ICUR2022
2nd International Conference on Urban Risks
LISBON 23-25 JUNE

Assessing present and future suitability of major European cities to the Asian Tiger mosquito, a vector of dengue and Zika

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Abstract:

The Asian Tiger mosquito (*Aedes albopictus*) is already established in many countries of Europe and cities are particularly vulnerable to the spread of vector-borne diseases. We evaluated the suitability of 62 large urban areas in Europe to the establishment of this mosquito, based on the level of agreement between published predictions of its potential distribution. We classified levels of suitability and uncertainty according to the number of matching models at a 25 km cell size and retrieved the predominant class within the boundaries of each urban area. We analysed 7 independent predictions for current conditions and 5 for future conditions (2050-2080), as well as changes in classes between the two timeframes. Currently, 60% of the cities are suitable to the mosquito, 8% are unsuitable and 32% show high uncertainty. In the future, 87% will be suitable and none will be unsuitable, including cities in the British Isles and Scandinavia, which will have to adapt their public health policies.

Keywords: *Aedes albopictus*, invasive disease-vectors, European cities, present conditions, future climate

1. Introduction

The Asian Tiger mosquito (*Ae. albopictus*) is increasingly colonizing temperate regions (Bonizzoni, Gasperi, Chen, & James, 2013). This mosquito is a competent vector of several diseases, such as dengue and Zika, and is now present in 30 countries in Europe (ECDC, 2019). Urban areas are particularly vulnerable to the spread of vector-borne diseases, due to the supply of mosquito breeding sites through man-made water containers and irrigation, to the availability of potential hosts via the contact with humans and to the dynamics of urban flows. Furthermore, in a context of climate change, the urban heat island (UHI) effect can amplify the expected rise in temperatures in cities which are currently too cold, but that could sustain the establishment of the mosquito in the future (Li et al., 2014; Metelmann et al., 2019).

The expansion of *Ae. albopictus* to urban areas in temperate regions is a major public health concern. The aim of this study was to evaluate the suitability of large cities in Europe to the establishment of the species, considering present-day conditions and future climatic scenarios, measured from modelling results published independently in the last 8 years. The assessment of current and future timeframes allows evaluating temporal trends in suitability to the species, which are of relevance for anticipating the exposure of urban dwellers to vector-borne diseases transmitted by the *Ae. albopictus*.

2. Methodology

The first step consisted in identifying studies that had statistical estimates of the potential distribution of *Ae. albopictus* for Europe. We carried out a literature search and contacted experts that had published modelling

results since 2012. From the contacts made, we collected 7 independent predictions for present-day conditions and 5 for the period 2050-2080, based on climatic projections (Caminade et al., 2012; Campbell et al., 2015; Ding, Fu, Jiang, Hao, & Lin, 2018; Kraemer et al., 2019, 2015; Proestos et al., 2015; Rogers, 2015; Santos & Meneses, 2017). The spatial resolution of the models, ranging originally from 1 to 50 km, was harmonized to 25 km. Afterwards, we identified thresholds of suitable and unsuitable for the species, by overlapping the models with a dataset of known occurrences (Kraemer et al., 2015) and excluding the values below the 5th percentile threshold (Radosavljevic & Anderson, 2014).

The next step consisted in evaluating the agreement between models and retrieving the levels of (un)suitability and uncertainty with regard to the estimated suitability to the mosquito. This was measured by summing the number of matching models regarding the estimated presence (coded as 1) or absence (coded as 0) of the mosquito in each grid cell. We assumed that the cells with a higher number of matching models would represent a high agreement with low uncertainty, either towards unsuitability, when the sum of values were closed to zero, or towards suitability, when the sum of values was close to 7 (for present-day conditions) or 5 (for future conditions).

Conversely, the cells where only about half the models agreed and the sum of values was close to the middle range (between 3 and 4), would represent areas of high uncertainty and lower consensus regarding the suitability to the mosquito. Each cell was then classified into one of three categories: 1) unsuitable with low uncertainty; 2) high uncertainty; 3) suitable with low uncertainty. This was done separately for present-day and future conditions. We then quantified changes of category between the two timeframes and assess potential future trajectories of suitability to *Ae. albopictus.*

This evaluation was carried out for the country capitals and other large cities in Europe, whose boundaries were obtained from the Urban Audit 2018 (EUROSTAT (ESTAT) GISCO, 2018). We used the limits of 62 functional urban areas (FUA), which correspond to a densely inhabited city and a less populated commuting zone with a strongly connected labour market, classified as metropolitan areas (between 250,000 and 1.5 million people) or large metropolitan areas (above 1.5 million people). We evaluated the level of suitability of each urban area according to the category with wider spatial coverage within its boundaries.

3. Results and Conclusions

Under present-day conditions, 60% of the large urban areas in Europe are suitable and 8% are unsuitable to the establishment of the *Ae. albopictus*. Unsuitable cities are located in the northeast of the continent, in Scandinavia and the Baltic regions, such as Copenhagen, Goteborg, Riga and Vilnius. For cities located in the British Isles and Central Europe, such as Leeds, Edinburgh, Berlin and Prague, the models show a high disagreement and the level of suitability to the mosquito is currently uncertain (Figure 1). However, the suitability to the mosquito will increase in most of these cities in the future.

In about 40 years, none of the urban areas considered will be unsuitable and only 13% will show high uncertainty. The strongest variation is seen in Scandinavian cities, with Goteborg and Copenhagen changing from unsuitable under current conditions to suitable with low uncertainty in the future; all the other urban areas of the region will also become suitable. A similar trend is verified in Ireland, the United Kingdom and central European countries, with most of the cities becoming suitable to the mosquito in the future, such as London, Dublin, Berlin, Munich, Salzburg or Krakow (Figure 1).

These findings show that the exposure of urban areas to vector-borne diseases will increase in the future. This risk is virtually absent today in northern and central Europe, but most models agree with a substantial increase in suitability to *Ae. albopictus* in these regions. European countries will have to adjust their public health policies and implement vector surveillance and control measures, to prevent the potential spread of diseases such as dengue or Zika, and decrease the exposure of their urban areas.

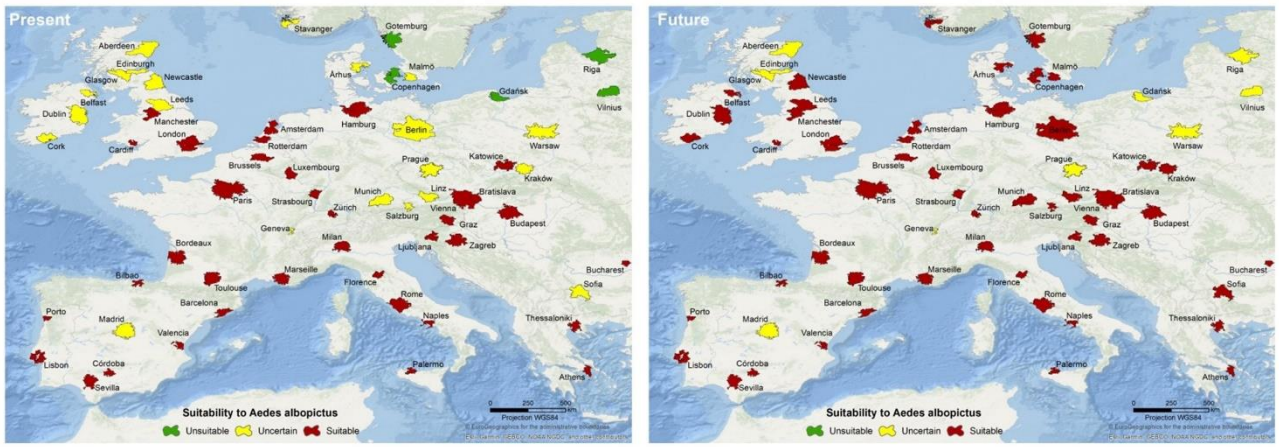

Figure 1 – Suitability to *Aedes albopictus* for large urban areas in Europe, for present-day (left) and future conditions (right)

Acknowledgments

This work was financed by national funds through FCT—Portuguese Foundation for Science and Technology, I.P., under the framework of the project TRIAD - health Risk and social vulnerability to Arboviral Diseases in mainland Portugal [PTDC/GES-OUT/30210/2017]. César Capinha was supported by Portuguese National Funds through FCT, I.P., under the programme of 'Stimulus of Scientific Employment – Individual Support' within the contract 'CEECIND/02037/2017'.

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