Aedes albopictus invasion across Africa: the time is now for cross-country collaboration and control

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The distribution of *Aedes albopictus* across west Africa is well documented. However, little has been done to synthesise data and establish the current distribution of this invasive vector in central and east Africa. In this Viewpoint, we show that *A albopictus* is establishing across Africa, how this is potentially related to urbanisation, and how establishment poses risks of near-term increases in arbovirus transmission. We then use existing species distribution maps for *A albopictus* and *Aedes aegypti* to produce consensus estimates of suitability and make these estimates accessible. Although urban development and increased trade have economic and other societal gains, the resulting potential changes in *Aedes*-borne virus epidemiology require a discussion of how cross-country collaboration and mitigation could be facilitated. Failure to respond to species invasion could result in increased transmission of *Aedes*-associated pathogens, including dengue, chikungunya, and Rift Valley fever viruses.

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See **Online** for appendix

Introduction

In March, 2022, WHO launched the Global Arbovirus Initiative,[1] a strategic plan to tackle re-emerging arboviruses with epidemic potential. Three arboviruses—Rift Valley fever virus, chikungunya virus, and Zika virus—are also listed on the WHO Priority Blueprint,[2] targeting them for research and development because of geographical expansion and propensity to cause epidemics. Alongside these re-emerging arboviruses, at least 33 other mosquito-borne viruses are present in Africa.[3] Historically, however, aside from Rift Valley fever virus, evidence suggests limited outbreaks of arboviral disease in Africa.[4] The extent to which this is due to spatially restricted, low-level transmission or under-reporting is unknown. Mordecai and colleagues[5] presented evidence of spatially restricted transmission of arboviruses because of the current climate but argued that disease burden could change from malaria to arboviruses in the next 30–50 years due to climate change. In this Viewpoint, we argue that the epidemiology of at least five arboviruses is already changing in Africa due to urbanisation and the spread of invasive *Aedes* mosquitoes. Therefore, the time for increased, coordinated surveillance and control of arboviral infections across Africa is now.

The complex biology of domestic *Aedes* in Africa

Molecular studies using microsatellite loci support the separation of *Aedes aegypti* into two distinct subspecies: *Aedes aegypti aegypti* and the ancestral *Aedes aegypti formosus*, which is native to Africa.[6,7] *A a aegypti* is the most important vector of dengue virus, chikungunya virus, and Zika virus globally. Evidence suggests that it evolved from *A a formosus*, adapting to human-dominated environments facilitated by ships travelling from Africa to the Americas during the 19th century and early 20th century.[8] *A a formosus* was historically found in forested areas, with larval habitats in tree holes and a feeding preference predominantly for non-human hosts. However, this subspecies has been recorded in peri-urban and urban areas in the past decade and, with larval habitats including artificial containers, suggests adaptation to deforestation and urbanisation in Africa.[9] Furthermore, *A a aegypti* has now been recorded in coastal areas of Africa, probably being reintroduced and hybridised with *A a formosus*.[10] The introduction of *A a aegypti* to Africa and hybridisation with *A a formosus* has implications for arbovirus transmission. Aubry and colleagues[11] showed that *A a aegypti* is more competent for dengue virus and Zika virus than *A a formosus*. This provides a potential explanation for increased reporting of arbovirus outbreaks in west Africa in the past 10 years.[4] Although we are not aware of studies comparing the competence of *Aedes albopictus* with *A aegypti* for *Aedes*-borne viruses, the effects of the reintroduction of *A a aegypti* in Africa might be exacerbated by the invasion of *A albopictus*, with two competent arbovirus vectors now emerging in peri-urban and urban environments.

A albopictus invasion and peri-urbanisation

The first published observations of *A albopictus* in mainland Africa are from approximately 30 years ago in Nigeria and South Africa (figure 1; appendix p 8).[13] Subsequent records of *A albopictus* are absent from South Africa. Whether this is due to effective prevention measures, little or no thorough surveillance, or other factors (eg, low environmental suitability) requires further assessment. After establishment in Nigeria, the species was detected in Cameroon in 1999, Gabon in 2006, the Central African Republic in 2009, and the Republic of the Congo in 2011 (figure 1; appendix p 8). Between 2012 and 2022, *A albopictus* was detected in an additional eight African countries. Genetic analyses support that the establishment of *A albopictus* in Cameroon and the Central African Republic occurred near to the years of first detection.[14,15] Further genetic studies are, however, required to improve understanding of the origin, distribution, and variation of *A albopictus* populations across Africa.

The spread of *A albopictus* across Africa and emergence of frequent arboviral outbreaks is probably facilitated by increasing trade and urbanisation. Increased global

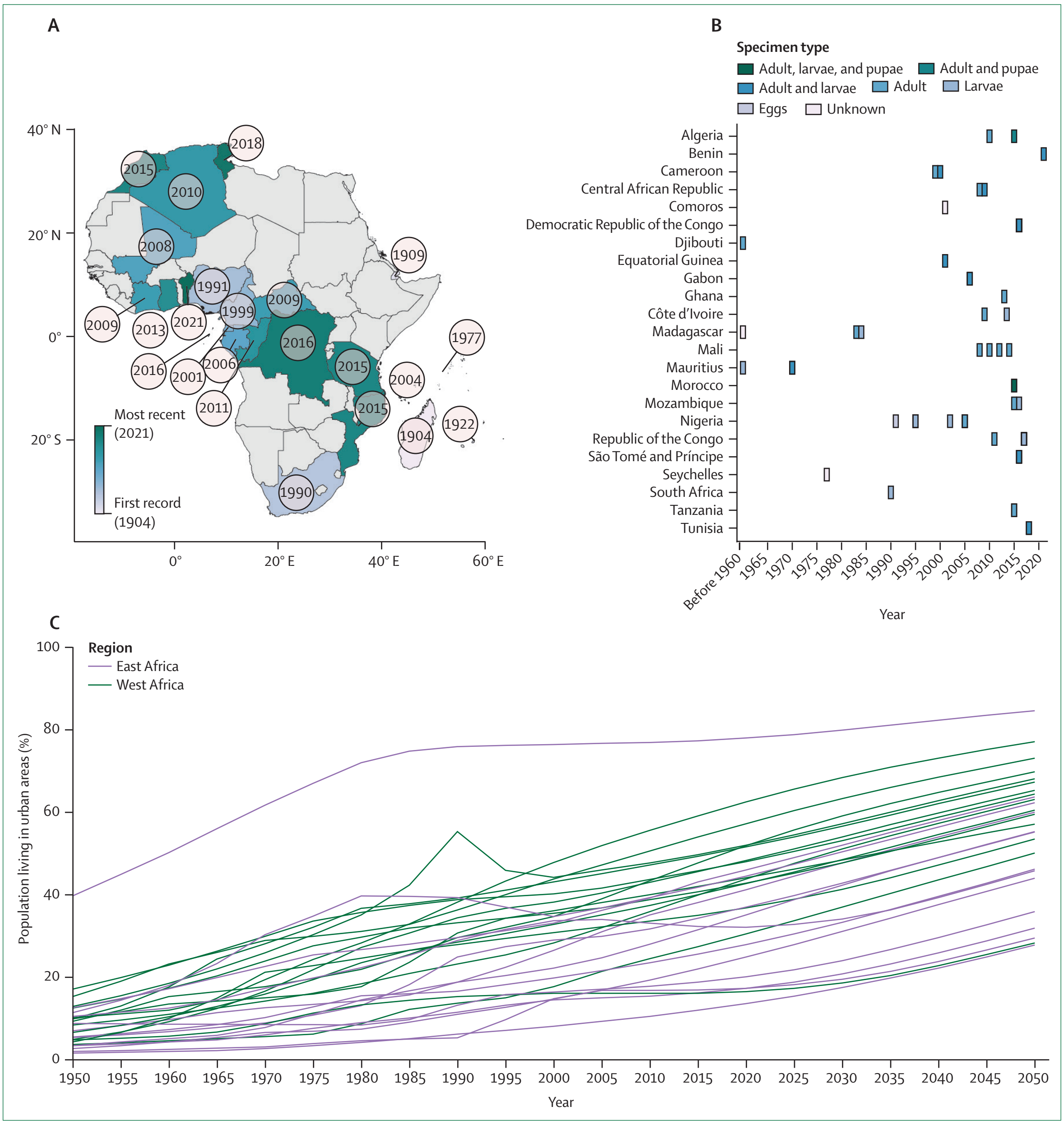

***Figure 1:* *Aedes albopictus* emergence in Africa**

(A) Year of first detection of *A albopictus* in each country. Map created with Quantum Geographic Information System version 3.4.4. (B) Life stages detected per country. The presence of multiple life stages, we assume, implies strong evidence of species establishment. Generated with ggplot2 version 3.3.5 and R version 4.0.5. (C) Changes in urbanicity in east and west Africa between 1950 and 2050. Data from World Bank.[12] East Africa includes Burundi, Djibouti, Eritrea, Kenya, Malawi, Mozambique, Rwanda, Somalia, South Sudan, Tanzania, Uganda, Zambia, and Zimbabwe. West Africa includes Benin, Burkina Faso, Côte d'Ivoire, The Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, and Togo. Generated with ggplot2 version 3.3.5 and R version 4.0.5.

For **QGIS** see https://www.qgis.org

For **ggplot2** see https://ggplot2.tidyverse.org/

connectivity has accelerated insect spread,[8] with *A albopictus* now present on every continent except Antarctica.[16] Urbanisation changes several dynamics associated with suitability for both *A a aegypti* and *A albopictus*, including increased artificial larval habitats and increased density of human hosts.[17] Epidemics of *Aedes*-borne viruses have long been associated with urban areas in South America and Asia.[18,19] We propose that until the early 2000s, many African countries might not have had sufficiently connected and populated urban and peri-urban areas to support the widespread invasion of *A a aegypti* and *A albopictus*, unlike countries in South America and Asia. In 1960, the earliest year for which global urbanisation and total population data are available, a mean 52% of populations in South American countries lived in urban areas compared with approximately 15% in west Africa and 17% in east Africa.[12] African countries have since rapidly urbanised, with a steady increase in the proportion of the population living in urban areas (figure 1). During 2020, this proportion increased to a mean 48% in west Africa and 31% in east Africa (appendix p 7). Past and future spread of *A albopictus* and *A a aegypti* have been analysed for the USA and Europe, incorporating forecasted changes in urbanisation and human mobility.[20] Similar estimates for Africa are based only on models fit to US species-occurrence data and with human mobility forecasts only from Namibia. As also acknowledged by Kraemer and colleagues,[20] these model extrapolations are probably inadequate for predicting spread dynamics in Africa. However, because of the paucity of longitudinal entomological data, these extrapolations are the only currently available estimates.

Epidemiological implications

Outside Africa, *A albopictus* has been implicated in major outbreaks of dengue virus and chikungunya virus.[21] *A albopictus* is more frequently associated with peri-urban environments and generalist blood-feeding than *A a aegypti*, with their ecological niches only partly overlapping. These features have implications not only for dengue virus, chikungunya virus, and Zika virus, but also for the role of *A albopictus* in potentially changing the epidemiology of Rift Valley fever virus and yellow fever virus. *A albopictus* is competent for both viruses and, because of its generalist host-feeding behaviour, might affect transmission from wildlife to humans.[22] The potential role of *A albopictus* in Rift Valley fever virus transmission in peri-urban areas remains to be quantified (NE/W003333/1). However, there is also evidence implicating *A albopictus* in yellow fever virus transmission, leading to urban outbreaks occurring due to the sylvatic transmission cycle.[23]

Although we agree with Mordecai and colleagues[5] that the burden of disease associated with *A aegypti* might increase because of increased climatic suitability for this species in the next 30–50 years, areas of central and east Africa are suitable for *A albopictus* and could currently be suitable for arbovirus transmission facilitated by this species.

Through a systematic review of the literature, Buchwald and colleagues[4] showed that the frequency and burden of *Aedes*-borne arboviral outbreaks in west Africa have shifted from rural to urban areas, resulting in increasingly large epidemics, with *A albopictus* being an important vector in this region. Outbreaks of dengue virus and chikungunya virus in Cameroon and Gabon coincide with the spread of *A albopictus* in these countries.[24] *A albopictus* was subsequently shown to be the main vector of chikungunya virus, dengue virus, and Zika virus during the outbreaks in Gabon in 2007.[24–26] Furthermore, earlier outbreaks of dengue virus in the Seychelles were associated with *A albopictus*,[27] and this species was a contributing vector to an outbreak of chikungunya virus in the Republic of the Congo in 2011.[28] Vector competence experiments with field-collected mosquitoes also show the ability of *A albopictus* to transmit these viruses in countries such as Morocco (ie, chikungunya virus, dengue virus, Zika virus, and yellow fever virus),[29] and the Central African Republic (ie, chikungunya virus).[30]

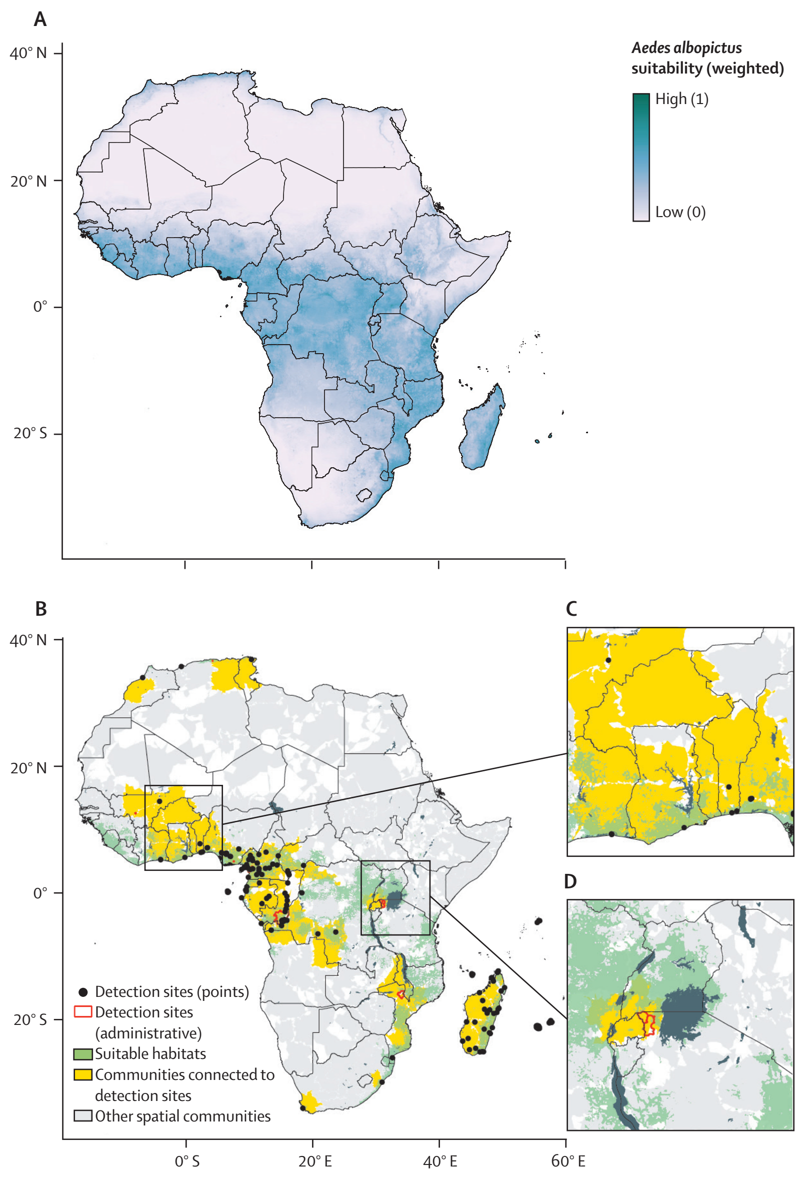

***Figure 2:* *Aedes albopictus* environmental suitability and road-connected communities that could inform surveillance**

(A) Mean weighted environmental suitability for *A albopictus* across Africa derived from synthesising existing niche mapping estimates (appendix p 2). (B) Spatial communities connected via roads to sites where *A albopictus* has been detected, indicating potential routes of road-based spread. Yellow areas indicate communities connected via roads to known detection sites. Green areas indicate suitable habitats for *A albopictus*, established by our consensus approach. A binary surface was obtained by overlaying known occurrence records and the weighted consensus surface to identify a threshold value containing 90% of observations. (C) Zoomed image of sections of west Africa. (D) Zoomed image of sections of east Africa. Maps created with Quantum Geographic Information System version 3.4.4.

In the past decade, arbovirus infections have been reported in east African countries that previously had not reported or detected these diseases, including chikungunya virus in Ethiopia (2016 onwards) and Rwanda (2015),[31–33] dengue virus in Ethiopia (2013 onwards),[34] and Zika virus in Sudan (2012).[35] Both Ethiopia and Sudan have low environmental suitability for *A albopictus* according to our consensus map (figure 2); however, increased arbovirus transmission in these countries might be related to *A a aegypti* presence. Similarly, *A albopictus* might be established in countries where potential arboviruses have not yet been detected. Buchwald and colleagues[4] recommended capacity strengthening and increased disease surveillance in west Africa. We argue that these recommendations do not only apply to west Africa as east and central Africa are at risk of the effects of urbanisation and the invasion of non-native *Aedes*.

Facilitating cross-country surveillance and control

Establishing the extent of *A albopictus* spread, particularly across east Africa, is required to inform predictions of *Aedes*-borne virus risk and to focus control. For most African countries, the occurrence of *A albopictus* is known only from sporadically surveyed locations, or from studies focused on other disease vectors (appendix p 8). As argued by Kraemer and colleagues,[15] maps of predicted environmental suitability can be used to prioritise surveillance efforts in places where *A albopictus* has not yet been reported. However, their use is dependent on accessibility to stakeholders, alongside information on prediction uncertainty. Through systematic searches (appendix p 2), we identified ten maps for *A albopictus* and 13 maps for *A aegypti*. Of these maps, we were able to obtain nine georeferenced files for *A albopictus* and eight georeferenced files for *A aegypti* to produce consensus surfaces and surfaces detailing model uncertainty (figure 2; appendix pp 2–3). Our consensus maps are available for download for 12 months after publication of this Viewpoint via an interactive app.

For the **interactive app** see https://www.lstmed.ac.uk/projects/aedes-distribution-maps

Road and river transport, as well as airports and seaports, probably facilitate within-country and between-country spread of *A albopictus*.[36–38] However, the relative contribution of each of these routes to the spread of *A albopictus* across Africa is unknown. We advocate further research in this area. For example, focusing on roads, we identified connected communities in which *A albopictus* spread is most probable using network analysis detailed by Strano and colleagues[39] (appendix pp 3–4) and overlaying the output with known occurrence sites of *A albopictus* (figure 2). We show that there are communities spanning national borders where *A albopictus* has been detected in one country but not the other. These communities include one in northwest Tanzania that is connected to Uganda, Rwanda, and the Democratic Republic of the Congo and detection sites in Benin and Ghana that are connected to Togo and Burkina Faso (figure 2). These interconnected communities are risks for the road-based transport of *A albopictus* to African countries that have yet to report *A albopictus* populations. Communities in the vicinity of known occurrence sites of *A albopictus* could be included in surveillance operations to identify possible areas of expansion; connected communities spanning multiple countries require cross-country discussion and collaboration with regards to surveillance efforts.

As per the WHO Regional Framework for monitoring invasive species, management approaches for *Aedes* control can be grouped into prevention, surveillance, and response.[40] Prevention applies to environmentally suitable countries that are yet to record established populations of *A albopictus* and involves preventing and anticipating vector introduction. Surveillance applies to countries where *A albopictus* populations have been detected and involves monitoring local populations and preventing further spread. Response applies to countries where *A albopictus,* or *Aedes*-borne viruses, are fully established or anticipated and control is required to prevent large-scale outbreaks. For countries such as those in east Africa, maps (figure 2) could be used to inform sentinel surveillance at sites of potential introduction. *A albopictus* surveillance could also be integrated into entomological surveillance programmes for malaria or other vector-borne diseases.[41] Comprehensive surveillance operations have proven effective in preventing *A albopictus* invasion, as shown by seaport surveillance in South Africa[42] and by control at ports in other continents.[43] We acknowledge that we have focused on road-based spread of *A albopictus* and that quantifying transmission by other routes, including rivers, sea, and air, would be valuable.

The COVID-19 pandemic clearly showed that working in isolation does not contribute to success in global health security, and that countries do not have uniform surveillance capacities for the detection and monitoring of health threats. Multicountry collaborations would allow some countries to use skills from neighbouring countries and facilitate the sharing of available resources to quickly detect invasive disease vectors and associated arboviruses and institute control strategies. These collaborations would enable learning and sharing of best practices and would help establish continent-level early warning systems, which is an aim of the Africa Centres for Disease Control and Prevention via the establishment of Regional Collaborating Centres.[44] Such centres have focused on strengthening surveillance and laboratory systems in response to disease outbreaks. However, they should also be used to report invasive vectors.

Regarding existing surveillance systems, east African member states implemented the Integrated Disease Surveillance and Response in 1998, a strategy developed by WHO Regional Office for Africa, for strengthening communicable diseases surveillance in their countries.[45] Other efforts include the East African Integrated Disease

Search strategy and selection criteria

We searched Web of Science to identify research articles reporting the first detection of *Aedes albopictus* in African countries between database inception and April 28, 2022. The search terms used were “albopictus” AND <country>, where the country was one of 54 African countries (appendix p 7). There were no date or language restrictions. The title and abstract of returned articles were screened with the inclusion criteria: indication that *A albopictus* was detected in the country and that the country reporting detection was one of the 54 African countries of interest. The full text was obtained for 178 (98·89%) of 180 articles meeting the criteria. We processed full-text articles in chronological order. For each country, we stopped screening manuscripts when we had established that all life stages of *A albopictus* were detected (ie, adults, pupae, larvae, and eggs). If only one life stage was reported in a publication, the next publication in chronological order was screened for that country and information on additionally detected life stages was recorded, if applicable. All articles identified for full-text screening were processed. However, data were not extracted if a country had reported the detection of all life stages at a previous date.

Surveillance Network, which aims to combine disease surveillance systems in the region.[46] Highlighting health threats in neighbouring countries is good practice and should lead to immediate multicountry collaboration on how to mitigate the risks of these threats. Furthermore, the African Union has established a continental watch that produces multihazard analyses once a week that aim to provide early warning information to different member states. Analysis of *A albopictus* distribution across Africa should be among the key variables considered in such systems, with its inclusion leading to multicountry collaboration through a clearly defined framework approved and upheld by member states.

An online app facilitating access to georeferenced data on *Aedes* and *Aedes*-borne viruses in Africa could be useful for the WHO Global Arbovirus Initiative and could be used to facilitate cross-country surveillance and reporting. A centralised app could also provide information on different interventions that could be implemented to mitigate *A albopictus* spread and distribution, establishing best practices that could enable learning and comparing for regional *A albopictus* control. The development of an intracountry app will not only help to monitor the distribution of *A albopictus* in the region, but would also assist in quickly detecting associated arbovirus disease outbreaks. Systems exist that could incorporate such a dashboard. We have reached out to members of the WHO Integrated Disease Surveillance and Response strategy to discuss the possibility of incorporating an *A albopictus* surveillance dashboard in their existing framework. Furthermore, we have developed a prototype app that can be accessed for 12 months after publication of this Viewpoint. We anticipate that our consensus maps will support multicountry surveillance for the detection and monitoring of *A albopictus* and other arbovirus vectors in the region, with the increased detection of this species in African countries during the past decade warranting immediate cross-country collaboration and response.

Contributors

JL and JSL conceptualised this Viewpoint and curated, validated, and visualised the data. JL analysed the data and established the methods. JSL acquired funding. JL, AWW, and JSL wrote the original draft. All authors interpreted the data and reviewed and edited this Viewpoint.

Declaration of interests

We declare no competing interests.

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References

1 WHO. Launch of the Global Arbovirus Initiative. 2022. https://www.who.int/news-room/events/detail/2022/03/31/default-calendar/global-arbovirus-initiative (accessed Oct 26, 2022).

2 WHO. Blueprint for R&D preparedness and response to public health emergencies due to highly infectious pathogens. 2015. https://www.who.int/publications/m/item/blueprint-for-r-d-preparedness-and-response-to-public-health-emergencies-due-to-highly-infectious-pathogens (accessed Oct 26, 2022).

3 Braack L, Gouveia de Almeida AP, Cornel AJ, Swanepoel R, de Jager C. Mosquito-borne arboviruses of African origin: review of key viruses and vectors. *Parasit Vectors* 2018; **11:** 29.

4 Buchwald AG, Hayden MH, Dadzie SK, Paull SH, Carlton EJ. *Aedes*-borne disease outbreaks in west Africa: a call for enhanced surveillance. *Acta Trop* 2020; **209:** 105468.

5 Mordecai EA, Ryan SJ, Caldwell JM, Shah MM, LaBeaud AD. Climate change could shift disease burden from malaria to arboviruses in Africa. *Lancet Planet Health* 2020; **4:** e416–23.

6 Powell JR. Mosquitoes on the move. *Science* 2016; **354:** 971–72.

7 Gloria-Soria A, Ayala D, Bheecarry A, et al. Global genetic diversity of *Aedes aegypti*. *Mol Ecol* 2016; **25:** 5377–95.

8 Tatem AJ, Hay SI, Rogers DJ. Global traffic and disease vector dispersal. *Proc Natl Acad Sci USA* 2006; **103:** 6242–47.

9 Xia S, Dweck HKM, Lutomiah J, et al. Larval sites of the mosquito *Aedes aegypti formosus* in forest and domestic habitats in Africa and the potential association with oviposition evolution. *Ecol Evol* 2021; **11:** 16327–43.

10 Rose NH, Sylla M, Badolo A, et al. Climate and urbanization drive mosquito preference for humans. *Curr Biol* 2020; **30:** 3570–79.

11 Aubry F, Dabo S, Manet C, et al. Enhanced Zika virus susceptibility of globally invasive *Aedes aegypti* populations. *Science* 2020; **370:** 991–96.

12 The World Bank. Population, total. 2022. https://data.worldbank.org/indicator/SP.POP.TOTL?most_recent_year_desc=false (accessed Oct 26, 2022).

13 Savage HM, Ezike VI, Nwankwo AC, Spiegel R, Miller BR. First record of breeding populations of *Aedes albopictus* in continental Africa: implications for arboviral transmission. *J Am Mosq Control Assoc* 1992; **8:** 101–03.

14 Kamgang B, Ngoagouni C, Manirakiza A, Nakouné E, Paupy C, Kazanji M. Temporal patterns of abundance of *Aedes aegypti* and *Aedes albopictus* (Diptera: Culicidae) and mitochondrial DNA analysis of *Ae albopictus* in the Central African Republic. *PLoS Negl Trop Dis* 2013; **7:** e2590.

15 Kamgang B, Brengues C, Fontenille D, Njiokou F, Simard F, Paupy C. Genetic structure of the tiger mosquito, *Aedes albopictus*, in Cameroon (Central Africa). *PLoS One* 2011; **6:** e20257.

16 Kraemer MUG, Sinka ME, Duda KA, et al. The global distribution of the arbovirus vectors *Aedes aegypti* and *Ae albopictus*. *eLife* 2015; **4:** e08347.

17 Gratz NG. Emerging and resurging vector-borne diseases. *Annu Rev Entomol* 1999; **44:** 51–75.

18 Njoh AJ. Urbanization and development in sub-Saharan Africa. *Cities* 2003; **20:** 167–74.

19 Brathwaite Dick O, San Martín JL, Montoya RH, del Diego J, Zambrano B, Dayan GH. The history of dengue outbreaks in the Americas. *Am J Trop Med Hyg* 2012; **87:** 584–93.

20 Kraemer MUG, Reiner RC Jr, Brady OJ, et al. Past and future spread of the arbovirus vectors *Aedes aegypti* and *Aedes albopictus*. *Nat Microbiol* 2019; **4:** 854–63.

21 Rezza G. *Aedes albopictus* and the reemergence of dengue. *BMC Public Health* 2012; **12:** 72.

22 Gubler DJ. *Aedes albopictus* in Africa. *Lancet Infect Dis* 2003; **3:** 751–52.

23 Centers for Disease Control. *Aedes albopictus* introduction into continental Africa, 1991. *MMWR Morb Mortal Wkly Rep* 1991; **40:** 836–38.

24 Paupy C, Ollomo B, Kamgang B, et al. Comparative role of *Aedes albopictus* and *Aedes aegypti* in the emergence of dengue and chikungunya in central Africa. *Vector Borne Zoonotic Dis* 2010; **10:** 259–66.

25 Leroy EM, Nkoghe D, Ollomo B, et al. Concurrent chikungunya and dengue virus infections during simultaneous outbreaks, Gabon, 2007. *Emerg Infect Dis* 2009; **15:** 591–93.

26 Grard G, Caron M, Mombo IM, et al. Zika virus in Gabon (central Africa)—2007: a new threat from *Aedes albopictus? PLoS Negl Trop Dis* 2014; **8:** e2681.

27 Metselaar D, Grainger CR, Oei KG, et al. An outbreak of type 2 dengue fever in the Seychelles, probably transmitted by *Aedes albopictus* (Skuse). *Bull World Health Organ* 1980; **58:** 937–43.

28 Mombouli JV, Bitsindou P, Elion DO, et al. Chikungunya virus infection, Brazzaville, Republic of the Congo, 2011. *Emerg Infect Dis* 2013; **19:** 1542–43.

29 Amraoui F, Ben Ayed W, Madec Y, et al. Potential of *Aedes albopictus* to cause the emergence of arboviruses in Morocco. *PLoS Negl Trop Dis* 2019; **13:** e0006997.

30 Ngoagouni C, Kamgang B, Kazanji M, Paupy C, Nakouné E. Potential of *Aedes aegypti* and *Aedes albopictus* populations in the Central African Republic to transmit enzootic chikungunya virus strains. *Parasit Vectors* 2017; **10:** 164.

31 Mengesha Tsegaye M, Tayachew A, Belay D, Alemu A, Beyene B. The first laboratory confirmation of chikungunya outbreak in Ethiopia. *Virus Evolution* 2019; **5** (suppl 1)**:** A35 (abstr).

32 Takele D. Factors associated with chikungunya fever virus outbreak in Ethiopia, June 2016. *Int J Infect Dis* 2020; **101:** 246.

33 Seruyange E, Ljungberg K, Muvunyi CM, et al. Seroreactivity to chikungunya and West Nile viruses in Rwandan blood donors. *Vector Borne Zoonotic Dis* 2019; **19:** 731–40.

34 Abyot Bekele W, Mesfin M, Wubayehu K, et al. The first acute febrile illness investigation associated with dengue fever in Ethiopia, 2013: a descriptive analysis. *Ethiop J Health Dev* 2016; **28:** 155–61.

35 Soghaier MA, Abdelgadir DM, Abdelkhalig SM, et al. Evidence of pre-existing active Zika virus circulation in Sudan prior to 2012. *BMC Res Notes* 2018; **11:** 906.

36 Eritja R, Palmer JRB, Roiz D, Sanpera-Calbet I, Bartumeus F. Direct evidence of adult *Aedes albopictus* dispersal by car. *Sci Rep* 2017; **7:** 14399.

37 Miller MJ, Loaiza JR. Geographic expansion of the invasive mosquito *Aedes albopictus* across Panama—implications for control of dengue and chikungunya viruses. *PLoS Negl Trop Dis* 2015; **9:** e0003383.

38 Müller GC, Tsabari O, Traore MM, et al. First record of *Aedes albopictus* in inland Africa along the River Niger in Bamako and Mopti, Mali. *Acta Trop* 2016; **162:** 245–47.

39 Strano E, Viana MP, Sorichetta A, Tatem AJ. Mapping road network communities for guiding disease surveillance and control strategies. *Sci Rep* 2018; **8:** 4744.

40 van den Berg H, Velayudhan R, Ejov M. Regional framework for surveillance and control of invasive mosquito vectors and re-emerging vector-borne diseases (2014–2020). 2013. https://apps.who.int/iris/handle/10665/344862 (accessed Oct 26, 2022).

41 Chanda E. Disregarding reservoirs of disease vectors: a surveillance paradox in Africa. *EClinicalMedicine* 2020; **29-30:** 100629.

42 Cornel AJ, Hunt RH. *Aedes albopictus* in Africa? First records of live specimens in imported tires in Cape Town. *J Am Mosq Control Assoc* 1991; **7:** 107–08.

43 van den Hurk AF, Nicholson J, Beebe NW, et al. Ten years of the tiger: *Aedes albopictus* presence in Australia since its discovery in the Torres Strait in 2005. *One Health* 2016; **2:** 19–24.

44 Africa Center for Disease Control and Prevention. Regional collaborating centres. 2022. https://africacdc.org/regional-collaborating-centres/ (accessed Oct 26, 2022).

45 Mghamba JM, Mboera LEG, Krekamoo W, et al. Challenges of implementing an integrated disease surveillance and response strategy using the current health management information system in Tanzania. *Tanzan Health Res Bull* 2004; **6:** 57–63.

46 East African Community. East African Integrated Disease Surveillance Network. 2022. https://www.eac.int/health/disease-prevention/east-african-integrated-disease-surveillance-network (accessed Oct 26, 2022).