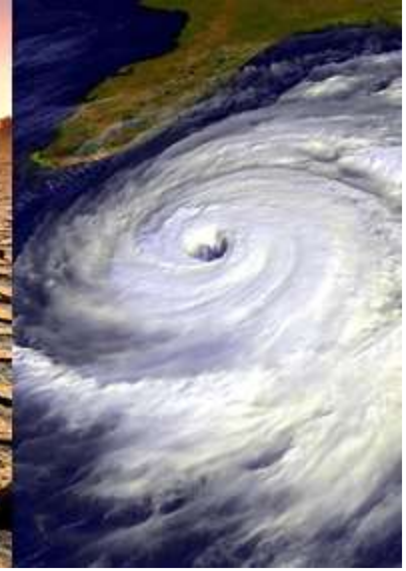
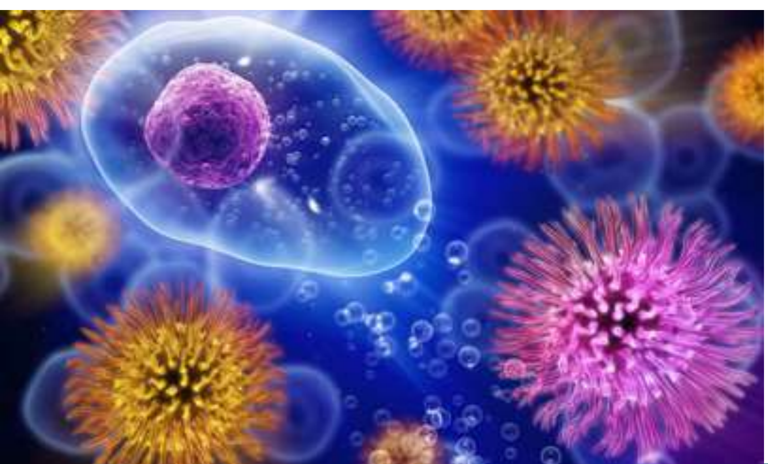




Impact of Climate Change on Infectious Diseases



GENEESKUNDIGE DAGEN UA, 17-9-2021

STEVEN VAN DEN BROUCKE

SVANDENBROUCKE@ITG.BE

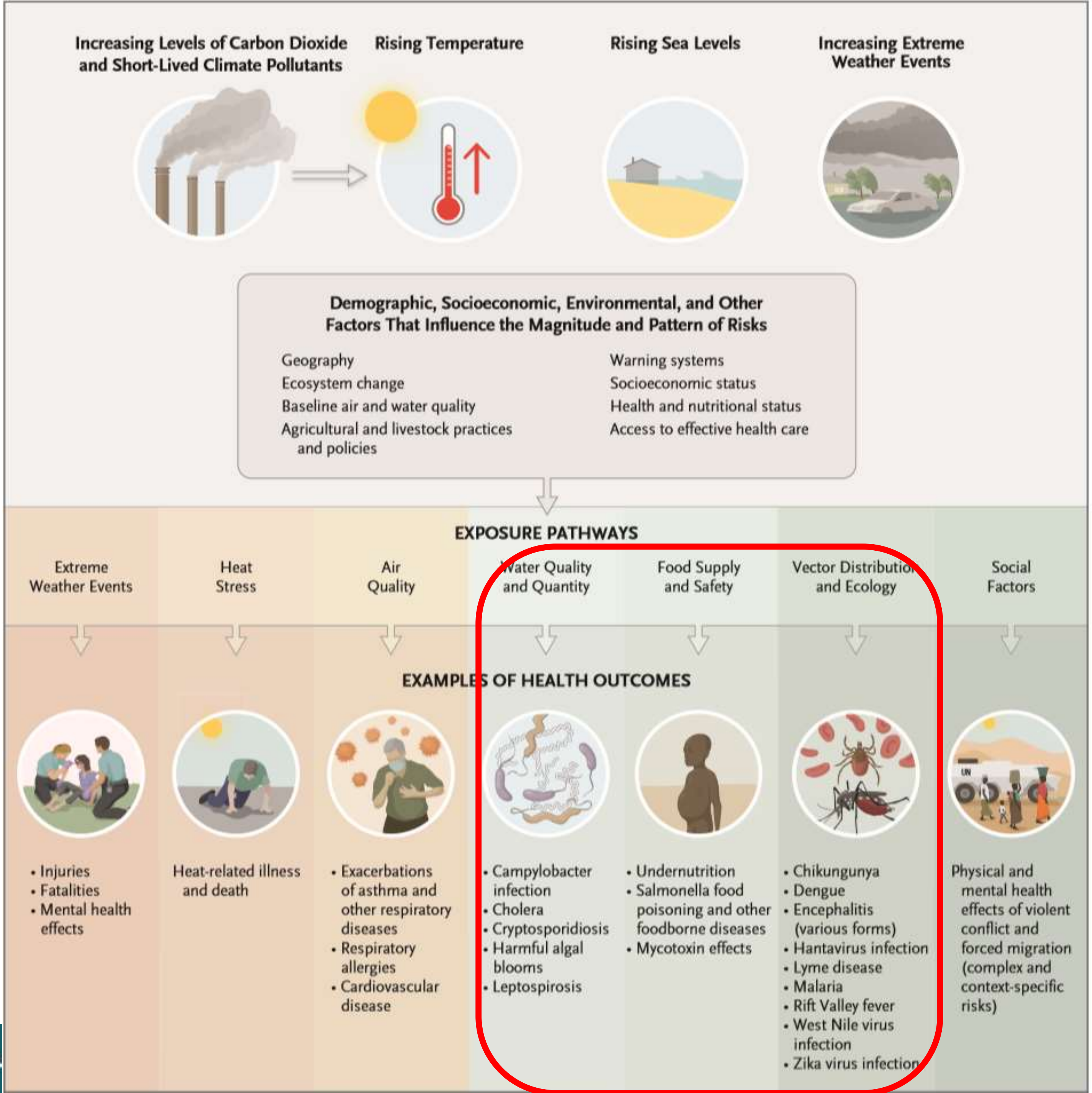
Key Messages

- Complex ++++, multifactorial

- The human response to a prediction is very unpredictable

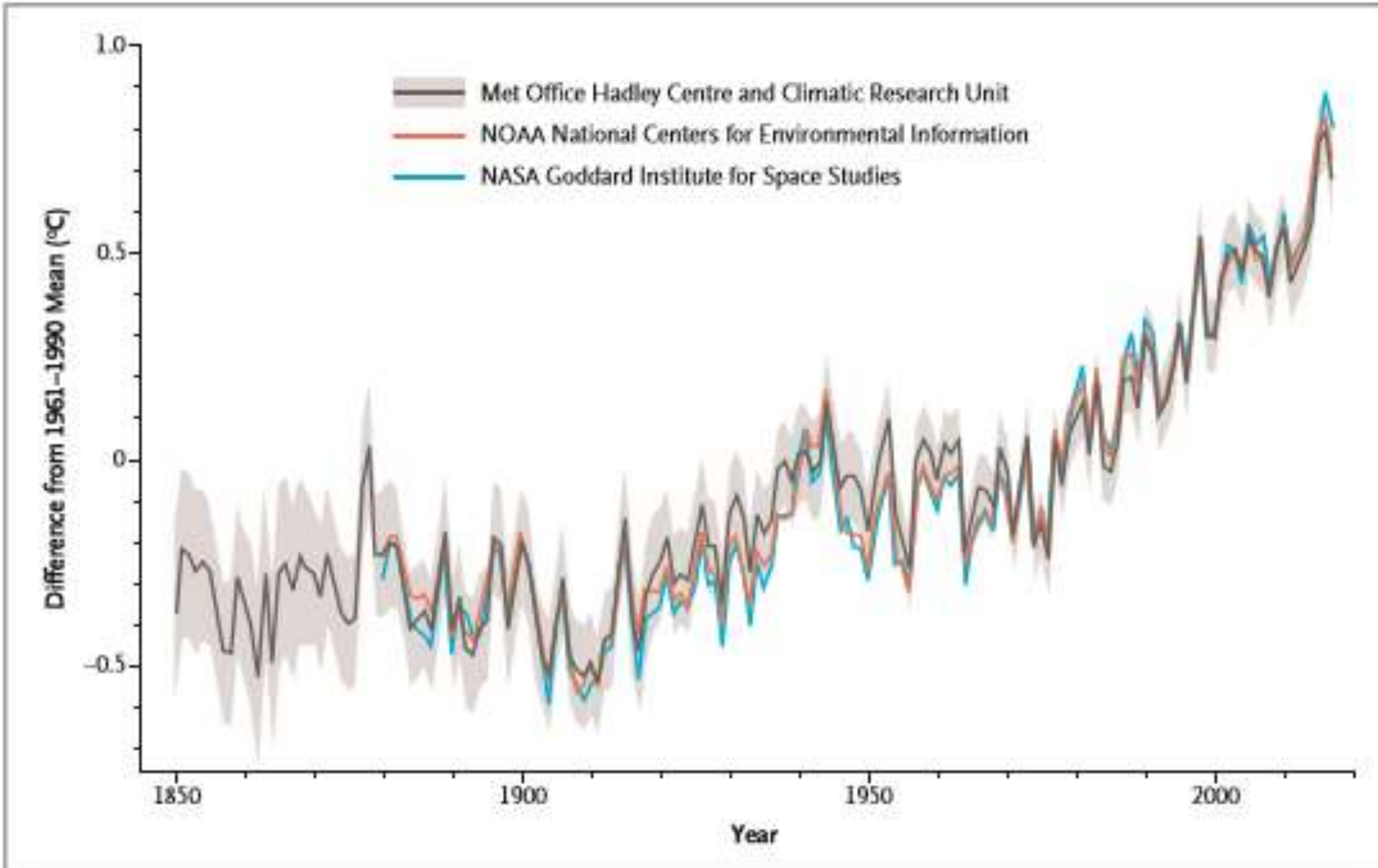
- Micro-organisms and vectors don’t read textbooks, nor scientific publications that tell them how to behave

- Good surveillance is crucial: observe, don’t panic!



Increasing Levels of Carbon Dioxide and Short-Lived Climate Pollutants
Rising Temperature
Rising Sea Levels
Increasing Extreme Weather Events
Demographic, Socioeconomic, Environmental, and Other Factors That Influence the Magnitude and Pattern of Risks
Geography
Ecosystem change
Baseline air and water quality
Agricultural and livestock practices and policies
Warning systems
Socioeconomic status
Health and nutritional status
Access to effective health care
EXPOSURE PATHWAYS
Extreme Weather Events
Heat Stress
Air Quality
Water Quality and Quantity
Food Supply and Safety
Vector Distribution and Ecology
Social Factors
EXAMPLES OF HEALTH OUTCOMES
UN
• Injuries
• Fatalities
• Mental health effects
Heat-related illness and death
• Exacerbations of asthma and other respiratory diseases
• Respiratory allergies
• Cardiovascular disease
• Campylobacter infection
• Cholera
• Cryptosporidiosis
• Harmful algal blooms
• Leptospirosis
• Undernutrition
• Salmonella food poisoning and other foodborne diseases
• Mycotoxin effects
• Chikungunya
• Dengue
• Encephalitis (various forms)
• Hantavirus infection
• Lyme disease
• Malaria
• Rift Valley fever
• West Nile virus infection
• Zika virus infection
Physical and mental health effects of violent conflict and forced migration (complex and context-specific risks)

Temperature Evolution



N ENGL J MED 380;3 NEJM.ORG JANUARY 17,2019

Temperature Projection

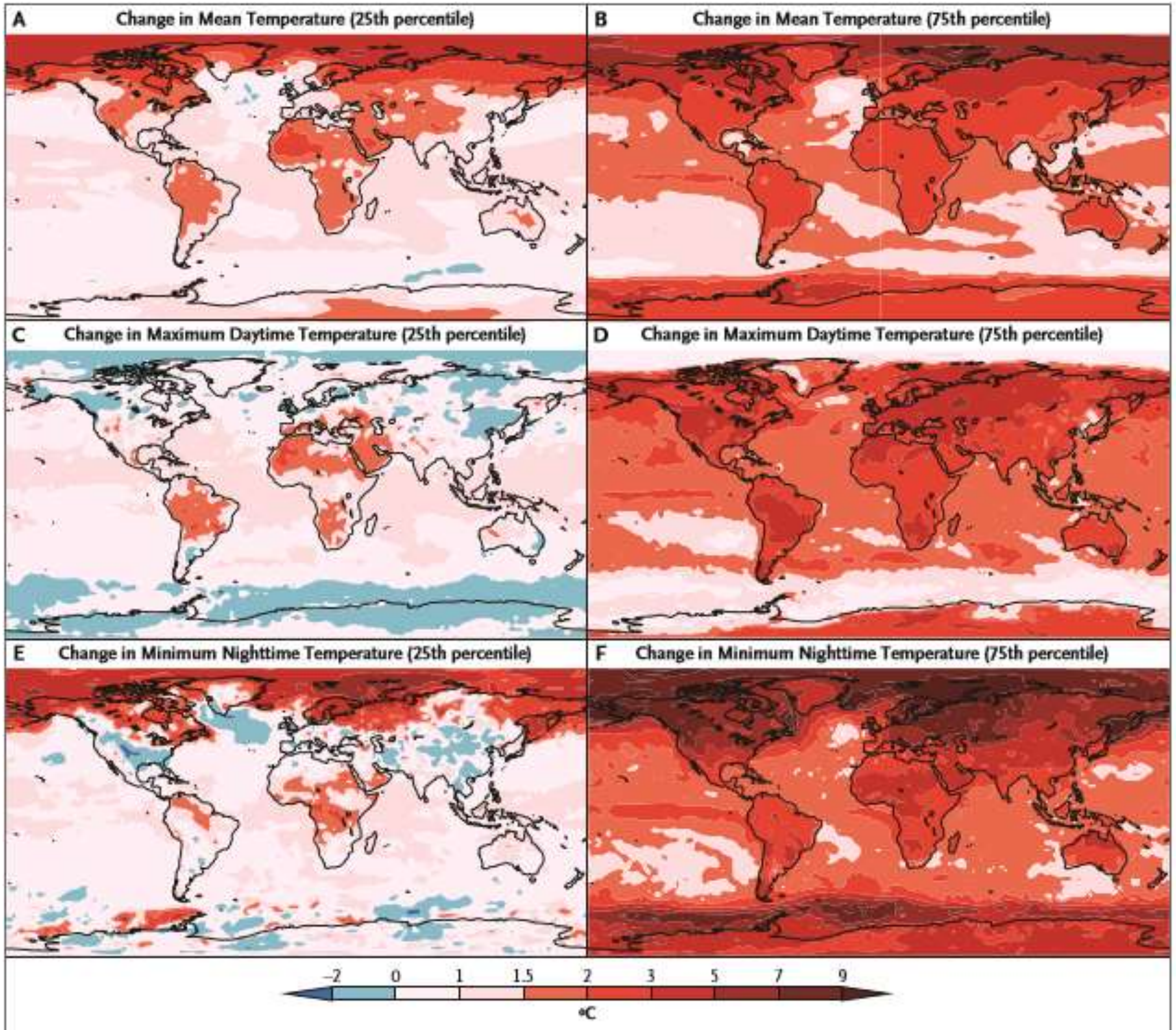
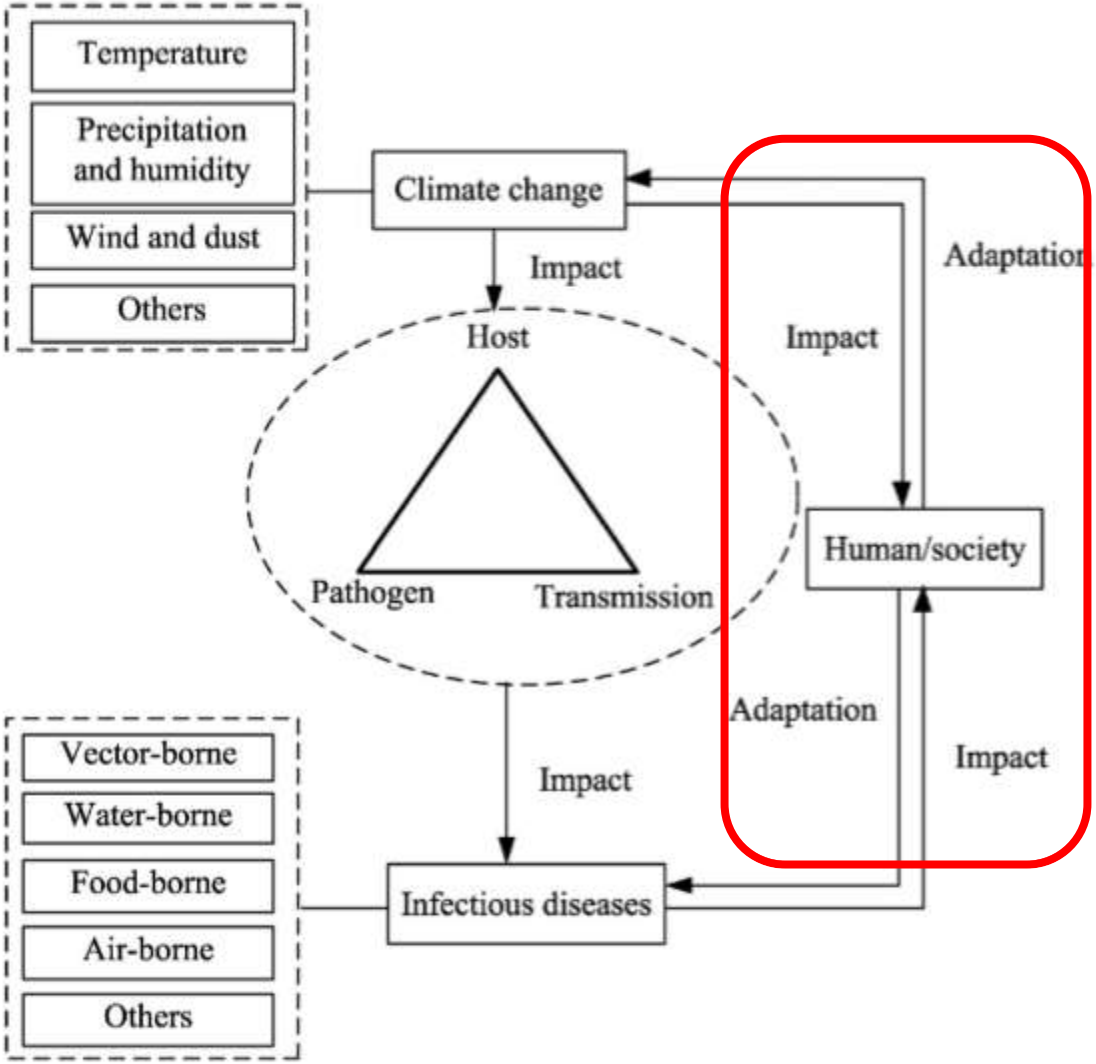


Figure 2. Potential Regional Temperature Changes in a World That Warms to 1.5°C above the Preindustrial Mean Temperature.
At each location in the maps, the 25th percentile and 75th percentile values of the range of possible projected changes in yearly mean, maximum daytime, and minimum nighttime temperatures are shown in a world with a global mean temperature that is 1.5°C warmer than preindustrial times, which could occur within three decades at current rates of warming. Adapted from Seneviratne et al.[13]

Impact Climate Change on Infectious Diseases



X. Wu et al. / Environment International 86 (2016) 14–23

Temperature

- Pathogen
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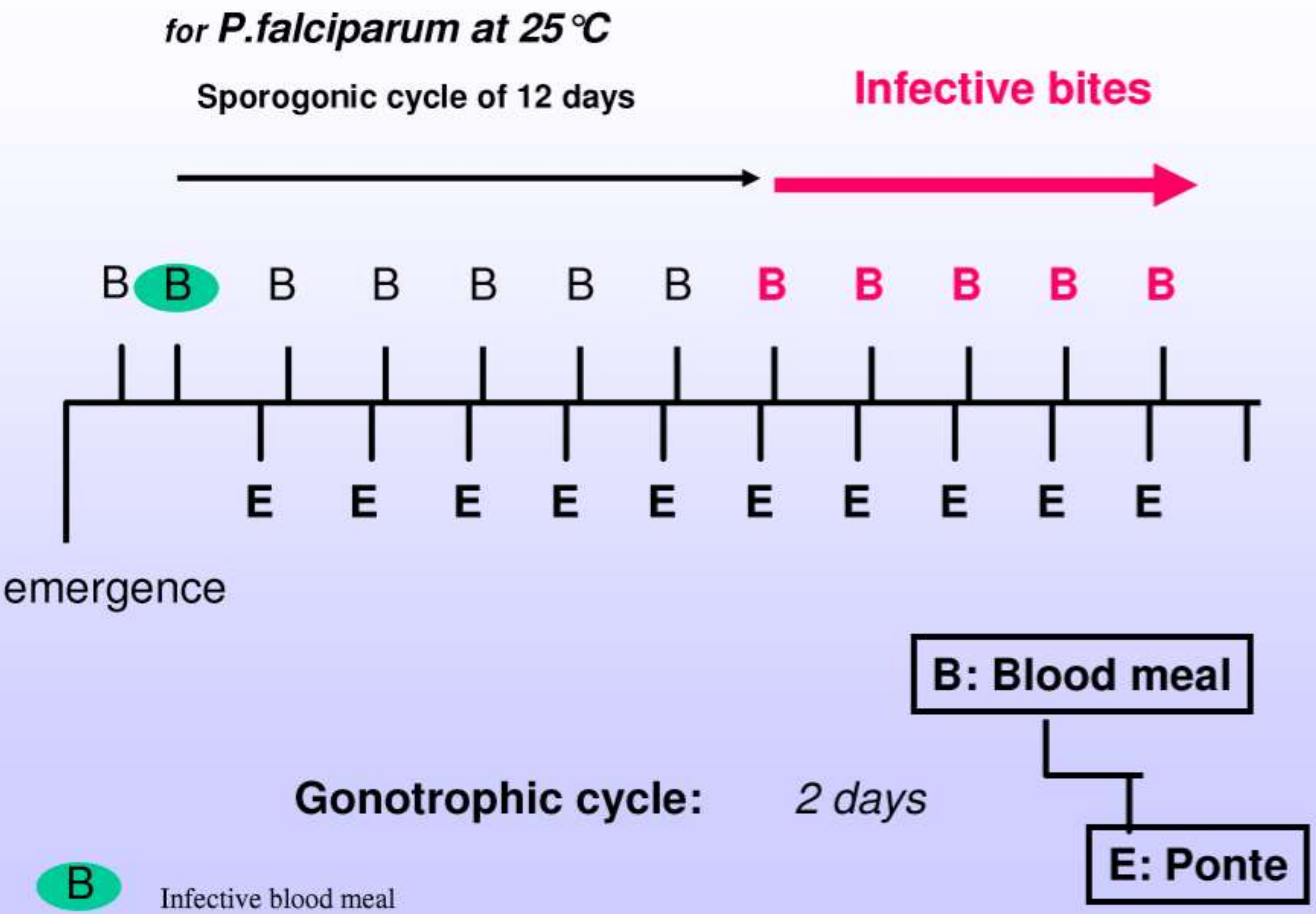
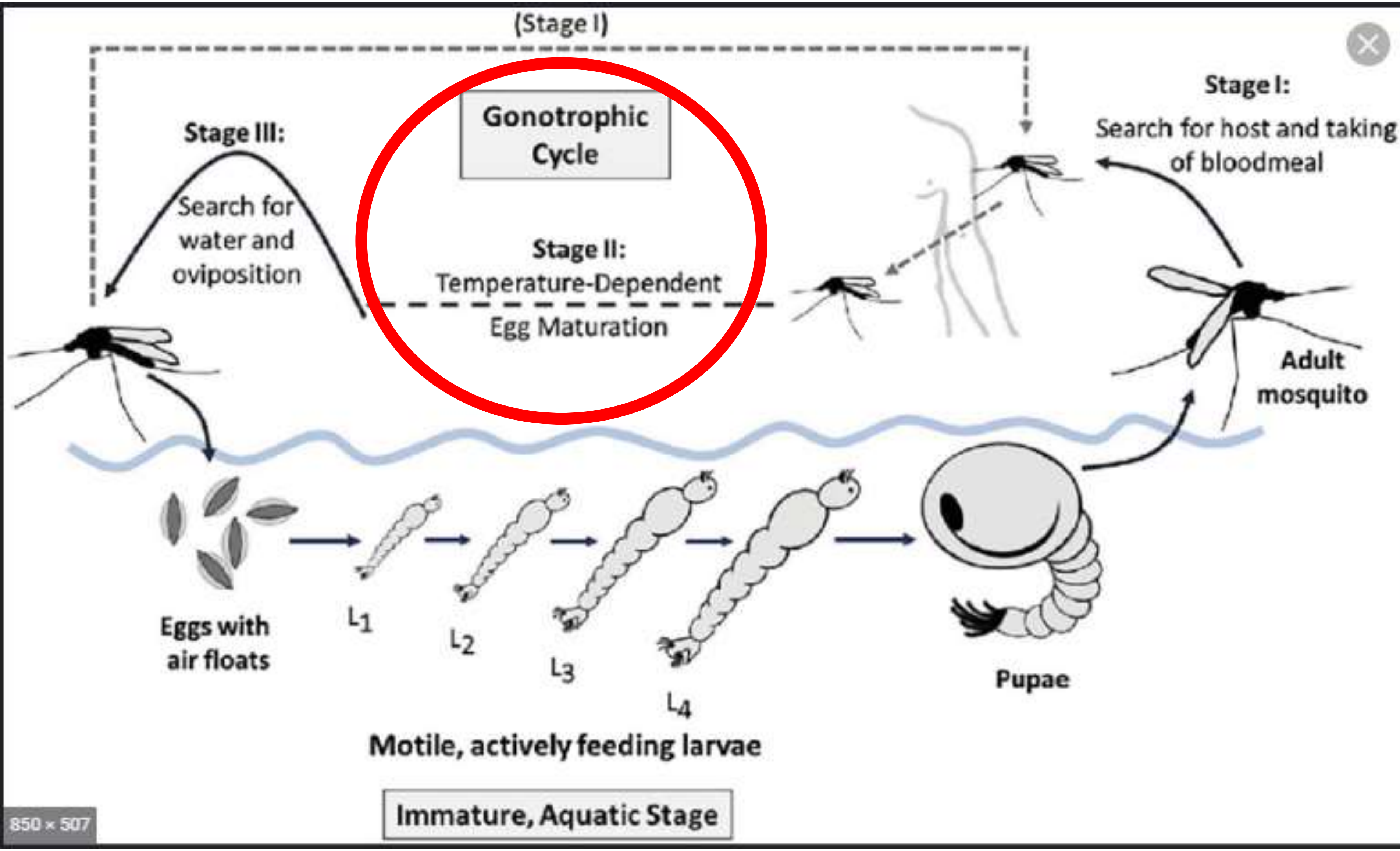
  - Campylobacter: outcompeted by other bacteria when °T rises, UV-light blocks Campylobacter
  - Algal bloom
  - Vibrio spp. ↑
- Vector/host
  - Insects in low-latitude regions -- > mid- or high latitude regions: expansion
  - China: winter temp. rises -- > *Oncomelania* ↑ -- > *Schistosoma japonicum* ↑ -- > distribution to new areas
  - *Aedes aegypti* larvae die when > 34 °C, adult mosquitos die when > 40 °C
  - ***Anopheles* needs T > 16 °C (winterisotherm)**

Infective life of a vector





Weather-driven malaria transmission model with gonotrophic and sporogonic cycles

January 2019 · Journal of Biological Dynamics 13(3):1-37

Weather-driven malaria transmission model with gonotrophic and sporogonic cycles

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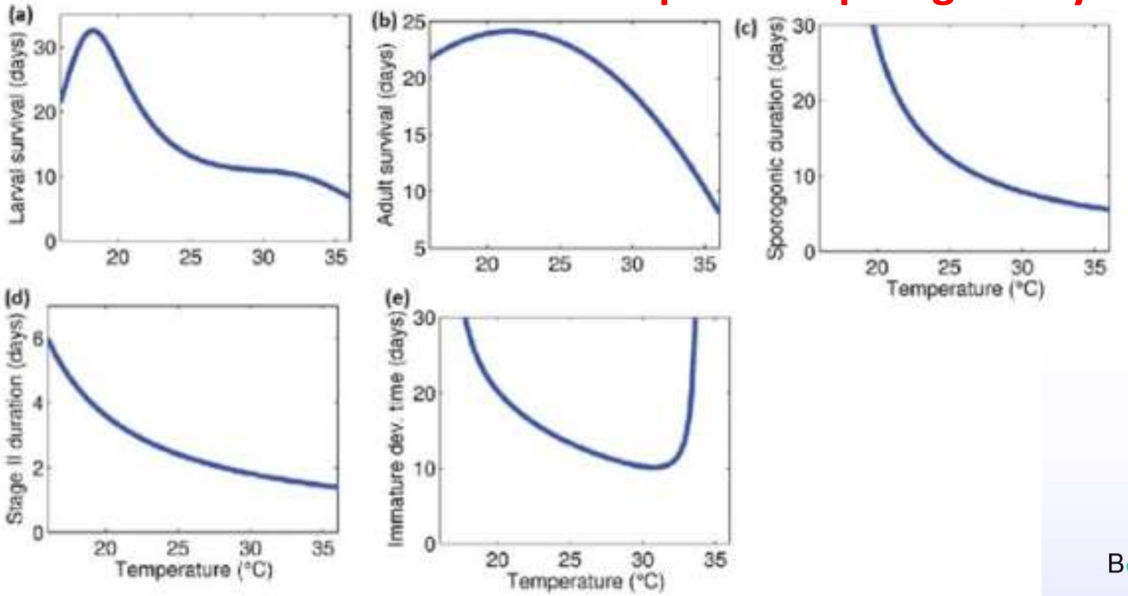
Survival mosquitoes **Sporogonic cycle**

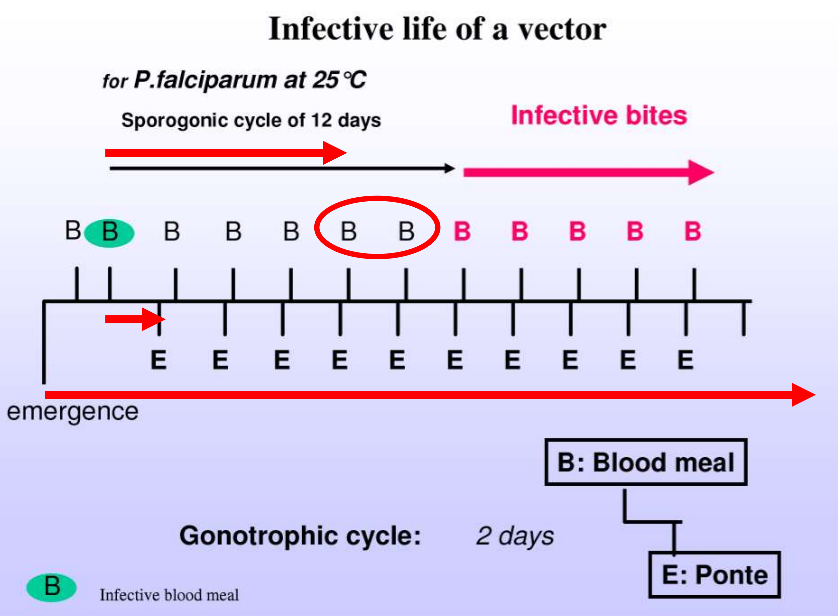


Gonotropic cycle

Figure

Caption

Figure 3. Profile of temperature-dependent parameters of the model {(1)-(3)}: (a) Survival time of larvae, (μ L (T W)) −1 (b) Survival time of adult mosquitoes, (μ M (T W)) −1 (c) Sporogonic cycle duration in adult female mosquitoes, (κ M (T A)) −1 (d) Duration of Stage II of the gonotrophic cycle, (θ Y (T A)) −1 ,



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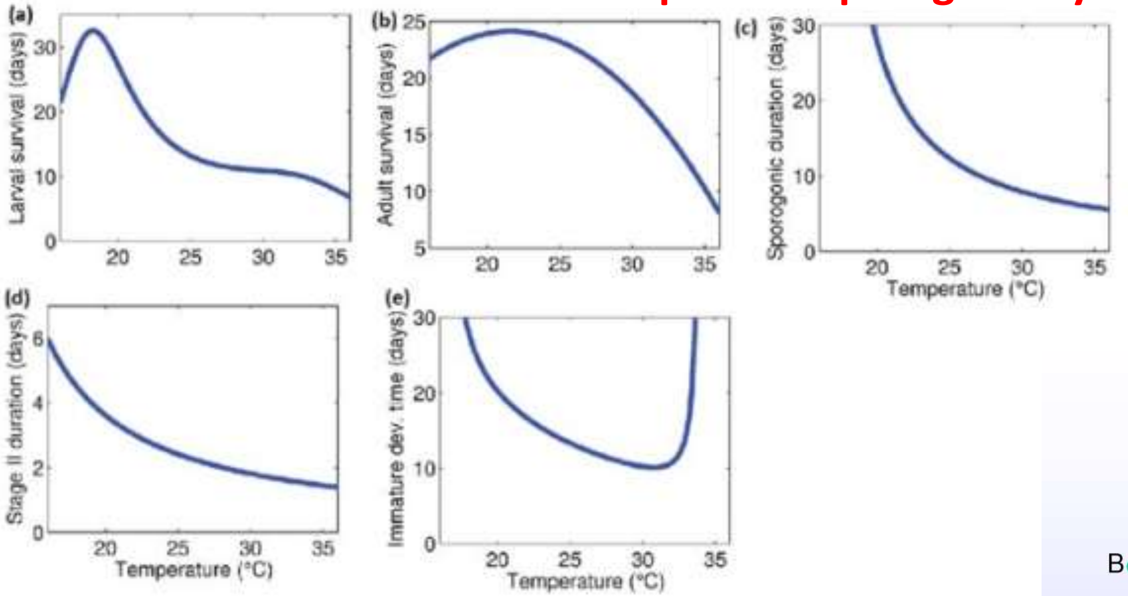
January 2019 · Journal of Biological Dynamics 13(3):1-37

Survival mosquitoes Sporogonic cycle



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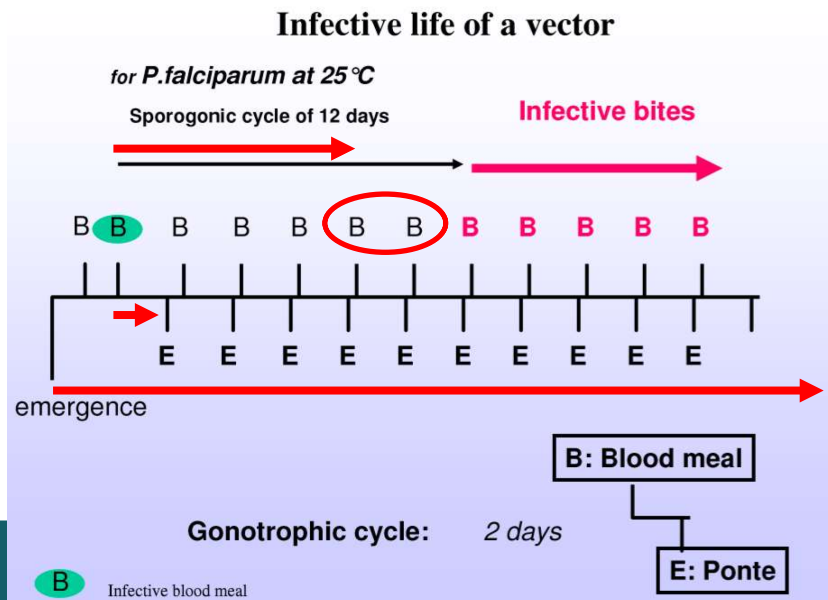

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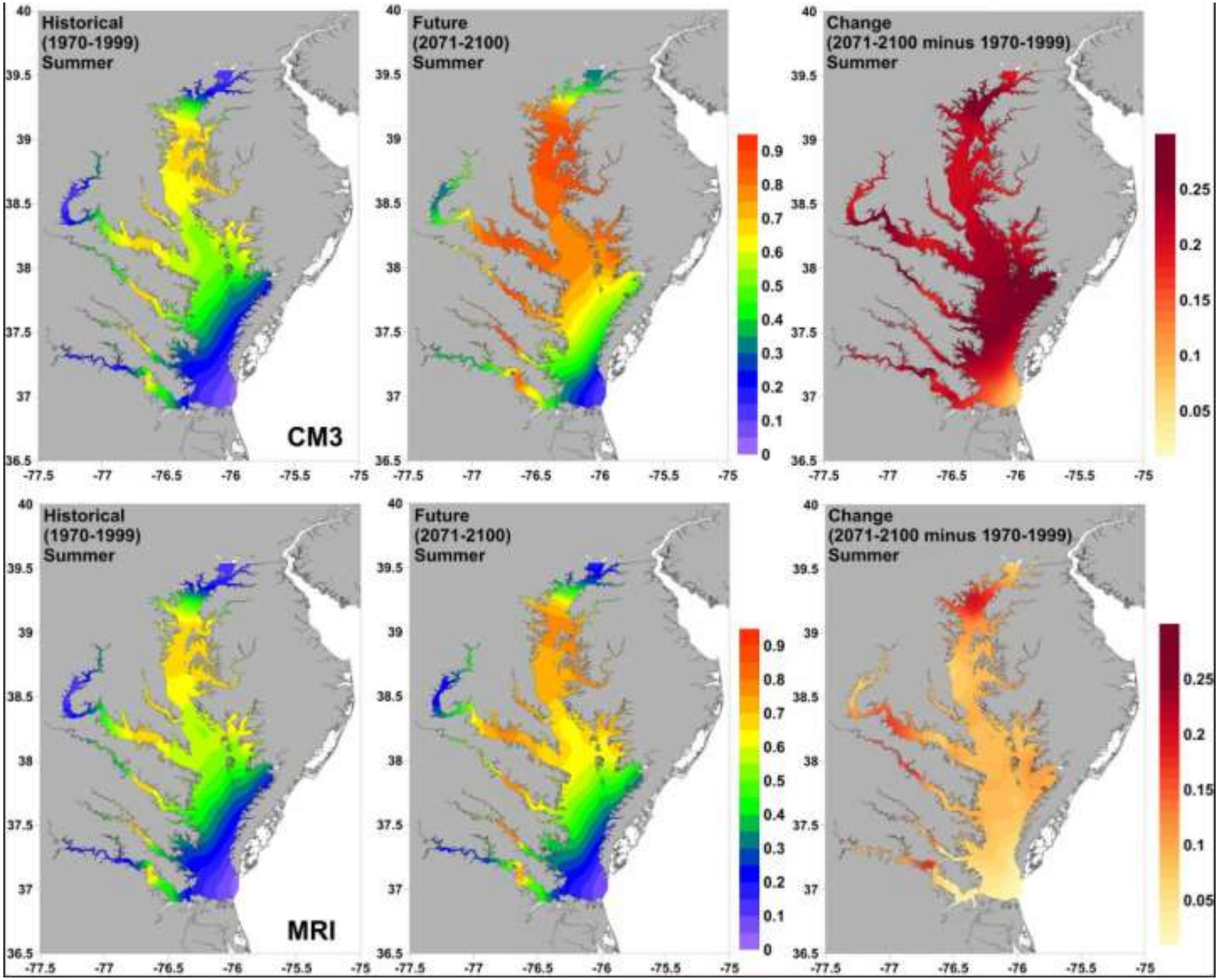
Warming climate could increase bacterial impacts on Chesapeake Bay shellfish, recreation



Vibrio vulnificus

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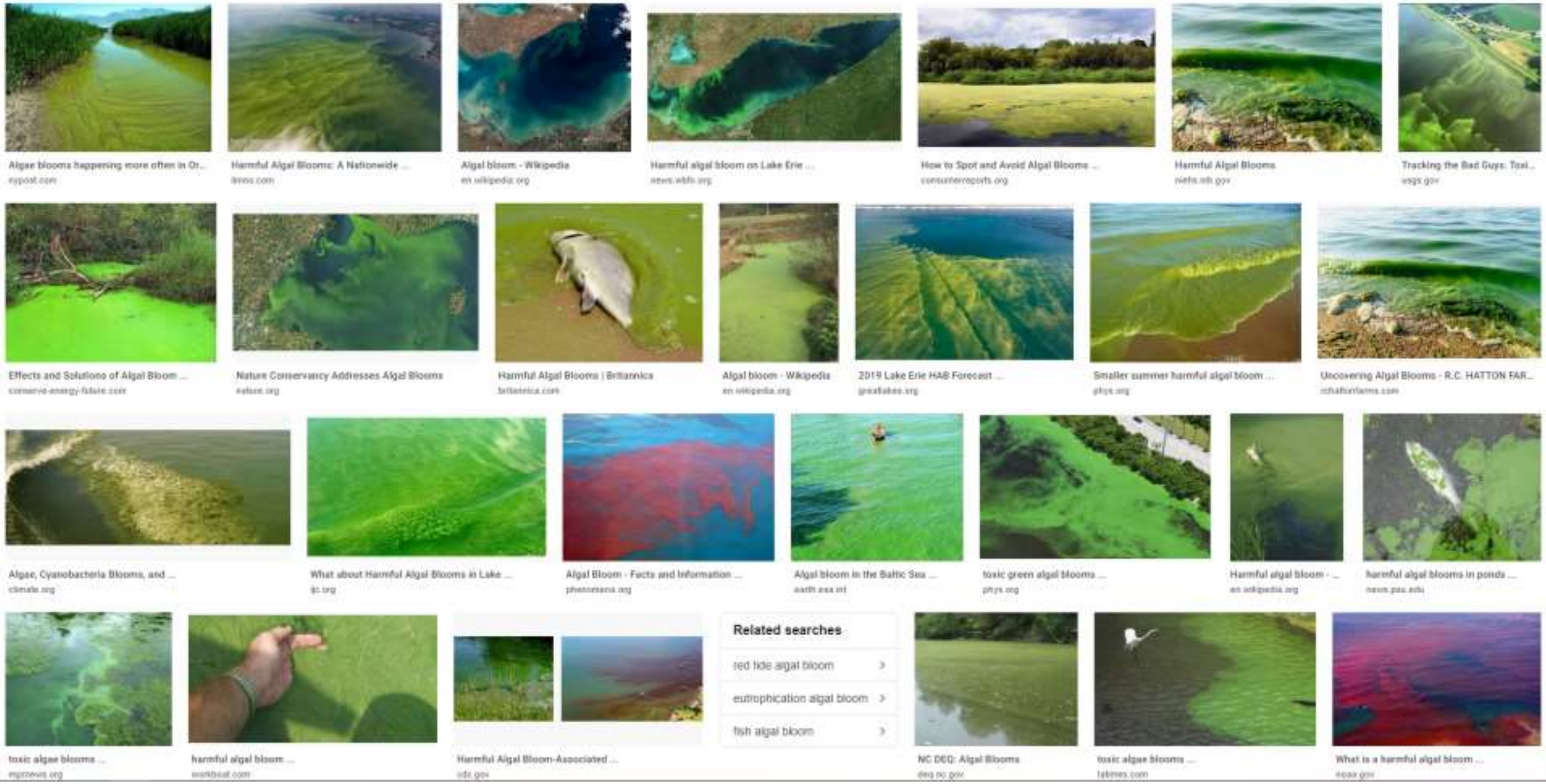
Algae blooms



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Ticks

Medlock *et al. Parasites & Vectors* 2013, **6**:1
http://www.parasitesandvectors.com/content/6/1/1

Parasites & Vectors

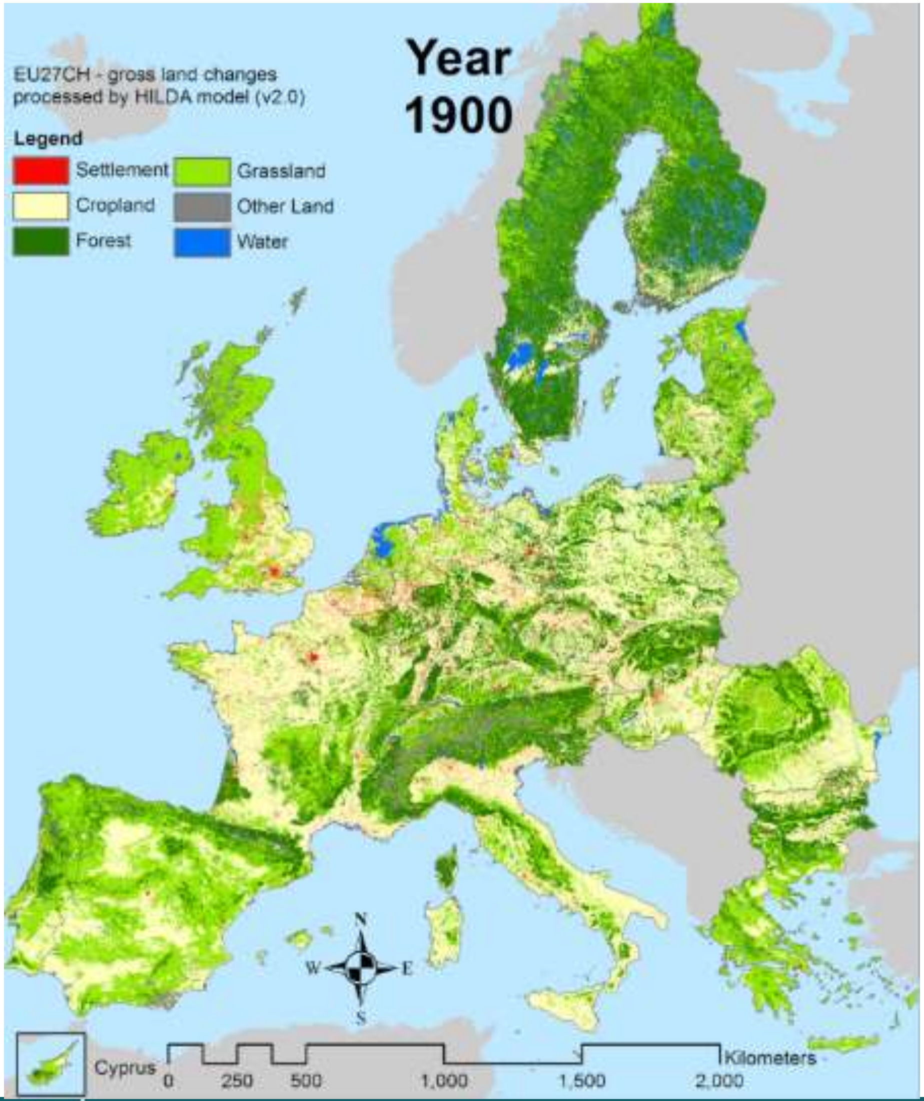
REVIEW **Open Access**

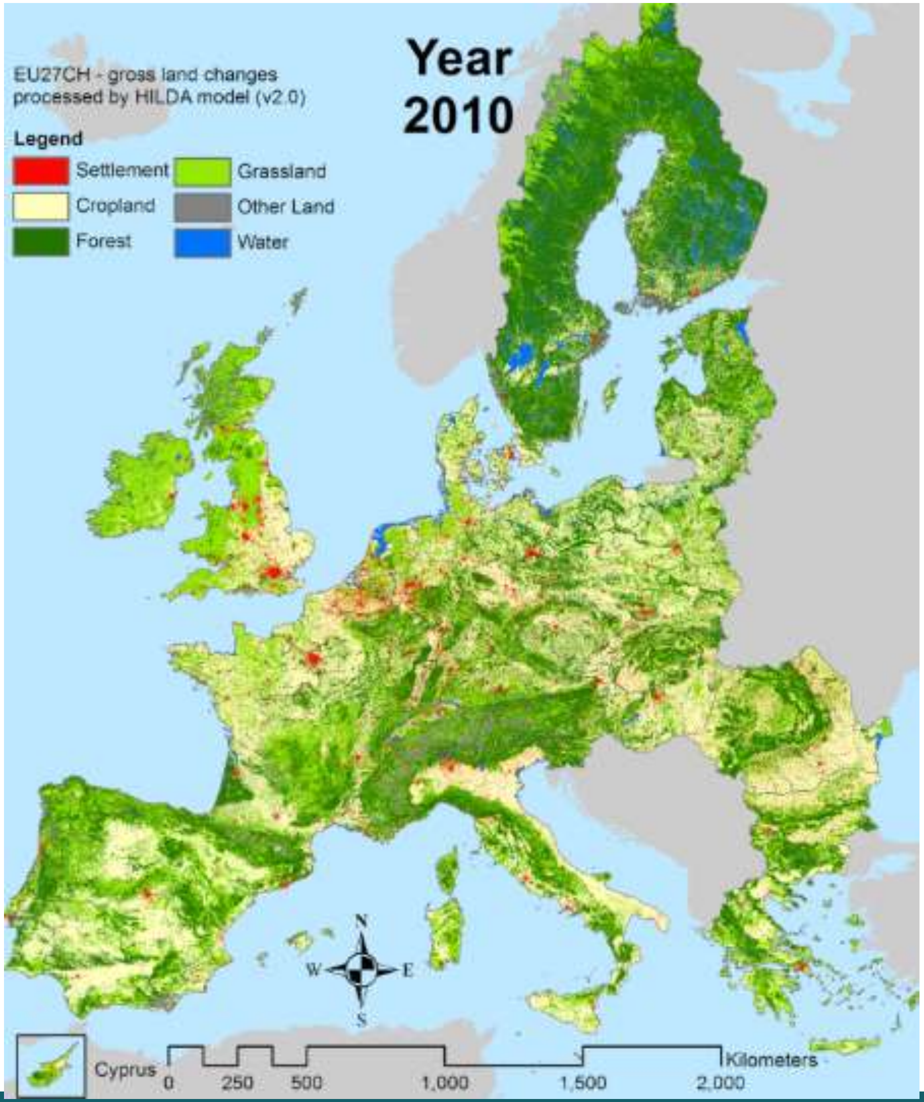
Driving forces for changes in geographical distribution of *Ixodes ricinus* ticks in Europe

- Northern latitude: moves up
  - Southern latitude: decrease? If humidity decreases -- > less tick survival
- Altitude: higher
- Nymphs and larvae: feed on small rodents and bigger wildlife
- Adult ticks: feed only on big wildlife
- Ticks need +/- 80% humidity

Reforestation in Europe, 1950 – 2002 : +2%

CO2 stimulates vegetation!!!





HTTPS://WWW.WASHINGTONPOST.COM/NEWS/WORLDVIEWS/WP/2014/12/04/WATCH-HOW-EUROPE-IS-GREENER-NOW-THAN-100-YEARS-AGO/

Tick surveillance

Pathogens transmitted by ticks

- Lyme (Borrelia Burgdorferi/Afzelii, Garinii)
- Anaplasma
- Ehrlichia
- Bartonella
- Babesia
- Rickettsia: RMSF, R. conori, Japanese spotted fever,…
- Tularemia: Francisella tularensis
- Colorado Tick fever, Powassan virus
- Hemorragic fevers: Crimean-Congo, Omsk,..
- FSME (Frühsommer meningo-encephalitis) = TBE
- TBRL: Tick Born Relapsing Fever (B. duttonii, hermsii,…)

A tularemia lesion on the dorsal skin of the right hand

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Oncomelania hupensis

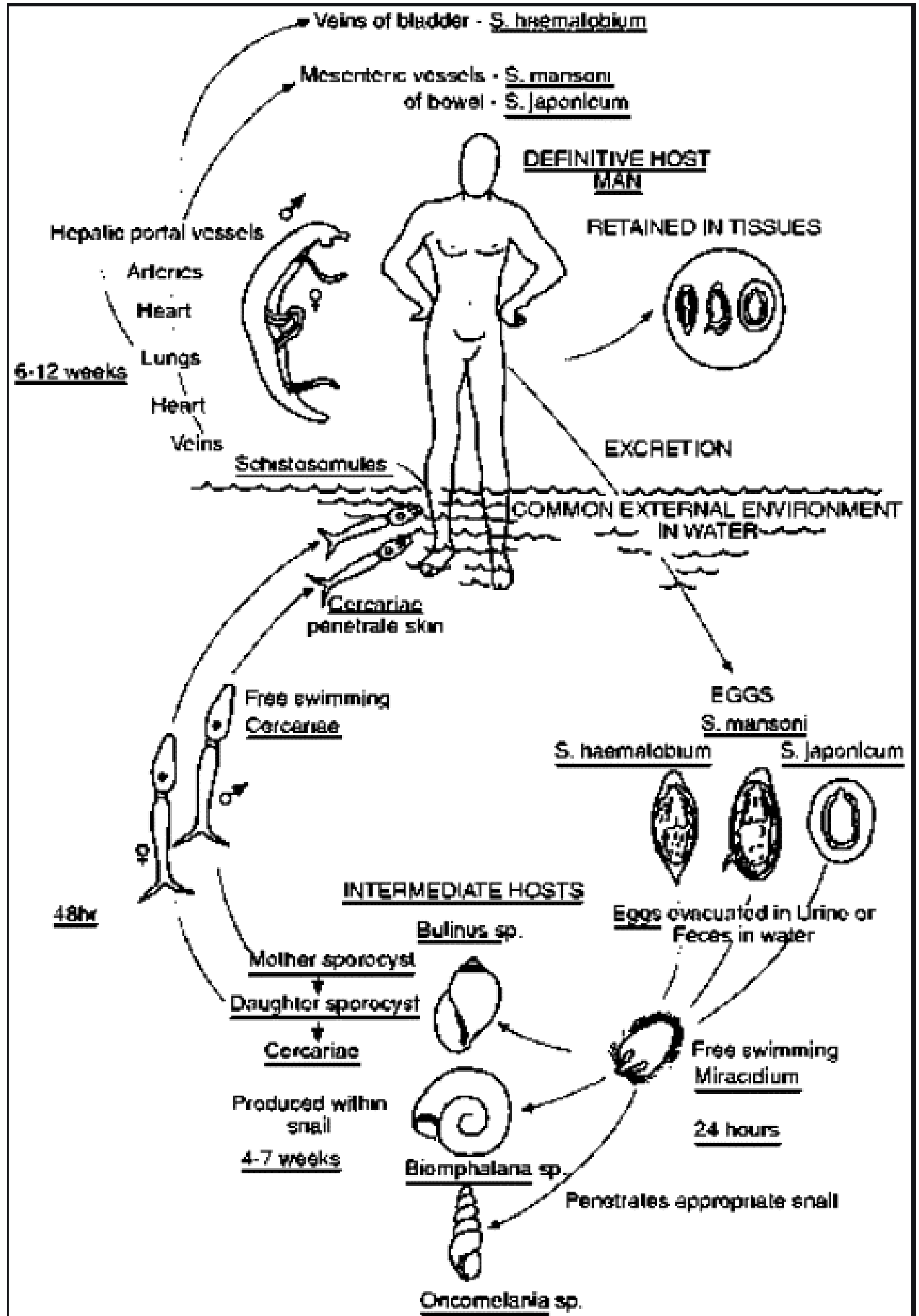

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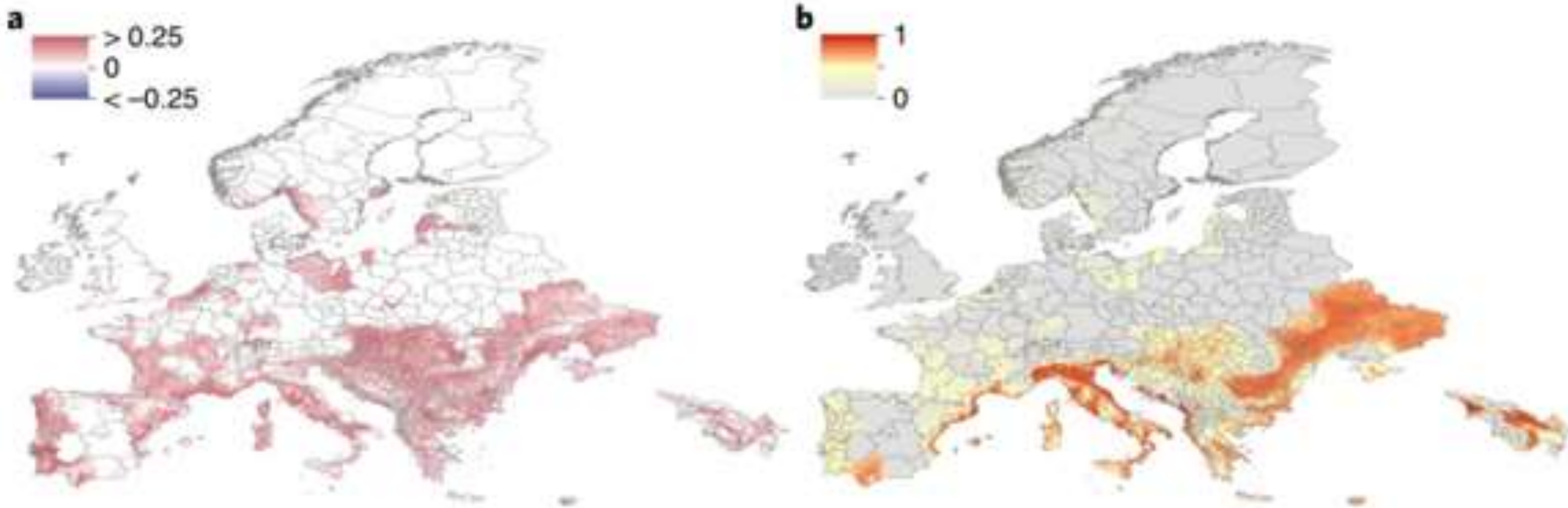
Fig. 3: Predicted future spread of *Ae. albopictus* in Europe.



a, The expansion (red) and contraction (blue) of *Ae. albopictus* between 2020 and 2050 under the medium climate scenario RCP 6.0, with emissions peaking in 2080. **b**, The predicted distribution of *Ae. albopictus* and predicted habitat suitability for the presence of *Ae. albopictus* in 2050. Pixels with no predicted suitability are in grey.

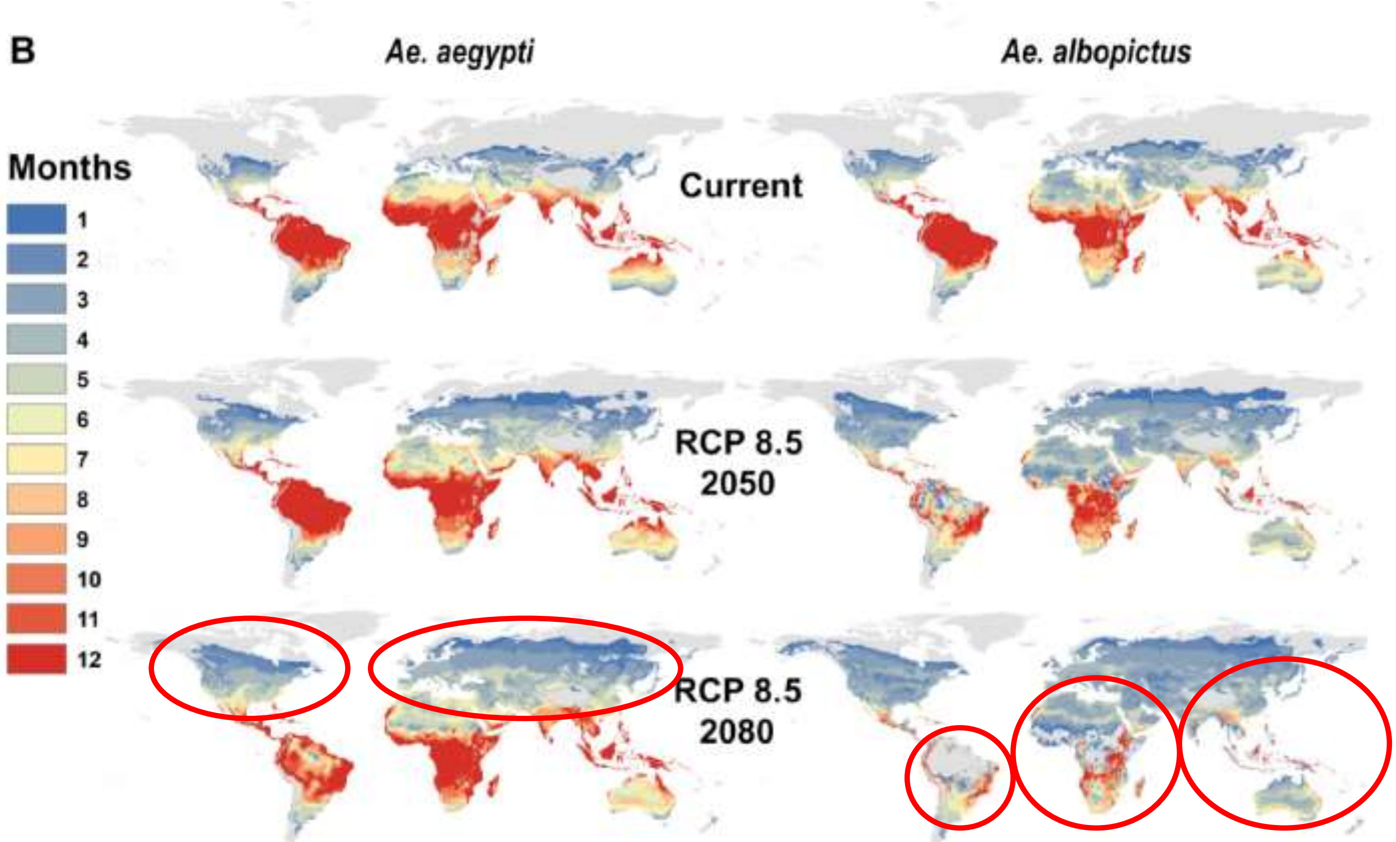
Past and future spread of the arbovirus vectors *Aedes aegypti* and *Aedes albopictus*

Moritz U. G. Kraemer, Robert C. Reiner Jr, [...] Nick Golding

Nature Microbiology **4**, 854–863(2019) | Cite this article

Aedes-borne diseases | a model

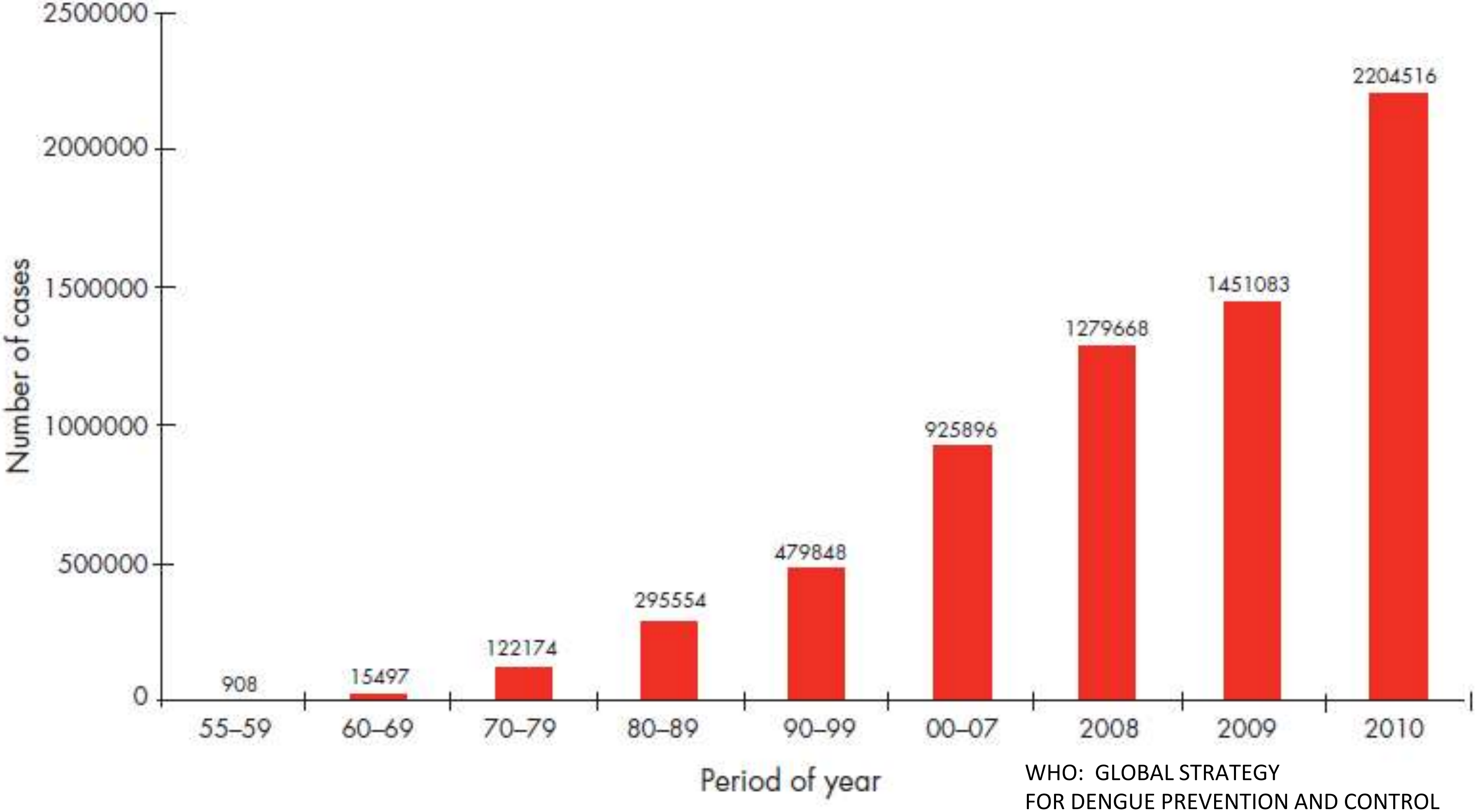
Mapping future temperature suitability for transmission scenarios for *Aedes aegypti* and *Ae. albopictus (most applicable to dengue)*



Maps of monthly suitability based on a temperature threshold corresponding to the posterior probability that scaled *R0* > 0 is greater or equal to 97.5%, for transmission by *Ae. aegypti* and *Ae. Albopictus* for predicted mean monthly temperatures under current climate and future scenarios for 2050 and 2080: b. RCP 8.5 in HadGEM2-ES.

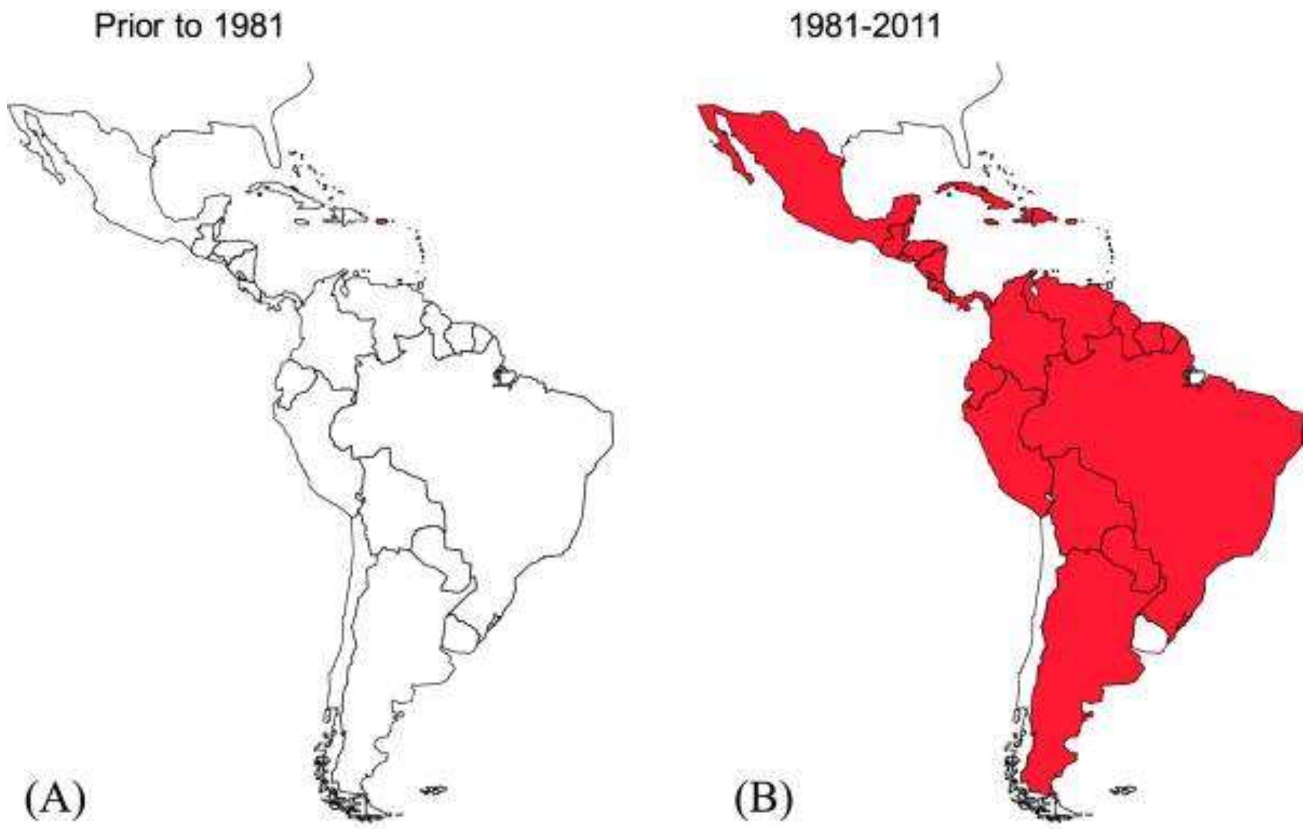
Dengue

Figure 1. Average number of dengue and severe dengue cases reported to WHO annually in 1955–2007 and number of cases reported in recent years, 2008–2010



WHO: GLOBAL STRATEGY
FOR DENGUE PREVENTION AND CONTROL

Spread of Dengue in the Americas



Adapted from Gubler, 1998

Trop Med Health. 2011 Dec; 39(4 Suppl): 3–11.

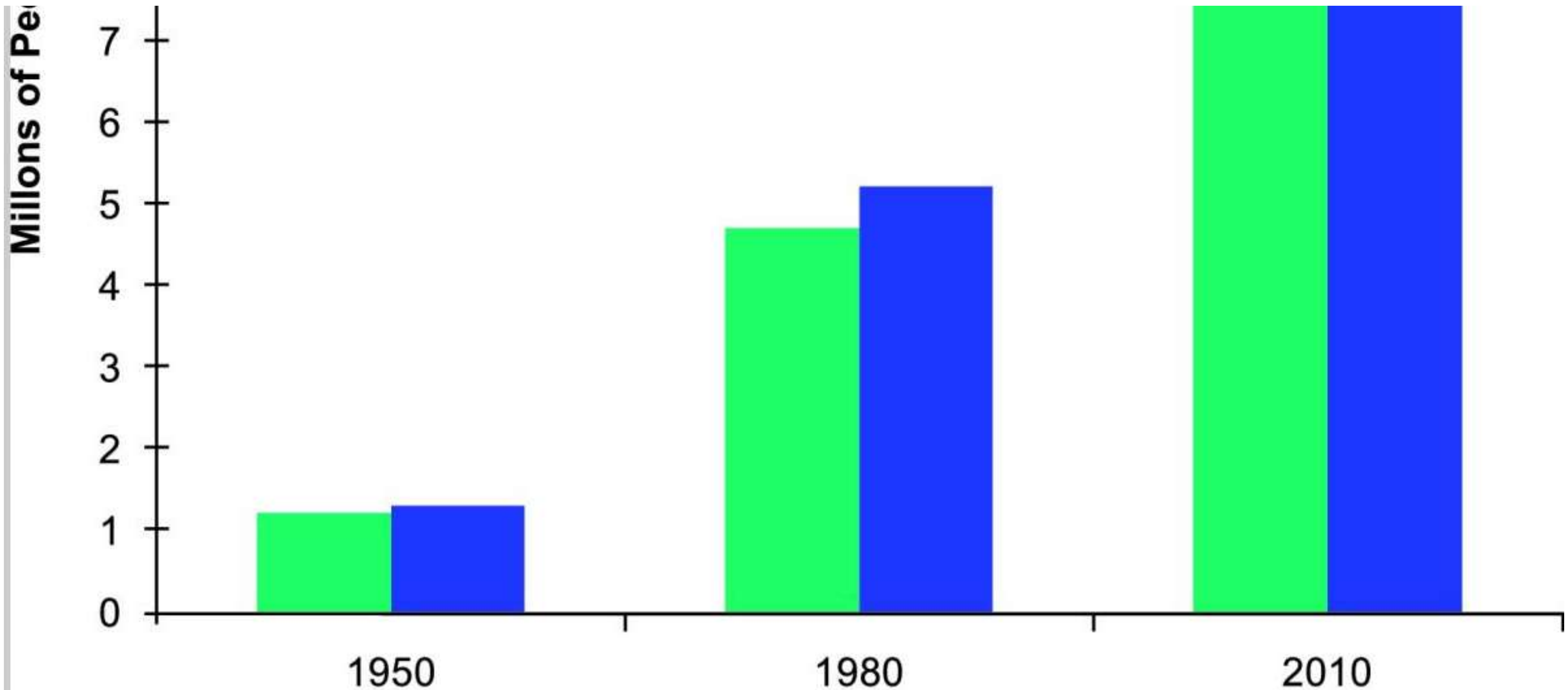
Tropical Medicine and Health

BMC

Trop Med Health. 2011 Dec; 39(4 Suppl): 3–11. PMCID: PMC3317603
Published online 2011 Aug 25. doi: 10.2149/tmh.2011-S05 PMID: 22500131

Dengue, Urbanization and Globalization: The Unholy Trinity of the 21st Century

Duane J. Gubler



1. Mean population of Dhaka, Bangkok, Jakarta, Manila and Saigon.
2. Mean population of Rio de Janeiro, Sao Paulo, San Juan ,Caracas

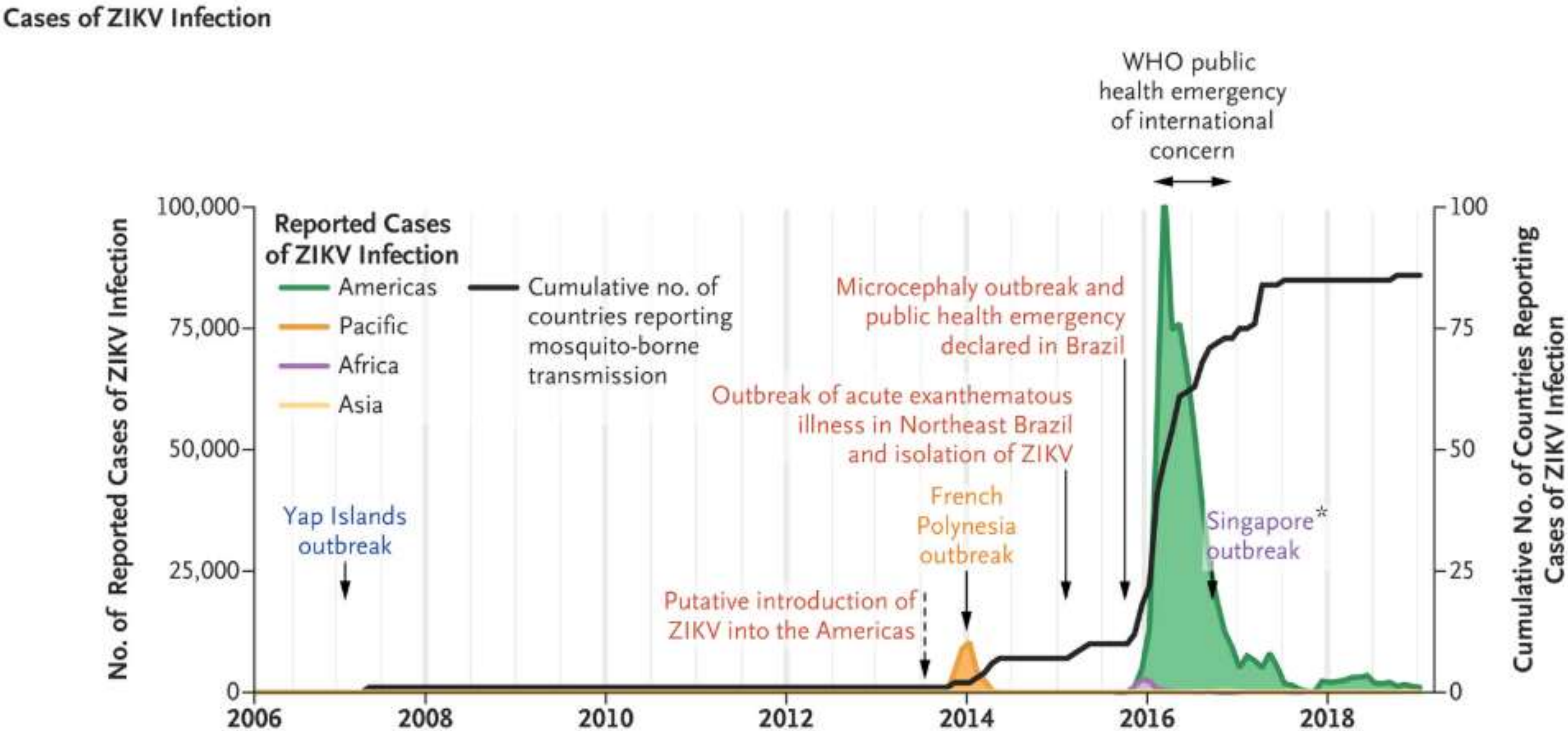
Dengue drivers

Major Drivers of the increased Incidence and Geographic Spread of Dengue

- Lack of effective mosquito control
- Changing life styles
- Unplanned urbanization
- Globalization

Trop Med Health. 2011 Dec; 39(4 Suppl): 3–11.

Zika


Cases of ZIKV Infection
WHO public health emergency of international concern
Reported Cases of ZIKV Infection
Americas
Pacific
Africa
Asia
Cumulative no. of countries reporting mosquito-borne transmission
Microcephaly outbreak and public health emergency declared in Brazil
Outbreak of acute exanthematous illness in Northeast Brazil and isolation of ZIKV
Yap Islands outbreak
French Polynesia outbreak
Singapore* outbreak
Putative introduction of ZIKV into the Americas
No. of Reported Cases of ZIKV Infection
Cumulative No. of Countries Reporting Cases of ZIKV Infection
100,000
75,000
50,000
25,000
0
100
75
50
25
0
2006
2008
2010
2012
2014
2016
2018

Precipitation

- Fecal pathogens ↑
- But… water scarcity also ↑ diarrhea rates in < 5y: reduced hygiene
- Flooding: *hantavirus* ↑, *leptospirosis* ↑

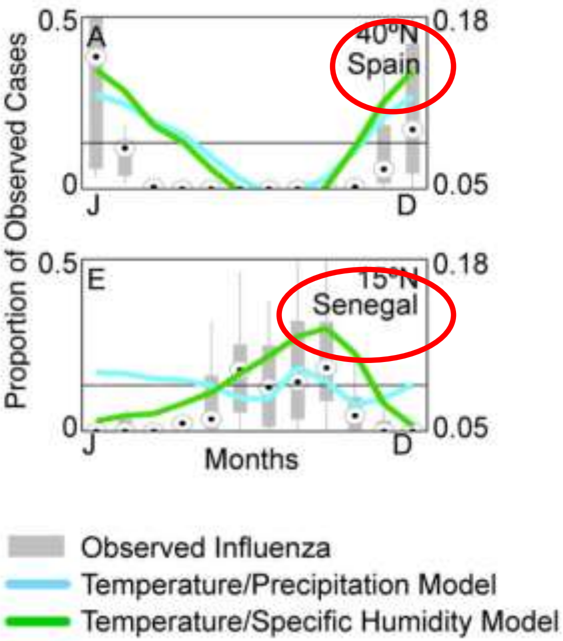
Flooding and the Threat of Infectious Disease

Drought

- ↑ Concentration of water-borne pathogens (Salmonella,...)
- Rotten organic material accumulate in pools: *Culex* ↑ -- > WNV ↑

Humidity

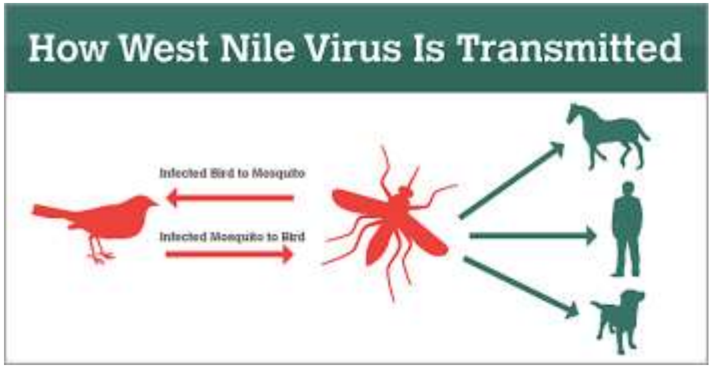
- Cold temperature and relative low humidity: air-borne pathogens like influenza ↑
- *Anopheles* : needs > 60 °C humidity to transmit malaria
- Low humidity: unfavorable for ticks and fleas



West Nile Virus

Outbreak in USA

- Autums 1999 : sudden mortality in crows and flamingoes in Bronx Zoo, New York
- Cases of human encephalitis (67 cases with 7 death)
- How did the virus arrive in the USA?
  - ✓ migrating birds
  - ✓ smuggled birds
  - ✓ lost birds



Followed by a warm winter and summer droughts

USGS
science for a changing world

CDC
SAFER - HEALTHIER - PEOPLE

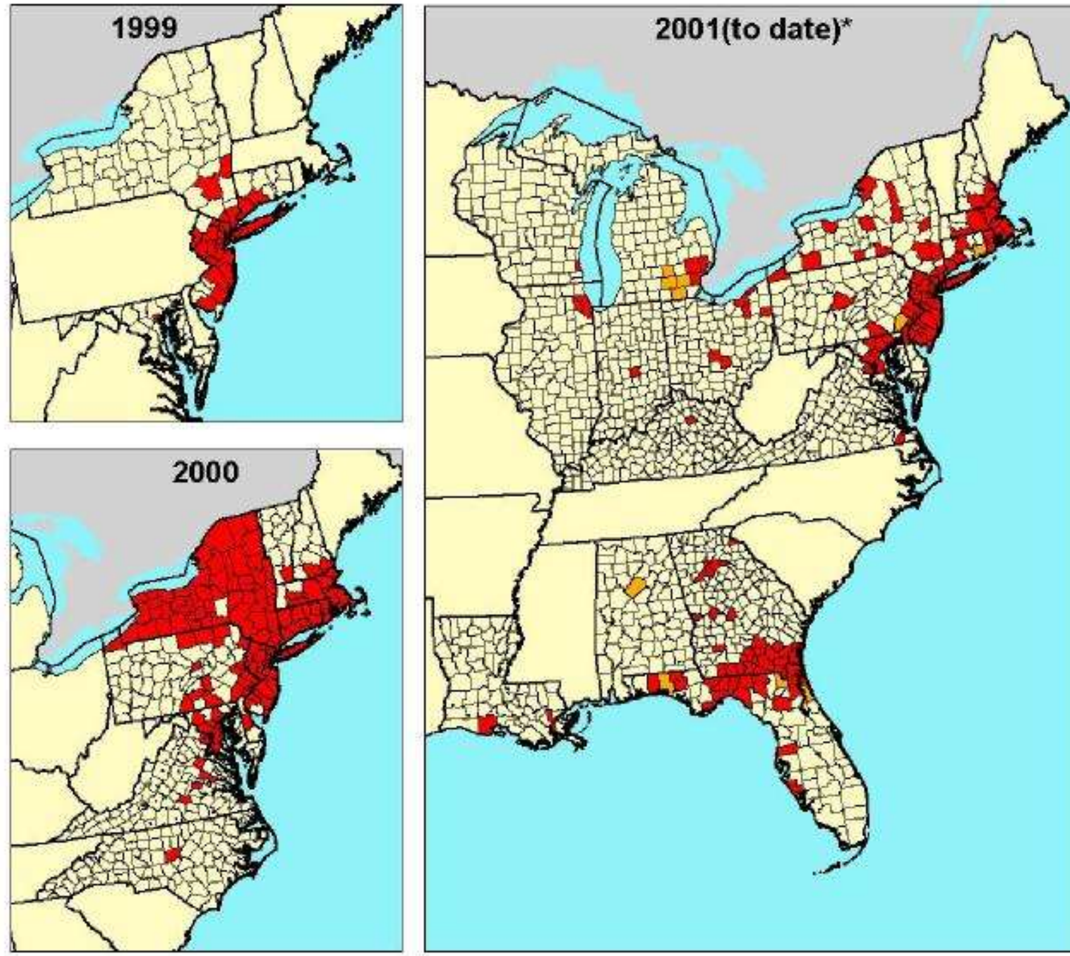
West Nile Virus Activity 1999 - 2001

This map shows all counties in the United States that reported West Nile virus activity in 1999 and 2000, as well as current 2001 status. This surveillance includes positive test results from humans, horses, wild birds, sentinel chickens, or mosquitoes.

- West Nile Virus Activity Reported to Centers for Disease Control and Prevention and Verified (9/10/01)*
- West Nile Virus Activity Reported by State Agencies (9/7/01)*

200 0 200 400 600 800 Kilometers

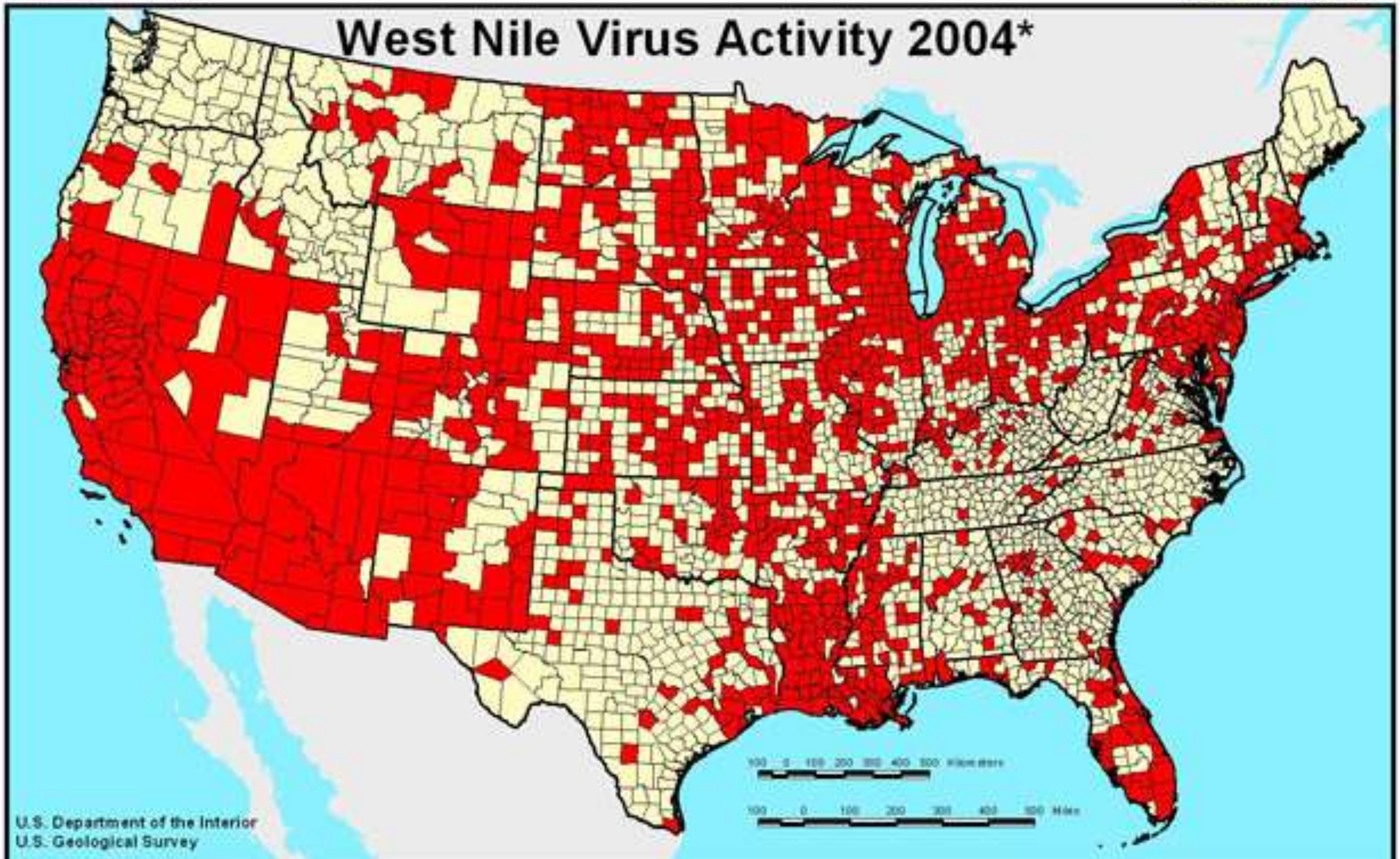
200 0 200 400 600 Miles



U.S. Department of the Interior
U.S. Geological Survey

CINDI Center for Integration of Natural Disaster Information

In September 2002 WNV arrived in California



*West Nile Virus Activity Reported to Centers for Disease Control and Prevention and Verified (10/05/04)

This map shows all counties in the United States that reported West Nile virus activity in 2004 This surveillance includes positive test results from humans, horses, wild birds, sentinel chickens, or mosquitoes.

Sunshine

- ↑ Concentration of *V. cholera*

Wind

- Asian dust storms: Influenza A ↑ (downwind)
- Transport of pathogens across oceans
- Mosquitoes: reduces biting opportunities, but extend flight distance

Other factors

- Crop failure -- > malnutrition -- > immunity ↓ -- > infections

Extreme weather events

Key studies that assess the relationship between extreme weather events and infectious diseases.[a]

Extreme weather events	Disease type	Authors, year	Main findings
El Nino	Vector-borne disease	Epstein (1999)	Increasing outbreaks of emerging diseases were linked to El Nino event.
		Haines and Patz (2004)	Outbreaks and epidemic of malaria were positively connected with El Nino events in many regions.
		…dsay et al. (2000)	Strikingly less malaria were found in the El Nino year than in the preceding year in the Usambara Mountains, Tanzania.
		… (2000)	Record of hantavirus cardiopulmonary syndrome has been found to be related to El Nino events in the Colorado Plateau.
	Wa…	…	The risk of symptoms associated with diarrhea is twice the previous when exposed to southern California coastal waters during an El Nino winter.
La Nina	V…	…	…kungunya fever epidemic was connected with the drought incurred by La Nina.
		…	…ar produced an epidemic of West Nile fever and Japanese encephalitis.
	V…	…	…ross diarrhea symptom during a La Nina winter.
Quasi-Biennial Oscillation (QBO)	Vecto…	…	…be linked to the incidence of Ross River virus in south-eastern …
Heatwaves	Vector-borne dis…	…	…tbreak of West Nile fever in Israel in 2000.
	Air-borne disease	…	…rbidity and mortality from infectious respiratory …
Drought	Water-borne disease	Epste…	…cially in refugee camps.
	Vector-borne disease	Khasnis and …	…ulmonary syndrome (HPS).
		Wang et al. (2010)	…
		Shaman et al. (2002)	…would increase, during the …
		Chretien et al. (2007)	Th… h droughts.
Flood	Water-borne disease	MacKenzie et al. (1994)	Flood … s *Cryptosporidium* infection.
		Reacher et al. (2004)	A significant … ociated with depth of flooding in the town of Lewes …
	Vector-borne disease	Epstein (1999)	Floods in Mozambique le… yphoid and cholera
		Mackenzie et al. (2000)	Strong rain or flood can lead to … River fever
		Ahern et al. (2005)	After a flood, such diarrheal disease … olera may grow
		Woodruff et al. (1990)	Increases in diarrhea and malaria inciden…s were observed after floods in 1988 in Khartoum, Sudan.
		Nielsen et al. (2002)	There have been reported increases in lymphatic filariasis in different areas.
		Cordova et al. (2000)	There have also been reported increases in arbovirus disease after flood
		Chen (1999)	Hemorrhagic Fever with Renal Syndrome diseases may increase during flooding
		CDC (2000)	HPS diseases may also increase during flooding
		Leal-Castellanos et al. (2003)	Leptospirosis diseases may also increase during flooding in different areas.
Hurricane	Vector-borne disease	Epstein (2000)	Following the hurricane, malaria and dengue fever occurred in Honduras and in Venezuela.
Cyclone	Vector-borne disease	Sanders et al. (1999)	A cyclone tends to increase the incidence of leptospirosis.
	Water/food-borne disease	Shultz et al. (2005)	A cyclone tends to increase the incidence of cholera.

!TIME CORRELATION ≠ CAUSALITY!

Predictions from the past

Status of Major Vector-borne Diseases and Predicted Sensitivity to Climate Change*

Disease	Populations at Risk, Millions†	Prevalence of Infection, Millions‡	Present Distribution	Possible Change of Distribution as a Result of Climatic Change
Malaria	2100	270	Tropics, subtropics	Highly likely
Lymphatic filariases	900	90.2	Tropics, subtropics	Likely
Onchocerciasis	90	17.8	Africa, Latin America	Likely
Schistosomiasis	600	200	Tropics, subtropics	Very likely
African trypanosomiasis	50	25 000 new cases per year	Tropical Africa	Likely
Leishmaniasis	350	12 million infected + 400 000 new cases per year	Asia, southern Europe, Africa, South America	Not known
Dracunculiasis	63	1	Tropics (Africa, Asia)	Unlikely
Arboviral diseases				
Dengue	...	...	Tropics, subtropics	Very likely
Yellow fever	...	...	Africa, Latin America	Likely
Japanese encephalitis	...	...	East and Southeast Asia	Likely
Other arboviral diseases	...	...	Tropical to temperate zones	Likely

*Data from World Health Organization.[11]
†Based on a world population estimated at 4.8 billion (1989).
‡Ellipses indicate no estimates available.

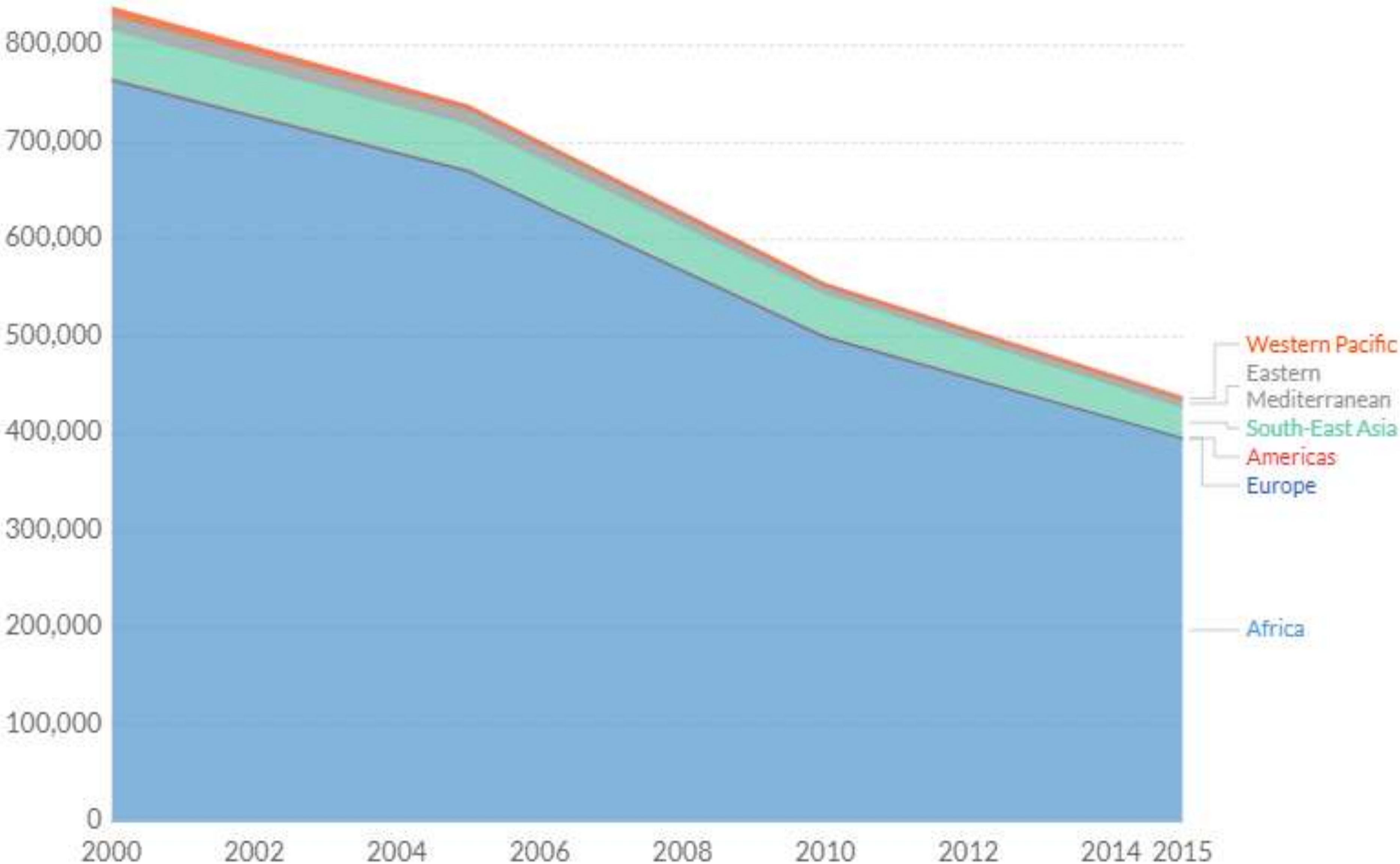
JAMA, January 17, 1996—Vol 275, No. 3

Prediction

change scenarios,[41,42] risk of malaria epidemics would rise substantially in both tropical and temperate regions. An estimated 1 million additional fatalities per year could be attributed to climate change by the middle of the next century, according to one model.[43]

JAMA, January 17, 1996—Vol 275, No. 3

Global malaria deaths by world region



Source: WHO Global Health Observatory (2016)

Interactive Map Malaria Incidence

- https://ourworldindata.org/malaria

Status of Major Vector-borne Diseases and Predicted Sensitivity to Climate Change*

Disease	Populations at Risk, Millions†	Prevalence of Infection, Millions‡	Present Distribution	Possible Change of Distribution as a Result of Climatic Change
Malaria	2100	270	Tropics, subtropics	Highly likely
Lymphatic filariases	900	90.2	Tropics, subtropics	Likely
Onchocerciasis	90	17.8	Africa, Latin America	Likely
Schistosomiasis	600	200	Tropics, subtropics	Very likely
African trypanosomiasis	50	25 000 new cases per year	Tropical Africa	Likely
Leishmaniasis	350	12 million infected + 400 000 new cases per year	Asia, southern Europe, Africa, South America	Not known
Dracunculiasis	63	1	Tropics (Africa, Asia)	Unlikely
Arboviral diseases				
Dengue	...	...	Tropics, subtropics	Very likely
Yellow fever	...	...	Africa, Latin America	Likely
Japanese encephalitis	...	...	East and Southeast Asia	Likely
Other arboviral diseases	...	...	Tropical to temperate zones	Likely

*Data from World Health Organization.[7]
†Based on a world population estimated at 4.8 billion (1989).
‡Ellipses indicate no estimates available.

The NEW ENGLAND JOURNAL of MEDICINE

REVIEW ARTICLE

Caren G. Solomon, M.D., M.P.H., *Editor*

The Imperative for Climate Action to Protect Health

Andy Haines, M.D., and Kristie Ebi, M.P.H., Ph.D.

The World Health Organization (WHO) estimated that approximately 250,000 deaths annually between 2030 and 2050 could be due to climate change–related increases in heat exposure in elderly people, as well as increases in diarrheal disease, malaria, dengue, coastal flooding, and childhood stunting.[16] This is a conser-

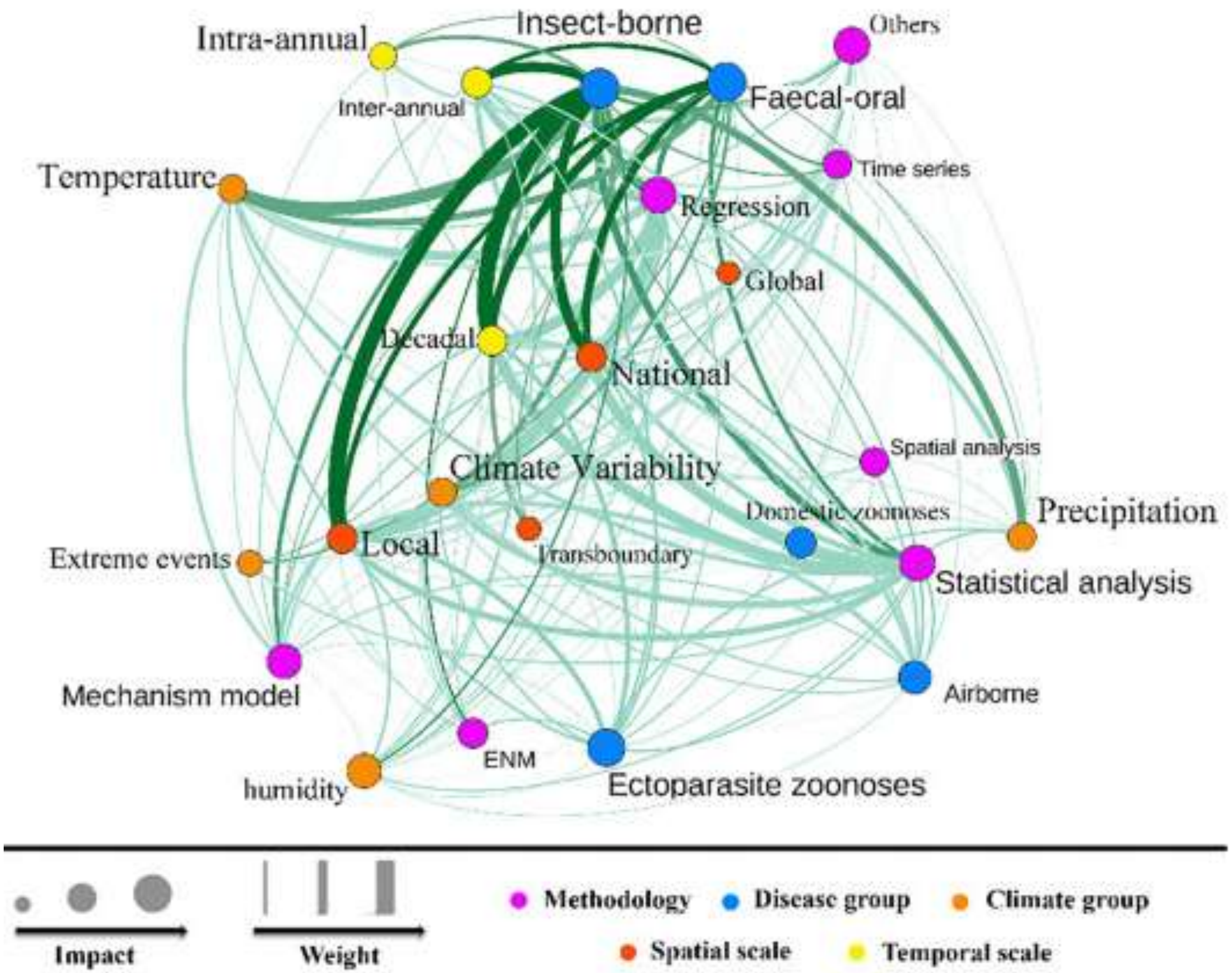
Cavé : Bias in Media

DE TROPEN IN EUROPA: DE VERRADERLIJKE STREKEN VAN VIRUSSEN, VLEERMUIZEN, TIJGERMUGGEN EN REUZENTEKEN

Behalve verzengende hittegolven, een dalend grondwaterpeil en straks misschien een verbod om uw zwembad te vullen of uw tuin te sproeien, heeft de klimaatverandering nog andere, onverwachte gevolgen. Steeds meer muggensoorten en andere insecten die gevaarlijke, zelfs dodelijke tropische ziekten kunnen overbrengen, voelen zich thuis in onze contreien. Slapen wij om malaria, knokkelkoorts en de westnijlziekte af te houden, straks allemaal onder een muskietennet? 'Het is niet uitgesloten dat het ebolavirus een geschikte gastheer vindt bij onze inheemse vleermuizen.'

'ALS WE NIET SNEL EN ACCURAAT INGRIJPEN, KAN OOK BIJ ONS EEN EPIDEMIE UITBREKEN'

Complex



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Thanks