The impact of climate change on infectious diseases

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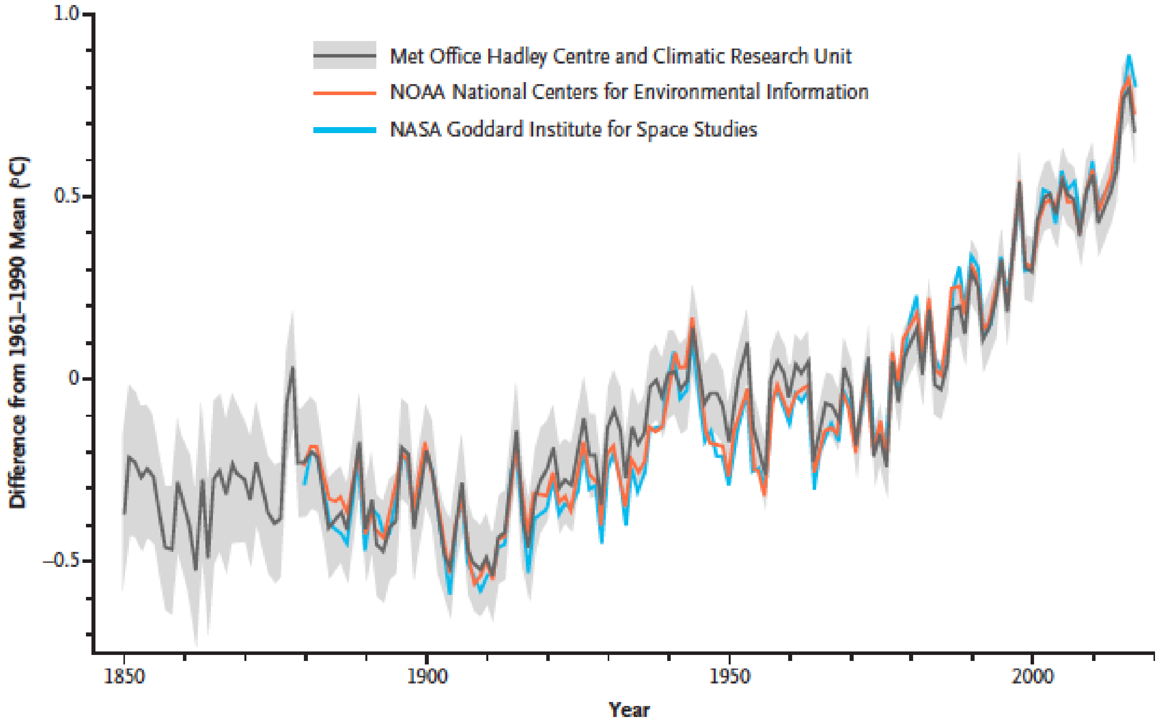
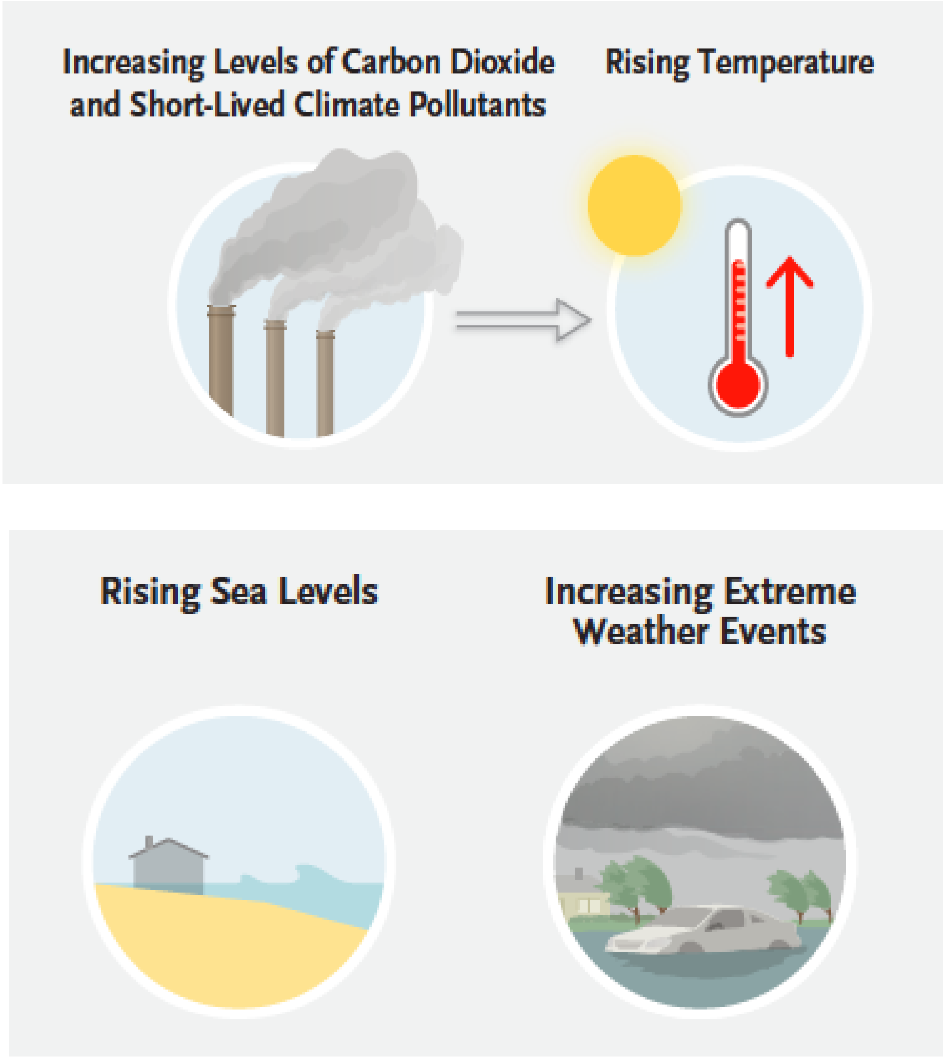
Conferința de Medicina călătorului, 21-23 Septembrie 2023, on line

Climate change



Annual global mean temperature anomalies relative to the means during 1961–1990



Haines A, Ebi K NEJM 2019

Journal of Travel Medicine
International Society of Travel Medicine
Promoting healthy travel worldwide
Established 1991
Journal of Travel Medicine, 2023, 1–3
https://doi.org/10.1093/jtm/taad015
Perspective

Perspective

Climate change and glacier melting: risks for unusual outbreaks?

Ryan Varghese, BPharm[1,2,†], Pal Patel, BTech[3,†], Dileep Kumar, PhD[1,4,5,*] and Rohit Sharma, MD, PhD[6,*]

Approximately 58% (218 of the 375) of ID that humanity has ever encountered have been exacerbated by climatic changes.

Increasing global warming, could awake the viral and bacterial pathogens trapped in glaciers and permafrost in a dormant state.

In **2014,** researchers managed to revive a **giant dormant virus** that had been isolated from **Siberian permafrost**, rendering it contagious for the first time in 30.000 years, quoting it as **a 'recipe for disaster'**

In **2021**, another team of scientists sequenced the genetic material of several novel viral species present in samples obtained from the **Tibetan Plateau in China** on the glacier ice. **Of the 33 viruses, 28 were novel and ~15.000 years old.**

The effects of spillovers involving latent viruses, following glacier melting, need to be studied thoroughly.

Major health risks associated with climate change

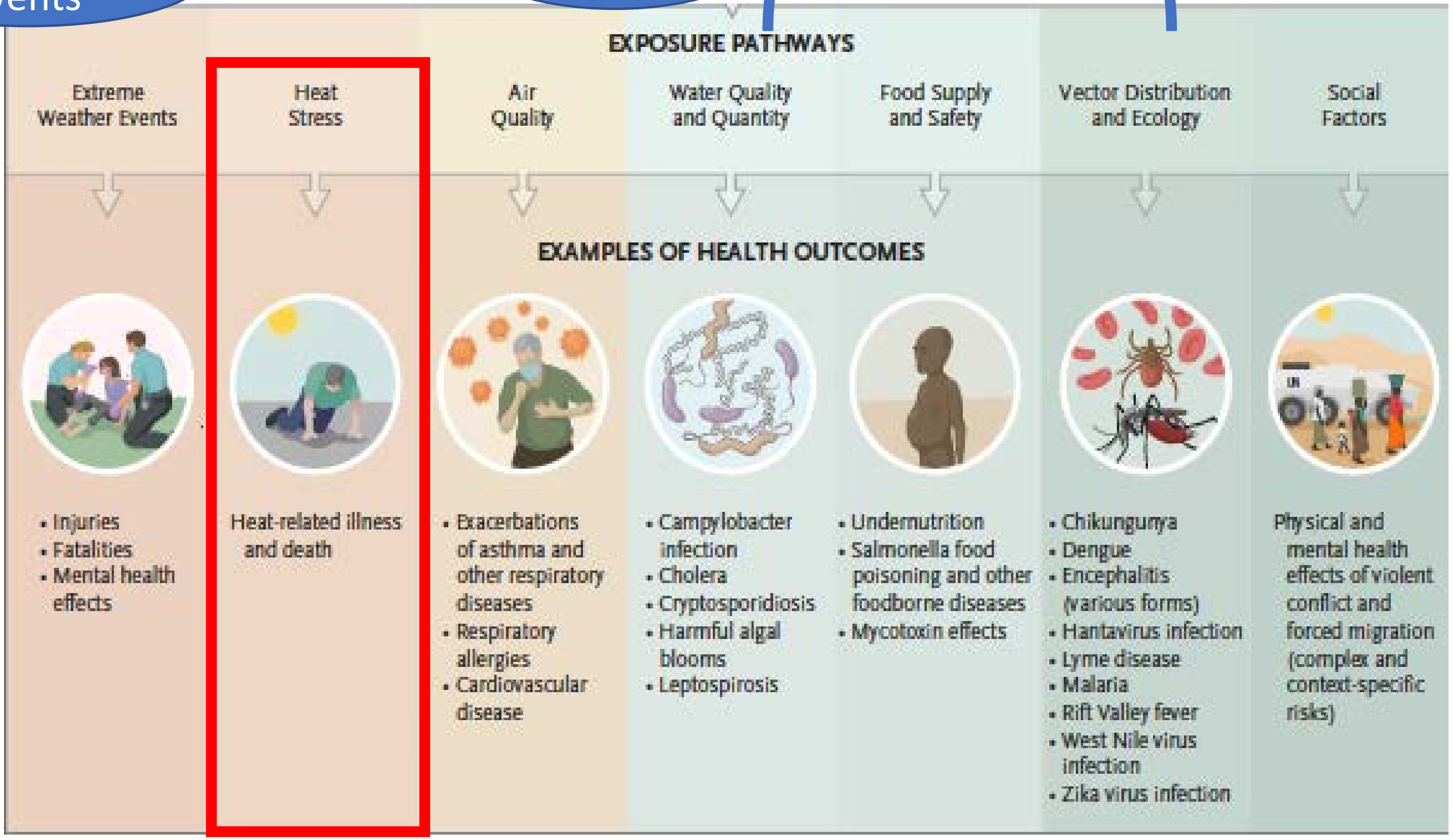
Extreme events

Rising temperatures

Air quality

Climate-sensitive infectious diseases

INDICATORS

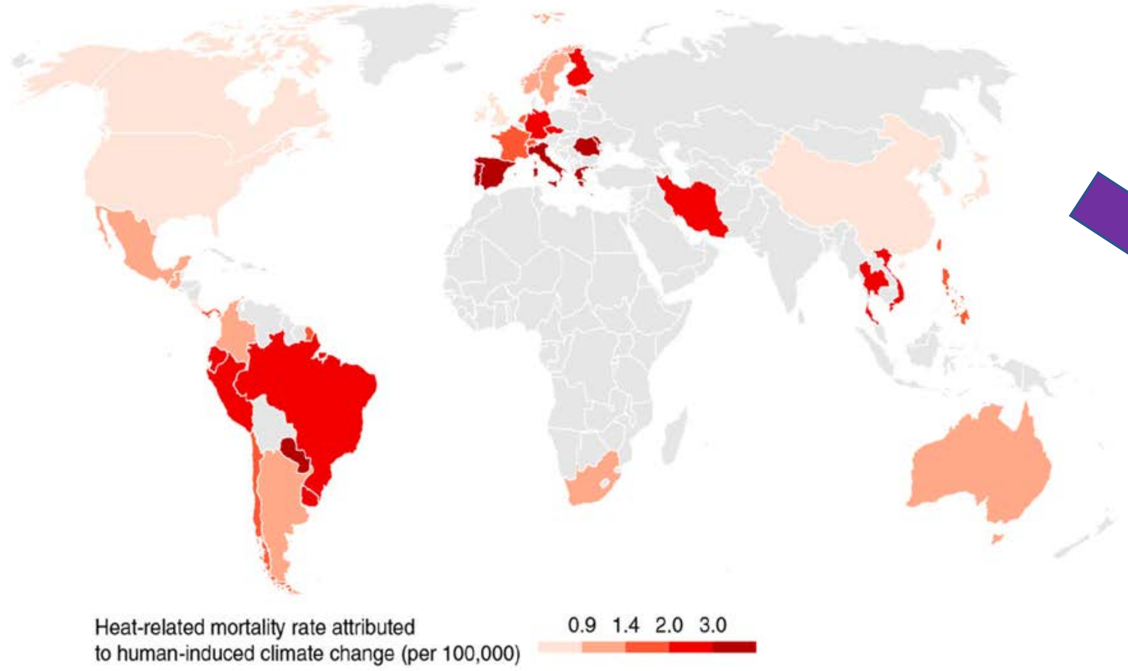


Haines A, Ebi K NEJM 2019

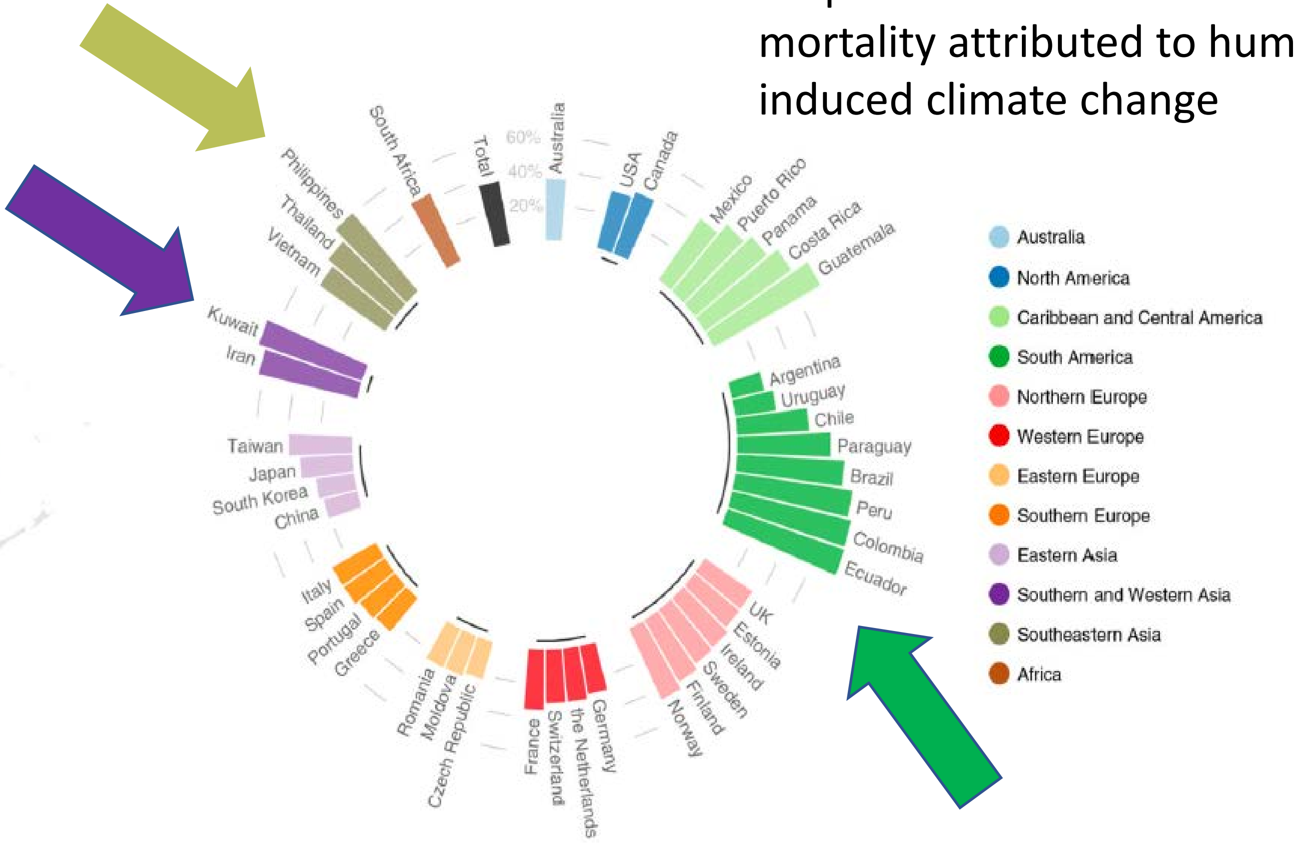
The ***Lancet* Countdown in Europe** is a collaboration of 44 leading researchers, established to monitor the links between health and climate change in Europe and to support a robust, evidence-informed response to protect human health.

van Daalen KR et al. Lancet 2022

Heat-related deaths attributable to human-induced climate change



Proportion of heat-related mortality attributed to human-induced climate change

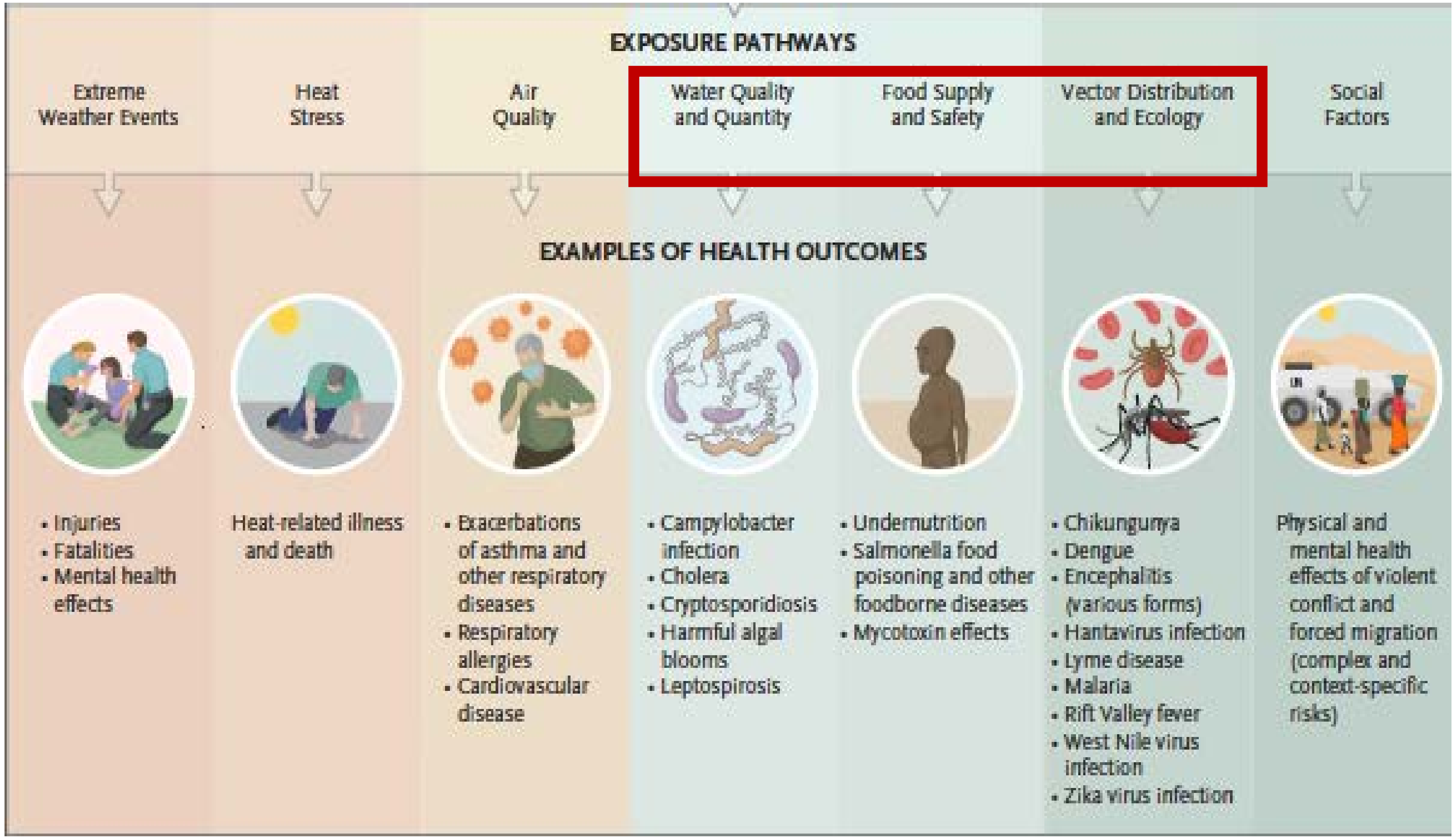


Vulnerability to heat exposure has increased steadily across all European regions, with an increase of 6% from 1990 to 2019. Although northern Europe is the most vulnerable region, the highest relative increase of 9·8% is observed in central Europe

Heat-related mortality and the contribution of human-induced climate change, 1991–2018

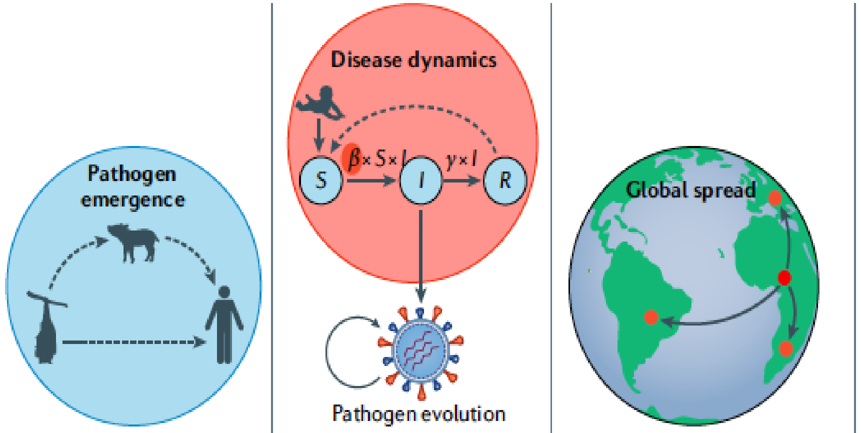
Vicedo-Cabrera et al.Nat Clim Chang. 2021

Major health risks associated with climate change



Haines A, Ebi K NEJM 2019

Effects of climatic, technological and demographic change on disease emergence, dynamics and spread



Climatic change	Drives range shifts for reservoir species	Affects transmission and susceptibility	Affects the geographical range of vectors
Technological change			
Transportation	Improved global surveillance		Air transit and high-speed rail affect pace and range of spread
Health care		Vaccination affects dynamics	Improved care reduces burden
Demographic change			
Population growth and land use	Increased contact with reservoir species	Population numbers affect evolution, birth rates affect dynamics	Larger population travelling
Urbanization	Depends on species	Density affects contact rate	Urban population more connected
Ageing	Imunosenescence affects spillover risk	Ageing population increases transmission	Possible larger burden

susceptible (S), infected (I), recovered (R)

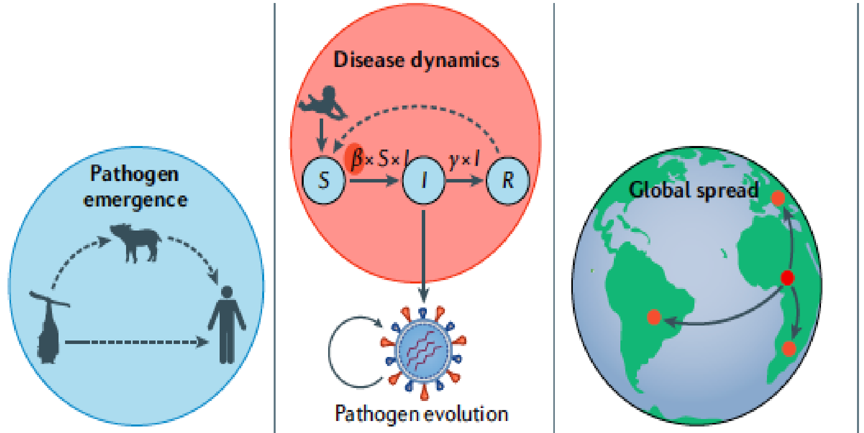
B=transmission rate; γ = recovery rate.

Climate change:

- **Emergence**: drives shifts for reservoirs species
- **Disease dynamics**: affects transmission and susceptibility
- **Global spread**: affects the geographical range of vectors

Baker RE.et al. Nature Reviews Microbiology 2022

Effects of climatic, technological and demographic change on disease emergence, dynamics and spread



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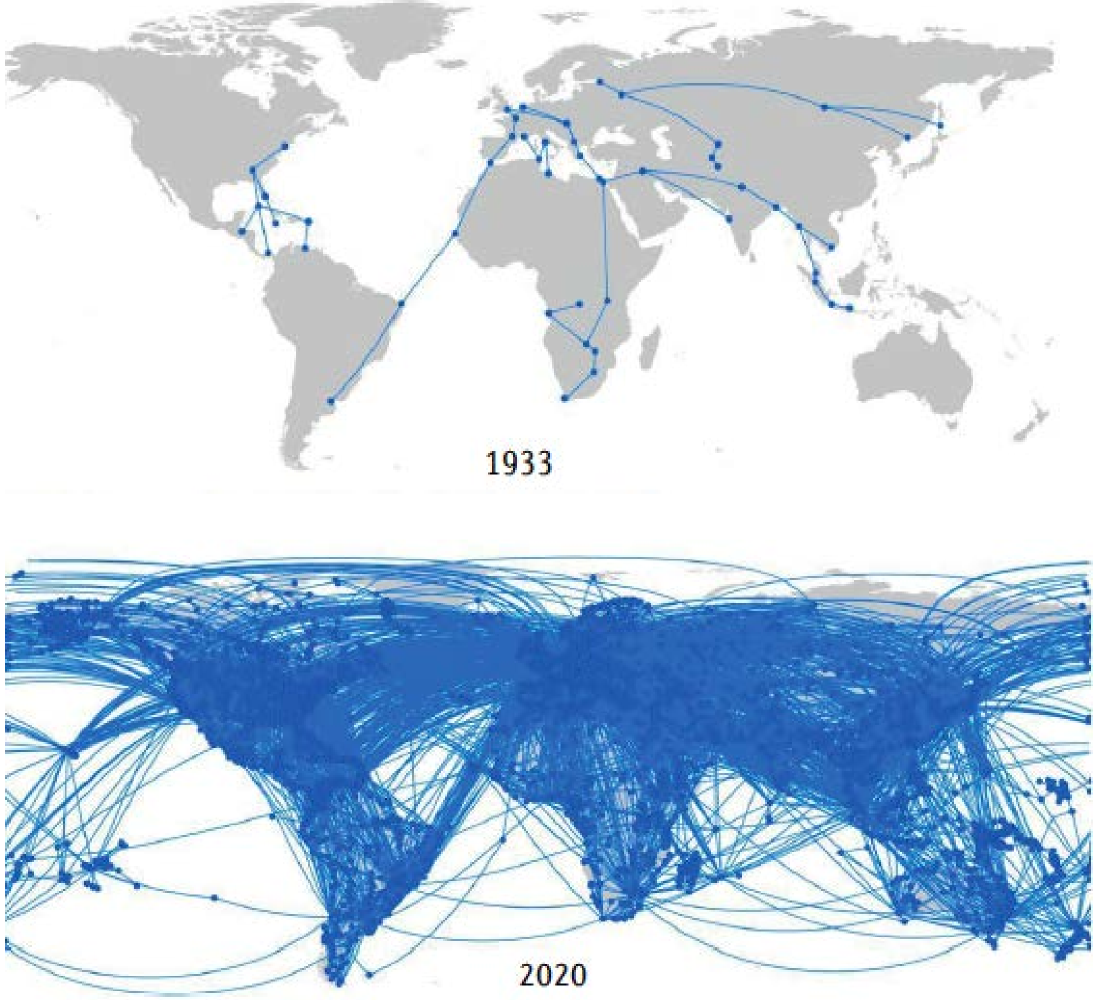
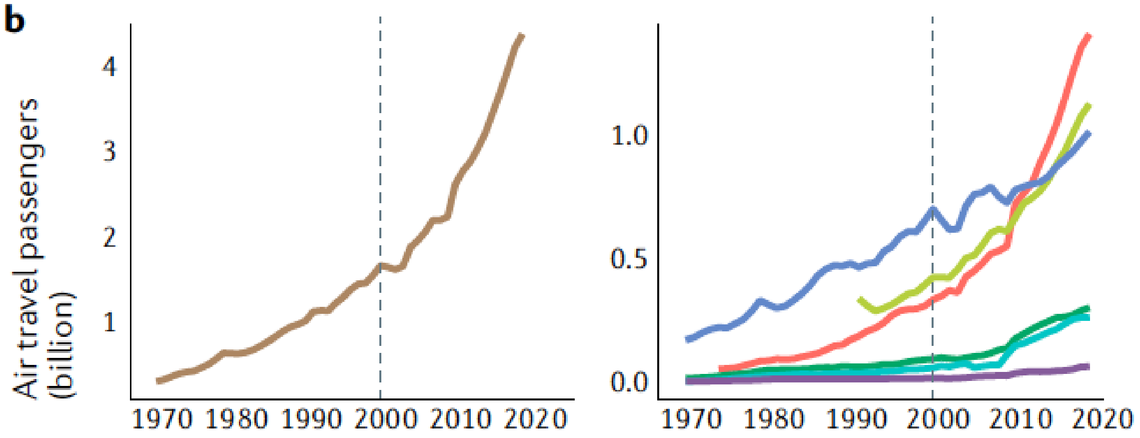
Technological changes:

- **Emergence**: improve global surveillance for emergent pathogens
- **Disease dynamics**: vaccination affects susceptibility
- **Global spread**: air travel

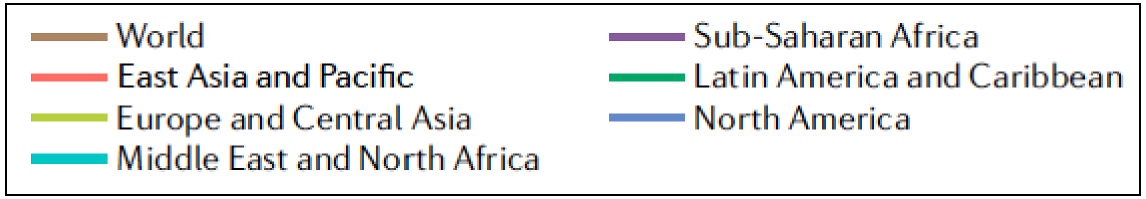
Baker RE.et al. Nature Reviews Microbiology 2022

Technological changes: the global international air travel network expanded substantially from 1933 to 2020



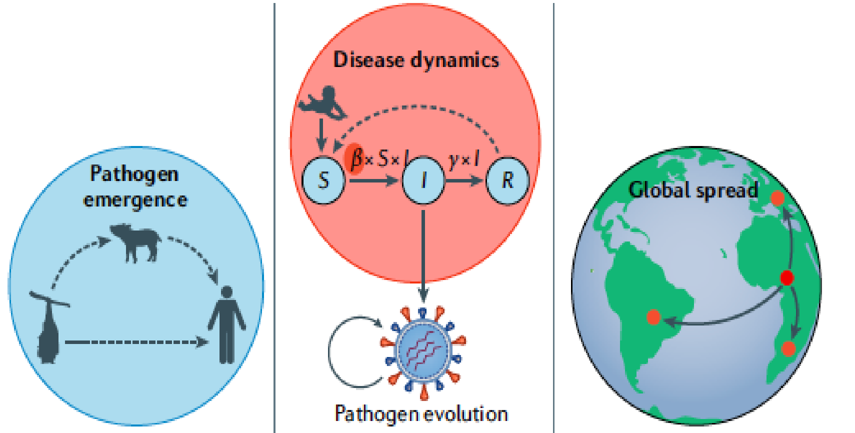


Air travel passengers (billions)



Baker RE.et al. Nature Reviews Microbiology 2022

Effects of climatic, technological and demographic change on disease emergence, dynamics and spread



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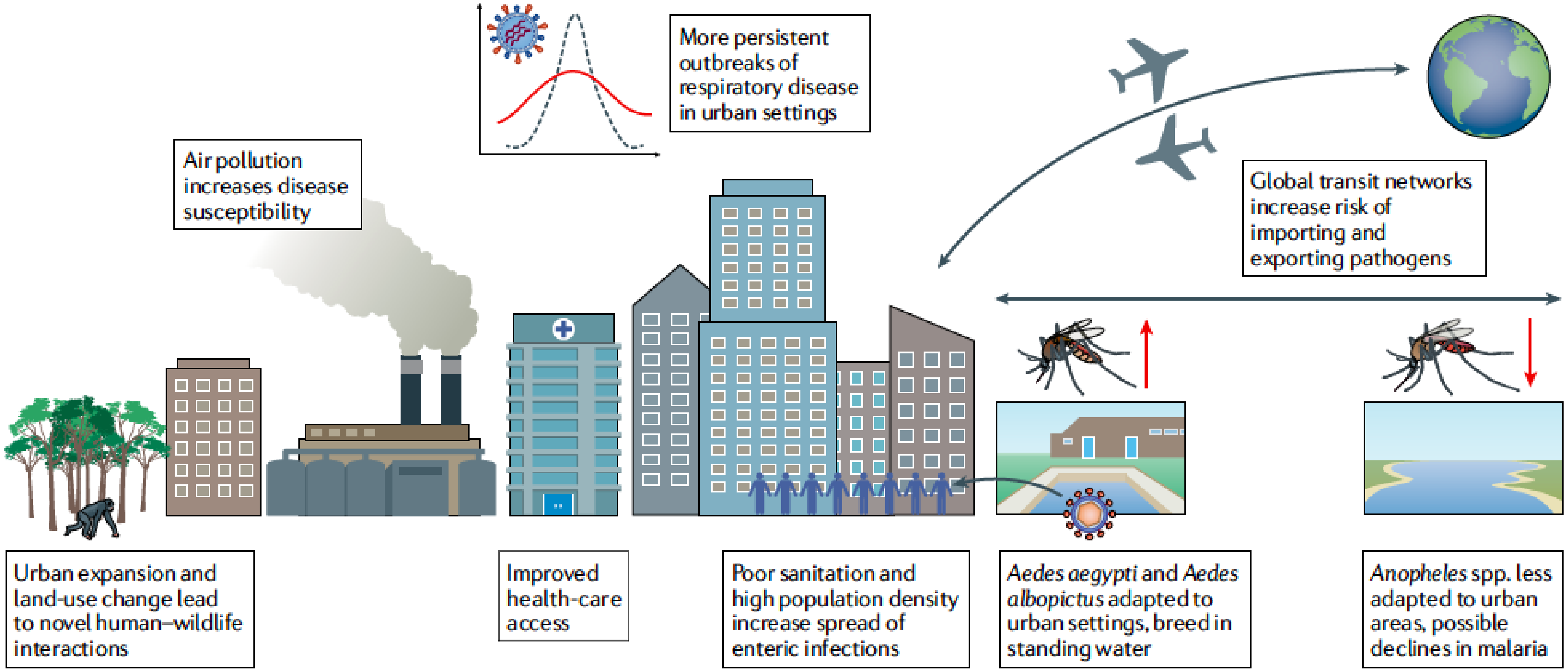
Demographic changes

- **Emergence**: increase contact with reservoir species
- **Disease dynamics**: density increases contact rate, aging increases susceptibility
- **Global spread**: urban population more connected

Baker RE.et al. Nature Reviews Microbiology 2022

Impacts of urbanization on infectious disease



Interactions between urbanization and infectious disease are complex, with **increased urbanization driving both positive and negative changes to global disease burden.**

Baker RE.et al. Nature Reviews Microbiology 2022

Hazard-Vulnerability-Exposure-Disease

Climate hazard
- Heat
- Drought
- Rain
- Flood

Vulnerabilities
- Bio-medical
- Demographic
- Geographic
- Socio-economic
- Socio-political

Pathogens
- Food-borne
  - Campylobacter
  - Salmonella
- Water-borne
  - Cholera
  - Cryptosporidiasis
  - Leptospirosis
- Vector-borne
  - Chikungunya
  - Dengue*
  - Lyme
  - Malaria*
  - West Nile*
  - Zika

Food-borne diseases (FBD) influenced by climate change

Food-borne disease (FBD)

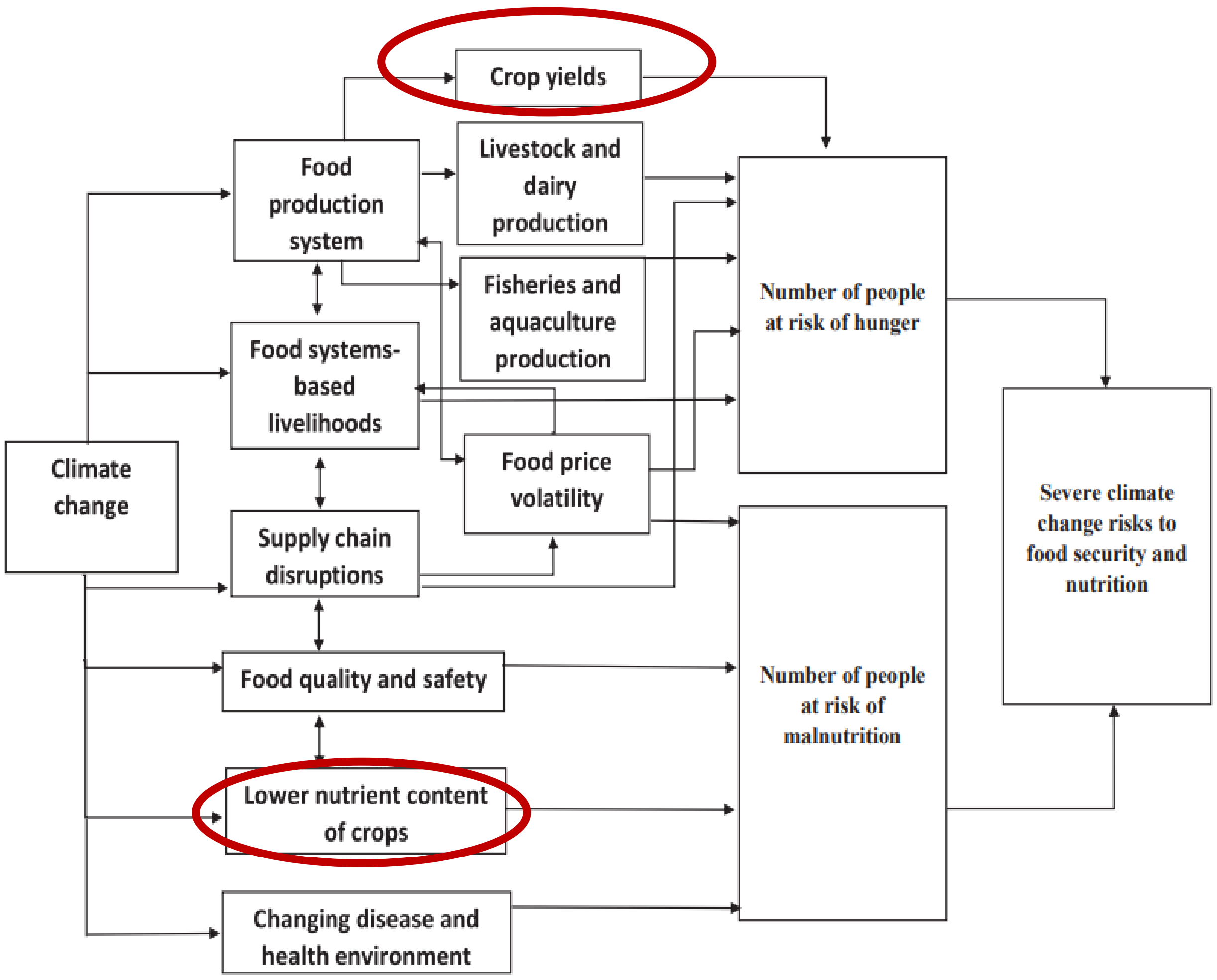
= caused by contamination of food and occur at any stage of the food production, delivery and consumption chain. They can result from several forms of environmental contamination including pollution in water, soil or air, as well as unsafe food storage and processing.

- **Impact:**
  - 1 in 10 people fall ill after eating contaminated food worldwide
  - 125.000 children die each year due to unsafe food
  - US $ 110 billion lost each year in productivity and medical expenses resulting from unsafe food in low- and middle income countries

- Ex:Norovirus, Salmonella, Clostridium perfringens, Campylobacter, E. coli O157:H7, Listeria, Toxoplasma

https://www.who.int/activities/estimating-the-burden-of-foodborne-diseases

Impacts of climate change on food and nutrition (1)



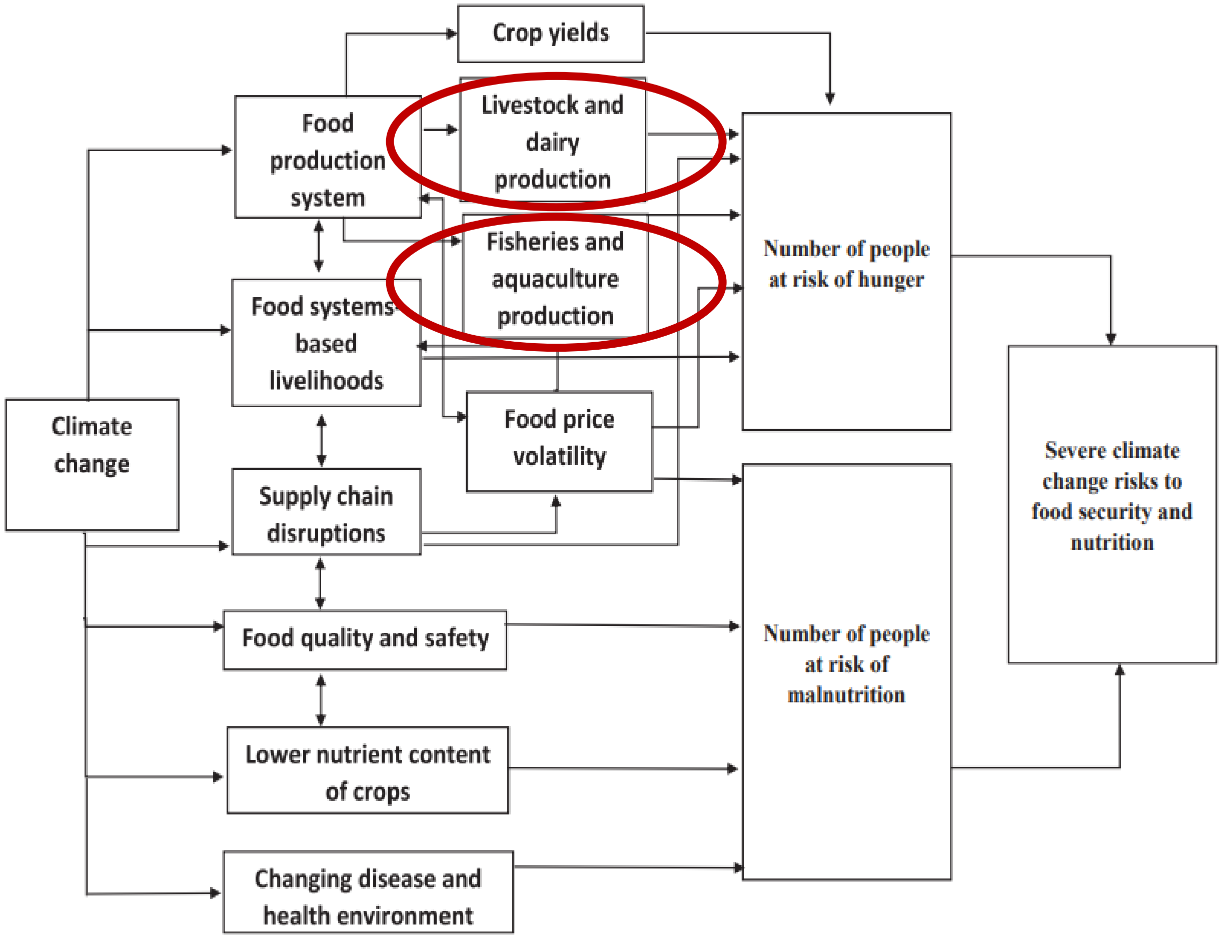
- **Micronutrients in crops** (e.g., phosphorus, potassium, calcium, sulphur, magnesium, iron, zinc, copper, and manganese) will **decrease** by **5–10 %** with a 3.5 ◦C warming.
- **Decline in zinc** content -> **150–220 million people** being affected by zinc deficiency
- **Decrease in protein** and **micronutrient** content in **rice** - > **600 million people** at risk of micronutrient deficiency by 2050.

- Since 1961 the growth of agricultural total factor productivity **slowed down** by **21%.**
- An average negative effect of 5.3% for three staple crops (5.9% for maize, 4.9% for wheat and 4.2% for rice

A. Mirzabaev et al. Climate Risk Management 39 (2023) 100473

B. Food, Fibre, and Other Ecosystem Products. In: Climate Change 2022: Impacts, Adaptation and Vulnerability

Impacts of climate change on food and nutrition (2)



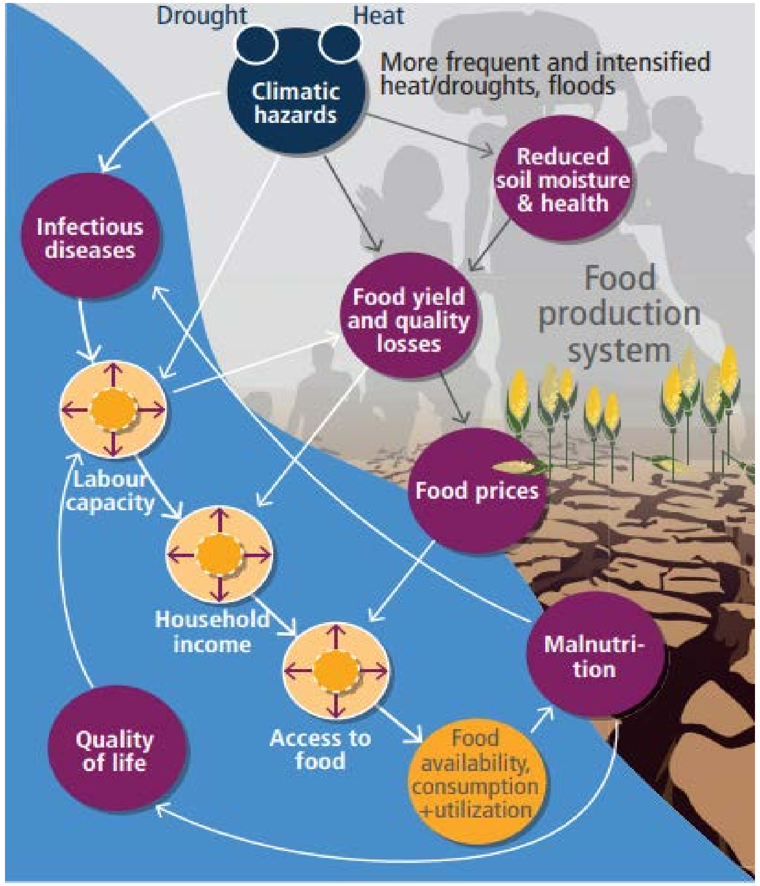
- **Livestock production**
- with **direct impacts** of heat stress on mortality and productivity, and **indirect impacts** on grassland quality, shifts in species distribution and range changes in livestock diseases (eg - range expansion of arthropod vectors that spread the bluetongue virus, increase in the number of cases of anthrax and Rift Valley fever).

- **Aquatic systems**
- 4.1% global loss for several fish populations
- temperature increases, acidification, salt intrusion, oxygen deficiency, floods and droughts will negatively impact production, with reduced fisheries catches between 5.3 and 7 % by 2050.

A. Mirzabaev et al. Climate Risk Management 39 (2023) 100473

B. Food, Fibre, and Other Ecosystem Products. In: Climate Change 2022: Impacts, Adaptation and Vulnerability

Impacts of climate change on food and nutrition (3)



- Especially vulnerable groups, such as women, children, low-income households, Indigenous or other minority groups and small-scale producers, who are at higher risk of malnutrition,).
- Additional 1.7 billion people at risk of undernourishment by 2050, 1.3 billion by 2085, and 1.1 billion by 2100.

LIVELIHOOD LOSS

250,000 deaths per year between 2030 and 2050
and
500,000 deaths per year as a consequence of changes in diet and body weight

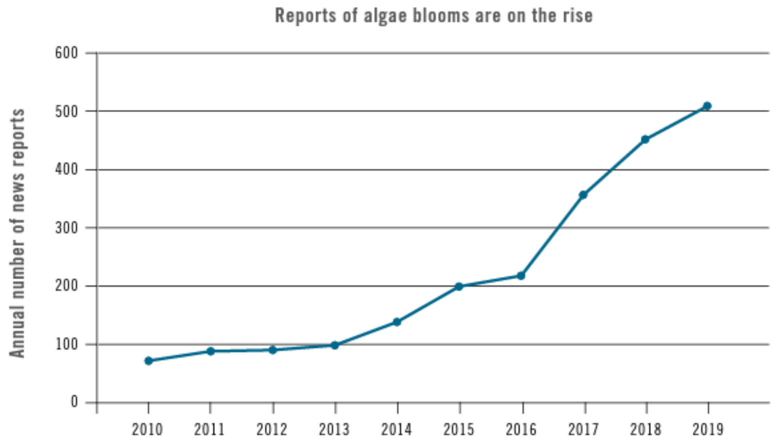
Food, Fibre, and Other Ecosystem Products. In: Climate Change 2022: Impacts, Adaptation and Vulnerability

The effect of climate change on FBD (1)

Increases in **algal bloom**

- Deadly for marine animals and damages coastal ecosystems.
- Sargassum blooms adversely affect shore-based activities.
- Increased cases of human shellfish and reef fish poisoning (ciguatera)

FIGURE 4. ESTIMATED NUMBER OF ALGAL BLOOMS IN THE UNITED STATES OF AMERICA SINCE 2010, BASED ON DATA COMPILED BY THE ENVIRONMENTAL WORKING GROUP

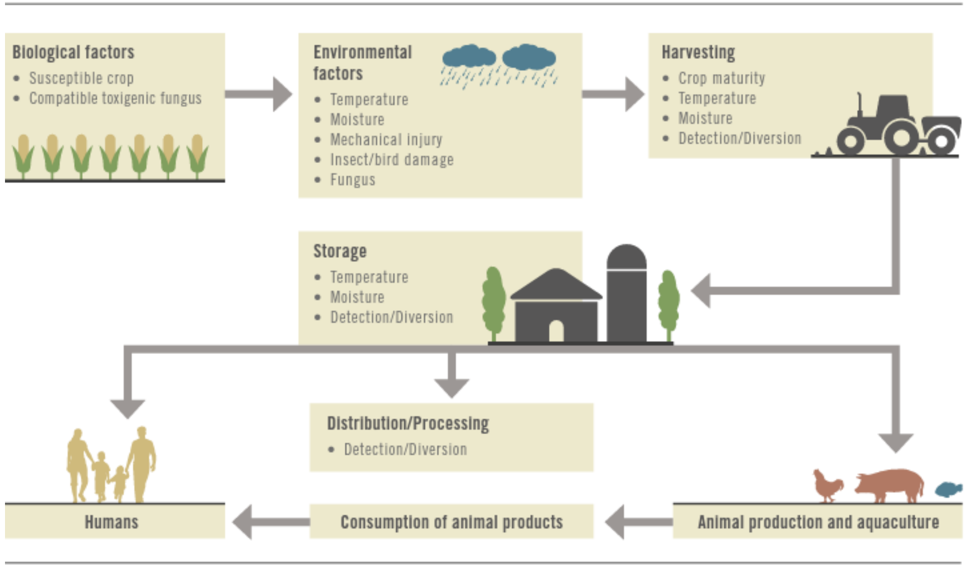


Increased bioaccumulation of **heavy metals** such as **mercury, arsenic, lead, chromium.**

- 140 million people in more than 50 countries drink water with levels of As contamination that are far higher than the WHO provisional guideline value of 10 µg/ L
- In the US (2010-2017), water systems contaminated with As, along with disinfection chemicals, significantly enhanced the risk of cancer, contributing to 87 % of the total number of estimated cancer cases.

FAO. 2020. Climate change: Unpacking the burden on food safety. Food safety and quality series No. 8. Rome. https://doi.org/10.4060/ca8185en

The effect of climate change on FBD (2)



Increases the risk for **fungal growth** and **mycotoxin formation**

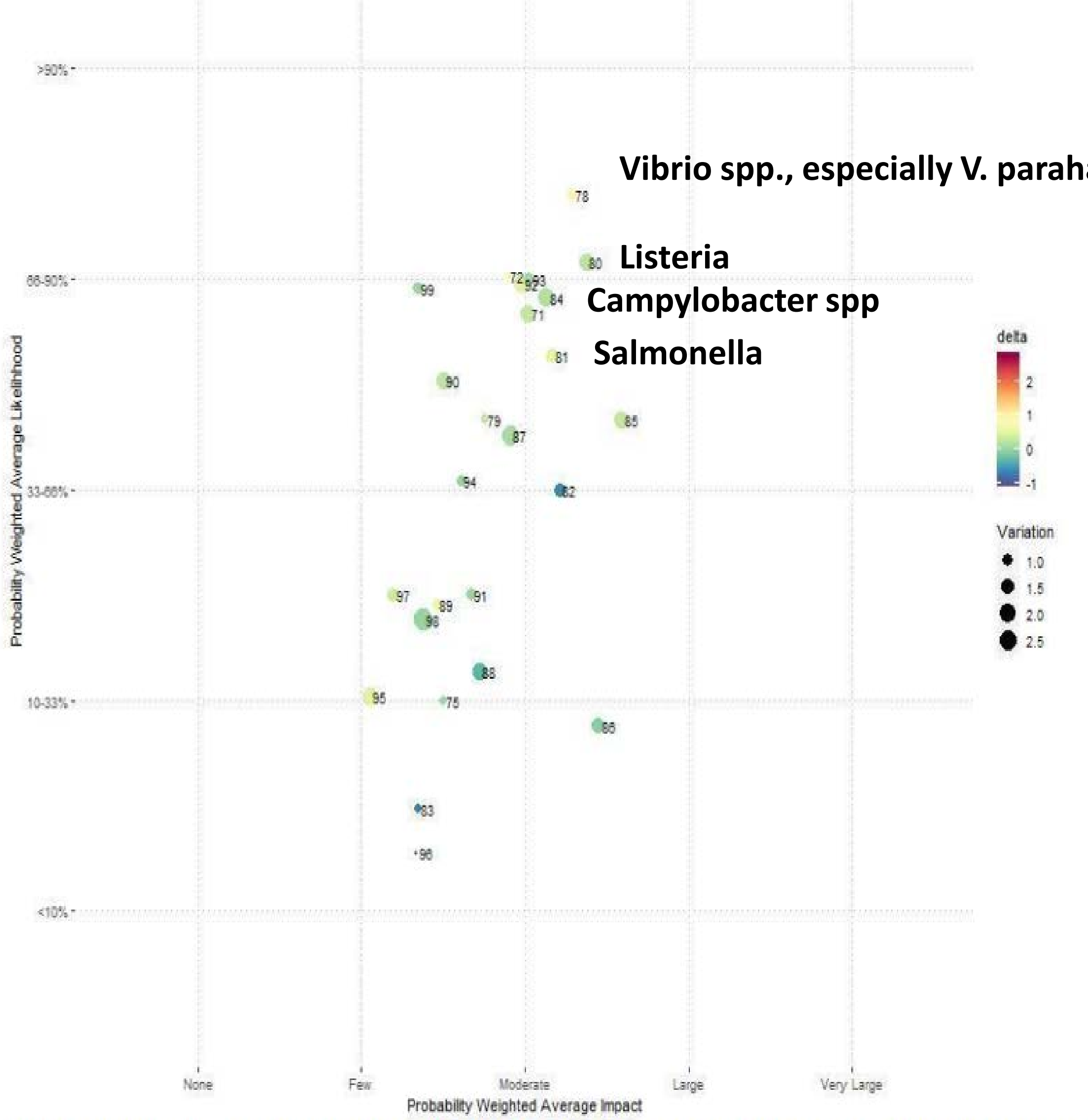
The major toxigenic species found in food and feed:
Aspergillus
Fusarium
Penicillium
Claviceps

Aflatoxins	55%	
Ochratoxin A	29%	
Fumonisins	61%	in cereal grains
Deoxynivalenol	58%	report 2006-2016
Zearalenone	46%	

- ❑ **Carcinogenic**
- ❑ Associated with the most global DALYs (636 869) due to liver cancer

FAO. 2020. Climate change: Unpacking the burden on food safety. Food safety and quality series No. 8. Rome. https://doi.org/10.4060/ca8185en

Future biological hazards to human health



Weighted average values for impact are plotted on the x-axis and those for likelihood on the y-axis. Colours of the circles correspond to delta values and their sizes to variance values.

- Between 2000 and 2014, the number of **cholera** cases during El Niño events increased by 50 000 in East Africa
- Peru: *Vibrio parahaemolyticus* was associated with the arrival of El Niño conditions
- Alaska, US: warmer water temperatures associated with the emergence of outbreaks of *V. parahaemolyticus*
- Species of *Vibrio spp*: tetrodotoxin, a potent neurotoxin, which can be found in shellfish
- Increase of 1 °C in the weekly ambient temperatures in resulted in a 5 to 10 percent increase in **salmonellosis** cases
- US: for every 1 unit increase in extreme temperature events there was an increase of 4.1 percent in risks; 5.6 percent increase in the **salmonellosis** risk was associated with a 1 unit increase in extreme precipitation events

EFSA. Maggiore A, Afonso A, Barrucci F, De Sanctis G, 2020. Climate change as a driver of emerging risks for food and feed safety, plant, animal health and nutritional quality

Water-borne diseases (WBD) influenced by climate change

Water-borne diseases (WBD) – definition

= *diseases that develop mainly in the digestive system of the human body and are mediated by water or water-related foods (such as fish and shellfish), fruits, and vegetables*

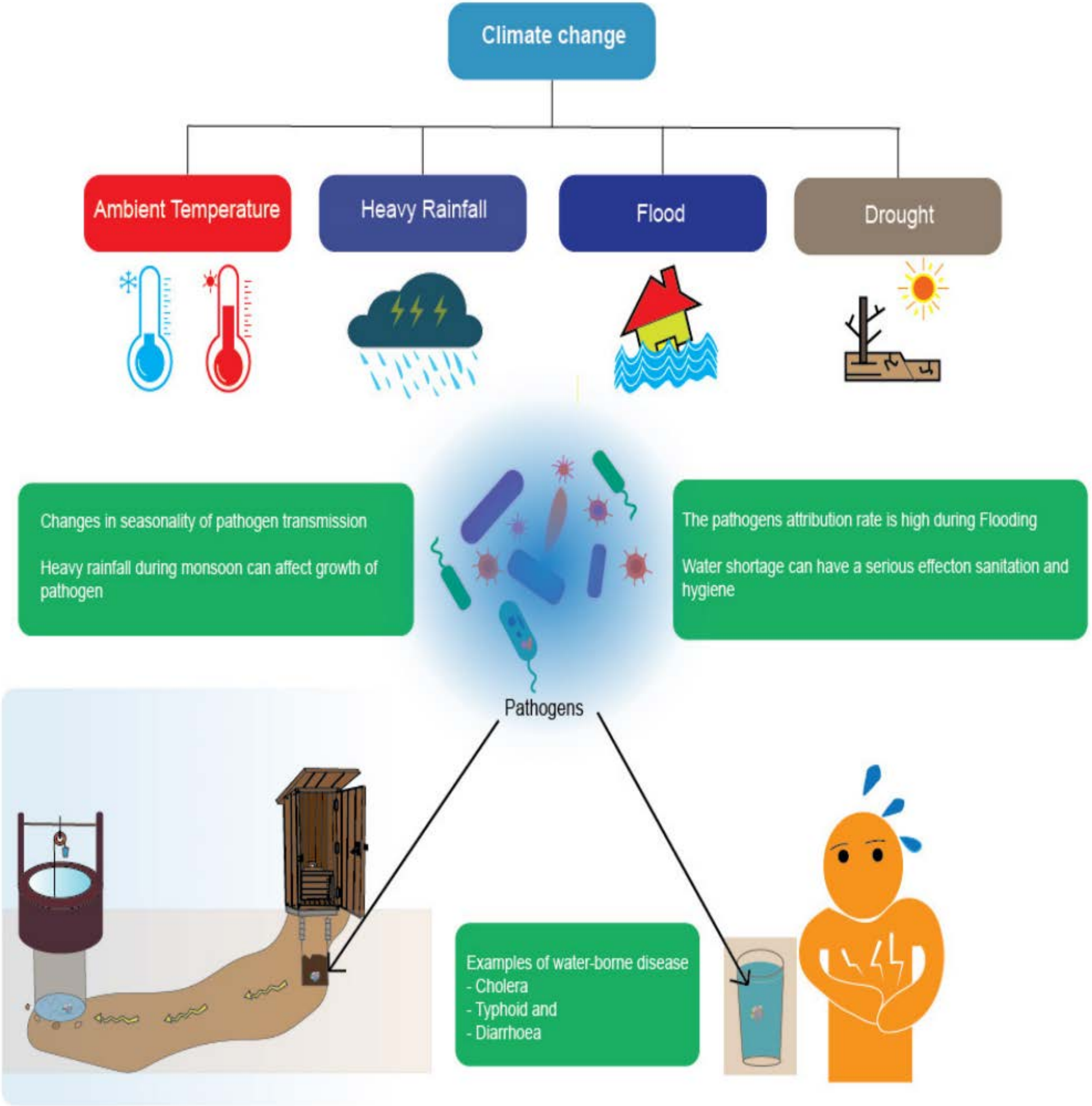
- Humans can be exposed by washing, bathing, and/or drinking contaminated water

- Ex: **cholera, salmonellosis, typhoid, hepatitis A and E, diarrhea, leptospirosis, giardiasis, shigellosis, amoebiasis, dracunculiasis, cryptosporidiosis, *Campylobacter* enteritis, and poliomyelitis**

Impacts of climate change on the occurrence of WBD

Vibrio cholerae = **the most common pathogen** linked to extreme climate change processes

The chance of developing ***Salmonella*** infections increases by **5–10%** with **every 1^{0}C increase in global temperature**



Jung Y-J, et al. Water, 2023

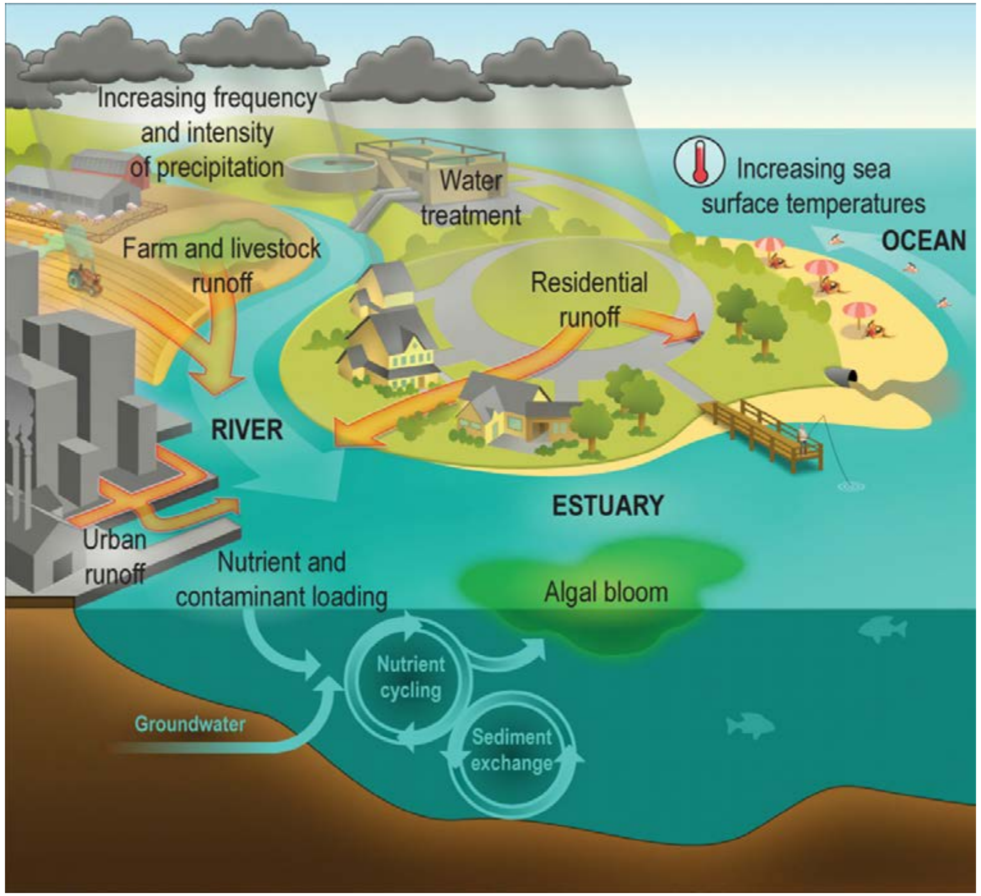
The effect of climate change on WBD

Direct impact

Extreme events
- Floods
- Sea-level rise
- Drought

Fecal-oral pathogens in the environment

Contamination of water



Indirect impact

Climatic factors:
- Temperature
- Humidity

Can alter pathogen survival, replication and virulence

Other issues
- Agriculture
- Water resource management
- Conflicts
- Displacement

The impact of climate change on diarrheal disease is projected to be **higher in Asia and Africa**

Cisse. Acta Tropica, 2019
Levy, et al. Curr Environ Health Rep, 2018
https://health2016.globalchange.gov/water-related-illness

Typical extreme climate events and common WBDs in the SE Asian countries (1999–2018)

Country	Extreme Climate Events	Common WBDs	Source of Drinking Water
Brunei	Floods, sea-level rise, heat waves	**Diarrhea**	Surface water (rivers) and tap water
Myanmar	Floods, cyclones, droughts	**Acute diarrhea**, **cholera**, dysentery, **typhoid**	Surface water (rivers and lakes), and groundwater (tube and dug wells)
Cambodia	Floods, droughts, typhoons	**Diarrhea**, **typhoid**	Surface water (rivers), and groundwater (hand-dug wells)
Indonesia	Tropical cyclones, floods, droughts, tsunamis	**Diarrhea**, **cholera**, **typhoid**, leptospirosis	Surface water (rivers) and groundwater
Laos	Floods and droughts	**Diarrhea**, **cholera**	Surface water (rivers; the Mekong) and groundwater
Malaysia	Floods, rainfall-induced landslides, and droughts	**Cholera**, **typhoid**	Surface water (rivers), tap water, spring water, and groundwater
Philippines	Typhoons, ambient temperatures, heat waves, floods	**Cholera**, **acute bloody diarrhea**, **typhoid**	Surface water (rivers, lakes, and river basins) and groundwater reservoir
Thailand	Sea-level rise, floods, droughts	**Cholera**, **typhoid**, paratyphoid	Groundwater and surface water (river basins)
Vietnam	Sea-level rise, floods, droughts	**Cholera**, dysentery, **typhoid**, **diarrhea**	Surface water (rivers; the Red and Mekong rivers) and groundwater

Jung Y-J, et al. Water, 2023

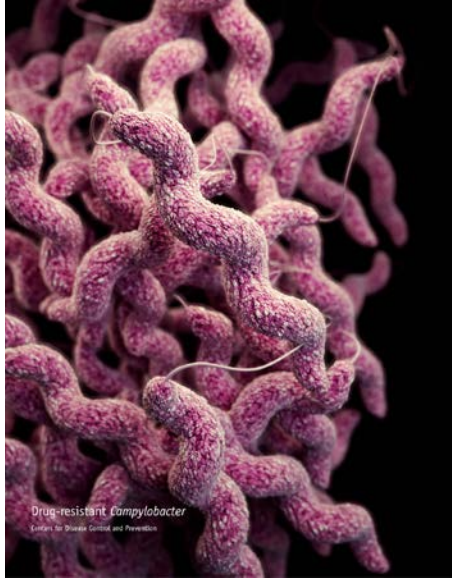
Outbreaks in high-income countries

- **US**
  - ➢ WBD outbreaks have been increasingly reported during the past 10 years – **primarily** associated with an increasing number of reported ***Legionella* outbreaks**
  - ➢ Outbreaks caused by **parasites**: *Giardia duodenalis*, *Cryptosporidium*

- **Switzerland**
  - ➢ *Salmonella*
  - ➢ *Listeria*
  - ➢ *Norovirus*
  - ➢ *Campylobacter*

Beer, et al. CDC, 2015
FOPH, 2022

Campylobacter infections to increase due to climate change in Northern Europe



- *Campylobacter* incidence is linked to increases in **temperature** and especially **precipitation in the week before** illness, suggesting a non-food transmission route

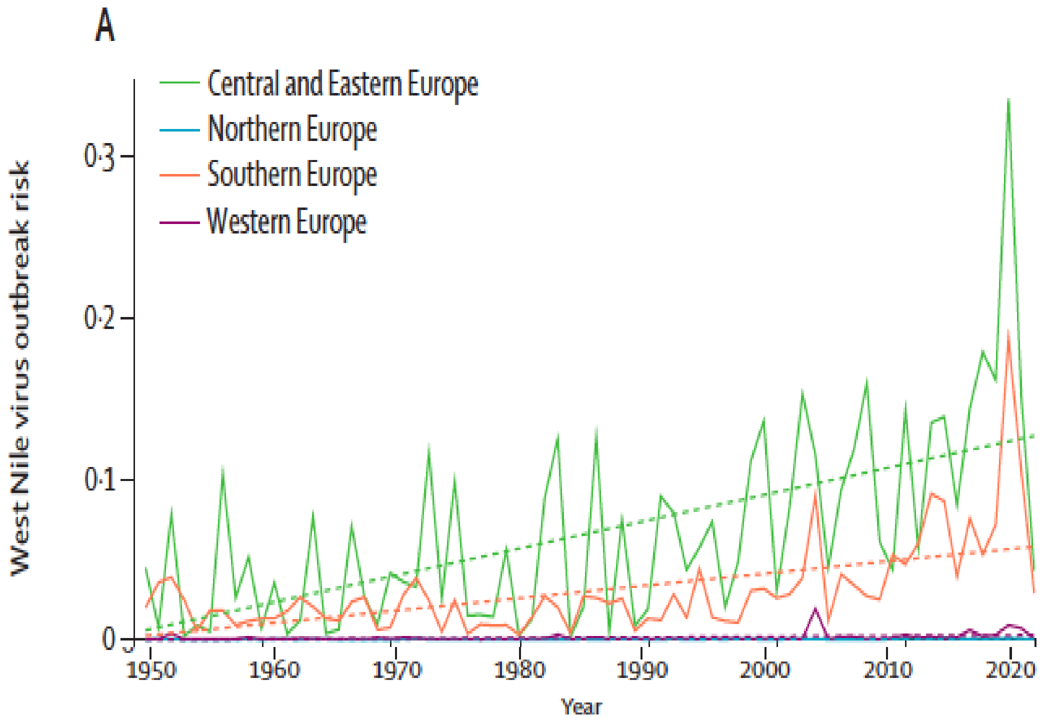
- Scandinavia may experience a **doubling** of *Campylobacter* cases by the end of the 2080s, corresponding to around **6,000 excess cases per year caused only by climate change**

Kuhn KG, et al. Scientific Reports, 2020

Vector-borne diseases (WBD) influenced by climate change

Vector-borne diseases influenced by climate change
West Nile Virus

West Nile outbreak risk



van Daalen KR et al. Lancet 2022

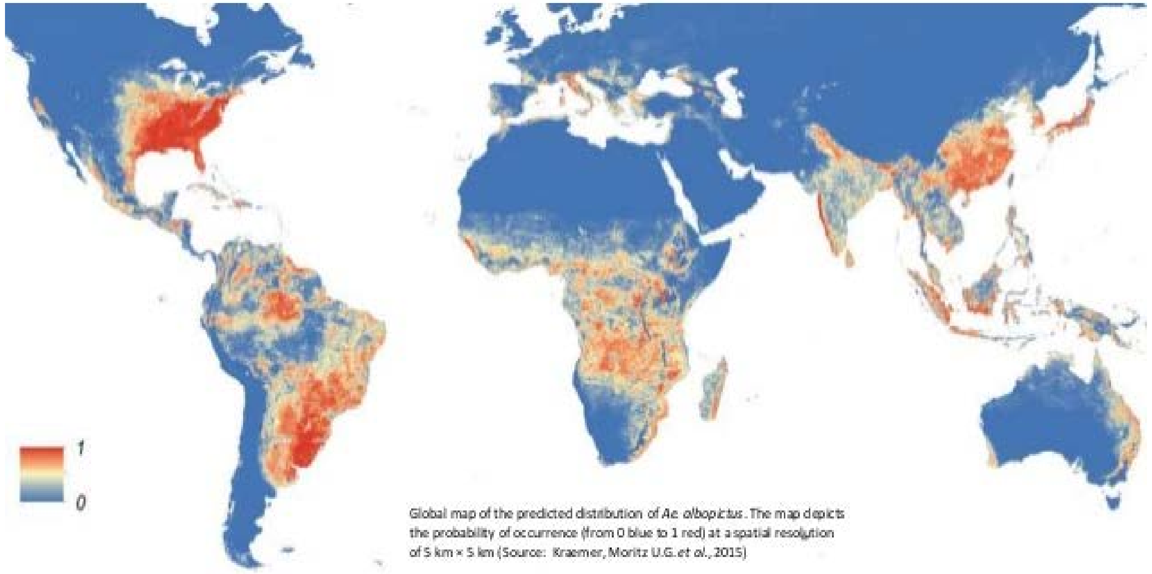
West Nile Virus in Europe

- ↑ ambient temperature = ↑ vectorial capacity of the *Culex* mosquito vector, and thus ↑ outbreak probability.
- European countries have had a large ↑ in the intensity, frequency, and geographical expansion of WNV outbreaks.
- 2018 outbreak has been the largest yet (11 European, 1584 locally acquired infections)

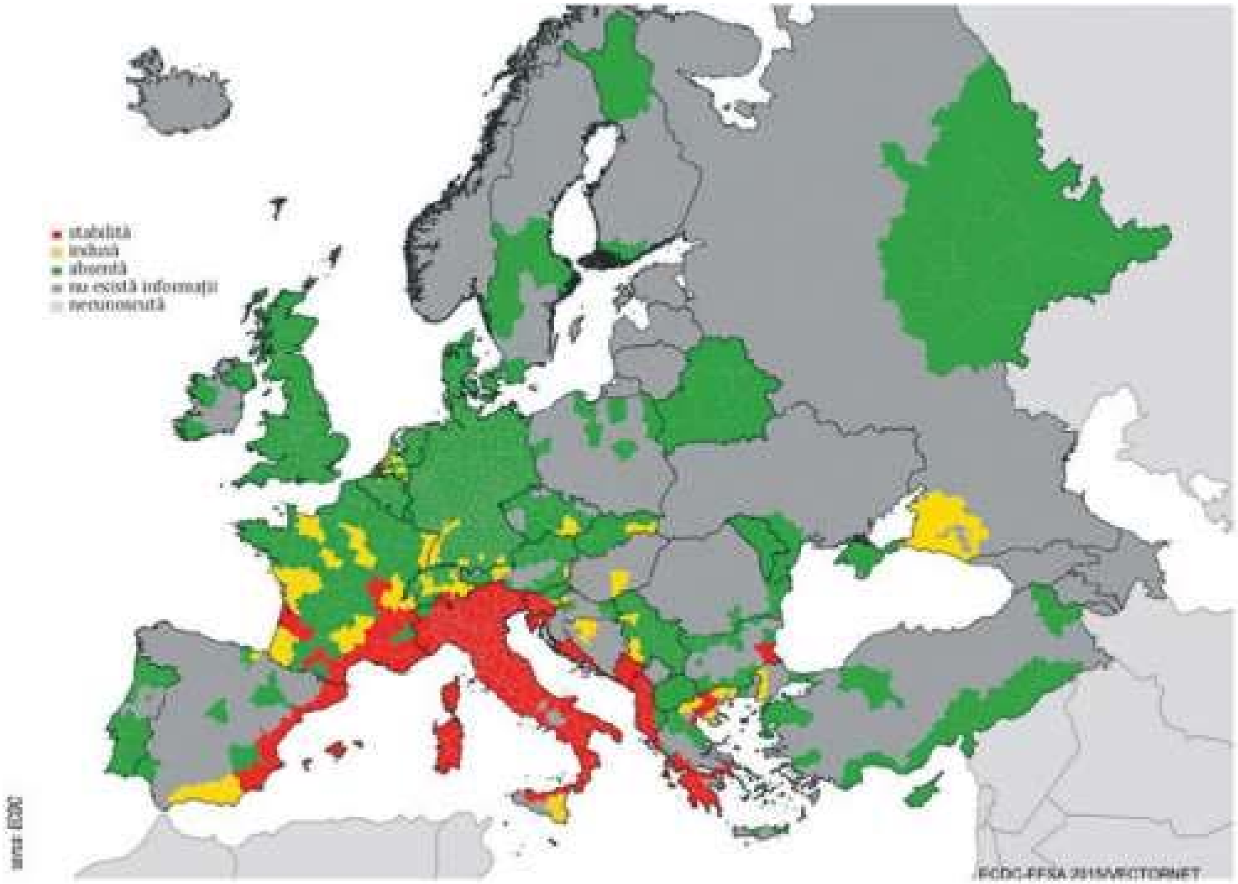
Aedes albopictus a global challenge: the most invasive mosquito species

Aedes albopictus – a global challenge

- *A. albopictus* can be currently found in temperate and tropical Asia, most of Pacific Ocean islands, Africa, Northern and Latin America and southern Europe. It is now considered to be the most invasive mosquito species.



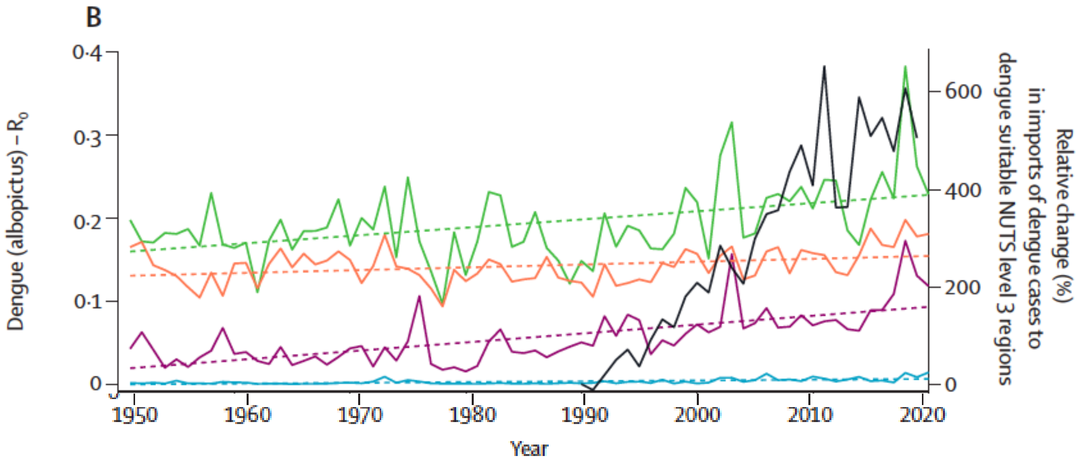
Global map of the predicted distribution of *Ae. albopictus*. The map depicts the probability of occurrence (from 0 blue to 1 red) at a spatial resolution of 5 km × 5 km (Source: Kraemer, Moritz U.G. *et al.*, 2015)



Vector-borne diseases influenced by climate change

Dengue Virus

Dengue outbreak risk

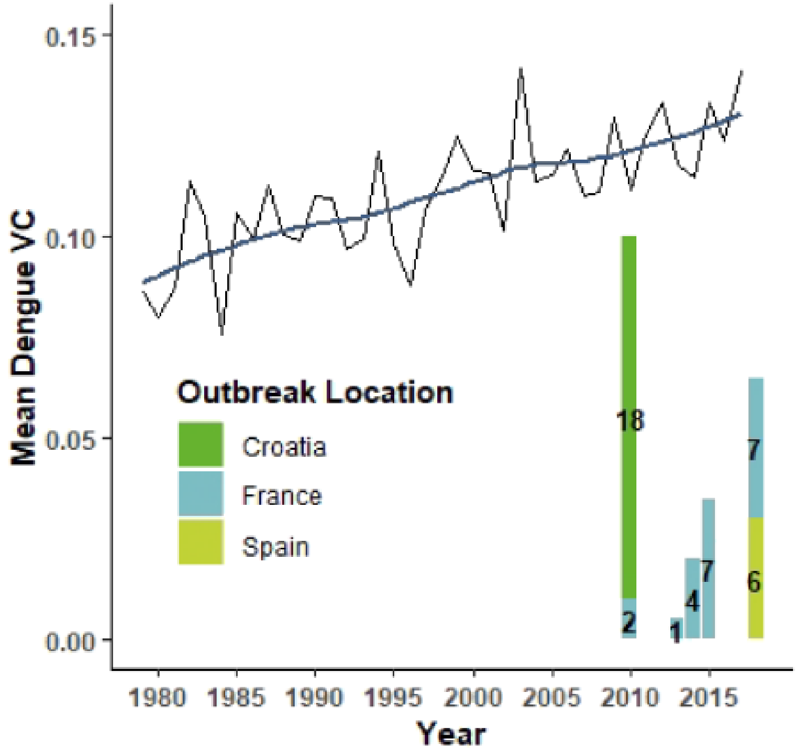


The basic reproduction rate ($R0$) and length of transmission season for dengue combining information on temperature, rainfall, mosquito abundance, and human population density.

In the period 1986–2020, ($R0$) has increased by 17·3% in Europe compared with 1951–1985

van Daalen KR et al. Lancet 2022

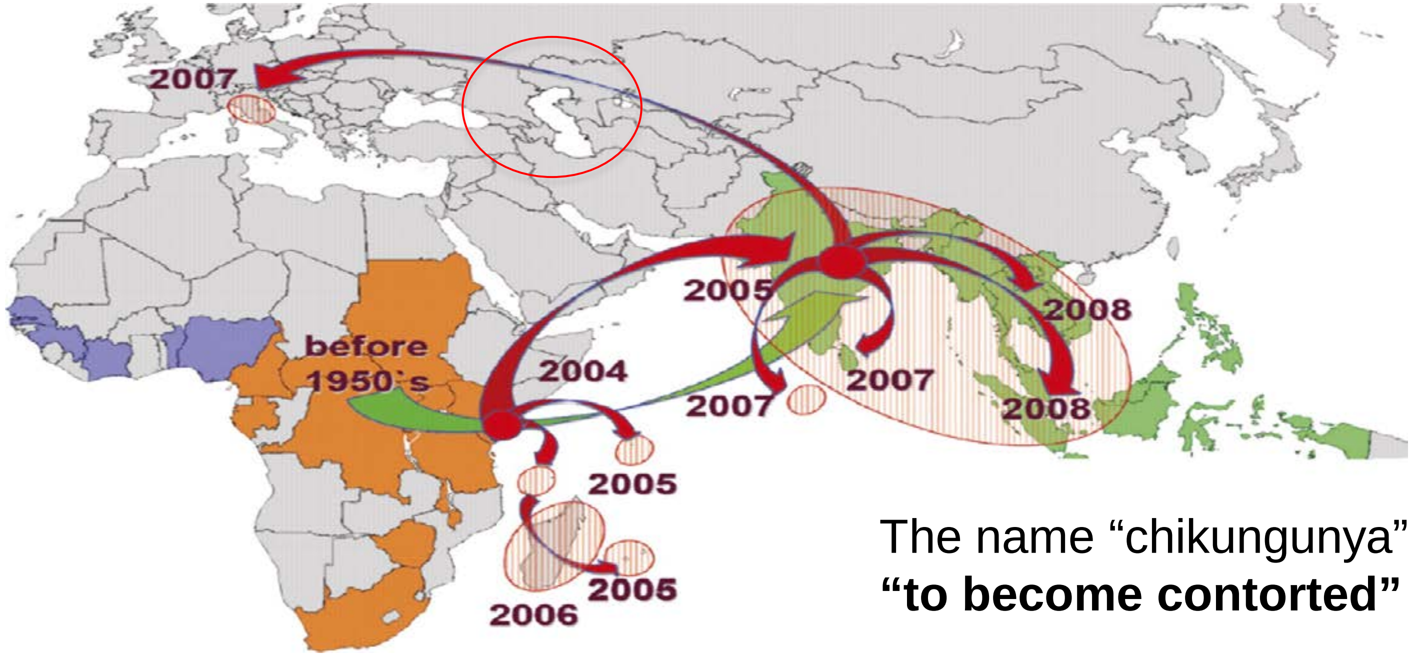
Vectorial capacity (VC) of *Aedes albopictus* from 1979-2018 for the European regions that have experienced local autochthonous transmission of dengue

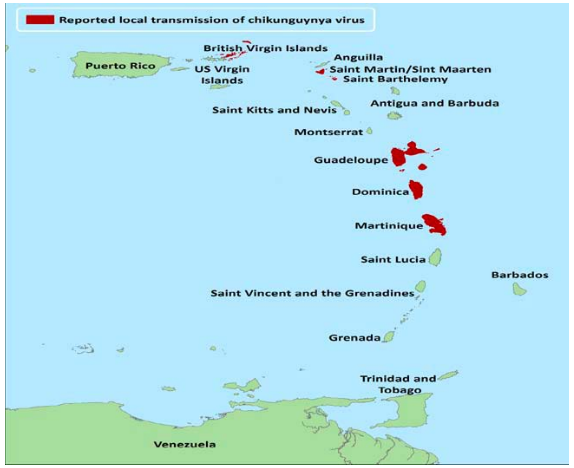


Lillepold K et al. J Trav Med 2019

Vector-borne diseases influenced by climate change

Chikungunya Virus (CHIKV)

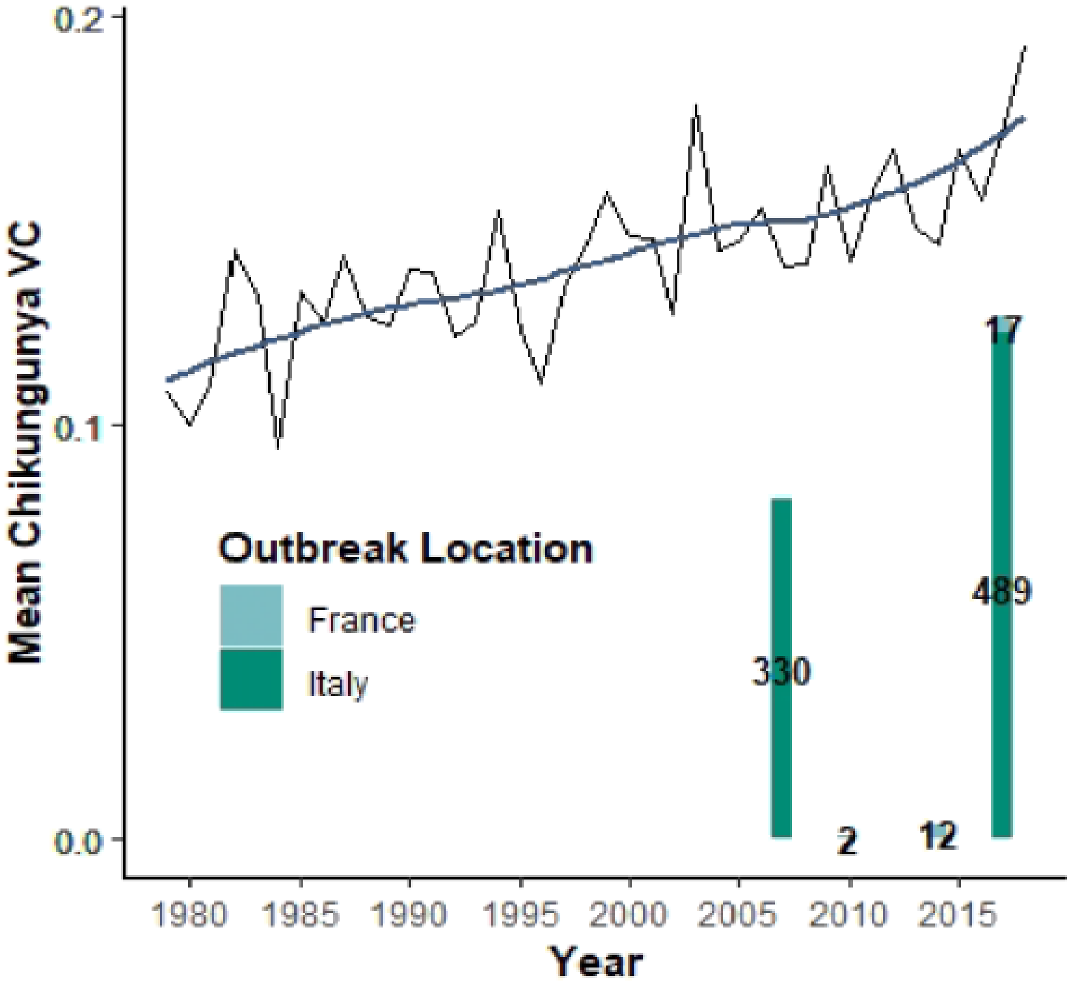




The name “chikungunya” means
“to become contorted”

- First isolated in Tanzania 1952-1953
- Often occurs in large outbreaks with high attack rates
- CHIKV has been a significant public health concern in **Asian and African countries, where most epidemics occurred in the 1960s and 1990s**

Vector-borne diseases influenced by climate change Chikungunya Virus (2)



Lillepold K et al. J Trav Med 2019

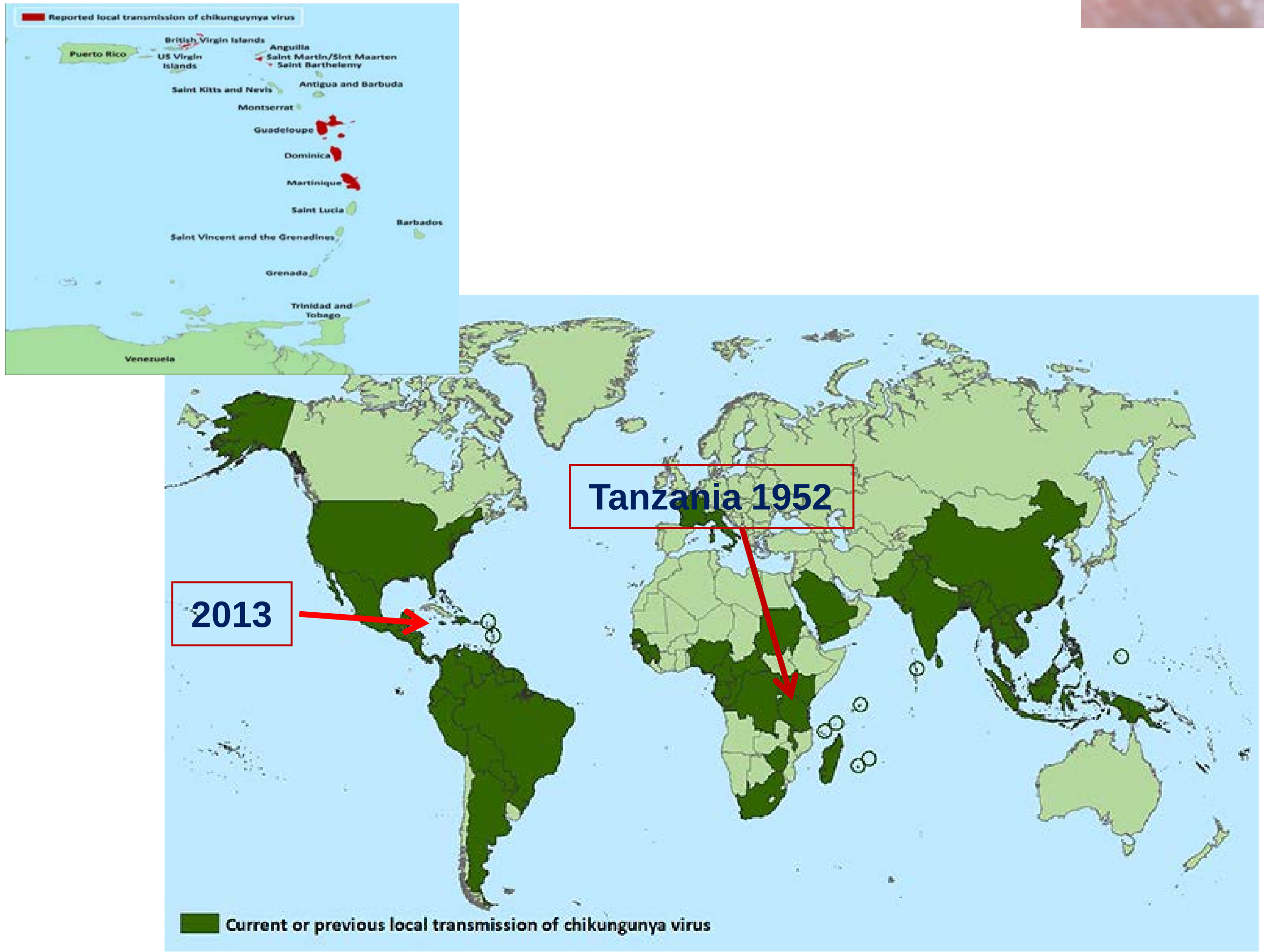
Risk of Chikungunya spreading in EU is high due to travel importation

Rezza G J Trav Med, 2018

Chikungunya virus infection spread in Americas

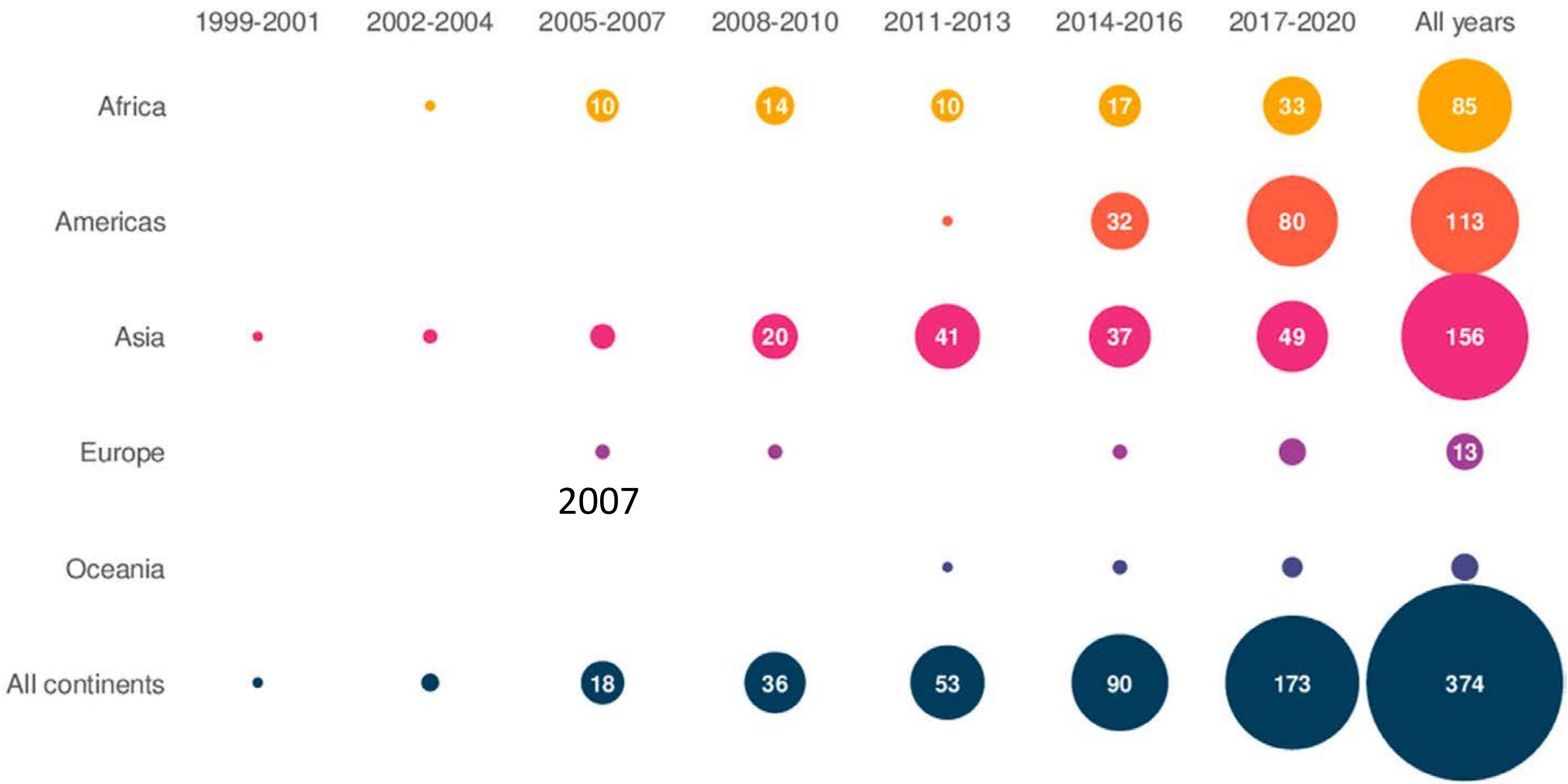
- In 2013, **first locally-acquired cases in the Americas** reported on islands in the Caribbean

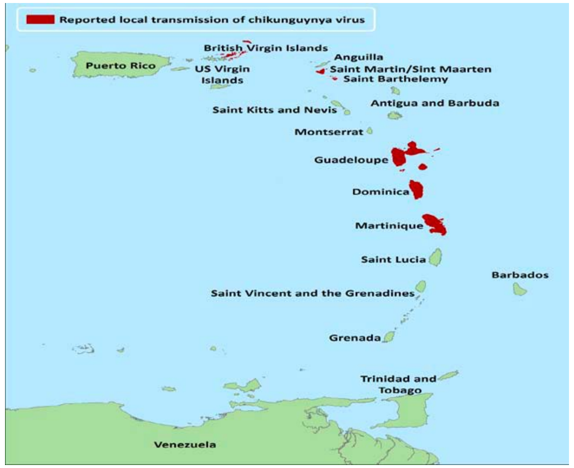
- February 2014:
  - seven Caribbean countries have reported locally-acquired cases
  - >1,000 laboratory-confirmed cases have been reported



Chikungunya fact sheet – CDC, WHO 2016

The global epidemiology of chikungunya from 1999 to 2020: A systematic literature review to inform the development and introduction of vaccines





Chikungunya Virus (CHIKV) is newly emerging in Middle East, Pacific, American, and European countries

Bettis AA, et al. et al. (2022) The global epidemiology of chikungunya from 1999 to 2020: A systematic literature review to inform the development and introduction of vaccines. PLoS Negl Trop Dis 16(1): e0010069. https://doi.org/10.1371/journal.pntd.0010069

Constant surveillance is imperative in Europe!

All the pre-requisites for autochthonous transmission of both **Dengue** virus and **Chikungunya** virus:

- vectors (*A. albopictus*),
- climatic conditions (present in Europe),
- **viremic returned travellers,**

D. Tomasello, P. Schlagenhauf Travel Medicine and Infectious Disease 2013

Conclusions

- By 2080 Scandinavia may experience 6000 excess cases of *Campylobacter* per year caused only by climate change
- A climatic event can trigger cascading risk pathways of causality connected vulnerabilities and result in large-scale waterborne outbreaks
- Western Europe could be facing large outbreaks of WNV irrespective of the future degree of climate change

Conclusions

- Early warning systems can trigger action and response to infectious diseases threat events, thereby reducing the burden of disease

- The use of big data for public health purposes can generate a paradigm shift, toward **active, targeted strategies to predict and prevent epidemics** before they start

- Improvements in public health capacities can help reduce the incidence of cross-border infectious disease threat events