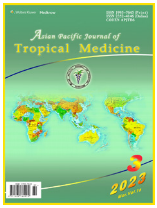

Perspective

Asian Pacific Journal of Tropical Medicine

apjtm.org

doi: 10.4103/1995-7645.372287

Impact Factor: 3.041

Why Kenya should worry about *Anopheles stephensi*

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On the 18th of February, the Kenya Medical Research Institute (KEMRI) raised an alarm that it had detected *Anopheles (An.) stephensi* in Laisamis and Saku sub counties of Marsabit county during a routine mosquito surveillance[1,2]. Up until this announcement, the invasive mosquito had been reported in other horn of African countries: Djibouti (2012), Ethiopia (2016), Sudan 2021, Somali and Yemen 2019, Somaliland 2022 and even in Nigeria in 2020[2]. It is believed that the mosquito, competent in transmitting the two malaria parasites that pose the greatest risk: *Plasmodium falciparum* and *Plasmodium vivax* originated from South Asia and the Middle East, including large parts of the Arabian Peninsula[3].

The announcement caused great alarm in the local media. According to Kenya malaria indicator survey of 2020, prevalence of malaria in Kenya stands at 5.8% with an estimated 3.5 million new clinical cases and 10 700 deaths reported in the country every year[4]. The risk is more on pregnant women and children. Until now, the malaria transmission in Kenya was driven by *An. gambiae* and *An. funestus* which are known to be the world's most efficient malaria vectors. However, these vectors have been limited to mainly the coast and western Kenya where the weather is warm and humid. Furthermore, malaria has historically been a disease confined to rural locations in Africa as the traditional malaria vectors (*An. gambiae s.l* and *An. funestus*) don't cope very well with polluted water in urban centres[5]. These factors have ensured that urban areas in Africa have remained malaria free.

However, *An. stephensis* thrives in urban settings. It is a container breeding mosquito and can breed in cisterns, jerrycans, tyres, open tanks, sewers, overhead tanks, underground tanks, and polluted environments. Furthermore, the mosquito is invasive, it spreads very fast to new areas and can adapt to various climatic conditions unlike the traditional malaria vectors whose survival in cold temperatures in high altitude areas was restricted. These characteristics are concerning because Kenyan urban centers and cities like Nairobi, Mombasa, Kisumu, Nakuru and Eldoret are expanding rapidly due to rural urban migration driven by powerful forces: rural poverty and the search for economic opportunity and landscape degradation and climate change. Already, about 40% of the African population is urban, and this proportion is expected to rise to 60% by 2050[6]. These cities are mostly riddled with poor waste management and sewage systems and lack reliable running water leading to storage of water everywhere. These coupled with over-crowding, offer perfect conditions for this *An. stephensi*.

To exacerbate the problem, many traditional anti-malaria tools are harder to implement against *An. stephensi* whose resting and feeding behaviours are quite different from other vectors. Most of the conventional intervention tools like insecticide residual spraying or long-lasting insecticidal nets may not work or may not be as effective to contain this species[7]. *An. stephensi* also exhibits an alarming resistance to most publicly available insecticides[8].

If *An. stephensi* spreads into cities like Nairobi, the consequences are likely to be serious. First, intense malaria could spread to the inner-city areas that, until now, have had little or no transmission. Since this mosquito feeds on human blood and is a perfect container breeder, our urban centers riddled with overcrowding and increased containers in the environment provide perfect conditions for it to thrive and spread the disease. To exacerbate the problem, most urban settings, like Nairobi have been areas of none to low malaria transmission thus the population don't have the acquired immunity against malaria and are likely to be knocked down very fast. Also, since these urban centres haven't been the focus for malaria control programmes, they are likely to be caught off guard in case of outbreaks. The ramifications will be great!

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How to cite this article: Owino EA. Why Kenya should worry about *Anopheles stephensi*. Asian Pac J Trop Med 2023; 16(3): 99-101.

Article history: Received 24 February 2023 Revision 13 March 2023
Accepted 20 March 2023 Available online 28 March 2023

Secondly, we will no longer be able to assume that in the long run, the process of urban development is inexorably bringing us closer to the goal of malaria elimination. So far, we have been lucky that while many health problems are exacerbated by the ongoing process of urbanization, malaria has tended to be "built out" with improved housing and gradual pollution of the landscape. The traditional malaria vectors (*An. gambiae* and *An. funestus*) cannot breed in small containers, or in water with organic pollution. However, with the new invasive species, we may find that when we build new suburbs, we are effectively building malaria into the landscape, not building it out like previously. Already, ongoing urbanization and immigration into urban centers have resulted in cities with extensive areas of urban agriculture, untended green space, and unplanned urban sprawl with poor water management; characteristics shared with rural sites. Consequently, mosquito vectors including both *An. arabiensis* and *An. gambiae* are able to maintain malaria transmission[5], in some cases, at prevalence rates up to 30 to 40%[9]. This coupled with new invasion by *An. stephensi* could pose a significant threat to Kenya's efforts to control and eliminate malaria.

Additionally, the malaria from the cities will be exported to the rural areas. Regions in western Kenya and the Coast where the more efficient traditional malaria vectors *An. gambiae* and *An. funestus* thrive and have a parasite reservoir present within the local human populations are likely to suffer more. Spikes are likely to occur especially after holiday seasons like Christmas when most town dwellers go on vacation in their rural homes to spend time with family. Furthermore, predictions show that the densely populated urban centers in these traditional malaria endemic zones are likely to suffer more from *An. stephensi* expansion due to high population density and conducive environmental and ecological factors like temperature[10].

In short, if *An. stephensi* does spread through urban Kenya, it will make a bad situation much worse. One study projected that *An. stephensis* could put an additional 126 million people in the world at risk of the disease if allowed to spread unchecked[10]. A good example is Djibouti which was on the verge of malaria elimination before the arrival of *An. stephensi* in 2012 when the country reported only 27 presumed or confirmed malaria cases. However, by 2020, the country's malaria caseload had reached over 73 000[7]. The mosquito is very competitive and efficient in malaria transmission[10]. This is a mosquito on the move whose establishment could have detrimental ramifications.

Therefore, Kenya must increase collaboration and encourage integrated management of *An. stephensi*. Since this is an urban malaria vector, there needs to be multisectoral collaboration. Ministries of Agriculture, Health, Education, Environment, Sanitation, Water Resources, and county governments all need to work together. Besides, national responses to *An. stephensi* should be integrated with efforts to control malaria and *Aedes (Ae.) aegypti*-borne diseases, such as dengue fever, yellow fever, and chikungunya where feasible. This can save both money and lives.

The country also needs to strengthen surveillance to determine the extent of the spread of *An. stephensi* and its role in transmission. Right now, we are still in the dark about the extent of the spread and the impact *An. stephensi* has on malaria transmission in Kenya. Confirming both would be important in laying down management strategies to protect against disease outbreaks, particularly in urban settings in the coming years. Besides, a better understanding of the role and invasive reach of *An. stephensi* may help scientists and public health officials track and trace its local mosquito relative *Ae. aegypti*. *Ae. aegypti*, the primary vector of arboviruses like dengue fever, chikungunya and yellow fever shares the same breeding sites with *An. stephensi*. Therefore, by trying to understand and deal with the issue of *An. stephensi* coming to Africa, health officials will also be understanding the problem of *Ae. aegypti* invading more areas than ever before.

Similarly, it would be necessary to develop guidance for national malaria control programmes on appropriate ways to respond to *An. stephensi*. The programme currently available was focused on dealing with the non-container breeding mosquitoes; *An. gambiae s.l* and *An. funestus* might not work effectively for the urban *An. stephensi*.

It would also be important to improve information exchange. Awareness of *An. stephensi* should be boosted in communities most at risk. They should be advised to frequently replenish stored water for domestic use and to keep their environments free of disposed of containers as these could be good breeding grounds for this invasive species.

Lastly, it would be vital to prioritize research to evaluate the impact of interventions and tools against *An. stephensi*. A global policy and cross-border collaboration between the affected countries in the horn of Africa might be necessary because with climate change and increased travel, the mosquito is likely to reach far and beyond Africa with catastrophic consequences. Eradicating *An. stephensi* from the horn of Africa would be much cheaper, in the long run, than leaving it to spread to towns and cities throughout Africa, and then spend many years using expensive and partially effective interventions. Just like in the *An. gambiae* invasion of Brazil in the 1930s, the world needs to mobilise vigorous, disciplined, and sustained campaigns to completely eradicate *An. stephensis*. If the world would have failed to eradicate *An. gambiae* from Brazil, we might for the last 80 years have seen African levels of malaria transmission intensity in much of South and Central America. Besides, billions of dollars would have been spent to sustain interventions and additional tens of millions of deaths recorded.

Conflict of interest statement

The author declares there is no conflict of interest.

Funding

The authors received no extramural funding for the study.

Author´s contributions

EAO conceived and drafted the manuscript. EAO revised critically and prepared the final version of the manuscript. EAO approved the manuscript for publication.

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