Advances in Entomology, 2026, 14(2), 111-129
https://www.scirp.org/journal/ae
ISSN Online: 2331-2017
ISSN Print: 2331-1991

A Review of Emerging Threats in Malaria Control: The Role of *Anopheles stephensi* in Nigeria's Urban Malaria Resurgence

Amarachi Keziah Ezeike[1], Simon Pierre Yinyang Danga[2*], Valentine Chukwuna Ezenwa[3], Chinaza Favour Chukas[1], Malachy Chigozie Ugwu[1], Udoka Chukwubuofu Nwangwu[4], Linda Onyeka Anagu[1], Angus Nnamdi Oli[1], Charles Okechukwu Esimone[1]

[1]Department of Pharmaceutical Microbiology and Biotechnology, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria
[2]Department of Biological Sciences, Faculty of Science, University of Garoua, Garoua, Cameroon
[3]Integrity Research Laboratory, Oko, Anambra State, Nigeria
[4]Federal Ministry of Health, National Arbovirus and Vectors Research Centre, Enugu, Enugu State, Nigeria
Email: *dangayisipi@yahoo.fr

How to cite this paper: Ezeike, A.K., Danga, S.P.Y., Ezenwa, V.C., Chukas, C.F., Ugwu, M.C., Nwangwu, U.C., Anagu, L.O., Oli, A.N. and Esimone, C.O. (2026) A Review of Emerging Threats in Malaria Control: The Role of *Anopheles stephensi* in Nigeria's Urban Malaria Resurgence. *Advances in Entomology*, **14**, 111-129.
https://doi.org/10.4236/ae.2026.142007

Received: January 22, 2026
Accepted: March 28, 2026
Published: March 31, 2026

Abstract

Anopheles stephensi, traditionally an Asian vector of malaria, has recently emerged as a significant threat in sub-Saharan Africa, including Nigeria. Unlike other malaria vectors, *An. stephensi* thrives in urban settings, exploiting artificial water sources, which facilitates its survival even in arid conditions. This adaptability raises public health concerns, as Nigeria, already facing a high malaria burden, now risks increased transmission in densely populated urban areas. This review provides a comprehensive analysis of the biology, ecology, and vectorial capacity of *An. stephensi*, alongside an assessment of its impact on malaria transmission dynamics in Nigeria. Notably, *An. stephensi* thrives in urban environments due to its preference for artificial water containers, raising the risk of malaria in densely populated cities. This paper outlines the challenges this vector poses to existing malaria control measures, which were primarily designed for rural settings, and examines *An. stephensi*'s resistance to traditional insecticides. Proposed strategies to address this emerging threat include enhanced surveillance, integrated vector management (IVM), genetic control methods, and community-based interventions. Without proactive intervention, *An. stephensi* may complicate Nigeria's malaria eradication efforts, necessitating coordinated, adaptive responses to limit its impact on public health.

Keywords

Anopheles stephensi, Malaria Threat, Malaria Control, Nigeria

1. Introduction

Malaria remains a significant global health concern, with sub-Saharan Africa bearing the highest burden, particularly due to *Plasmodium falciparum*, which causes the deadliest form of the disease. Malaria has historically been considered a disease confined to rural locations [1] [2]. Over 90 million people worldwide face a risk of contracting malaria every year. Nigeria alone accounts for a disproportionate share of the global malaria burden, contributing approximately 29% of all malaria cases and 26% of malaria-related deaths worldwide, according to recent World Health Organization estimates [3]. In 2023, this translated to over 75 million estimated malaria cases in Nigeria, underscoring the country's position as the epicentre of malaria transmission in sub-Saharan Africa [3]. Recent analyses of urban malaria transmission dynamics in south-eastern Nigeria further highlight how persistent vector populations and increasing insecticide resistance sustain this exceptionally high burden [4].

Current urbanization and immigration to urban centers have led to widespread urban agriculture, neglected green space, and unplanned urban sprawl with inadequate water management in cities. Such regions have similarities with rural locations, and thus mosquito vectors potentially harboring both *Anopheles arabiensis* and *Anopheles gambiae* can sustain malaria transmission at even 30% to 40% prevalence in some situations [5].

Since the Horn of Africa's Djibouti City reported an uncommon urban malaria outbreak in 2012, there have been yearly reports of outbreaks that are getting worse. Further research revealed the existence of *An. stephensi*, an Asian mosquito species that is known to flourish in urban settings. The World Health Organization issued a vector alert urging aggressive mosquito surveillance in the area after *An. stephensi* was discovered in Ethiopia, Sudan, and Nigeria since that initial report [6].

An. stephensi, indigenous to regions across South Asia and the Arabian Peninsula, has been extending its distribution throughout Africa in the past decade. It is reported to flourish in urban environments, in contrast to other malaria species that predominantly inhabit rural areas. Originating from its native region, it is recognized as an efficient vector for malaria, mostly due to its ability to transmit both *Plasmodium vivax* and the more lethal *P. falciparum*, which are responsible for the majority of human malaria cases [3].

An. stephensi favors artificial water storage, which enables it to persist throughout the year and maintain activity during arid periods, in contrast to *An. gambiae*, which flourishes in rural areas and during the wet season. Additionally, studies reveal that *An. stephensi* prefers to rest within barns or sheds instead of houses; thus, methods of controlling mosquitoes like protective nets and indoor chemical spraying might not work. The discovery of *An. stephensi* in Africa, which was first observed in Djibouti in 2012, took the continent by surprise because of the remarkable strides it had achieved in the fight against malaria. Although it has been further observed in Nigeria, Somalia, and Sudan, it might also exist in other nations. According to a recent study in The Lancet Global Health, immediate action is required to stop the proliferation of this vector because malaria could infect nations where the disease is not normally endemic [7]. Its capacity to survive dry seasons and flourish in urban environments has raised serious concerns. Given that over 40% of Africans live in cities, a 2020 study calculated that the *An. stephensi* mosquito would render a further 126 million individuals vulnerable to malaria infection [8].

2. Urban Malaria Epidemiology and the Emerging Threat of *Anopheles stephensi*

Malaria is a mosquito-borne disease transmitted exclusively by female *Anopheles* mosquitoes and remains a major public health challenge in tropical and subtropical regions, particularly sub-Saharan Africa [3]. While mosquitoes are also vectors of other diseases such as dengue, yellow fever, chikungunya, lymphatic filariasis, and viral encephalitides, malaria continues to account for the greatest burden of morbidity and mortality in the region [9] [10].

Traditionally, malaria transmission in Africa has been associated with rural environments, where dominant vectors such as *Anopheles gambiae* complex species breed in natural or semi-natural water bodies. However, rapid urbanization, population growth, and inadequate urban infrastructure have increasingly altered malaria epidemiology. Urban malaria transmission is now sustained by human-modified environments, including informal settlements, poor drainage systems, construction sites, and widespread domestic water storage practices, which provide stable breeding habitats for mosquitoes even in densely populated cities.

The emergence of *Anopheles stephensi* in Africa represents a fundamental shift in urban malaria risk. Unlike indigenous African vectors, *An. stephensi* is highly adapted to urban and peri-urban settings, readily exploiting artificial containers such as overhead tanks, wells, barrels, and discarded receptacles for breeding. Its ability to thrive in polluted water, tolerate a wide range of temperatures, and coexist closely with human populations has enabled it to drive major urban malaria outbreaks in South Asia and, more recently, the Horn of Africa.

Vector behavioural adaptability further complicates control efforts in urban environments. Although *Anopheles* mosquitoes are generally nocturnal, changes in biting behaviour, such as earlier evening feeding prior to bed net use, have been observed in African settings, partly in response to widespread insecticide-treated net coverage [11]. Such behavioural plasticity may enhance the transmission potential of *An. stephensi* in urban Nigeria, where conventional malaria control strategies have largely been designed for rural vectors.

Given Nigeria's rapid urban expansion and existing challenges in water management and vector surveillance, the establishment of *An. stephensi* poses a serious threat to malaria control gains. Its presence raises concerns about sustained urban transmission, an increased malaria burden in cities, and reduced effectiveness of traditional control interventions. Understanding the changing epidemiology of urban malaria is therefore critical for developing targeted surveillance and control strategies suited to Nigeria's evolving urban landscape.

3. *Anopheles* Mosquitoes as Agents of Malaria Transmission

Human malaria is transmitted primarily by infected female *Anopheles* mosquitoes, with transmission dynamics strongly influenced by vector ecology, behaviour, and adaptation to human environments [12]. In Nigeria and much of sub-Saharan Africa, malaria transmission has historically been driven by indigenous vectors within the *Anopheles gambiae* sensu *lato* complex; principally *Anopheles gambiae sensu stricto*, *Anopheles coluzzii*, and *Anopheles arabiensis*, as well as *Anopheles funestus* in many settings [12] [13].

These native vectors are typically associated with rural and peri-urban environments, breeding in natural or semi-permanent water bodies such as puddles, marshes, rice fields, and stream margins. Behaviourally, *An. gambiae s.l.* exhibits strong anthropophily, nocturnal feeding, and predominantly endophagic and endophilic tendencies, making it a highly efficient vector and particularly susceptible to indoor interventions such as long-lasting insecticidal nets (LLINs) and indoor residual spraying (IRS) [14] [15].

In contrast, *Anopheles stephensi* represents a distinct ecological and behavioural departure from Nigeria's traditional malaria vectors. Unlike *An. gambiae s.l.*, *An. stephensi* is highly adapted to urban environments, exploiting artificial container habitats such as overhead tanks, barrels, wells, construction sites, and discarded containers for larval development [16] [17]. This container-breeding behaviour closely resembles that of *Aedes* mosquitoes rather than African *Anopheles* species, enabling *An. stephensi* to thrive in densely populated cities where natural breeding sites are limited [6] [18].

Feeding and resting behaviours also differ markedly. While *An. gambiae s.l.* is predominantly endophagic, *An. stephensi* displays greater behavioural plasticity, feeding both indoors and outdoors and resting in diverse locations, which may reduce the effectiveness of indoor-focused control strategies [17]. Additionally, *An. stephensi* demonstrates flexible host-feeding patterns, maintaining anthropophily while also feeding opportunistically on animals, facilitating its persistence across heterogeneous urban landscapes [16].

These contrasts have major implications for malaria control in Nigeria. Current national strategies have been optimized for rural, indoor-biting vectors such as *An. gambiae s.l.* and *An. funestus*. The introduction of *An. stephensi*, with its urban, container-breeding ecology and behavioural flexibility, threatens to undermine existing gains by expanding malaria transmission into urban settings traditionally considered lower-risk [6] [18]. Consequently, the emergence of *An. stephensi* necessitates a re-evaluation of vector control paradigms in Nigeria, with increased emphasis on urban surveillance, larval source management, and community-based habitat reduction alongside established indoor interventions.

4. Biology and Urban Ecological Adaptations of *Anopheles stephensi*

Among the approximately 500 recognized species within the genus *Anopheles*, only about 30 are considered efficient malaria vectors, including *Anopheles stephensi* [19]-[21]. This species exists in three recognized biological forms: type, intermediate, and mysorensis, which can be differentiated based on egg morphology [19]-[21]. These forms exhibit distinct ecological and behavioural traits that influence their vectorial capacity. The mysorensis form is predominantly zoophilic and is therefore considered a less effective malaria vector, whereas the type and intermediate forms are highly anthropophilic and play a significant role in malaria transmission [15] [22].

Anopheles stephensi displays several biological characteristics that distinguish it from indigenous African malaria vectors and facilitate its success in urban environments. The species is strongly anthropophilic, exhibits endophagic feeding behavior (feeding indoors), and shows endophilic resting tendencies, traits that enhance human-vector contact in densely populated settings [23]. Unlike many African vectors that rely on natural or semi-natural aquatic habitats, the immature stages of *An. stephensi* are commonly found in anthropogenic water-holding containers such as overhead tanks, barrels, wells, fountains, cisterns, and other artificial receptacles prevalent in urban and peri-urban areas [22] [23].

Larval development in *An. stephensi* is particularly well-suited to urban conditions. The larvae of the type and intermediate forms preferentially exploit clean water stored in domestic containers, while the mysorensis form is more frequently associated with natural habitats [22]. This capacity to utilize a wide range of artificial breeding sites allows *An. stephensi* populations to persist independently of rainfall patterns, supporting continuous transmission in cities. Rapid development in these stable container habitats further enhances population growth and vector density in urban settings.

Adult survival and feeding behaviour further contribute to the vectorial efficiency of *An. stephensi*. Upon emergence, adults seek sugar sources for energy-demanding activities such as mating, flight, and host-seeking, while females require blood meals to support egg development [24]. Although feeding is predominantly nocturnal, urban studies have shown a strong preference for human hosts, even in environments where alternative animal hosts are available, increasing the risk of sustained human-to-human transmission [19]-[22]. Under favourable conditions, adult *An. stephensi* mosquitoes can survive for a month or longer, providing sufficient time for parasite development and onward transmission [25].

Seasonal survival strategies may further enhance the persistence of *An. stephensi* populations. Aestivation during hot or dry periods has been proposed as a mechanism enabling survival through unfavourable environmental conditions, while diapause may occur in populations inhabiting the northern limits of the species' range [26]. These adaptive traits collectively underscore the capacity of *An. stephensi* to establish stable populations in urban environments and pose a substantial challenge to malaria control strategies traditionally designed for rural vectors.

4.1. Adult

Anopheles stephensi adults are light brown to grey in hue and small to medium in size. The adult body is organized into three primary regions: the head, thorax, and abdomen. Compound eyes, antennae, sensory palps, and a long projecting feeding proboscis are all located on the head [27]. Males' palps are club-shaped at the ends, while females' palps are cylindrical and roughly the length of the proboscis [28]. Pale bands are seen on the maxillary palps. Palpi are speckled and have equal apical and subapical pale streaks. The locomotive unit is the thorax, which has three sets of legs, two wings, and halteres. When viewed dorsally, the thorax scutum is coated in wide, pale scales and setae. Pale spots are seen on nearly all veins of the wings, with three dark patches. The reproductive system (male testes and associated glands, and female egg formation) and digestive organs are located in the abdomen. During blood feeding, the female abdomen's segmented parts may notably enlarge (**Figure 1**). Typically, abdominal segments have light scales and lack black scale tufts [27]. The resting posture of *Anopheles* mosquitoes, which is with the abdomen pointed away from the body, further distinguishes them from other mosquito genera [29].

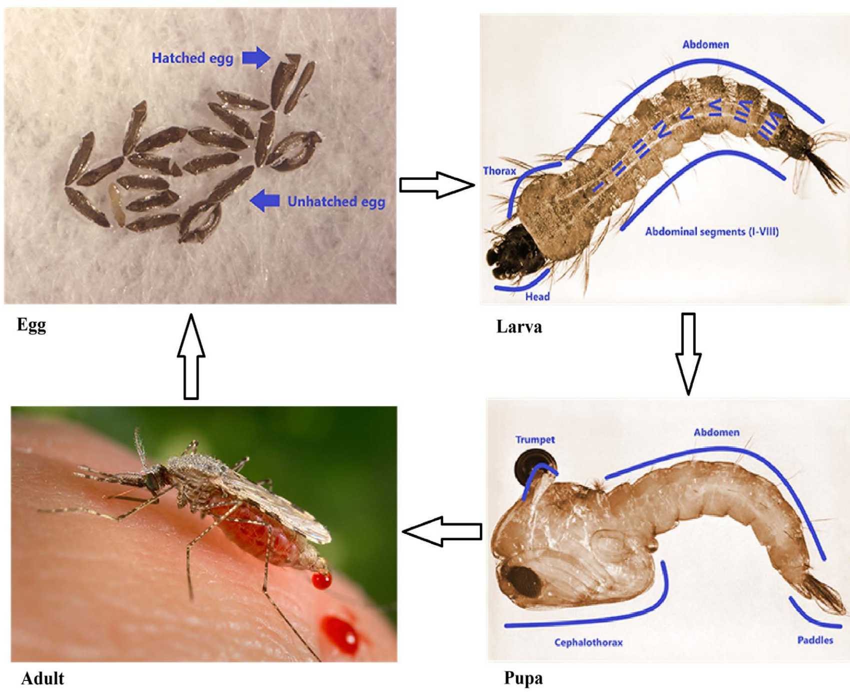

Figure 1. Life cycle of *Anopheles stephensi* (credit: James Gathany, CDC), cited by Abdullah and Barry (modified) [27].

4.2. Egg

The egg of *Anopheles stephensi* is skiff-shaped and dark brown to black in color (**Figure 1**). According to Malhotra *et al.* [30], the ventral egg surface is coated in uniformly fine tubercles. On either side of the lateral surface of the egg are floats. Three biological phenotypes are recognized in the species: type, intermediate, and mysorensis have different egg sizes and ridge counts on the egg float [22] [28]. The average dimensions of the egg are 154.6 µm in breadth and 473.9 µm in length [28].

Within 48 - 72 hours following a blood meal, female *Anopheles* mosquitoes typically oviposit between 50 and 300 eggs directly on the water surface. Egg hatching generally occurs within 24 - 72 hours under favourable tropical conditions, and *Anopheles* eggs lack true desiccation resistance, making delayed or dormant hatching impossible [31] [32]. This biological constraint applies both to indigenous Nigerian vectors such as *Anopheles gambiae sensu lato* and to the invasive *An. stephensi*. However, *An. stephensi* often exhibits a slightly faster egg-to-larva transition (approximately 24 - 48 hours) and gains a substantial ecological advantage by ovipositing in stable, man-made water containers typical of urban environments, where hatching success is more consistent than in the ephemeral, rain-dependent breeding sites preferred by native vectors [15] [17] [18]. In contrast, *Aedes* eggs may remain viable for months before hatching due to environmental stimuli such as rainfall, which submerges eggs in water and reduces oxygen availability. They must adapt to the prevailing environmental conditions in order to survive [28].

4.3. Larva

The larval head of *Anopheles stephensi* is longer than wide, strongly sclerotized, and bears distinct pairs of setae, antennae, and mouthparts (**Figure 1**). While these features are broadly shared with indigenous Nigerian malaria vectors such as *Anopheles gambiae sensu lato* and *Anopheles funestus*, *An. stephensi* larvae are more frequently encountered in clean, artificial water-holding containers, including overhead tanks, wells, and household storage vessels, rather than in the temporary rain-dependent habitats preferred by native vectors [6] [17]. Setae 5-7-C are long and branched in the larval head, while seta 1-A is short and unbranched [27]. The abdomen is composed of ten segments and is narrower than the thorax. Segments IV-VII have short tergal plates; setae 9-10-T are both branched; and abdominal seta 1-I has three to five branches [27] [33]. The primary characteristic of *Anopheles* larvae is the absence of a respiratory siphon; instead, the larvae use a spiracular device situated in the eighth segment of the abdomen to obtain oxygen [34]. Larvae can feed on organic debris and algae in the water because they are parallel to the water's surface and contain palmate setae on the dorsal surface of their abdomens, which assist them in clinging to the water's surface tension. Before becoming pupae, larvae go through four larval instars. Larvae are small (~1 mm) in their first instar and become larger as they develop, reaching ~5 to 8 mm in their final fourth instar [27].

4.4. Pupa

When seen from the side, the *Anopheles stephensi* pupa, also called a tumbler, has a comma-like form. Because they are incapable of feeding, pupae regularly surface to take in oxygen through the respiratory tubes, or air trumpets, at the dorsal surface of the cephalothorax (**Figure 1**) [29]. Two wide swimming paddles are located at the posterior end of the abdomen. After a few days, the adult emerges from the pupa, and it soon gains the ability to fly.

5. Importance of Accurate Identification of *Anopheles stephensi* in Nigeria

Accurate identification of *Anopheles* mosquito species is fundamental to effective malaria vector surveillance and control, as control strategies and insecticide selection depend heavily on species-specific behavioural and ecological traits [35]. Precise species identification enables assessments of vector competence, insecticide susceptibility, feeding and resting behaviour, and breeding ecology, all of which are essential for designing targeted and cost-effective vector control interventions.

In Nigeria, malaria transmission has historically been driven by indigenous vectors such as *Anopheles gambiae*, *Anopheles coluzzii*, and *Anopheles arabiensis* [12] [36], alongside several secondary vectors including *Anopheles merus*, *Anopheles rivulorum*, *Anopheles parensis*, *Anopheles vaneedeni*, and *Anopheles leesoni* [37] [38]. These species often coexist in ecologically interdependent assemblages, with distinct behavioural patterns and insecticide susceptibility profiles that influence malaria transmission dynamics [12] [39].

The emergence of *Anopheles stephensi* presents a significant diagnostic challenge within this established vector landscape. Morphologically, *An. stephensi* shares similarities with members of the *An. gambiae* complex, particularly *An. arabiensis*, increasing the likelihood of misidentification when using conventional morphological keys alone. While morphological identification remains a cost-effective and widely applied approach at state and local levels, it may be insufficient for reliably detecting *An. stephensi*, especially in early invasion stages or mixed-species populations.

The consequences of misidentification can be substantial. Historical evidence from Zimbabwe demonstrated how confusion between vector and non-vector species within the *An. gambiae* complex led to inappropriate insecticide policy decisions and masked insecticide resistance in the true vector population [39]-[41]. Similar misclassification involving *An. stephensi* could result in ineffective control strategies, particularly in urban settings where this species exhibits distinct breeding and feeding behaviours.

Molecular diagnostic tools, therefore, play a critical role in confirming species identity. Multiplex PCR assays targeting species-specific genetic markers are routinely used in national reference laboratories and research institutions to distinguish closely related *Anopheles* species [42] [43]. Additionally, DNA sequencing of mitochondrial and nuclear markers, particularly the cytochrome oxidase subunit I (COI) gene and the internal transcribed spacer 2 (ITS2) region (**Table 1**), has proven highly effective for species differentiation, phylogenetic analysis, and confirmation of invasive populations [38] [44]-[47] [48]. The ITS2 locus, in particular, is increasingly used as a diagnostic marker due to its ability to resolve cryptic species within anopheline complexes [45].

Table 1. Details of *Anopheles* spp. and their sequence accession numbers [49].

No.	Subgenus	Series	Species	ITS2		COI
				GenBank ID	Length (bp)	GenBank ID
1	*Anopheles*	Anopheles	*An. plumbeus*	JQ928897	335	JF966740
2	*Anopheles*	Anopheles	*An. sacharovi*	AY114208	314	KM389466
3	*Anopheles*	Anopheles	*An. maculipennis*	AY137814	292	JF966746
4	*Anopheles*	Anopheles	*An. messeae*	AY648996	305	NA
5	*Anopheles*	Anopheles	*An. martinius*	NA	NA	NA
6	*Anopheles*	Anopheles	*An. labranchiae*	AY253849	305	NA
7	*Anopheles*	Anopheles	*An. melanoon*	AM271001	302	NA
8	*Anopheles*	Anopheles	*An. persiensis*	AY137844	286	NA
9	*Anopheles*	Anopheles	*An. atroparvus*	AY634532	307	NA
10	*Anopheles*	Anopheles	*An. claviger*	AY129232	346	JF966742
11	*Anopheles*	Anopheles	*An. algeriensis*	NA	NA	NA
12	*Anopheles*	Anopheles	*An. marteri*	NA	NA	NA
13	*Anopheles*	Myzorhynchus	*An. pseudopictus*	GU478907	430	KM389468
14	*Anopheles*	Myzorhynchus	*An. hyrcanus*	GU478906	430	JF966743
15	*Anopheles*	Myzorhynchus	*An. peditaeniatus*	AF543862	451	NA
16	*Anopheles*	Myzorhynchus	*An. nigerrimus*	NA	NA	NA
17	*Cellia*	Myzomyia	*An. apoci*	AY445826	404	JF966747
18	*Cellia*	Myzomyia	*An. dthali*	JF966738	380	KM389470
19	*Cellia*	Myzomyia	*An. rhodesiensis*	NA	NA	NA
20	*Cellia*	Myzomyia	*An. sergentii*	AY533851	423	NA
21	*Cellia*	Myzomyia	*An. culicifacies*	A JF966735	370	JF966744
22	*Cellia*	Myzomyia	*An. fluviatilis*	T GQ926591	379	JF966741
23	*Cellia*	Myzomyia	*An. fluviatilis*	U GQ926589	379	NA
24	*Cellia*	Myzomyia	*An. fluviatilis*	V DQ344526	379	NA
25	*Cellia*	Neocellia	*An. moghulensis*	JQ928806	378	KM389469
26	*Cellia*	Neocellia	*An. superpictus*	X AY941117	357	JF966745
27	*Cellia*	Neocellia	*An. superpictus*	Y AY941112	378	NA
28	*Cellia*	Neocellia	*An. superpictus*	Z AY941111	378	NA
29	*Cellia*	Neocellia	*An. pulcherrimus*	AY515172	354	JF966748
30	*Cellia*	Neocellia	*An. stephensi*	EU346652	471	JF966739
31	*Cellia*	Paramyzomyia	*An. multicolor*	AY564229	547	NA
32	*Cellia*	Paramyzomyia	*An. turkhudi*	AY456391	399	KM389467
33	*Cellia*	Paramyzomyia	*An. cinereus*	NA	NA	NA
34	*Cellia*	Pyretophorus	*An. subpictus*	GQ870337	576	NA
35	NA	NA	*Culex pipiens*	JQ958369	336	JQ958372

Despite their accuracy, molecular approaches are often constrained by cost, infrastructure requirements, and technical expertise, limiting their routine deployment in many malaria-endemic settings [49]. As a result, reliance on morphology alone remains common in routine surveillance, potentially contributing to the under-detection or delayed recognition of *An. stephensi* incursions. *The morphological similarity between* An. *stephensi* and indigenous African vectors, combined with historical gaps in molecular surveillance capacity, may partly explain why the species remained undetected in Africa until its confirmed emergence in the Horn of Africa [18] [50].

Given the public health implications of *An. stephensi* establishment in Nigerian cities, there is a growing need to integrate molecular confirmation into routine surveillance systems. The adoption of simplified PCR protocols, portable molecular platforms, or other rapid field-deployable diagnostic tools could bridge the gap between accuracy and feasibility. Strengthening diagnostic capacity will be essential for early detection, monitoring spread, and implementing timely, evidence-based vector control strategies tailored to the unique biology of *An. stephensi*.

Since its first appearance outside Asia in 2012, *Anopheles stephensi* has rapidly spread into urban areas across the Horn of Africa and beyond. These invasions, captured through entomological and molecular surveillance, have been published in peer-reviewed literature. **Table 2** identifies representative emergence events.

Table 2. Documented the first records of *Anopheles stephensi* in non-native urban locations.

City	Country	Year	Citation
Djibouti City	Djibouti	2012	Faulde *et al.* [16]
Kebri Dehar	Ethiopia	2016	Carter *et al.* [51]
Dire Dawa	Ethiopia	2016	Carter *et al.* [51]
Port Sudan	Sudan	2016	Al Eryani *et al.* [52]
Mannar (Island)	Sri Lanka	2016	Gayan Dharmasiri *et al.* [53]
Jaffna	Sri Lanka	2017	Surendran *et al.* [17]
Tuti Island, Khartoum	Sudan	2018	Al Eryani *et al.* [52]
Bossaso	Somalia	2019	Al Eryani *et al.* [52]
Berbera	Somalia	2020	Al Eryani *et al.* [52]
Biliri	Nigeria*	2020	WHO [54] vector alert
Aden City	Yemen	2021	Allan *et al.* [55]
Al Mukalla	Yemen	2021	Al Eryani *et al.* [52]
Zabid	Yemen	2021	Al Eryani *et al.* [52]
Accra	Ghana*	2022	WHO [54] vector alert

*For some countries, first detections were initially reported through WHO-coordinated entomological surveillance and vector alerts prior to publication in peer-reviewed journals.

6. The Emergence of Nigerian *Anopheles stephensi*: Evidence and Implications

Recent entomological surveillance has confirmed the presence of *Anopheles stephensi* in Nigeria. The first documented detection occurred in 2020 in the Biliri Local Government Area of Gombe State, northeastern Nigeria (**Figure 2**). Mosquito specimens were collected from artificial water-holding containers within urban and peri-urban settings, consistent with the known ecology of *An. stephensi*.

Figure 2. Map indicating the location of the initial discovery of *Anopheles stephensi* in Nigeria [56].

Initial identification was conducted using morphological keys to screen Anopheline larvae and adults suspected to be non-native vectors. Due to the morphological similarity between *An. stephensi* and indigenous members of the *Anopheles gambiae sensu lato* complex, molecular confirmation was subsequently performed using PCR-based species identification assays at national reference laboratories in collaboration with the Nigerian Institute of Medical Research (NIMR) and the National Malaria Elimination Programme (NMEP).

This detection represents a significant milestone in malaria vector surveillance in Nigeria, as *An. stephensi* is uniquely adapted to urban transmission environments, where over half of Nigeria's population resides. Its establishment, therefore, poses a heightened risk of increased malaria transmission in densely populated cities [54].

Nigeria's NMEP, with technical support from the U.S. President's Malaria Initiative (PMI), has since expanded surveillance capacity for *An. stephensi*. In November 2022, PMI supported targeted training of entomology technicians and researchers across multiple Nigerian states to strengthen morphological screening and molecular diagnostic capabilities for the early detection and monitoring of this invasive vector [56].

The introduction and spread of *An. stephensi* in Nigeria is likely facilitated by increased urbanization, climate suitability, and international trade and transport networks, which collectively enhance opportunities for passive dispersal and establishment in urban centers.

7. Implications of *Anopheles stephensi* for Malaria Epidemiology in Nigeria

Nigeria bears the highest malaria burden globally, accounting for a substantial proportion of cases and deaths worldwide, and the introduction of *Anopheles stephensi* threatens to further complicate malaria control efforts in the country [54]. Unlike indigenous African malaria vectors that predominantly sustain transmission in rural settings, *An. stephensi* is highly adapted to urban environments, where it breeds efficiently in artificial water containers and thrives in close proximity to dense human populations [8] [22].

Evidence from the Horn of Africa illustrates the epidemiological consequences of *An. stephensi* establishment in urban areas. In Djibouti, malaria incidence increased dramatically following the detection of *An. stephensi* in 2012, rising from fewer than 3000 reported cases annually to tens of thousands within a decade, coinciding with the vector's urban proliferation [16] [57]. Similarly, entomological and epidemiological investigations in Ethiopia have confirmed widespread urban colonization by *An. stephensi*, with the vector demonstrating competence for transmitting both *Plasmodium falciparum* and *Plasmodium vivax* [58] [59].

Modeling studies further underscore the magnitude of this threat. Using climatic suitability and urbanization trends, Sinka *et al.* [22] estimated that the continued spread of *An. stephensi* could place over 120 million additional people in Africa at risk of malaria, predominantly in urban and peri-urban settings. In Ethiopia, projections suggest that *An. stephensi* establishment could lead to substantial increases in malaria incidence, particularly in cities previously considered low-risk, if existing control strategies remain unchanged [59].

Nigeria's rapid urban growth amplifies this concern. More than 40% of Nigeria's population now resides in urban areas, many characterized by informal settlements, unreliable piped water supply, and widespread household water storage; conditions highly favourable for *An. stephensi* breeding [6] [60]. If transmission dynamics similar to those observed in the Horn of Africa were to emerge in Nigerian cities such as Lagos, Kano, or Ibadan, the result could be a marked increase in urban malaria prevalence, placing additional strain on already burdened health systems.

Furthermore, *An. stephensi* presents unique challenges for malaria control due to its behavioral and ecological plasticity, including container breeding, tolerance of polluted water, and documented resistance to multiple classes of insecticides [8] [61]. These traits reduce the effectiveness of conventional vector control tools primarily designed for rural malaria vectors and highlight the risk of urban malaria resurgence.

These findings suggest that the establishment of *An. stephensi* in Nigeria could fundamentally alter malaria epidemiology by expanding transmission into urban environments. Proactive surveillance, urban-adapted vector control strategies, and the integration of *An. stephensi* into national malaria elimination frameworks is therefore critical to preventing a reversal of malaria control gains in Nigeria.

8. *Anopheles stephensi* Control Issues in Nigeria

Nigeria's current vector control measures mainly target the two main malaria vectors in sub-Saharan Africa, *Anopheles gambiae* and *Anopheles funestus*. Because *An. stephensi*'s breeding grounds are frequently located in urban areas; these methods, which include indoor residual spraying (IRS) and insecticide-treated bed nets (ITNs), may be less successful against the species [56].

An increasing problem for malaria control efforts worldwide is insecticide resistance, and *An. stephensi* is no different. The efficiency of existing chemical control strategies is limited by reports that *An. stephensi* populations have acquired resistance against multiple insecticide classes. Since pyrethroids are a major component of vector management in Nigeria, the development of *An. stephensi* may compromise the performance of these treatments [54].

9. Nigeria's Present and Future *Anopheles stephensi* Control Methods

Active surveillance for *Anopheles stephensi* is essential in Nigeria, particularly in urban and peri-urban areas where the species is most likely to establish. The development of a coordinated network of entomological surveillance sites in high-risk locations can support the early detection of incursions and guide timely, evidence-based responses. Surveillance data are also critical for tailoring control strategies to local ecological conditions and for monitoring the effectiveness of interventions over time.

Given the container-breeding ecology of *An. stephensi*, Larval Source Management (LSM) represents one of the most immediate and practical control strategies. LSM approaches, including source reduction, environmental modification, larviciding, and improved water management, are particularly effective in urban settings where breeding sites are often fixed, accessible, and man-made [62]. Targeting overhead tanks, household water storage containers, construction sites, wells, and discarded receptacles can substantially reduce larval habitats and suppress adult mosquito populations. When systematically implemented, LSM can complement adult-focused interventions and reduce reliance on insecticides alone [63]-[65].

Community-based habitat reduction is a critical component of sustainable *An. stephensi* control. Public engagement initiatives that educate communities on the identification and elimination of potential breeding sites, such as emptying unused containers, covering water storage vessels, and improving sanitation, can significantly limit mosquito proliferation. Community participation is especially important in informal urban settlements where centralized vector control services may be limited. Empowering households and local leaders to take ownership of vector reduction enhances intervention coverage and long-term effectiveness [54] [56] [64].

Integrated Vector Management (IVM) provides a framework for combining these practical measures with chemical and biological interventions. In urban contexts, IVM strategies that prioritize environmental management and larval control are particularly well-suited to addressing the ecological flexibility of *An. stephensi*. Adult control measures, including targeted indoor residual spraying and insecticide-treated nets, may still play a role but are unlikely to be sufficient on their own given the vector's breeding behaviour and potential for outdoor or early-evening biting [63].

Advanced technologies such as Wolbachia-based approaches and the sterile insect technique (SIT) offer promising long-term options for *An. stephensi* control. These methods aim to suppress mosquito populations or reduce vector competence through interference with reproduction. However, they remain largely experimental, require substantial infrastructure and technical capacity, and may not be immediately deployable at scale in Nigeria. As such, these approaches are best considered as complementary tools within a broader IVM strategy rather than standalone solutions [63] [64].

Overall, effective control of *An. stephensi* in Nigeria will depend on prioritizing feasible, cost-effective, and community-driven interventions, particularly LSM and habitat reduction, while gradually integrating advanced technologies as surveillance capacity and operational readiness improve. Aligning these strategies with urban planning, water management policies, and community engagement initiatives will be essential to mitigating the public health threat posed by this invasive vector.

10. Conclusion

Anopheles stephensi's invasion of Nigeria poses a serious threat to public health and could undo the progress achieved in combating malaria. In highly populated cities, *An. stephensi*, an urban-adapted vector with a high capacity for *Plasmodium falciparum* transmission, has the potential to significantly increase malaria transmission. Strict surveillance, innovative vector control techniques, and community involvement are all necessary to counter this menace. *An. stephensi* could further entrench malaria in Nigerian urban centres if prompt and concerted action is not taken, making the fight to eradicate malaria more difficult.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Robert, V., Macintyre, K., Keating, J., Trape, J., Duchemin, J., Warren, M., *et al.* (2003)

Malaria Transmission in Urban Sub-Saharan Africa. *The American Journal of Tropical Medicine and Hygiene*, **68**, 169-176. https://doi.org/10.4269/ajtmh.2003.68.169

[2] Pierre, D.S., Okechukwu, E. and Nchiwan, N. (2014) Larvicidal and Phytochemical Properties of *Callistemon rigidus* R. Br. (Myrtaceae) Leaf Solvent Extracts against Three Vector Mosquitoes. *Journal of Vector Borne Diseases*, **51**, 216-223. https://doi.org/10.4103/0972-9062.141763

[3] WHO (2022) World Malaria Report 2022. World Health Organization. https://www.who.int/teams/global-malaria-programme/reports/world-malaria-report-2022

[4] Ezeike, A.K., Danga, S.P.Y., Ezenwa, V.C., Chukas, C.F., Ogudu, E.O., Nwosu, C.M., *et al.* (2026) Urban Evolution of Insecticide Resistance and Susceptibility Patterns of *Anopheles coluzzii* in Southeastern Nigeria: Implications for Malaria Vector Control. *Malaria Journal*, **25**, Article No. 86. https://doi.org/10.1186/s12936-025-05760-5

[5] Overgaard, H.J., Reddy, V.P., Abaga, S., Matias, A., Reddy, M.R., Kulkarni, V., *et al.* (2012) Malaria Transmission after Five Years of Vector Control on Bioko Island, Equatorial Guinea. *Parasites & Vectors*, **5**, Article No. 253. https://doi.org/10.1186/1756-3305-5-253

[6] Sinka, M.E., Pironon, S., Massey, N.C., Longbottom, J., Hemingway, J., Moyes, C.L., *et al.* (2020) A New Malaria Vector in Africa: Predicting the Expansion Range of *Anopheles stephensi* and Identifying the Urban Populations at Risk. *Proceedings of the National Academy of Sciences of the United States of America*, **117**, 24900-24908. https://doi.org/10.1073/pnas.2003976117

[7] Allan, R., Budge, S. and Sauskojus, H. (2023) What Sounds Like *Aedes*, Acts Like *Aedes*, but Is Not *Aedes*? Lessons from Dengue Virus Control for the Management of Invasive *Anopheles*. *The Lancet Global Health*, **11**, e165-e169. https://doi.org/10.1016/s2214-109x(22)00454-5

[8] Takken, W. and Lindsay, S. (2019) Increased Threat of Urban Malaria from *Anopheles stephensi* Mosquitoes, Africa. *Emerging Infectious Diseases*, **25**, 1431-1433. https://doi.org/10.3201/eid2507.190301

[9] Kamareddine, L. (2012) The Biological Control of the Malaria Vector. *Toxins*, **4**, 748-767. https://doi.org/10.3390/toxins4090748

[10] Sana, N., Muhammad, F.M. and Talhat, M. (2016) Mosquito Management—A Review. *Journal of Entomology and Zoology Studies*, **4**, 73-79.

[11] Owusu-Ofori, A.K., Parry, C. and Bates, I. (2010) Transfusion-Transmitted Malaria in Countries Where Malaria Is Endemic: A Review of the Literature from Sub-Saharan Africa. *Clinical Infectious Diseases*, **51**, 1192-1198. https://doi.org/10.1086/656806

[12] Sinka, M.E., Bangs, M.J., Manguin, S., Rubio-Palis, Y., Chareonviriyaphap, T., Coetzee, M., *et al.* (2012) A Global Map of Dominant Malaria Vectors. *Parasites & Vectors*, **5**, Article No. 69. https://doi.org/10.1186/1756-3305-5-69

[13] Akpan, G.E., Adepoju, K.A., Oladosu, O.R. and Adelabu, S.A. (2018) Dominant Malaria Vector Species in Nigeria: Modelling Potential Distribution of *Anopheles gambiae* Sensu Lato and Its Siblings with Maxent. *PLOS ONE*, **13**, e0204233. https://doi.org/10.1371/journal.pone.0204233

[14] Padonou, G.G., Gbedjissi, G., Yadouleton, A., Azondekon, R., Razack, O., Oussou, O., *et al.* (2012) Decreased Proportions of Indoor Feeding and Endophily in *Anopheles gambiae* S.L. Populations Following the Indoor Residual Spraying and Insecticide-Treated Net Interventions in Benin (West Africa). *Parasites & Vectors*, **5**, Article No. 262. https://doi.org/10.1186/1756-3305-5-262

[15] Thomas, S., Ravishankaran, S., Justin, N.A.J.A., Asokan, A., Mathai, M.T., Valecha, N., *et al.* (2017) Resting and Feeding Preferences of *Anopheles stephensi* in an Urban Setting, Perennial for Malaria. *Malaria Journal*, **16**, Article No. 111. https://doi.org/10.1186/s12936-017-1764-5

[16] Faulde, M.K., Rueda, L.M. and Khaireh, B.A. (2014) First Record of the Asian Malaria Vector *Anopheles stephensi* and Its Possible Role in the Resurgence of Malaria in Djibouti, Horn of Africa. *Acta Tropica*, **139**, 39-43. https://doi.org/10.1016/j.actatropica.2014.06.016

[17] Surendran, S.N., Sivabalakrishnan, K., Sivasingham, A., Jayadas, T.T.P., Karvannan, K., Santhirasegaram, S., *et al.* (2019) Anthropogenic Factors Driving Recent Range Expansion of the Malaria Vector *Anopheles stephensi*. *Frontiers in Public Health*, **7**, Article 53. https://doi.org/10.3389/fpubh.2019.00053

[18] Mnzava, A., Monroe, A.C. and Okumu, F. (2022) *Anopheles stephensi* in Africa Requires a More Integrated Response. *Malaria Journal*, **21**, Article No. 156. https://doi.org/10.1186/s12936-022-04197-4

[19] Sweet, W.C., and Rao, B.A. (1937) Races of *Anopheles stephensi* Liston, 1901. *The Indian Medical Gazette*, **72**, 665-674.

[20] Subbarao, S.K., Vasantha, K., Adak, T., Sharma, V.P. and Curtis, C.F. (1987) EGG-Float Ridge Number in *Anopheles stephensi*: Ecological Variation and Genetic Analysis. *Medical and Veterinary Entomology*, **1**, 265-271. https://doi.org/10.1111/j.1365-2915.1987.tb00353.x

[21] Choochote, W., Min, G., Intapan, P.M., Tantrawatpan, C., Saeung, A. and Lulitanond, V. (2014) Evidence to Support Natural Hybridization between *Anopheles sinensis* and *Anopheles kleini* (Diptera: Culicidae): Possibly a Significant Mechanism for Gene Introgression in Sympatric Populations. *Parasites & Vectors*, **7**, Article No. 36. https://doi.org/10.1186/1756-3305-7-36

[22] Sinka, M.E., Bangs, M.J., Manguin, S., Coetzee, M., Mbogo, C.M., Hemingway, J., *et al.* (2010) The Dominant Anopheles Vectors of Human Malaria in Africa, Europe and the Middle East: Occurrence Data, Distribution Maps and Bionomic Précis. *Parasites & Vectors*, **3**, Article No. 117. https://doi.org/10.1186/1756-3305-3-117

[23] Zhou, G., Zhong, D., Yewhalaw, D. and Yan, G. (2024) *Anopheles stephensi* Ecology and Control in Africa. *Trends in Parasitology*, **40**, 102-105. https://doi.org/10.1016/j.pt.2023.11.011

[24] Ramirez, G., Broeckling, C., Herndon, M., Stoltz, M., Ebel, G.D. and Dobos, K.M. (2024) Investigating the Lipid Profile of *Anopheles stephensi* Mosquitoes across Developmental Life Stages. *Comparative Biochemistry and Physiology Part D: Genomics and Proteomics*, **52**, Article ID: 101312. https://doi.org/10.1016/j.cbd.2024.101312

[25] Matthews, J., Bethel, A. and Osei, G. (2020) An Overview of Malarial *Anopheles mosquito* Survival Estimates in Relation to Methodology. *Parasites & Vectors*, **13**, Article No. 233. https://doi.org/10.1186/s13071-020-04092-4

[26] Dao, A., Yaro, A.S., Diallo, M., Timbiné, S., Huestis, D.L., Kassogué, Y., *et al.* (2014) Signatures of Aestivation and Migration in Sahelian Malaria Mosquito Populations. *Nature*, **516**, 387-390. https://doi.org/10.1038/nature13987

[27] Alomar, A.A. and Alto, B.W. (2023) *Anopheles stephensi* Liston, 1901 (insecta: Diptera: Culicidae). *EDIS*, **2022**, 1-7. https://doi.org/10.32473/edis-in1381-2022

[28] Dhiman, S., Tyagi, V., Sharma, A., Srivastava, A., Rabha, B., Sukumaran, D., *et al.* (2017) Morphometric and Morphological Appraisal of the Eggs of *Anopheles stephensi* (Diptera: Culicidae) from India. *Journal of Vector Borne Diseases*, **54**, 151-156. https://doi.org/10.4103/0972-9062.211690

[29] Foster, W.A. and Walker, E.D. (2019) Mosquitoes (Culicidae). In: Mullen, G.R. and Durden, L.A., Eds., *Medical and Veterinary Entomology*, Elsevier, 261-325. https://doi.org/10.1016/b978-0-12-814043-7.00015-7

[30] Malhotra, P.R., Jatav, P.C. and Chauhan, R.S. (2000) Surface Morphology of the Egg of *Anopheles stephensi stephensi* sensu Stricto (Diptera, Culicidae). *Italian Journal of Zoology*, **67**, 147-151. https://doi.org/10.1080/11250000009356307

[31] Service, M. (2012) Medical Entomology for Students. 5th Edition, Cambridge University Press. https://doi.org/10.1017/cbo9781139002967

[32] Becker, N., Petric, D., Zgomba, M., Boase, C., Madon, M., Dahl, C., and Kaiser, A. (2010) Mosquitoes and Their Control. 2nd Edition, Springer. https://doi.org/10.1007/978-3-540-92874-4

[33] Tyagi, B.K., Munirathinam, A. and Venkatesh, A. (2015) A Catalogue of Indian Mosquitoes. *International Journal of Mosquito Research*, **2**, 50-97.

[34] Burkett-Cadena, N.D. (2013) Mosquitoes of the Southeastern United States. University of Alabama Press. https://doi.org/10.2307/jj.30347333

[35] Dahan-Moss, Y., Hendershot, A., Dhoogra, M., Julius, H., Zawada, J., Kaiser, M., *et al.* (2020) Member Species of the *Anopheles gambiae* Complex Can Be Misidentified as *Anopheles leesoni*. *Malaria Journal*, **19**, Article No. 89. https://doi.org/10.1186/s12936-020-03168-x

[36] Akogbéto, M.C., Salako, A.S., Dagnon, F., Aïkpon, R., Kouletio, M., Sovi, A., *et al.* (2018) Blood Feeding Behaviour Comparison and Contribution of *Anopheles coluzzii* and *Anopheles gambiae*, Two Sibling Species Living in Sympatry, to Malaria Transmission in Alibori and Donga Region, Northern Benin, West Africa. *Malaria Journal*, **17**, Article No. 307. https://doi.org/10.1186/s12936-018-2452-9

[37] Ogola, E.O., Fillinger, U., Ondiba, I.M., Villinger, J., Masiga, D.K., Torto, B., *et al.* (2018) Insights into Malaria Transmission among *Anopheles funestus* Mosquitoes, Kenya. *Parasites & Vectors*, **11**, Article No. 577. https://doi.org/10.1186/s13071-018-3171-3

[38] Burke, A., Dandalo, L., Munhenga, G., Dahan-Moss, Y., Mbokazi, F., Ngxongo, S., *et al.* (2017) A New Malaria Vector Mosquito in South Africa. *Scientific Reports*, **7**, Article No. 43779. https://doi.org/10.1038/srep43779

[39] Stevenson, J. and Norris, D. (2016) Implicating Cryptic and Novel Anophelines as Malaria Vectors in Africa. *Insects*, **8**, Article 1. https://doi.org/10.3390/insects8010001

[40] Domingos, A., Direito, A., Alves, G., Máquina, P., Jorge, C.P., Martins, J.F., *et al.* (2025) Characterization of *Anopheles* Species and Entomological Indicators Following Indoor Residual Spraying Campaign in Cuando Cubango, Angola. *Insects*, **16**, Article 892. https://doi.org/10.3390/insects16090892

[41] Choochote, W. and Saeung, A. (2013) Systematic Techniques for the Recognition of *Anopheles* Species Complexes. In: Manguin, S., Ed., *Anopheles mosquitoes—New Insights into Malaria Vectors*, InTech. https://doi.org/10.5772/54853

[42] Koekemoer, L.L., Kamau, L., Hunt, R.H. and Coetzee, M. (2002) A Cocktail Polymerase Chain Reaction Assay to Identify Members of the *Anopheles funestus* (Diptera: Culicidae) Group. *The American journal of tropical medicine and hygiene*, **66**, 804-811. https://doi.org/10.4269/ajtmh.2002.66.804

[43] Cohuet, A., Simard, F., Toto, J., Kengne, P., Coetzee, M. and Fontenille, D. (2003) Species Identification within the *Anopheles funestus* Group of Malaria Vectors in Cameroon and Evidence for a New Species. *The American Journal of Tropical Medicine and Hygiene*, **69**, 200-205. https://doi.org/10.4269/ajtmh.2003.69.200

[44] Burke, A., Dahan-Moss, Y., Duncan, F., Qwabe, B., Coetzee, M., Koekemoer, L., *et al.* (2019) *Anopheles parensis* Contributes to Residual Malaria Transmission in South Africa. *Malaria Journal*, **18**, Article No. 257. https://doi.org/10.1186/s12936-019-2889-5

[45] Oshaghi, M.A., Yaaghoobi, F. and Abaie, M.R. (2006) Pattern of Mitochondrial DNA Variation between and within *Anopheles stephensi* (Diptera: Culicidae) Biological Forms Suggests Extensive Gene Flow. *Acta Tropica*, **99**, 226-233. https://doi.org/10.1016/j.actatropica.2006.08.005

[46] Cywinska, A., Hunter, F.F. and Hebert, P.D.N. (2006) Identifying Canadian Mosquito Species through DNA Barcodes. *Medical and Veterinary Entomology*, **20**, 413-424. https://doi.org/10.1111/j.1365-2915.2006.00653.x

[47] Kumar, N.P., Rajavel, A.R., Natarajan, R. and Jambulingam, P. (2007) DNA Barcodes Can Distinguish Species of Indian Mosquitoes (Diptera: Culicidae). *Journal of Medical Entomology*, **44**, 1-7. https://doi.org/10.1603/0022-2585(2007)44[1:dbcdso]2.0.co;2

[48] Balkew, M., Mumba, P., Dengela, D., Yohannes, G., Getachew, D., Yared, S., *et al.* (2020) Geographical Distribution of *Anopheles stephensi* in Eastern Ethiopia. *Parasites & Vectors*, **13**, Article No. 35. https://doi.org/10.1186/s13071-020-3904-y

[49] Karimian, F., Oshaghi, M.A., Sedaghat, M.M., Waterhouse, R.M., Vatandoost, H., Hanafi-Bojd, A.A., *et al.* (2014) Phylogenetic Analysis of the Oriental-Palearctic-Afrotropical Members of *Anopheles* (Culicidae: Diptera) Based on Nuclear rDNA and Mitochondrial DNA Characteristics. *Japanese Journal of Infectious Diseases*, **67**, 361-367. https://doi.org/10.7883/yoken.67.361

[50] Ali, S., Samake, J.N., Spear, J. and Carter, T.E. (2022) Morphological Identification and Genetic Characterization of *Anopheles stephensi* in Somaliland. *Parasites & Vectors*, **15**, Article No. 247. https://doi.org/10.1186/s13071-022-05339-y

[51] Carter, T.E., Yared, S., Gebresilassie, A., Bonnell, V., Damodaran, L., Lopez, K., *et al.* (2018) First Detection of *Anopheles stephensi* Liston, 1901 (Diptera: Culicidae) in Ethiopia Using Molecular and Morphological Approaches. *Acta Tropica*, **188**, 180-186. https://doi.org/10.1016/j.actatropica.2018.09.001

[52] Al-Eryani, S.M., Irish, S.R., Carter, T.E., Lenhart, A., Aljasari, A., Montoya, L.F., *et al.* (2023) Public Health Impact of the Spread of *Anopheles stephensi* in the WHO Eastern Mediterranean Region Countries in Horn of Africa and Yemen: Need for Integrated Vector Surveillance and Control. *Malaria Journal*, **22**, Article No. 187. https://doi.org/10.1186/s12936-023-04545-y

[53] Gayan Dharmasiri, A.G., Perera, A.Y., Harishchandra, J., Herath, H., Aravindan, K., Jayasooriya, H.T.R., *et al.* (2017) First Record of *Anopheles stephensi* in Sri Lanka: A Potential Challenge for Prevention of Malaria Reintroduction. *Malaria Journal*, **16**, Article No. 326. https://doi.org/10.1186/s12936-017-1977-7

[54] World Health Organization (2023) WHO Initiative to Stop the Spread of *Anopheles stephensi* in Africa (Advocacy Brief). World Health Organization. https://www.who.int/publications/i/item/WHO-UCN-GMP-2022.06

[55] Allan, R., Weetman, D., Sauskojus, H., Budge, S., Hawail, T.B. and Baheshm, Y. (2023) Confirmation of the Presence of *Anopheles stephensi* among Internally Displaced People's Camps and Host Communities in Aden City, Yemen. *Malaria Journal*, **22**, Article No. 1. https://doi.org/10.1186/s12936-022-04427-9

[56] U.S. President's Malaria Initiative (2023) Nigeria Malaria Operational Plan FY 2023. U.S. Agency for International Development. https://files.givewell.org/files/DWDA%202009/Malaria%20Consortium/US_Presi-

dents_Malaria_Initiative_Nigeria_Malaria_Operational_Plan_FY_2023.pdf

[57] de Santi, V.P., Khaireh, B.A., Chiniard, T., Pradines, B., Taudon, N., Larréché, S., *et al.* (2021) Role of *Anopheles stephensi* Mosquitoes in Malaria Outbreak, Djibouti, 2019. *Emerging Infectious Diseases*, **27**, 1697-1700. https://doi.org/10.3201/eid2706.204557

[58] Kolaczinski, J., Al-Eryani, S., Chanda, E. and Fernandez-Montoya, L. (2021) Comment On: Emergence of the Invasive Malaria Vector *Anopheles stephensi* in Khartoum State, Central Sudan. *Parasites & Vectors*, **14**, Article No. 588. https://doi.org/10.1186/s13071-021-05080-y

[59] Hamlet, A., Dengela, D., Tongren, J.E., Tadesse, F.G., Bousema, T., Sinka, M., *et al.* (2022) The Potential Impact of *Anopheles stephensi* Establishment on the Transmission of *Plasmodium falciparum* in Ethiopia and Prospective Control Measures. *BMC Medicine*, **20**, Article No. 135. https://doi.org/10.1186/s12916-022-02324-1

[60] United Nations (2022) World Urbanization Prospects: The 2022 Revision. UN Department of Economic and Social Affairs.

[61] Samake, J.N., Yared, S., Hassen, M.A., Zohdy, S. and Carter, T.E. (2024) Insecticide Resistance and Population Structure of the Invasive Malaria Vector, *Anopheles stephensi*, from Fiq, Ethiopia. *Scientific Reports*, **14**, Article No. 27516. https://doi.org/10.1038/s41598-024-78072-4

[62] Keziah, E.A., Nukenine, E.N., Yingyang Danga, S.P. and Esimon, C.O. (2016) Synergistic Activity of a Mixture of *Lantana camara* and *Ocimum gratissimum* Leaves Extracts against *Aedes aegypti* Larvae (Diptera: Culicidae). *Journal of Mosquito Research*, **6**, 1-10. https://doi.org/10.5376/jmr.2016.06.0023

[63] Ismail, R.B.Y., Bozorg-Omid, F., Osei, J.H.N., Pi-Bansa, S., Frempong, K.K., Ofei, M.K., *et al.* (2024) Predicting the Environmental Suitability for *Anopheles stephensi* under the Current Conditions in Ghana. *Scientific Reports*, **14**, Article No. 1116. https://doi.org/10.1038/s41598-024-51780-7

[64] WHO (2022) Global Framework for the Response to Malaria in Urban Areas. World Health Organization.

[65] Keziah, E.A., Nukenine, E.N., Danga, S.P.Y., Younoussa, L. and Esimone, C.O. (2015) Creams Formulated with *Ocimum gratissimum* L. and *Lantana camara* L. Crude Extracts and Fractions as Mosquito Repellents against *Aedes aegypti* L. (Diptera: Culicidae). *Journal of Insect Science*, **15**, 45-45. https://doi.org/10.1093/jisesa/iev025