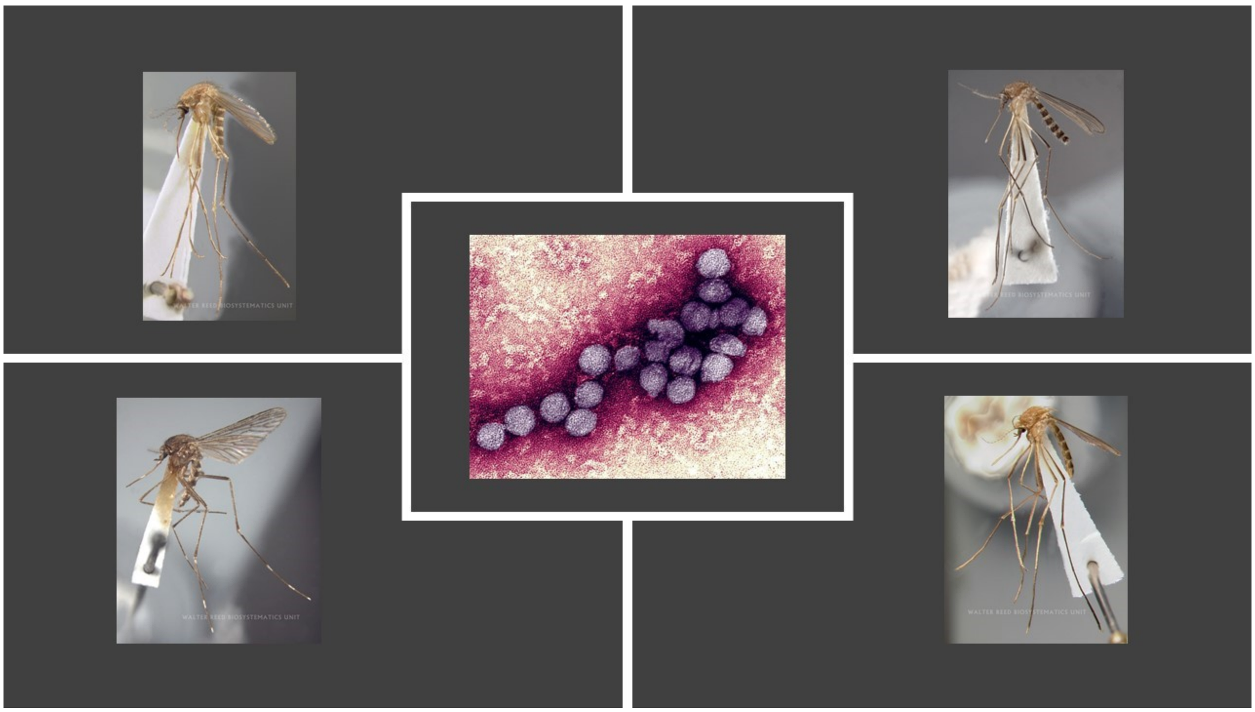
West Nile Virus: CONUS
Vector Hazard Report:



(Photo: Getty Images, WRBU)

Compiled by David Pecor and Alexander Potter, WRBU

November 2019

West Nile Virus

I. Disease Background: West Nile virus (WNV) fever is a mosquito-borne illness characterized by fever, headache, muscular pain, and rash. Around 1 in 150 people will develop serious complications involving the liver and nervous system. This more serious form of WNV is known as a neuroinvasive disease, West Nile encephalitis, or West Nile poliomyelitis. People at a higher risk of developing this more serious form of WNV infections are those with conditions that weakened immune systems (such as organ transplants, HIV/Aids patients, etc.), very young or old patients, and pregnant mothers. Almost 80% of people infected with WNV will see no symptoms. The etiological agent, West Nile virus, is named after the district of Uganda where the virus was first isolated. It is a Flavivirus closely related to viruses causing Japanese encephalitis and St. Louis encephalitis. Infection with WNV is most often asymptomatic. The incubation period ranges from 1 to 14 days and clinically resembles a mild dengue-like illness. WNV is the most common mosquito-borne arbovirus in the continental United States.

II. Military Impact and Historical Perspective: WNV was first isolated in 1937 and was one of the earliest human arboviral infections to be documented. The first known outbreak/epidemic was recognized in 1951 in Israel where 123 out of 303 inhabitants of a small town were infected without any morbidity. Several sizeable outbreaks occurred in Egypt from 1951 until 1954 as well. The 1970's and 1980's saw WNV outbreaks become more infrequent. The epidemiology and symptomatology began to change in 1996 when the virus changed from having rural foci to becoming an urban disease when an outbreak was seen in Bucharest, Romania in the same year. From this point on, West Nile radiated throughout the Middle East, North Africa, and Europe (Sejvar, 2003). West Nile was originally introduced to New York City in 1999 through an imported strain circulating through Israel and Tunisia. This sparked a substantial outbreak in the continental USA during the following years up until 2010, and has since spread and become established from Canada to Venezuela. Within 5 years of the first confirmed human cases of WNV in the United States the virus had been detected in all but four states: Alaska, Hawaii, Maine, and Washington. Since then, WNV has been detected in the District of Columbia and every one of the lower 48 states. The CDC reports 50,830 (24,657 neuroinvasive) confirmed cases and 2,330 deaths from the United States between 1999 and 2018. However, there have been estimates that over 3 million people were infected with WNV in the US during the initial outbreak between 1999 and 2010 with ~780,000 of those cases resulting in sickness (Petersen et al., 2012). Undoubtedly, WNV has been the cause of many cases classified as fevers of unknown origin in military personnel. Infection with WNV will complicate diagnoses by medical personnel, since West Nile fever cannot be clinically distinguished from many other arboviral fevers. Epidemics of West Nile fever are infrequent today, and continued long-term surveillance for virus activity can rarely be justified when considering other health care demands. Reduction of mosquito populations by ULV spraying may be useful as a means of disease control. The most feasible long-term control strategies involve reducing vector breeding by environmental management techniques. Personal protective measures to prevent mosquito bites are the most practical means of avoiding infection with WNV.

West Nile Virus

III. Transmission Cycle(s): WNV has been isolated from several species of birds and mammals. Wild birds are considered the primary disease reservoir for WNV and may reintroduce the virus during annual migrations. Infections in mammals often fail to produce virus levels that are high enough to infect mosquito vectors. WNV has been detected in many species of mosquitoes naturally, especially *Culex* spp. which are primarily bird-feeders. Vector competency studies clearly implicate mosquitoes in the transmission of WNV to humans (Turell, 2001). Studies have shown in laboratory settings, WNV can replicate from 14°C in mosquitoes up to 45°C in some avian hosts. WNV replicates quickly in mosquitoes when temperatures exceed 25°C, however, temperatures above 30°C have slowed the growth and replication of WNV in the vector species *Culex univittatus* (Paz, 2015). Precipitation has played a key role in WNV incidence in the USA as well. One study showed that in weeks with one or more days of precipitation of 50mm or higher there was shown to be a 33% in WNV infections reported that week and in the following two weeks (Soverow, *et al*., 2009). Infected mosquitoes can transmit WNV for life.

IV. Additional Resources:

CDC West Nile Virus Background

WHO West Nile Virus Background

APHC Fact Sheet

HealthMap

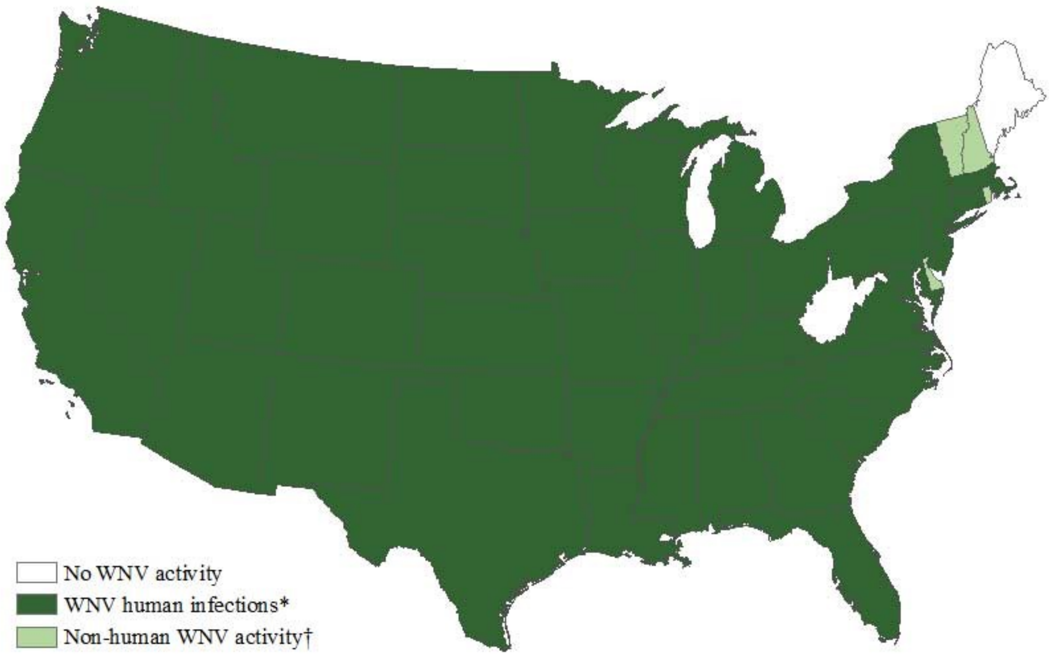
Petersen, L.R., Carson, P.J., Biggerstaff, B.J., et al. (2012). Estimated cumulative incidence of West Nile virus infection in US adults, 1999-2010. Epidemiology & Infection, 141(3): 591-595.

Asnis, D.S., Conetta, R., Teixeira, A.A. et al. (2000). The West Nile Virus Outbreak of 1999 in New York: The Flushing Hospital Experience. Clinical Infectious Diseases, 30:3: 413-418.

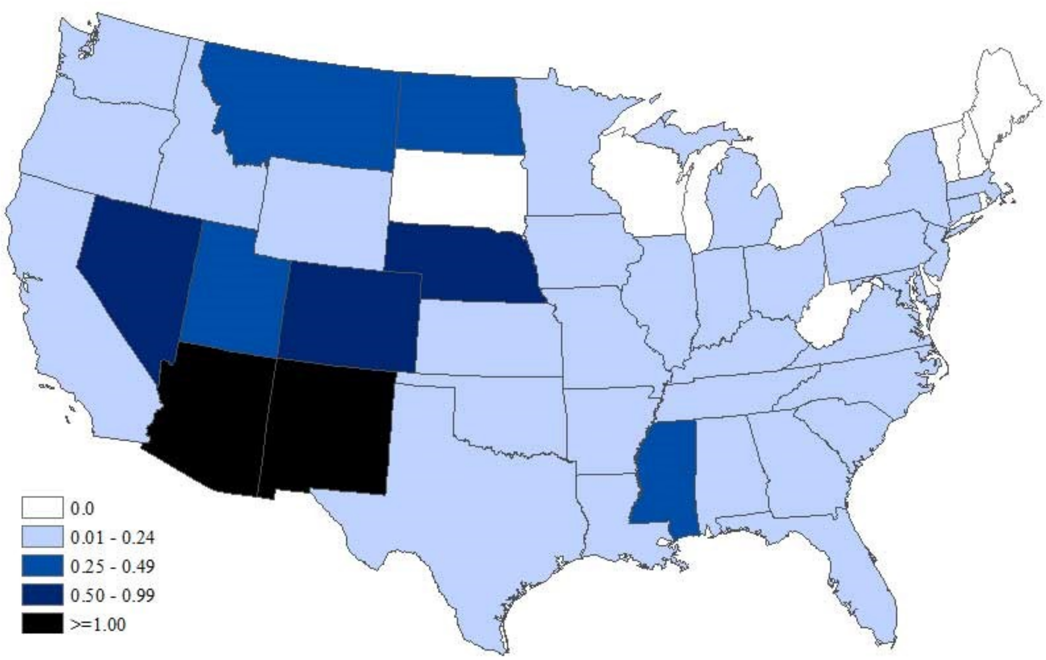
Paz, S. (2015). Climate change impacts on West Nile virus transmission in a global context. Philosophical Transactions of the Royal Society B, 370: 20130561.

Turell, M. J., O'Guinn, M. L., Dohm, D. J., & Jones, J. W. (2001). Vector competence of North American mosquitoes (diptera: culicidae) for West Nile virus. Journal of medical entomology, 38(2), 130-134.

Stoto, M.A., Dausey, D.J., Davis, L.M. *et al*. (2005). Learning from Experience: The Public Health Response to West Nile Virus, SARS, Monkeypox, and Hepatitis A Outbreaks in the United States. RAND Corporation.



West Nile Virus Activity by State 2019 ([CDC](CDC))



West Nile Virus Neuroinvasive Disease Incidence per 100,000 population by State 2019 ([CDC](CDC))

Culex spp.

I. Vector Surveillance and Suppression: Reduction of mosquito populations by ultra-low volume (ULV) spraying may be useful as a means of disease control. The most feasible long-term control strategies involve reducing vector breeding by environmental management techniques. Personal protective measures to prevent mosquito bites are the most practical means of avoiding infection with WNV. Consult AFPMB Technical Guide No. 13: Dispersal of Ultra Low Volume (ULV) Insecticides by Cold Aerosol and Thermal Fog Ground Application Equipment; AFPMB Technical Guide No. 24: Contingency Pest Management Guide, and AFPMB Technical Guide No. 40: Methods for Trapping and Sampling Small Mammals for Virologic Testing.

II. Reported Insecticide Resistance:

Stancil, J.D. (2000). Insecticide Resistance and Resistance Mechanisms in the Southern House Mosquito, *Culex quinquefasciatus*. LSU Historical Dissertations and Theses. 7299.

.Richards, S.L., Balaney, J.A.G., White, A.V., et al. (2018). Insecticide Susceptibility Screening Against *Culex* and *Aedes* (Diptera: Culicidae) Mosquitoes From the United States. Journal of Medical Entomology, 55(2): 398-407.

III. Vector Identification:

Darsie Jr, R. F., & Ward, R. A. (2005). Identification and geographical distribution of the mosquitoes of North America, north of Mexico. University Press of Florida.

Harrison, B. A., Byrd, B. D., Sither, C. B., & Whitt, P. B. (2016). The mosquitoes of the Mid-Atlantic region: an identification guide. Cullowhee, NC: Western Carolina University.

CDC Pictorial Key to Common Mosquitoes of the US

IV. Additional Resources:

CABI, 2017. *Culex quinquefasciatus* (southern house mosquito). In: Invasive Species Compendium. Wallingford, UK: CAB International. https://www.cabi.org/isc/datasheet/86848

Vincent, G.P., Davis, J.K., Wimberly, M.C., et al. (2018). Permethrin Susceptibility for the Vector *Culex tarsalis* and a Nuisance Mosquito *Aedes vexans* in an Area Endemic for West Nile Virus. BioMed Research International, 2018: 2014764.

Lampman, R.L. & Novak, R.J. (1996). Oviposition Preferences of *Culex pipiens* and *Culex restuans* for Infusion-Baited Traps. Journal of the American Mosquito Control Association, 12(1):23-32.

WRBU Catalog

Culex (*Cux.*) *pipiens* Linnaeus, 1758

Bionomics:

Larvae of *Cx. pipiens* are found in numerous and variable breeding places ranging from highly polluted cesspits to clear water pools and containers. Both shaded and unshaded larval habitats are utilized by this species. Females readily feed on humans both indoors and outdoors at night, however, they typically feed almost exclusively on birds.

Medical Importance:

Adult *Cx. pipiens* have been found naturally infected with Sindbis virus, West Nile viruses, Rift Valley fever virus and is a primary vector of periodic Bancroftian filariasis.

Associated Arboviruses:

AHSV, AINOV, FMV, GROV, ITV, JEV, LACV, LMV, OCKV, ROCV, SFV, TAHV, TURV, TVTV, TYUV, VEEV, USUV, *Wuchereria bancrofti*

WRBU Catalog

Romo, H., Papa, A., Kading, R., et al. (2018). Comparative Vector Competence of North American *Culex pipiens* and *Culex quinquefasciatus* for African and European Lineage 2 West Nile Viruses. The American Journal of Tropical Medicine and Hygiene, 98(6): 1863-1869.

Culex (*Cux.*) *quinquefasciatus* Say, 1823

Bionomics:

Immatures of *Cx. quinquefasciatus* have been found in domestic and peri-domestic habitats with clean or polluted water. Typical larval localities are sewers, ditches, agricultural seepage pits, etc. This species is an opportunistic feeder but primarily anthropophilic. *Cx. quinquefasciatus* feeds indoors and outdoors at night and will rest both indoors and outdoors as well. Larvae can be found in bodies of water containing a high degree of organic pollution and close to human habitation. Females readily enter houses at night and bite man in preference to other mammals (Sirivanakarn 1976).

Medical Importance:

This species is a vector of avian malaria, a primary vector of *Wuchereria bancrofti*, Western equine encephalomyelitis, St. Louis encephalitis and West Nile.

Associated Arboviruses:

AMTV, APEUV, APV, BEFV, BUNV, CHIKV, CHPV, CWV, EEEV, EHDV, GFV, INGV, JEV, KOTV, KOWV, KRIV, KUNV, MAGV, MVEV, NEPV, NTAV, ORIV OROV, PARAV, ROCV, RVFV, SFSV, SFV, STRV, TURV, USUV, VEEV, VSAV, VSIV, VSNJV, WANV, ZEGV, *P. relictum*

WRBU Catalog

VectorBase

Hannon, E.R., Jackson, K.C., Biggerstaff, B.J., et al. (2019). Bloodmeal Host Selection of *Culex quinquefasciatus* (Diptera: Culicidae) in Las Vegas, Nevada, United States. Journal of Medical Entomology, 56(3): 603-608.

Culex (*Cux.*) *restuans* Theobald, 1901

Bionomics:

Immatures of *Culex restuans* are often found in ditches, artificial containers, stream pools and a wide array of other habitats. Females have been known to lay 10 times the number of egg clutches in larval sites with added nutrients as opposed to solely water. Populations tend to reach their peak in spring and tend to decrease in number by early fall. *Culex restuans* is primarily ornithophilic, however, is known to opportunistically feed on other vertebrates including humans – even entering houses to feed. Adults overwinter in the eastern United States while their eggs and young die out during the winter season.

Medical Importance:

Culex restuans is considered a vector of Mermet Virus (MERV), St. Louis encephalitis (SLEV), West Nile Virus (WNV).

Associated Arboviruses:

EEEV, HPV, MERV

WRBU Catalog

Yu, D., Madras, N., & Zhu, H. (2018). Temperature-driven population abundance model for *Culex pipiens* and *Culex restuans* (Diptera: Culicidae). Journal of Theoretical Biology, 443: 28-38.

Culex (*Cux.*) *tarsalis* Coquillett, 1896

Bionomics:

Immatures can be found in a wide array of habitats both shaded and sunlit such as ditches, irrigation systems, ground pools, animal foot prints, etc. There does seem to be some specificity, however, as foul water habitats seem to be preferred. Immatures have been located in mountainous regions up to 9,000 feet. Adult females are aggressive, day-time biters who readily enter houses to feed. Females have been observed flying 4 km upwind and males traveling 1.6 km upwind suggesting that the adults are strong fliers. Host preference is largely dependent on host availability. In rural habitats *Culex tarsalis* seems to be primarily ornithophilic. In more developed habitats the species will opportunistically feed on cattle, horses, and man. *Culex tarsalis* is multivoltine and is typically active from late spring to early fall in temperate zones, however, in sub-tropical areas it's capable of breeding year round. Some frequented resting sites for adults are small, artificial structures such as chicken coops and naturally created shelters such as woodrat burrows. Females may be found during colder months overwintering in basements, caves, and other similar locations.

Medical Importance:

Culex tarsalis is believed to be the chief vector of western equine encephalitis virus under natural conditions. The virus has been isolated from wild-caught *C. tarsalis* on several occasions in areas in which the disease was both epidemic and epizootic. The viruses of both St. Louis and California encephalitis have been isolated from this mosquito. It also a vector of West Nile Virus.

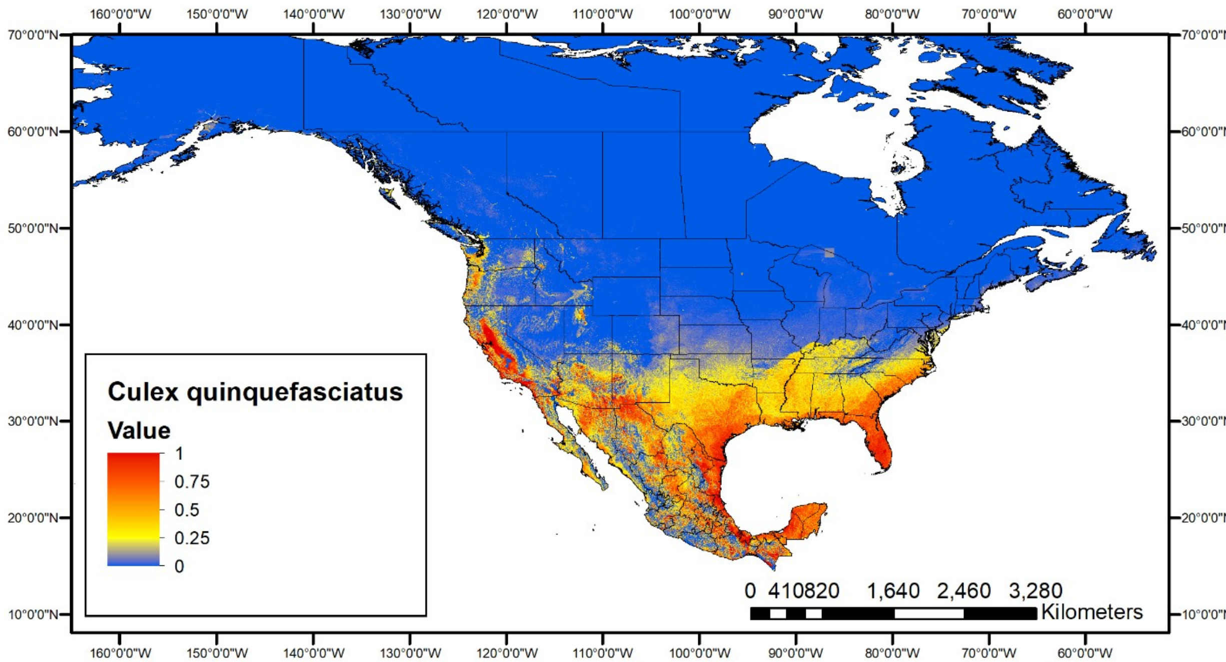
Associated Arboviruses:

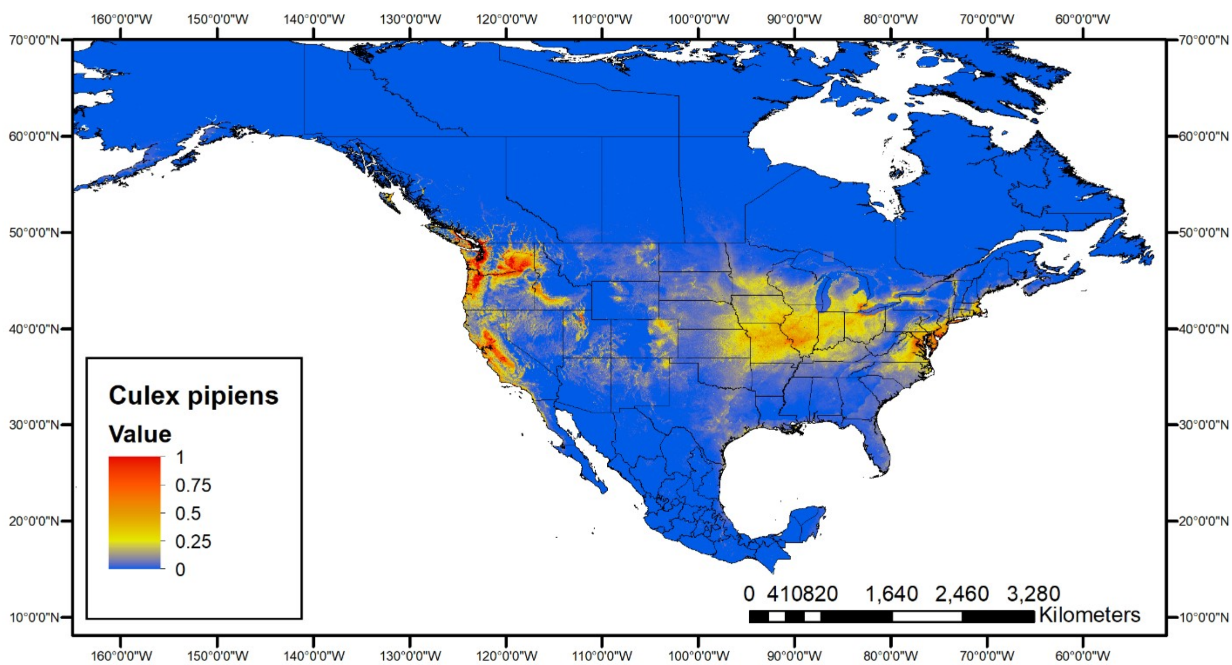
FLAV, GLOV, HPV, JCV, JSV, KEDV, LLSV, LOKV, MDV, MRV, NTAV, PGAV, ROCV, SFV, SHOV, TURV, VEEV, WSLV, *Plasmodium* spp.

WRBU Catalog

Dunphy, B.M., Kovach, K.B., Gehrke, E.J., et al. (2019). Long-term surveillance defines spatial and temporal patterns implicating *Culex tarsalis* as the primary vector of West Nile virus. Scientific Reports, 9: 6637.

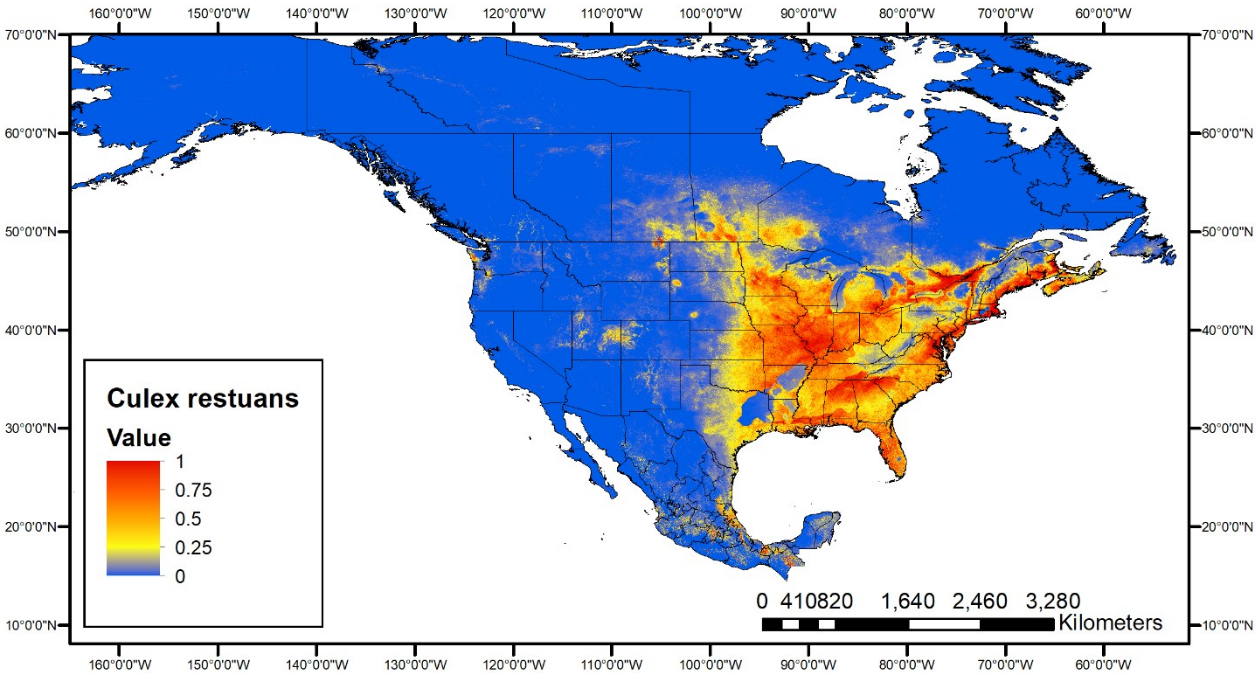
Habitat Suitability Models

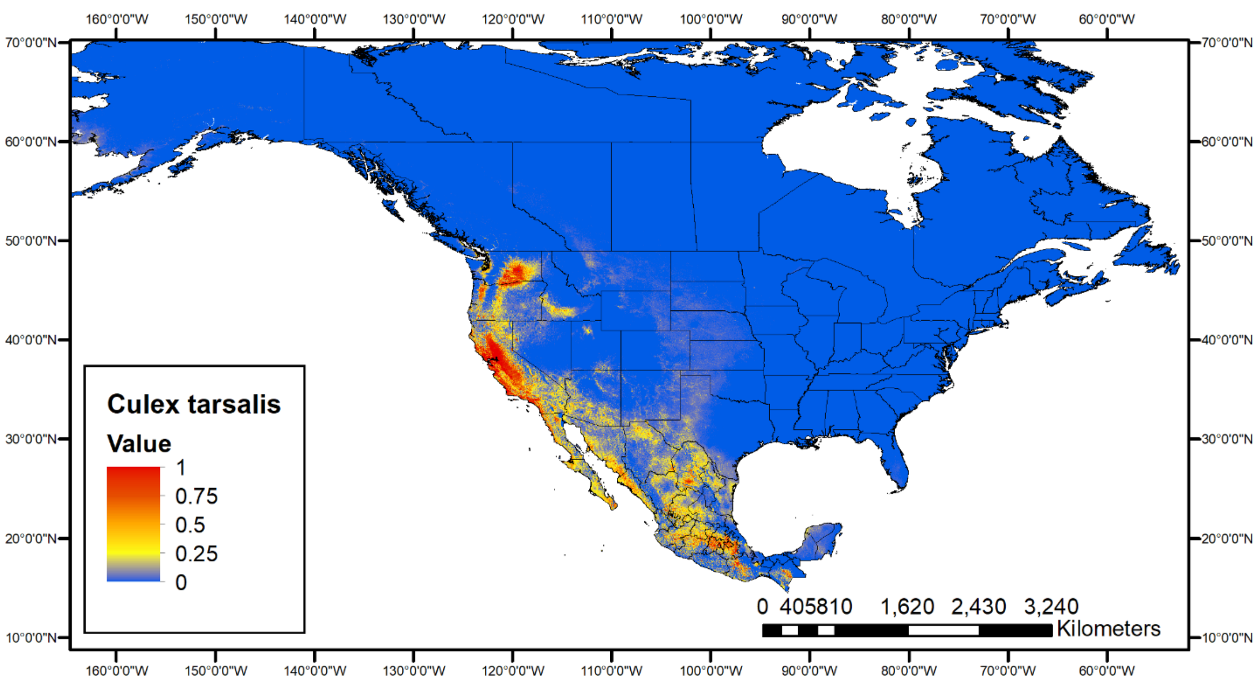




Habitat suitability models developed using maximum entropy (MaxEnt). Models developed by Alexander Potter, Oak Ridge Institute for Science and Education Fellow, WRBU.

Maximum Entropy Habitat Suitability Models





Habitat suitability models developed using maximum entropy (MaxEnt). Models developed by Alexander Potter, Oak Ridge Institute for Science and Education Fellow, WRBU.

Bionomics Table: Additional Vectors

Species Name	Biting Times	Host Preference	Feeding Behavior	Resting Behavior
Aedes (*Stg.*) *aegypti* (Linnaeus, 1762)	06:00-18:00	Primarily Anthropophilic	Exophagic and Endophagic	Exophilic and Endophilic
Aedes (*Stg.*) *albopictus* (Skuse, 1895)	Day	Primarily Anthropophilic but opportunistically Zoophilic	Primarily Exophagic but Endophagic on occasion	Primarily Exophilic
Aedes (*Adm.*) *vexans* (Meigen, 1830)	Night	Anthropophilic and Zoophilic	No data	No data
Coquillettidia (*Coq.*) *perturbans* (Walker, 1856)	18:00-06:00	Primarily Anthropohilic but opportunistically Zoophilic	No data	No data
Culex (*Cux.*) *salinarius* Coquillett, 1904	Night	Anthropophilic and Zoophilic	Exophagic and Endophagic	Exophilic
Culiseta (*Cli.*) *melanura* (Coquillett, 1902)	No data	Primarily Zoophilic	No data	No data
Psorophora (*Jan.*) *ferox* (von Humboldt, 1819)	Day and Night	Anthropophilic and Zoophilic	No data	No data

Table of Arboviruses

Abbreviation	Arbovirus	Abbreviation	Arbovirus
AHSV	African Horsesickness Virus	AINOV	Aino Virus
AMTV	Arumowot Virus	APEUV	Apeu Virus
APV	Agua Preta Virus	BEFV	Bovine Ephemeral Fever Virus
BUNV	Bunyamwera Virus	CHIKV	Chikungunya Virus
CHPV	Chandipura Virus	CWV	Cape Wrath Virus
EEEV	Eastern Equine Encephalitis Virus	EHDV	Epizootic Hemorrhagic Disease of Deer Virus
FLAV	Flanders Virus	FMV	Fort Morgan Virus
GFV	Gabek Forest Virus	GLOV	Gray Lodge Virus
GROV	Guaroa Virus	HPV	Hart Park Virus
INGV	Ingwavuma Virus	ITV	Israel Turkey Meningoencephalitis Virus
JCV	Jamestown Canyon Virus	JEV	Japanese Encephalitis Virus
JSV	Jerry Slough Virus	KEDV	Kedougou Virus
KOTV	Kotonkan Virus	KOWV	Kowanyam Virus
KRIV	Kairi Virus	KUNV	Kunjin Virus
LACV	La Crosse Virus	LLSV	Llano Seco Virus
LMV	Las Maloyas Virus	LOKV	Lokern Virus
MAGV	Maguari Virus	MDV	Main Drain Virus
MRV	Mitchell River Virus	MVEV	Murray Valley Encephalitis Virus
NEPV	Nepuyo Virus	NTAV	Ntaya Virus
OCKV	Ockelbo Virus	ORIV	Oriboca Virus

Abbreviation	Arbovirus	Abbreviation	Arbovirus
OROV	Oropuche Virus	PARAV	Para Virus
PGAV	Pongola Virus	ROCV	Rocio Virus
SFSV	Sandfly Fever Sicilian Virus	SFV	Semliki Forest Virus
SHOV	Shokwe Virus	STRV	Stratford Virus
TAHV	Tahyna Virus	TURV	Turlock Virus
TVTV	Trivittatus Virus	TYUV	Tyuleniy Virus
USUV	Usutu Virus	VEEV	Venezuelan Equine Encephalitis Virus
VSAV	Vesicular Stomatitis, Alagoas Serotype Virus	VSIV	Vesicular Stomatitis, Indiana Serotype Virus
VSNJV	Vesicular Stomatitis, New Jersey Serotype Viurs	WANV	Wanowrie Virus
WSLV	Wesselsbron Virus	ZEGV	Zegla Virus

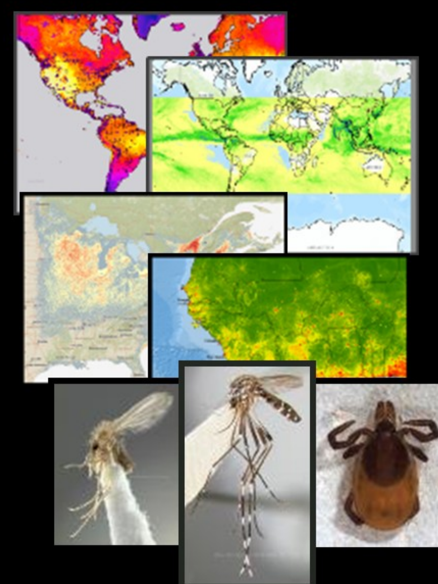
References

1. Asnis, D.S., Conetta, R., Teixeira, A.A. et al. (2000). The West Nile Virus Outbreak of 1999 in New York: The Flushing Hospital Experience. Clinical Infectious Diseases, 30:3: 413-418.
2. Carpenter & LaCasse. (1955). Mosquitoes of North America (North of Mexico).
3. Darsie Jr, R. F., & Ward, R. A. (2005). Identification and geographical distribution of the mosquitoes of North America, north of Mexico. University Press of Florida.
4. Harrison, B. A., Byrd, B. D., Sither, C. B., & Whitt, P. B. (2016). The mosquitoes of the Mid-Atlantic region: an identification guide. Cullowhee, NC: Western Carolina University.
5. Jackson, B. T., PauJson, S. L., Youngman, et al. (2005). Oviposition preferences of Culex restuans and Culex pipiens (Diptera: Culicidae) for selected infusions in oviposition traps and gravid traps. J Am Mosq Control Assoc 21, 360-365.
6. Lampman, R.L. & Novak, R.J. (1996). Oviposition Preferences of *Culex pipiens* and *Culex restuans* for Infusion-Baited Traps. Journal of the American Mosquito Control Association, 12(1):23-32.
7. Paz, S. (2015). Climate change impacts on West Nile virus transmission in a global context. Philosophical Transactions of the Royal Society B, 370: 20130561.
8. Petersen, L.R., Carson, P.J., Biggerstaff, B.J., et al. (2012). Estimated cumulative incidence of West Nile virus infection in US adults, 1999-2010. Epidemiology & Infection, 141(3): 591-595.
9. Sejvar, J.J. (2003). West Nile Virus: An Historical Overview. The Ochsner Journal, 5(3): 6-10.
10. Soverow, J.E., Wellenius, G.A., Fisman, D.N. & Mittleman, M.A. (2009). Infectious Disease in a Warming World: How Weather Influenced West Nile Virus in the United States (2001-2005). Environmental Health Perspectives, 117(7).
11. Stancil, J.D. (2000). Insecticide Resistance and Resistance Mechanisms in the Southern House Mosquito, *Culex quinquefasciatus*. LSU Historical Dissertations and Theses. 7299.
12. Stoto, M.A., Dausey, D.J., Davis, L.M. *et al*. (2005). Learning from Experience: The Public Health Response to West Nile Virus, SARS, Monkeypox, and Hepatitis A Outbreaks in the United States. RAND Corporation.
13. Vincent, G.P., Davis, J.K., Wimberly, M.C., et al. (2018). Permethrin Susceptibility for the Vector *Culex tarsalis* and a Nuisance Mosquito *Aedes vexans* in an Area Endemic for West Nile Virus. BioMed Research International, 2018: 2014764.

Additional Resources

1. Dunphy, B.M., Kovach, K.B., Gehrke, E.J., et al. (2019). Long-term surveillance defines spatial and temporal patterns implicating *Culex tarsalis* as the primary vector of West Nile virus. Scientific Reports, 9: 6637.
2. Hannon, E.R., Jackson, K.C., Biggerstaff, B.J., et al. (2019). Bloodmeal Host Selection of *Culex quinquefasciatus* (Diptera: Culicidae) in Las Vegas, Nevada, United States. Journal of Medical Entomology, 56(3): 603-608.
3. Kovach, T.J. & Kilpatrick, A.M. (2018). Increased Human Incidence of West Nile Virus Disease near Rice Fields in California but Not in Southern United States. The American Journal of Tropical Medicine and Hygiene, 99(1): 222-228.
4. McMillan, J.R., Marcet, P.L., Hoover, C.M., et al. (2019). Feeding Success and Host Selection by *Culex quinquefasciatus* Say Mosquitoes in Experimental Trials. Vector-Borne and Zoonotic Diseases, 19(7)
5. Nguyen, C., Gray, M., Burton, T.A., et al. (2019). Evaluation of a novel West Nile virus transmission control strategy that targets *Culex tarsalis* with endectocide-containing blood meals. PLoS Neglected Tropical Diseases, 13(3): e0007210.
6. Reisen, W.K. & Wheeler, S.S. (2019). Overwintering of West Nile Virus in the United States. Journal of Medical Entomology, 1-10.
7. Romo, H., Papa, A., Kading, R., et al. (2018). Comparative Vector Competence of North American *Culex pipiens* and *Culex quinquefasciatus* for African and European Lineage 2 West Nile Viruses. The American Journal of Tropical Medicine and Hygiene, 98(6): 1863-1869.
8. Tokarz, R.E. & Smith, R.C. (2019). Crossover Dynamics of *Culex* (Diptera: Culicidae) Vector Populations Determine WNV Transmission Intensity. Journal of Medical Entomology, 1-8.
9. Vincent, G.P., Davis, J.K., Wimberly, M.C., et al. (2018). Permethrin Susceptibility for the Vector *Culex tarsalis* and a Nuisance Mosquito *Aedes vexans* in an Area Endemic for West Nile Virus. BioMed Research International, 2018: 2014764.
10. Yu, D., Madras, N., & Zhu, H. (2018). Temperature-driven population abundance model for *Culex pipiens* and *Culex restuans* (Diptera: Culicidae). Journal of Theoretical Biology, 443: 28-38.

Request a Vector Hazard Report by contacting the WRBU: NMNH-WRBU@si.edu



The published material reflects the views of the authors and should not be construed to represent those of the Department of the Army or the Department of Defense.