West Nile Review: 15 Years of Human Disease in South Dakota, 2002-2016

By Lon Kightlinger, MSPH, PhD

Abstract

During the past 15 years, 2002-2016, West Nile virus (WNV) has emerged in South Dakota resulting in 509 neuroinvasive disease (NID) cases, 745 hospitalizations and 38 deaths. *Culex tarsalis* is the state's primary mosquito vector. South Dakota's average annual incidence of WNV-NID and death rate are the highest of any state in the U.S. WNV cases have been reported from all counties in the state. All age groups have been infected with cases peaking in the 40-44 year age group, but deaths peaking in cases 70 years and older. Although South Dakota's WNV season lasts six months, May-October, the first week of August has been the peak week of WNV disease onsets. West Nile is now enzootic in South Dakota. Every citizen, local mosquito control programs, medical and public health infrastructures must continue to prevent and respond to annual WNV outbreaks, and prepare for the next arboviral disease to emerge.

In 2002 an African arbovirus emerged in South Dakota. During the subsequent 15 years, 2,359 South Dakotans have been reported with West Nile disease, including 745 hospitalized and 38 deaths. There have also been 206 donated blood units discarded due to contamination with West Nile virus (WNV) in South Dakota. Assumedly, tens of thousands of other unreported South Dakotans have also been infected.

WNV is a mosquito-borne flavivirus first described in Uganda, East Africa, in 1937.[1] Sixty-two years later the virus was first detected in the Western Hemisphere during the summer of 1999 in New York.[2] During the next three years, WNV swarmed across North America, reaching South Dakota in 2002. South Dakota's first WNV detection was in a Brown County crow on July 22, 2002, followed by a human case onset on July 23, 2002. South Dakota's first WNV death was the following year in July 2003. By 2006 WNV had spread to all contiguous 48 United States and four Canadian provinces. WNV is now enzootic in most of temperate North America and is expected to persist as a public health threat to South Dakota into the foreseeable future.

The primary vector of WNV in South Dakota is the night-biting *Culex tarsalis* mosquito.[3] Although birds are the primary reservoir of WNV, humans are among the incidental mammalian hosts. Human infection is generally asymptomatic or mild, with approximately 20 percent of human WNV infections provoking acute self-limited febrile illness (non-neuroinvasive) characterized by fever, headache, fatigue and myalgia, and less than 1 percent of patients developing more severe neuroinvasive disease (NID) syndromes including meningitis, encephalitis and acute flaccid paralysis or poliomyelitis.[4] Long-term sequelae include cognitive lapses, functional difficulties and neurologic dysfunction.[5] Approximately 9 percent of WNV-NID cases are fatal. WNV neuroinvasive and non-neuroinvasive cases are mandatory reportable disease events in South Dakota and the U.S.

Since 1999 there have been 45,975 human WNV disease cases and 2,005 WNV-associated deaths reported in the U.S. (Table 1). In South Dakota 2,359 human WNV disease cases, including 509 WNV-NID cases and 38 WNV-associated deaths, have been reported since 2002 when the virus was first detected in the state. The peak epidemic year in South Dakota was 2003 when 1,039 human WNV cases and 14 deaths were reported, accounting for 44 percent of all cases and 37 percent of South Dakota deaths historically. The fewest WNV cases were reported in 2011 (n=2).

South Dakota has experienced a disproportionate WNV morbidity and mortality burden with 0.3 percent of the U.S.' population, but 2.1 percent of the WNV neuroinvasive

Table 1. West Nile virus human cases, United States and South Dakota, 1999-2016:**
WNV Neuroinvasive cases (NID), NID rate,* WNV non-NID cases, WNV-associated deaths and viremic blood donors.

	United States						South Dakota					
Year	NID cases	NID rate*	Non-NID cases	Total cases	Deaths	Blood donors	NID cases	NID rate*	Non-NID cases	Total cases	Deaths	Blood donors
1999	59	0.0	3	62	7	NA	Pre	Pre	Pre	Pre	Pre	NA
2000	19	0.0	2	21	2	NA	Pre	Pre	Pre	Pre	Pre	NA
2001	64	0.0	2	66	10	NA	Pre	Pre	Pre	Pre	Pre	NA
2002	2,946	1.0	1,210	4,156	284	NA	14	1.8	23	37	0	NA
2003	2,866	1.0	6,996	9,862	264	714	170	22.0	869	1,039	14	63
2004	1,148	0.4	1,391	2,539	100	224	6	0.8	45	51	1	3
2005	1,309	0.4	1,691	3,000	119	417	35	4.5	194	229	2	18
2006	1,495	0.5	2,774	4,269	177	361	38	4.8	75	113	3	12
2007	1,227	0.4	2,403	3,630	124	352	48	6.0	160	208	6	21
2008	689	0.2	667	1,356	44	174	11	1.4	28	39	0	3
2009	386	0.1	334	720	32	116	6	0.7	15	21	0	1
2010	629	0.2	392	1,021	57	144	4	0.5	16	20	0	0
2011	486	0.2	226	712	43	137	0	0.0	2	2	0	0
2012	2,873	0.9	2,801	5,674	286	703	62	7.4	141	203	3	42
2013	1,267	0.4	1,202	2,469	119	431	57	6.8	92	149	3	26
2014	1,347	0.4	858	2,205	97	344	12	1.4	45	57	0	0
2015	1,455	0.5	720	2,175	146	345	11	1.3	29	40	0	2
2016*	1,140	0.4	898	2,038	94	275	35	4.1	116	151	6	16
TOTAL	**21,405**	**0.4**	**24,570**	**45,975**	**2,005**	**4,737**	**509**	**4.2**	**1,850**	**2,359**	**38**	**207**
Median	1,188	0.4	878	2,190	99	345	14	1.8	45	57	1	8

*NID cases per 100,000 population per year.

**Provisional as of Jan. 17, 2017.

Pre – Pre-emergence.

NA – Blood donations testing not available.

cases and 1.9 percent of deaths. The annualized incidence for WNV-NID in the U.S. has been 0.4 cases per 100,000 population per year (Table 2). Upper Great Plains states have had the highest average annual incidence of WNV-NID. The five highest WNV-NID incidence states include South Dakota 3.1, North Dakota 2.6, Nebraska 1.8, Wyoming 1.6 and Colorado 1.3 cases per 100,000 population per year. The high rate of WNV-NID is graphically evident in the national incidence map showing county-level incidence (Figure 1).[6] The dark swath of high incidence counties runs from north Texas up the Great Plains concentrating in the Dakotas and Nebraska. The annualized incidence for total WNV cases (neuroinvasive and non-neuroinvasive) also ranks South Dakota with the highest incidence in the country, 15.1 cases per 100,000 population per year, and the other above-mentioned states also ranking as top incidence states. The overall national WNV death rate (non-annualized) was 0.62 deaths per 100,000 population from 1999 to 2016. South Dakota has had the highest WNV death rate with 3.93 deaths per 100,000 during those years. Other states with high WNV death rates again include our neighboring states Nebraska, Wyoming and North Dakota.

Human WNV cases have been reported in all 66 South Dakota counties and in at least 320 communities over the 15 years (Figure 2 and Table 3). Counties with the highest incidence of WNV illness include Marshall 74.5 cases per 100,000 per year, Sanborn 67.9, Potter 63, Sully 58.3 and Perkins 58.1; whereas counties with the most cases reported are among the state's most populated counties, Brown 292 cases, Pennington 197, Minnehaha 150, Hughes 87 and Davison 85 cases. Counties with the lowest WNV annualized incidence include Union 8.8, Yankton 8.3, Lincoln 7.4, Minnehaha 5.9 and Custer 5.7 cases per 100,000 population per year.

People of all races, sexes and ages have been infected and sickened by WNV in South Dakota. South Dakota males have been disproportionately affected by WNV with 56 percent of the 2,359 WNV cases having been male and 44 percent female. Race stratification shows WNV disease rates at 90.5 percent White, 8 percent American Indian,

Table 2. West Nile virus neuroinvasive disease (NID), total cases, deaths and rates reported to CDC, 1999-2015 (rates calculated with 2010 census).

State	NID cases	NID annualized rate*	Total cases	Total annualized rate*	Deaths	Death rate** (non-annualized)
Alabama	170	0.2	254	0.3	16	0.33
Alaska	0	0.0	0	0.	0	0
Arizona	906	0.8	1,539	1.3	98	1.53
Arkansas	227	0.4	307	0.6	25	0.86
California	3,055	0.5	5,589	0.8	227	0.61
Colorado	1,190	1.3	5,213	5.8	111	2.21
Connecticut	85	0.1	130	0.2	3	0.08
Delaware	20	0.1	41	0.3	3	0.33
Florida	265	0.1	354	0.1	22	0.12
Georgia	209	0.1	383	0.2	29	0.30
Hawaii	0	0.0	1	0.0	0	0
Idaho	198	0.7	1,315	4.7	27	1.72
Illinois	1,383	0.6	2,214	1.0	140	1.09
Indiana	363	0.3	641	0.5	39	0.60
Iowa	226	0.4	461	0.8	18	0.59
Kansas	287	0.6	553	1.1	26	0.91
Kentucky	106	0.1	154	0.2	15	0.35
Louisiana	971	1.2	1,580	1.9	101	2.23
Maine	2	0.0	2	0.0	0	0
Maryland	213	0.2	328	0.3	32	0.55
Massachusetts	99	0.1	129	0.1	9	0.14
Michigan	948	0.5	1,121	0.6	94	0.95
Minnesota	252	0.3	644	0.7	19	0.36
Mississippi	673	1.3	1,270	2.4	71	2.39
Missouri	420	0.4	561	0.5	42	0.70
Montana	155	0.9	554	3.1	11	1.11
Nebraska	604	1.8	3,558	10.8	63	3.45
Nevada	125	0.3	289	0.6	5	0.19
New Hampshire	5	0.0	6	0.0	0	0
New Jersey	148	0.1	233	0.1	20	0.23
New Mexico	283	0.8	566	1.5	22	1.07
New York	575	0.2	785	0.2	67	0.35
North Carolina	46	0.0	61	0.0	6	0.06
North Dakota	310	2.6	1,557	12.9	19	2.82
Ohio	658	0.3	927	0.4	65	0.56
Oklahoma	426	0.6	716	1.1	54	1.44
Oregon	33	0.0	168	0.2	2	0.05
Pennsylvania	330	0.1	523	0.2	29	0.23
Rhode Island	12	0.1	17	0.1	2	0.19
South Carolina	43	0.1	64	0.1	5	0.11
South Dakota	***459***	***3.1***	***2,208***	***15.1***	**32**	**3.93**
Tennessee	204	0.2	278	0.2	19	0.30
Texas	2,919	0.6	4,907	1.1	260	1.03
Utah	133	0.3	347	0.7	9	0.33
Vermont	3	0.0	10	0.1	0	0
Virginia	104	0.1	155	0.1	13	0.16
Washington	48	0.0	87	0.1	2	0.03
West Virginia	14	0.0	20	0.1	2	0.11
Wisconsin	140	0.1	239	0.2	18	0.32
Wyoming	167	1.6	735	7.2	17	3.02
United States	**20,212**	**0.4**	**43,794**	**0.8**	**1909**	**0.62**

*Cases per 100,000 population per year.

**Deaths per 100,000 population.

0.4 percent other race, and 1.1 percent unknown race, which is proportionately similar to the state's population race percentages. The elderly are at highest risk of developing WNV-NID disease. The median age of South Dakota WNV-NID cases was 52 years, while the WNV non-neuroinvasive case median age was 44 years, and the death median age was 80 years. Both case numbers and incidence peaked in the 40-44 year age group (Figure 3). However, 24 percent of NID cases and 85 percent of deaths were among individuals 70 years of age and older.

The WNV human disease season runs from May to October in South Dakota (Figure 4). The peak week of illness onset has been during the second week of August; however, if the 2003 WNV epidemic cases are removed, the remaining year's cases peak during the first week of August. The most case onsets during a single week were during the second week of August during the 2003 epidemic with 213 cases. During the other years the most case onsets were during the first week of August 2012 (n=49). Ninety percent of South Dakota's human WNV cases occurred during the nine-week period from the second week of July through the second week of September. South Dakota's six-month WNV season starts with 0.4 percent of patient illness onsets during the month of May, 2.0 percent in June, 19.7 percent in July, 59.8 percent in August, 17.4 percent in September and 0.7 percent of illness onsets during October. Since the infectious mosquito bite occurs two days to two weeks prior to onset of disease symptoms, mosquito control and bite prevention should take place before and during the peak disease onset periods.

Over the past 15 years, human WNV infection has caused extensive disease and death in South Dakota and is likely to threaten the public's health into the future. South Dakota health care providers should be alert for patients with WNV neuroinvasive and non-neuroinvasive symptoms, use appropriate laboratory testing, and report cases to the South Dakota Department of Health. No

Figure 1. Average annual incidence of West Nile virus neuroinvasive disease reported to CDC by county, 1999-2015.

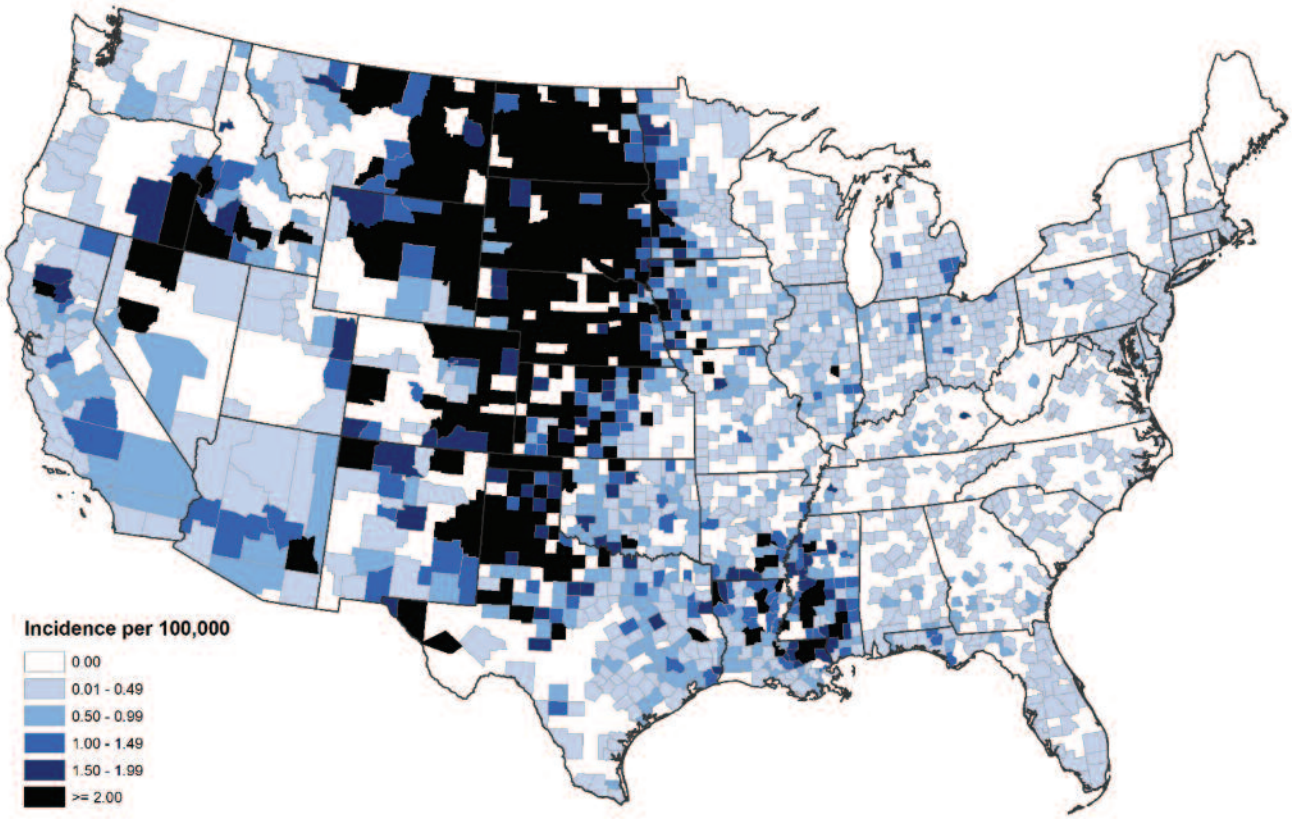


Table 3. Human WNV cases and annualized incidence (cases per 100,000 population per year) in South Dakota counties, 2002-2016.

County	Cases	Incidence
Aurora	12	29.5
Beadle	63	24.1
Bennett	16	31.1
BonHomme	17	16.0
Brookings	57	11.9
Brown	292	53.3
Brule	23	29.2
Buffalo	9	31.4
Butte	67	44.2
Campbell	11	50.0
CharlesMix	58	42.4
Clark	26	47.0
Clay	37	17.8
Codington	43	10.5
Corson	14	23.0
Custer	7	5.7
Davison	85	29.1
Day	30	35.0
Deuel	7	10.7
Dewey	37	46.5
Douglas	22	48.9
Edmunds	24	39.3

County	Cases	Incidence
FallRiver	31	29.1
Faulk	20	56.4
Grant	22	19.9
Gregory	12	18.7
Haakon	14	48.2
Hamlin	24	27.1
Hand	17	33.0
Hanson	19	38.0
Harding	7	37.2
Hughes	87	34.1
Hutchinson	27	24.5
Hyde	8	37.6
Jackson	12	26.4
Jerauld	9	29.0
Jones	8	53.0
Kingsbury	33	42.7
Lake	32	19.0
Lawrence	39	10.8
Lincoln	50	7.4
Lyman	25	44.4
Marshall	52	74.5
McCook	19	22.5

County	Cases	Incidence
McPherson	14	38.0
Meade	49	12.8
Mellette	9	29.3
Miner	11	30.7
Minnehaha	150	5.9
Moody	10	10.3
OglalaLakota	38	18.6
Pennington	197	13.0
Perkins	26	58.1
Potter	22	63.0
Roberts	35	23.0
Sanborn	24	67.9
Spink	52	54.0
Stanley	14	31.5
Sully	12	58.3
Todd	22	15.3
Tripp	32	37.8
Turner	43	34.3
Union	19	8.8
Walworth	21	25.7
Yankton	28	8.3
Ziebach	7	16.7
South Dakota	**2,359**	19.3

WNV vaccine is available. City, tribal and county officials should assure appropriate mosquito control for their communities, and all citizens should protect themselves and their families from mosquito bites.[7] The unpredicted emergence of WNV in South Dakota demonstrates that an exotic, tropical virus can become enzootic in a temperate Great Plains state. We must stand prepared to detect and combat other mosquito and tick transmitted diseases, such as Zika, St. Louis encephalitis and Ross River fever, by maintaining local mosquito control competence, insect surveillance, climate monitoring and laboratory testing capacity.

Figure 2. Distribution of human West Nile cases, South Dakota 2002-2016. Each dot represents one case randomly distributed within counties.

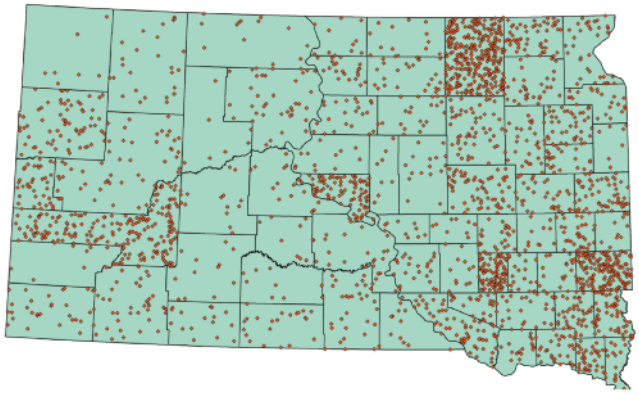


Figure 3. West Nile human cases and deaths by five-year age groups, South Dakota 2002-2016.

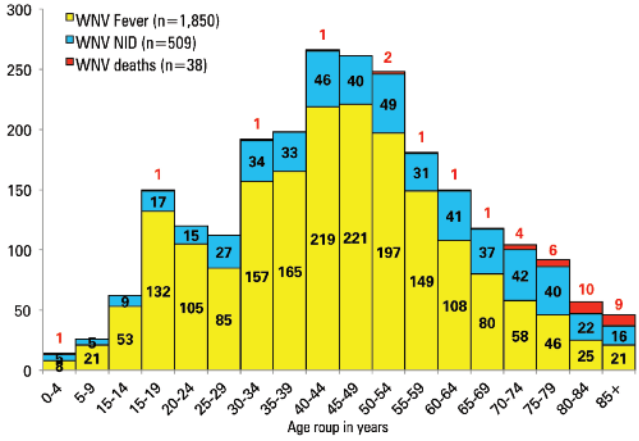
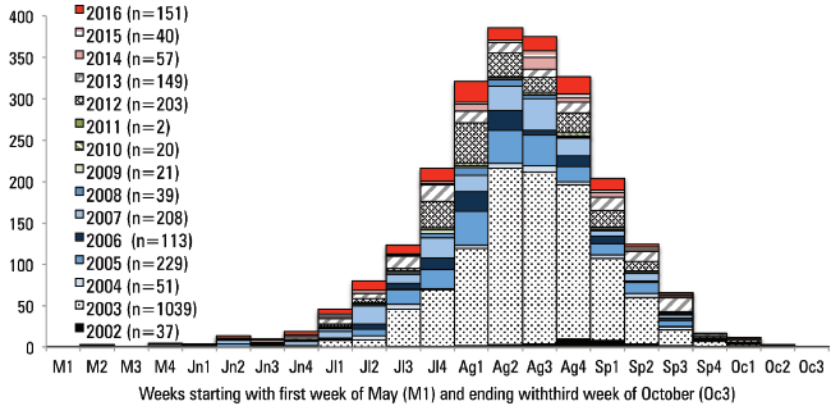


Figure 4. West Nile human cases by week of WNV season, South Dakota 2002-2016.



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