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From Sporadic Outbreaks to Endemicity: Drivers, Transition, and Response Gaps of Aedes-Borne Arboviruses in Temperate Europe

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Abstract

Dengue and Chikungunya, two Aedes-transmitted arboviruses, are spreading worldwide. Recently, both diseases caused the first-time autochthonous outbreaks in temperate Europe. This review aims to describe the factors driving the spread of both arboviruses in European temperate regions and to describe the transition from importation-based sporadic outbreaks to sustained local transmission. All available literature on both diseases was collected from databases such as Web of Science, Scopus, and PubMed, as well as from ECDC rapid risk assessments, World Health Organization documents, and surveillance reports of Santé publique France up to 2026. Public health measures and strategies available and used in Europe to contain both diseases are compared and discussed. The time to outbreak for dengue and chikungunya is decreasing sharply in recent years. For each additional degree of summer temperature, the outbreak hazard is increased by a factor of 1.55 (95% CI 1.30–1.85) after adjustment for health expenditure, importation of infected individuals and of Aedes mosquitoes, as well as for land use. Detection and control of outbreaks, however, are not keeping pace with the increasing risk. Detection latency has become the main constraint for public health intervention, because an outbreak can be contained as soon as it is identified. Therefore, public health response has to change from a reactive to an anticipatory style to face the emerging transmission regime in temperate Europe, which is shifting from an importation-driven pattern to a partially self-sustaining transmission regime.

Keywords

dengue, chikungunya, *Aedes albopictus*, climate change, vector-borne disease surveillance

1. Introduction

1.1 A Break Point in European Arbovirology

The dengue and chikungunya arboviruses are spreading rapidly worldwide and have become major public health threats for countries in European regions. Recently, importation cases as well as locally acquired cases of chikungunya have been reported in mainland France. This season has marked a break point in European arbovirology. The French national surveillance system reported 1,073 imported cases of chikungunya in mainland France in 2025. Of these, 800 or so cases were locally acquired in all the regions of the mainland. These cases were far in excess of the cumulative number of locally acquired cases of chikungunya reported in

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the preceding 15 years in the northern latitudes [1]. It remains to be determined whether these cases will represent interannual variations or the beginning of a shift towards endemicity in Europe.

Recent transmission episodes of dengue and *Aedes*-borne chikungunya arboviruses were reported from several non-endemic temperate countries in Europe as well as from Southern Hemisphere countries. Spatial distribution of both the vectors and arboviruses is extending.

1.2 Quantitative Dynamics and Significance

Time-to-event analyses were conducted to assess the change in the risk of establishment and first outbreaks of dengue and *Aedes*-borne chikungunya in the EU. Importantly, time-to-outbreak for dengue and chikungunya has decreased sharply over the last 35 years, and time between the first and second outbreaks has decreased from an average of 12 years to a few months. A multivariate analysis was also conducted to identify factors that influenced the outbreak hazard. Importantly, summer temperature increased the outbreak hazard by a factor of 1.55 (95% CI 1.30–1.85) after health expenditure, importation of infected individuals and mosquitoes, and land use had been taken into account [2]. The location of the first cases during dengue outbreaks in Italy was determined by importation pressure of infected individuals rather than local determinants and was modeled using a recently developed dengue transmission model [3].

1.3 Aims and Research Questions

This review focuses on whether surveillance and control measures are adequate to face the emerging transmission regime. It is organised around three research questions.

RQ1: What are the climatic, entomological, and epidemiological determinants of the change from sporadic, mainly importation-driven outbreaks to recurrent local transmission?

RQ2: To what extent does the current increase in the number of autochthonous dengue and chikungunya cases actually reflect an increase in transmission, or rather an increase in surveillance, in the accuracy of case definition, or in the quantity or quality of diagnosis?

RQ3: How do current EU surveillance architectures, existing vector-control measures, and licensed and recommended vaccines for DENV and CHIKV compare with the emerging transmission regime?

2. Theoretical Background and Methodology

2.1 Empirical Basis and Analytical Framework

Here, we use longitudinal surveillance data on *Aedes albopictus* as well as on local cases of dengue and chikungunya in several EU regions. We estimate the time interval between the introduction of *Aedes albopictus* in a given region and the first local transmission events. We project the number of outbreaks that could occur in the 2060s in the surveillance areas of the 1990–2024 period under a high-emission scenario.

The core of this review are the four components that, based on the available evidence, explain the range expansion of *Aedes*-borne arboviruses to temperate Europe. These four components are described in detail in the above sections and are represented schematically in Fig. 1. Importantly, the three drivers of range expansion (climate, vector and importation) interact multiplicatively on the transmission risk, whereas the response capacity (which is constrained by detection latency in particular) determines whether an outbreak that occurs as a result of increased transmission risk is brought under control or not. Thus, the causal framework described in the above sections will be returned to in the Discussion section and used to address each of the three research questions in turn.

2.2 Review Design and Justification

This review is a narrative literature review with thematic synthesis, addressing the three research questions posed above. The three themes into which the findings from the literature have been synthesized correspond to the three research questions posed above, i.e., the drivers of range expansion (RQ1), the evidence for a transition from importation to local transmission (RQ2), and the adequacy of current surveillance, control, and vaccination for the emerging transmission regime (RQ3). The first theme identifies the factors that determine

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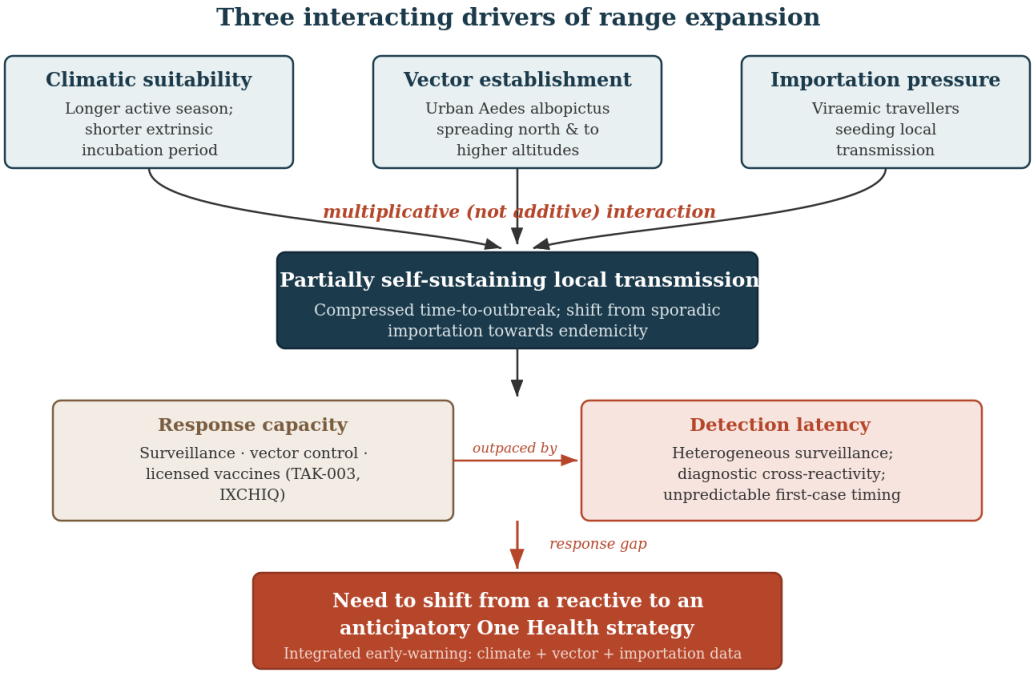
the transition from importation by viraemic travelers to local transmission. The second theme investigates the evidence for an increase in the number of autochthonous dengue and chikungunya cases and for a shift towards endemicity in temperate Europe. The third theme assesses the capacity of current European surveillance and control systems and outlines the areas that require improvement.

Figure 1: The factors that determine the range expansion of Aedes-borne arboviruses in temperate Europe and their interactions. The four main factors that influence the spread of Aedes-borne arboviruses in temperate Europe are climate, the vector, importation, and response. Climatic suitability for the vector to complete its life cycle, vector establishment in new areas, importation of infected individuals and/or mosquitoes, and response in terms of detection and control measures interact to generate partially self-sustaining local transmission. The main determinant of the response, however, is detection latency, which, as previously noted, outpaces response capacity. Therefore, the response gap, which motivates a shift from a reactive to an anticipatory strategy, is determined by detection latency



2.3 Search Strategy

For the literature search, three main databases (PubMed, Web of Science and Scopus) and several institutional databases (surveillance reports, outbreak updates, rapid risk assessments) of the European Centre for Disease Prevention and Control (ECDC), World Health Organization (WHO), and of Santé publique France have been queried. The literature search used the following search terms: (dengue OR chikungunya) AND (autochthonous OR local transmission) AND (Europe OR temperate) AND (*Aedes albopictus* OR climate). The main body of evidence consisted of peer-reviewed articles and official surveillance reports published between 1990 and 2026. Preference was given to the most up-to-date literature published after 2020. For all included sources, backward citation tracking was performed.

3. Literature Review

3.1 Drivers of Range Expansion (RQ1)

The main factors driving the *Aedes albopictus* range expansion to new areas are climate (temperature), vector (*Aedes albopictus*), and importation (viraemic travelers). Importation of the virus by viraemic travelers into already colonized areas by *Aedes albopictus* can lead to the establishment of the virus in new areas. Importation of virus has already led to the establishment of virus in at least 14 EU/EEA countries [4]. The vector is continuing to spread to higher altitudes and to more northern latitudes [3].

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Aedes albopictus is highly adapted to urban environments and can establish suitable ecological niches within temperate regions, far north of the established Mediterranean distribution area of this vector species. In large Central European cities, the number of breeding sites of *Aedes albopictus* as well as the number of human–vector contacts are determined by local features of the urban environment, rather than by large-scale climate variables. Thus, in addition to higher temperatures, urbanization across Europe can create stable habitats for introduced arboviruses to be transmitted between viraemic travelers. In colonized cities with sufficient habitat structures and human contact, these cities can act as stable foci for further spread to urban as well as non-urban environments.

Importation pressure by viraemic travelers is the third factor that can determine whether an introduction of a vector carrying a virus will become a self-limited event or not. Importation pressure refers to the volume of viraemic travelers importing the virus into regions where *Aedes albopictus* is already established, the seasonality of importation, and the origin of the imported virus. Importation pressure can be influenced by various factors, including travel restrictions, climate, and vector ecology. For example, in 2025 France recorded around a thousand imported chikungunya cases [3,5]. Importation pressure by viraemic travelers can seed local transmission, provided the vector is abundant, the season is lengthening, and importation pressure is ongoing [2,3]. Thus, the three drivers of range expansion of *Aedes*-borne arboviruses do not act independently but rather multiplicatively to raise transmission risk.

3.2 Evidence of Transition (RQ2)

There is evidence that there is a transition to higher levels of dengue transmission in temperate Europe. The interval between a vector introduction and the first cases due to local transmission, as well as the interval between the first and second outbreaks of the same virus has been reported to shorten by about an order of magnitude in recent years [6]. The recent outbreaks of chikungunya [7] as well as West Nile virus [7] in Europe have also been commented upon by the European Centre for Disease Prevention and Control (ECDC). Recent outbreaks of chikungunya have been reported in 27 outbreaks on the European continent, a record number [7].

Dengue cases have been reported as autochthonous in France, Italy, and Spain [6]. Although so far the cases have been reported as isolated, there is already evidence of clustered local transmission of dengue in some areas of the Iberian Peninsula, including in Catalonia [6]. Given the global dengue cases reported in 2024, which exceeded 14 million cases and resulted in 10,000 deaths [8], the challenge that dengue will pose to Europe in the near future will be considerable.

Chikungunya on the island of La Réunion in 2024–2025 is an example of the large scale of the transmission between a competent established vector and a large susceptible population. In the space of a single year, tens of thousands of cases and hundreds of deaths occurred among a population of around 900 000 people. The island of La Réunion is situated outside of temperate Europe, in the region of the Indian Ocean, and is not currently expected to have continuous arboviral transmission events. However, this example does give an indication of the scale of potential outbreaks.

3.3 Response Capacity and Its Limits (RQ3)

Outbreaks can be controlled if they are detected early enough. This has already been shown for an outbreak of chikungunya in the summer of 2025 in Bergerac. The cases were actively searched for, and, following the identification of the first cases, vector control was put in place to try and bring the outbreak under control [1]. Modeling of previous outbreaks in Italy, where all of the outbreaks had occurred in areas with well-established surveillance systems for arboviruses, also found that control measures could be put in place and brought under control within about 2 weeks of the outbreak being identified [3].

However, other factors, for example, differences in practice between countries/regions, undiagnosed cases of dengue and cross-reactivity with other flaviviruses (e.g. Zika virus, West Nile virus) in current serological tests [6] could also have an impact on the time of detection of a new outbreak of disease.

Vaccination against dengue and chikungunya is another important tool. Although the dengue vaccine TAK-003 has not been recommended for use in mass immunization campaigns because of the risk of enhanced disease due to serotype 2 in dengue-naive individuals, it could be considered for individuals who travel to endemic countries and have increased risk of infection [9,10]. The live-attenuated chikungunya vaccine

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VLA1553 (IXCHIQ) was approved by the US Food and Drug Administration for the prevention of Chikungunya disease and has been authorized in the European Union for this indication. A virus-like-particle (VLP) vaccine candidate for chikungunya is in late-stage clinical evaluation [11,12]. A safety review of the vaccine VLA1553 (IXCHIQ) by the EMA following the La Réunion outbreak has established a restriction in relation to use in adults of 60 years of age and above [13]. As for the dengue vaccine, recommendations for the use of dengue and chikungunya vaccines in different countries are very diverse [14]. Therefore, in addition to the established mechanisms for the control of outbreaks of vector-borne diseases in Europe that are, however, not suitable for the early stages of an outbreak, there is a need for strengthening of the surveillance.

4. Discussion

The main message from the three research questions is that there is a single causal chain of factors that are increasing the climatic suitability of arboviral vectors. These factors (climate change, vector presence, and importation) are acting multiplicatively to increase the transmission risk, which is converted into an increased number of earlier and more frequent local outbreaks that will arise before systems can detect and contain them. An abundant urban *Aedes albopictus* population, an extended season of transmission, and ongoing importation of cases all contribute to a high risk of self-sustaining arboviral transmission.

The real question is how often outbreaks occur and how fast arboviruses spread to new latitudes. Improved surveillance might account for part of the observed increase in autochthonous cases, but temperature–hazard relationships studied in this review clearly indicate an increase in dengue transmission risk under a warming climate. However, the exact increase in risk remains to be determined. Containing outbreaks that have already been detected is in general possible. However, detection of outbreaks takes a lot of time, and therefore, the main constraint on containing outbreaks is not the response capacity but rather the time it takes for detection. As the ecological determinants of vector expansion act as multipliers [15], every newly colonized metropolitan area will become a new potential ignition point earlier than in the past. Therefore, it is not sufficient to intervene with a single measure, such as vector control or vaccination. An integrated One Health approach is needed, which uses temperature, vector-abundance, and importation data to set up early-warning systems that are able to detect the establishment of arboviruses before the first case appears in humans [2-4, 15].

4.1 Limitations

There are, however, several limitations inherent to this review. Firstly, the majority of single review papers that have investigated the key drivers of change for arboviral disease have been conducted as separate review papers and hence, at present, there is a lack of an integrated review paper that considers vector presence, climatic suitability and importation pressure within the framework of a single review paper (i.e. within the framework of this review paper). Importantly, the included studies varied with respect to study design, geographic location, and case definition. Furthermore, given that this review was of a narrative design, there is a greater potential for bias (i.e. selection and interpretation) in the synthesis of the included studies (i.e. in the findings) than would be the case in a systematic review of similar scope and objective. Importantly, for RQ2 (i.e. are there increases in numbers of autochthonous cases in Europe, and if so what are the reasons for such increases), surveillance for arboviral transmission (i.e. for vector-borne arboviral diseases) and for dengue and chikungunya in particular, and for case detection in general, varies between countries and even between regions within countries. Hence, some of the year-by-year numbers of cases and of outbreaks, for example, are likely to have been based upon sources of uneven quality [6]. RQ2 therefore cannot yet be answered with confidence. In addition to the limitations listed above, the forward projections in the included studies [2-4,7-10,15] depend upon a number of assumptions some of which are highly uncertain (e.g. future greenhouse-gas emissions). The evidence from many of the included studies [2-4,7-10,15] has been generated in countries with the most developed systems for surveillance for arboviral diseases (i.e. in France and in Italy), and hence there is a potential for underestimation of the extent of arboviral disease transmission in areas where there is a less than optimal system for detection of arboviral disease cases.

4.2 Future Research Directions

Future studies should aim to develop indicators to monitor the *Aedes*-borne arboviral disease transmission/detection in a harmonized manner across countries/regions and to develop early warning systems

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that integrate climate, vector, and importation information to anticipate outbreaks. Lastly, a systematic review should be conducted to evaluate the dengue and chikungunya vaccine policies for travelers to European countries from a global perspective.

5. Conclusion

This review gathered data and analyzed information regarding the *Aedes*-transmitted arboviruses in temperate Europe. The authors demonstrated how the increased climatic suitability, vector presence, and importation pressure act as multipliers to increase the transmission risk. However, the current surveillance, diagnostic, and vaccine policies for dengue and chikungunya are not sufficient to support a sustainable and anticipatory surveillance and response system. The current systems are mainly reactive, with a detection latency that prevents an effective control of newly established outbreaks, which are in part self-sustaining. Thus, European countries are shifting from considering arboviral outbreaks mainly as importation events to recognizing partially self-sustaining transmission cycles in newly colonized metropolitan areas. An anticipatory One Health approach is needed to set up early warning systems for arboviral diseases in European populations, which use temperature, vector abundance, and importation data.

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Conflicts of Interest

The authors declare no conflict of interest.

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