Climate and Health Summit
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Of Mice, Men and Mosquitoes

Vector-Borne Infections in a Changing Climate

Samantha Ahdoot, MD, FAAP

Assistant Professor of Pediatrics
Virginia Commonwealth University School of Medicine, Inova Campus

AAP Council on Environmental Health Executive Committee

Climate and Health Physician Liaison, Inova Health Systems, VA

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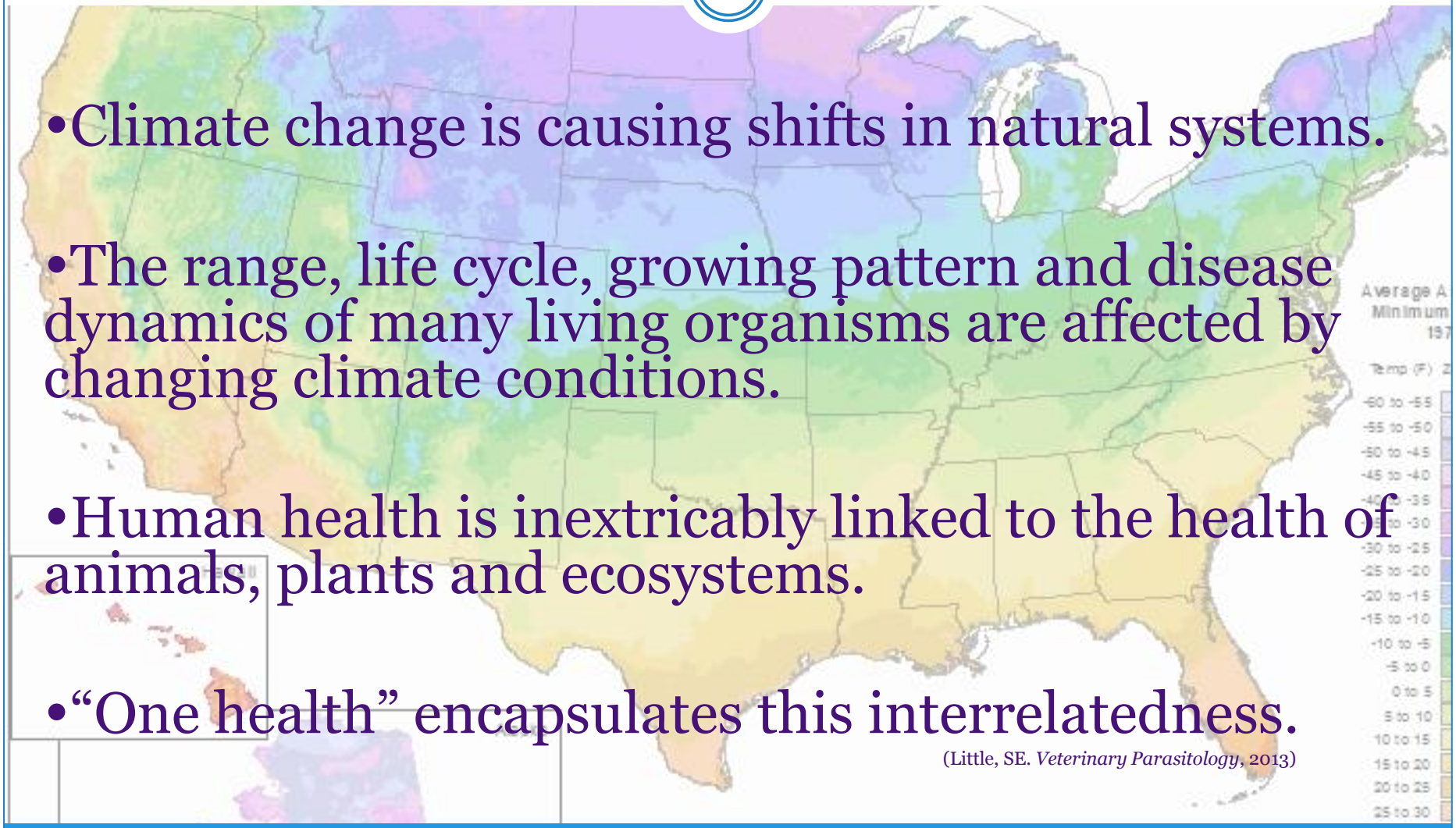
I have no relevant financial relationship in relation to this presentation.

"One Health"



- Climate change is causing shifts in natural systems.
- The range, life cycle, growing pattern and disease dynamics of many living organisms are affected by changing climate conditions.
- Human health is inextricably linked to the health of animals, plants and ecosystems.
- "One health" encapsulates this interrelatedness.

(Little, SE. *Veterinary Parasitology*, 2013)

“One Health”

Range Shifts

Temperature

VECTOR-BORNE DISEASE

Precipitation Patterns

Animal Life Cycles

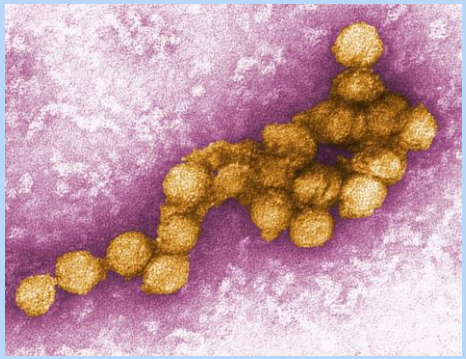
Climate Change and Infectious Diseases

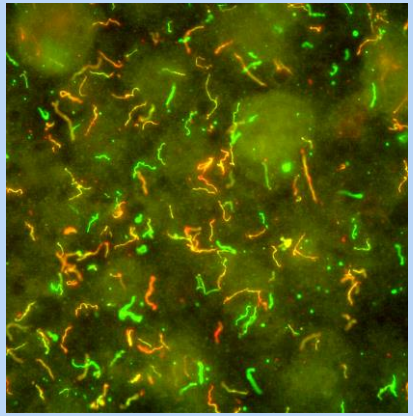
- Multiple confounding variables.
- Impacts of human activities such as land development, travel, time outdoors, air conditioning, self protection.
- Much easier to identify climate signal in wildlife disease.
- Changes in climate influence habitat suitability and reproductive rate for host, vector, and infectious organism of some infectious diseases.

Animal-parasite interactions for which field or experimental studies have linked climate change to altered disease risk.
Altizer S, *Science*, 2013

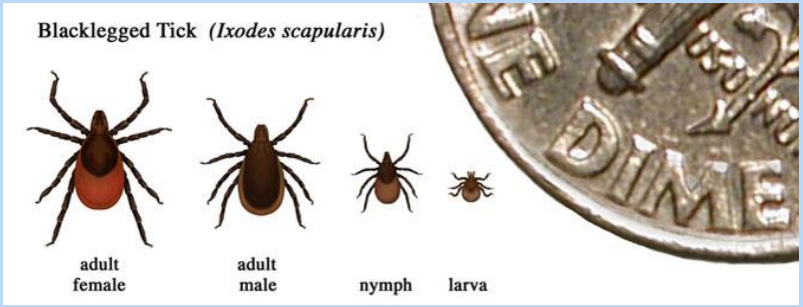
Climate Change and Vector-Borne Diseases

- ★ Lyme Disease
- ★ West Nile Virus
- ★ Dengue Fever
- ★ Chikungunya





Lyme Disease



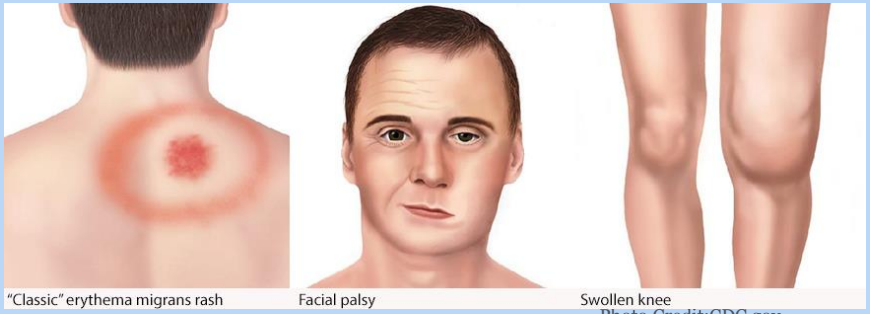


Photo Credit:CDC.gov

- Caused by the spirochete bacteria Borrelia burgdorferi.
- Transmitted by the Ixodes Scapularis tick in the northeastern, northcentral and mid-Atlantic regions, and by the Ixodes pacificus tick on the Pacific Coast.

Early Signs and Symptoms
(3-30 days post tick bite)

- Fever, chills, fatigue and Erythema Migrans rash in 70-80% patients.

Later Signs and Symptoms
(days to months post tick bite)

- Multiple EM rashes, meningitis, Bell's Palsy, carditis, arthritis

Lyme Disease

Source: phil.cdc.gov

- Affects about 300,000 people yearly (CDC).
- Boys 5-9 years at greatest risk.
- Below threshold temperature, tick mortality outstrips reproduction and populations die out or fail to become established (Basic Reproductive Number or $R_0 < 1$).
- Northward expansion of Ixodes Scapularis has been documented in North America.
- This has occurred coincident to, or after, rise in temperature in these regions, but not before.

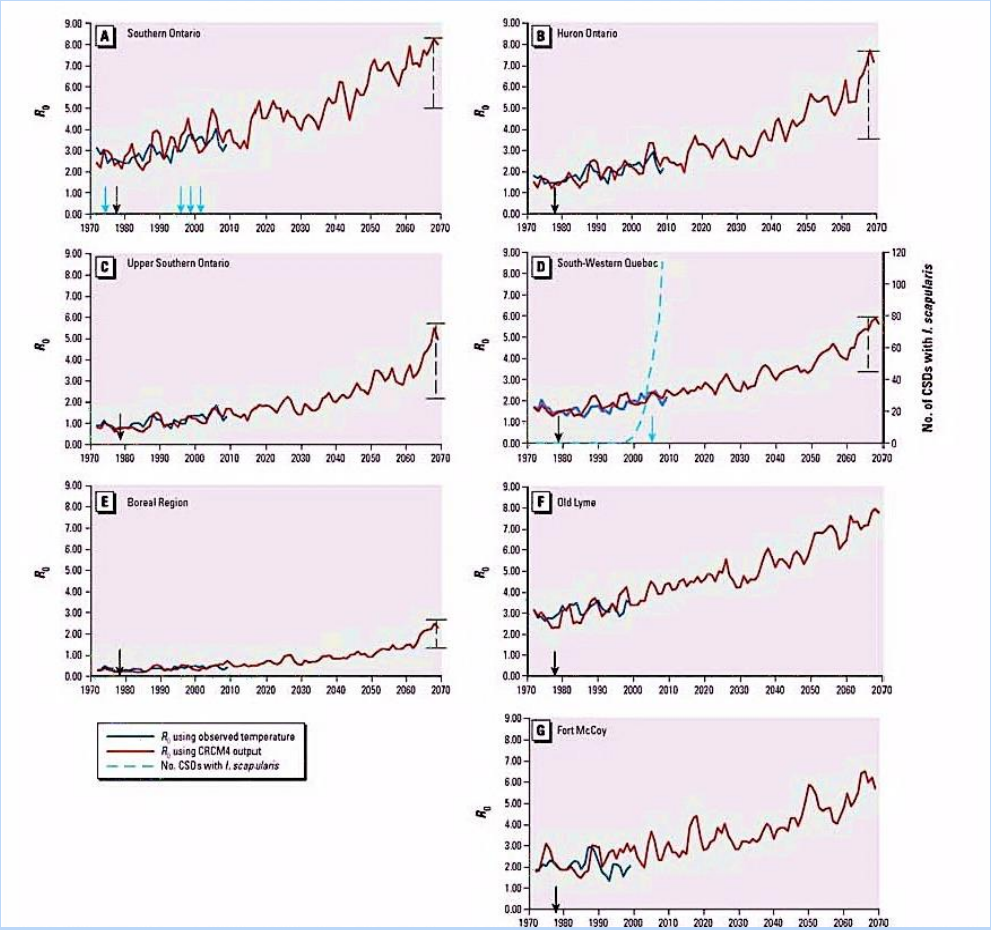
(Ogden, *Int J Health Geogr* 2008; Ogden, *Environ Health Perspect* 2014)

Ixodes Scapularis in North America
Rising R_0 1970-2070

R_0 increased from 2-3 (1970's) to 4 by 2000's

R_0 <1 1970's, >1 by 1990's

R_0 remained <1 throughout



R_0 1.5 1970's, 2.5 by 2000's

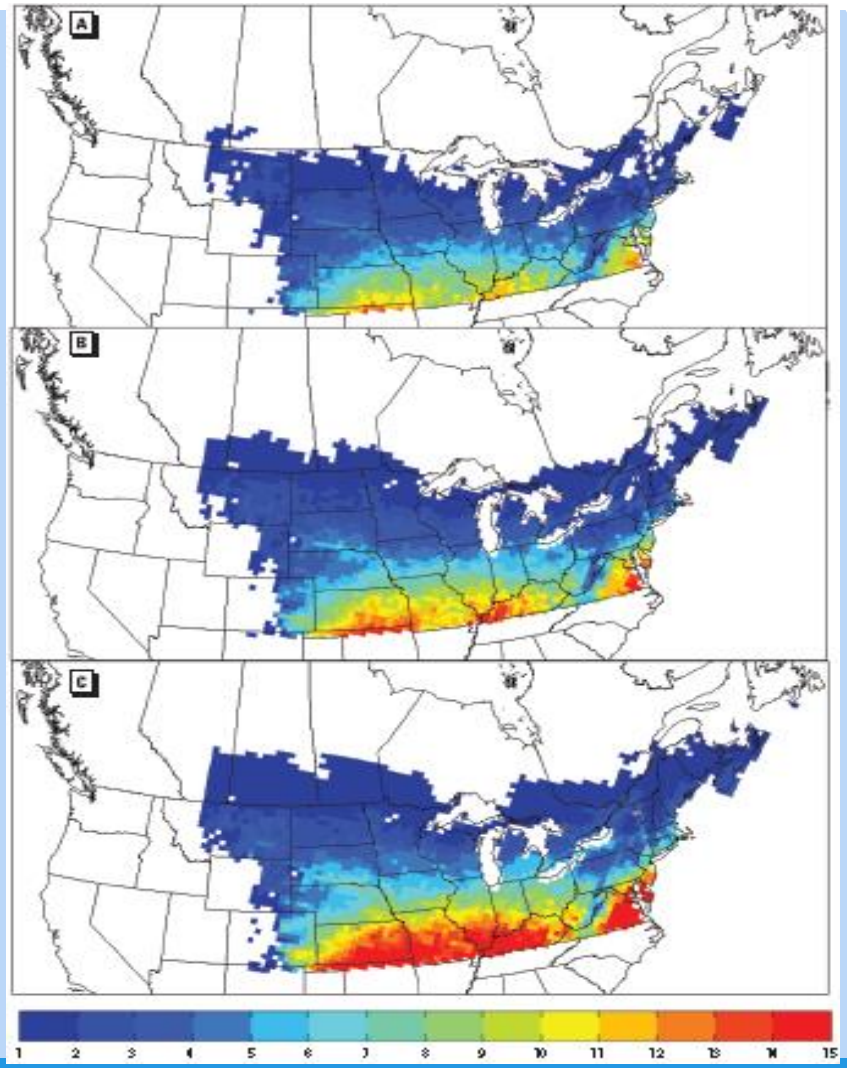
R_0 1.5 1970's, 2.5 by 2000's

R_0 3 1970's, 3.5 1999

No significant change

Source: Ogden, *Envir Health Perspect, 2014*

Northward Range Expansion

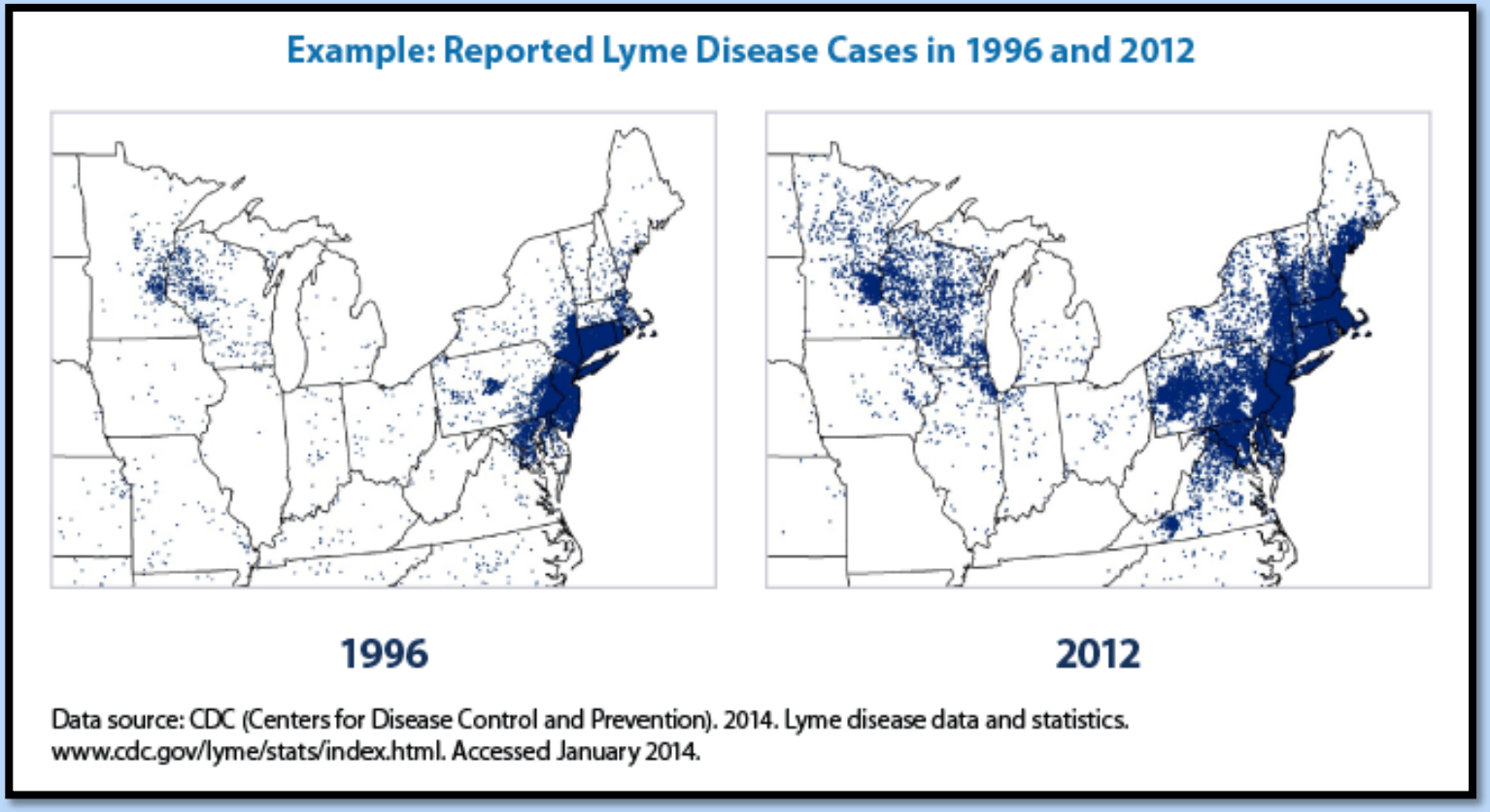


- Color scale represents the R_0 for Ixodes Scapularis tick.
- With warming, habitat suitable for Ixodes Scapularis tick population establishment (R_0>1) expands Northward.

A) estimated from observations 1971-2000
B) Projected for 2011-2040
C) Projected for 2041-2070

Source: Ogden, *Envir Health Perspect*, 2014

Lyme Disease in the U.S.



Among the states where Lyme disease is most common, New Hampshire and Delaware have experienced the largest increases in reported cases since 1991, followed by Maine, Vermont, and Massachusetts.

West Nile Virus

- The most prevalent flavivirus in the world. Carried primarily by Culex mosquitoes.
- Likely evolved in Africa. First isolated in 1937 in Uganda.
- 1950's-1980's spread to Middle East, India and Australia. More frequent outbreaks started in 1990's.
- First detected in U.S. in 1999 in New York City, by 2004 had spread across contiguous United States, then to Canada and Latin America.
- Human case numbers highly variable year to year.

Smith JC, *Journal of Infection* 2014, Harrigan RJ, *Global Change Biology* 2014, Wimberly MC, *Am J Trop Med Hyg* 2014

West Nile Virus

Transmission

- Most commonly transmitted to humans by mosquitoes (esp Culex).
- Additional routes of human infection have also been documented, but represent a very small proportion of cases:
  - Blood transfusions
  - Organ transplants
  - Exposure in a laboratory setting
  - From mother to baby during pregnancy, delivery, or breastfeeding

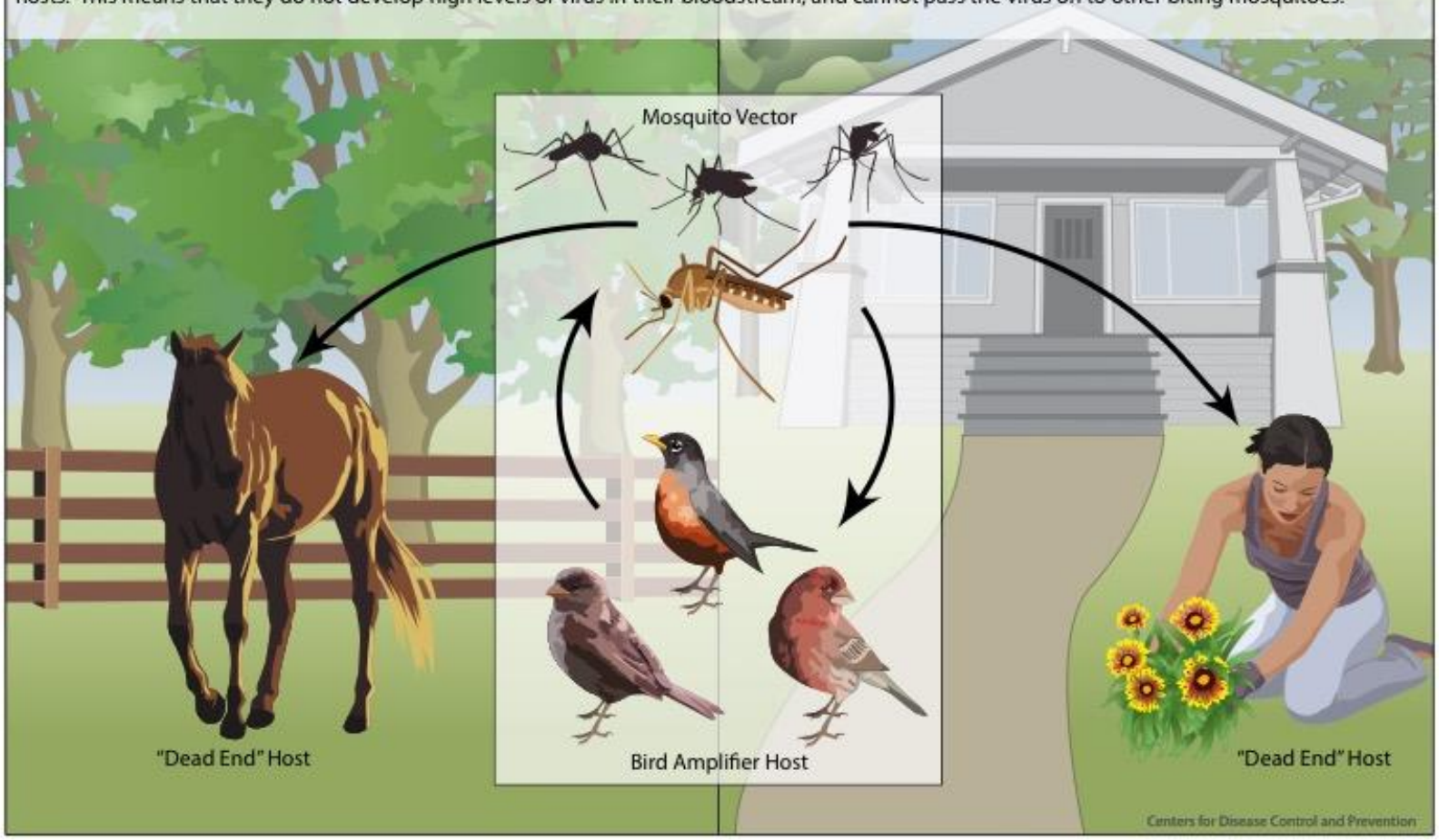
Signs and Symptoms

- No symptoms (70-80%)
- Febrile illness (about 20%)
  - Fever, headache, body aches, joint pains, vomiting, diarrhea, or rash.
  - Fatigue and weakness can last for weeks or months but complete recovery usual.
- Severe symptoms (<1%)
  - Encephalitis or meningitis, with headache, high fever, neck stiffness, disorientation, coma, seizures, or paralysis.
  - Recovery may take several weeks or months or may be permanent.
  - Fatal in about 10 percent of people with neurologic infection.

West Nile Virus Transmission Cycle

In nature, West Nile virus cycles between mosquitoes (especially *Culex* species) and birds. Some infected birds, can develop high levels of the virus in their bloodstream and mosquitoes can become infected by biting these infected birds. After about a week, infected mosquitoes can pass the virus to more birds when they bite.

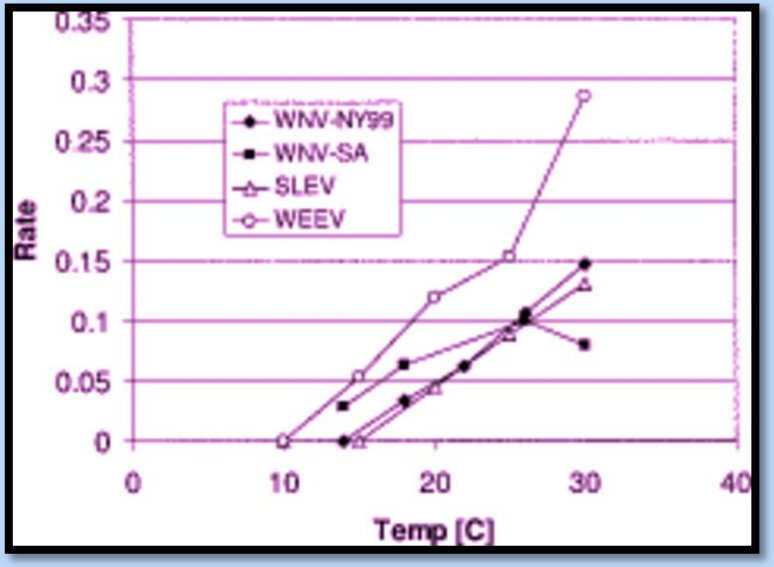
Mosquitoes with West Nile virus also bite and infect people, horses and other mammals. However, humans, horses and other mammals are 'dead end' hosts. This means that they do not develop high levels of virus in their bloodstream, and cannot pass the virus on to other biting mosquitoes.



West Nile and Climate Variables

- Elevated temperature has positive effect on mosquito population, survival, viral replication and WNV disease transmission. (Anyamba A, *PLoS One* 2014)

Rate of virus replication for WNV and other viruses, as a function of temperature, in 2 Culex host mosquito sp.



Reisen WK, *Journal of Medical Entomology* 2006

West Nile and Climate Variables

Reisen WK, *Journal of Medical Entomology 2006*

★Temperature has impacted the dispersal and amplification of West Nile Virus (WNV) in North America.

★WNV always dispersed into new areas during years with above-normal (30-yr mean) summer temperatures and amplification the following year occurred during summers with above-or normal temp.

★Activity decreased during cool summers (especially at northern latitudes).

West Nile Virus

- Drought may also be associated with increased disease activity.

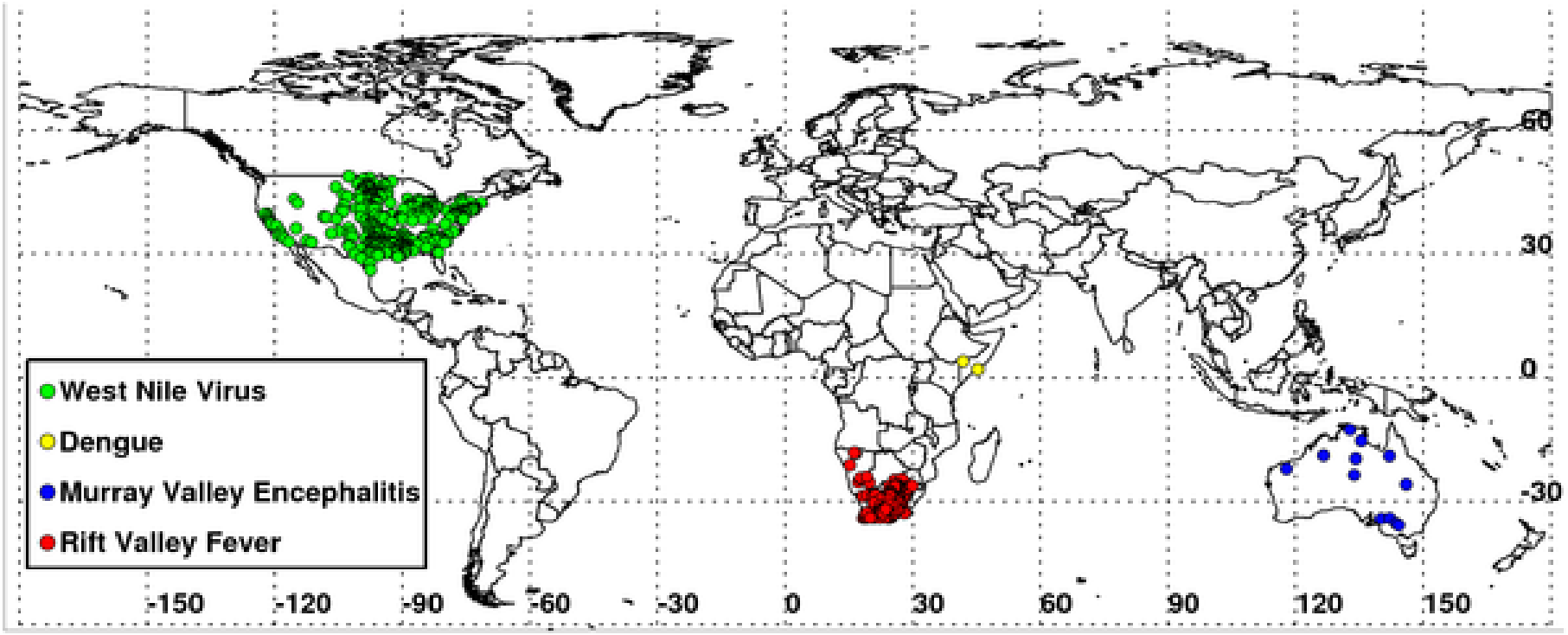
2012 outbreak in Southcentral US:

★One of most severe on record, with 5,674 cases, 2,873 cases neuroinvasive disease and 286 deaths. (CDC)

★Occurred during historic drought, precipitation lower than during Dust Bowl, and extreme high temperatures.

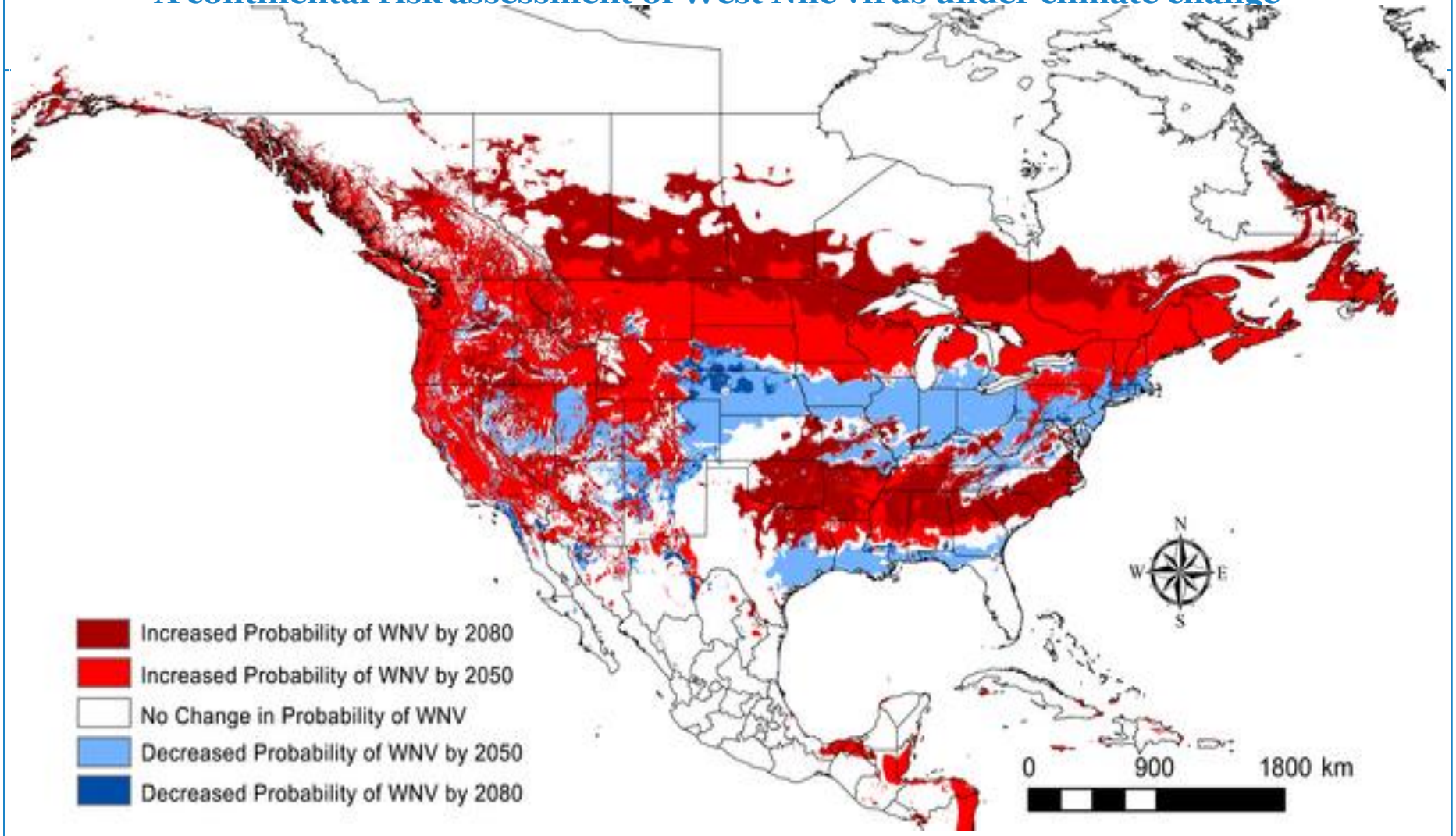
(Little SE, *Veterinary Parasitology* 2013)

Figure 5. Global distribution of epidemics/epizootics of vector-borne disease outbreaks during 2010–2012 associated with weather extremes, showing the outbreak locations of West Nile virus disease (US, 2012), dengue (East Africa, 2011), Rift Valley fever (Southern Africa, 2011), and Murray Valley encephalitis (Australia, 2011).



Anyamba A, Small JL, Britch SC, Tucker CJ, Pak EW, et al. (2014) Recent Weather Extremes and Impacts on Agricultural Production and Vector-Borne Disease Outbreak Patterns. PLoS ONE 9(3): e92538. doi:10.1371/journal.pone.0092538
http://127.0.0.1:8081/plosone/article?id=info:doi/10.1371/journal.pone.0092538

A continental risk assessment of West Nile virus under climate change



Global Change Biology
Volume 20, Issue 8, pages 2417-2425, 27 FEB 2014 DOI: 10.1111/gcb.12534
http://onlinelibrary.wiley.com/doi/10.1111/gcb.12534/full#gcb12534-fig-0005

Dengue Fever and Chikungunya

Dengue

- Likely originated in Africa or Asia.
- Most prevalent and rapidly spreading mosquito-borne viral disease in the world (400 million yearly per CDC).
- One of leading causes of death/hospitalization of children in tropics.
- 50% asymptomatic.
- Symptoms include high fever, severe headache/eye pain, muscle/bone pain, rash, may be followed by hemorrhagic manifestations.

(Sirisena P, *International Journal of Inf Dis* 2014)

Chikungunya

- First described in 1952 in Africa, but likely caused periodic outbreaks in tropical regions for centuries.
- Word translates to “to walk bent over”, due to severe joint pain.
- Symptoms include acute fever, muscle and joint pain, nonspecific rash. Only 4% asymptomatic.
- 20% patients have severe, recurrent joint pains after 1 year.
- Case fatality ratio 1 per 1000, primarily in newborns, elderly and debilitated.

(Morens DM, *NEJM* 2014)

Aedes Mosquitoes

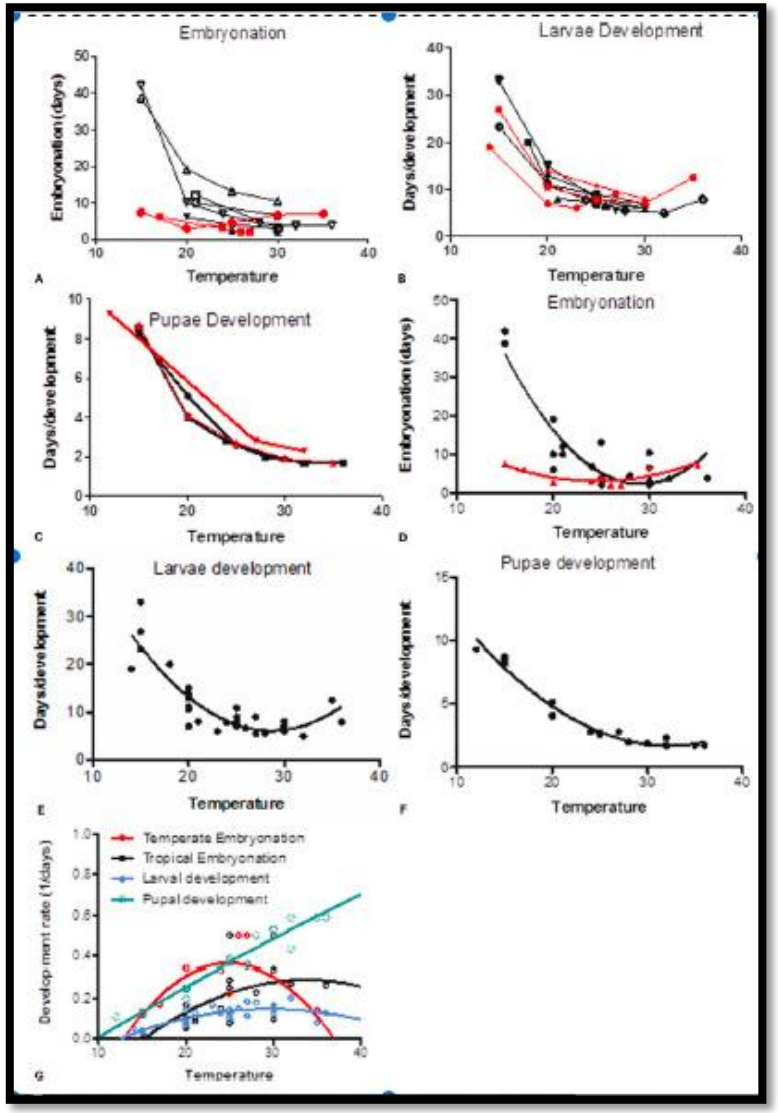
- Primary vectors for both Dengue and Chikungunya.
- Aedes aegypti (classic vector) and Aedes albopictus (Asian Tiger Mosquito).
- Chikungunya acquired mutations in 2004 that enabled it to be transmitted by Ae. albopicutus.
- Have adapted to sub-urban/rural areas where humans are present.

Role of Climate Factors

- The impacts of climate on these diseases are complex and incompletely understood.
- Both minimum and maximum temperatures limit mosquito development and survival.
- Increased temperature shortens mosquito development times, though this differs for tropical/temperate mosquito strains.
- Climate change can expand vector range, extend the transmission season, shorten the mosquito life cycle and reduce time to mosquito infectivity.(Sirisena P, International Journal of Inf Dis, 2014)
- Effects of precipitation on mosquito populations are incompletely understood. (Waldock, J. Pathogens and Global Health, 2013)

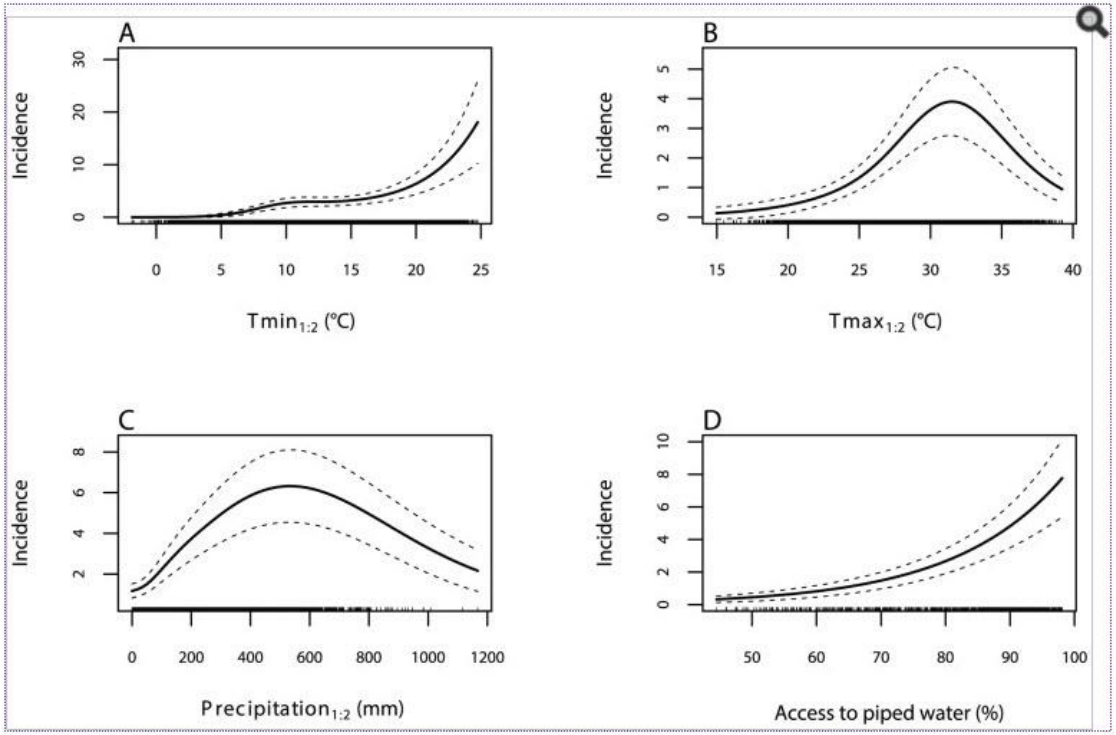
Effect of temperature on Aedes albopictus immature development

Waldock J, *Pathogens and Global Health* 2013



Climate Factors and Dengue

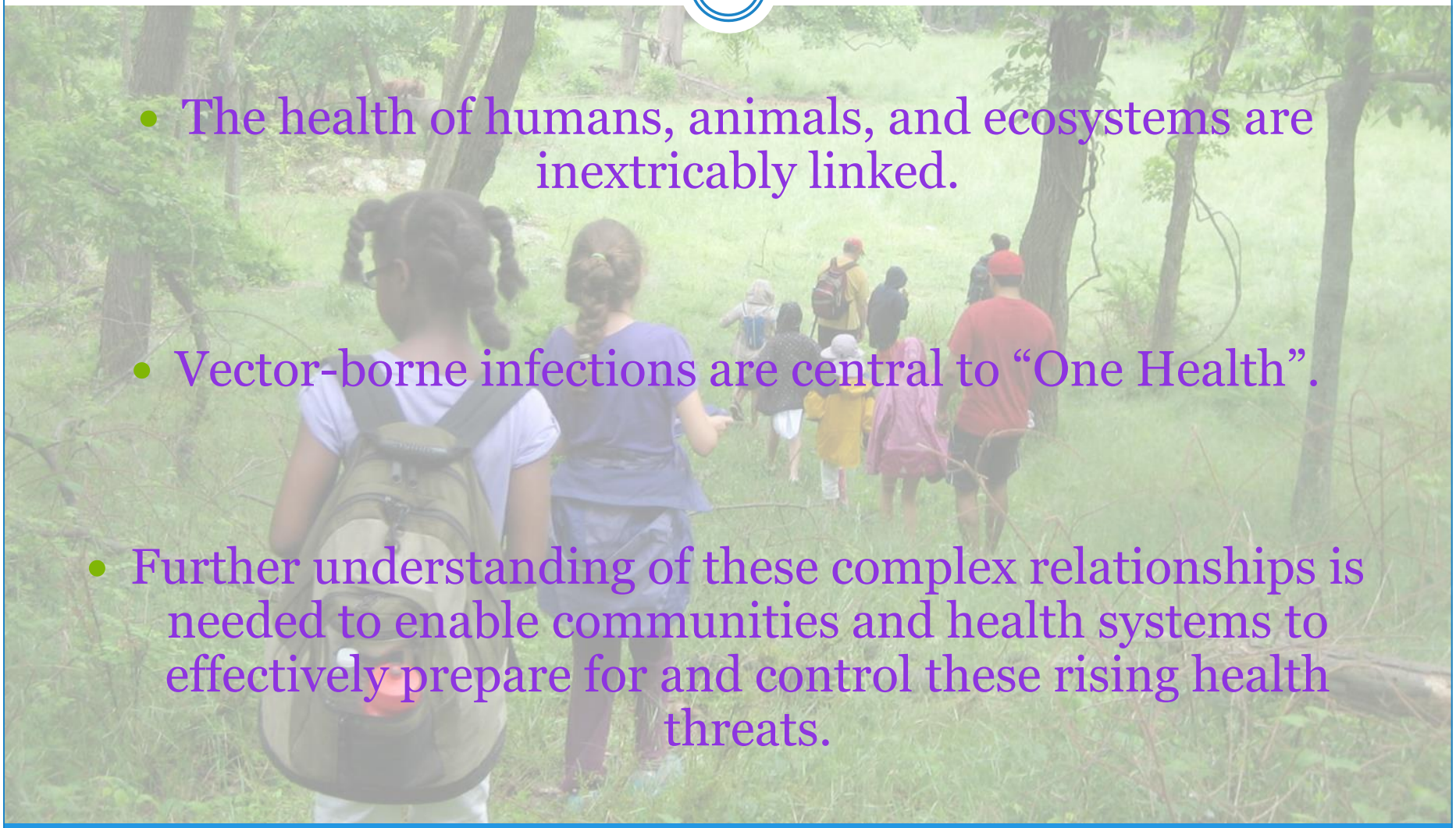
Estimated effects of weather variables on Dengue incidence in Mexico over 23 years. (Colon-Gonzalez, *PLOS Neglected Tropical Diseases* 2013)



GAM-estimated relationships.

The figure shows the GAM estimated relationships between average monthly dengue incidence and (A) $Tmin_{1:2}$, (B) $Tmax_{1:2}$, (C) $Precipitation_{1:2}$, and (D) the proportion of the population with access to piped water. Solid lines indicate the average expected number of dengue cases (cases/100,000 people per month); dashed lines indicate the estimated 95% Bayesian estimation confidence intervals.

“One Health”



- The health of humans, animals, and ecosystems are inextricably linked.
- Vector-borne infections are central to “One Health”.
- Further understanding of these complex relationships is needed to enable communities and health systems to effectively prepare for and control these rising health threats.

Climate Change and Child Health

Resources:

- American Academy of Pediatrics-Global Climate Change and Children's Health. Policy Statement and Tech Report, 2007.
- Climate Change, Challenges and Opportunities for Global Health. JAMA, 2014.
- American Public Health Association– Climate Change
- UNICEF- Climate Change and Children
- WHO- Climate Change and Human Health
- Lancet Commission on Climate Change and Health
- National Climate Assessment, GlobalChange.gov
- NASA- climate.nasa.gov
- NOAA- noaa.gov/climate.html