

# Emerging Arboviruses



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Atlantic Monthly, 1997

ASM Northeast regional meeting

20-21 October 2015

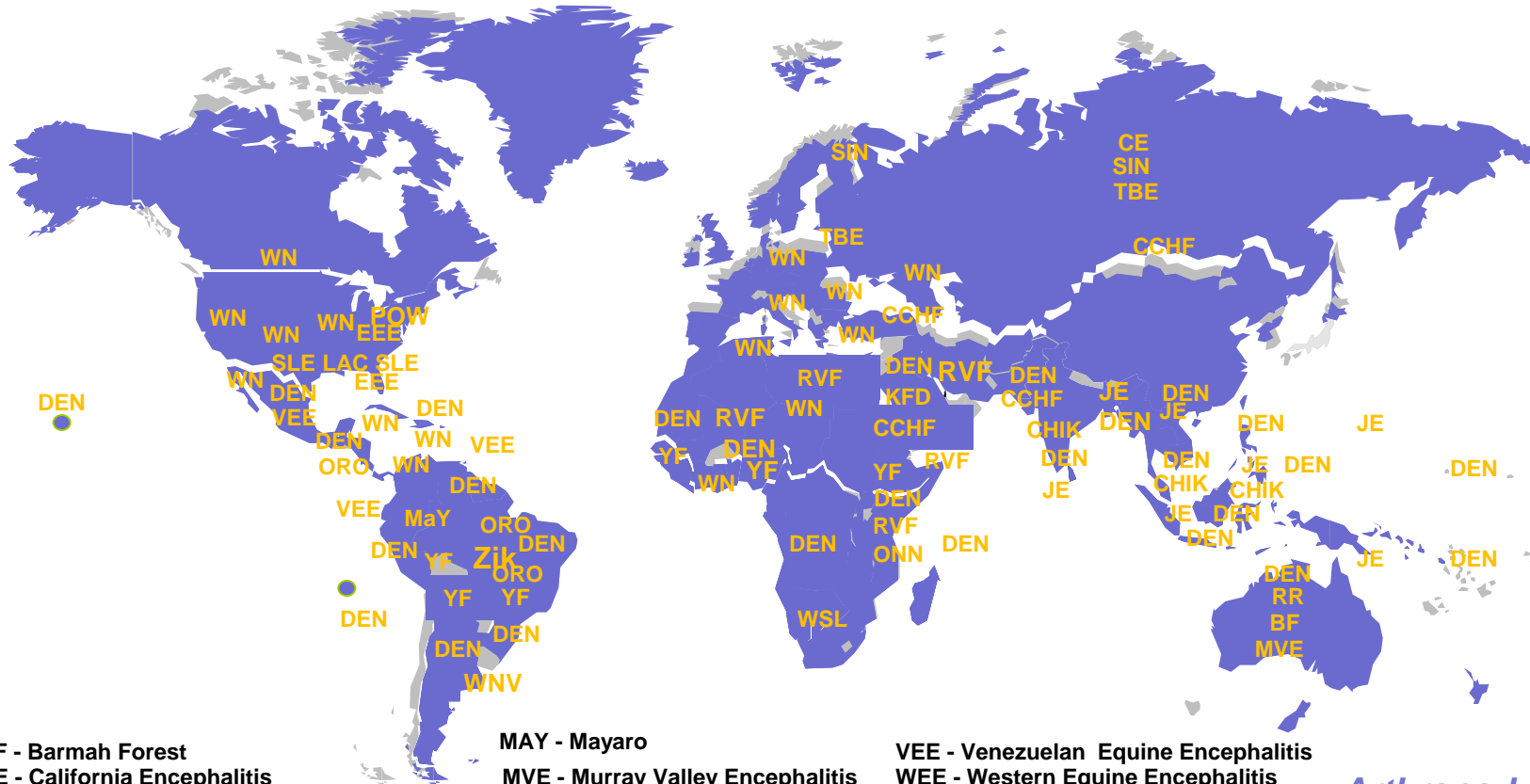


# Why have we seen such a dramatic increase in epidemic activity and geographic spread of vector-borne diseases?

- Background and concepts
- Reasons for epidemic transmission and spread
- Emerging mosquito-borne viruses
  - *West Nile virus*
  - *Dengue virus*
  - *Chikungunya virus*
- Risk in US



# Global Emergence of Epidemic Arboviral Diseases



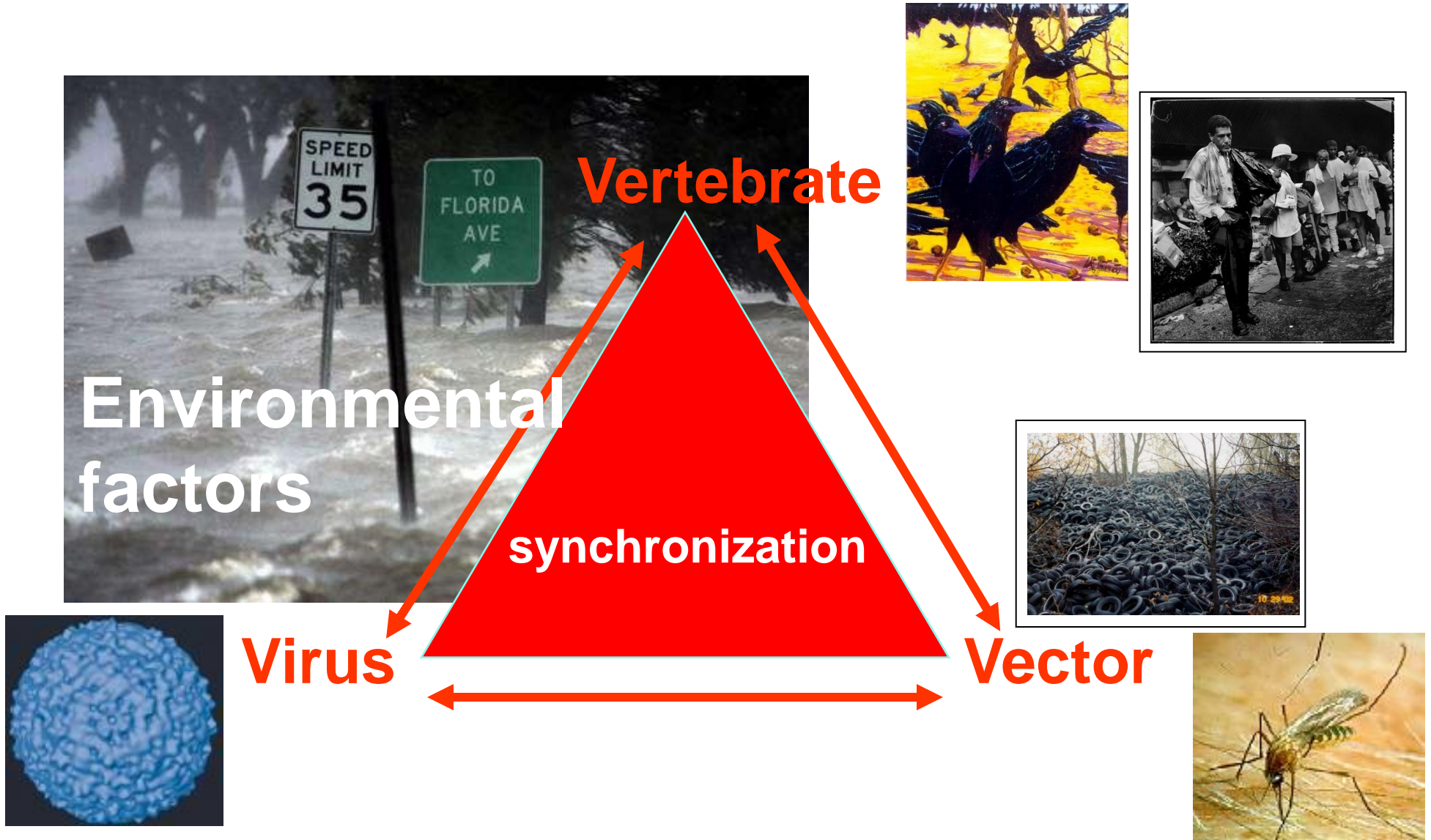
BF - Barmah Forest  
 CE - California Encephalitis  
 Chik - Chikungunya  
 CCHF - Congo-Crimean Hemorrhagic Fever  
 DEN - Dengue  
 EEE - Eastern Equine Encephalitis  
 JE - Japanese Encephalitis  
 KFD - Kyasanur Forest Disease  
 LAC - LaCrosse Encephalitis

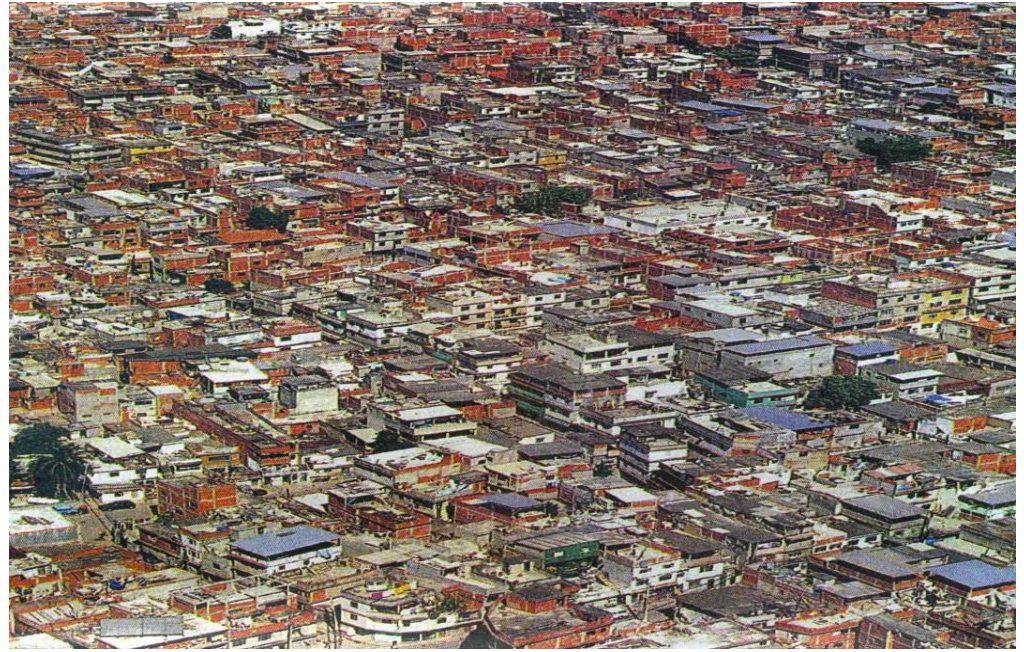
MAY - Mayaro  
 MVE - Murray Valley Encephalitis  
 ONN - O'nyong-nyong  
 ORO - Oropouche  
 RVF - Rift Valley Fever  
 RR - Ross River  
 SLE - St. Louis Encephalitis  
 SIN - Sinbis  
 TBE - Tick-Borne Encephalitis

VEE - Venezuelan Equine Encephalitis  
 WEE - Western Equine Encephalitis  
 WN - West Nile  
 WSL - Wesselsbron  
 YF - Yellow Fever  
 ZIK - Zika

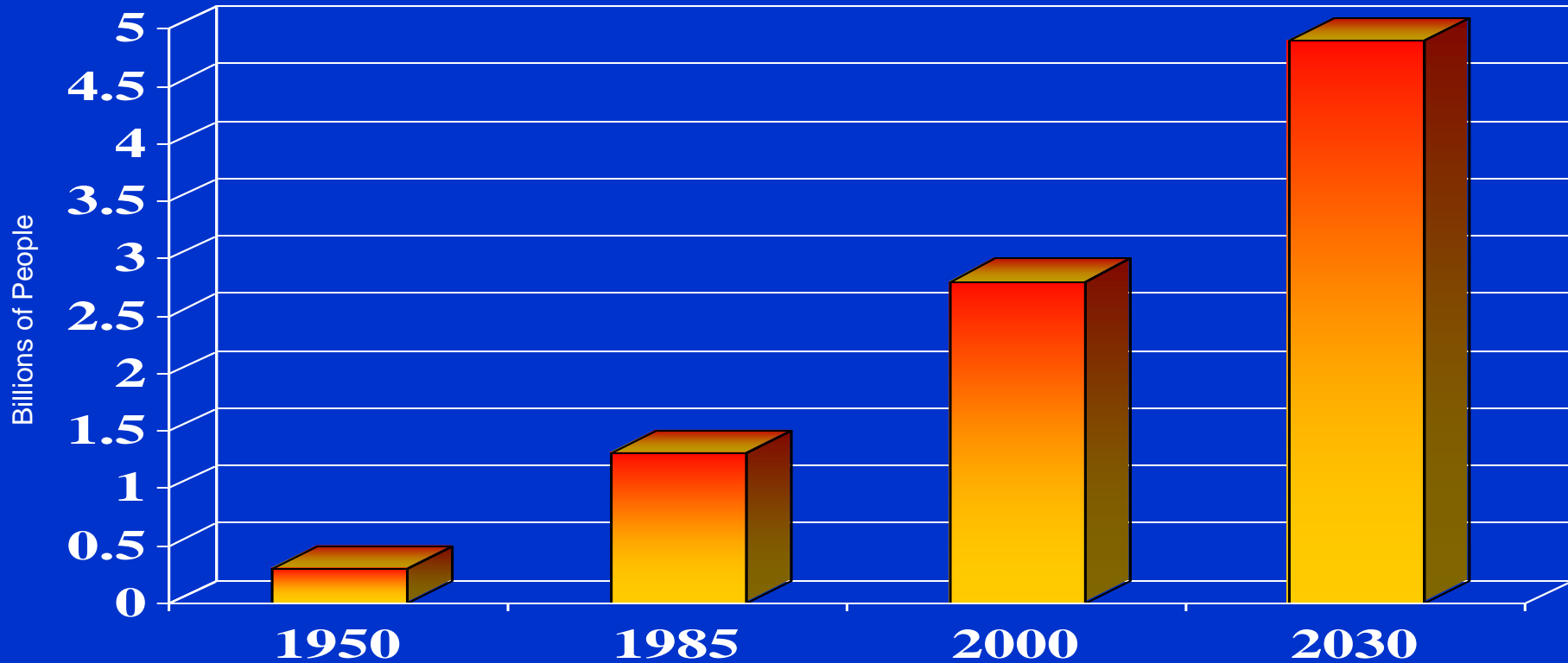
- Arthropod-borne (arbo) viruses:**
- Almost exclusively RNA viruses
  - >120 associated with human disease
  - Most imp't families Flaviviridae, Togaviridae, or Bunyaviridae
  - Significant global expansion in recent decades

# Important factors in emergence and spread of arthropod-borne viruses



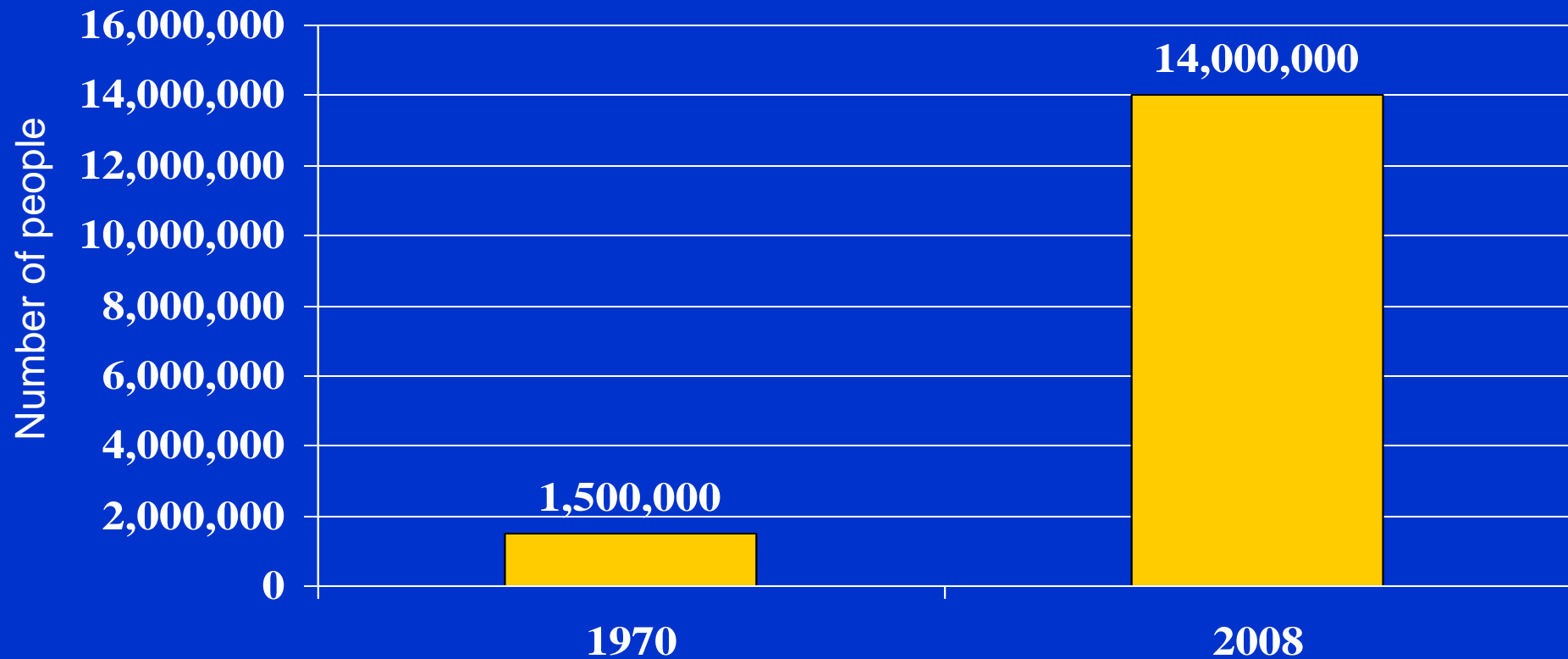


# Estimated Number of People Living in Urban Areas



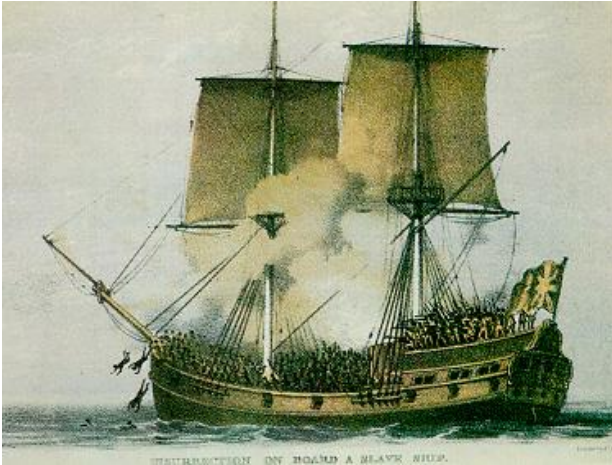
# Urbanization

## The Case of Dhaka, Bangladesh



Source: UN

# Mosquitoes that have travelled the world...



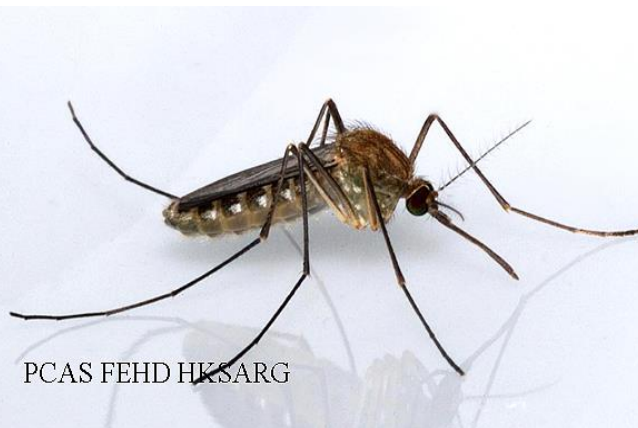
...and spread many viruses to humans



Photo courtesy of Paul Zborowski ©2004

*Aedes aegypti*

DENV, YFV, CHIK, etc.



PCAS FEHD HKSARG

*Culex pipiens*

WNV, SLEV, etc.



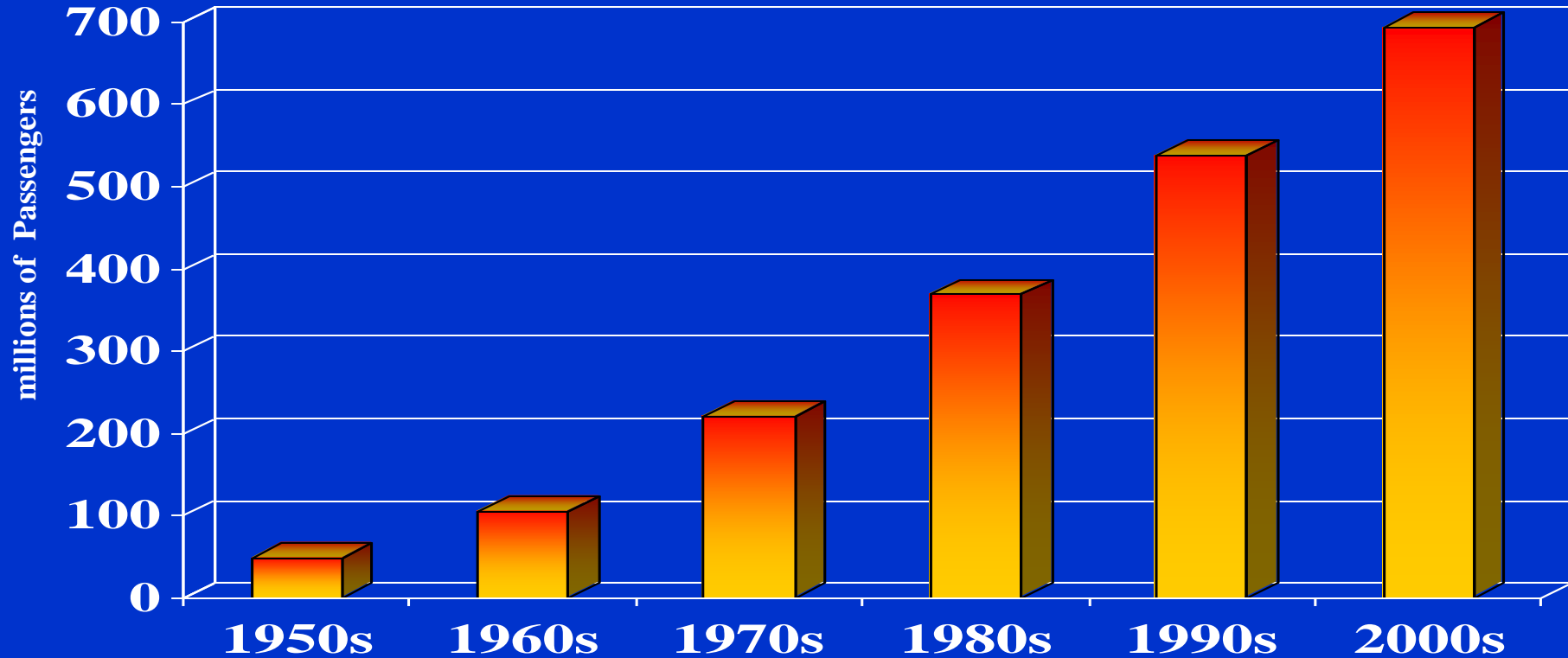
© Sean McCann

*Aedes albopictus*

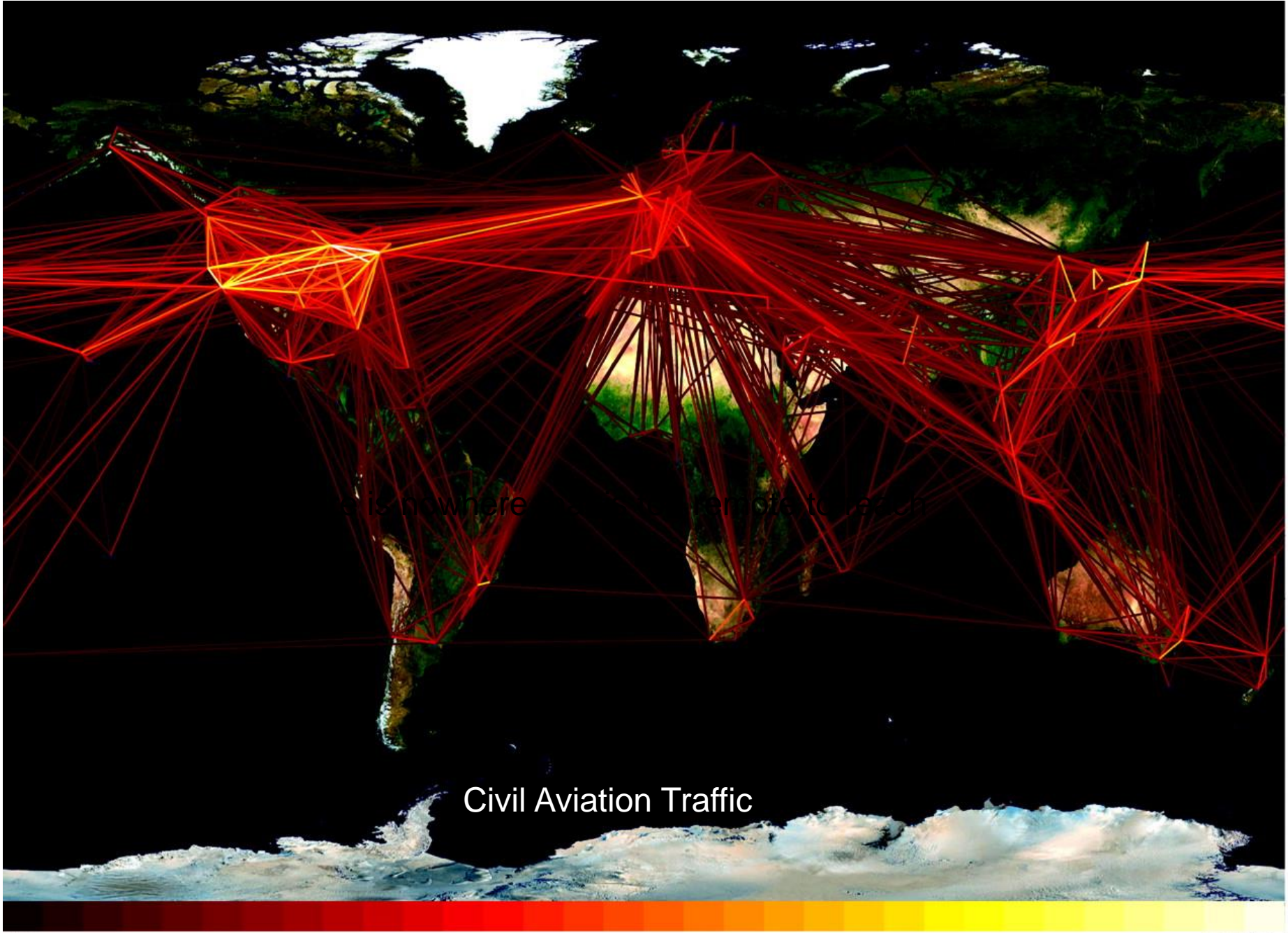
DENV, CHIK, etc.



# Mean Annual Number of Airline Passengers by Decade, United States, 1954-2007



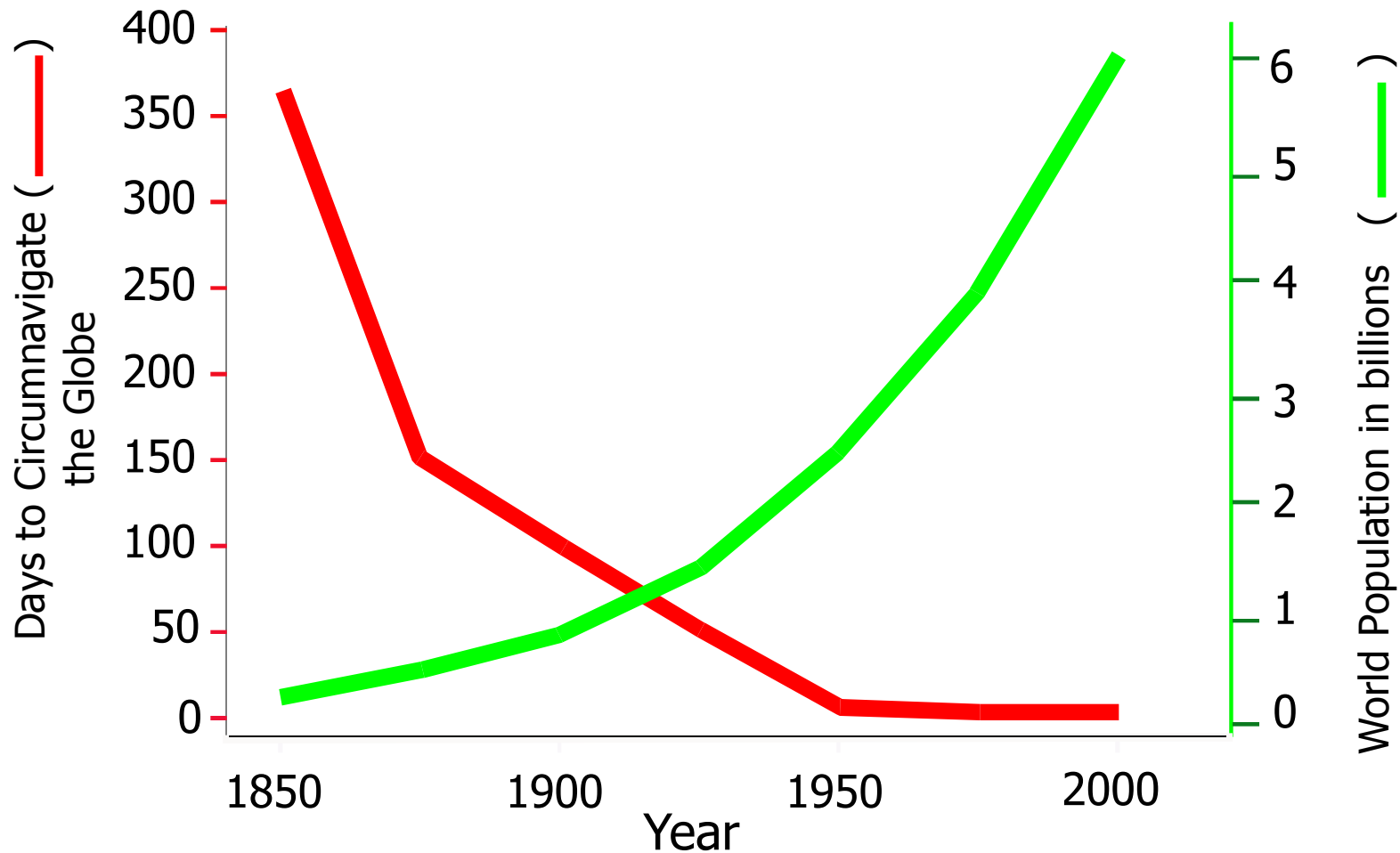
Source: RITA, DOT



10 Least frequent no. passengers / day

Hufnagel et al, 2004 PNAS Most frequent 25000

# Speed of Global Travel in Relation to World Population Growth

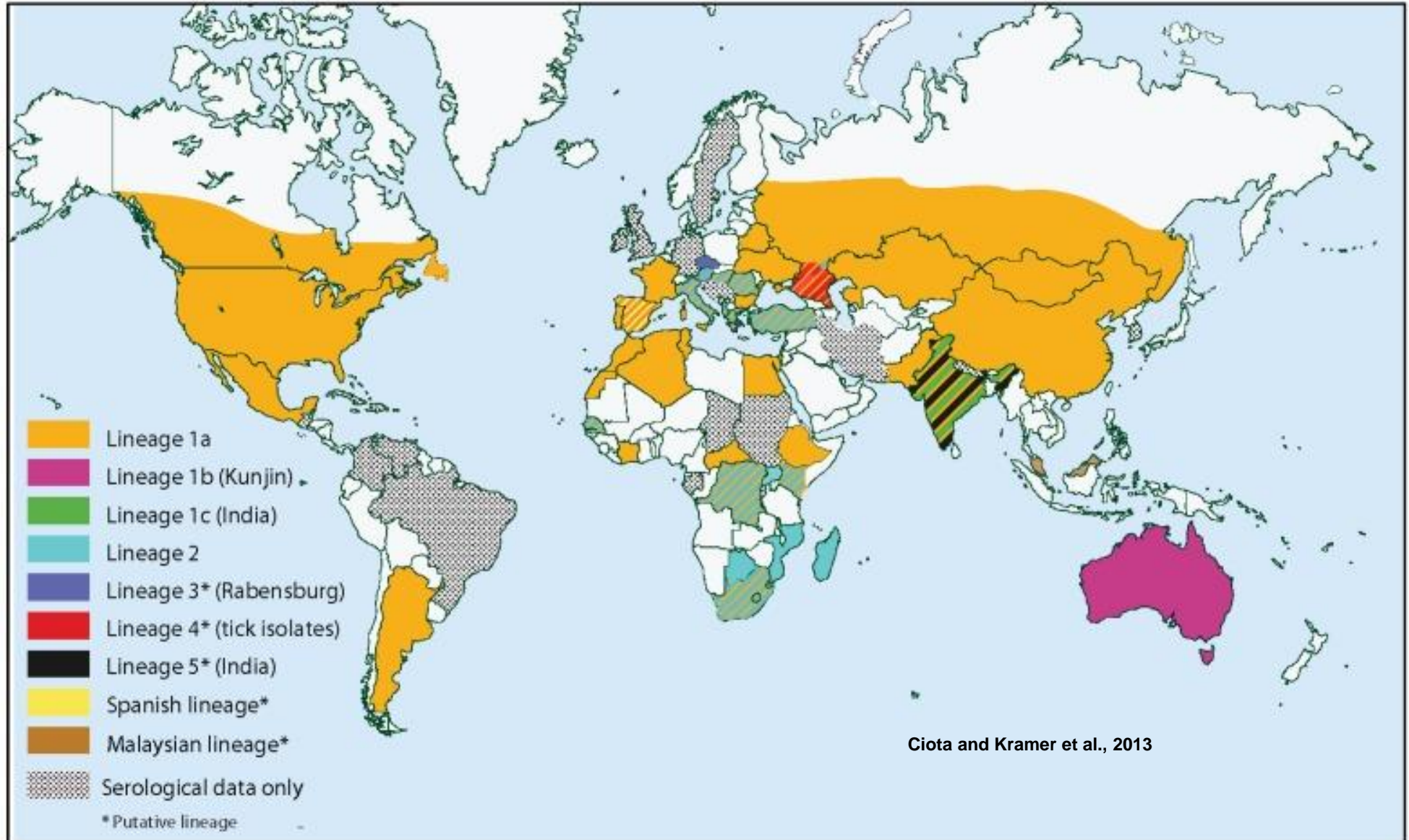


# Why have we seen such a dramatic increase in epidemic activity and geographic spread of vector-borne diseases?

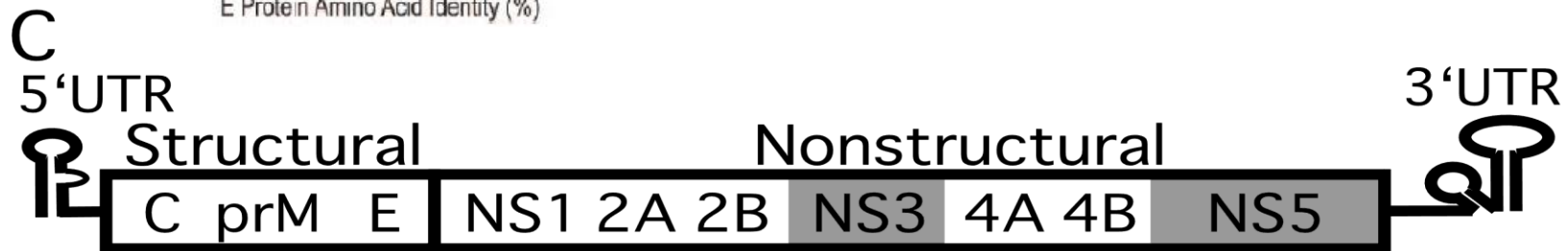
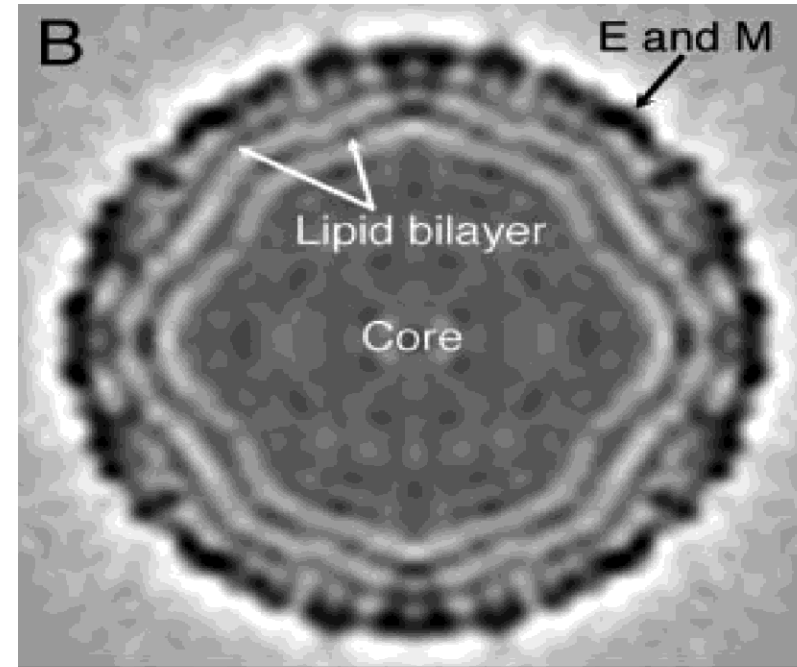
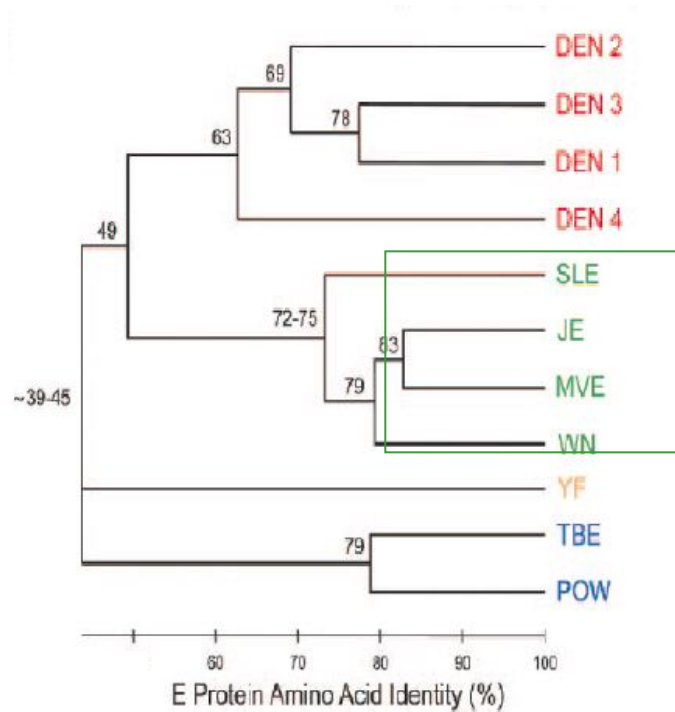
- Background and concepts
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  - *Chikungunya virus*
- Risk in US



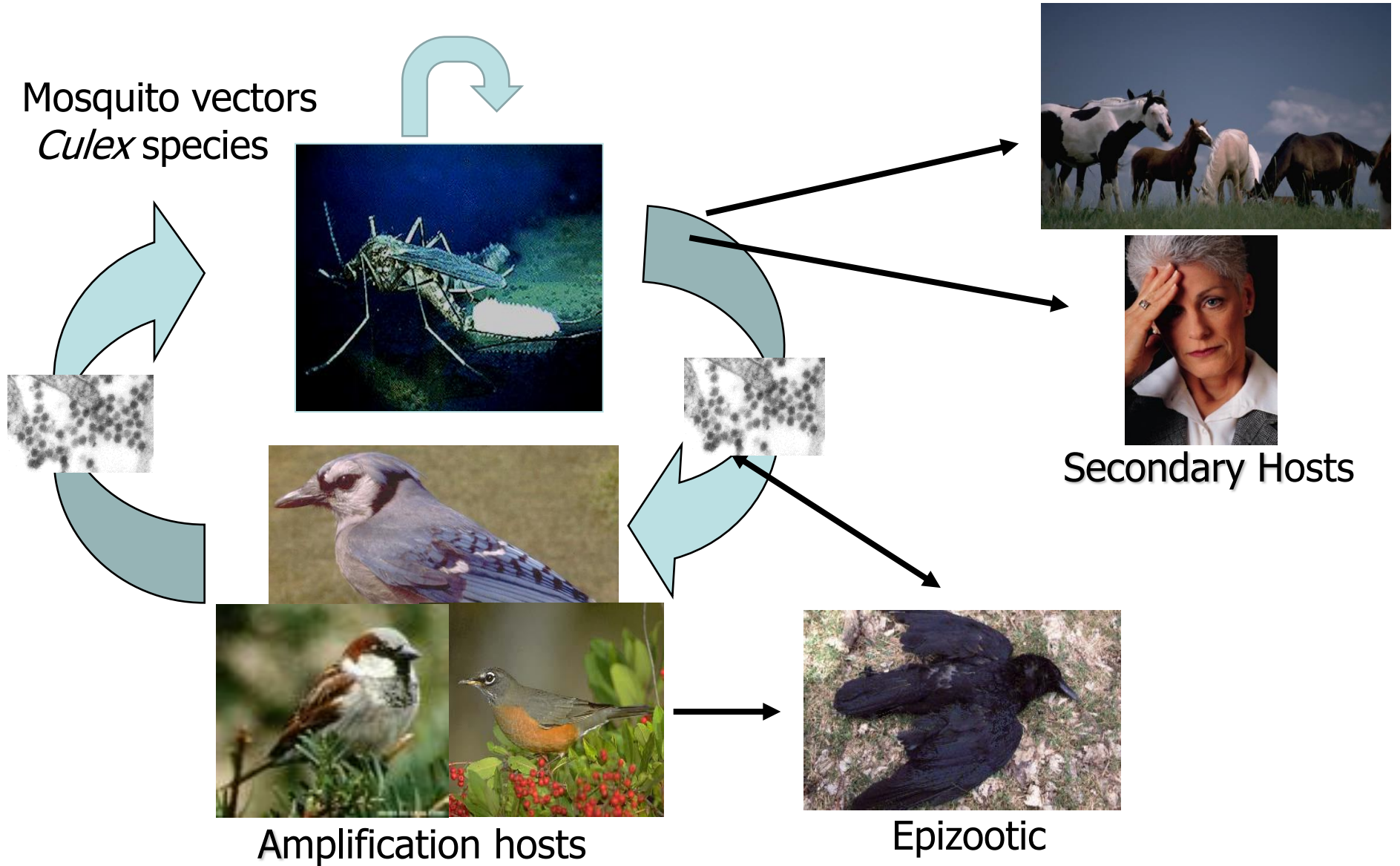
# West Nile virus- a case study for geographical expansion



# West Nile virus (*Flavivirus*; *Flaviviridae*)



# West Nile Virus Transmission Cycle



# Host competence: the vertebrate host



*Columba livia*

0% mortality  
LD<sub>50</sub>>10<sup>5</sup>



*Passer domesticus*

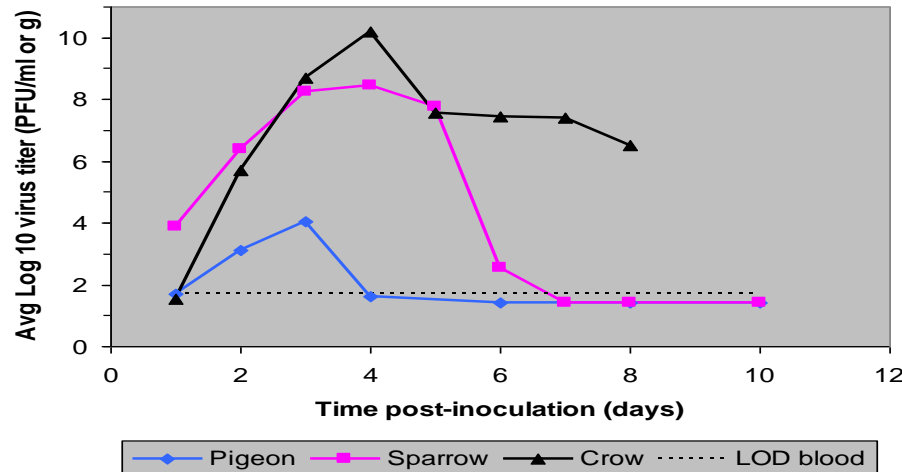
20% mortality  
LD<sub>50</sub>>10<sup>5</sup>



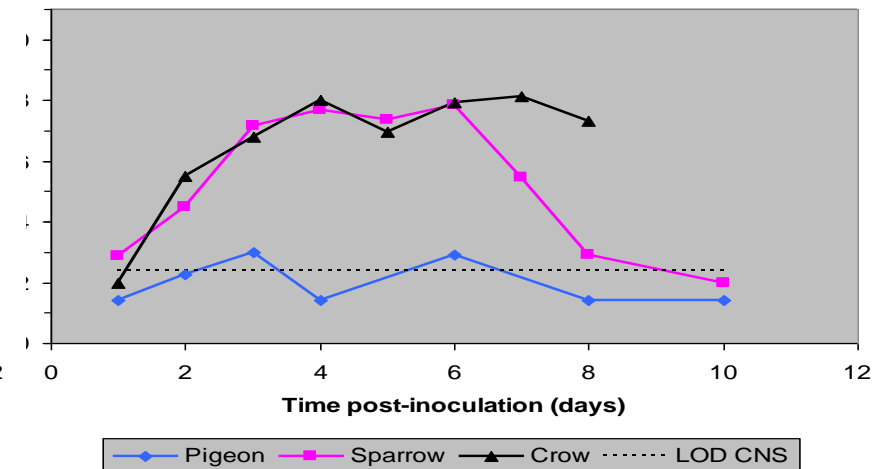
*Corvus brachyrhynchos*

100% mortality  
LD<sub>50</sub><10<sup>1</sup>

## Blood titers

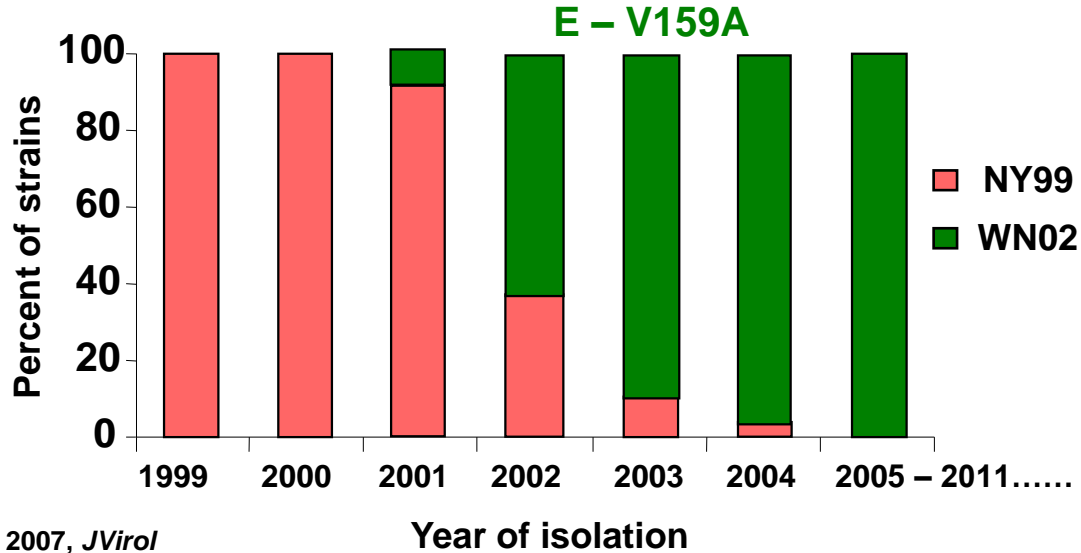


## Spinal cord titers

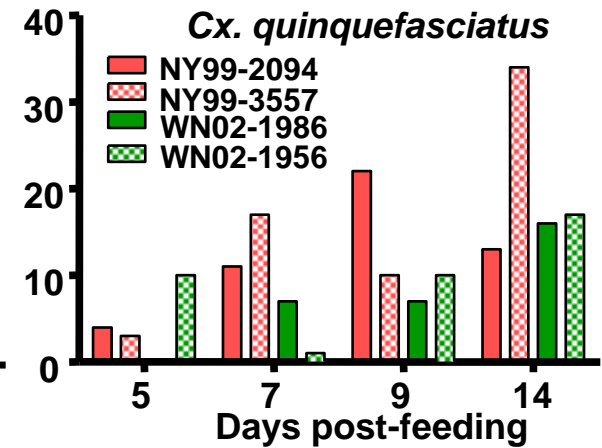
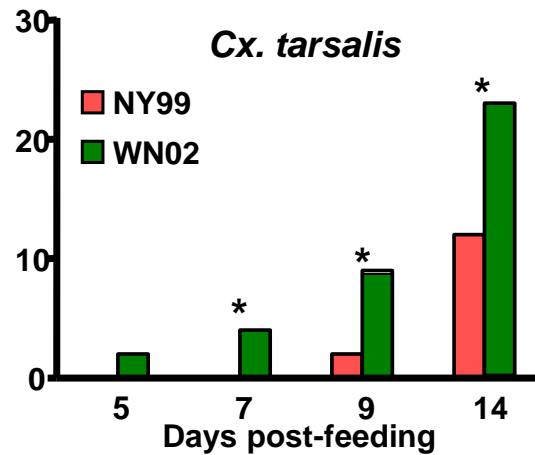
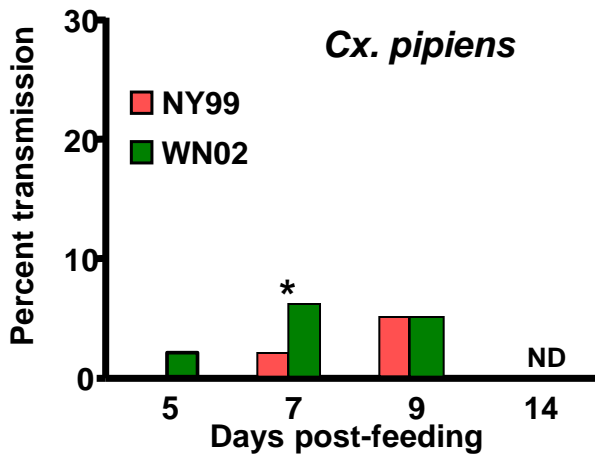




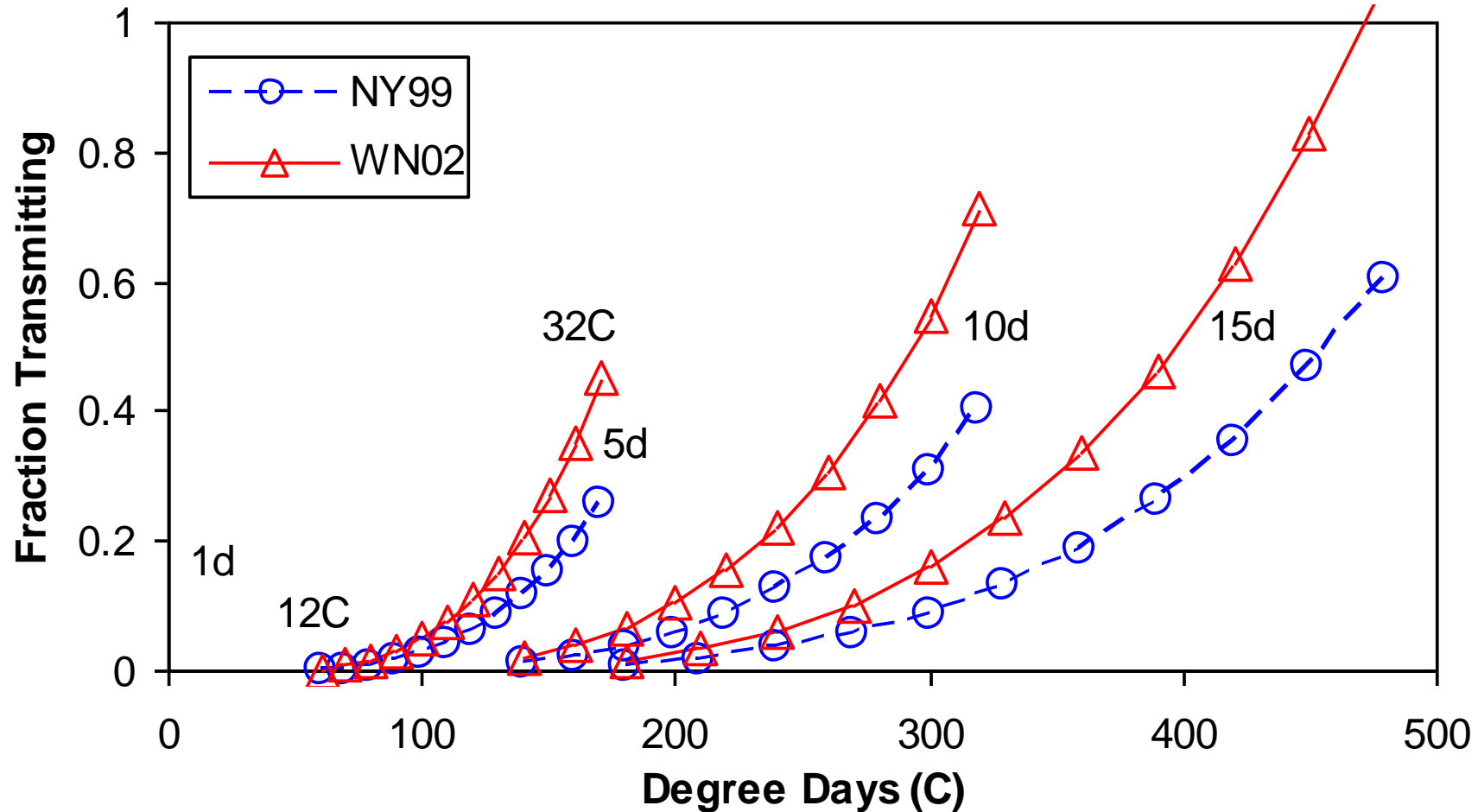
# West Nile virus strain displacement



Snappin *et al.*, 2007, *JVirol*  
 Ebel *et al.*, 2004, *AJTMH*; Moudy *et al.*, 2007, *AJTMH*



# Transmission accelerates with increasing temperature , $tT^4$ (fitted model)\*



\* Integrating viral genotype, time, temperature

# ENVIRONMENTAL FACTORS

## Importance of socioeconomic conditions and land use



[braceforimpactnow.blogspot.com](http://braceforimpactnow.blogspot.com)



**Pools at foreclosed homes raise West Nile  
threat in Dallas County**

**By THEODORE KIM / The Dallas Morning  
News**

**May 22, 2009**

[tkim@dallasnews.com](mailto:tkim@dallasnews.com)



Dengue

# Dengue

- **Worldwide Impact**
  - Currently > 2.5B at risk
  - 50-100M cases DEN fever per year
  - 250,000 – 500,000 cases of DHF
- **Virus Classification**
  - *Flaviviridae*, *Flavivirus*
  - Single-stranded, + sense, RNA genome
  - Enveloped virus

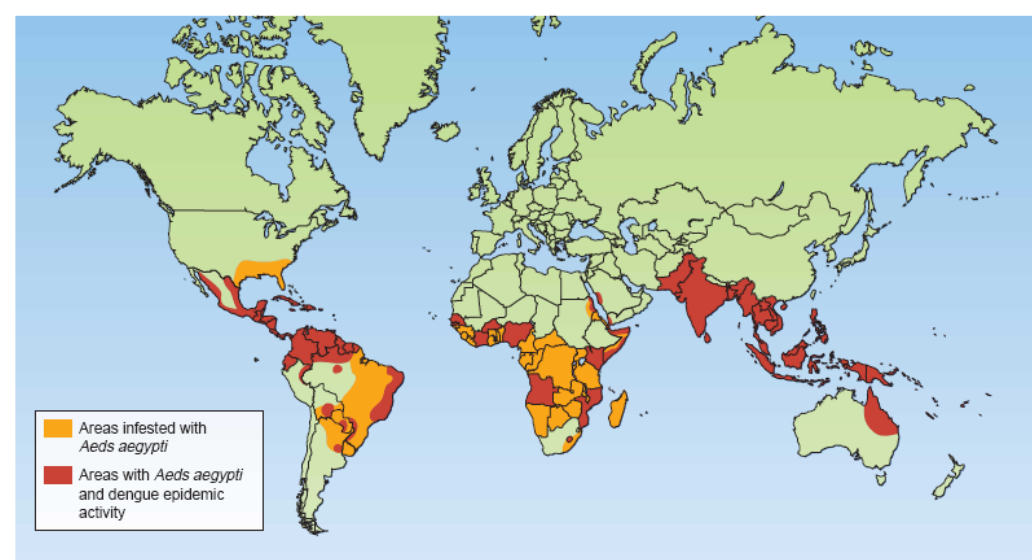
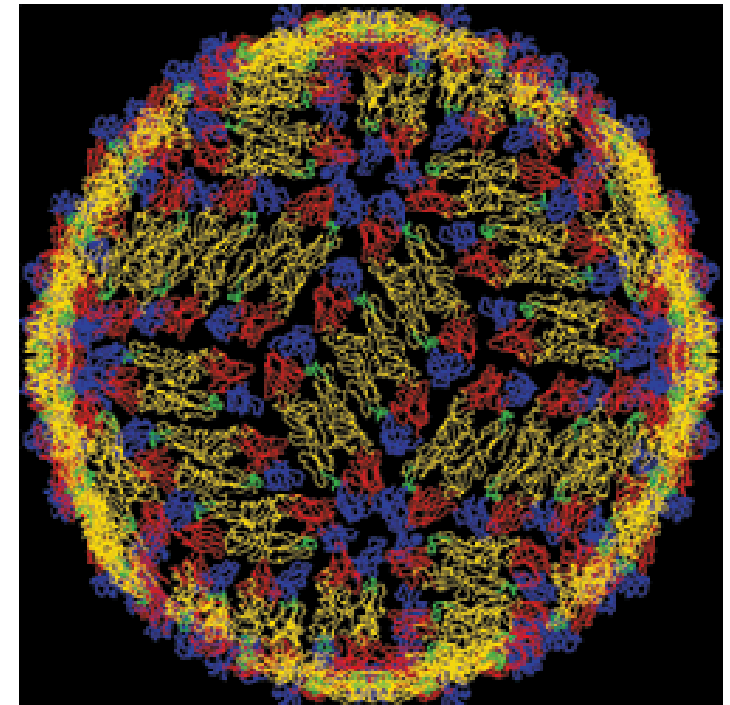


Figure 6 Dengue: its current distribution, and countries with *Ae. aegypti* and at risk of introduction.



Mature dengue virus viewed through cryo-electron micro-scopy

# Dengue Virus

- 4 genetically distinct serotypes
  - Lifetime homologous (within serotype) immunity
  - Short-term heterologous (between serotype) cross-protection
- Significant **variation** within serotypes (strains)

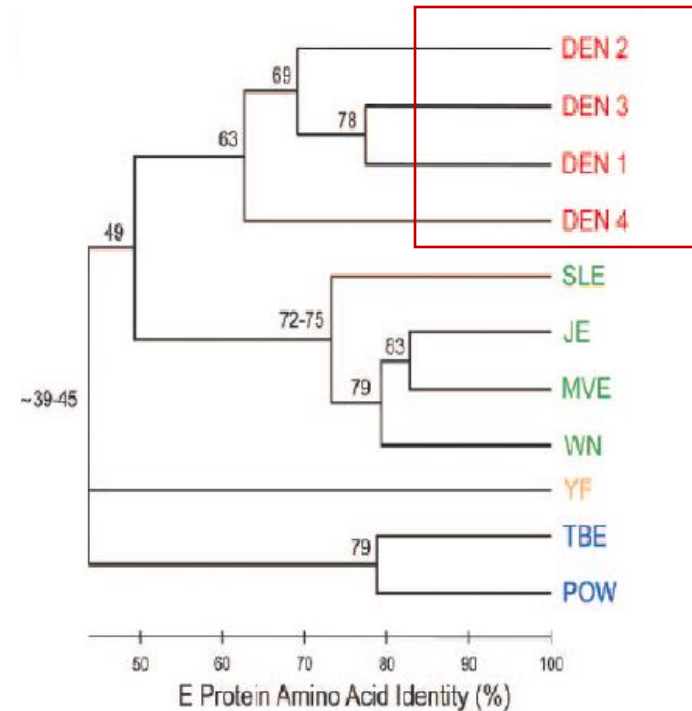
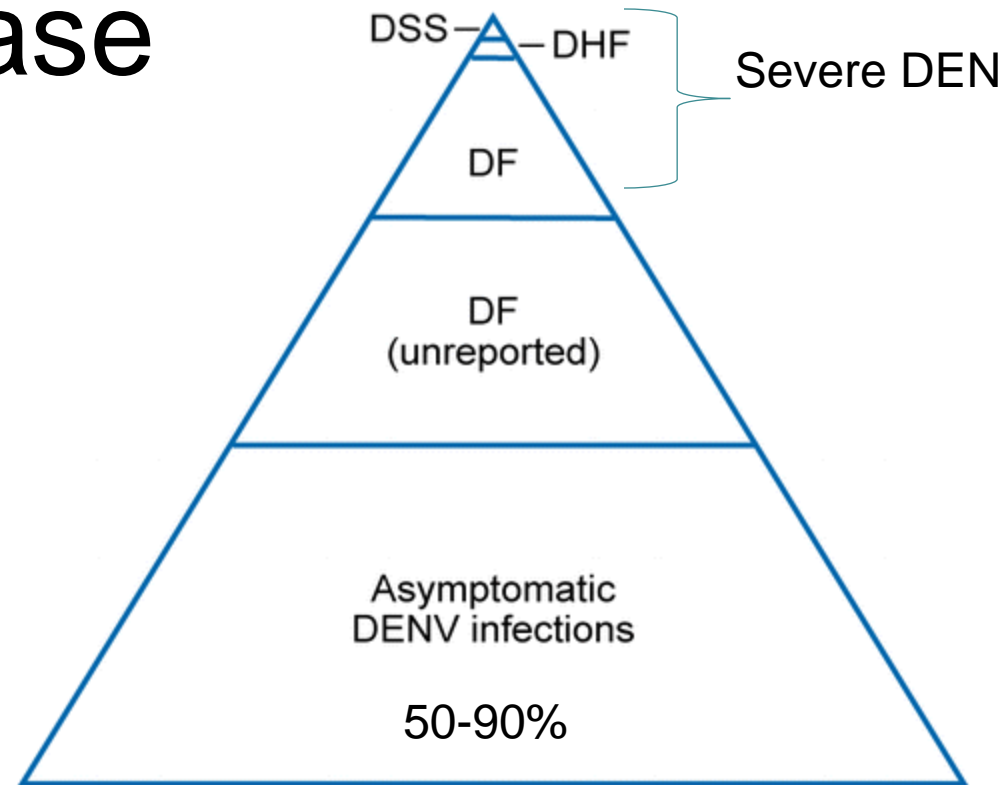


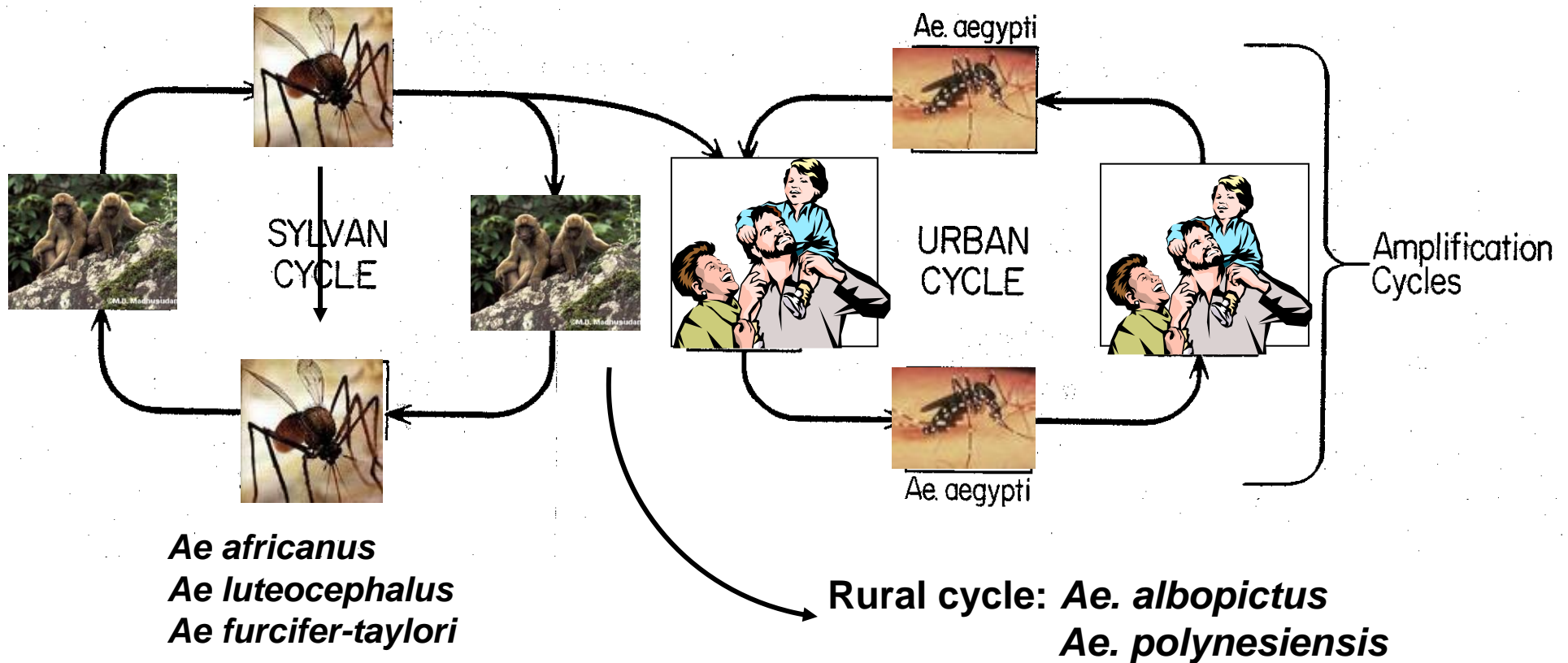
Figure. Partial phylogeny of flaviviruses

# Dengue disease

- **Dengue fever** (breakbone fever)
  - Fever, retro-orbital headache, muscle and joint pain, nausea/vomiting, rash
- **DHF/DSS** (~ 0.5-10%)-often associated with 2ndary infection with heterologous serotype
  - Fever
  - Hemorrhagic manifestations
  - Leaky capillaries
  - Low platelet count
  - DSS = DHF + signs of circulatory failure
- 2009 **WHO** classification:
  - Den without warning
  - Den with warning
  - Severe DEN

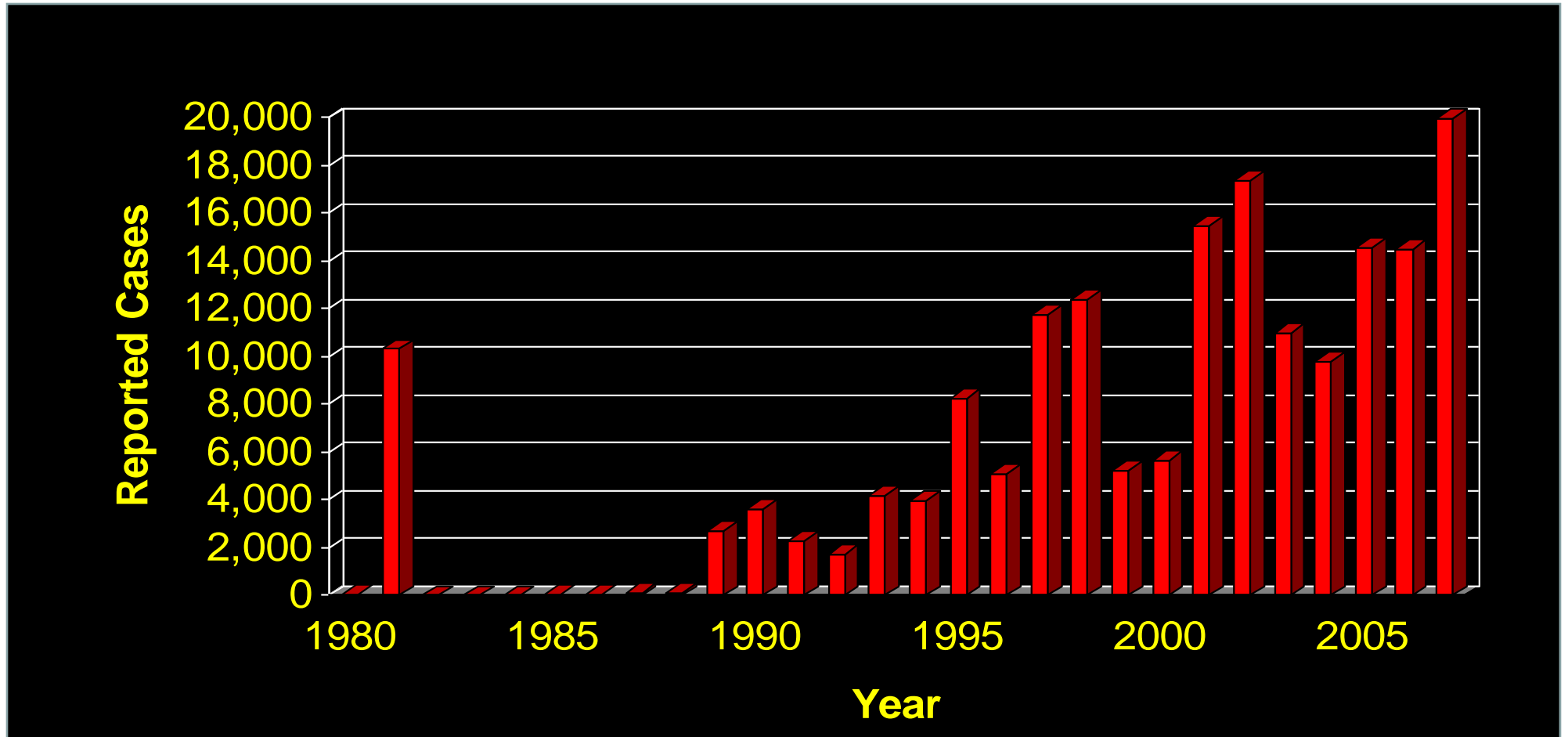


# Transmission Cycle





# DHF in the Americas (1980 – 2007)



\* Data: PAHO (Nov. 30, 2007)



# Chikungunya

(*Togaviridae: Alphavirus*)



In Swahili, “chikungunya” : “ that which contorts or bends “up”

## Disease:

High fever (103-104 F)

Rash

**Severe incapacitating arthritis/arthralgia**

— Generalized

— Usually acute

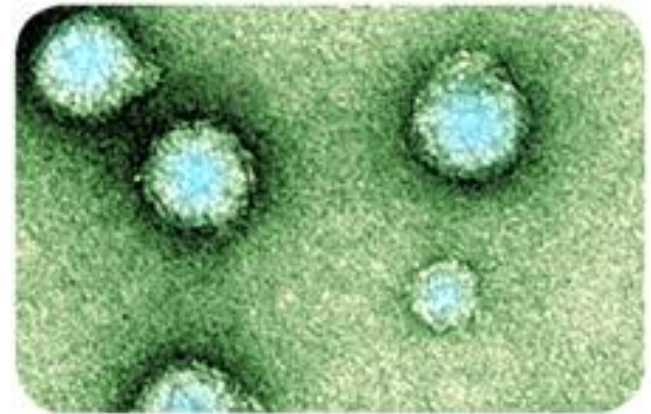
Rarely fatal



G. Pialoux et al., 2007, Lancet Infect Dis

A.M. Powers and C.H. Logue, 2007 J Gen Virol,

# Chikungunya Virus and Disease



- First isolated in Tanzania 1952
- Family - Togaviridae, Genus – Alphavirus
  - Single-stranded + RNA virus, enveloped
- Symptoms
  - Typical: Sudden onset of fever with severe joint pain (often hands/feet), headache, nausea, vomiting, rash, muscle pain
  - Joint pain can persist for weeks or months
  - Prior to recent outbreaks, no fatal cases
- Similar symptoms and range as dengue – misdiagnosed?

# CHIKV Transmission Cycle

## forested areas in West & Central Africa



eg. Forest redtail monkey



**Forest *Aedes* spp.**

- Ae africanus*
- Ae luteocephalus*
- Ae furcifer-taylori*



# CHIKV Transmission Cycle

urban areas Asia, Indian Ocean islands, Europe,  
Caribbean



*Aedes aegypti*



& *Ae. albopictus*



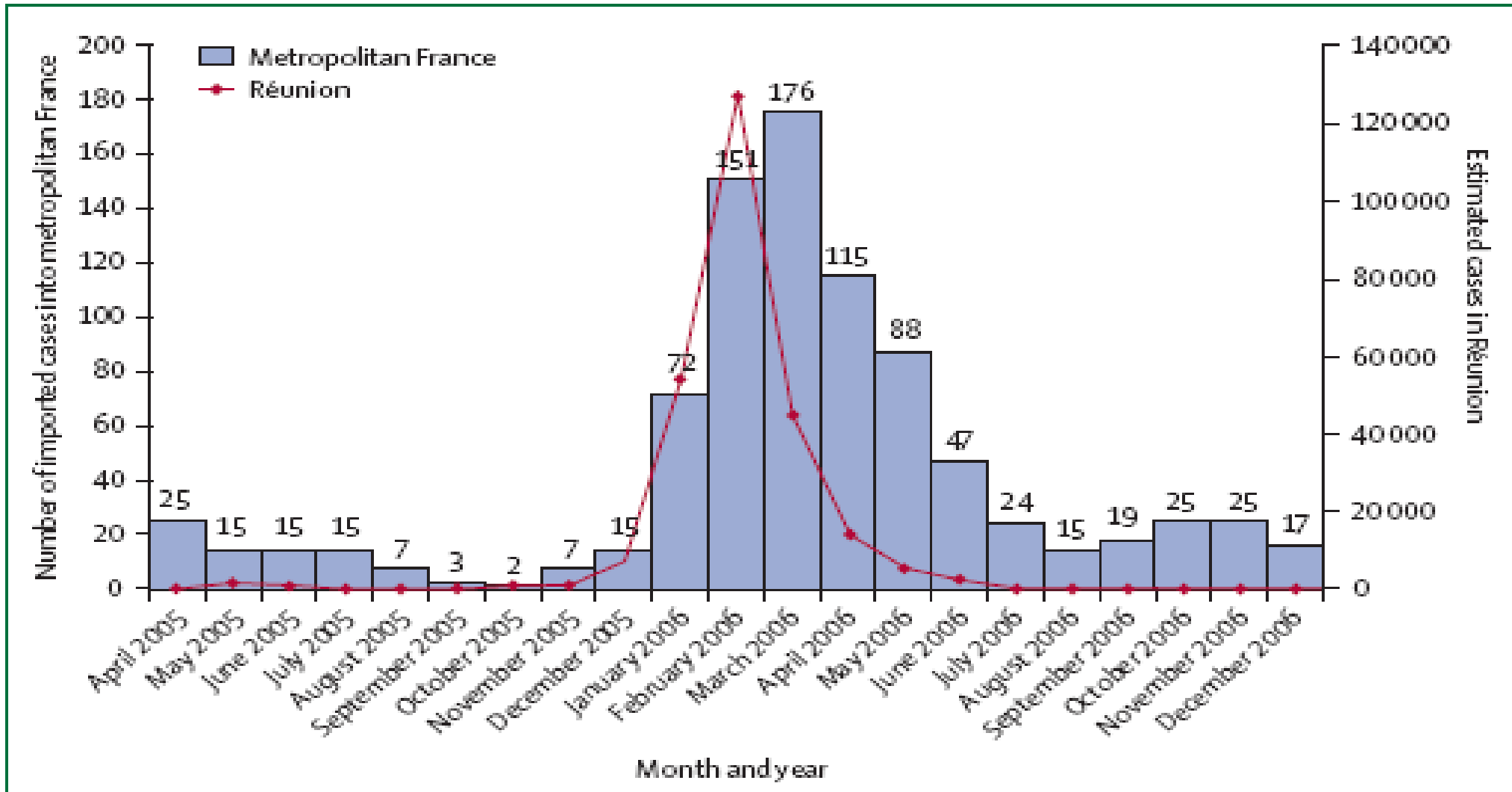
# Chikungunya outbreak 2004-2007



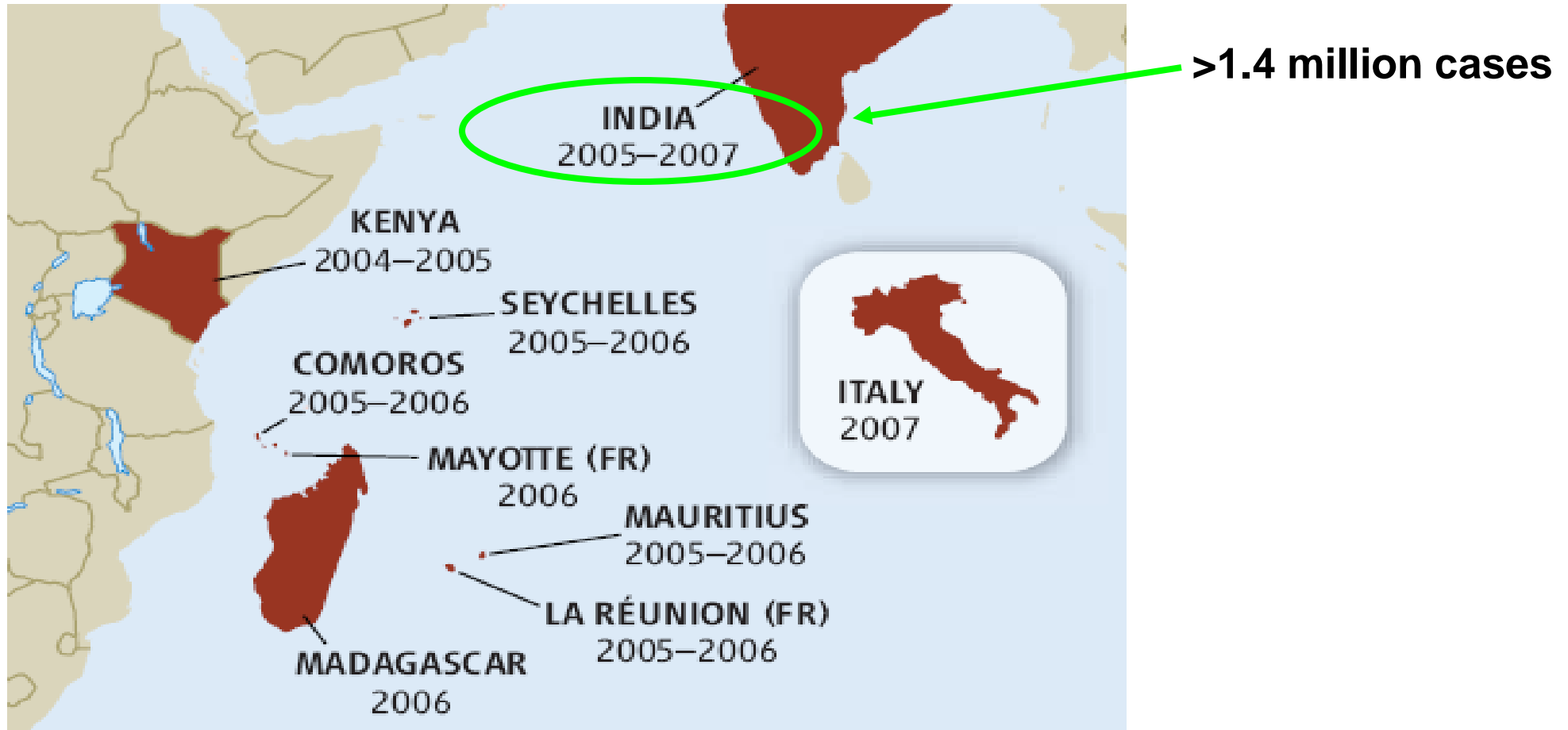
Enserink, M. (2007) Science 318: 1860-1861

# Chikungunya Virus Outbreak

## 878 imported cases to France

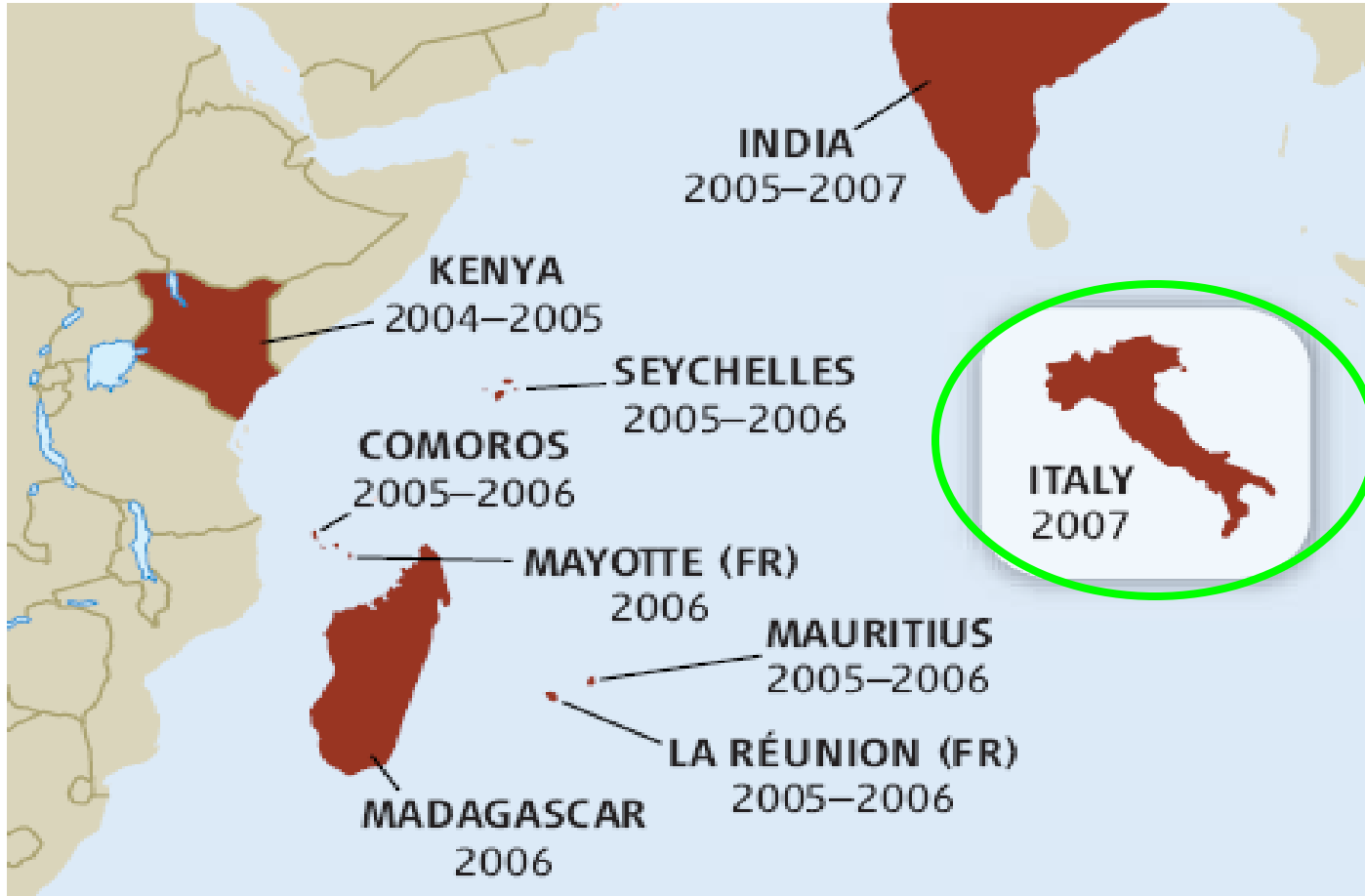


# Chikungunya outbreak 2004-2007





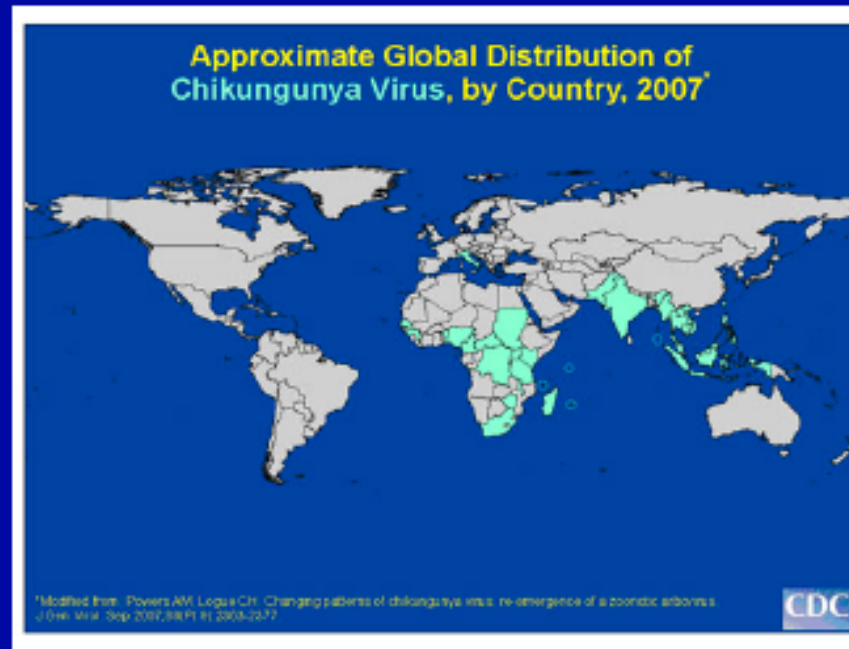
# Chikungunya outbreak 2004-2007



**New emergence in  
2007: ~270 cases**

# The Perfect Microbial Storm: Chikungunya

- ✘ A Virus from Africa (an alphavirus – Chikungunya)
- ✘ A mosquito from Asia (*Aedes albopictus*: tiger mosquito)
- ✘ A tourist from India (1.25 million human cases in 2006)
- ✘ A report of 270 people infected with Chikungunya in Ravenna, Italy



# Factors involved in re-emergence of Chikungunya virus

## ■ Biologic and genetic

- Non-immune population
- Adaptation of virus to new mosquito: *Ae. albopictus*

## ■ Ecologic conditions

- Standing water due to droughts
- Hot European summer
- Mosquito abundance

## ■ Social, economic, political

- International travel
- Previous introduction of *Ae. albopictus* into Reunion Island & Italy
- Delayed identification and control of initial outbreaks

## ■ Physical environment

- Stored water/artificial breeding sites







Pan American Health Organization



World Health Organization  
REGIONAL OFFICE FOR THE Americas

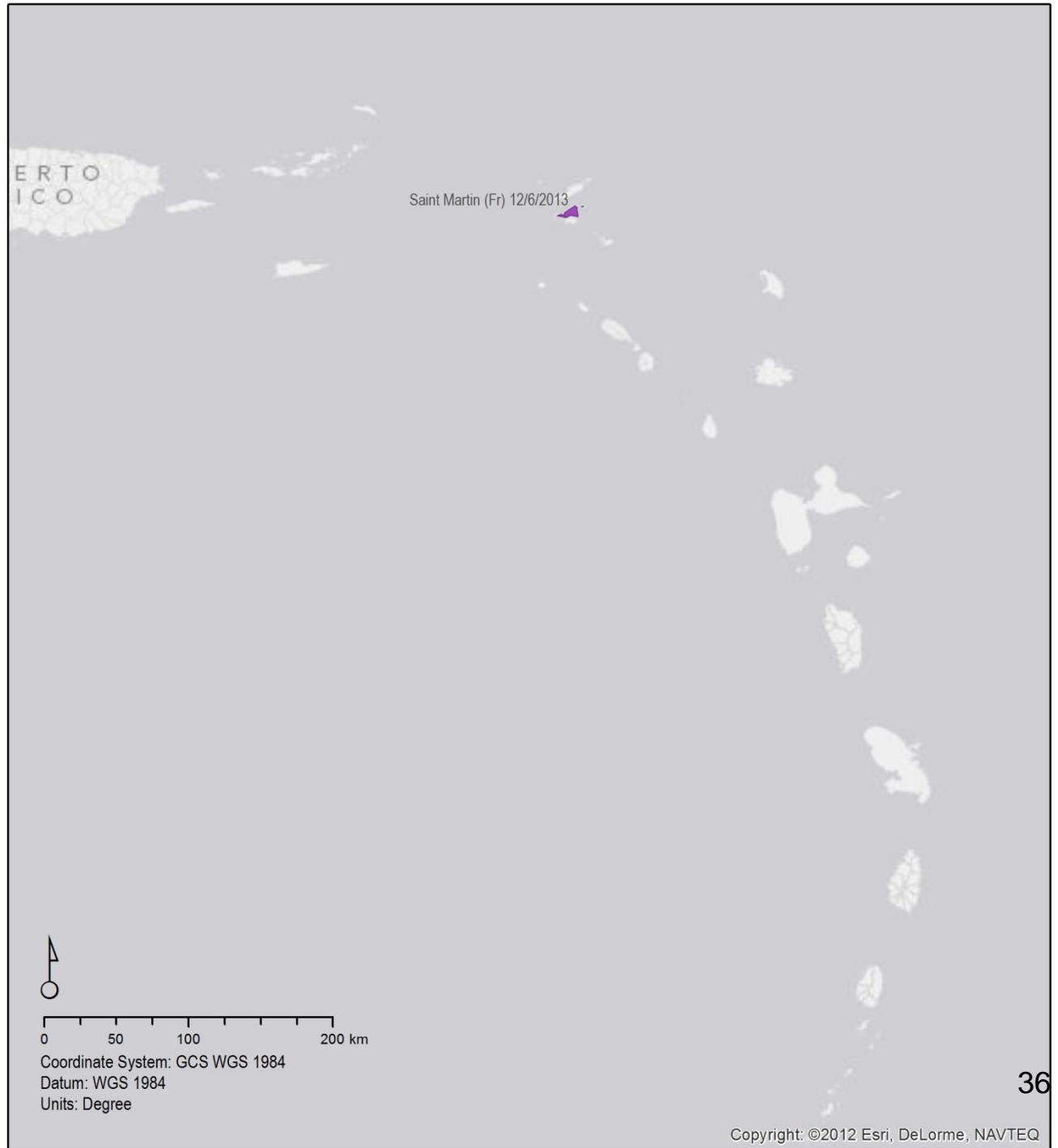
**Countries/territories with autochthonous transmission or imported cases of Chikungunya in the Americas**

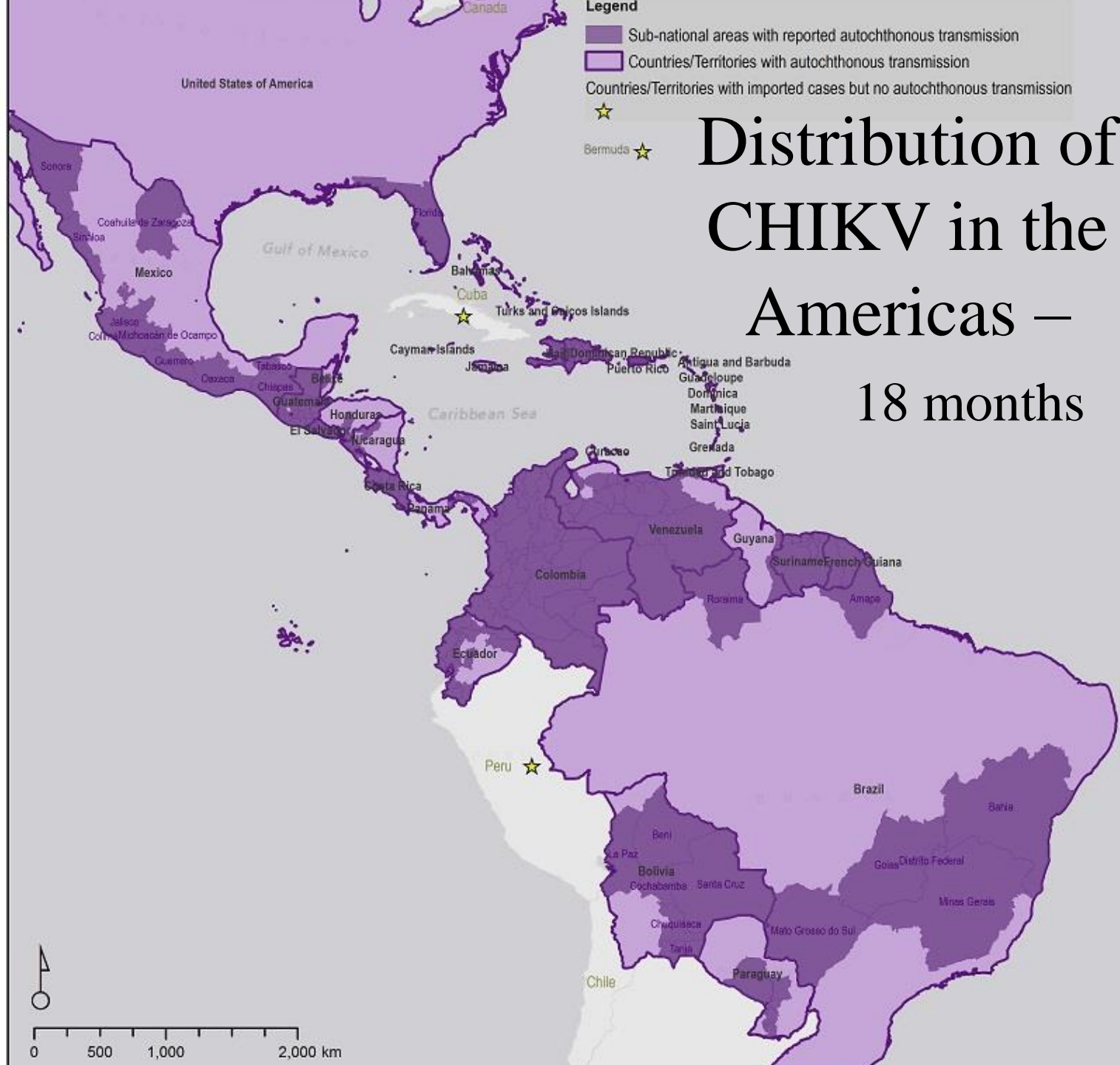
**Legend**

-  Countries/Territories with autochthonous transmission
-  Sub-national areas with confirmed autochthonous transmission

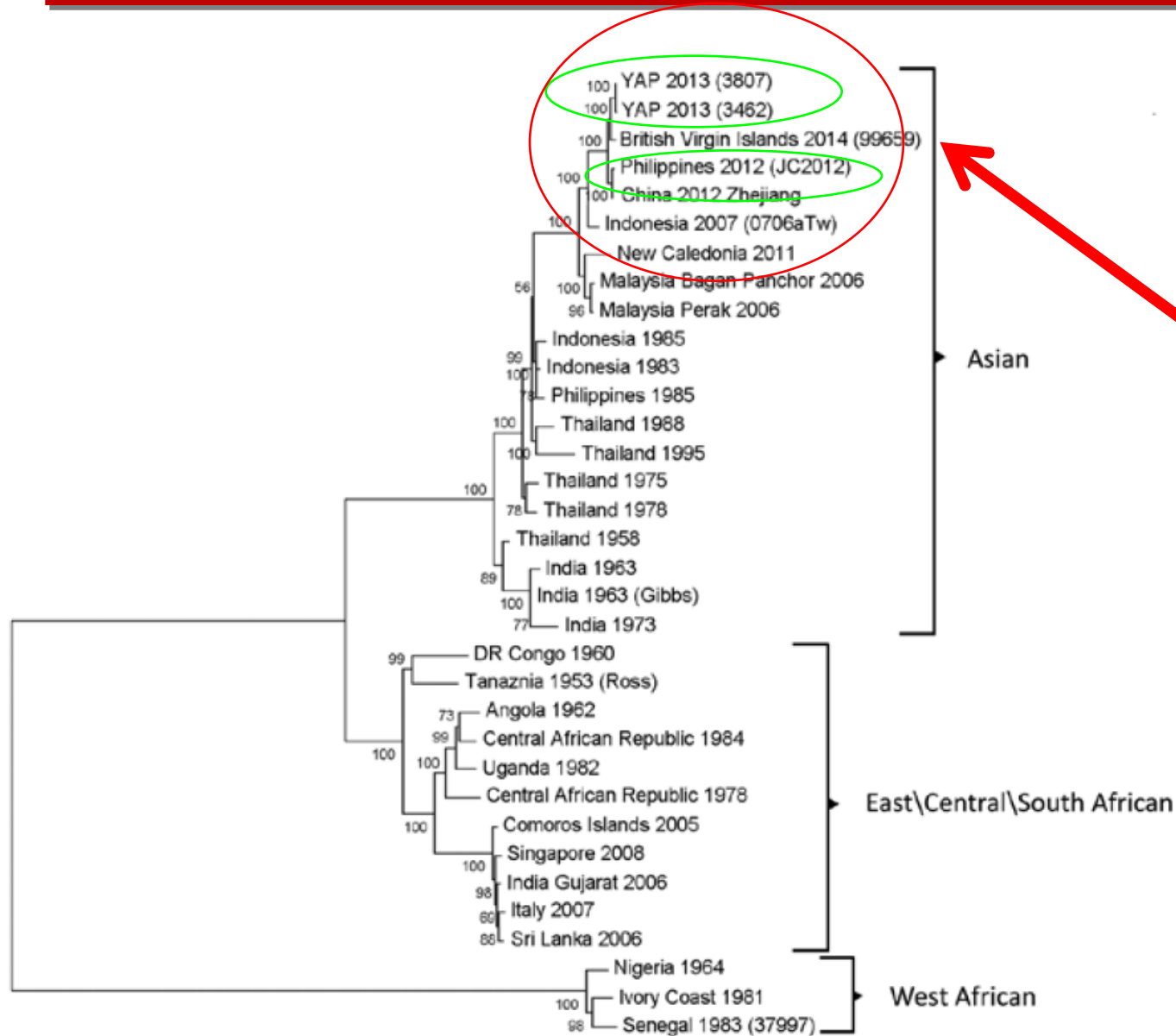
**6 December 2013**

St. Martin,  
French West Indies,  
Caribbean





# Asian CHIKV genotype circulating in Caribbean



Lanciotti. Emerg Infect Dis. 2014 Aug;20(8):1400-2.  
Leparc-Goffart. Lancet. 2014 Feb 8;383(9916):514.

# The 2<sup>nd</sup> perfect microbial storm: Chikungunya

- x A virus from Africa (an alphavirus – Chikungunya)
- x A mosquito from Africa (*Aedes aegypti*)
- x (A shipment from the Philippines)
- x A completely naïve population
- x Outbreak total :  
1,722,188, cases  
(PAHO 18 Sept 2015)



# Outline

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- Reasons for epidemic transmission and spread
- Emerging mosquito-borne viruses
  - *West Nile virus*
  - *Dengue virus*
  - *Chikungunya virus*
- Risk in US



Atlantic Monthly, 1997



# Dengue - Risk in U.S.?

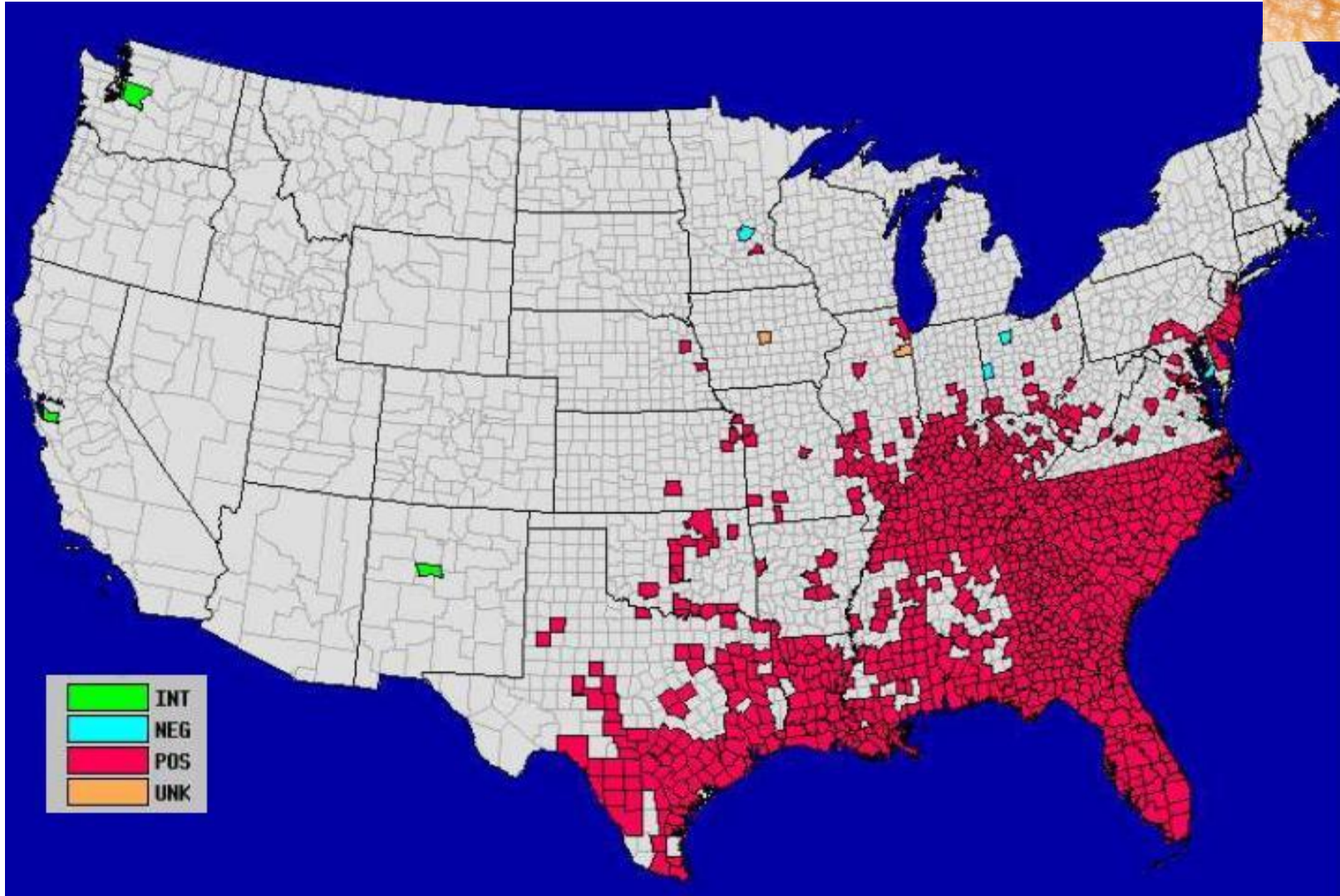
- Imported cases
  - 380 laboratory confirmed cases of dengue in 2013
  - Became notifiable in 2010
- *Ae. aegypti* & *Ae. albopictus* occur here (spreading)
- Local transmission
  - Texas: 1980 (23), 1986 (9), 1995 (7), 1997 (3), 1998 (1), 1999 (18), 2005 (25) **2013 (18)**
  - Hawaii: 2001 (122)
  - **Florida: 2009-10 (28)**
  - **New York: Suffolk County 2013 (1)**

# *CHIKV: Future Outlook for the Americas*

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- Large CHIKV outbreaks in tropical America will continue for several years
  - Millions of cases likely
  - Tens of thousands of travel-associated cases into US
- CHIKV outbreak potential in contiguous US:
  - *Aedes aegypti* present:
    - Sporadic autochthonous cases continue
    - Small focal outbreaks possible
    - US-Mexico border could be a problem area
  - Only *Aedes albopictus* present:
    - *Aedes albopictus* in Americas are competent vectors

# Distribution of *Ae. albopictus* in US, year 2000



[http://www.cdc.gov/ncidod/dvbid/Arbor/albopic\\_97\\_sm.htm](http://www.cdc.gov/ncidod/dvbid/Arbor/albopic_97_sm.htm)

# *Ae. albopictus* range expansion

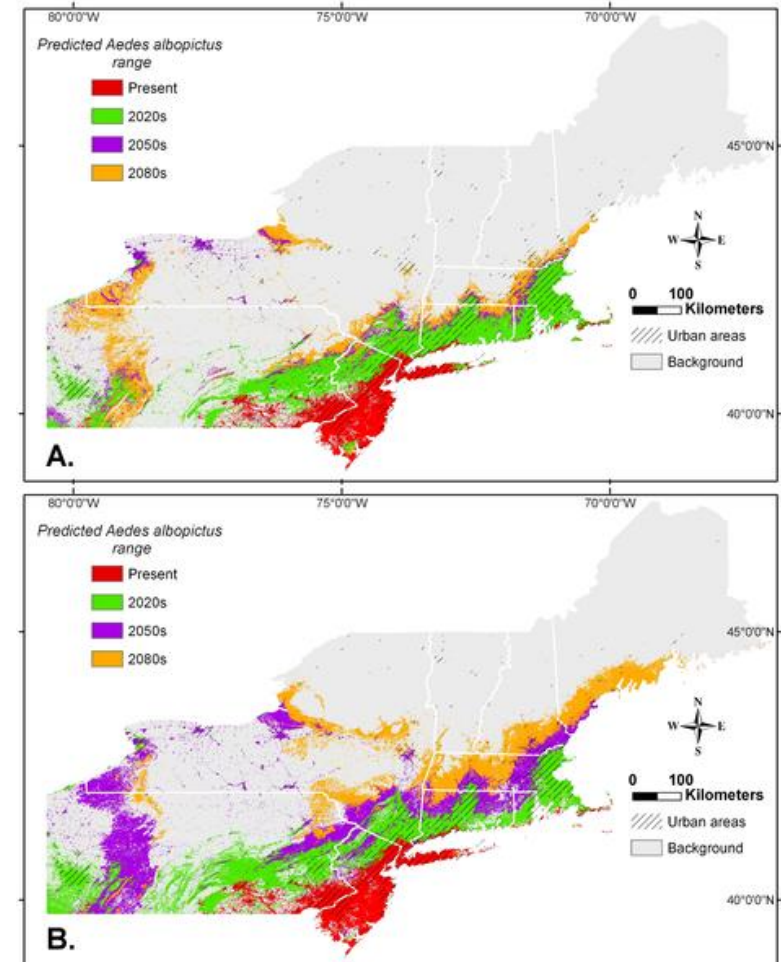
OPEN ACCESS Freely available online

PLOS ONE

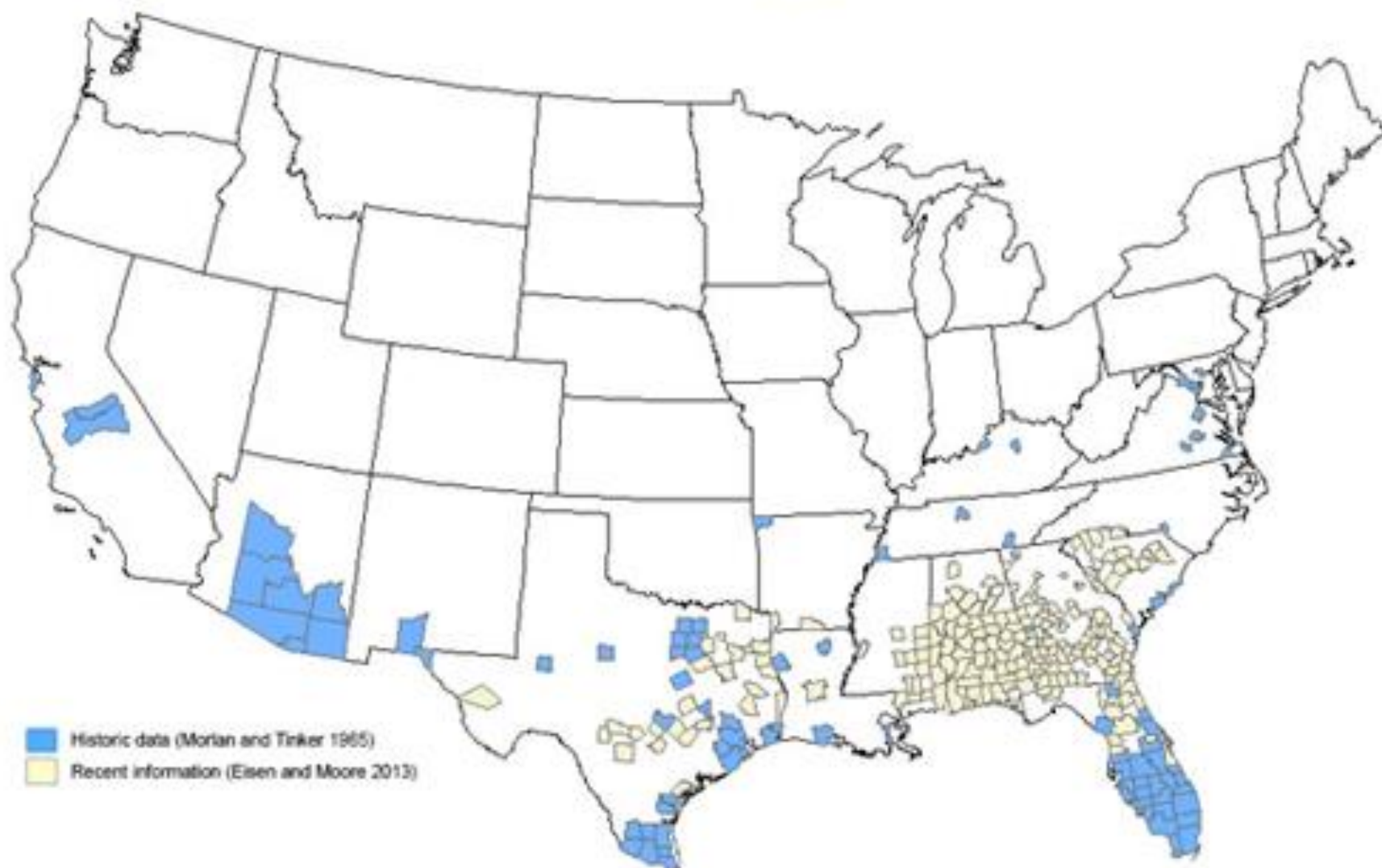
## Climate Change and Range Expansion of the Asian Tiger Mosquito (*Aedes albopictus*) in Northeastern USA: Implications for Public Health Practitioners

Ilia Rochlin<sup>1\*</sup>, Dominick V. Ninivaggi<sup>1</sup>, Michael L. Hutchinson<sup>2</sup>, Ary Farajollahi<sup>3,4</sup>

<sup>1</sup> Suffolk County Vector Control, Yaphank, New York, United States of America, <sup>2</sup> Division of Vector Management, Pennsylvania Department of Environmental Protection, Harrisburg, Pennsylvania, United States of America, <sup>3</sup> Mercer County Mosquito Control, West Trenton, New Jersey, United States of America, <sup>4</sup> Center for Vector Biology, Rutgers University, New Brunswick, New Jersey, United States of America



## Approximate distribution of *Aedes aegypti* in the United States\*



\*This map was developed using currently available information. *Aedes aegypti* mosquito populations (a known vector of chikungunya) may be detected in areas not shaded on this map, and may not be consistently found in all shaded areas. The shaded areas are NOT locations of chikungunya transmission.

# Exotic **Pathogens** That Have Recently Been Introduced to the US

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- Dengue Fever
- West Nile Fever
- Yellow Fever
- Mayaro Fever
- Chikungunya
- Ross River
- SARS
- Influenza
- Lassa Fever
- Monkeypox
- CJD/BSE
- HIV/AIDS
- Cholera
- E. coli O157
- Malaria
- Leishmaniasis
- Chagas Disease
- Cyclospora

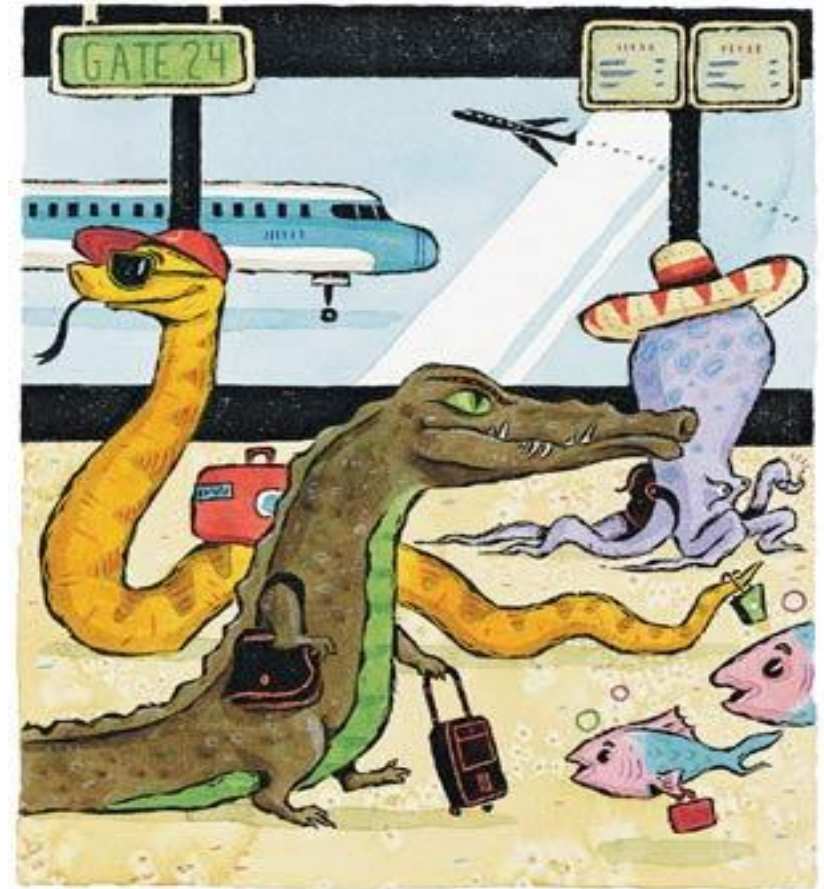
# Exotic **Mosquito Species** Recently Introduced and Established in the US

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- *Aedes (Stegomyia) albopictus*
- *Ochlerotatus (Aedes Finlaya) togoi*
- *Ochlerotatus (Aedes Finlaya) japonicus*
- *Aedes bahamensis*
- *Culex biscayensis*

# Live Animal Importation into the USA

- 47,000 mammals
  - 28 species of rodents
- 379,000 birds
- 2 million reptiles & poisonous snakes
- 49 million amphibians
- 223 million fish



U.S. Fish & Wildlife Service Data (2002)



# Factors that **Decrease** the Risk of Epidemic Transmission the United States

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- Living Conditions
  - Housing construction
  - Window and door screens
  - Reliable piped clean water systems
  - Air conditioning
- Human Behavior
  - Social practices
  - Television
- Human Population Density

# *Environmental Parameters Limit DENV (CHIKV) Transmission in the Contiguous States*

## *Example: 2005 Outbreak on the US-Mexico Border*

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- 8 times more infections in Matamoros
  - 4% infected in Brownsville
  - 32% in Matamoros
- Substantial *Aedes aegypti* infestations in both locations
- Different environmental conditions
  - 85% homes air conditioned in Brownsville; 29% in Matamoros
  - Lot size 3 times greater in Brownsville
- No air conditioning increased dengue risk 7 fold
- Smaller lot size increased dengue risk 15 fold





Dengue, West Nile virus, Chikungunya, Zika, Powassan, Heartland, ...  
**WHAT'S NEXT?**



*One World –  
One Health*

*Questions?*