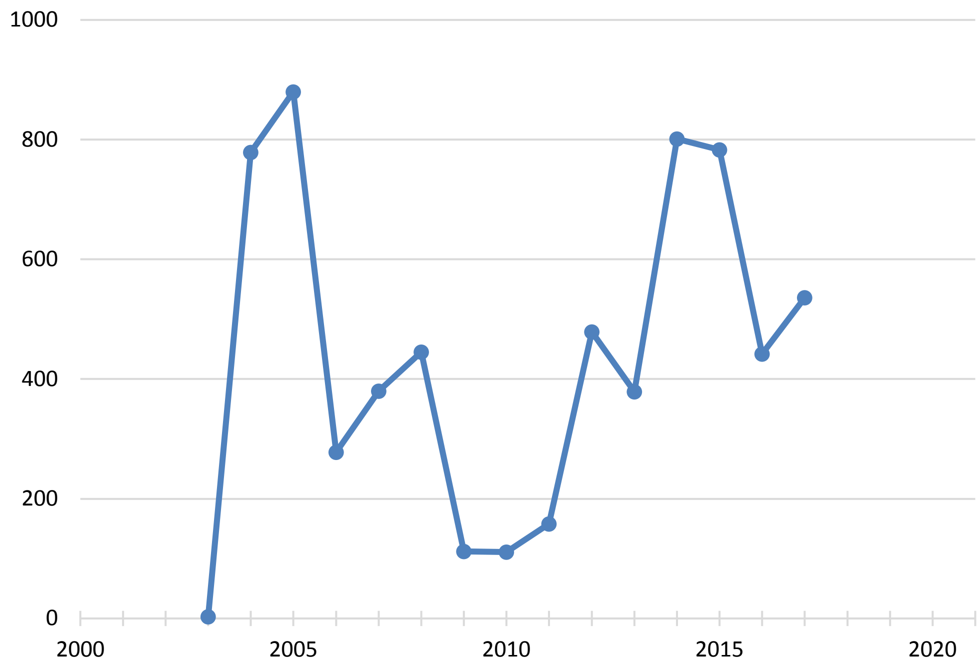
VECTOR-BORNE DISEASES

Warming temperatures and changes in precipitation can affect vector-borne pathogen transmission and disease patterns in California. West Nile Virus currently poses the greatest mosquito-borne disease threat.

Figure 1. Human West Nile Virus cases in California, 2003-2017



Source: CDPH, 2018

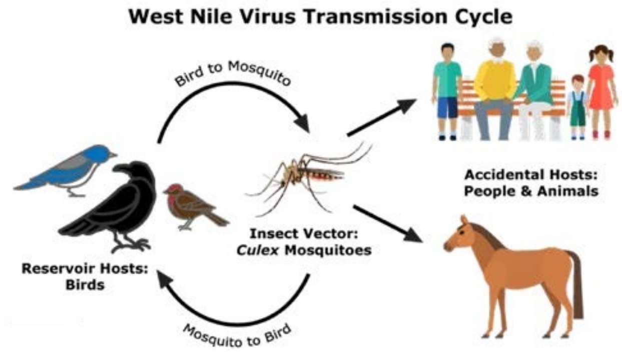
What does the indicator show?

Figure 1 shows human cases of West Nile Virus (WNV) reported in California. Of the 15 mosquito-borne viruses known to occur in California, WNV in particular continues to seriously impact the health of humans, horses and wild birds throughout the state (CDPH, 2016). First detected in the state in 2003 (when three cases were reported), WNV cases show no clear trend, varying from year to year over the 16-year period shown. The number of cases peaked in 2004-2005, and in 2014-2015.

Why is this indicator important?

Tracking vector-borne disease is critical for understanding the associations between disease prevalence and climate trends. Climate change will likely affect vector-borne disease transmission patterns. Changes in temperature and precipitation can influence seasonality, distribution, and prevalence of vector-borne diseases (USGRCP, 2016). In fact, due to their widespread occurrence and sensitivity to climatic factors, vector-borne diseases are some of the illnesses that have been most closely associated with climate change (Smith et al., 2014).

For most Californians, WNV poses the greatest mosquito-borne disease threat. The majority of infections are undetected and therefore not reported since symptoms can be very mild or absent. Symptomatic infections involve generalized health effects that may include fever, headache, body aches, nausea, vomiting, swollen lymph glands or a skin rash, and in some cases fatigue or weakness that lasts for weeks or months. “Neuroinvasive cases” (generally less than one percent of WNV infections) can result in encephalitis or meningitis, with symptoms that may include high fever, neck stiffness, disorientation, tremors, numbness and paralysis and coma, and in the most severe cases, death; the fatality rate is reported at 10 percent (CDC, 2015). Over the past decade, cases of WNV neuroinvasive disease have increased at a greater rate than non-neuroinvasive cases, although this is likely due to underreporting; the latter are milder cases which generally do not require medical attention. The number of human cases reported in California in 2015 (783) was the third highest since 2003 and the number of fatal cases (53) was the highest ever reported. As discussed below, drought appears to increase the prevalence of WNV. The record hot temperatures statewide and extended drought may have contributed to the elevated activity (CDPH, 2016).



Source: California Department of Public Health, 2018

Vector-borne diseases are caused by pathogens transmitted by living organisms, such as mosquitoes and ticks. In California, most vector-borne diseases are caused by viruses, bacteria or other pathogens spread from animal reservoirs to incidental humans and domestic animal hosts. West Nile Virus is an arthropod-borne virus, or arbovirus, which is the largest class of vector-borne human pathogens (NAS, 2016). *The virus is most commonly spread by the bite of an infected mosquito* (CDPH, 2018).

In addition to WNV, other mosquito-borne viruses that can cause significant illness are the western equine encephalomyelitis virus (WEEV) and St. Louis encephalitis virus (SLEV) (Reisen and Coffey, 2014). While WEEV has been detected only rarely in recent years (Bergren et al., 2014), SLEV has re-emerged in California starting in 2015 after over a decade without detection, causing three reported cases of human disease in 2016 (White et al., 2016). WEEV activity has been shown to decrease with increasing temperatures (Reeves et al., 1994), whereas SLEV activity and outbreaks have long been associated with elevated temperatures (Monath, 1980).

Two invasive mosquito species recently found in several California counties can potentially spread to other areas of the state: *Aedes aegypti* (the yellow fever mosquito) and *Aedes albopictus* (the Asian tiger mosquito) (see map posted at: https://arcg.is/00j1P8). Both mosquitoes have the potential to transmit several viruses, including Zika, dengue fever, chikungunya, and yellow fever viruses. Although all cases of these viruses detected in California through April 2017 have been associated with travel, the presence of its vectors adds to the potential risk of local mosquito-borne transmission of these viruses, especially if these species become more widely established in the state. The emergence of new infectious diseases associated with invasive species can be influenced by a number of factors, including land use changes (e.g., urbanization), the introduction of new hosts and climate change (NAS, 2016).

In addition to mosquito vectors, climate change will invariably impact the prevalence of tick-borne pathogens in California. Lyme disease, the most commonly reported tick-borne disease, is transmitted by the western blacklegged tick (*Ixodes pacificus).* The abundance of the western blacklegged tick is limited by abiotic conditions during the summer dry season (Swei et al., 2011). Prolonged hot dry periods may reduce tick abundance and therefore decrease Lyme disease risk in some locations, although if relative humidity is maintained, an increase in temperature may increase the number of infected ticks (Eisen et al., 2003). In contrast, the distribution of one vector of Rocky Mountain spotted fever (RMSF), the brown dog tick (*Rhipicephalus sanguineus),* may expand with increased frequencies of El Niño Southern Oscillation (ENSO) events. This could cause an increase in RMSF cases (Fisman et al., 2016). The on-going outbreak of RMSF in northern Mexico, which occasionally results in human cases in the United States through imported dogs or ticks, is a multifactorial problem involving climate and socioeconomic factors (Álvarez-Hernández et al., 2017).

Extreme precipitation events often associated with ENSO events are thought to impact hantavirus activity by expanding rodent habitat, particularly in normally arid habitats adjacent to humans (Carver et al., 2015). Hantavirus prevalence in rodents continues to be monitored in California in locations where rodents and humans may come in contact. Although the 2012 hantavirus outbreak in Yosemite National Park was associated with rodent habitat enrichment provided by cabin construction rather than with weather abnormalities, it was an example of how human hantavirus infection risk can increase when rodent densities are given the opportunity to increase.

What factors influence this indicator?

In California, changes in temperature and precipitation have been associated with WNV activity (Paull et al., 2017; Hartley et al., 2012). Such change may also alter the transmission risk of hantavirus and tick-borne diseases such as Lyme disease, by affecting the distribution and abundance of deer mice (host animal) and ticks (vector), respectively (Carver et al., 2015; Ogden and Lindsay, 2016). Finally, as discussed above, a changing climate may create conditions favorable for the establishment of invasive mosquito vectors in California (Ogden et al., 2014).

Above-normal temperatures are among the most consistent factors associated with WNV outbreaks (Hahn et al., 2015). Mild winters have been associated with increased WNV transmission possibly due, in part, to less mosquito and resident bird mortality. Warmer winter and spring seasons may also allow for transmission to start earlier. Such conditions also allow more time for virus amplification in bird-mosquito cycles, possibly increasing the potential for mosquitoes to transmit WNV to people*.* The effects of increased temperature are primarily through acceleration of physiological processes within mosquitoes, which results in faster larval development and shorter generation times, faster blood meal digestion and therefore more frequent mosquito biting, and shortening of the incubation period time required for infected mosquitoes to transmit WNV (Hoover and Barker, 2016).

A useful measure of the efficiency of transmission of a vector-borne pathogen is the number of bites or blood meals required by the vector before the pathogen can be transmitted. Investigators have studied the efficiency of transmission of mosquito-borne pathogens when mosquitoes were incubated at different temperatures (Reisen et al., 2006). They report that with increasing temperatures, fewer blood meals are required for transmission and there is a higher probability that the virus can be transmitted within a mosquito's lifetime. Similar data have been used to delineate the effective global distribution of different malaria parasites and how climate change may have altered this pattern (Chaves and Koenraadt, 2010; Parham and Michael, 2010).

Precipitation and associated hydrological impacts also influence the likelihood of WNV transmission. Expected shifts of winter precipitation from snow to rain at high elevations (see *Precipitation* indicator) will limit water storage and cause spring runoff to occur earlier and faster, which would result in increased mosquito habitat during wet years (DWR, 2017). Periods of elevated rainfall (for example during El Niño events) can increase immature habitats for mosquitoes and increase population survival due to higher humidity (Linthicum et al., 2016).

During periods of drought, especially in urban areas, mosquitoes tend to thrive more due to changes in stormwater management practices. Under drought conditions, mosquitoes in urban areas can reach higher abundance due to stagnation of underground water in stormwater systems that would otherwise be flushed by rainfall. Runoff from landscape irrigation systems mixed with organic matter can also create ideal mosquito habitat (Hoover and Barker, 2016). Drought conditions may also force birds to increase their utilization of suburban areas where water is more available, thereby bringing these WNV hosts into contact with urban vectors (Reisen, 2013). Drought was found to be an important predictor of reported annual WNV neuroinvasive disease cases in California and nationwide (Paull et al., 2017).

Although a changing climate will likely alter the distribution of disease vectors in both time and space, it is important to recognize the role of social and environmental drivers (USGCRP, 2016). Vector-borne disease transmission can be influenced by such factors as how pathogens adapt and change, the availability of susceptible hosts, human behavior (for example time spent indoors), and mosquito and vector control programs. These factors were found to be major drivers of changes in mosquito populations over the last eight decades in areas on both coasts of North America (Rochlin et al., 2016).

Technical Considerations

Data Characteristics

California has a comprehensive mosquito-borne disease surveillance program that has monitored mosquito abundance and mosquito-borne virus activity since 1969 (CDPH, 2017). Statewide, diagnosis of human infection with WNV and other arboviruses is performed at the California Department of Public (CDPH) Health Viral and Rickettsial Disease Laboratory, nine local county public health laboratories, and multiple commercial laboratories. Human WNV cases in California have been reported to the Centers for Disease Control and Prevention (CDC) since the virus was first detected in 2003. Surveillance also includes monitoring virus activity in mosquitoes and vertebrate hosts that enzootically amplify the virus for purposes of providing warning of human disease risk. In addition to mosquito-borne diseases, CDPH works with local, state, and federal agencies, universities, the medical community and others in its efforts to monitor, prevent, and control rodent-, flea-, and tick-borne diseases.

Strengths and Limitations of the Data

For human disease surveillance, local mosquito control agencies rely on the detection and reporting of confirmed cases to plan emergency control and prevention activities. However, human cases of mosquito-borne viruses are an insensitive surveillance measure because less severe fever cases are rarely diagnosed and most infected persons do not develop disease (CDPH, 2017). With WNV, most people infected do not develop symptoms and these infections are not detected, except by blood bank screening.

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