Challenge of prevention and control of arboviruses in the US

Atlantic Monthly, 1997

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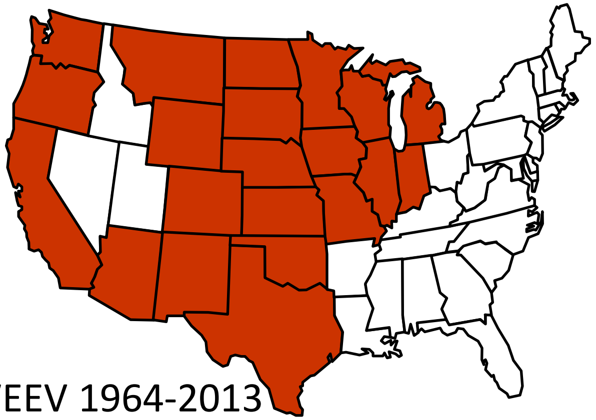
Wadsworth Center, New York State Dept Health

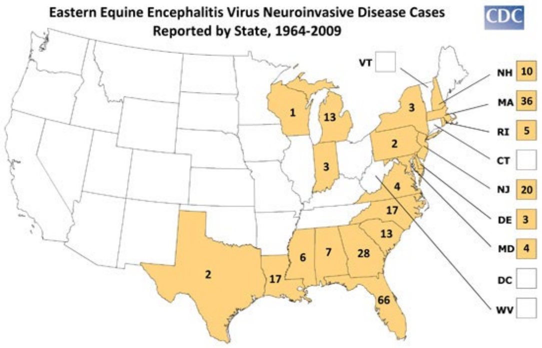
National Academies

Mitigating Arboviral Threats and Strengthening Arboviral Preparedness

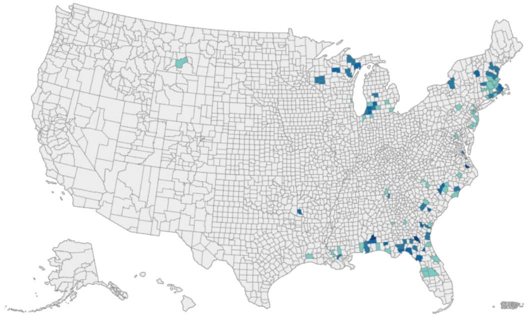
December 2023



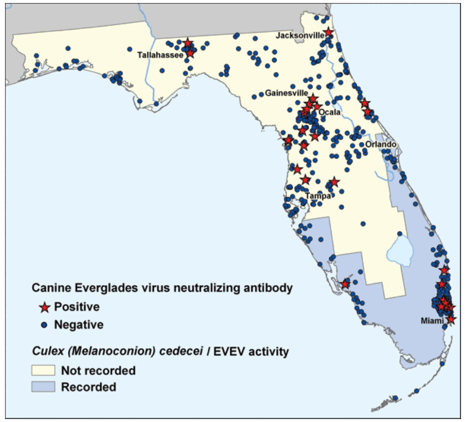
WEEV 1964-2013



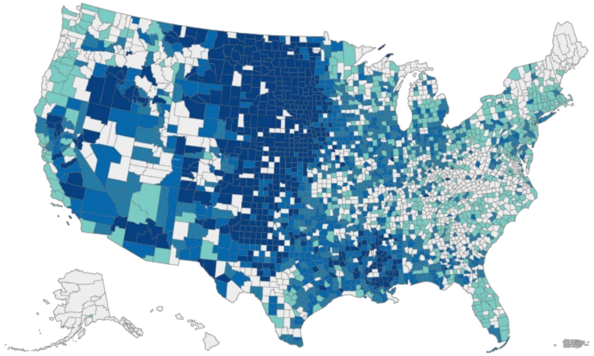
EEEV 1964-2009



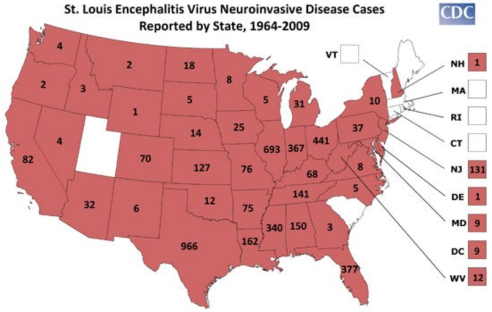
EEEV 2003 - 2022



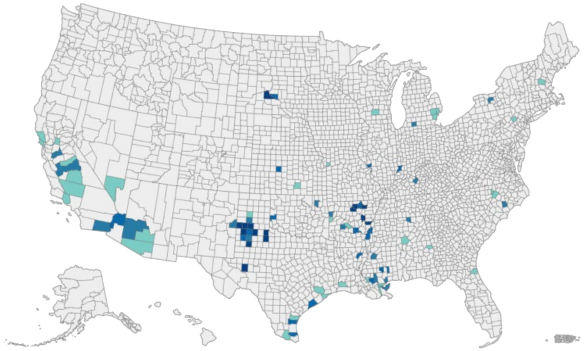
VEE II 2003-4 Coffey et al 2011



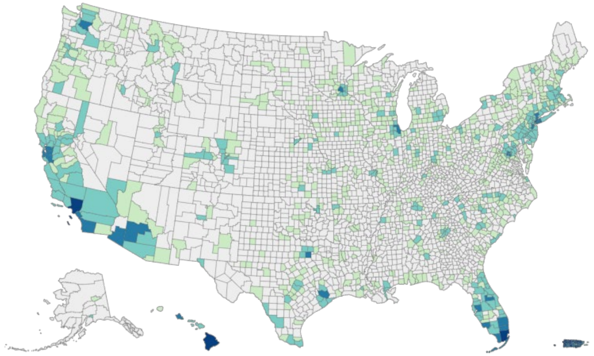
WNV NID 1999-2022



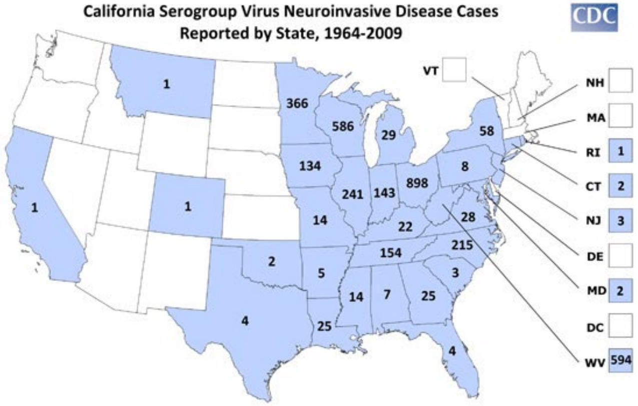
SLEV 1964-2009



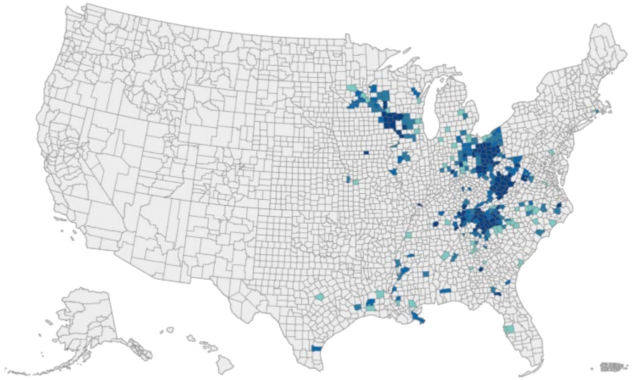
SLEV 2003 – 2022



DENV 2010 – 2022



CAL serogp 1964-2009



CAL serogp 2003 - 2022

Endemic mosquito-borne viruses of medical importance in the US

CDC Arbonet

Successful introductions to US of mosquito-borne arboviruses and mosquitoes with disease-association: established threats

- **Yellow fever virus**
  - Small outbreaks 1693 – 1793, when large outbreak occurred in Philadelphia killing 10% of population
- **Dengue virus**
  - United States: local cases of dengue have been reported in FLA, HI, TX, AZ, CA, but most cases introduced with travelers
  - 2022: Travel-associated cases 1026 (68% FLA); locally transmitted 47
  - PR 6 travel; 525 locally transmitted
- **West Nile virus** first detected in US in 1999 in NYC after activity in Middle East. Enzootic in US since 1999/2000
- **Chikungunya virus**
  - 2014 - 2022, chikungunya virus disease cases were reported among U.S. travelers returning from affected areas in the Americas (4556 continental US ; 52 PR and Virgin islands). Local transmission identified in FlA (12) TX (1), PR and the U.S. Virgin Islands (5125) .
- **Zika virus**
  - In 2015 and 2016, large outbreaks of Zika virus in the Americas, resulting in an increase in travel-associated cases in US states, widespread transmission in PR and the US Virgin Islands, and limited local transmission in FlA and TX.
  - In 2017, the number of reported Zika virus disease cases in the United States started to decline.
  - Since 2018, there have been no reports of Zika virus transmission by mosquitoes in the continental United States; and in 2019, none in the territories.
- **Others**
  - VEEV, EEEV, SLEV, MAYV
- **Mosquitoes**: Aedes spp : aegypti, albopictus; Culex spp; pipiens, quinquefasciatus, lactator

Two mosquito-borne viruses that pose potential threat of Introduction to US

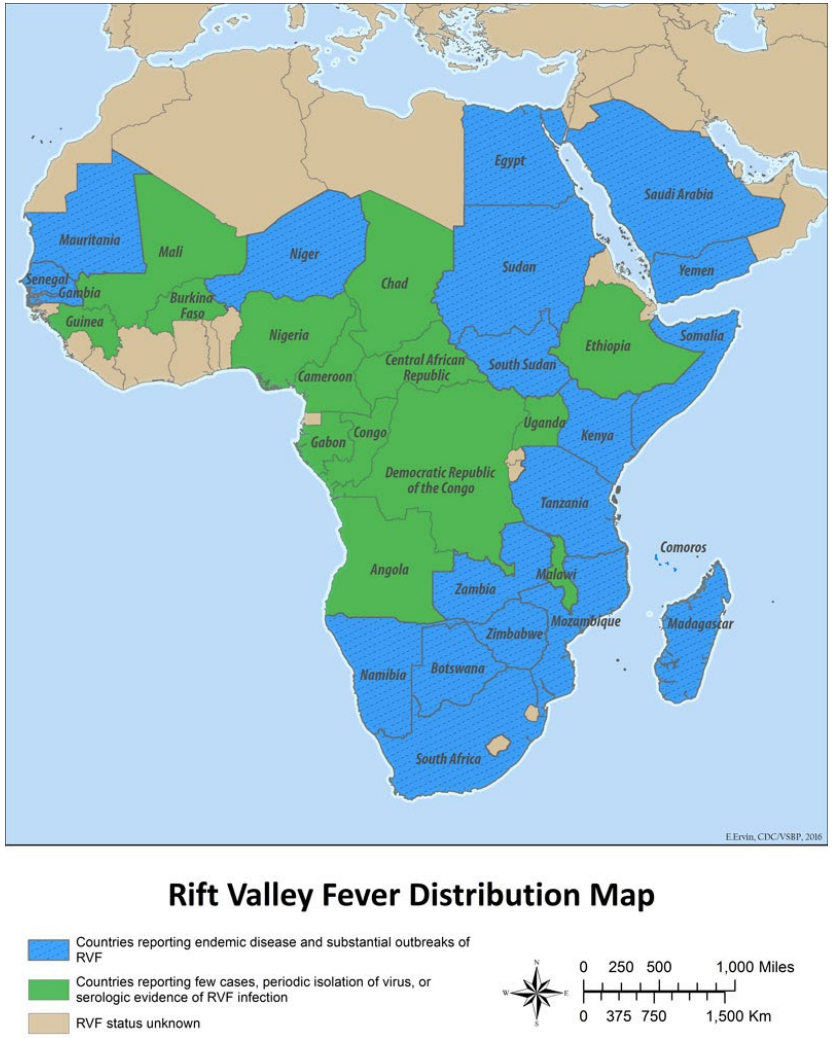
Japanese encephalitis distribution map

Amarillovirales order

Flaviviridae family

Orthoflavivirus genus

CDC



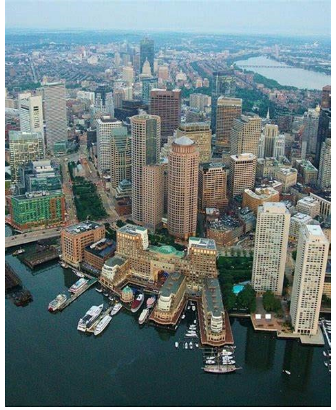
Bunyavirales order

Phenuiviridae family

Phlebovirus genus

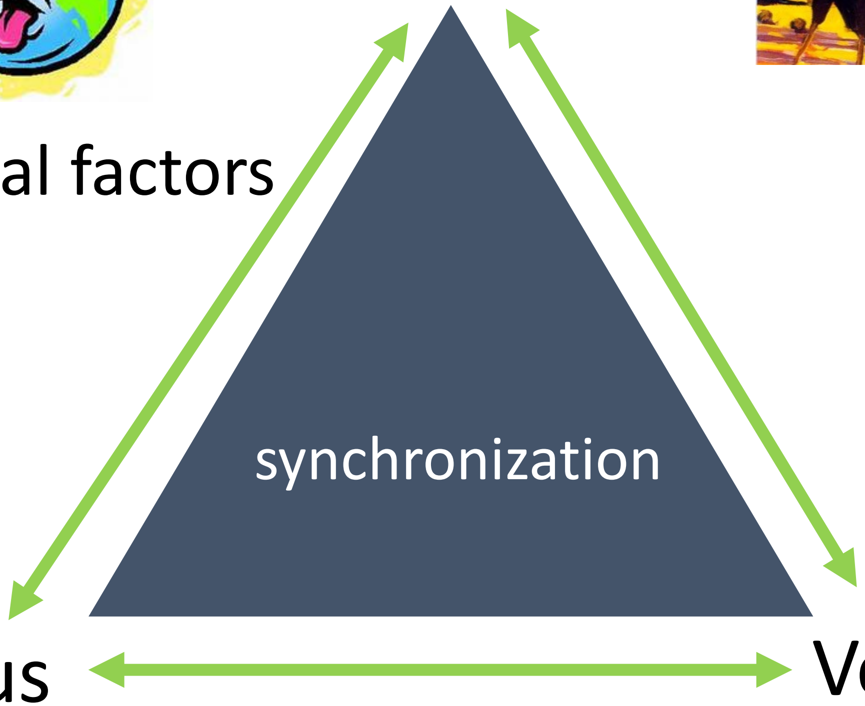
Important factors driving the emergence and establishment of arboviruses

Blogspot.com



Environmental factors

Pinterest.es



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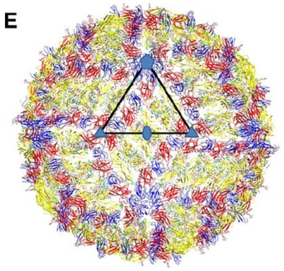
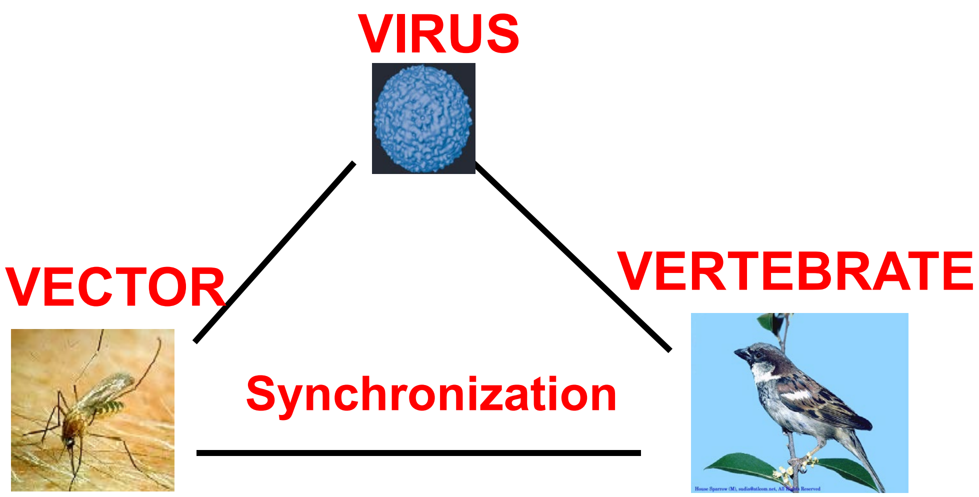


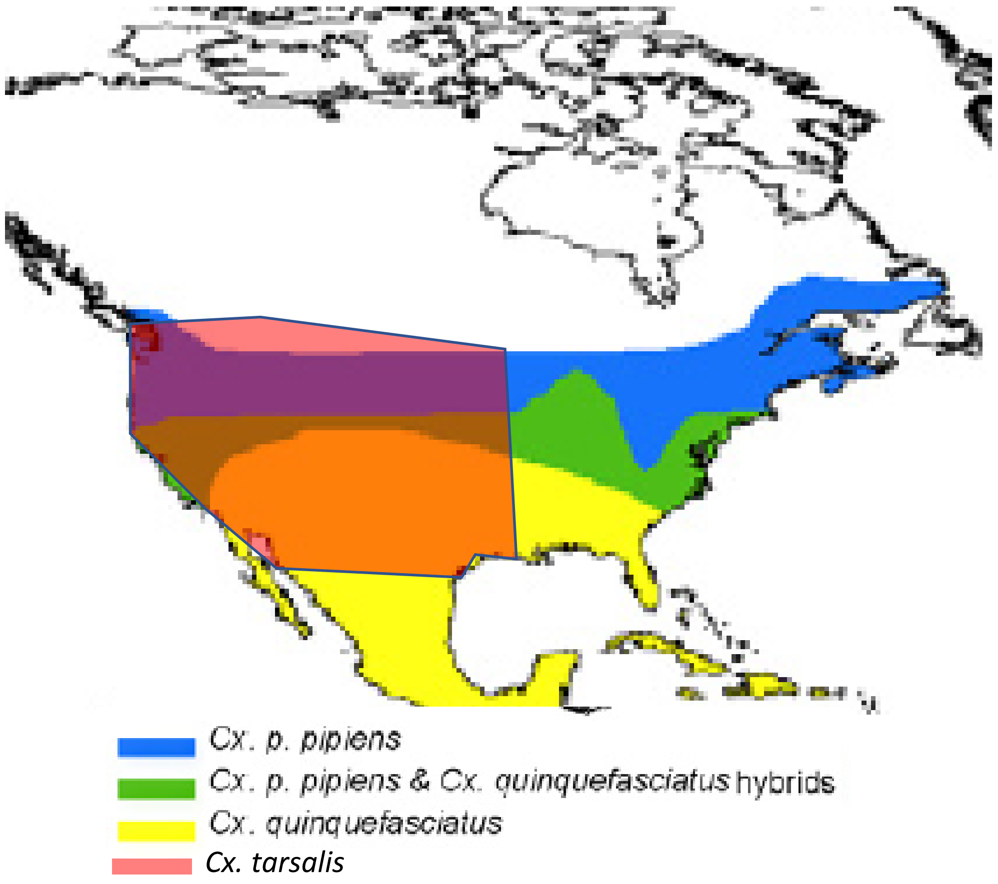
Areas to focus on to prevent successful establishment and spread of introduced arboviruses

- PREPARATION / COORDINATED COMMUNICATION NETWORKS
- INTEGRATED REAL TIME SURVEILLANCE
- RAPID DIAGNOSTICS
- COUNTER MEASURES: VECTOR CONTROL, THERAPEUTICS, VACCINES
- RESEARCH: BASIC AND APPLIED
- SOCIAL SCIENCE ASPECTS: COMMITMENT OF LOCALS; ADDRESS ROOT CAUSES, E.G. POVERTY, PLASTIC WASTE

West Nile virus: Multiple mosquito vectors with different ecology, behavior

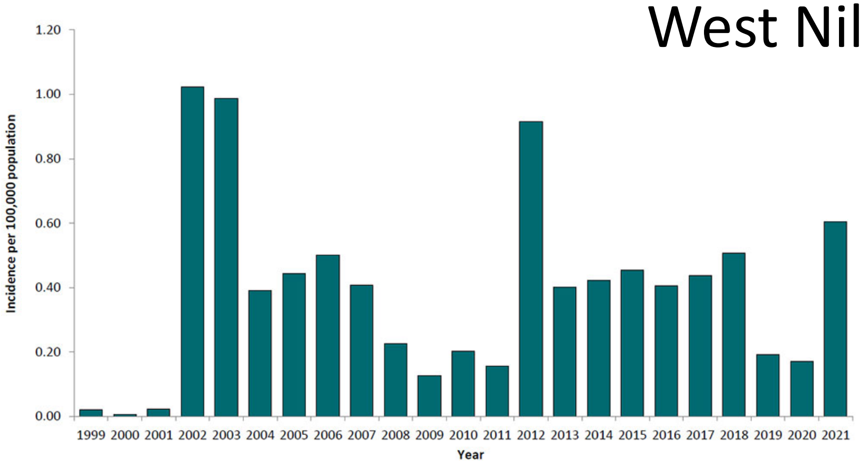
- **Dominant West Nile virus vectors vary spatially**
  - **West*: Culex tarsalis* – floodwater breeder, mixed bird/mammal feeding**
  - **East*: Culex pipiens* –container breeder, ornithophilic**
  - **South*: Culex quinquefasciatus* - container breeder, mixed bird/mammal feeding**





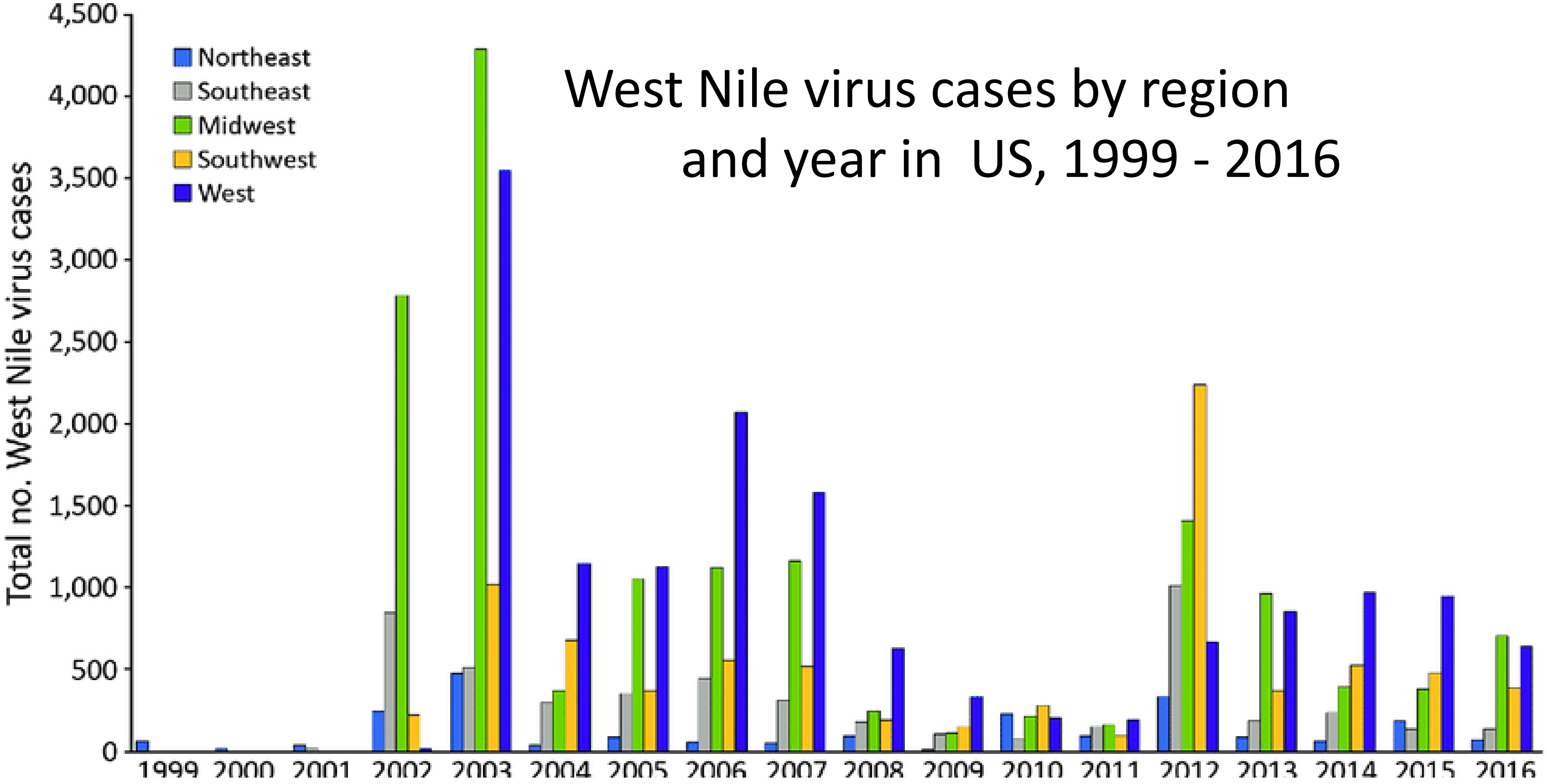
Farajollahi, et al, Kilpatrick 2011 Inf. Gen, Evol.

West Nile virus cases in US, 1999 - 2021



<u>Humans, N America, 1999-2020</u>
3.5M infections, 705K illnesses;
25.2K WNND, 2300 deaths

West Nile virus cases by region and year in US, 1999 - 2016

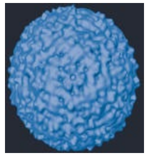


CDC

Aedes aegypti-transmitted viruses

Chikungunya
Dengue
Zika
Yellow fever

Virus factors
DENV subtype
Strain Virulence



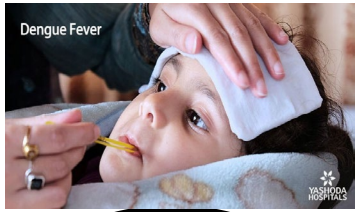
VIRUS

Extrinsic factors
Rainfall
Temperature
Urbanization

Synchronization

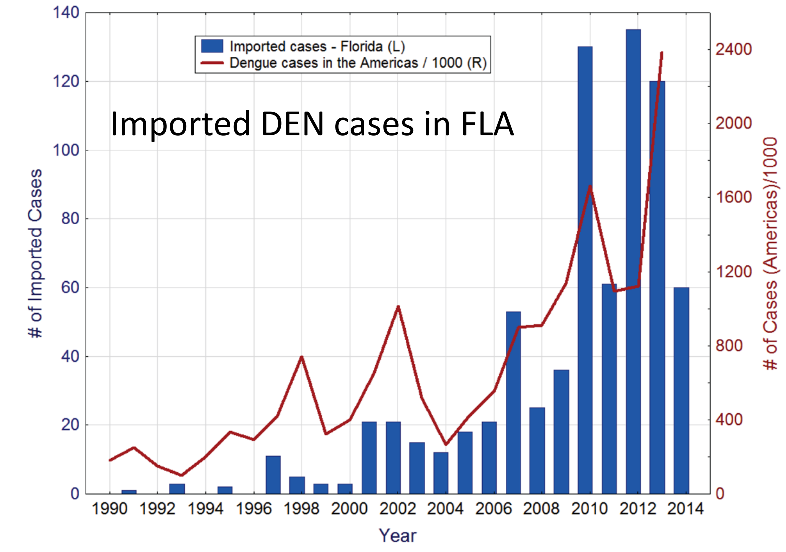
VECTOR

HUMAN

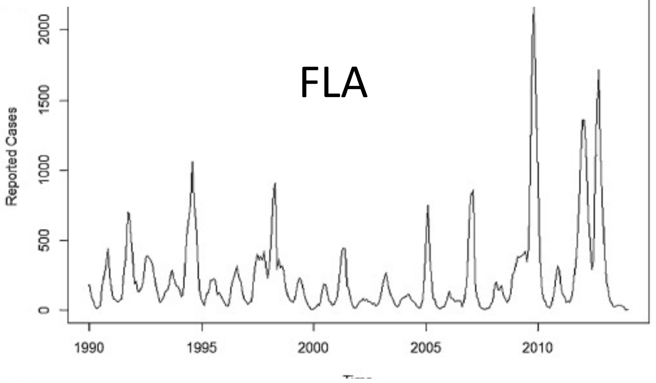


Vector factors
Aedes abundance
Population genetics
Vectorial capacity
Breeding site availability

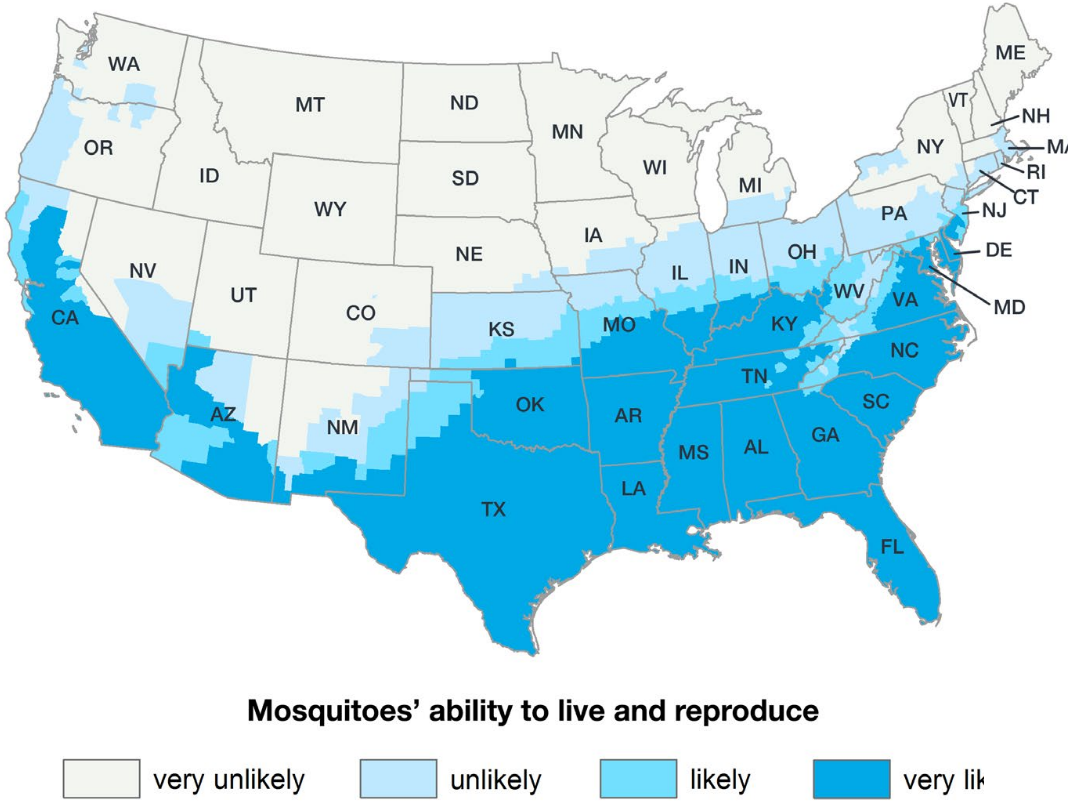
Host factors
Immune status
Age
Exacerbating conditions



Locally transmitted DEN cases



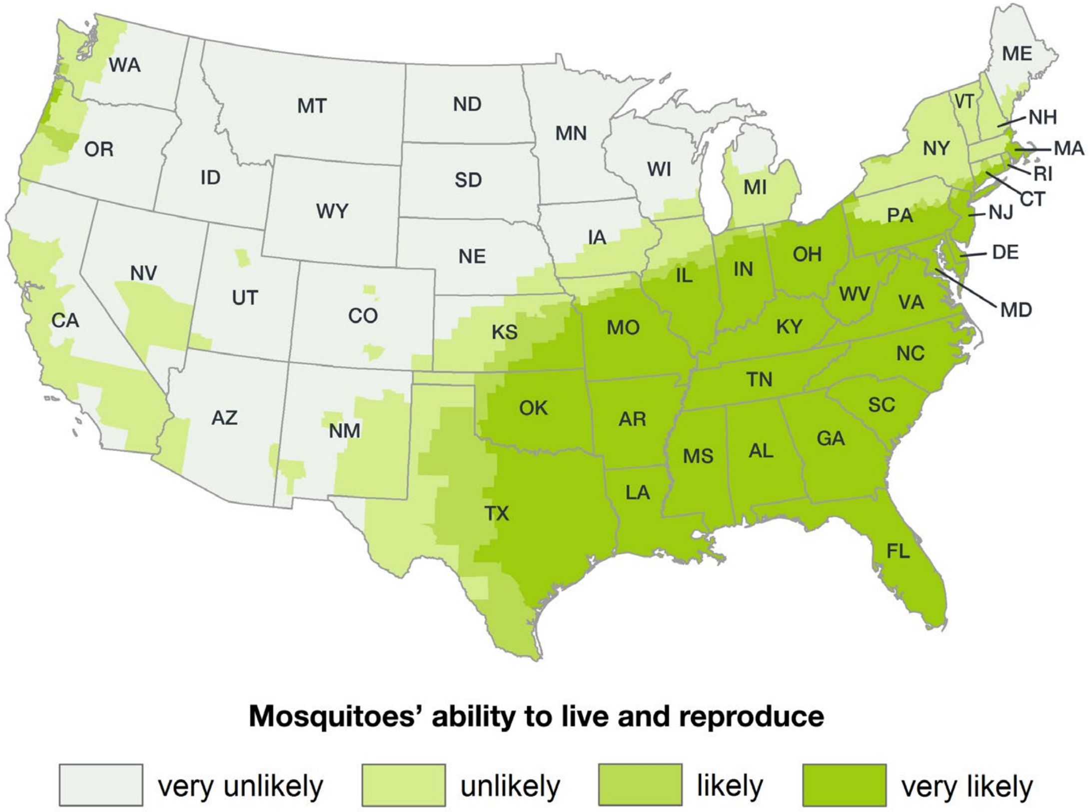
PAHO, FLA Dept Health, CDC, US Census



Aedes aegypti

ESTIMATED potential range of Aedes aegypti and Aedes albopictus in the United States, 2017

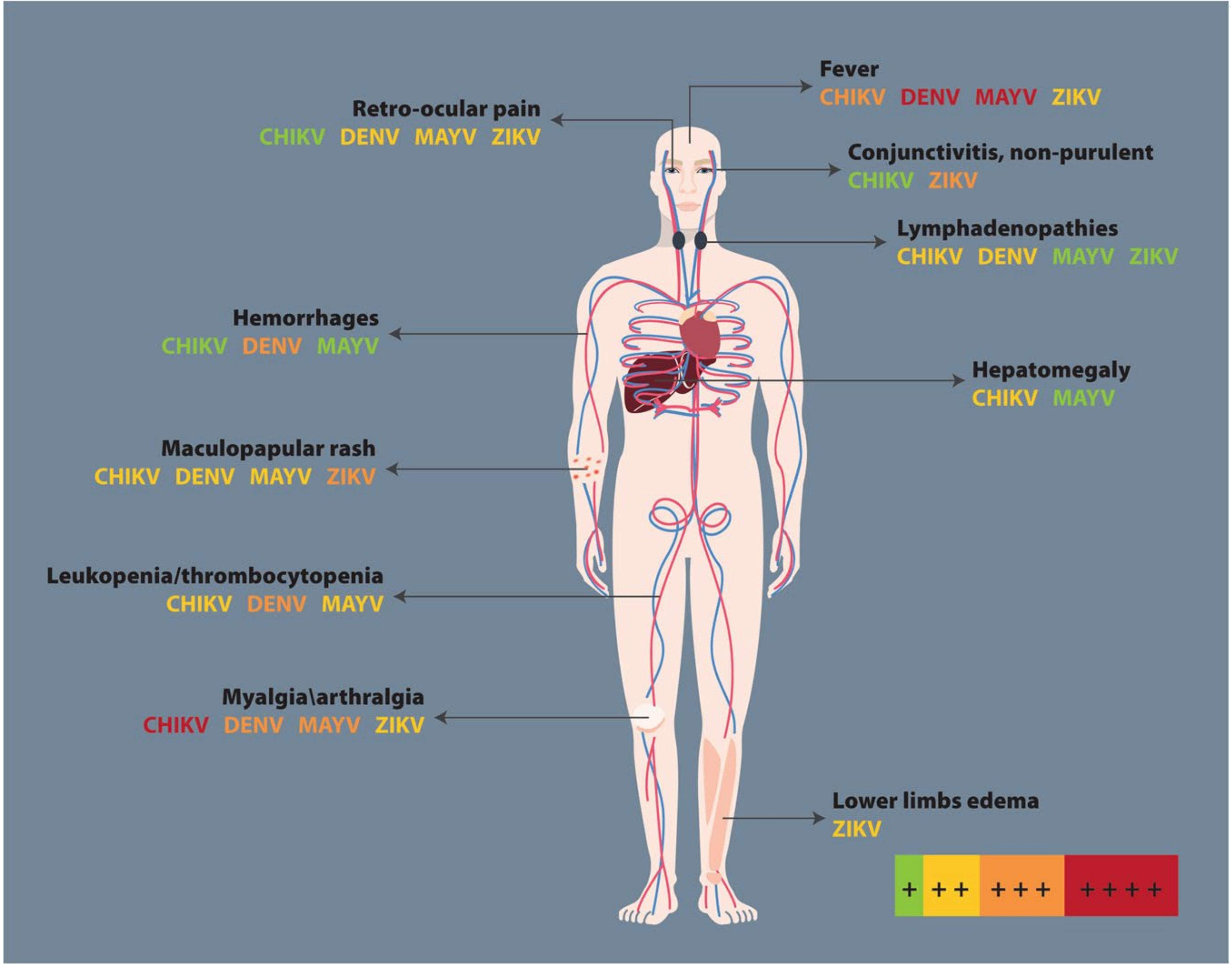
Aedes albopictus



* CDC has updated the estimated range maps for *Ae. aegypti* and *Ae. albopictus* mosquitoes by using a model that predicts possible geographic ranges for these mosquitoes in the contiguous United States. The model used county-level records, historical records, and suitable climate variables to predict the likelihood (very low, low, moderate, or high) that these mosquitoes could survive and reproduce if introduced to an area during the months when mosquitoes are locally active. Maps are not meant to represent risk for spread of any specific disease. (See Johnson TL et al. Modeling the environmental suitability for *Aedes (Stegomyia) aegypti* and *Aedes (Stegomyia) albopictus* (Diptera: Culicidae) in the contiguous United States. *Jrl Med Entomol*. Sept. 2017;[ahead of print].)

U.S. Department of Health and Human Services
Centers for Disease Control and Prevention

CS264451-F
February 16, 2018



Fever
CHIKV DENV MAYV ZIKV
Retro-ocular pain
CHIKV DENV MAYV ZIKV
Conjunctivitis, non-purulent
CHIKV ZIKV
Lymphadenopathies
CHIKV DENV MAYV ZIKV
Hemorrhages
CHIKV DENV MAYV
Hepatomegaly
CHIKV MAYV
Maculopapular rash
CHIKV DENV MAYV ZIKV
Leukopenia/thrombocytopenia
CHIKV DENV MAYV
Myalgia\arthralgia
CHIKV DENV MAYV ZIKV
Lower limbs edema
ZIKV
+
++
+++
++++

Emerging tick-borne diseases

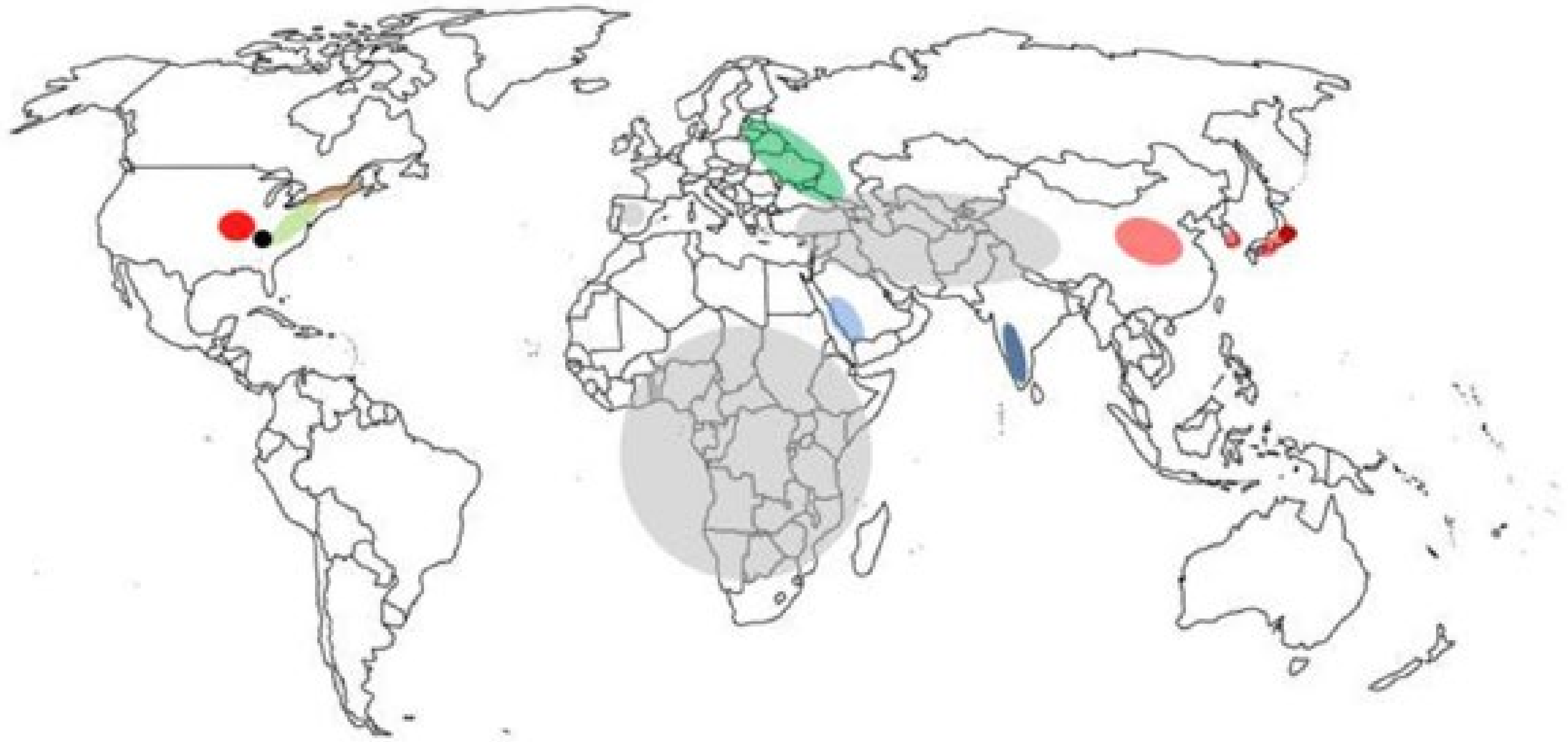
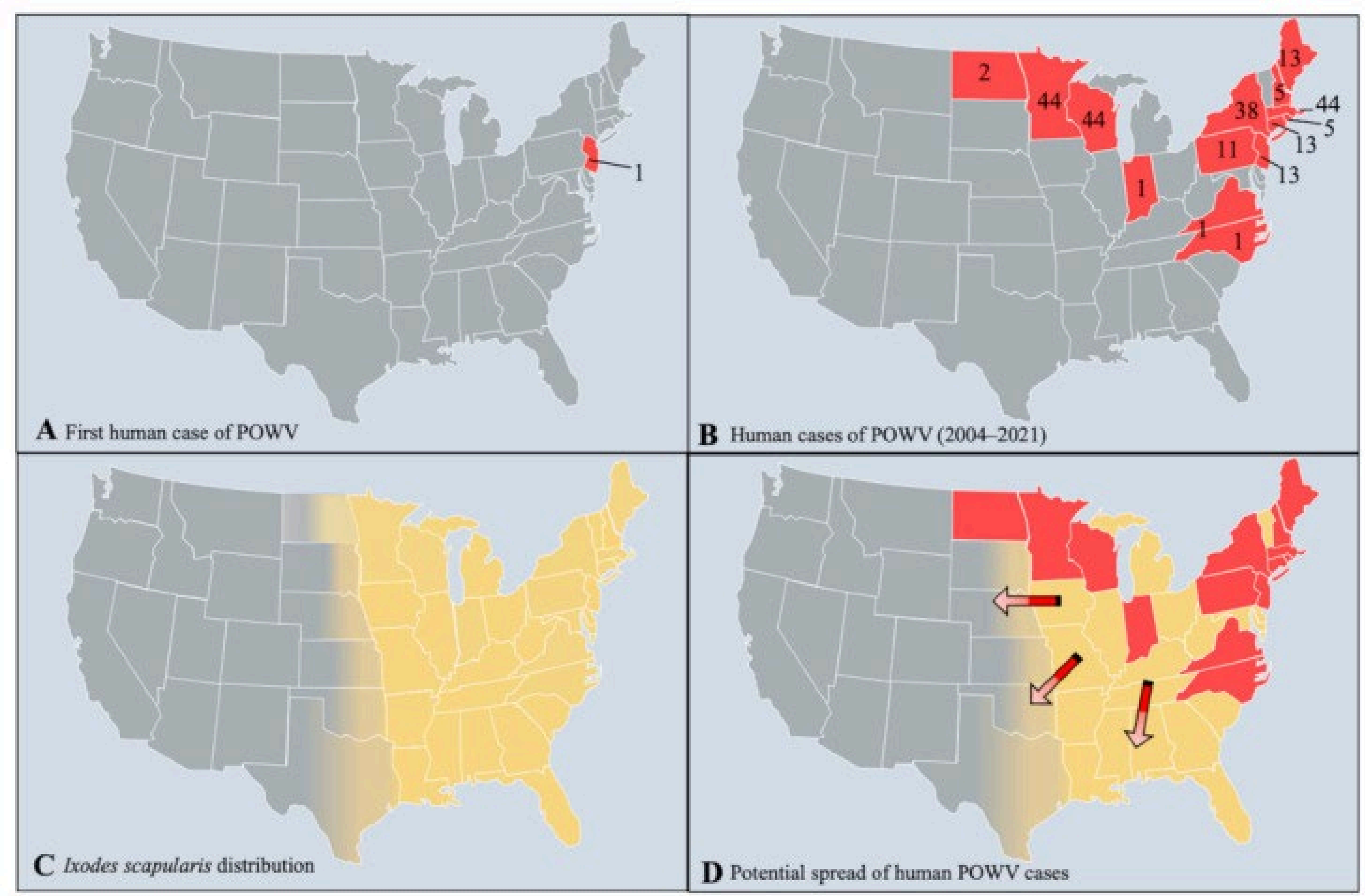
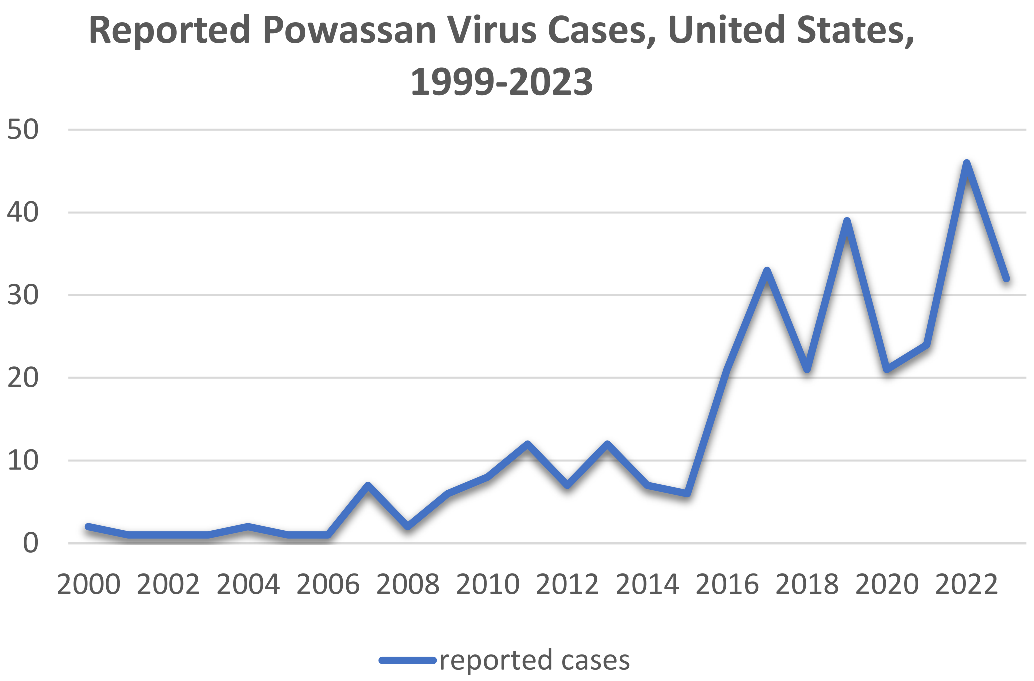


FIGURE 2 | Map of the world showing location of tick-borne disease outbreaks caused by emerging viruses. The regions marked are severe fever and thrombocytopenia syndrome virus (pale red), Heartlands virus (red), Crimean-Congo haemorrhagic fever virus (gray), Kysanur Forest disease virus (blue), Alkurma haemorrhagic fever virus (light blue), Powassan virus (brown), deer tick virus (pale green), Bourbon virus (black), Tofla virus (brown), and African swine fever virus (green).

Mansfield KL et al. 2017 Front. Cell. Infecct. Microbiol 7:298

The distribution of Powassan virus (*Flaviviridae*, Flavivirus) cases and *Ixodes scapularis*





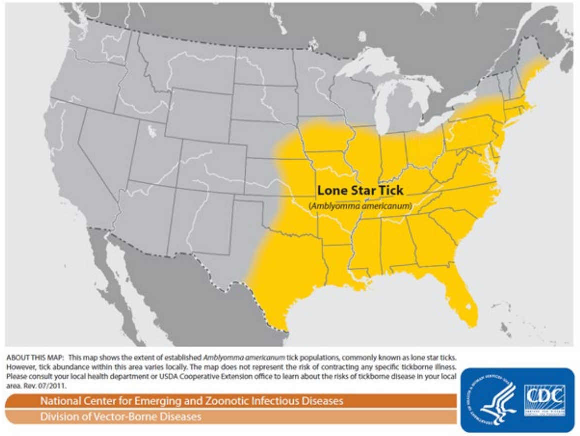
Hassett EM, Thangamani S. Microorganisms. 2021 Nov 9;9(11):2317.

Ixodes scapularis

Emergence of novel tick-borne viruses in northeastern US

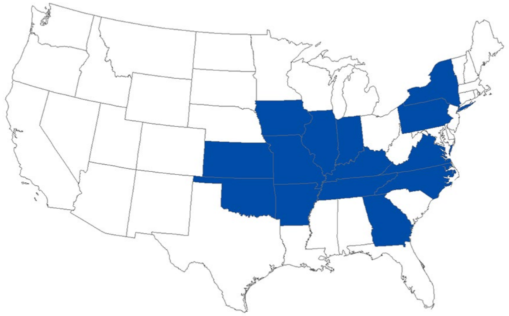
Lone Star Tick – TickEncounter (uri.edu)

https://web.uri.edu/tickencounter/species/lone-star--tick/



Heartland virus

- Family: *Phenuiviridae* , Genus *Bandavirus*



Negative-sense RNA; S, M, L segments

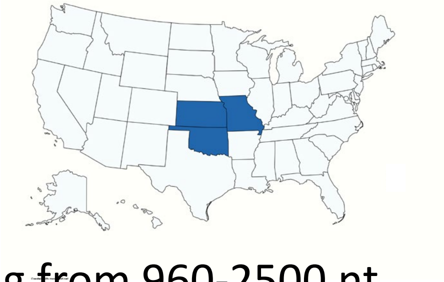
Most closely related to Dabie bandavirus (SFTSV, severe fever with thrombocytopenia syndrome virus)

1000's of human clinical cases in China

First identified in Missouri, 2009

Bourbon virus

- Family: *Orthomyxoviridae*, Genus: *Thogotovirus*



6 segments ranging from 960-2500 nt

First isolated from sick patient in Bourbon County, Kansas, 2014

3-8 cases, most recent park employee in MO, 2017

Isolated from *A. americanum* near index cases

Field evidence of infected *Haemaphysalis longicornis* (Virginia) and recent isolation from lone star ticks in New Jersey

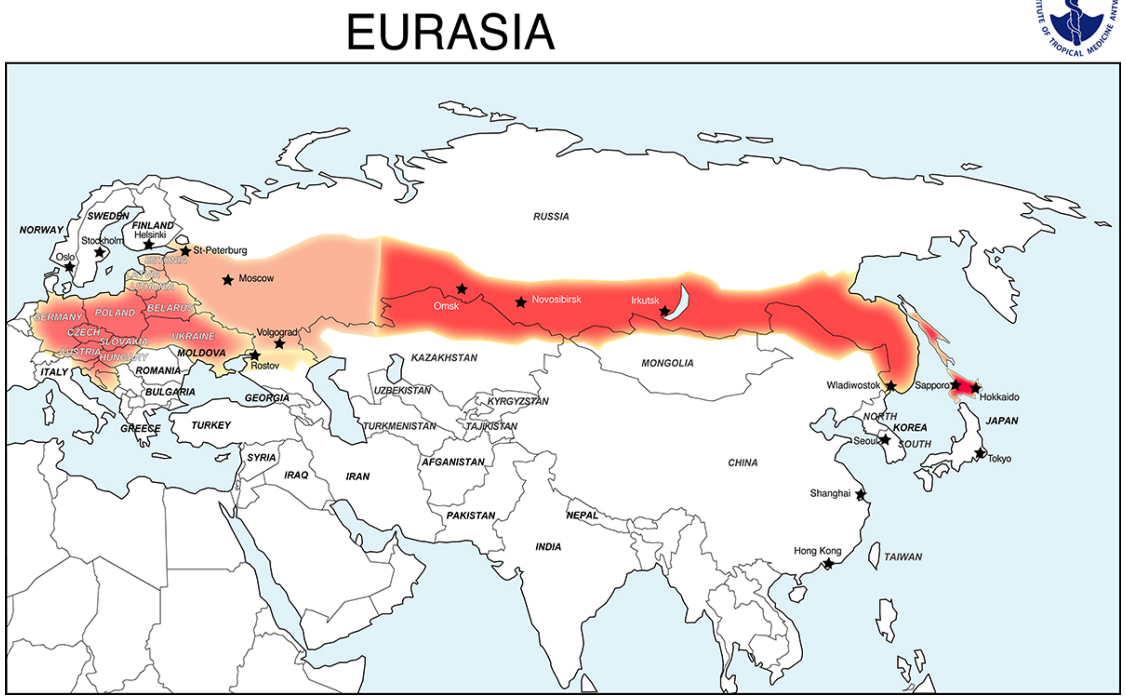
CDC Centers for Disease Control and Prevention
CDC 24/7: Saving Lives, Protecting People™

Thank you to Alex Ciota and Alan Dupuis for slide

A New Phlebovirus Associated with Severe Febrile Illness in Missouri | NEJM
https://www.nejm.org/doi/full/10.1056/NEJMoa1203378

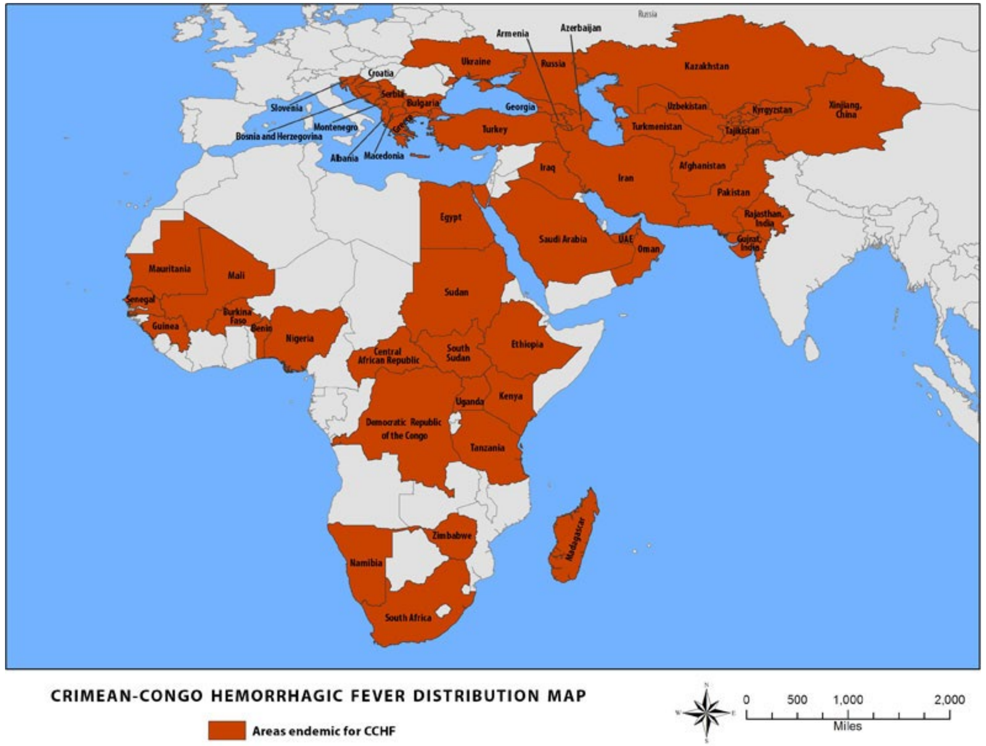
Statistics & Maps | Heartland virus | CDC
https://www.cdc.gov/heartland-virus/statistics/index.html

Tick-borne viruses that poses threat of introduction to US



Tick-borne encephalitis

Amarillovirales order
Flaviviridae family
Orthoflavivirus genus



Bunyavirales order
Nairoviridae family
Orthonairovirus genus.

https://www.regentstreetclinic.co.uk/tick-encephalitis/

CDC

Surveillance and control challenges

- Anthropogenic changes to the environment (Anthropocene epoch)
- Evolving situation due to climate change, extreme weather events. Modeling important
- Complexity of cycles – distinct regional vectors; invasive vectors, multi-host vectors, invasive viruses – need a One Health approach
- Genetics: Virus mutations common with RNA viruses; 4 serotypes of DENV
- Diagnostics: problem with cross-reactivity, long lasting IgM, high throughput specific diagnostics vs broadly reacting diagnostics; expense; training; similarity of symptoms - DENV, CHIKV, ZIKV,MAYV leptospirosis, more
- Counter measures : Lack of effective approved treatments and vaccines; lack of stockpiles of approved vaccines; no consensus has emerged for a dominant proteinaceous entry receptor for any flavivirus
- Control challenge - mobility of people, high speed travel, high numbers of travelers
- Clinical trials difficult to conduct because Incidence of infection is low and can be focal; many arboviruses do not have good animal models
- Coincident outbreaks (COVID; DENV and ZIKV)
- Needs: Innovative surveillance and mosquito control methods ; long term support for public health programs rather than reactive response; research support for long term projects
- Community support

Yellow fever, Dengue, West Nile, Chikungunya, Rift Valley fever, Zika

WHAT'S NEXT?

Going forward

Reinforce a **One Health** approach

Maintain strong **public health** infrastructure

Global surveillance with international cooperation and sharing of data and resources

Pay attention to **other arboviruses** that pose threat: e.g., JEV, TBEV, USUV, SFTS,

Early and rapid reporting of human and zoonotic disease outbreaks

Scientific communication to public, and among scientists and with funding agencies

Broad multi-disciplinary **research** programs

Rapid **technology transfer from bench**

Thank you!