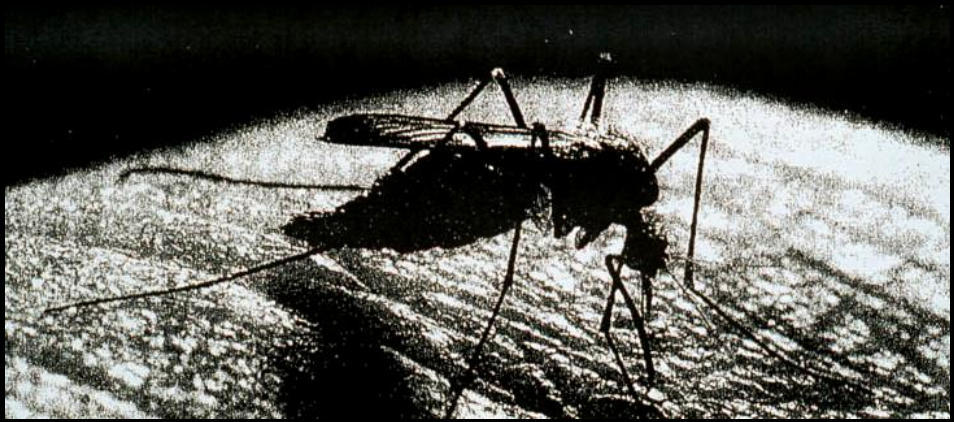
Impact of climate change on vector-borne diseases



Climate change and Infectious Diseases
CHE webinar, 05 Dec 2019

Dr Cyril Caminade
Institute of Infection and Global Health, University of Liverpool
Cyril.Caminade@liverpool.ac.uk

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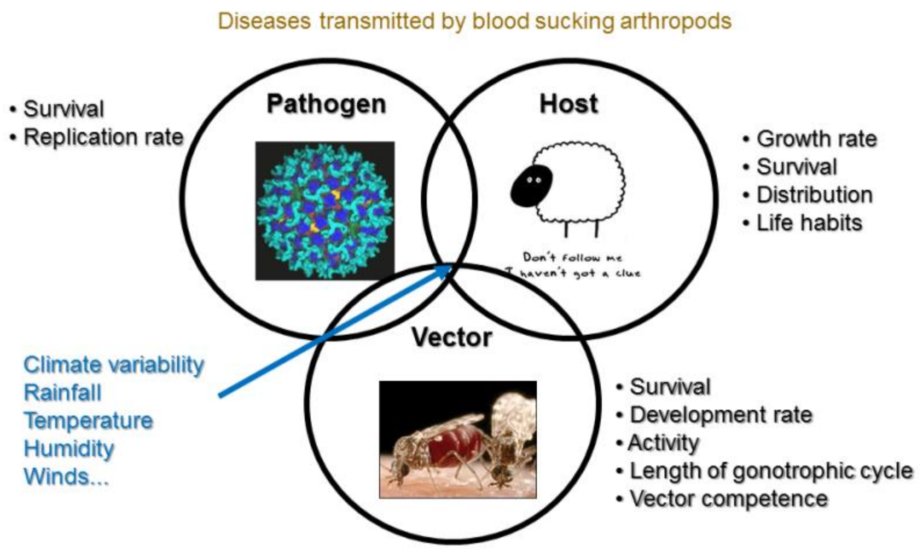
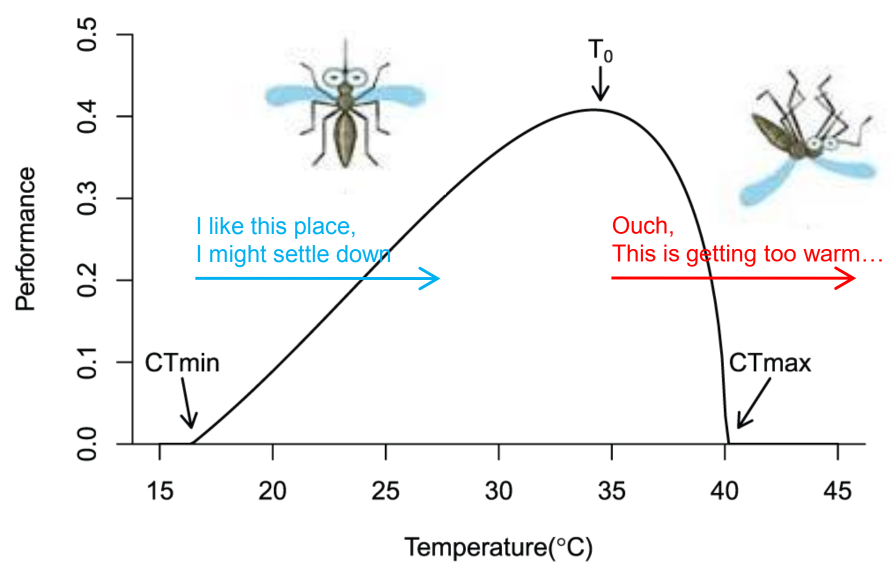
Climate change impacts on VBDs

VBDs are climate sensitive



Vectorial capacity = f(Tº)



Lafferty KD and Mordecai EA 2016 - F1000Research 2016, 5:2040

Modelling the impact of climate variability on VBD burden, development of early warning systems (seasonal to climate change time scales).

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Temperature effect on vector biting rates (b)

Scott et al., 2000, J Med Entomol 37(1):89–101

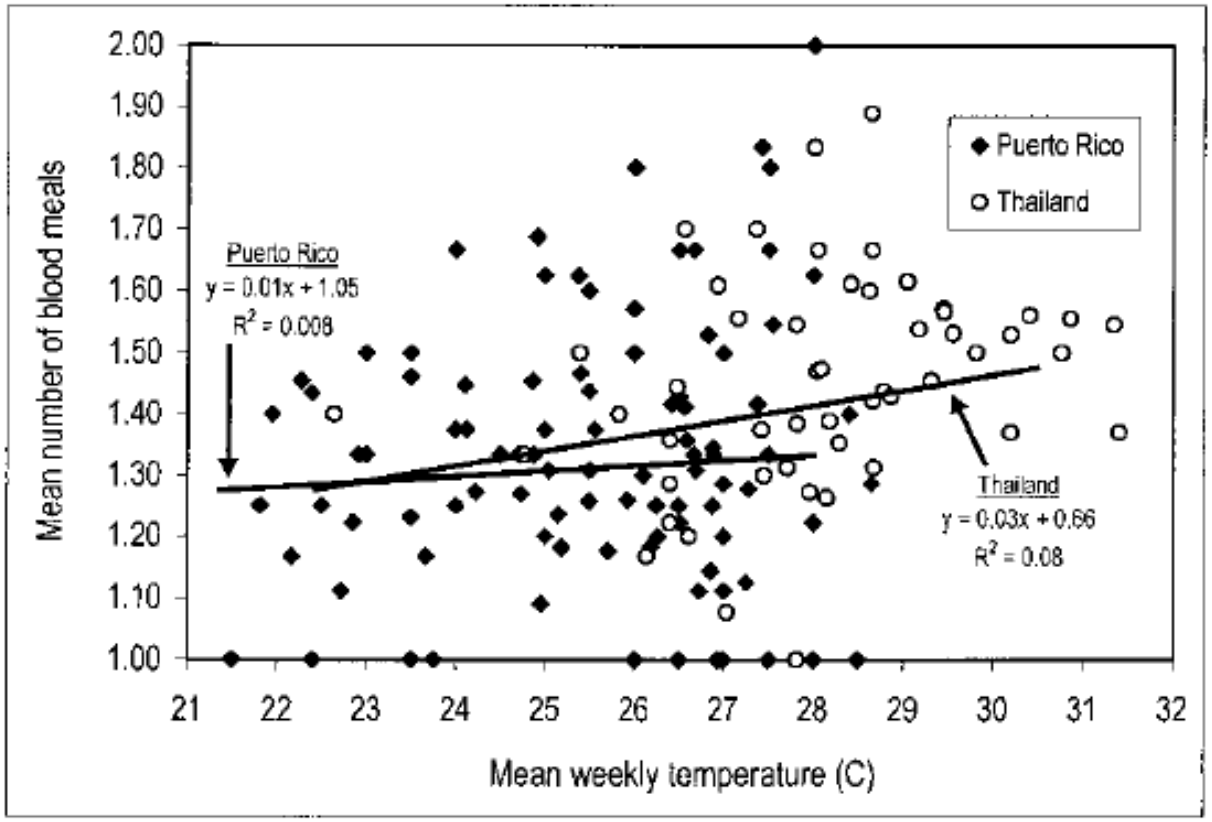

Fig. 5. Relationship between temperature and blood-feeding frequency of female *Ae. aegypti* collected weekly in Thailand (1990–1992) and Puerto Rico (1991–1993). Linear regression lines and equations for each site are included.

Biting rates:

Number of mosquito bites per day per host.

When temperature increases, biting rate increases.

Left:
Biting rates of Ae. aegypti, the yellow fever mosquito; it can transmit dengue, Zika & yellow fever viruses.

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Temperature effect on vector development & mortality (μ)

Brady et al., 2013, Parasite and Vectors 6:351

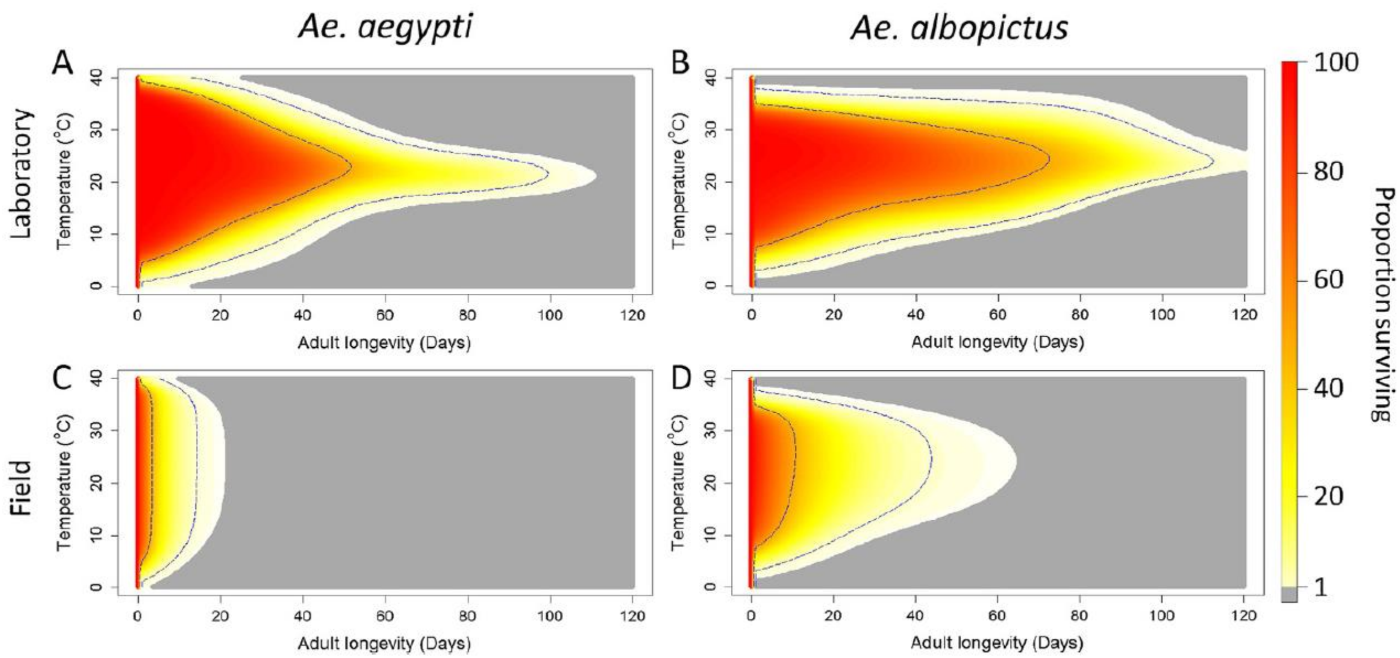


Figure 4 The distribution of adult female *Aedes aegypti* and *Aedes albopictus* survival across a range of temperatures under laboratory conditions (A and B) and field conditions (C and D). Colours from red to yellow show survival from 100% - 1% of the population remaining. Grey indicates <1% of the population remaining. Dotted blue lines show the limits for 50% and 95% of the original population remaining.

Ae. aegypti, the yellow fever mosquito

Ae. albopictus, the Asian tiger mosquito

Development rate and mortality:

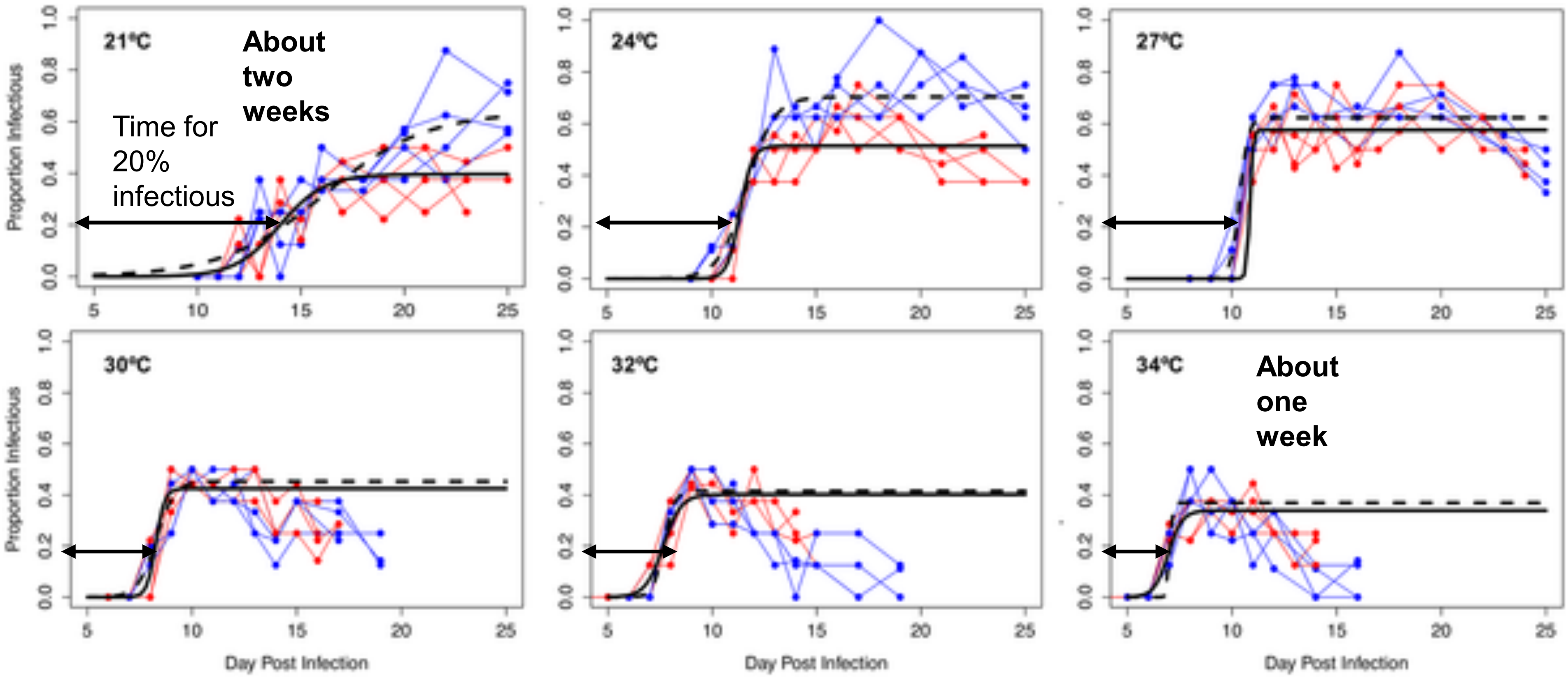
Mosquitoes develop faster at high temperature - if temperature exceeds about 35-37°C mortality tends to increase. Eggs can overwinter &/or resist desiccation.

Water is needed for breeding sites.

Significant differences between the lab and the field!

Temperatures effect on Extrinsic Incubation Period (**EIP**)

Shapiro et al., 2017, Plos Biology 15(10)



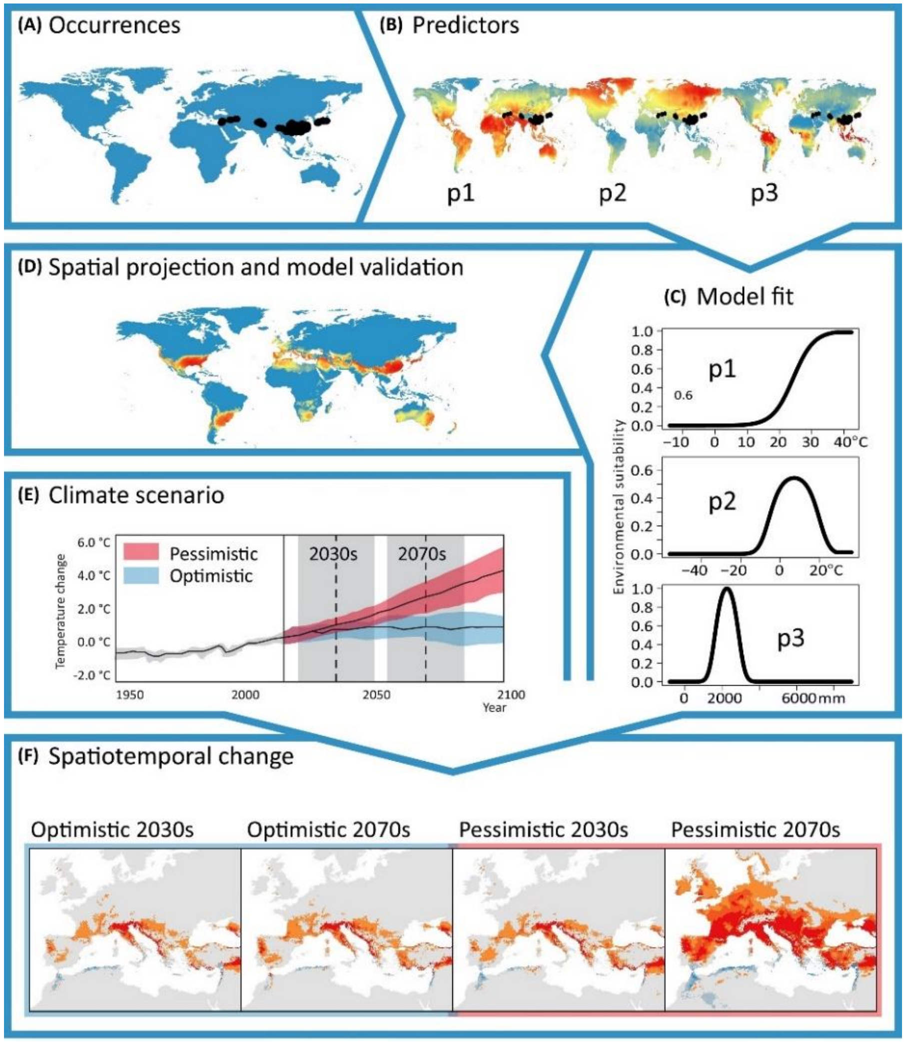
The Extrinsic Incubation Period (EIP) - example for *P. falciparum* and *An. gambiae*: time required for the pathogen to develop inside the mosquito vector before it becomes infectious (when the pathogen is detected in their salivary glands).

When temperature increases, the EIP decreases e.g. it shortens.

If the temperature is too low, mosquito dies before the pathogen can replicate in their body e.g. before becoming infectious (about 30days life span in the field).

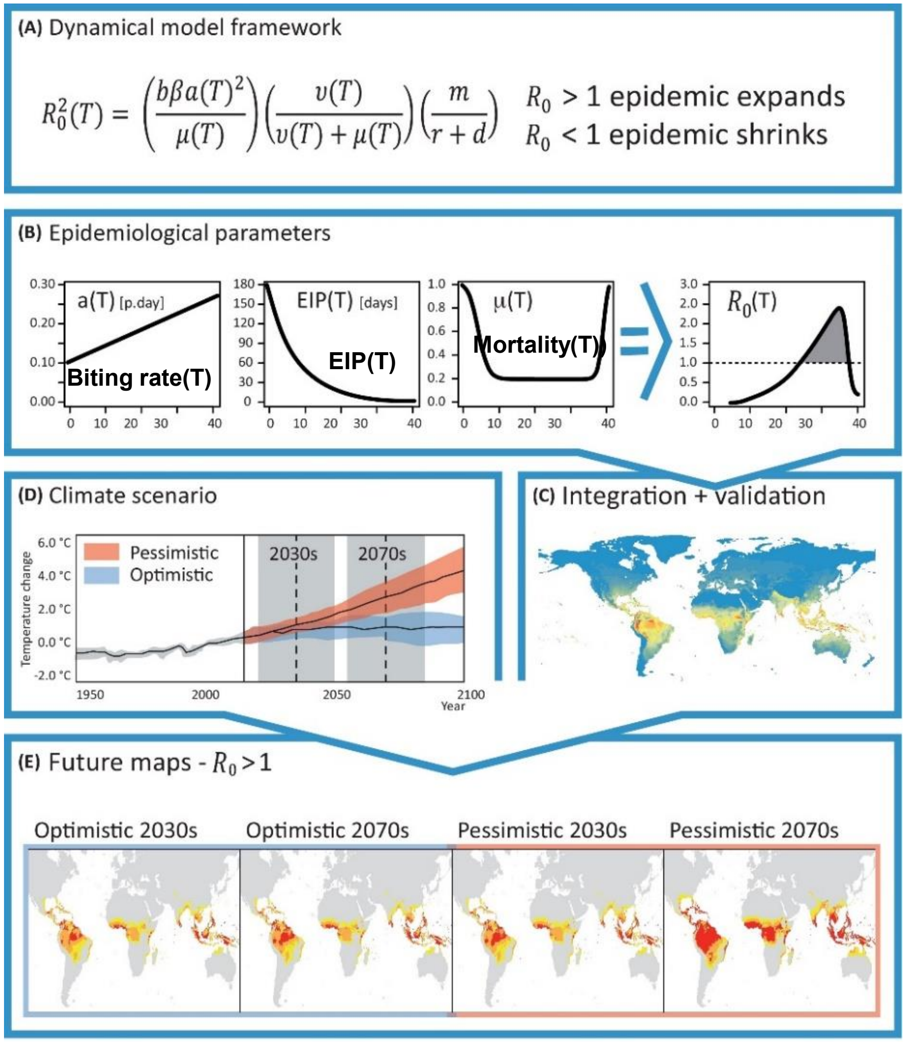
Methods to model the impact of climate on VBDs

Statistical models



Stat models: Maxent, BRTs, Bayesian models, Mahalanobis distance…

Mechanistic models



Mechanistic models: SEIR/SIR, R0, Fuzzy logic, climate envelope…

Tjaden et al. (2018). Trends in Parasitology 34(3): 227-245. http://dx.doi.org/10.1016/j.pt.2017.11.006

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Disclaimer: many factors affect VBDs

Rank*	Driver
1	Changes in land use or agricultural practices
2	Changes in human demographics and society
3	Poor population health (e.g., HIV, malnutrition)
4	Hospitals and medical procedures
5	Pathogen evolution (e.g., antimicrobial drug resistance, increased virulence)
6	Contamination of food sources or water supplies
7	International travel
8	Failure of public health programs
9	International trade
10	**Climate change**

Woolhouse and Gowtage-Sequeria, EID, CDC 2005

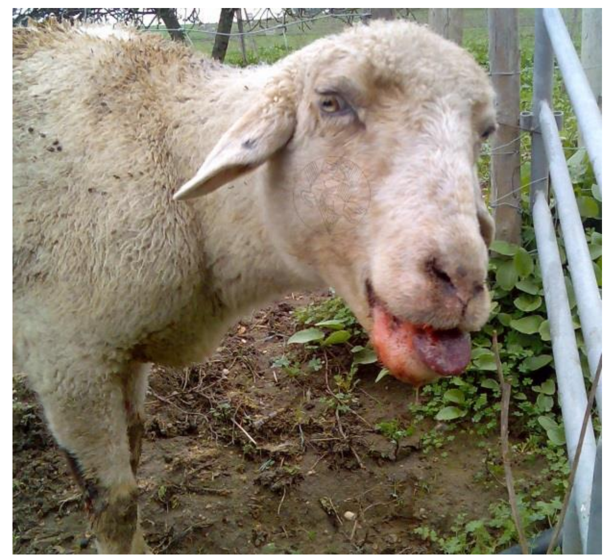
Impacts of VBDs

2^{nd} Plague pandemic 15^{th} century

Malaria in Africa

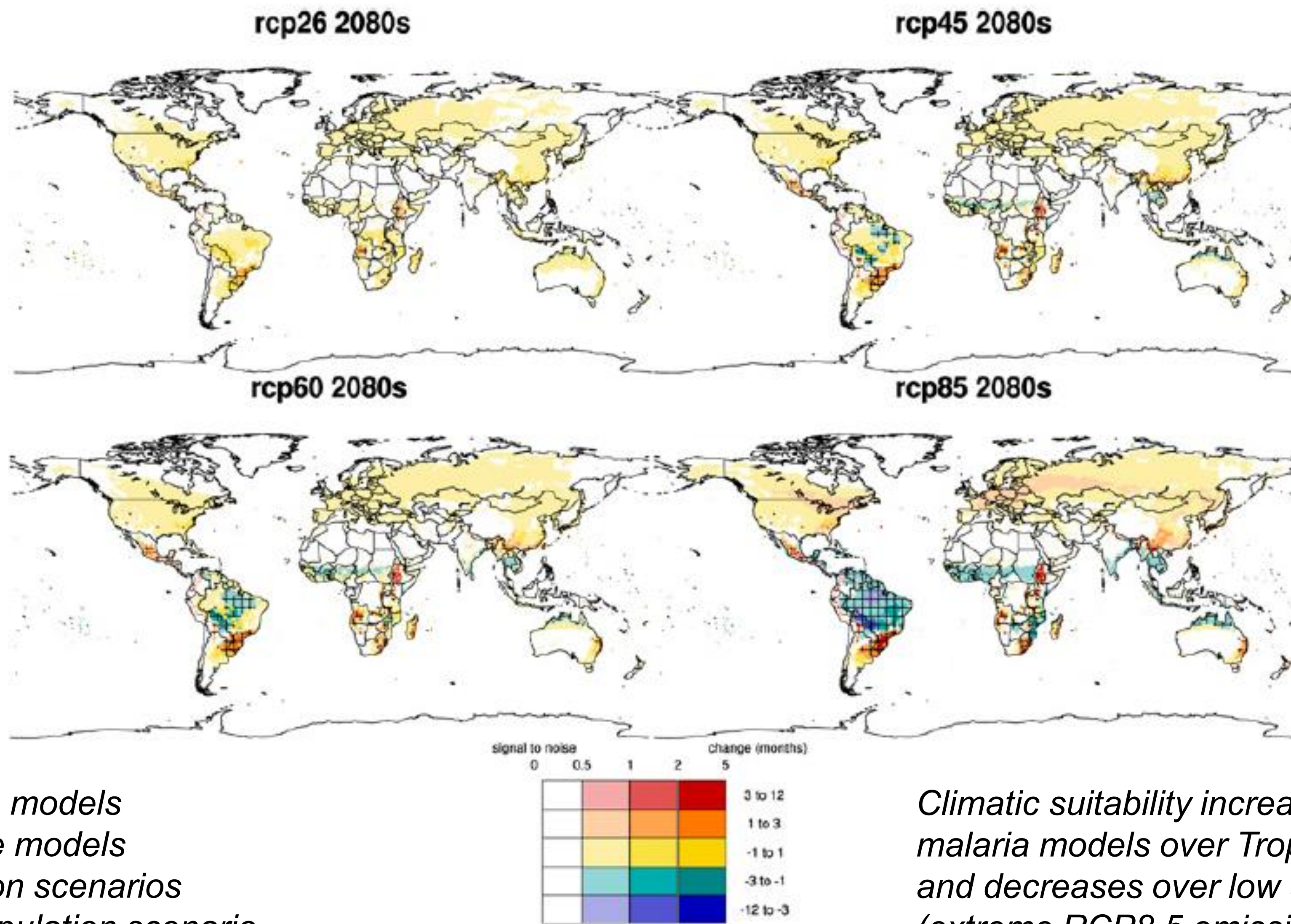
Zika outbreak in Latin America 2015-2016

Bluetongue outbreak in Northern Europe Aug-Sep-Oct 2006



Yellow fever outbreak – Angola, DRC 2015-2016

Climate change impact on malaria



5 Malaria models
5 Climate models
4 emission scenarios
SSP2 population scenario

Climatic suitability increases for all malaria models over Tropical highlands and decreases over low altitude regions (extreme RCP8.5 emission scenario – 2080s).

Caminade et al. (2014). PNAS 111(9): 3286-3291. doi: 10.1073/pnas.1302089111.

Is malaria moving to higher altitude & latitude?

Altitudinal Changes in Malaria Incidence in Highlands of Ethiopia and Colombia

A. S. Siraj,[1]* M. Santos-Vega,[2]* M. J. Bouma,[3] D. Yadeta,[4] D. Ruiz Carrascal,[5,6] M. Pascual[2,7]†

The impact of global warming on insect-borne diseases and on highland malaria in particular remains controversial. Temperature is known to influence transmission intensity through its effects on the population growth of the mosquito vector and on pathogen development within the vector. Spatiotemporal data at a regional scale in highlands of Colombia and Ethiopia supplied an opportunity to examine how the spatial distribution of the disease changes with the interannual variability of temperature. We provide evidence for an increase in the altitude of malaria distribution in warmer years, which implies that climate change will, without mitigation, result in an increase of the malaria burden in the densely populated highlands of Africa and South America.

Dhimal *et al. Malaria Journal* 2014, **13**(Suppl 1):P26
http://www.malariajournal.com/content/13/S1/P26

MALARIA JOURNAL

POSTER PRESENTATION **Open Access**

Altitudinal shift of malaria vectors and malaria elimination in Nepal

Meghnath Dhimal[1,2*], Bodo Ahrens[2,3], Ulrich Kuch[4]

From Challanges in malaria research: Core science and innovation
Oxford, UK. 22-24 September 2014

Acta Tropica xxx (2013) xxx–xxx

Contents lists available at SciVerse ScienceDirect

Acta Tropica

journal homepage: www.elsevier.com/locate/actatropica

ELSEVIER

A first report of *Anopheles funestus* sibling species in western Kenya highlands

Eliningaya J. Kweka[a,b,*], Luna Kamau[c], Stephen Munga[b], Ming-Chieh Lee[d], Andrew K. Githeko[b], Guiyun Yan[d]

[a] Tropical Pesticides Research Institute, Division of Livestock and Human Health Disease Vector Control, P.O. Box 3024, Arusha, Tanzania
[b] Centre for Global Health Research, Kenya Medical Research Institute, P.O. Box 1578, Kisumu, Kenya
[c] Centre for Biotechnology Research and Development, Kenya Medical Research Institute, P.O. Box 54840, Nairobi 00200, Kenya
[d] Program in Public Health, University of California, Irvine, CA 92697, USA

Dhimal *et al. Parasites & Vectors* 2014, **7**:540
http://www.parasitesandvectors.com/content/7/1/540

Parasites & Vectors

RESEARCH **Open Access**

Species composition, seasonal occurrence, habitat preference and altitudinal distribution of malaria and other disease vectors in eastern Nepal

Meghnath Dhimal[1,2,3,4*], Bodo Ahrens[2,3] and Ulrich Kuch[4]

OPEN ACCESS Freely available online

PLOS | ONE

First Evidence and Predictions of *Plasmodium* Transmission in Alaskan Bird Populations

Claire Loiseau[1]*, Ryan J. Harrigan[2], Anthony J. Cornel[3], Sue L. Guers[4], Molly Dodge[1], Timothy Marzec[1], Jenny S. Carlson[3], Bruce Seppi[5], Ravinder N. M. Sehgal[1]

The Asian tiger mosquito *Ae. albopictus*

Ae. albopictus

Main introduction routes

Figure 2. Main Aedes albopictus *inroduction routes: (A) Used tyres. (B),(C) Lucky Bamboo (*Dracaena *spp.).*

Scholte & Schaffner, 2007

Rapid spread worldwide

Wikimedia commons

blue: original distribution, cyan: areas where introduced in the last 30 years.

Rapid spread in Europe

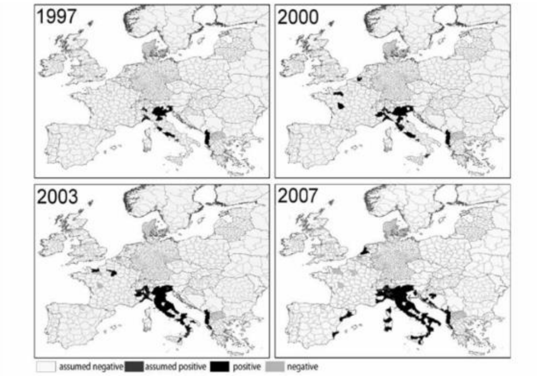
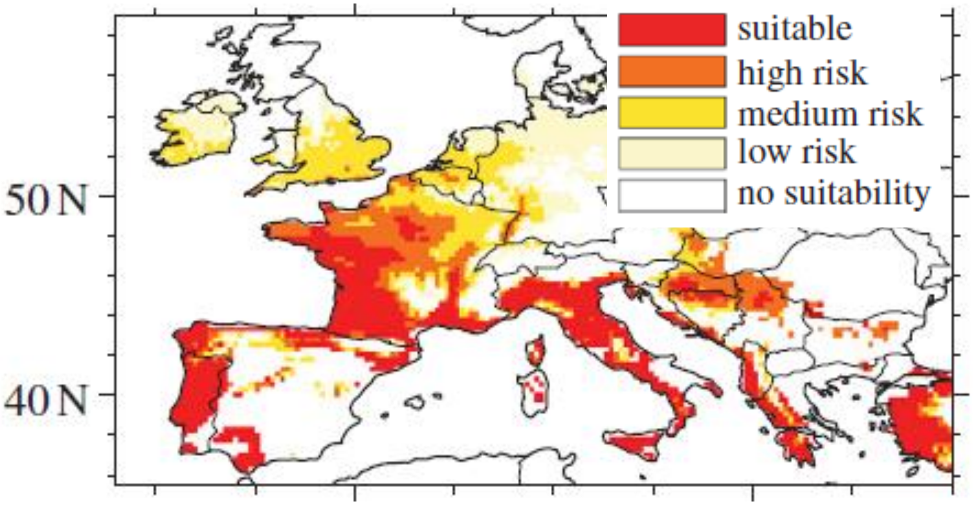


Figure 3. Presence of Aedes albopictus *in Europe per province for the years 1997-2007. Data to complete this figure were kindly made available by Roberto Romi (Italy), Roger Eritja and David Roiz (Spain), Eleonora Flacio (Switzerland), Charles Jeannin (France), Anna Klobučar (Croatia), Zoran Lukac (Bosnia and Herzegovina), Igor Pajovic and Dusan Petrić (Serbia and Montenegro), Bjoern Pluskota (Germany), Anna Samanidou-Voyadjoglou (Greece). The map was made by Patrizia Scarpulla. The 2007 outbreak of Chikungunya virus in Italy is indicated with an arrow in the 2007 box.*

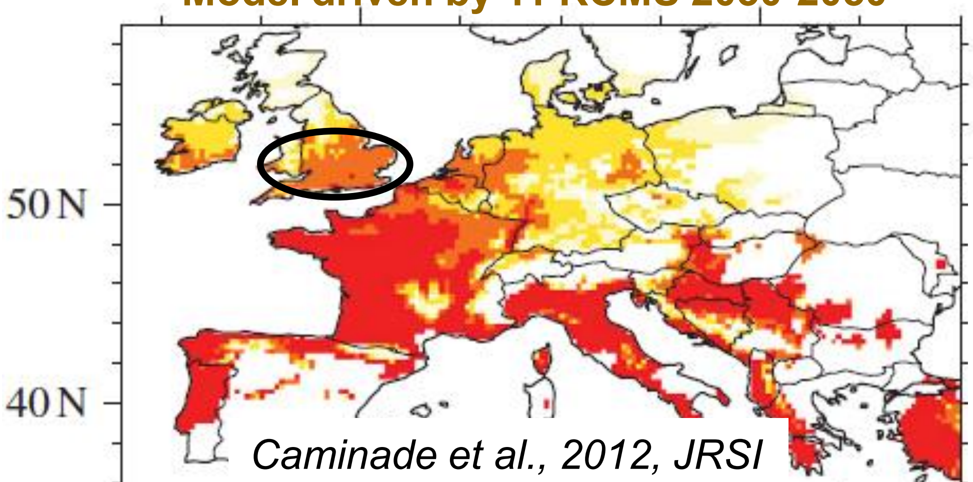
Scholte & Schaffner, 2007

Ae. albopictus: model scenarios vs observations

Model driven by climate obs (EOBS) 1990-2009



Model driven by 11 RCMS 2030-2050

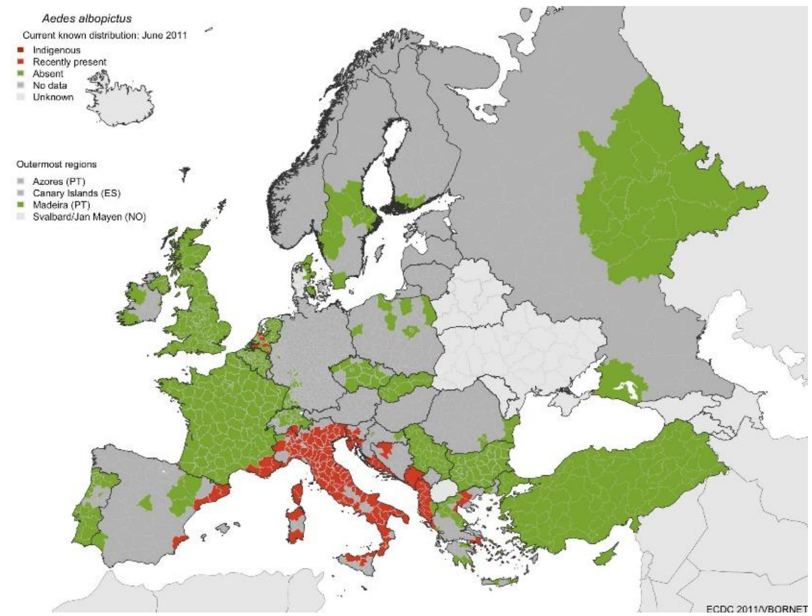


Model based on an overwintering criterion (Tjanuary >0C, Rain_annual>500mm) and different thresholds in annual Temperature:

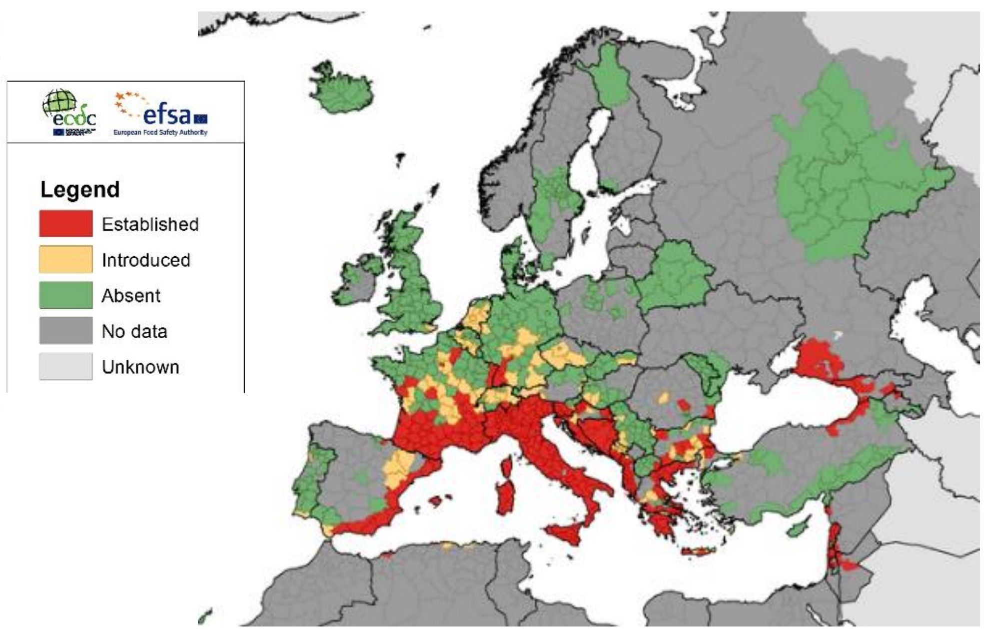
suitable 12C< T_annual
high risk 11C< T_annual < 12C
medium risk: 10C< T_annual < 11C
low risk: 9C< T_annual < 10C
no suitability: T_annual < 9C

Future risk increase: Benelux, Balkans, western Germany, the southern UK
Future risk decrease: Spain and Mediterranean islands

ECDC Obs – June 2011



ECDC Obs – Aug 2019

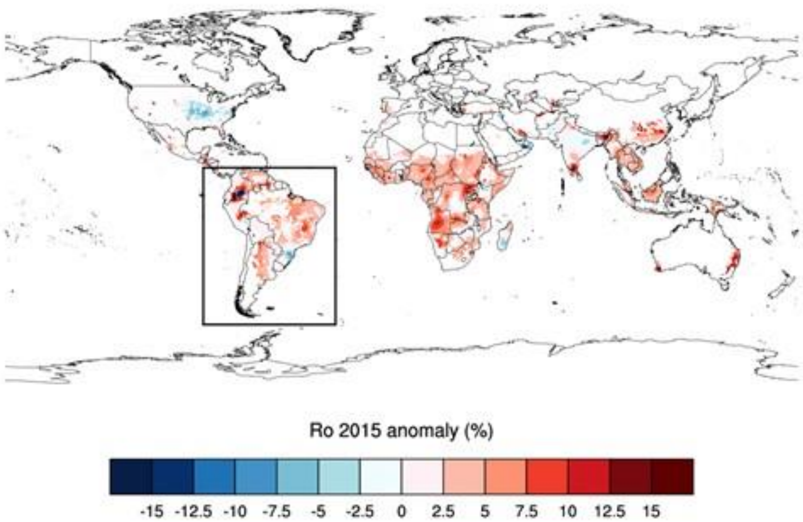


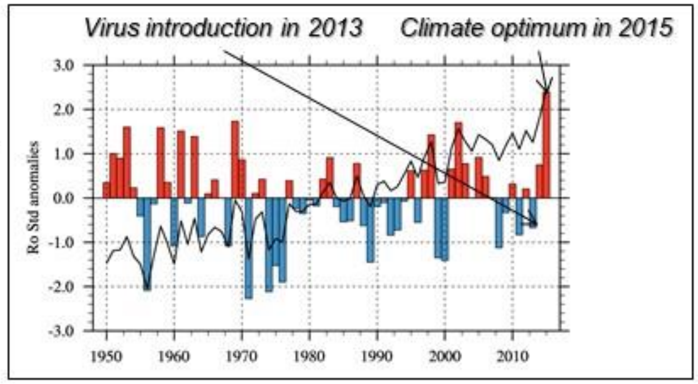
Zika outbreak in Latin America and El Niño

NIHR Health Protection Research Unit in Emerging and Zoonotic Infections

Global risk model for vector-borne transmission of Zika virus reveals the role of El Niño 2015

Cyril Caminade[a,b,1], Joanne Turner[a], Soeren Metelmann[b,c], Jenny C. Hesson[a,d], Marcus S. C. Blagrove[a,b], Tom Solomon[b,e], Andrew P. Morse[b,c], and Matthew Baylis[a,b]





The Washington Post

El Niño on a warming planet may have sparked the Zika epidemic, scientists report

SCIENTIFIC AMERICAN

E&E NEWS

El Niño and Global Warming Blamed for Zika Spread

Mosquito-borne diseases like Zika can be extremely sensitive to climatic changes

"temperature conditions related to the 2015 El Niño climate phenomenon were exceptionally conducive for mosquito-borne transmission of ZIKV over South America"

Caminade et al., PNAS 2017

LSTM Liverpool School of Tropical Medicine | University of Liverpool | Institute of Infection and Global Health | Public Health England | Funded by NHS National Institute for Health Research

Climate and the outbreak of Zika virus in 2015-16

Global warming leads to much quicker spread of the Zika virus because the increased temperature, "makes mosquitoes mature faster, . . . bite more due to having a higher metabolism, and makes the Zika virus inside of them incubate faster."

— *Al Gore on Tuesday, October 11th, 2016 in a speech*

SCIENTIFIC AMERICAN.

Cart 0

E&E NEWS

CLIMATE

El Niño and Global Warming Blamed for Zika Spread

Mosquito-borne diseases like Zika can be extremely sensitive to climatic changes

By Kavya Balaraman, E&E News on December 21, 2016 Véalo en español

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Global risk model for vector-borne transmission of Zika virus reveals the role of El Niño 2015

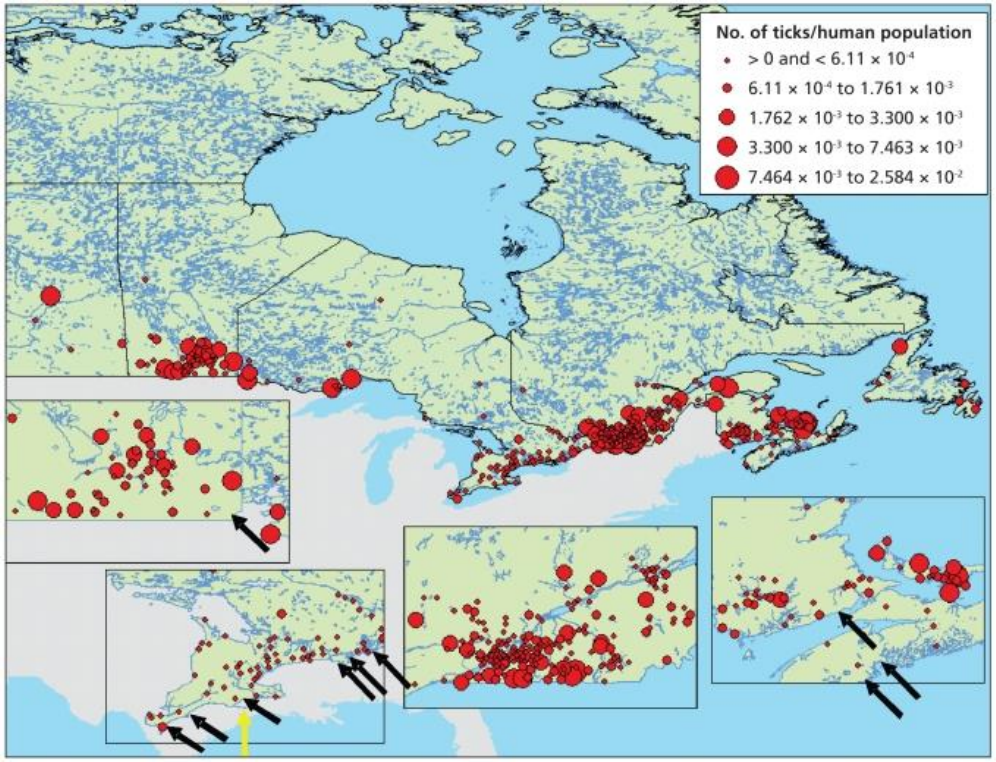
Cyril Caminade[a,b,1], Joanne Turner[a], Soeren Metelmann[b,c], Jenny C. Hesson[a,d], Marcus S. C. Blagrove[a,b], Tom Solomon[b,e], Andrew P. Morse[b,c], and Matthew Baylis[a,b]

[a]Department of Epidemiology and Population Health, Institute of Infection and Global Health, University of Liverpool, Liverpool CH64 7TE, United Kingdom; [b]Health Protection Research Unit in Emerging and Zoonotic Infections, University of Liverpool, Liverpool L69 3GL, United Kingdom; [c]Department of Geography and Planning, School of Environmental Sciences, University of Liverpool, Liverpool L69 7ZT, United Kingdom; [d]Department of Medical Biochemistry and Microbiology, Zoonosis Science Center, Uppsala University, Uppsala 751 23, Sweden; and [e]Department of Clinical Infection, Microbiology and Immunology, Institute of Infection and Global Health, University of Liverpool, Liverpool L69 7BE, United Kingdom

"There's a window of temperature that's ideal, and when you look at 2015, the numbers were in the right range," said Cyril Caminade, research associate with the university's Institute of Infection and Global Health and author of the study.

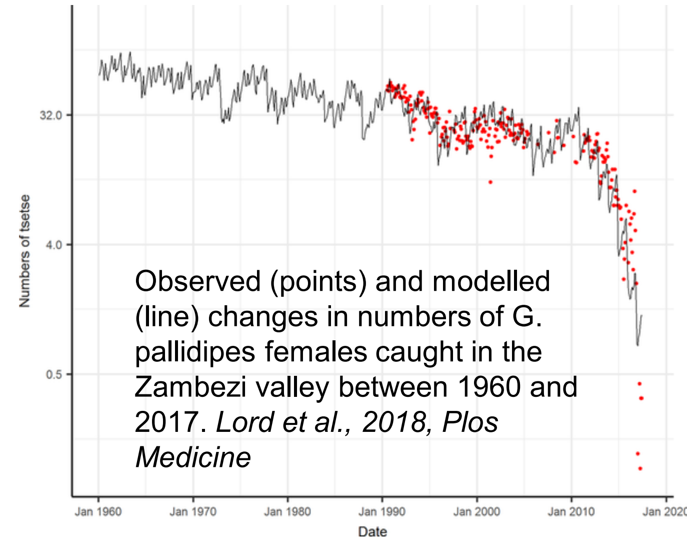
https://www.scientificamerican.com/article/el-nino-and-global-warming-blamed-for-zika-spread/
http://www.pnas.org/content/early/2014/01/30/1302089111.abstract

Other VBDs examples



The distribution of ***Ixodes scapularis***, reflecting information submitted to provincial and federal public health agencies from January 1990 to December 2003 and to the Lyme Disease Association of Ontario for 1993 to 1999 *Ogden et al., 2008*

African Trypanosomiasis in Zambezi valley



Observed (points) and modelled (line) changes in numbers of G. pallidipes females caught in the Zambezi valley between 1960 and 2017. *Lord et al., 2018, Plos Medicine*

Tick-borne encephalitis northern Russia

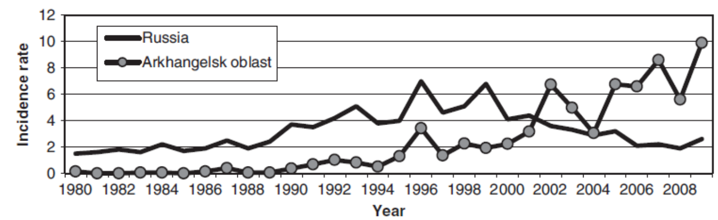
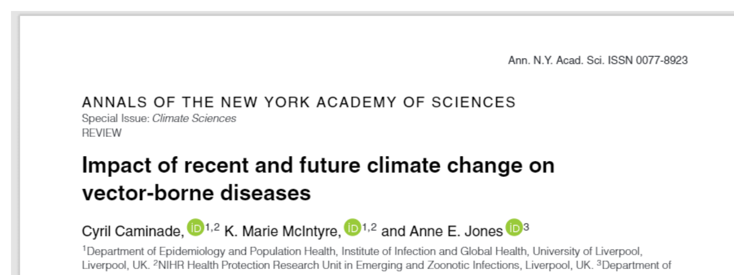


Fig. 3. TBE incidence in AO and in Russia as a whole in 1980—2009. *Tokarevich et al., 2011*

Caminade C., K.M. McIntyre and A.E. Jones (2018). Ann. of the New York Acad. of Sc., http://dx.doi.org/10.1111/nyas.13950


Ann. N.Y. Acad. Sci. ISSN 0077-8923

ANNALS OF THE NEW YORK ACADEMY OF SCIENCES
Special Issue: *Climate Sciences*
REVIEW

Impact of recent and future climate change on vector-borne diseases

Cyril Caminade,[1,2] K. Marie McIntyre,[1,2] and Anne E. Jones[3]
[1]Department of Epidemiology and Population Health, Institute of Infection and Global Health, University of Liverpool, Liverpool, UK. [2]NIHR Health Protection Research Unit in Emerging and Zoonotic Infections, Liverpool, UK. [3]Department of Mathematical Sciences, University of Liverpool, Liverpool, UK

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Other infectious diseases affected by climate change…

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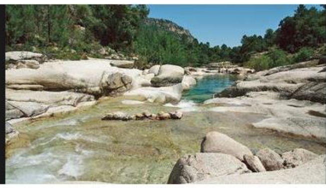
Actualité Santé › Santé publique

Comment la bilharziose, maladie tropicale, s'est invitée en Corse

Par Guillaume Mollaret | Publié le 17/05/2016 à 12:10



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Russia

Anthrax outbreak triggered by climate change kills boy in Arctic Circle

Seventy-two nomadic herders, including 41 children, were hospitalised in far north Russia after the region began experiencing abnormally high temperatures

This article is 12 months old
13,305 | 394
Alec Luhn in Moscow
Monday 1 August 2016 21.12 BST

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TheDailyClimate
SUSTAINABILITY

Has Climate Change Made Lyme Disease Worse?

As Lyme disease spreads across the U.S., those in its path cope with a debilitating, bewildering array of maladies, misery and afflictions

By Marianne Lavelle on September 22, 2014

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Mothers May Pass Lyme Disease to Children in the Womb

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Brain-eating amoeba claims year's third life in Sindh

Naegleria fowleri, the brain-eating amoeba, has claimed another life in Karachi: a young man of around 29 years of age who died due to infection caused by the deadly microorganism at a private hospital on June 28, the Sindh Health Department disclosed on Tuesday.

"Ali Amjad, a teacher by profession and a resident of KDA Scheme No 1 in Karachi, was admitted to the Aga Khan

In This Story
Tag
- Naegleria Fowleri
- Sindh
- Health

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Conclusions

- Climate impacts vector borne diseases distribution (breeding sites – development and survival of vectors, pathogen development rate inside the vector e.g. EIP…)
- Increasing evidences that climate change already played a role in the background over the past 20 years: worrying trends have been observed in different temperate, arctic and highland regions.
- Many factors to consider to anticipate the real future of infectious diseases (socio-economic, demography, land use changes, drug and insecticide resistance, technological break through…).
- Need to use different disease modelling approaches and ensemble of climate models, emission & population scenarios to assess uncertainties, and these can be quite large!
- Model validation is critical but difficult - validation relies on the quality of health and climate data!
- Climate change is already affecting our health directly (climatic extremes: heat waves, floods, air pollution…) and will have significant indirect effects from macro to micro scale e.g. on freshwater and oceanic resources, agriculture, livelihoods, population migration… It only started…