West Nile Virus

Identification

1. Indicator Description

This indicator looks at the incidence of West Nile virus disease in the United States since 2002. West Nile virus disease is a mosquito-borne viral disease that can cause symptoms such as headache, body aches, joint pains, vomiting, diarrhea, and rash, as well as more severe neurologic symptoms, such as encephalitis and meningitis (CDC, 2024b). The spread of West Nile virus is affected by mosquito abundance; population fluctuations and infection rates among mosquito and bird hosts; human population patterns, awareness, and behavior; habitat; climate; and other factors. West Nile virus disease is notifiable, and long-term data may be useful for understanding the effects of climate change on vector-borne diseases because variations in weather have an impact on disease vectors such as mosquitoes. Since warmer temperatures may allow for expansion of mosquitoes' distribution and accelerate the mosquito life cycle, biting rates, and the rate at which the virus replicates, warming temperatures associated with climate change could increase the risk of West Nile virus disease in humans (USGCRP, 2016). West Nile disease is one of several mosquito-borne diseases that CDC tracks (www.cdc.gov/vector-borne-diseases/about/index.html; Rosenberg et al., 2018).

Components of this indicator include:

- Annual incidence of reported human neuroinvasive West Nile virus disease in the United States (Figure 1).
- Average annual incidence of human neuroinvasive West Nile virus disease by state (Figure 2).

2. Revision History

August 2016:	Indicator published.
April 2021:	Updated indictor with data through 2019.
September 2023:	Updated indicator with data through 2021.
December 2024:	Updated indicator with data through 2023.

Data Sources

3. Data Sources

This indicator is based on annual numbers of neuroinvasive West Nile virus disease cases reported nationally, compiled by the Centers for Disease Control and Prevention's (CDC's) Division of Vector-Borne Diseases. Incidence was calculated using the most recent mid-year population estimates for each year from the U.S. Census Bureau.

4. Data Availability

All of the data for this indicator are publicly available on CDC and Census Bureau websites.

EPA obtained the data for this indicator from CDC's website. Prior to 2005, CDC compiled only confirmed neuroinvasive cases, but in 2005 it also began to track confirmed, non-neuroinvasive cases. CDC's data present neuroinvasive and non-neuroinvasive cases; however, only neuroinvasive cases are used for this indicator for reasons described in Section 5.

Although data are available for years prior to 2002 for neuroinvasive disease cases, this indicator starts in 2002 because neuroinvasive West Nile virus did not become a nationally notifiable disease until 2002. Prior to 2002, only some states voluntarily reported neuroinvasive West Nile virus disease cases.

CDC's national and state-level data are available online at: www.cdc.gov/west-nile-virus/data-maps/historic-data.html. Through the years, these data have also been published in CDC's Morbidity and Mortality Weekly Reports (MMWR), which are available at: www.cdc.gov/mmwr/mmwr_nd/index.html. Due to concerns about patient confidentiality, underlying county-level data are not available publicly or they are combined into multi-year averages before being made publicly available. Cumulative and annual data and maps of reported cases of West Nile virus are posted online at: www.cdc.gov/west-nile-virus/data-maps/historic-data.html.

Following CDC's standard practice, incidence has been calculated using population estimates on July 1 of each calendar year. These population estimates are publicly available from the U.S. Census Bureau's Population Estimates Program at the following locations:

- 2000–2009: www.census.gov/data/tables/time-series/demo/popest/intercensal-2000-2010-state.html
- 2010–2019: www.census.gov/data/tables/time-series/demo/popest/2010s-state-total.html
- 2020 and later: www.census.gov/data/tables/time-series/demo/popest/2020s-state-total.html

Methodology

5. Data Collection

This indicator is based on the annual reported number of neuroinvasive West Nile virus disease cases as compiled by CDC.

State and local health departments report weekly case counts for West Nile virus disease cases following CDC's case definitions through the National Notifiable Diseases Surveillance System (NNDSS) or through ArboNET. NNDSS and ArboNET are public health surveillance systems for the reporting of individual cases of disease and conditions to state, local, and territorial health departments, which then forward case information to CDC. The provisional state-level data are reported in CDC's MMWR. After all states have verified their data, CDC publishes an annual surveillance summary for West Nile virus disease and other notifiable diseases.

Health care providers nationwide follow standardized definitions for what constitutes neuroinvasive and non-neuroinvasive cases of West Nile virus, but these definitions have changed over time (see Section 8). West Nile virus disease became a nationally notifiable disease in the United States in 2002. As such, state and local health departments work with health care providers to obtain case reports for West Nile virus disease based upon these definitions. Because of the substantial morbidity associated with

neuroinvasive West Nile disease, detection and reporting is assumed to be more consistent and complete for neuroinvasive cases than for non-neuroinvasive cases. Therefore, this indicator covers only neuroinvasive cases.

6. Indicator Derivation

Figure 1. Reported West Nile Neuroinvasive Disease Cases in the United States, 2002–2023

Figure 1 shows national incidence by year since 2002, when West Nile virus disease first became notifiable. National incidence of neuroinvasive West Nile virus disease was calculated using the total number of West Nile virus neuroinvasive disease cases and the national population for each year from 2002 through 2023. EPA calculated incidence by dividing the number of cases per year by the corresponding population on July 1 in the same calendar year. EPA then multiplied the per-person rate by 100,000 to generate a normalized incidence rate per 100,000 people. This is CDC's standard method of expressing the incidence of West Nile virus disease.

Figure 2. Reported West Nile Neuroinvasive Disease Cases by State, 2002–2023

Figure 2 shows the average annual incidence for each state, averaged over the period from 2002 to 2023. EPA calculated annual incidence for each state as described above, then averaged all years of data for each state to arrive at an average annual rate for the full period of record.

7. Quality Assurance and Quality Control

Each state has established laws mandating that health providers report cases of various diseases (including West Nile virus disease) to their health departments. Each state health department verifies its data before sharing them with CDC. NNDSS is the primary system by which health surveillance data are conveyed to CDC for national-level analyses.

Starting in 1990, CDC launched the National Electronic Telecommunications System for Surveillance (NETSS), replacing mail and phone-based reporting. As of July 1, 2004, West Nile virus disease data are no longer reported through NETSS and instead are reported to CDC through ArboNET. In 2000, CDC developed the National Electronic Disease Surveillance System (NEDSS) Base System (NBS). This central reporting system sets data and information technology standards for departments that provide data to CDC, ensuring that data are submitted quickly, securely, and in a consistent format.

Using Council of State and Territorial Epidemiologists (CSTE) case definitions, CDC provides state and local health departments and health providers with comprehensive guidance on laboratory diagnosis and case classification criteria, ensuring that all health providers and departments classify West Nile virus disease cases consistently throughout the United States.

State health officials use various methods to ascertain cases, including passive surveillance initiated by health care providers, laboratory-based surveillance, and "enhanced surveillance" (CDC, 2024a). State officials check the data and remove duplicate reports before submitting annual totals to CDC.

Analysis

8. Comparability Over Time and Space

West Nile virus disease data collection follows case definitions established by CSTE to ensure consistency and comparability across the country. The national case definitions for West Nile virus disease and neuroinvasive West Nile virus disease have changed over time, however. CDC's website provides more information about these changes at: https://ndc.services.cdc.gov/conditions/arboviral-diseases-neuroinvasive-and-non-neuroinvasive. It is not possible to control for these case definition changes, and these definition changes necessitate careful comparisons of data from multiple years.

9. Data Limitations

Factors that may have an impact on the confidence, application, or conclusions drawn from this indicator are as follows:

1. CDC's national West Nile virus disease case definitions have changed a few times since West Nile virus disease became a notifiable disease. As discussed in Section 8, it is not possible to control for these case definition changes, which adds some uncertainty to the indicator.

2. As described in Section 10, many cases of West Nile virus disease may not be reported due to incomplete diagnosis and reporting, which means this indicator underestimates the true incidence of the disease (CDC, 2024a). The reporting rate may vary over time and space as a result of differences in funding and emphasis among state surveillance programs.

3. As an indicator of climate change, West Nile virus disease is limited due to several confounding factors:

    - Vector control efforts and public health education may counteract the increase in cases expected due to warming climates.

    - Importantly, there are several factors driving changes in incidence of West Nile virus disease other than climate. Several of these factors have not been well-quantified or studied. Possible factors include changes in the geographic distribution of mosquitoes or changes to bird populations due to non-climate-related factors such as land use changes (e.g., suburbanization, deforestation, and reforestation).

    - Human exposure depends upon socioeconomic and cultural factors, land use, health care access, and living conditions (Gage et al., 2008; Gubler et al., 2001; Hess et al., 2012; Lafferty, 2009; Wilson, 2009).

4. West Nile virus surveillance data capture the location of the patient's residence, which is not necessarily the location where the individual was infected.

5. West Nile virus has a short history of transmission in the United States, which prevents direct observation of long-term climate trends' impacts on West Nile virus disease incidence.

6. West Nile virus disease may be less useful than tick-borne Lyme disease for understanding the long-term effects of climate change on vector-borne diseases because shorter-term variations in weather have more of an impact on mosquitoes than on other disease vectors such as ticks (USGCRP, 2016).

10. Sources of Uncertainty

The main source of uncertainty for this indicator stems from its dependence on surveillance data. Surveillance data can be subject to underreporting and misclassification. Because diagnosis of West Nile virus disease is often determined based upon clinical symptoms, lack of symptoms or delayed symptoms may result in overlooked or misclassified cases. Furthermore, surveillance capabilities can vary from state to state, or from year to year based upon budgeting and personnel.

Another issue is that surveillance data are captured by county of residence rather than county of exposure. Reports of West Nile virus disease may therefore occur in states with limited pathogen populations. For example, a tourist from New York may be infected with West Nile virus while visiting California but not be identified as a West Nile virus disease case until he or she returns home to New York. This type of situation may result in underreporting in areas of high West Nile virus incidence and overreporting in areas of low West Nile virus incidence.

For a discussion of the uncertainties associated with the U.S. Census Bureau's intercensal estimates, see: www.census.gov/programs-surveys/popest/technical-documentation/methodology.html.

11. Sources of Variability

The incidence of West Nile Virus disease is likely to display variability over time and space due to:

- Changes in populations of mosquitoes and host species (e.g., birds) over time.
- Spatial distribution of mosquitoes and changes in their distribution over time.
- The influence of climate on the activity and seasonality of mosquitoes.
- The influence of temperature on the incubation period of West Nile virus in mosquitoes.
- Variability in human population over time and space.

This indicator accounts for these factors by presenting a broad multi-year national trend in Figure 1. EPA has reviewed the statistical significance of these trends (see Section 12).

12. Statistical/Trend Analysis

Ordinary least-squares linear regression analyses show that national trends in the incidence of neuroinvasive cases of West Nile virus are not statistically significant to a 95 percent level ($p < 0.05$). The regression slope for the national incidence rate per 100,000, from 2002 to 2023, is -0.013 per year, with $p = 0.14$. State-level trends have not been examined for significance.

Because nationally reported data from CDC are only available for the most recent 20 years, this metric is too short-lived to be used for assessing long-term climate trends. With continued data collection, future versions of this indicator should be able to paint a more statistically robust picture of long-term trends in West Nile virus disease incidence.

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