Assessing the current and future suitability to the Asian Tiger mosquito, a dengue and Zika vector, in major cities in Europe

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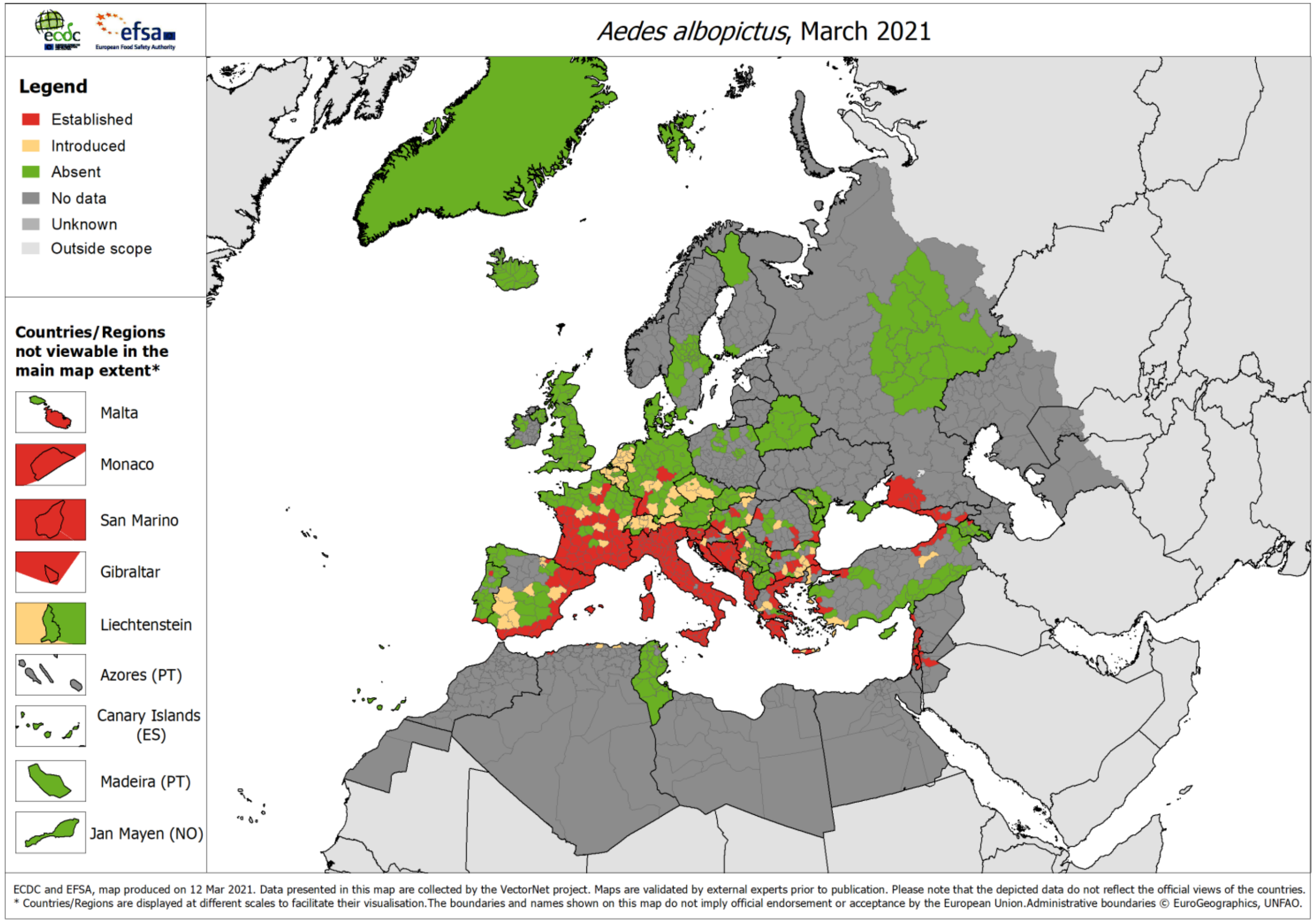
[O27] Climate change and infectious disease: a critical urban health challenge

8th July 2021

Background



European Centre for Disease Prevention and Control

https://www.ecdc.europa.eu/en/publications-data/aedes-albopictus-current-known-distribution-march-2021

- Origin in Southeast Asia
- Albania 1979, Italy 1990
- Competent vector for dengue, Zika and Chikungunya
- Outbreaks in Croatia, France, and Italy
- Climate change may increase suitability
- Urban areas particularly vulnerable:
  - heat island effect, higher urban temperature amplifies climate change
  - supply of mosquito breeding sites in man-made water containers and through irrigation
  - availability of potential hosts and dynamics of urban movements - increased risk of disease spread

Published predictions of suitability – data collected

- Public health concerns fostered research on the suitability to the establishment of the species in Europe
- Different suitability models developed – distinct data sources and methods, equally valid estimates of the potential distribution of the species

- **Do they agree?**
- **Consensus levels differ over Europe?**
- **Hotspots of (dis)agreement?**
- **Suitability in urban areas?**
- **Variations expected in the future?**

References models	Geog. coverage	Spatial resolution	Present-day period	Future period	Scenario	Modelling technique
Caminade et al. (2012[19])	Europe	0.25° ~25 km	1960–2009	2030–2050	SRES A1B	GIS-based (overwintering and seasonal activity); Multi-criteria decision analysis
Campbell et al. (2015)[8]	Global	0.16666° ~18 km	1950–2000	2041–2060	SRES B1	MaxEnt
Ding et al. (2018)[11]	Global	0.05° ~5 km	1970–2000			Support vector machine (SVM); Gradient boosting machine (GBM); random Forest (RF)
Kraemer et al. (2015[12], 2019[5])	Global	0.04166° ~5 km	1960–2014	2050	RCP 6.0	Boosted regression trees (BRT)
Proestos et al. (2015)[7]	Global	0.46875° ~50 km	2000–2009	2045–2054	SRES A2	Fuzzy-logic
Rogers (2015)[52]	Global	0.5° ~55 km	1961–1990	2080 (estimated for 2050 by linear interpolation)	SRES B1	K-means clustering; Nonlinear discriminant analysis
Santos and Meneses, (2017)[13]	Global	30 arc-sec ~1 km	1950–2000			MaxEnt

eLIFE — RESEARCH ARTICLE

The global distribution of the arbovirus vectors *Aedes aegypti* and *Ae. albopictus*

Moritz UG Kraemer, Marianne E Sinka, Kirsten A Duda, Adrian QN Mylne, Freya M Shearer, Christopher M Barker, Chester G Moore, Roberta G Carvalho, Giovanini E Coelho, Wim Van Bortel, Guy Hendrickx, Francis Schaffner, Iqbal RF Elyazar, Hwa-Jen Teng, Oliver J Brady, Jane P Messina, David M Pigott, Thomas W Scott, David L Smith, GR William Wint, Nick Golding, Simon I Hay

nature microbiology — ARTICLES

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

Moritz U. G. Kraemer, Robert C. Reiner Jr, Oliver J. Brady, Jane P. Messina, Marius Gilbert, David M. Pigott, Dingdong Yi, Kimberly Johnson, Lucas Earl, Laurie B. Marczak, Shreya Shirude, Nicole Davis Weaver, Donal Bisanzio, T. Alex Perkins, Shengjie Lai, Xin Lu

PHILOSOPHICAL TRANSACTIONS B — rstb.royalsocietypublishing.org — Research

Climate change influences on global distributions of dengue and chikungunya virus vectors

Lindsay P. Campbell, Caylor Luther, David Moo-Llanes, Janine M. Ramsey, Rogelio Danis-Lozano and A. Townsend Peterson

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Dengue: recent past and future threats

David J. Rogers

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Present and future projections of habitat suitability of the Asian tiger mosquito, a vector of viral pathogens, from global climate simulation

Y. Proestos, G. K. Christophides, K. Ergüler, M. Tanarhte, J. Waldock and J. Lelieveld

Journal of the Royal Society Interface — J. R. Soc. Interface (2012) 9, 2708–2717

Suitability of European climate for the Asian tiger mosquito *Aedes albopictus*: recent trends and future scenarios

Cyril Caminade, Jolyon M. Medlock, Els Ducheyne, K. Marie McIntyre, Steve Leach, Matthew Baylis and Andrew P. Morse

Global and Planetary Change 78 (2011) 54–64 — ELSEVIER

Projection of climatic suitability for *Aedes albopictus* Skuse (Culicidae) in Europe under climate change conditions

Dominik Fischer, Stephanie Margarete Thomas, Franziska Niemitz, Björn Reineking, Carl Beierkuhnlein

Acta Tropica 178 (2018) 155–162 — ELSEVIER

Mapping the spatial distribution of *Aedes aegypti* and *Aedes albopictus*

Fangyu Ding, Jingying Fu, Dong Jiang, Mengmeng Hao, Gang Lin

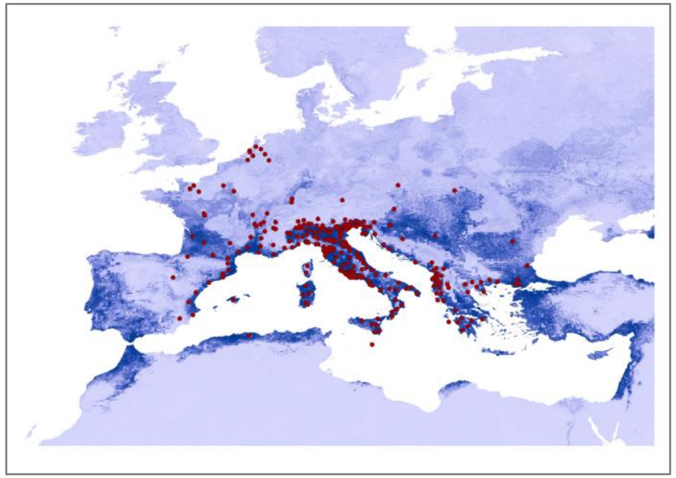
Acta Tropica 168 (2017) 80–90 — ELSEVIER

An integrated approach for the assessment of the *Aedes aegypti* and *Aedes albopictus* global spatial distribution, and determination of the zones susceptible to the development of Zika virus

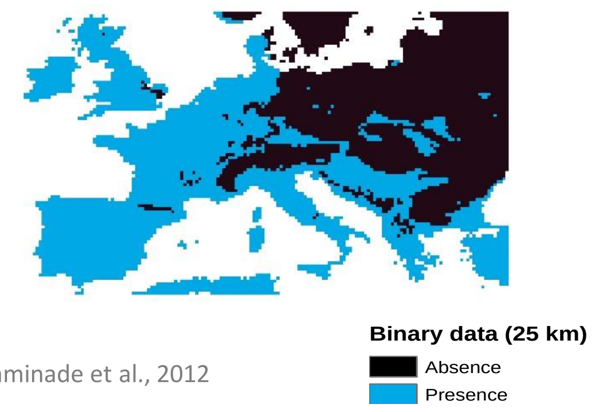
José Santos, Bruno M. Meneses

Published predictions of suitability – consensus analysis

Transform continuous data in presence/absence	Harmonise spatial resolution	Identify patterns of common and divergent areas	Identify future trajectories	Functional Urban Areas (GISCO)
Identify thresholds based on percentiles of known occurrences (fixed omission)	Up/downscale values to 25 km resolution	Nr. matching cells Classify level of consensus	Difference between major categories among two timeframes	Spatial overlap with classes distribution, present and future conditions



Database of known occurrences (Kraemer et al., 2015).
n=335

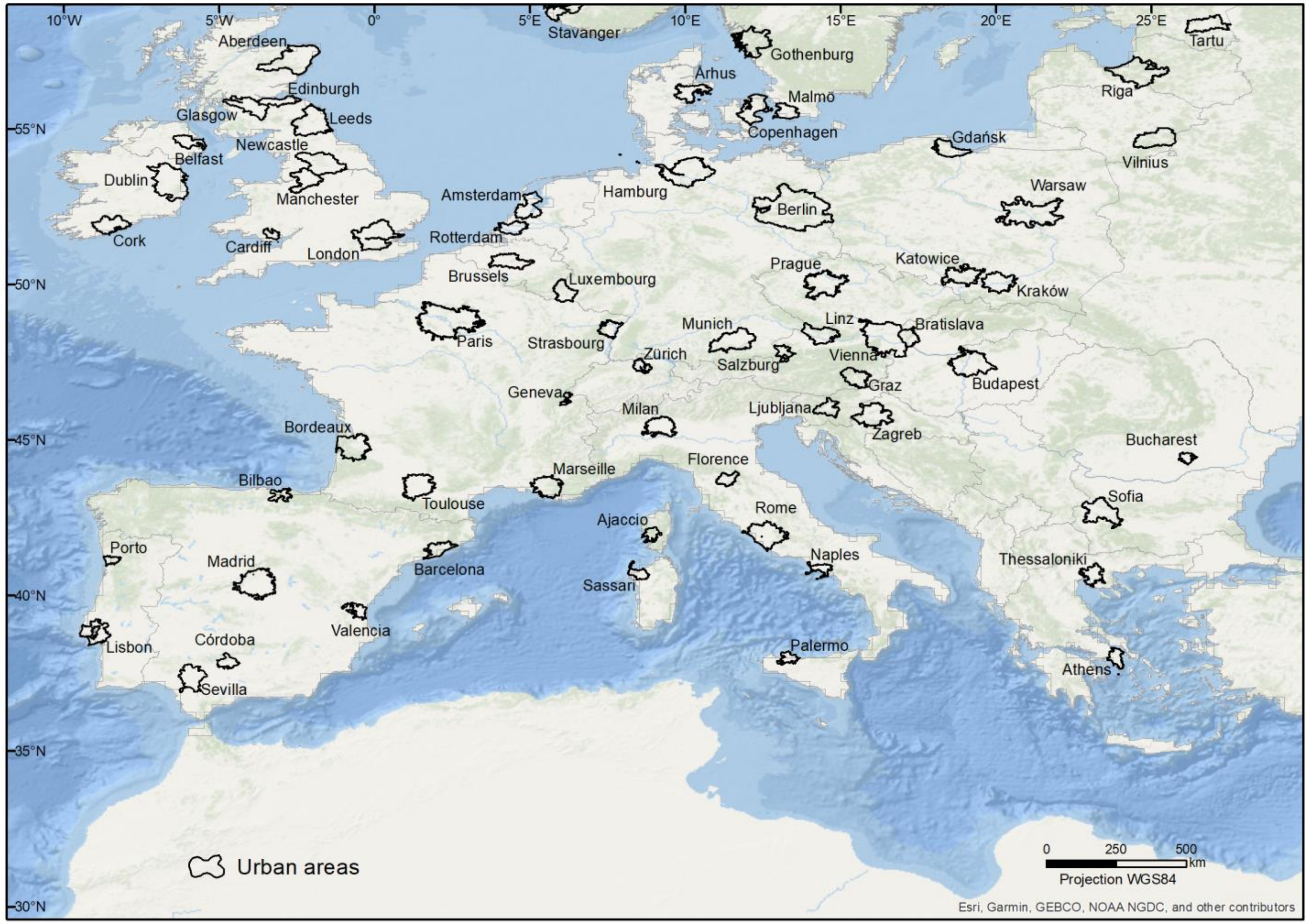


Caminade et al., 2012

Categories	Present (7 models)	Future (5 models)
Unsuitable, low uncertainty	5 to 7 models agree unsuitable	4 to 5 models agree unsuitable
High uncertainty	Only 3 or 4 models agree	Only 2 or 3 models agree
Suitable, low uncertainty	5 to 7 models agree suitable	4 to 5 models agree suitable

Published predictions of suitability – consensus analysis

Functional urban area (FUA) - a city and its commuting zone. A densely inhabited city and a less densely populated commuting zone whose labor market is highly integrated with the city (*OECD, 2012*).



62 metropolitan areas

- Large metropolitan (above 1.5 million people)
- Metropolitan (250.000 to 1.5 million people)

3 medium-size urban areas

- 3 medium areas (100.000 to 250.000 people), in Corsica, Sardinia and Estonia

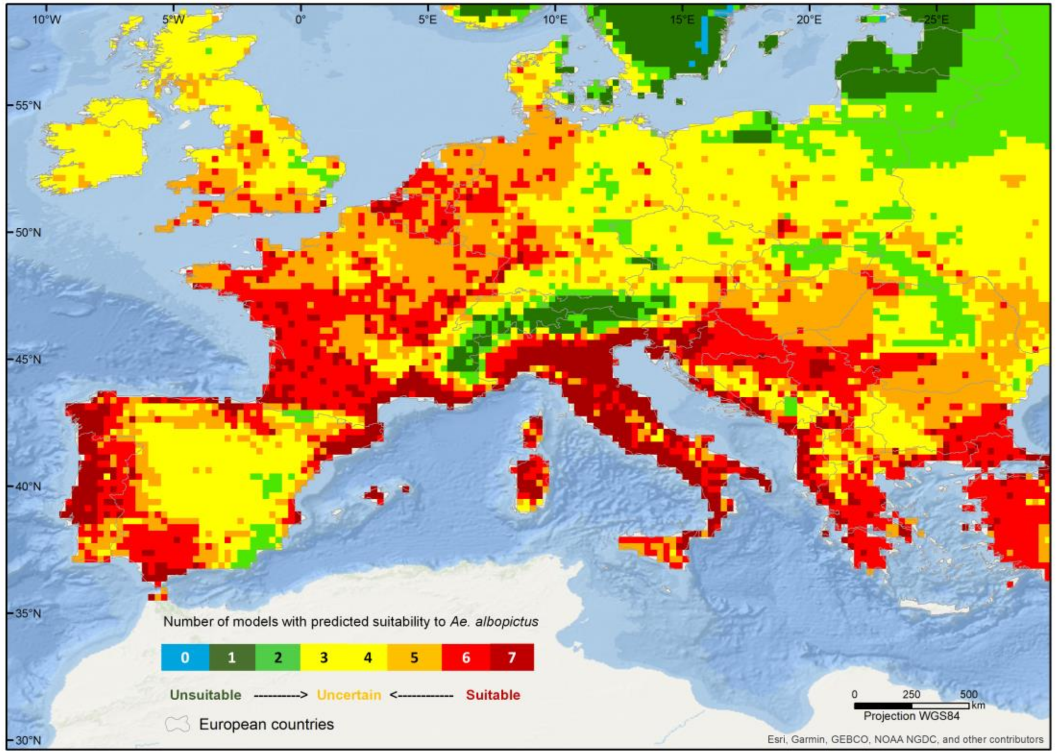
Suitability of urban areas to the presence of *Aedes albopictus*

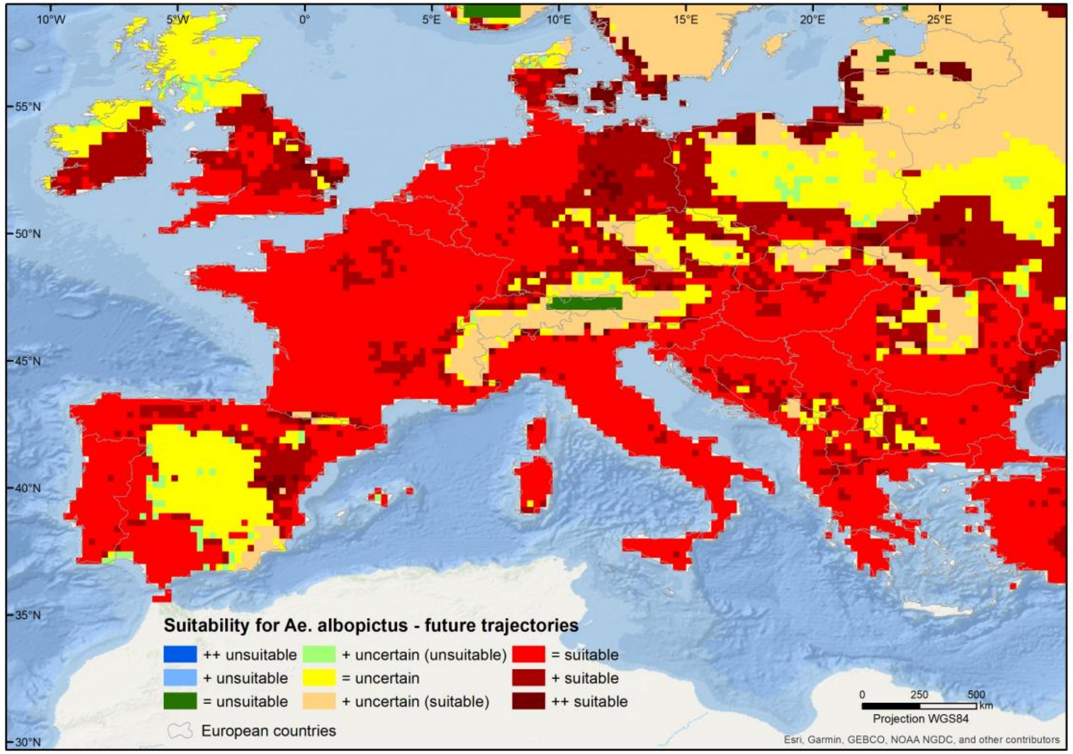
- Suitability class per 25 km cell, using the 3 major categories (traffic light scheme)
- Spatial overlap between cells and urban areas boundaries
- *Baseline scenario* - assigning to each urban area the category with wider spatial coverage (majority, >50%)
- *Worst-case scenario* – 1/3 urban area covered by a more unfavorable variation than given by the baseline

Traffic-light scheme

(green)	Most favorable situation from the human viewpoint (unsuitable with low uncertainty)
(yellow)	High uncertainty, regarding either suitability and unsuitability
(red)	Most negative situation, with suitability for the mosquito being consensual across models

Results - consensus analysis in Europe





Present conditions

Areas of high uncertainty (high disagreement between models) mainly in eastern Europe, northern Britain, Ireland and central Spain

Table S2. Classification and color scheme defined to represent the major categories and future trajectories of suitability for *Ae. albopictus*

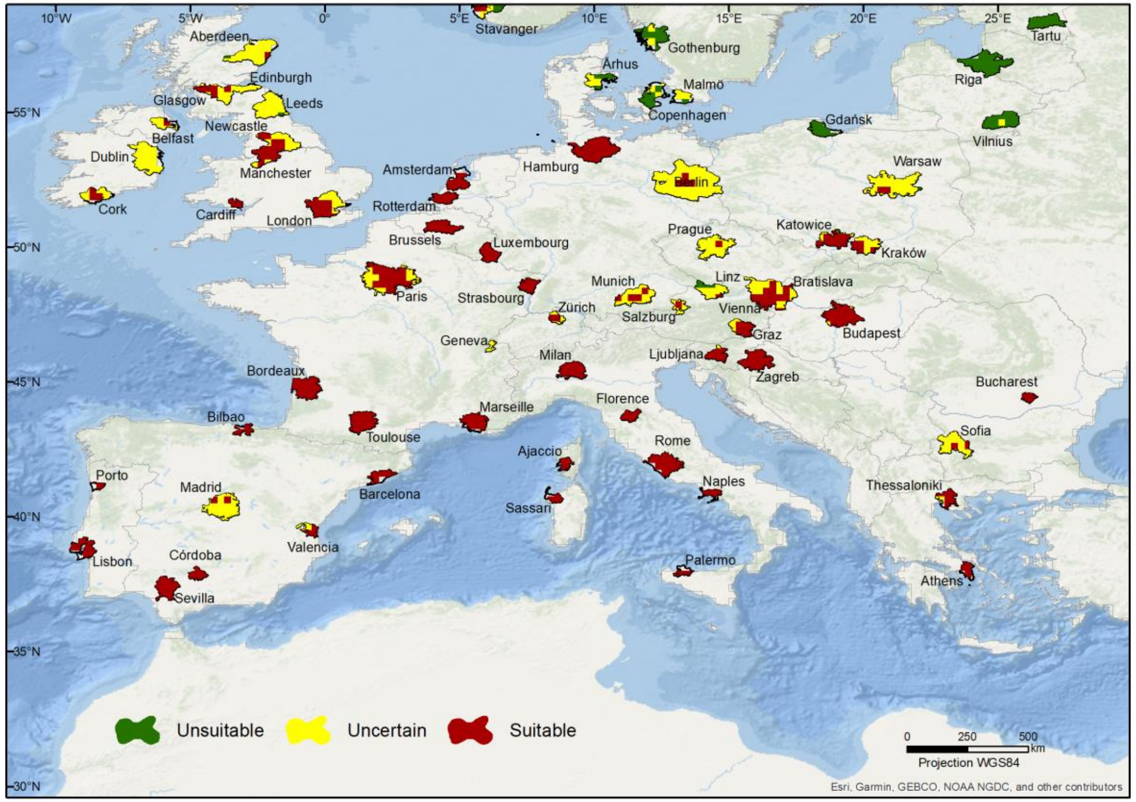
	Timeframe		Trajectory	
Major categories	***Present***	***Future***	***Code***	***Description***
Unsuitable, low uncertainty	1	1	=	Equally unsuitable
		2	+	Higher uncertainty (towards suitable)
		3	++	Much more suitable
High uncertainty	2	1	+	More unsuitable
		2	=	Equal uncertainty
		3	+	More suitable
Suitable, low uncertainty	3	1	++	Much more unsuitable
		2	+	Higher uncertainty (towards unsuitable)
		3	=	Equally suitable

Future trajectories

Suitable regions will encompass 21% more area, adding to the 47% of the continent that is suitable nowadays

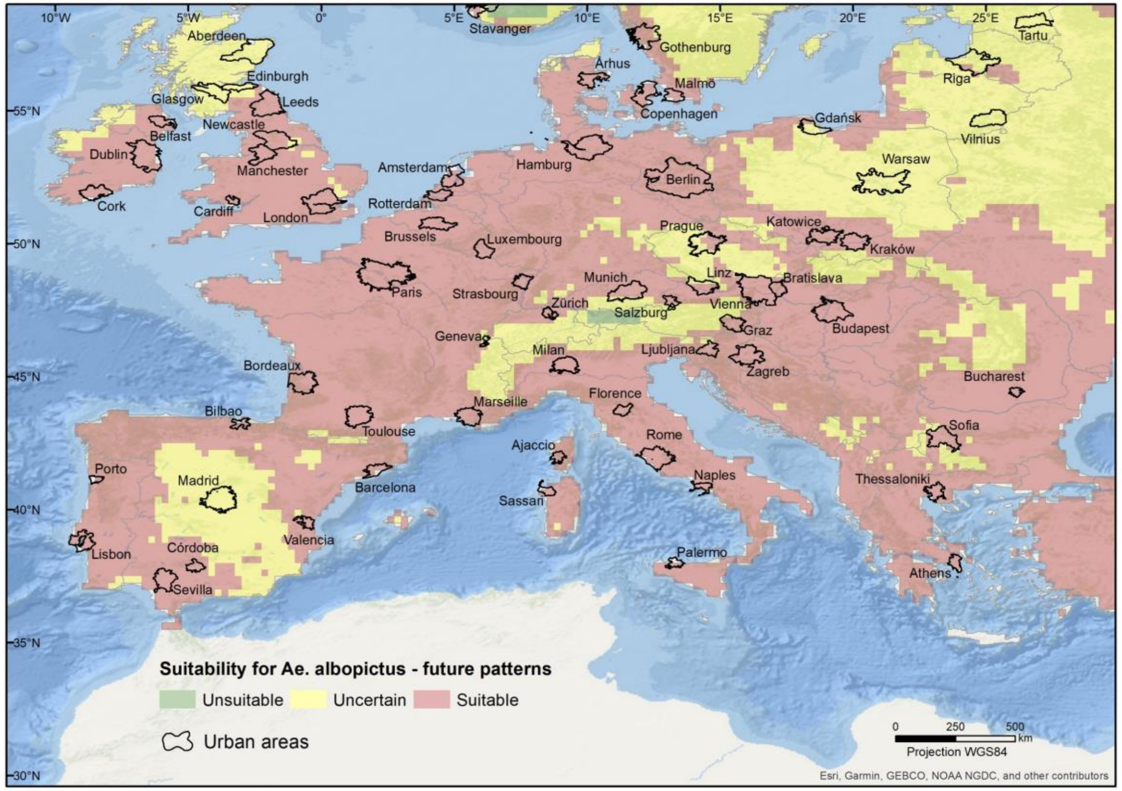
Results - consensus analysis in urban areas

Present conditions



- 12% unsuitable
- 39% uncertain
- 49% suitable

Future conditions



- 0% unsuitable
- 17% uncertain
- 83% suitable

Results - consensus analysis in urban areas

Main city (country)	P	F
Aberdeen(UK)	Uncertain	Uncertain
Ajaccio (FR)	Suitable	Suitable
Amsterdam (NL)	Suitable	Suitable
Århus (DK)	Unsuitable	Suitable
Athens (EL)	Suitable	Suitable
Barcelona (ES)	Suitable	Suitable
Belfast (UK)	Uncertain	Suitable
Berlin (DE)	Uncertain	Suitable
Bilbao (ES)	Suitable	Suitable
Bordeaux (FR)	Suitable	Suitable
Bratislava (SK)	Uncertain	Suitable
Brussels (BE)	Suitable	Suitable
Bucharest (RO)	Suitable	Suitable
Budapest (HU)	Suitable	Suitable
Cardiff (UK)	Suitable	Suitable
Copenhagen	Unsuitable	Suitable
Cordoba (ES)	Suitable	Suitable
Cork (IE)	Uncertain	Suitable
Dublin (IE)	Uncertain	Suitable
Edinburgh (UK)	Uncertain	Uncertain
Florence (IT)	Suitable	Suitable
Gdansk (PL)	Unsuitable	Uncertain
Geneva (CH)	Uncertain	Suitable

Main city (country)	P	F
Glasgow (UK)	Uncertain	Uncertain
Gothenburg (SE)	Unsuitable	Suitable
Graz (AT)	Suitable	Suitable
Hamburg (DE)	Suitable	Suitable
Katowice (PL)	Suitable	Suitable
Kraków (PL)	Uncertain	Suitable
Leeds (UK)	Uncertain	Suitable
Linz (AT)	Uncertain	Suitable
Lisbon (PT)	Suitable	Suitable
Ljubljana (SI)	Suitable	Suitable
London (UK)	Uncertain	Suitable
Luxembourg (LU)	Suitable	Suitable
Madrid (ES)	Uncertain	Uncertain
Malmö (SE)	Uncertain	Suitable
Manchester (UK)	Suitable	Suitable
Marseille (FR)	Suitable	Suitable
Milan (IT)	Suitable	Suitable
Munich (DE)	Uncertain	Uncertain
Naples (IT)	Suitable	Suitable
Newcastle	Uncertain	Suitable
Oporto (PT)	Suitable	Suitable
Palermo (IT)	Suitable	Suitable
Paris (FR)	Uncertain	Suitable

Main city (country)	P	F
Prague (CZ)	Uncertain	Suitable
Riga (LV)	Unsuitable	Uncertain
Rome (IT)	Suitable	Suitable
Rotterdam (NL)	Suitable	Suitable
Salzburg (AT)	Uncertain	Suitable
Sassari (IT)	Suitable	Suitable
Sevilla (ES)	Suitable	Suitable
Sofia (BG)	Uncertain	Suitable
Stavanger (NO)	Unsuitable	Suitable
Strasbourg (FR)	Suitable	Suitable
Tartu (EE)	Unsuitable	Uncertain
Thessaloniki (EL)	Suitable	Suitable
Toulouse (FR)	Suitable	Suitable
Valencia (ES)	Uncertain	Suitable
Vienna (AT)	Uncertain	Suitable
Vilnius (LT)	Unsuitable	Uncertain
Warsaw (PL)	Uncertain	Uncertain
Zagreb (HR)	Suitable	Suitable
Zürich (CH)	Uncertain	Suitable

Unsuitable (green)
Uncertain (yellow)
Suitable (red)

- Cities located in northern Europe expected to undergo the most severe changes (from unsuitable to suitable)

  Arhus, Copenhagen, Gothenburg, Stavanger

- Cities of central Europe, Great Britain and Ireland are expected to become suitable (from uncertain today)

  Berlin, Dublin, Geneva, London, Prague, Vienna

- Uncertainty remains in the future for cities such as:

  Edinburgh, Madrid, Munich, Warsaw

Conclusions

Patterns and trends of suitability to Aedes albopictus:

- ✓ Nowadays, West and South Europe suitable. Climate change will aggravate conditions (increase suitability)
- ✓ In about 30 years, *Ae. albopictus* will find suitable areas in 68% of the European continent
- ✓ 83% of large urban areas (out of 65 analyzed) predicted as suitable in the future (2050). None unsuitable
- ✓ Suitability to *Aedes albopictus* in Europe raises public health concerns. Need to integrate monitoring and control measures of vectors

Consensus analysis of existing models:

- ✓ Transformation of the original data. Details specific to each model were lost
- ✓ Able to identify hotspots of high and low suitability for *Ae. albopictus,* and areas with high inter-model mismatch (uncertainty)
- ✓ Contribute to transfer scientific outputs (numerous and divergent) into tangible and consensual policies

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Wide and increasing suitability for *Aedes albopictus* in Europe is congruent across distribution models

Sandra Oliveira, Jorge Rocha, Carla A. Sousa & César Capinha

Scientific Reports **11**, Article number: 9916 (2021) | Cite this article

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Abstract

The Asian tiger mosquito (*Aedes albopictus*), a vector of dengue, Zika and other diseases, was introduced in Europe in the 1970s, where it is still widening its range. Spurred by public health concerns, several studies have delivered predictions of the current and future distribution of the species for this region, often with differing results. We provide the first joint analysis of

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