tested for viral RNA by CVEC using a multiplex RT-PCR that detects WNV as well as St Louis encephalitis (SLEV) and western equine encephalomyelitis (WEEV) viruses (Chiles et al. 2004).

Chickens

Sera were collected biweekly from 10 hens within each of 9 flocks within the KMVCD. Individual blood samples were collected on strips of filter paper and then sent to California Department of Public Health (CDPH) Viral and Rickettsial Disease Laboratory (VRDL) for testing for IgG antibody by an indirect enzyme immunoassay (EIA) (Reisen et al. 1994). Positives were confirmed by indirect fluorescent antibody (IFA) and end-point plaque reduction neutralization tests (PRNT).

Free Ranging Birds

Birds were collected biweekly using mist nets and grain baited traps, banded and a blood sample taken (0.1 ml into 0.9 ml saline). Samples were clarified by centrifugation and then screened for antibody by an EIA (Chiles and Reisen 1998), with positives confirmed and identified by PRNT. Sera confirmed as positive, but without a 4X difference between WNV and SLEV end point titers were listed as unidentified Flavivirus.

Humans and Equines

Human and equine case information was provided by the Kern County Department of Public Health and by the California West Nile Virus Surveillance Information Center.

RESULTS

WNV was initially detected in a dead American Crow collected on May 25th. Within the next two weeks virus activity also was detected by positive mosquito pools, seroconverted sentinel chickens and additional dead birds. This activity was localized around the city of Bakersfield. By the end of June virus activity had begun to move out of the city and by the end of the season was active in all of the surrounding communities.

In 2007, 124 out of 332 dead birds tested positive for WNV (Table 2). The most frequently reported bird was for the first time not the American Crow, but the House sparrow. Ninety-three of the 124 positives were represented by four species of birds, House Sparrows (28), American Crows (26), Western Scrub-Jays (23), and House Finches (16). Since the dead bird program relies on the public to find and report the dead birds, most of the dead birds were found in metropolitan Bakersfield. A sparse human population and large numbers of scavengers most likely reduced the effectiveness of the dead bird program in rural areas.

From March through early November 2008, 6,111 *Aedes melanimon* Dyar, 21,240 *Culex quinquefasciatus* Say, and 15,298 *Culex tarsalis* Coquillett mosquitoes from Kern MVCD were tested for virus infection in 1,264 pools, of which 207 were positive for WNV. Only one *Ae. melanimon* pool tested positive and we felt that this species did not play a significant role in virus maintenance or amplification. *Culex quinquefasciatus* and *Cx tarsalis* were the major vectors for WNV transmission activity in 2007 (Table 1). Infection rates per 1,000 (MIRs/1000) for *Cx quinquefasciatus* and *Cx tarsalis* exceeded the epidemic threshold of 5.0 during June in Bakersfield, and stayed above this threshold until August. Epidemic levels were not attained until July in the southeast and August in the northwest parts of Kern County. Epidemic levels dropped below the epidemic threshold in September in Bakersfield and the Southeast and October in the northwest.

A total of 77 chickens from 9 flocks seroconverted to WNV during the 2007 surveillance season (Table 2). The first chicken infections occurred before 11 June, with 2 chickens from one flock within Bakersfield confirmed. By the end of the season WNV had spread throughout all 9 flocks generating 75 additional seroconversions. July and August had the most seroconversions with 28 and 21, while September and October had significantly fewer with 15 and 11, respectively. This reduction in seroconversions was attributed to the lack of availability of replacement chickens.

The free-ranging bird seroprevalence program detected 164 EIA positives during 2007 that were represented by 5 species of birds (Table 3). There were 4 additional positives among the other 33 species tested. Positivity rates of the five main species ranged from 4% to 57%. As expected the five species that were infected most frequently were year round residents.

Only four confirmed positive WNV equine cases were detected, with two fatalities. All four of these cases were in the metropolitan Bakersfield area. This decrease in positive cases most likely was due to increases in planned as well as natural immunization of the equine population in Kern County.

Overall, 139 laboratory confirmed human cases were reported, with four fatalities. One hundred thirteen of these cases were located in or around the metropolitan Bakersfield Area. The rest were located in small agrarian communities on the valley floor (Table 2).

DISCUSSION

Surveillance indicators detected virus activity at approximately the same time throughout the Bakersfield area in late May and early June. All indicators not only increased throughout the summer, but spread to the outlying areas of the floor of the central valley of Kern County. Indicators continued to detect virus activity throughout the summer, finally subsiding in late September. There were a few chickens and one mosquito pool that tested positive in early October, but these most likely were infected in late September.

There were some distinct differences in WNV activity in 2007 compared to 2004 – 2006. In 2004 WNV activity started in the southeastern corner of the valley, moved into Bakersfield and then to the west side of the valley. In 2005 WNV activity appeared first within the city of Bakersfield and then spread outward, finally affecting every surveillance site across the valley floor. In 2006 there was one early positive and then a six week period of negative activity, before activity began increasing. During 2007 virus transmission was intense and amplification rapid. There were no gaps as in 2006 and activity spread very quickly, unlike 2004 and 2005. Within a 4 week period in 2007, WNV was detected across the entire valley portion of Kern County. While the virus was active in all areas of Kern County, transmission was most intense within the greater Bakersfield area.

Overall, mosquito infection and sentinel chicken seroconversion rates were similar to previous virus years (Table 4); however, carefully examining the timing and distribution of these data during 2007 indicated important differences. Warm spring temperatures led to elevated mosquito infection rates within Bakersfield during June that was followed closely by human cases that rose to epidemic levels by July. The number of free ranging bird positives may have declined, but a closer look reveals that 13.5 % of the overall birds tested in 2007 had seroconverted, compared to 20% in 2006. This can be partly attributed to the 70% decrease in birds tested. We feel that this decrease in birds tested is related to not only the increased virus activity and the natural increased mortality that comes with it, but on the natural fluctuations in the bird populations. Significant decreases in bird populations may increased the risk of tangential transmission to humans. In agreement, the number of human cases in Kern County increased 175% compared to 2006, with 138 cases with 4 fatalities, placing the county in at an epidemic status with an overall incidence of 17.8 per 100,000 population. Virus activity slowed in late September and finally subsided in October, when *Cx. tarsalis* entered diapause (Bellamy and Reeves 1963, Nelson 1964).

We feel that there were two significant factors that helped drive increases in *Culex tarsalis* and *Cx. quinquefasciatus* population abundance and virus activity. The first of these was the natural fluctuation in the environmental conditions of precipitation, temperature, and river flow. In 2007 Kern County had 2.5 inches of rain, about 40% of the average, and was in drought conditions. There were two periods of moderately heavy precipitation, one in late February and early March, and again in late April and early May, which left large amounts

of surface water as breeding sources for *Cx. tarsalis* just prior to the normal transmission season. Kern County also had a considerable number of days with temperatures that were well above average from February through July. This early period of above average temperatures may have expedited the development of the F1 generation of the *Cx. tarsalis* as well as the overwintering *Cx. quinquefasciatus* larvae. This expedited development combined with the abundance of untreated breeding sources led to a higher mosquito abundance at the beginning of transmission season. The main source of water in Bakersfield other than rainfall is the Kern River, whose source is in the Sierra Nevadas. With the lack of a plentiful snow pack the previous winter, the river through Bakersfield and to the SW portion of the valley remained completely dry throughout the entire year. As the earlier mentioned untreated breeding sources dried up, it combined with the lack of river water to minimize the amount of sources for the production of *Cx. tarsalis*.

A second significant factor was the drastic rise in foreclosed homes in the Bakersfield area. From April to September of 2007 there were 2,080 homes foreclosed in the Bakersfield area, compared to 91 for the same time period in 2006. This increase of over 2,000% left many abandoned swimming pools turning ‘green’ during the transmission season. We feel that the lack of natural breeding sources and the abundance of “green” pools created ideal conditions for the expansion of *Cx. quinquefasciatus* within the urban area. These increases prompted Kern MVCD to perform aerial surveys to identify “green” pools in August. They also accepted the publics help in reporting “green” pools. The KMVCD treated 809 pools in 2007 compared to 398 in 2006, indicating that with the aerial survey and the public complaints were able to identify many more “green” pools in 2007 that needed treatment.

In summary, enzootic activity was detected by all surveillance methods in all areas within Kern County during 2007. There were some unique conditions, both natural and man made that led to an increase of mosquito abundance and virus transmission. It will be interesting to see where WNV will reemerge during 2008 and whether or not the predictions of another long hot summer and the continued rise in foreclosure rates continue to have a significant impact on the virus cycle and create another epidemic year.

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REFERENCES CITED

Bellamy RE, Reeves WC. The winter biology of Culex tarsalis (Diptera:Culicidae) in Kern County, California. Ann. Entomol. Soc. Am. 1963; 56:314–323.

Carroll B, Takahashi R, Barker C, Reisen WK. The Reappearance of West Nile Virus in Kern County During 2005. Proc. & Papers Mosq. Vector Control Assoc. Calif. 2006; 74:12–15.

Carroll B, Takahashi R, Reisen WK. West Nile Virus Activity in Kern County during 2006. Proc. & Papers Mosq. Vector Control Assoc. Calif. 2007; 75:15–20.

Chiles RE, Green EN, Fang Y, Reisen WK, Edman JD, Brault AC. Surveillance for arboviruses in California mosquito pools: Current and future protocols. Proc. & Papers Mosq. Vector Control Assoc. Calif. 2004; 72:15–17.

Chiles RE, Reisen WK. A new enzyme immunoassay to detect antibodies to arboviruses in the blood of wild birds. J. Vector Ecol. 1998; 23:123–135. [PubMed: 9879069]

Cummings RF. Design and use of a modified Reiter gravid mosquito trap for mosquito-borne encephalitis surveillance in Los Angeles County, California. Proc.& Papers Mosq. Vector Control Assoc. Calif. 1992; 60:170–176.

Hom A, Houchin A, McCaughey K, Kramer VL, Chiles RE, Reisen WK, Tu E, Glaser C, Cossen C, Baylis E, Eldridge BF, Sun B, Padgett K, Woods L, Marcus L, Hui LT, Castro M, Husted S. Surveillance for msoquito-borne encephalitis activity and human disease, including West Nile virus in California, 2003. Proc.& Papers Mosq. Vector Control Assoc. Calif. 2004; 72:48–54.

Hom A, Marcus L, Kramer VL, Cahoon B, Glaser C, Cossen C, Baylis E, Jean C, Tu E, Eldridge BF, Carney R, Padgett K, Sun B, Reisen WK, Woods L, Husted S. Surveillance for mosquito-borne encephalitis virus activity and human disease, including West Nile virus, in California, 2004. Proc.& Papers Mosq. Vector Control Assoc. Calif. 2005; 73:66–77.

Nelson RL. Parity in winter populations of Culex tarsalis Coquillett in Kern County, California. Am. J. Hyg. 1964; 80:242–253. [PubMed: 14215835]

Reisen WK, Presser SB, Lin J, Enge B, Hardy JL, Emmons RW. Viremia and serological responses in adult chickens infected with western equine encephalomyelitis and St. Louis encephalitis viruses. J. Am. Mosq. Control Assoc. 1994; 10:549–555. [PubMed: 7707063]

Sudia WD, Chamberlain RW. Battery-operated light trap, an improved model. Mosq. News. 1962; 22:126–129.

Takahashi RM, Reisen WK, Barker CM. Invasion of Kern County by West Nile virus. Proc.& Papers Mosq. Vector Control Assoc. Calif. 2005; 73:20–23.

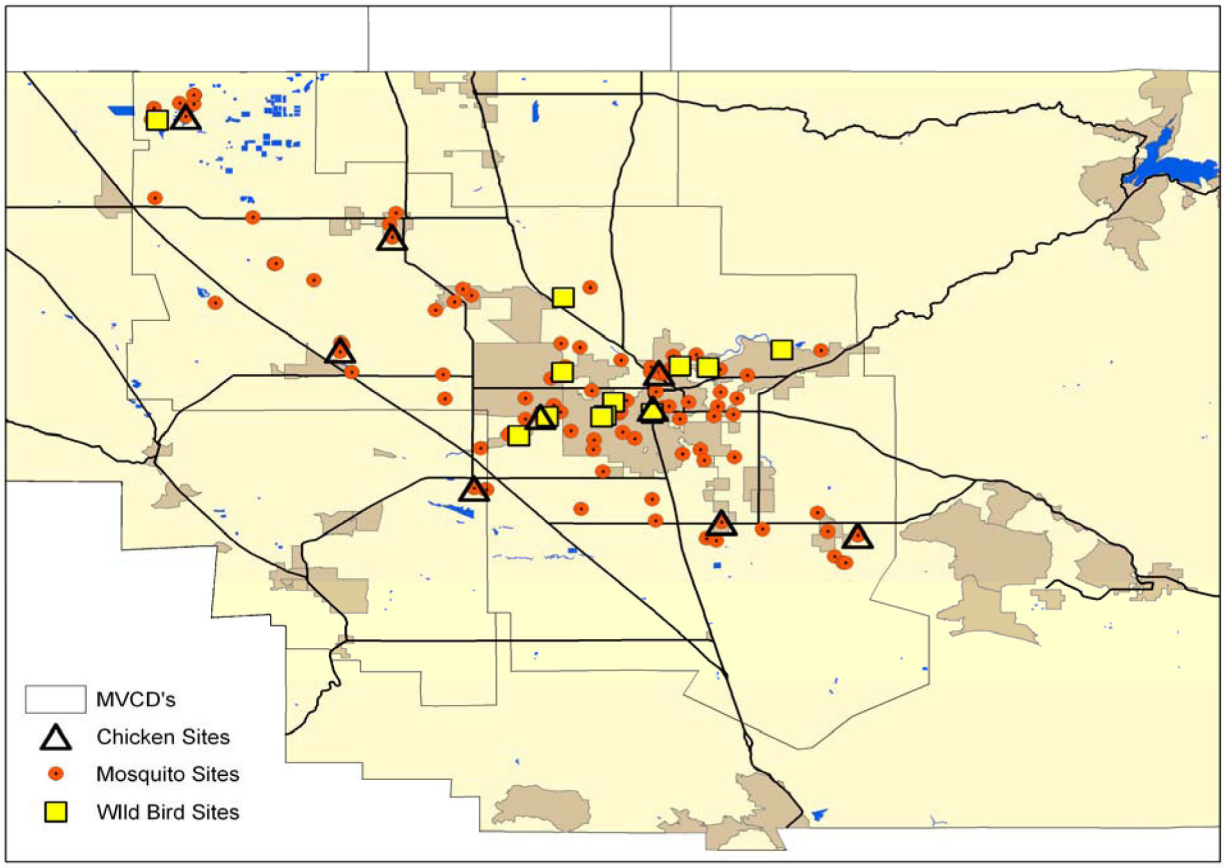

Figure 1.
Surveillance sites in Kern County 2007.

Table 1

Mosquito infection rates (MIR) in Kern County, 2007.

Species	Pools	Total Tested	WNV Positive	MIR/1000
Aedes melanimon	137	6,111	1	.2
Culex quinquefasciatus	693	21,240	140	6.6
Culex tarsalis	409	15,298	65	4.2
Total	1,264	43,649	206	4.7

Table 2

Summary of positive surveillance results by cities within Kern County, 2007.

City	Mosquitoes (Pos pools)	Chickens (Seroconversions)	Dead Birds pos. for WNV	Equine WNV cases	Human WNV cases	Free Ranging Birds (number seropositive)
Arvin	30	20	0	0	6	0
Bakersfield	158	33	115	4	113	167
Buttonwillow	5	6	1	0	2	0
Delano	0	0	2	0	0	0
Fellows	0	0	1	0	0	0
Frazier Park	0	0	0	0	1	0
Lamont	5	0	0	0	8	0
Lake Isabella	0	0	1	0	0	0
Lost Hills	4	9	0	0	0	1
McFarland	0	0	0	0	1	0
Shafter	3	0	0	0	3	0
Taft	0	0	1	0	0	0
Tehachapi	0	0	1	0	0	0
Wasco	2	9	0	0	4	0
Weldon	0	0	1	0	0	0
Wofford Heights	0	0	1	0	0	0
Totals	206	77	124	4	138	168

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Table 3

Species of free ranging birds testing positive for Flavivirus, Kern County, 2007.

Species	# Tested	# Positive	Percent Positive
California Quail (Resident)	57	23	43.5
House Finch (Resident)	182	40	20.9
House Sparrow (Resident)	311	20	4.1
Mourning Dove (Semi-Resident)	204	69	39.3
Western Scrub Jay (Resident)	27	12	57.3
Others (33 Species)	385	4	2.0
Totals	864	168	21.7

Table 4

Number of Surveillance measures positive for WNV in Kern County, 2004–2008.

		2004	2005	2006	2007
Positive Human Cases		60	68	50	138
Positive Equine Cases		47	26	4	4
Positive Sentinel Chicken Seroconversions		101	121	89	77
Dead Birds	Tested	159	240	118	332
	Positive	87	44	24	124
Mosquito Pools	Tested	1367	1596	1868	1264
	Positive	214	235	217	207
Free Ranging Birds	Tested	3400	3476	4036	1242
	EIA positive	157	412	811	168

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