Impact of Climate Change on Infectious Diseases

STEVEN VAN DEN BROUCKE
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!
- Countries with poorest response capacity -- > biggest victims
The Imperative for Climate Action to Protect Health

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

The 2021 report of the Lancet Countdown on health and climate change: code red for a healthy future

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
- 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
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.11
Vector-borne diseases

- Pathogen
- Vector
- Environment
- Host
- Susceptible population
Impact Climate Change on Infectious Diseases

Poorest counties weakest response capacity
Temperature

Pathogen
- **Extrinsic incubation period malaria** ↓ : 26 days at 20 °C, 13 days at 25 °C
- Salmonella: reproduction rises with temperature (water)
- 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)
Infectedive life of a vector

for *P.falciparum* at 25°C

Sporogonic cycle of 12 days → Infective bites

- Emergence:
  - B: Blood meal
  - E: Punte

Gonotrophic cycle: 2 days

- B: Infective blood meal
Weather-driven malaria transmission model with gonotrophic and sporogonic cycles

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

Survival mosquitoes Sporogonic cycle

Gonotropcic 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.

Infective life of a vector

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Cold

Warm

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Survival mosquitoes  Sporogonic cycle

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Malaria in Europe

Clinical Microbiology and Infection
Volume 22, Issue 6, June 2016, Pages 487-493

Review

Malaria in Europe: emerging threat or minor nuisance?

E.T. Piperaki 1, G.L. Daikos 2

Show more

https://doi.org/10.1016/j.cmi.2016.04.023

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Anopheles in Europe today

Fig. 1. Geographical distribution of three important malaria vectors: *Anopheles* atroparvus (red), *An. labranchiae* (green) and *An. sacharovi* (purple). Adapted from Kuhn et al. [21].
Dissapearance of malaria?

- End 19th century: °T drop
- Swamps eliminated
- Cattle in separated cowsheds
- ‘Kininistation’
- DDT

Remember: Europe has ‘eradicated’ malaria in the past! So very unlikely it will return
Outbreak in Greece 2011

- 1974: malaria eradicated
- Sporadic reports autochthonous transmission
- 2009: locally acquired *P. vivax* malaria consistently every year
- 2011: 42 cases
- Migrant workers from Pakistan and Afghanistan: orange harvesting in a region where *Anopheles sacharovi* was present
If pinguins in the Antwerp Zoo stay outside, should they take malaria prophylaxis?
Total number of Plasmodium species?

- 172

- Birds, reptiles, mammals (apes, antelopes, ...)

- Avian malaria is transmitted by the Culex mosquitoes

→ Penguins in open air should take malaria prophylaxis

CAVE: ANTHROPOCENTRIC POINT OF VIEW!
Temperature

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

— A photo of a Korean man’s hand after he was infected with Vibrio vulnificus. New England Journal of Medicine
Temperature

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### Algal bloom
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Cave: Anthropocentric Point of View!
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Ticks

**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**

*Publication bias; to prove the absence of something = hard ++*
Reforestation in Europe, 1950 – 2002: +2%

CO2 stimulates vegetation!!!
Pathogens transmitted by ticks

- **Hard 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

- **Soft ticks**
  - TBRL: Tick Born Relapsing Fever (B. duttonii, hermsii, ...) = soft tick
Tick surveillance
Temperature

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Oncomelania hupensis
Schistosomiasis
Schistosomiasis, periportal fibrosis
Schistosomiasis, hematuria
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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
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 $R_0 > 0$ 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

(A) Prior to 1981

(B) 1981-2011

Adapted from Gubler, 1998
Prediction 2050: 65% world population in cities = 5 billion people!
Dengue drivers

Major Drivers of the increased Incidence and Geographic Spread of Dengue

- Lack of effective mosquito control
- Changing life styles
- Unplanned urbanization
- Globalization
Main conclusions and options for response

Main conclusions

In early October, nine cases of autochthonous dengue were confirmed in the EU, three in Spain and six in France, in three separate outbreaks. These are the first autochthonous dengue cases in continental EU/EEA Member States that were reported this year [1]. Prior to these cases, no autochthonous dengue cases had been reported in continental EU/EEA Member States since 2017. Epidemiological investigations are ongoing.

There is no epidemiological link between the two outbreaks in France (five cases in Saint Laurent du Var, one case in Montpellier), and it is uncertain whether the cases in Spain were infected in the region of Murcia or in the Province of Cádiz. The virus was likely to have been introduced into these areas through viraemic travellers returning from endemic areas.

Sporadic autochthonous cases, or small clusters, of dengue fever occasionally occur in Europe after the introduction of Dengue virus (DENV) by viraemic travellers into areas where *Aedes albopictus* mosquitoes have become established and during the season when *Ae. albopictus* are active, and temperatures are favourable. Locally acquired dengue cases were documented in southern France in 2010, 2013, 2014 and 2015. In Spain, this is the first recorded cluster of locally acquired dengue cases, which was not unexpected since *Ae. albopictus* has been present in the country since 2004.

Detection of further cases in the affected regions and elsewhere is possible. *Ae. albopictus* is normally active in the area of Saint Laurent du Var until the beginning of November, while in Montpellier the active period for *Ae. albopictus* can even last until early December, as reported for December 2014. The prolonged active period was possibly related to flooding in the area.

*Ae. albopictus* is active in several provinces in Spain. In previous seasons, *Ae. albopictus* was found to be active until the beginning of December [2-5]. It may, to a limited extent, also be active during winter, but this activity is unlikely to be sufficient to sustain transmission.

The risk that visitors to the affected areas may become infected and introduce the virus to their country of residence cannot be excluded [6]. However, historically, dengue outbreaks in Europe have had a maximum of seven reported autochthonous cases and always occurred during the season of high vector activity. Therefore, the likelihood of onward local transmission and of introduction of the virus from France and Spain into other receptive areas in the EU/EEA with subsequent sustained local transmission is very low.
Zika

Pathogens don’t read textbooks!!!
Precipitation

- Fecal pathogens ↑
- But... water scarcity also ↑ diarrhea rates in < 5y: reduced hygiene
- Flooding: *hantavirus* ↑, *leptospirosis* ↑
- After heavy rains --> Rift-Valley Fever epidemics
Leptospirosis

Fayne et al 1999
Vrees voor massale besmetting rattenziekte na Titan Run

03/10/2015 om 08:15 door werner rommers

 +/- 2500 participants
9 seroconversions
3 symptomatic
1 intensive care
Rift Valley

Syria → Mozambique
Rift Valley fever
Drought

↑ Concentration of water-borne pathogens (Salmonella,...)

Rotten organic material accumulate in pools: *Culex* ↑ -- > West-Nile Virus ↑

Humidity
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.

<table>
<thead>
<tr>
<th>Extreme weather events</th>
<th>Disease type</th>
<th>Authors, year</th>
<th>Main findings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Outbreaks and epidemics of malaria were positively connected with El Nino events in many regions.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Riedel et al. (2000)</td>
<td>Strikingly less malaria were found in the El Nino year than in the preceding year in the Usambara Mountains, Tanzania.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dushay et al. (2000)</td>
<td>Record of hantavirus cardiopulmonary syndrome has been found to be related to El Nino events in the Colorado Plateau.</td>
</tr>
<tr>
<td>La Nina</td>
<td>Vector-borne disease</td>
<td>Shultz et al. (2003)</td>
<td>The risk of symptoms associated with diarrhea is twice the previous when exposed to southern California coastal waters during an El Nino winter.</td>
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<td>Fumonoura fever epidemic was connected with the drought incurred by La Nina.</td>
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<td>Vector-borne disease</td>
<td>Epstein (1999)</td>
<td>There was an outbreak of West Nile fever in Israel in 2000.</td>
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<tr>
<td>Heatwaves</td>
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**Note:** TIME CORRELATION ≠ CAUSALITY!
Predictions from the past

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<th>Disease</th>
<th>Populations at Risk, Millions†</th>
<th>Prevalence of Infection, Millions‡</th>
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<td>Leishmaniasis</td>
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*Data from World Health Organization.†
†Based on world population estimated at 4.8 billion (1989).
‡Ellipses indicate no estimates available.
Prediction

change scenarios, 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.
Prediction from the past were ALL correct!!

... but for some in the opposite direction!

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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. This is a conser-
Cavé : Bias in Media

De tropen in Europa: de verraderlijke streken van

Virusen, veermuizen, tijgermuggen en reuzentekens

Als we niet snel en kan ook bij ons een accuraat ingrijpen, epidemië uitbreken
Complex
Stop Climate Change now cause we will all die of infectious diseases!!!!
Stop climate Change now but be aware that it is a Complex Multifactorial matter, that the human response to predictions is a priori unpredictable but that the countries with the poorest response capacity will be the biggest victims. That micro-organisms don’t always behave as we think they will. That further study and good surveillance is needed and that we should observe, prevent and react but not panic!
Thanks