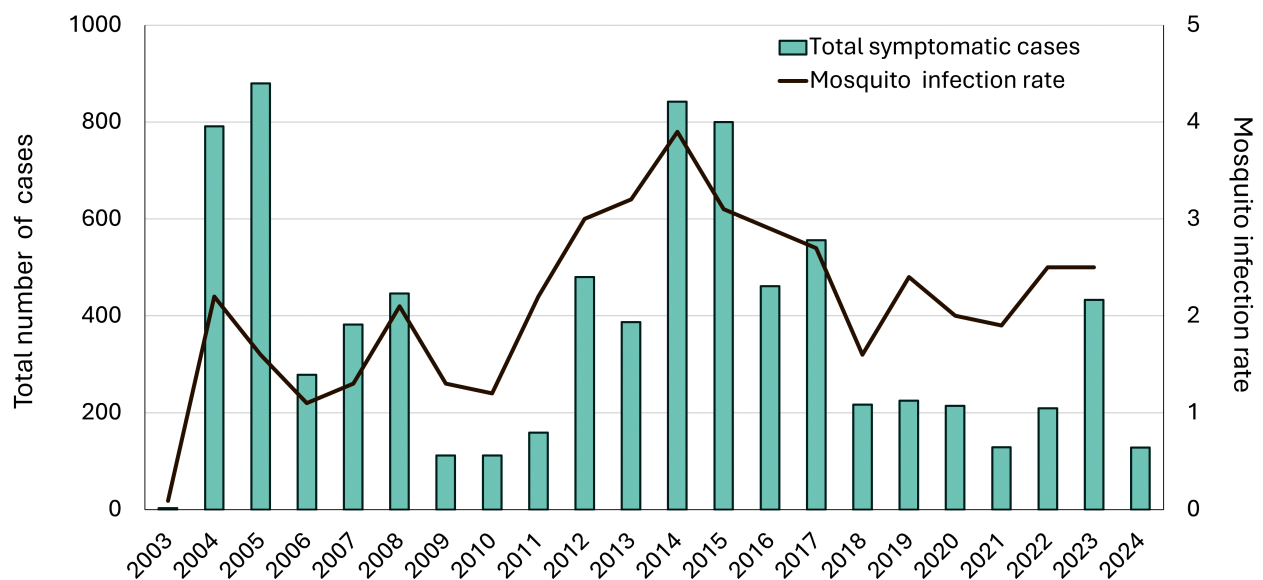


5.5 Vector-Borne Diseases

A changing climate alters the conditions under which vector-borne diseases spread. Such diseases are transmitted to people and animals by the bites of infected arthropods, such as mosquitoes and ticks, whose life cycles are strongly influenced by environmental conditions. Monitoring vector-borne diseases will become increasingly important as climate change reshapes their risk and burden, both within and beyond California.

Figure 5.5.1. West Nile Virus (WNV).

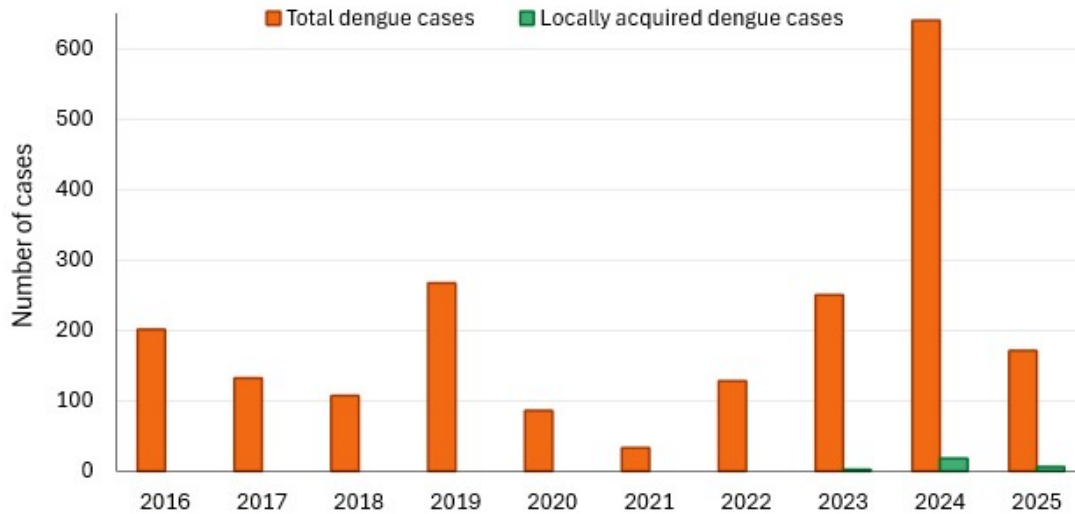


Human WNV cases and minimum infection rates in mosquitoes in California, 2003-2024.

Source: [CDPH West Nile Virus Website](#) (2025c).

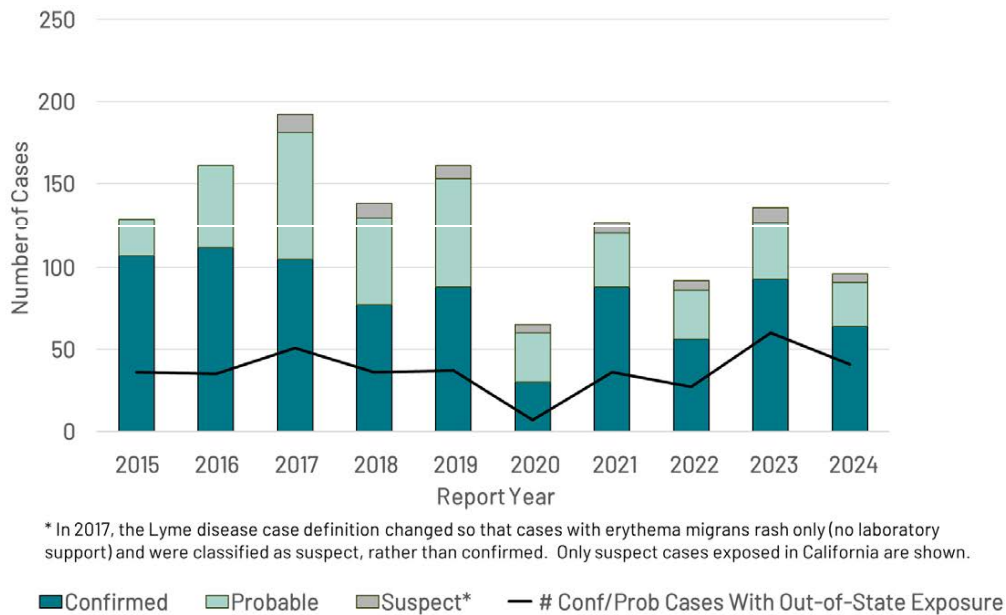


Figure 5.5.2. Dengue.



Travel-associated and locally acquired dengue cases in California, 2016-2025. Source: [CDPH Dengue Webpage](#) (2025a).

Figure 5.5.3. Lyme Disease.



Reported Lyme disease cases in California, 2015-2024. Source: CDPH (2024).



What does the indicator show?

Vector-borne diseases are caused by pathogens that are transmitted to people and other animals through the bites of infected arthropods, known as vectors, including mosquitoes and ticks. The abundance and distribution of vectors and animals that can act as reservoirs, as well as transmission of pathogens carried by vectors, are affected by climate-driven environmental changes in temperature and precipitation patterns.

Many cases of vector-borne diseases go unreported, largely because their reporting depends on people seeking medical care and receiving appropriate diagnostic testing. Asymptomatic infections are common for some of these diseases, and symptoms such as fatigue and headaches are often mild and nonspecific, making them difficult to distinguish from other common illnesses. Severe cases are rare but can result in serious health complications and even death.

Mosquito-borne diseases

Mosquito-borne diseases under surveillance in California include endemic diseases, such as West Nile virus (WNV) and St. Louis encephalitis virus (SLEV). These viruses are carried by *Culex* mosquito species found throughout much of the state. Additional cases of diseases such as those caused by dengue, chikungunya, and Zika viruses, are typically associated with international travel, although invasive populations of *Aedes* mosquitoes in California make local transmission of these viruses possible. The transmission of all mosquito-borne diseases is influenced by temperature, which regulates the rate of mosquito development, frequency of biting and the time required for a mosquito to become infectious after biting an infected host.

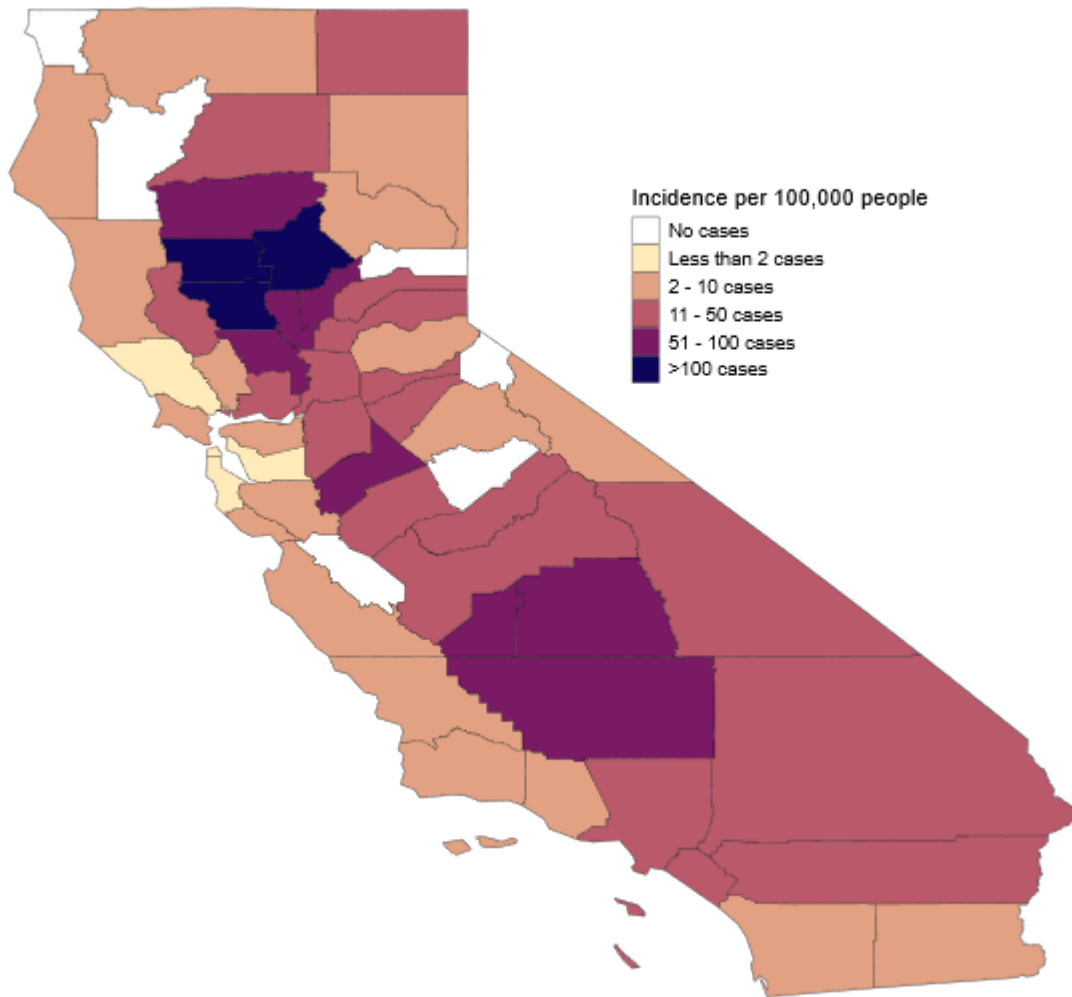
For most Californians, WNV poses the greatest vector-borne disease threat (Snyder et al., 2020). This virus circulates primarily among birds, which act as reservoirs, and *Culex* mosquito vectors and has caused human disease in California every year since it was first detected in 2003. Most infections are asymptomatic, with 20% of infected people developing fever and flu-like symptoms, and less than 1% developing severe, and sometimes fatal neurological illnesses (CDC, 2021). Approximately 10% of the severe cases are fatal (CDC, 2025b).



Statewide, the number of West Nile virus cases varies from year to year. Symptomatic infections peaked in 2004-2005 and 2014-2015, with a smaller uptick in 2023. Infection rates in *Culex* mosquitoes (minimum infection rate, or MIR; see *Technical Considerations*) follow similar year-to-year fluctuations as human cases ([Figure 5.5.1](#)). WNV was first detected in the state in 2003, when three human cases were reported: one each in Imperial, Orange, and Riverside counties. WNV transmission quickly expanded across the state, with most counties (46 of 58) reporting at least one case and nearly all (54 of 58) detecting viruses in the environment by 2005 (CDPH, 2005). Spatially, hot spots of West Nile virus infection in mosquitoes have often been detected in the Los Angeles metropolitan area and the Central Valley, typically in the same areas that experience a high burden of human disease (Bayles et al., 2024). However, the highest incidence (cases per 100,000 people) typically occurs in the northern Central Valley, a sparsely populated part of the state where rice agriculture supports significant mosquito production in the summer months ([Figure 5.5.4](#)).



Figure 5.5.4. WNV Cases by County.



Cumulative incidence of symptomatic WNV cases by county in California, 2003 – 2025. Source: CDPH (2026a).

Cases of WNV in California are predicted to rise over the next 20 years with increasing temperatures due to climate change (Parker, 2024). WNV cases are driven in part by the proportion of *Culex* mosquitoes infected with WNV, as measured by the MIR. The MIR typically increases as temperatures rise due to the shortened incubation period in the mosquito vector and more frequent feeding on hosts by the mosquito (see *What factors influence this indicator?*). MIR along with mosquito abundance levels at local



scales are used to evaluate human risk and inform the response of local vector control agencies as outlined in the California Mosquito-Borne Virus Surveillance and Response Plan (CDPH, 2026b). In areas without human WNV cases reported, and where mosquito testing is conducted, the mosquito MIR provides a measure of transmission risk in the environment.

Because most vector-borne infections are asymptomatic or mild, patients may not seek treatment or diagnostic testing. As a result, severe cases of WNV, which involve neurological symptoms, are more likely to be detected and reported than mild febrile illness or asymptomatic infections. For every neuroinvasive case reported, there are an estimated 30 to 70 cases of febrile illness (Mostashari et al., 2001). Given that most human WNV infections are not detected or reported, mosquito infection rates provide a robust indication of WNV activity in the environment.

Before WNV was introduced to the state, endemic mosquito-borne pathogens such as western equine encephalomyelitis virus (WEEV) and SLEV were regularly detected in California. After the introduction of West Nile virus, the detection of both viruses declined, with the last environmental detection of WEEV in 2007 (MVCAC, 2008). SLEV re-emerged in California in 2015 after more than a decade without detection (Danforth et al., 2022; White et al., 2016). Since 2015, SLEV has been detected annually through environmental surveillance and has caused 63 cases of symptomatic illness (CDPH, 2024).

Additional mosquito-borne viruses of concern in California include those that are typically associated with international travel: dengue, chikungunya, and Zika. Of these, dengue causes the greatest burden of disease globally. Like WNV, most people infected with dengue virus experience no symptoms, but severe cases can become life-threatening within hours. Because there are four different strains of the dengue virus, a person can contract dengue more than once in their lifetime and those with a history of dengue infection are more likely to experience severe dengue if they are infected again (CDPH, 2025a).

Dengue virus has become a global health crisis in recent years, surging from 505,430 cases worldwide in 2000 to 6.5 million in 2023 and 14.6 million in 2024 (PAHO, 2025),



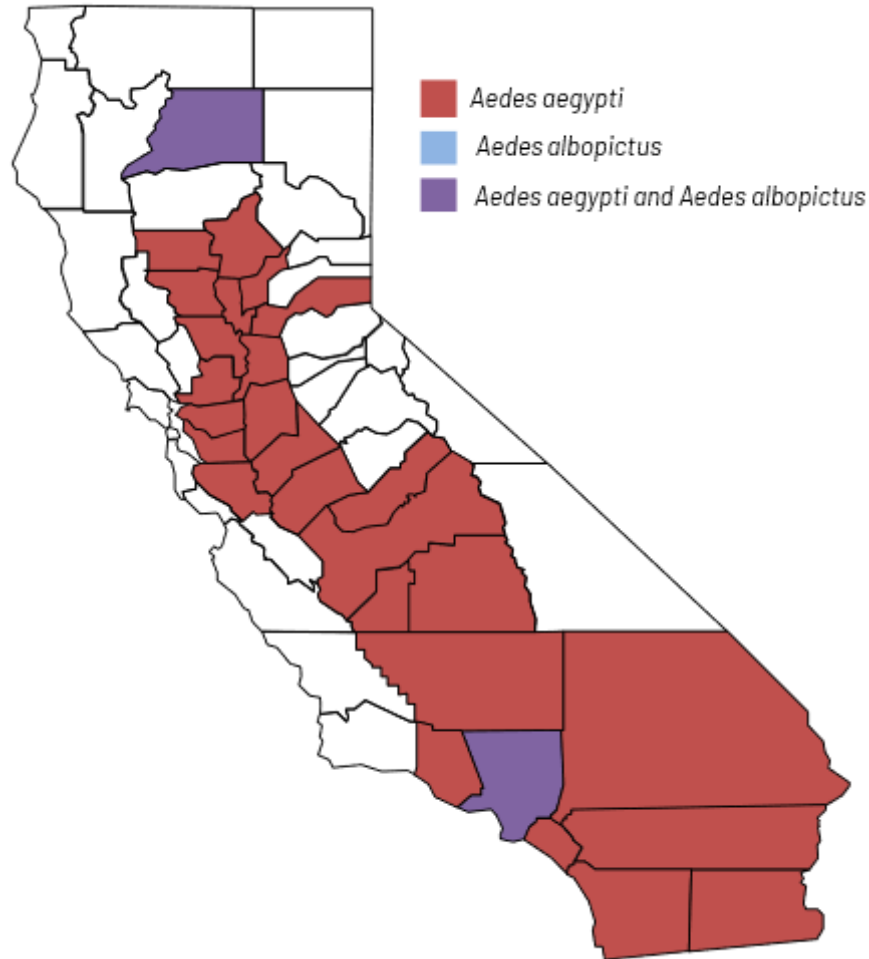
likely due to the combined effects of international travel, climate change, and the rapid expansion of dengue vectors into new areas (Abbasi, 2025; WHO, 2023). Cases of dengue reported in California (**Figure 5.5.2**) are predominately associated with international travel, but limited local transmission of dengue virus was reported in Los Angeles County in 2023 (2 cases), in three counties in southern California in 2024 (18 cases total for Los Angeles, San Diego, and San Bernardino counties), and in Los Angeles County in 2025 (6 cases) (Feaster et al., 2024; CDPH, 2024, 2025a, 2025d).

Aedes aegypti is the primary worldwide vector of dengue, chikungunya, and Zika viruses, and *Aedes albopictus* is also capable of transmitting these viruses. These mosquito species are not native to California, but repeated introductions attributed to global and domestic shipping and transport have resulted in established populations in California (Metzger et al., 2017; Porse et al., 2015). Invasive *Aedes* mosquitoes are currently established in 26 counties across the state (**Figure 5.5.5**), making it possible for returned travelers to introduce historically travel-associated viruses into local mosquito populations.

Local transmission of dengue in California is very rare and constrained by low temperatures compared to endemic areas in the tropics. Currently, temperatures in parts of southern California with invasive *Aedes* mosquitoes support local transmission for just a couple months of the year (VectorSurv Maps, 2025). With additional warming, currently cooler parts of the state may become more suitable for local transmission (Gorris et al., 2024) and the proportion of the year that is suitable for local transmission may increase (Mordecai et al., 2017). The number of travel-associated cases is also predicted to increase as climate change intensifies the transmission of these viruses in currently endemic areas (Childs et al., 2025).



Figure 5.5.5. Distribution of invasive *Aedes* mosquitoes in California.



Source: CDPH (2026a).

Tick-borne diseases

In addition to mosquito vectors, climate change can impact ticks, the pathogens they carry and their animal reservoirs. Unlike mosquitoes, the tick life cycle does not have an aquatic stage, but does have four distinct life stages: egg, larva, nymph, and adult. Depending on the infectious agent, ticks usually acquire pathogens in one life stage by feeding an animal reservoir and then passing those pathogens on to other animals or people in subsequent life stages (CDC, 2024). In general, ticks have a much longer life cycle than mosquitoes, taking two to three years to complete their life cycle from egg to



adult. Because ticks can typically live for multiple years, climate-driven changes in temperature and seasonal patterns influence the transmission of tick-borne diseases in unique ways compared to other vector-borne diseases.

Lyme disease is the most reported tick-borne disease in California ([Figure 5.5.3](#)), although it remains relatively rare on the west coast compared to other parts of the United States (CDC, 2025c). Lyme disease is caused by the bacteria *Borrelia burgdorferi*, which is transmitted by the western blacklegged tick (*Ixodes pacificus*) in California. Western blacklegged ticks occupy dense woodland, mixed forest, and coastal scrub habitats and acquire the pathogen in their larval or nymphal stage when feeding on an infected small mammal such as a deer mouse or a woodrat and can pass it to people in their nymphal or adult stage. Between 2015 and 2024, the average number of confirmed Lyme disease cases reported in California was 82 cases per year. Approximately 1 in 3 cases of Lyme disease in California occurred in people who were infected while traveling outside of the state (CDPH, 2024). Ticks carrying Lyme disease in California are more commonly found in the northern and central coastal regions and in the northern foothills of the Sierra Nevada (CDPH, 2025b).

Tribal Connection 5.5.1

The Wiyot Tribe, living around *Wigi* or Humboldt Bay since time immemorial, writes, “*Wiyot community members have noticed an increase of disease-carrying ticks within the region. Changes in temperature have allowed ticks to become more active in the spring and fall seasons. Humboldt County, as well as Santa Cruz and Sonoma, have higher than average rates of Lyme disease when compared to other regions of California (CDPH, 2021)*” (Wiyot Tribe, 2026).

Why is this indicator important?

Because vectors and reservoirs are sensitive to environmental conditions, changes in temperature and precipitation can influence the seasonality, distribution, and prevalence of vector-borne diseases (USGCRP, 2016). However, the impacts of climate change on vector-borne diseases in California will be diverse, varying by pathogen, vector, reservoir, and geography.



As vector-borne disease activity increases globally, increasing numbers of travelers may become infected while visiting areas where certain diseases are prevalent, return to California, and serve as a source of infection to local vectors. This possibility is particularly apparent for invasive *Aedes*-borne viruses, such as dengue, whereas returned travelers with Lyme disease may require care for their illnesses but are not likely to pass their infections on to local ticks. Increasing numbers of travel-associated and locally acquired cases will impact on the healthcare system and as transmission shifts to new areas, so will the needs, resources and capacity for vector control in different jurisdictions.

Vector-borne diseases cause significant illnesses in California and can be fatal. While most infections cause no apparent illness, severe and fatal cases are reported each year. Many individuals hospitalized for WNV experience long-term physical, cognitive, and functional complications, with 30–40% of patients discharged to long-term care or rehabilitation facilities, and more than half still experiencing symptoms a year after their initial illness (CDC, 2025b). Similarly, bleeding and/or shock resulting from severe dengue is considered a medical emergency and requires immediate medical attention (CDC, 2025a), while delay in Lyme disease diagnosis may lead to complications or rarely, post treatment Lyme disease syndrome (PTLDS) (Angell et al., 2025).

What factors influence this indicator?

The effects of climate change on vector-borne diseases can be complex and multifaceted, occurring in conjunction with other factors, such as land use change and human behavior. The diverse ecology of vector-borne diseases makes it challenging to predict exactly how climate change affects these diseases and the resulting alterations in their magnitude and geographic distribution. Below are examples of how climate change can influence the spread of vector-borne diseases (de Souza and Weaver, 2024; Ogden & Lindsay, 2016). For information about climate change impacts on other zoonotic diseases in California, see the *Zoonoses* emerging chapter.

Shifts in geographic range

Warmer temperatures and changing precipitation patterns may allow vectors and reservoirs to survive in geographic areas that were previously unsuitable. While some



areas may become more suitable with rising temperatures and changing precipitation patterns, others may become less suitable, surpassing thresholds that no longer support the physiological needs of vectors or reservoirs. Rising temperatures will shift the suitability for transmission of mosquito-borne pathogens according to the thermal stress tolerance of different vector species and the rate at which pathogens replicate inside vectors (Mordecai et al., 2019). Increases in Lyme disease cases in eastern North America have been attributed to climate change primarily at the northern edge of the geographic distribution of *Ixodes scapularis* (Gilbert et al., 2021). In California, the range of *Ixodes pacificus* is predicted to expand to one-third of the state, particularly in the northwest, south central, and southern coastal regions where winter precipitation is predicted to increase (Hahn et al., 2021, Eisen et al., 2018).

Shifts in seasonality

Because of the highly seasonal nature of prevailing precipitation patterns in California, changes in precipitation due to climate change will impact the seasonality of vector-borne disease transmission. The amount of winter and spring precipitation and snowpack determine the springtime abundance of rural vectors of WNV (Reisen et al., 2008). Even in the presence of strong seasonality in precipitation patterns, water management, particularly irrigated agriculture, can stabilize mosquito populations and virus transmission in agricultural areas (Kovach and Kilpatrick, 2024). Such patterns may contribute to differential impacts of climate change on *Culex* species occupying rural, agricultural areas (e.g., *Culex tarsalis*) compared to those found in urban habitats (e.g., *Culex pipiens* complex).

The abundance of *Ixodes pacificus* is limited by abiotic conditions during the summer dry season (Swei et al., 2011), which impact microclimates where certain tick life stages survive (Kilpatrick et al., 2017). Humidity from increased rainfall may limit the need for ticks to rehydrate in leaf litter and allow for more host seeking on emergent vegetation (Ogden and Lindsay, 2016).

The seasonality of host-seeking activity among *Ixodes pacificus* ticks in California is predicted to vary by region and climate scenario. Wetter future conditions may change host-seeking behavior in some regions (MacDonald et al., 2020). In northern California,



where lower temperatures and higher baseline humidity generally support tick activity, changing patterns of temperature and precipitation may alter the overlap between different stages of ticks (e.g., larvae and nymphs) in ways that affect pathogen transmission risk (Sambado et al., 2025b).

Warmer temperatures may also shift the seasonality of pathogen transmission in mosquito, tick and reservoir populations. Warmer winter temperatures may lengthen seasonal vector activity, particularly delaying the overwintering behavior of mosquitoes (Reisen et al., 2006; Diniz et al., 2017; Fyie et al., 2023), although periods of extreme heat negatively impact vector survival. Mosquito survival begins to decline at temperatures above 95°F (35°C) (Reisen, 1995), and in the Coachella Valley in southeastern California, *Culex* abundance is already known to decline during the hottest summer months (Reisen et al., 1992; Reeves et al., 1994; Ward et al., 2023). Increased frequency or duration of extreme heat events may make summer months in certain parts of the state less suitable for vector populations and shift seasonal peaks from a single summer peak to two peaks in the late spring and early fall.

Impacts of precipitation extremes

California oscillates between the precipitation extremes of drought and flood (Swain et al., 2018). Extreme precipitation events, such as droughts and floods, will have complex, even counterintuitive impacts on the transmission risk of mosquito-borne diseases. Since standing water is necessary for mosquito breeding, WNV cases sometimes, but not always, increase following rainfall and flooding events (Coalson et al., 2021). Decreases may occur after heavy rain events flush immature mosquitoes from their aquatic habitats (Benedum et al., 2018; Koenraadt & Harrington, 2008). While aquatic habitats available to mosquitoes contract under drought conditions, especially at seasonal timescales (Russell et al., 2025), higher infection rates in smaller mosquito populations have been observed in California's Central Valley following drought (Sambado et al., 2025a, MacDonald et al., 2025). Such elevated infection rates are thought to arise from increased contact between mosquito vectors and bird reservoirs (Paull et al., 2017). Drought may have contributed to the relatively high number of cases of WNV in 2014 and 2015 (CDPH, 2015; Sambado et al., 2025a).



Exposure-related human behavior

Warmer temperatures can lead people to spend more time outdoors, including more time outside in the spring and fall as seasons lengthen. This behavior increases the risk of getting bitten by infected vectors. Urban heat islands can amplify this effect in cities where mosquito-borne diseases can be prevalent. In natural areas, more time spent hiking and camping increase exposure risk to tick-borne diseases.

Travel outside of California to destinations with elevated risk for vector-borne disease transmission impacts case reporting within the state. The majority of cases of dengue, chikungunya, and Zika reported in the state are due to California residents who became infected while visiting countries where these viruses are endemic. Similarly, a significant proportion of tick-borne disease cases, including Lyme disease, result from out-of-state exposures, primarily in high-incidence states in the northeastern and midwestern United States. As a result, the impacts of climate change on vector-borne diseases beyond California's borders influence the burden of disease among California residents.

Additional factors

Additional anthropogenic factors that influence vector-borne disease transmission include changes in ecosystems and land use, socioeconomic status, the status of public health infrastructure, and response capacity (Carney et al., 2011; Rochlin et al., 2016; USGCRP, 2018). These diseases and their vectors and reservoirs have been linked with local-level factors such as income, housing conditions, and population density

(Donnelly et al., 2020; Harrigan et al., 2010; Hernandez et al., 2019; Hill et al., 2023; Watts et al., 2021). People in low-income communities may find it difficult to adopt protective measures to reduce exposure, such as using air conditioning, keeping areas in and around homes free of vector and reservoir habitat, and using insect repellent. Fewer educational resources may be accessible or available in lower-income communities, resulting in lower awareness of symptoms and risks of vector-borne diseases, and the importance of getting tested. Access to healthcare can also be a significant barrier to diagnosis and treatment for vector-borne diseases.



Technical considerations

Data characteristics

The California Department of Public Health Vector-Borne Disease Section coordinates statewide surveillance of all vector-borne diseases presented in this chapter, in collaboration with numerous local, state, and federal agencies, and members of the medical community. Testing for some human infections for vector-borne pathogens is performed at the California Department of Public Health's Viral and Rickettsial Disease Laboratory, the Centers for Disease Control and Prevention (CDC) as well as at local county public health laboratories and commercial laboratories. Surveillance also includes monitoring pathogen presence in mosquitoes, ticks, and their animal reservoirs.

Vector control agencies serving approximately 90% of the California population conduct surveillance and control for mosquito vectors. These agencies trap mosquitoes, sort and count them by species, and group female mosquitoes from the genus *Culex* into pools of ≤ 50 for virus testing, which is conducted at UC Davis or locally. A pool of mosquitoes is considered positive if at least one mosquito is infected. Minimum infection rate (MIR) – calculated as the number of positive mosquito pools divided by the total number of mosquitoes tested and multiplied by 1000 – provides a standardized measure of virus prevalence in *Culex* mosquitoes (CDPH, 2026b).

The ability to use surveillance data to support public health and vector control decisions in real-time is a key part of California's efforts to mitigate the growing effects of climate change on vector-borne disease incidence. California is a national leader in the development of such decision-support systems that are being used to inform local and state policies. Public-facing data on WNV and other vector-borne pathogens are provided via maps, reports, and other visualizations through the [CDPH Vector-Borne Disease Section website](#) and the [California West Nile Virus website](#). Statewide data on environmental surveillance of vectors and the pathogens they carry are managed, analyzed, and shared through the CalSurv data system, which is supported by funds from the state of California and housed at UC Davis through a partnership with CDPH and the Mosquito and Vector Control Association of California. The CalSurv system



provides a wide range of tools for data entry, analysis, and visualization that are used by agencies throughout California daily. Maps showing CalSurv's data are available at <https://maps.vectorsurv.org>.

Strengths and limitations of the data

This indicator uses surveillance data on vector activity, pathogen presence, and reported human infections to track how climate has impacted the occurrence of vector-borne pathogens over time.

Due to underreporting, human disease surveillance for vector-borne diseases is not a very sensitive measure of disease transmission. However, reporting human disease cases to local vector control agencies facilitates rapid response to emergent situations and is an essential complement to routine environmental surveillance activities. Routine environmental surveillance activities, including the trapping and testing of vectors and/or non-human hosts provides valuable and timely information about infection risk. In areas with robust mosquito testing, mosquito infection rates are especially useful indicators of West Nile virus transmission risk, and local vector control agencies can use mosquito infection rates to target mosquito control efforts. However, sampling effort and spatial coverage vary widely across the state, so the intensity of surveillance should be considered when comparing mosquito infection rates among counties and regions. Although 90% of California's population lives in areas with vector control agencies, not all agencies have the capacity to conduct robust mosquito surveillance and testing.



OEHHA acknowledges the expert contributions of the following to this report:



Andrea Lund PhD, MPH,
Vicki Kramer PhD
Anne Kjemtrup DVM, PhD, MPVM
Mary Danforth PhD
California Department of Public Health
Vector-Borne Disease Section
vbds@cdph.ca.gov

References

- Abbasi E (2025). The impact of climate change on travel-related vector-borne diseases: A case study on dengue virus transmission. *Travel Medicine and Infectious Disease* **65**: 102841.
- Angell KE, Broadhurst MJ, Dong JJ, Michaud TL, Degarege A, et al. (2025). Quantifying the public health impact of Lyme disease in Minnesota: A simulation analysis of reported and unreported cases. *Journal of Health Economics and Outcomes Research* **12**(2): 221-228.
- Bayles BR, George MF, and Christofferson RC (2024). Long-term trends and spatial patterns of West Nile virus emergence in California, 2004-2021. *Zoonoses and Public Health* **71**: 258-266.
- Benedum CM, Seidahmed OM, Eltahir EA, and Markuzon N (2018). Statistical modeling of the effect of rainfall flushing on dengue transmission in Singapore. *PLoS Neglected Tropical Diseases* **12**(12): e0006935.
- Carney RM, Ahearn SC, McConchie A, Glaser CA, Jean C, et al. (2011). Early Warning System for West Nile Virus Risk Areas, California, USA. *Emerging Infectious Diseases* **17**(8):1445-1454.
- CDC (2021). Centers for Disease Control and Prevention. General Questions about West Nile Virus. Retrieved February 15, 2022.
- CDC (2024). Centers for Disease Control and Prevention. [Life Cycles of Aedes Mosquitoes](#). Retrieved October 27, 2025.
- CDC (2025a). Centers for Disease Control and Prevention. [Dengue](#). Retrieved October 27, 2025.
- CDC (2025b). Centers for Disease Control and Prevention. West Nile Virus Key Messages. Retrieved December 10, 2025.
- CDC (2025c). Centers for Disease Control and Prevention. Lyme Disease Case Maps: Reported cases of Lyme disease, 2023. Retrieved July 13, 2026.
- CDPH (2005). *West Nile virus activity in California, 2005*. California Department of Public Health.
- CDPH (2015). [California sets record for West Nile virus activity](#). Press release 15-027. California Department of Public Health.
- CDPH Infectious Disease Branch (2021). *Epidemiologic Summaries of Selected Communicable Diseases in California, 2013 – 2019: Technical Notes*. California Department of Public Health Infectious Disease Branch.



CDPH (2024). California Department of Public Health. [Vector-Borne Disease Section Annual Reports](#). Retrieved October 24, 2025.

CDPH (2025a). California Department of Public Health Dengue Website. Accessed March 16, 2025.

CDPH (2025b). California Department of Public Health Lyme Disease Website. Accessed March 16, 2025.

CDPH (2025c). California Department of Public Health West Nile Virus Website. Accessed March 16, 2025.

CDPH (2025d). *Guidance for Surveillance of and Response to Invasive Aedes Mosquitoes and Dengue, Chikungunya, and Zika in California*. California Department of Public Health, Division of Communicable Disease Control.

CDPH (2026a). California Department of Public Health. Personal correspondence with Andrea Lund.

CDPH (2026b). *California Mosquito-Borne Virus Surveillance and Response Plan*. California Department of Public Health, Mosquito and Vector Control Association of California, and University of California.

Childs ML, Lyberger K, Harris MJ, Burke M, and Mordecai EA (2025). Climate warming is expanding dengue burden in the Americas and Asia. *Proceedings of the National Academy of Sciences* **122**(37): e2512350122.

Coalson JE, Anderson EJ, Santos EM, Madera Garcia V, Romine JK, et al. (2021). The complex epidemiological relationship between flooding events and human outbreaks of mosquito-borne diseases: a scoping review. *Environmental Health Perspectives* **129**(9): 096002.

Danforth ME, Snyder RE, Feiszli T, Bullick T, Messenger S, et al. (2022). Epidemiologic and environmental characterization of the Re-emergence of St. Louis Encephalitis Virus in California, 2015–2020. *PLoS Neglected Tropical Diseases* **16**(8): e0010664.

de Souza WM and Weaver SC (2024). Effects of climate change and human activities on vector-borne diseases. *Nature Reviews Microbiology* **22**(8): 476-491.

Diniz DF, de Albuquerque CM, Oliva LO, de Melo-Santos MA, and Ayres CF (2017). Diapause and quiescence: dormancy mechanisms that contribute to the geographical expansion of mosquitoes and their evolutionary success. *Parasites and Vectors* **10**(1): 310.

Donnelly MA, Kluh S, Snyder RE, and Barker CM (2020). Quantifying sociodemographic heterogeneities in the distribution of *Aedes aegypti* among California households. *PLoS Neglected Tropical Diseases* **14**(7): e0008408.

Eisen RJ, Feirer S, Padgett KA, Hahn MB, Monaghan AJ, et al. (2018). Modeling climate suitability of the western blacklegged tick in California. *Journal of Medical Entomology* **55**(5): 1133-1142.

Feaster M, Patrick R, Oshiro M, Kuan M, Goh Y-Y, et al. (2024). Notes from the field: First locally acquired dengue virus infections—Pasadena, California, October–December 2023. *Morbidity and Mortality Weekly Report* **73**(42): 955-956.

Fyie LR, Tronetti HR, Gardiner MM, and Meuti ME (2023). Potential for urban warming to postpone overwintering dormancy of temperate mosquitoes. *Journal of Thermal Biology* **115**: 103594.

Gilbert L (2021). The impacts of climate change on ticks and tick-borne disease risk. *Annual Review of Entomology* **66**(1): 373-388.



Gorris ME, Bartlow AW, Pitts T, and Manore CA (2024). Projections of *Aedes* and *Culex* mosquitoes across North and South America in response to climate change. *The Journal of Climate Change and Health* **17**: 100317.

Hahn MB, Feirer S, Monaghan AJ, Lane RS, Eisen RJ, et al. (2021). Modeling future climate suitability for the western blacklegged tick, *Ixodes pacificus*, in California with an emphasis on land access and ownership. *Ticks and Tick-borne Diseases* **12**(5): 101789.

Harrigan RJ, Thomassen HA, Buermann W, Cummings RF, Kahn ME, et al. (2010). Economic Conditions Predict Prevalence of West Nile Virus. *PLoS ONE* **5**(11): e15437.

Hernandez E, Torres R, and Joyce AL (2019). Environmental and sociological factors associated with the incidence of West Nile Virus cases in the northern San Joaquin Valley of California, 2011-2015. *Vector-borne and zoonotic diseases* **19**(11).

Hill M, Wilke AB, Fuller DO, Kummer AG, Ventura PC, et al. (2023). Environmental and socio-economic determinants of mosquito vector species presence and abundance in Los Angeles County, California. *Research Square* (pre-print).

Kilpatrick AM, Dobson ADM, Levi T, Salkeld DJ, Swei A, et al. (2017). Lyme disease ecology in a changing world: consensus, uncertainty and critical gaps for improving control. *Philosophical Transactions of the Royal Society of London B: Biological Sciences* **372**(1722): 20160117.

Koenraadt CJ and Harrington LC (2008). Flushing effect of rain on container-inhabiting mosquitoes *Aedes aegypti* and *Culex pipiens* (Diptera: Culicidae). *Journal of Medical Entomology* **45**(1): 28-35.

Kovach TJ and Kilpatrick AM (2024). Irrigation increases and stabilizes mosquito populations and increases West Nile virus incidence. *Scientific Reports* **14**: 19913.

MacDonald AJ, McComb S, O'Neill C, Padgett KA, and Larsen AE (2020). Projected climate and land use change alter western blacklegged tick phenology, seasonal host-seeking suitability and human encounter risk in California. *Global Change Biology* **26**(10): 5459-5474.

MacDonald AJ, Sousa D, Quandt A, Sambado S, Sipin TJ, et al. (2025). Extreme climate whiplash events drive divergent responses of mosquito-borne disease. *PNAS Nexus* **4**(8): 223.

Metzger ME, Hardstone Yoshimizu M, Padgett KA, Hu R, and Kramer VL (2017). Detection and establishment of *Aedes aegypti* and *Aedes albopictus* (Diptera: Culicidae) mosquitoes in California, 2011–2015. *Journal of Medical Entomology* **54**(3): 533-43.

Mordecai EA, Cohen JM, Evans MV, Gudapati P, Johnson LR, et al. (2017). Detecting the impact of temperature on transmission of Zika, dengue and chikungunya using mechanistic models. *PLOS Neglected Tropical Diseases* **11**(4): e0005568.

Mordecai EA, Caldwell JM, Grossman MK, Lippi CA, Johnson LR, et al. (2019). Thermal biology of mosquito-borne disease. *Ecology Letters* **22**(10): 1690-1708.

Mostashari F, Bunning ML, Kitsutani PT, Singer DA, Nash D, et al. (2001). Epidemic West Nile encephalitis, New York, 1999: results of a household-based seroepidemiological survey. *Lancet* **358**(9278): 261-4.

MVCAC (2008). *Proceedings and Papers of the Seventy-Sixth Annual Conference of the Mosquito and Vector Control Association of California*. Mosquito and Vector Control Association of California. Palm Springs, California.



Ogden NH and Lindsay LR (2016). Effects of climate and climate change on vectors and vector-borne diseases: ticks are different. *Trends in Parasitology* **32**(8): 646-656.

PAHO (2025). Pan American Health Organization. [Dengue Multi-County Grade 3 Outbreak](#). Retrieved October 24, 2025.

Parker N (2024). Exploring the role of temperature and other environmental factors in West Nile virus incidence and prediction in California counties from 2017–2022 using a zero-inflated model. *PLoS Neglected Tropical Diseases* **18**(6): e0012051.

Paull SH, Horton DE, Ashfaq M, Rastogi D, Kramer LD, et al. (2017). Drought and immunity determine the intensity of West Nile virus epidemics and climate change impacts. *Proceedings of the Royal Society B: Biological Sciences* **284**(1848): 20162078.

Porse CC, Kramer V, Yoshimizu MH, Metzger M, Hu R, et al. (2015). Public health response to *Aedes aegypti* and *Ae. albopictus* mosquitoes invading California, USA. *Emerging Infectious Diseases* **21**(10): 1827.

Reeves WC, Hardy JL, Reisen WK, and Milby MM (1994). Potential effect of global warming on mosquito-borne arboviruses. *Journal of Medical Entomology* **31**(3): 323-332.

Reisen WK (1995). Effect of temperature on *Culex tarsalis* (Diptera: Culicidae) from the Coachella and San Joaquin valleys of California. *Journal of Medical Entomology* **32**(5): 636-45.

Reisen WK, Cayan D, Tyree M, Barker CM, Eldridge B, and Dettinger M (2008). Impact of climate variation on mosquito abundance in California. *Journal of Vector Ecology* **33**(1): 89-98.

Reisen WK, Fang Y, Lothrop HD, Martinez VM, Wilson J, et al. (2006). Overwintering of West Nile virus in southern California. *Journal of Medical Entomology* **43**(2): 344-355.

Reisen WK, Hardy JL, Presser SB, Milby MM, Meyer RP, et al. (1992). Mosquito and arbovirus ecology in southeastern California, 1986–1990. *Journal of Medical Entomology* **29**(3): 512-524.

Rochlin I, Faraji A, Ninivaggi DV, Barker CM, and Kilpatrick AM (2016). Anthropogenic impacts on mosquito populations in North America over the past century. *Nature Communications* **7**:13604.

Russell MC, Bliss DA, Fischer GA, Riehle MA, Rappazzo KM, et al. (2025). Evaluating associations between drought and West Nile virus epidemics: A systematic review. *Microorganisms* **13**: 2851.

Sambado S, Sipin TJ, Rennie Z, Larsen A, Cunningham J, et al. (2025a). The paradoxical impact of drought on West Nile virus risk: insights from long-term ecological data. *Proceedings B* **292**(2054): 20251365.

Sambado S, Sparkman A, Swei A, MacDonald AJ, Young HS, et al. (2025b). Climate-driven variation in the phenology of juvenile *Ixodes pacificus* on lizard hosts. *Parasites & Vectors* **18**(1): 141.

Shaman J, Day JF, and Stieglitz M (2005). Drought-induced amplification and epidemic transmission of West Nile virus in southern Florida. *Journal of Medical Entomology*. 2005 **42**(2): 134-41.

Snyder R, Feiszli T, Foss L, Messenger S, Fang Y, et al. (2020) West Nile virus in California, 2003-2018: A persistent threat. *PLoS Neglected Tropical Diseases* **14**(11): e0008841.

Swain DL, Langenbrunner B, Neelin JD, and Hall A (2018). Increasing precipitation volatility in twenty-first-century California. *Nature Climate Change* **8**: 427–433.



Swei A, Meentemeyer R, and Briggs CJ (2011). Influence of abiotic and environmental factors on the density and infection prevalence of *Ixodes pacificus* (Acari: Ixodidae) with *Borrelia burgdorferi*. *Journal of Medical Entomology* **48**(1): 20-28.

USGCRP (2016). *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*. United States Global Change Research Group. Washington, DC.

USGCRP (2018). *Human Health. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*. United States Global Change Research Group. Washington DC.

VectorSurv Maps (2025). [Vectorborne Disease Surveillance Maps](#). Retrieved January 26, 2026.

Ward MJ, Sorek-Hamer M, Henke JA, Little E, Patel A, et al. (2023). A spatially resolved and environmentally informed forecast model of West Nile virus in Coachella Valley, California. *GeoHealth* **7**(12): e2023GH000855.

Watts MJ, Monteys VS, Mortyn PG, and Kotsila P (2021). The rise of West Nile Virus in Southern and Southeastern Europe: A spatial–temporal analysis investigating the combined effects of climate, land use and economic changes. *One Health* **13**: 100315.

WHO (2023). [Dengue – Global situation](#). World Health Organization Disease Outbreak News.

White GS, Symmes K, Sun P, Fang Y, Garcia S, et al. (2016). Reemergence of St. Louis Encephalitis Virus, California, 2015. *Emerging Infectious Diseases* **22**(12): 2185-2188.

Wiyot Tribe (2026). Impacts of Climate Change on the Wiyot Tribe. In: OEHHA 2026 Indicators of Climate Change in California.

