Implications of Climate Change and *Anopheles stephensi* Liston in Africa: Knowledge Gaps and Lessons from History

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Abstract

Purpose of Review The invasive Asian mosquito vector—*Anopheles stephensi* Liston, 1901—is poised to greatly complicate malaria eradication efforts across Africa. This species has been reported in an increasing number of African nations and has the potential to introduce malaria into most of Africa's largest cities. Climate change is a dominant force changing population dynamics across the continent and driving human populations to migrate to urban centers.

Recent Findings This work presents all high-quality surveillance data documenting *An. stephensi* to date, including an overlooked report of the species collected in Egypt in 1966. Finally, we provide detailed images of adult and larval morphology and bionomics descriptions.

Summary Based on our current knowledge of *Anopheles stephensi*, we explore how climate change may impact its distribution and malaria rates in the coming decades. We also identify key knowledge gaps related to this species invasion including the most up-to-date information on the taxonomy, morphological characters, and bionomics of *An. stephensi*. Tools that are publicly available via VectorMap are also presented along with guidance on strengthening surveillance programs targeting *An. stephensi* using these tools.

Keywords *Anopheles stephensi* · Malaria · Africa · VectorMap · WRBU

Introduction

The incursion of *Anopheles stephensi* Liston, 1901, into Africa is undermining decades of work to reduce malaria infections across the continent. Here, we present our current knowledge of this species spread and summarize tools currently available to track and predict its impact. Climate change may exacerbate the challenge to limit the expansion of *An. stephensi*, but there are lessons from the past that may be useful to guide our response.

The type locality of *An. stephensi* is Ellichpur, India, and its native range extends from the Indo-China region into the Middle East including Saudi Arabia and Oman [1]. It is widely reported that the first introduction of *An. stephensi* into continental Africa was in Djibouti in 2012, following surveillance of unprecedented malaria outbreaks in Djibouti City [2•]. However, this is erroneous, and our detailed literature search recovered documentation of *An. stephensi* larvae and adults collected from Ras Ghareb, Egypt along the coast of the Gulf of Suez in 1966 [3•]. There do not appear to be any other reports of this species found in Africa until it was detected in Djibouti. Since 2012, *An. stephensi* has been detected throughout Northeast Africa and as far South as Nigeria and Kenya [4•, 5•, 6•, 7•]. How exactly *An. stephensi* spread to Africa is still a mystery. Recent studies have shown that mosquito species are traveling great distances using high-altitude wind migration [8]. This may be a mechanism for *An. stephensi* to cross the Red Sea and spread across the continent [9]. However, other evidence suggests that given the distribution pattern so far, it is possible that marine cargo ships may be helping to spread this species [10]. A map of the current country-level distribution of *An. stephensi* in Africa is provided in Fig. 1, and a list of references confirming these detections for the first time is provided in Table 1.

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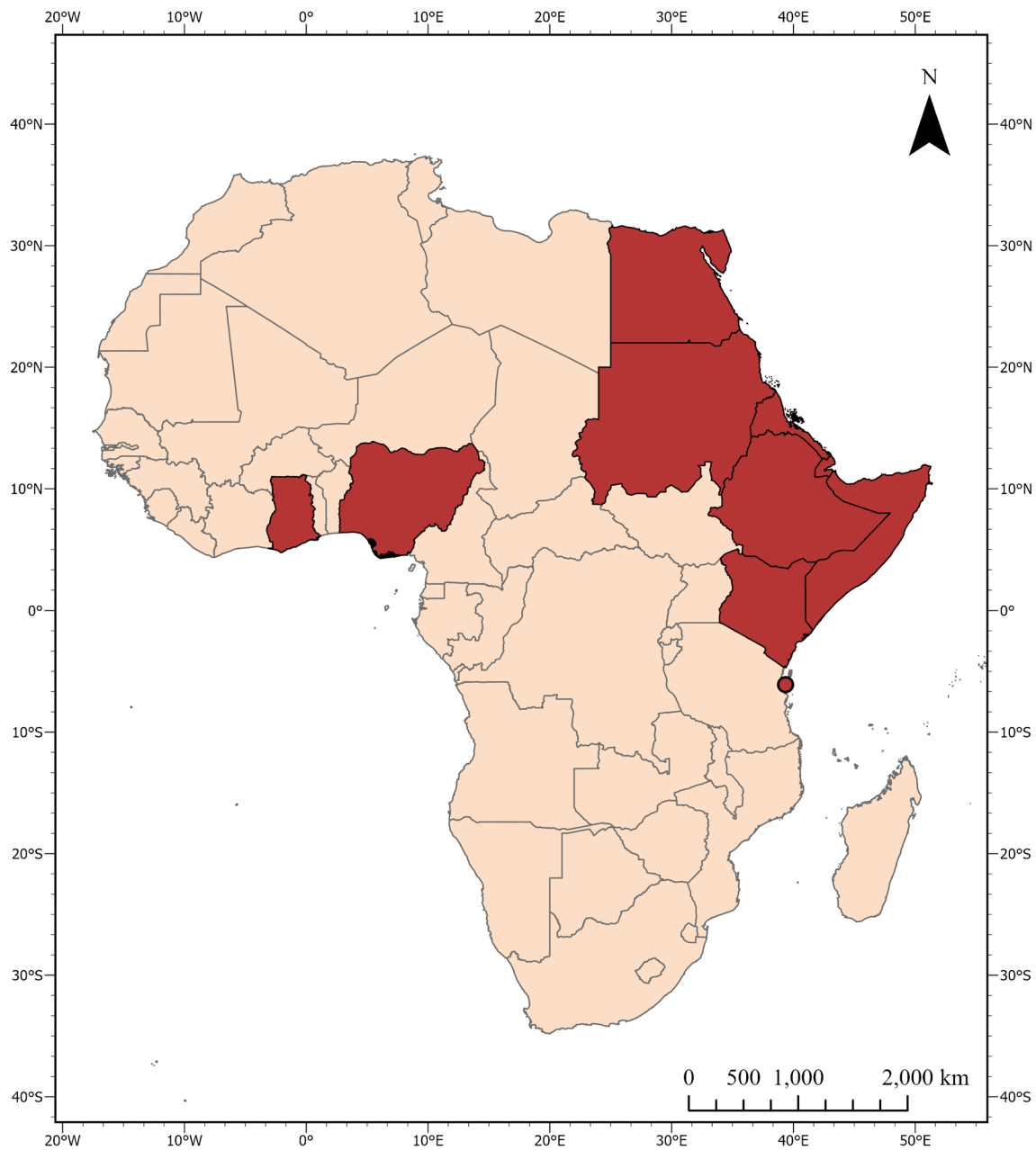
Fig. 1 Confirmed country-level distribution of *Anopheles stephensi* in Africa. Countries in red have confirmed the presence of *An. stephensi* on at least one occasion. Base map sourced from Global Administra-tive Areas (GADM) version 4.0: https://gadm.org/download_country.html. Accessed August 8, 2023

Anopheles stephensi has been implicated in severe malaria outbreaks in Djibouti where, until 2011, malaria was considered all but eradicated [2•, 13]. One study estimated that malaria rates in neighboring Ethiopia could increase by at least 50% if effective control measures for *An. stephensi* are not imple-mented [14]. As primarily an urban malaria vector, *An. ste-phensi* is wreaking havoc on populations not typically exposed to malaria or Africa's native malaria vector species. This invader is also a competent vector of both *Plasmodium falcipa-rum* and *P. vivax* malaria parasites, as well as O'nyong-nyong

virus, making it a formidable threat to human health [15, 16]. While climate change is not implicated as a cause of this inva-sive species introduction, it is highly likely to increase malaria rates across the continent as humans migrate from rural areas and concentrate in urban centers. Some predictions claim that up to 60% of the estimated 2.3 billion Africans will be urban dwellers by 2050 [17]. Indeed, several preliminary predictions of this species' potential distribution and impact on malaria transmission identify virtually every low-altitude urban area at risk for the highest levels of malaria burden increases [14, 18•].

Table 1 Confirmed country-level distribution of *Anopheles stephensi* in Africa with references and year of first reporting

Country	Year	Reference
Egypt*	1967	[3•]
Djibouti	2014	[2•]
Ethiopia	2021	[11]
Sudan	2021	[4•]
Nigeria	2022	[6•]
Eritrea	2023	[12•]
Ghana	2023	[12•]
Kenya	2023	[7•]
Somalia	2023	[5•]
Tanzania	2023	[12•]

*Detected in 1967, but not detected since

While mitigating the impact of *An. stephensi* in Africa is a daunting challenge, there are lessons from history that can offer guidance. Although the invasion of Africa by *An. stephensi* is a major event, it is not the first time a major malaria vector has invaded a continent outside its native range. The invasion of the African vector species *An. arabiensis* into Brazil—first detected in 1930—ended with the successful eradication of populations despite their establishment for over 10 years [19]. Here, we explore strategies that were implemented nearly 100 years ago that still contribute to the successful mitigation or eradication of *An. stephensi* in Africa.

Climate Change and Malaria in Africa

It should be noted that although the combined countries of Africa contribute less greenhouse gas emissions annually than larger, single countries such as the USA or China, they are far more vulnerable to the most severe consequences of climate change [20]. Already, the continent is feeling the impact of an overall decline in rainfall over the past 50 years, linked to climate change [21]. This decline in moisture availability has resulted in a "push" on populations from rural areas into urban zones as traditional subsistence agriculture becomes less dependable, while increasing urbanization also "pulls" populations into these areas in search of better economic opportunities [22]. This "push–pull" towards urban zones from rural areas is predicted to continue for the rest of the century [23]. In fact, urban land cover in Sub-Saharan Africa is predicted to expand by more than twelve times current levels by 2050 [17].

Rising average temperatures will have a direct impact on the entire life cycle of both mosquito vectors and malaria parasites. Temperature fluctuations have shown to either increase or decrease parasite development, with optimal to maximum suitability ranges all supporting development [24•]. Air temperature is therefore a useful predictor of malaria prevalence [25]. Studies show that certain regions, such as West and Central Africa, will see malaria rates drop, while others in Southern Africa may experience increased infection rates [26]. A study of global incidence of bird malaria also found a strong correlation between rising temperatures and *Plasmodium* infection rates among birds [27]. They suggested that temperature anomalies had more impact on infection rates than migratory routes, suggesting that climate change impacts risk of infection. Impacts of bird malaria are observed earlier than those in humans, as there are typically no interventions to mitigate malaria infection in wild bird populations [28].

A recent study demonstrated that temperature, rather than precipitation, may be a better indicator of when peak activity of *An. stephensi* may occur throughout the year [29] and in both *An. stephensi* and *An. gambiae* s.l., there is a close association of temperature to the environmental suitability of malaria transmission [30]. Duration and productivity of parasite development are highly correlated to temperature as well [11]. Monitoring changes in temperature and precipitation and relating that data to vector surveillance results will be key to fully understanding the impacts of climate change to malaria transmission.

Know the Vector, Know the Threat

To predict how climate change may impact *An. stephensi* spread across Africa, we must understand its taxonomic status and corresponding biology. The current taxonomic status of *An. stephensi* is unresolved, and there are three known egg phenotypes: the type form, *mysorensis* Sweet & Rao, and an intermediate form [31•]. In the Indian subcontinent, the type form is regarded as highly anthropophilic in urban areas, whereas the *mysorensis* form is primarily zoophilic and confined mostly to rural areas [32]. To date, egg morphology from *An. stephensi* material collected in Africa, including both urban and rural collections of *An. stephensi*, have yet to be reported. It is not known if the *mysorensis* form is present in Africa or if it will play a significant role in malaria transmission [33]. DNA analysis of the samples used to support the first report of *An. stephensi* in Djibouti corresponded to the type form [2•], and later network analysis using mtDNA COI barcodes for samples collected in Djibouti and Ethiopia again confirmed these populations as the "type form" of *An. stephensi*, with data analysis supporting at least two points of origin—one from India-Pakistan and one from the Arabian Peninsula. Phylogenetic analysis further revealed that *An. stephensi* specimens collected in Ethiopia and Djibouti were two distinct populations originating from different locations in Pakistan [31•].

Larval habitats of *An. stephensi* are highly unusual as compared to nearly all other *Anopheles* species in that they can include a range of artificial containers, such as domestic water storage or rainwater drainage systems [34], like those preferred by other problematic domesticated mosquitoes, (e.g., *Aedes aegypti* (Linnaeus, 1762)). Larvae of the *An. stephensi* 'mysorensis' form are also commonly found in earthenware containers in rural areas [35]. This similarity to the dengue fever vector *Ae. aegypti* offers an opportunity to modify existing vector surveillance and control efforts to target *An. stephensi*. Larvae have also been found to be highly saline-tolerant; however, it is not known if this observation is the type or *mysorensis* form, or some unidentified form [36]. Larvae of *An. stephensi* have demonstrated great ability to adapt to local environmental conditions as it spreads further into Africa [7•]. Therefore, characterizing the habitats of breeding sites will be an essential element of effective surveillance. In Table 2, we provide a comprehensive list of habitats where *An. stephensi* larvae have been collected in Africa based on published reports.

Female *An. stephensi* appear to be primarily endophilic and endophagic; however, exophilic/exophagic behavior has been observed during the warmer times of the year [38]. While considered highly anthropophilic, *An. stephensi* will also readily feed on domestic livestock [39]. A recent survey of *An. stephensi* in Chennai, India, found the highest densities of *Plasmodium*-infected adults associated with cattle sheds and other thatched roof structures, rather than human dwellings [37]. This suggests that *An. stephensi* may be feeding on humans inside their homes but exiting these structures to rest outside, which would render indoor residual

spraying efforts or indoor pyrethroid spray catches ineffective to control, or capture, host-seeking *An. stephensi*. It is important to note that routinely employed CDC light traps are not as effective for capturing adult *An. stephensi* as outdoor aspiration, resting boxes and animal baited traps [39].

Knowledge Gaps

Our team developed VectorMap (vectormap.si.edu)—a free, open-access data platform that preserves curated surveillance data to track the distribution of arthropod vectors, model their potential distribution in space and time, and analyze bionomic data, such as seasonality, host preferences, and feeding patterns [40, 41]. Users from around the world can submit their data directly to VectorMap using a web-based portal. A key feature of VectorMap is the detail at which each observation is documented, including information about the collection and identification methods, pathogen screening results, and voucher status [42]. These data can characterize our cumulative observations about vector distributions and highlight key knowledge gaps. VectorMap currently contains only 123 unique observation records for *An. stephensi* in Africa, representing 942 specimens collected from Djibouti, Egypt, Ethiopia, Kenya, Somalia, and the Sudan. A map displaying these records by stage (immatures or adults) is presented in Fig. 2. Each of these records were captured from published literature, but do not represent the complete distribution as we know it today. Recent reports of *An. stephensi* from Ghana, and Eritrea were reported during a 2023 World Health Organization regional meeting but have yet to publish surveillance data in peer-reviewed journals [12•]. Other distribution reports, such as Nigeria, have not reported locality information in sufficient detail to allow accurate mapping [6•]. The volume of publicly available, high-quality surveillance data targeting *An. stephensi* in Africa must be improved to track this species range and predict where it may be moving next more accurately. Even with our limited knowledge, there appears to be significant gaps in surveillance coverage already, particularly in central Africa. More concerning, not a single study of *An. stephensi* in Africa has thus far preserved morphological voucher specimens in a publicly accessible repository or institution. Perhaps this is due to how mosquito surveillance has changed in recent years. Modern surveillance is focused more on collection and testing adults for pathogens, rather than surveying the immature habitats. Reliance on adult surveillance for *An. stephensi* is not effective, as (1) the species are not overly attracted to light and (2) this species is establishing in urban, light pollution-heavy environments. For these reasons, *An. stephensi* can be hiding in plain sight and often missed in

Table 2 Verbatim descriptions of larval habitat of *Anopheles stephensi* in Africa

| Country	Larval Habitat	Reference
Egypt	Small pits at periphery of large saltwater pool	[3•]
Ethiopia	Abandoned car wash	
	Berkads	
	Broken bucket	
	Construction water storage reservoirs	
	Discarded tires	[2•, 3•, 4•]
	Discarded vehicle part	
	Steel drums	
	Temporary water storage reservoirs	
	Water tanks	
Kenya	Animal drinking points	
	River pan	[7•, 37]
	Tank	
	Tire	
	Water treatment plant	
Somalia	Berkads	[5•]
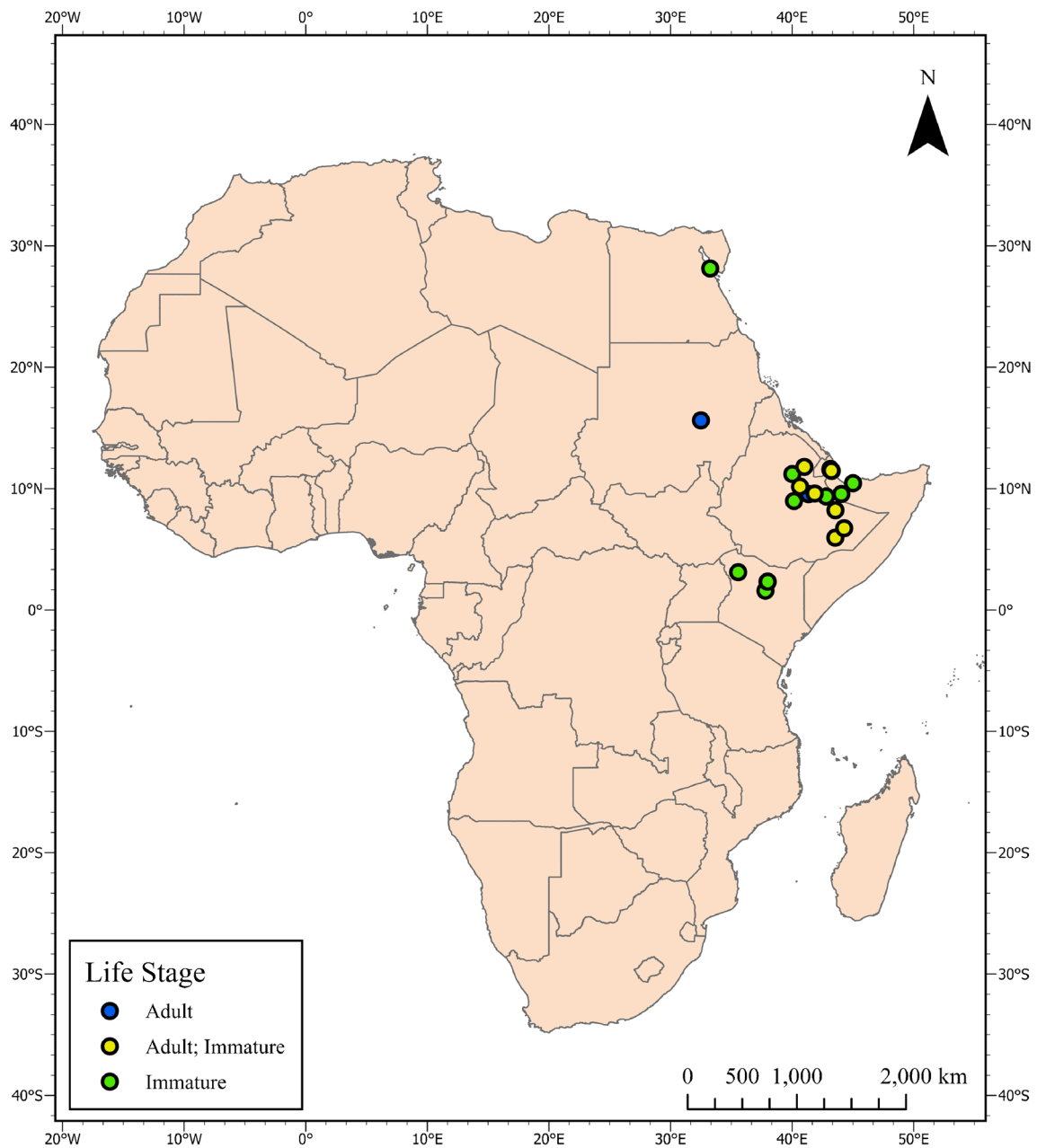
Fig. 2 Map of *Anopheles stephensi* surveillance results from VectorMap. Data were obtained from records published in the following institutions and accessed through the VectorMap data portal (http://www.vectormap.si.edu) on 21 July 2023 [2•, 3•, 4•, 5•, 6•, 7•, 37].

Base map sourced from Global Administrative Areas (GADM) version 4.0: https://gadm.org/download_country.html. Accessed August 8, 2023

routine surveillance efforts. WRBU has preserved genetic voucher material from the initial detection of *An. stephensi* in Djibouti along with morphological vouchers from across its native range as part of the National mosquito collection. However, more genetic material and morphological vouchers representing all life stages collected throughout Africa are urgently needed.

Population levels of mosquito vector species are highly dependent on environmental variables such as

temperature, precipitation, and vegetation [43, 44]. These variables can be used to model the distribution and seasonality of mosquito vector populations [45]. Geographic Information Systems (GIS) techniques are widely being implemented to make correlations between mosquito surveillance data and environmental observations [46]. GIS offers the capability to make more accurate predictions of where and when mosquito larvae are present within a given landscape.

With high-quality data, it is even possible to make predictions of how species ranges may be impacted in the coming decades due to expected impacts from climate change [47]. Standardization of accurate and precise field collection data and regular preservation of voucher specimens documenting *An. stephensi* observations will provide a foundation for the development of models and data-driven mitigation strategies. By linking vector surveillance data to environmental data and even human malaria incidence, we can gain a clearer understanding of where and when risk of infection is the highest and when implementation of control strategies will be the most effective.

Climate change is predicted to continue impacting the distribution of vector species in Africa over the course of this century [48]. A recent study modeling the potential shifts in distributions of *Aedes albopictus* (Skuse, 1895) and *Ae. aegypti* predicted some areas that currently support these species will become too hot and dry to support these populations while other areas that currently do not support these species may become more favorable by the end of the century [49]. Several studies have also predicted similar scenarios for malaria in Africa [26, 50]. For example, projected future climatic conditions are expected to cause increased suitability for malaria transmission in the East African highlands and further South into Sub-Saharan Africa where previously malaria transmission was rare [28]. It is imperative to establish robust surveillance systems that capture longitudinal datasets and routinely close gaps in surveillance coverage overtime. These data should iteratively update models on the projected distribution of *An. stephensi* as well as malaria risk, as new data is made available.

Morphological identification of both the larval and adult life stages will be essential to *An. stephensi* surveillance efforts in Africa. Given the difficulty associated with collecting adult *An. stephensi* specimens in urban environments, and the desire to screen these samples for *Plasmodium* infection, targeted larval collections may be the most effective way to confirm or rule out the presence of *An. stephensi*. However, without expert knowledge of diagnostic morphology and the capability to examine specimens at high magnification, this will be a major challenge to execute across Africa. Africa's most notorious native malaria vectors, members of the *An. gambiae* complex, look very similar to *An. stephensi* larvae, as are all members of the subgenus *Cellia*. This means *An. stephensi* cannot be readily distinguished from native species unless examined by a well-trained taxonomist. Support to develop training programs for local para-taxonomists across the continent is urgently needed so that more individuals are capable of confirming the presence of *An. stephensi* in its immature stages.

Identification keys are available for the adult and larval stages of *An. stephensi* [51–54]. However, these keys will need to be updated regularly as we learn the complete distribution of *An. stephensi* in Africa. As most mosquito control workers will be unfamiliar with this invasive species, we have provided diagnostic morphological characters for adult and larval stages in Figs. 3 and 4, respectively [1]. Field-ready identification tools covering both morphological and molecular approaches will also be essential. Morphological keys available on mobile devices covering all life stages, including images of immatures and eggs would support training of para-taxonomists to reliably identify specimens captured during surveillance and separate specimens for *Plasmodium* screening. Widespread use of field-based molecular screening tools would allow local confirmation of vector species and *Plasmodium* infection without the need for costly shipments to far flung laboratories.

A growing global concern is rising insecticide resistance (IR) among *Anopheles* species, particularly to pyrethroids, which are commonly used on insecticide-treated bed nets (ITNs) and for indoor residual spraying (IRS) [55]. Any surveillance system should therefore incorporate IR screening as well to identify where resistance may be developing. Resistance data should also be shared broadly so that local mosquito control workers have knowledge of what insecticide classes may be failing and which ones may still be effective. VectorMap also hosts, IRMap, a map service dedicated to preserving and sharing insecticide resistance surveillance results. A key feature of IRMap is to integrate molecular confirmations (e.g., kdr mutations) and traditional testing methods (CDC bottle assay) within a single, standardized data schema. This allows for multiple data streams to combine within the database for a more comprehensive view of resistance rates. Climate change is not considered a driver of IR in mosquitoes, rather an over reliance on chemical control of insects in general is to blame [56]. This also supports the non-chemical alternative of point-source reduction targeting larval habitats.

Finally, a streamlined data collection system and pipelines for open data sharing will greatly improve our knowledge and ensure that high-quality surveillance data detailing vector occurrence, pathogen detection, human disease incidence, and IR detections are all standardized and made freely available. Raw data should be made available for independent analyses, and the system should present data visualizations such as dynamic dashboards that provide real-time information to local decision makers and health planners [57].

Lessons from History

With such a daunting task before us, perhaps there are some lessons from history that can guide our response. Almost 100 years ago, another malaria vector colonized a new continent and quickly caused malaria cases to rise. In March 1930, R.C. Shannon reported some unusual larvae from a streambed at Natal, Brazil, and identified them as the major Afrotropical vector *Anopheles gambiae*. Molecular analyses

Fig. 3 Diagnostic characters of *Anopheles stephensi* adult female. Adult: **A** Habitus, adult female. **B** Head, adult female lateral view: (1) Palp segment 5 entirely pale; (2) maxillary palpus with pale bands; (3) erect head scales broad, white on vertex and dark brown laterally and posteriorly. **C** Thorax, adult female dorsal view; scutum with obvious pale scales in addition to setae; scutal fossa with scattered pale scales. **D** Wing, adult female lateral view: (1) Vein 1A with 3 dark spots; wing with pale spots present on nearly all veins. **E** Abdomen, adult female dorsal view: II–VII-Te without dark scale tufts. **F** Abdomen, adult female lateral view: V–VIII-S usually with pale scales [1]
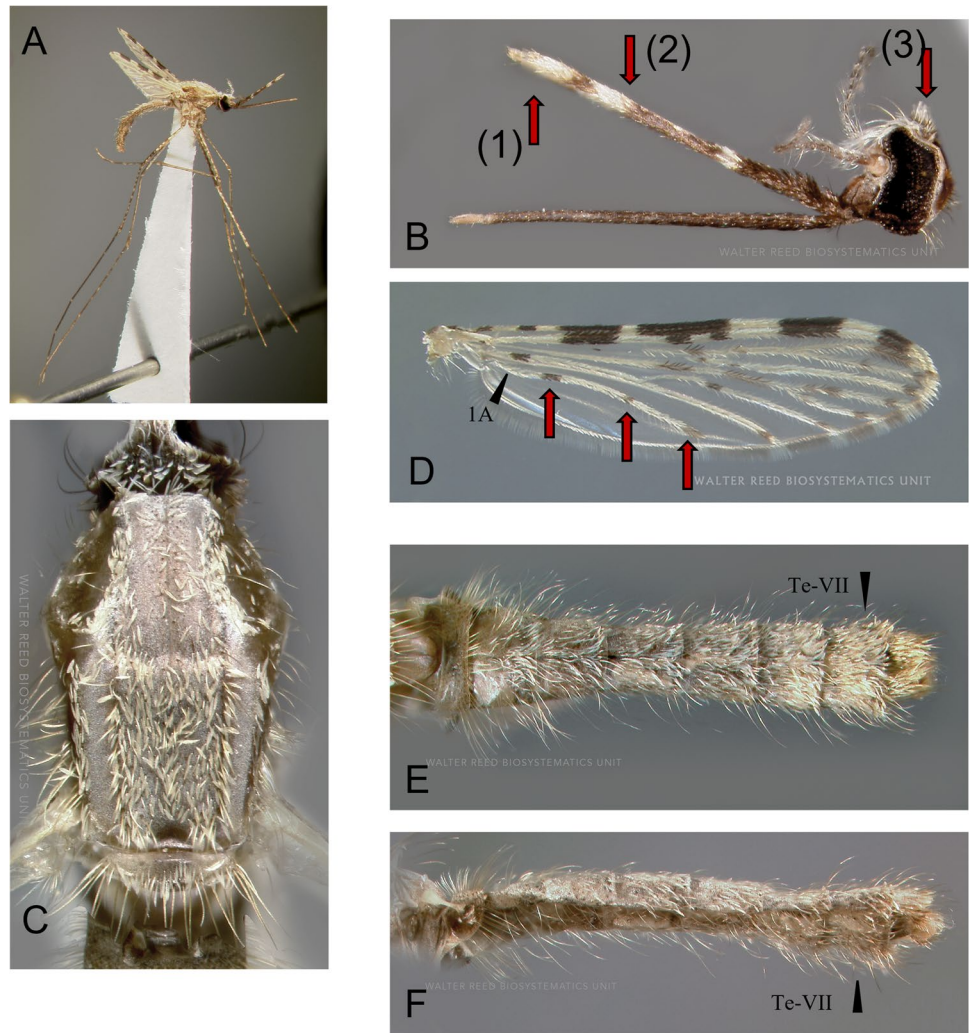
of preserved voucher specimens from these collections later confirmed these were its sister taxa—*Anopheles arabiensis* Patton, 1905 [58]. Nearly 10 years from the initial discovery of this invasive species in Brazil, one of the most ambitious and successful eradication campaigns was undertaken. Initially however, experts struggled to convince public authorities of the importance of this introduction and only after significant rises in malaria cases and deaths were proper resources allocated to the issue [19]. Fred Soper and D. B. Wilson described the issue this way:

> "That it was done only after the regional disaster of 1938 was due entirely to the fact that local health officers did not have the necessary authority to overcome the power of vested interests."

Even before widespread support for this issue was granted, the Brazilian Malaria Service (BMS) worked to characterize the bionomics of this invader in as much detail as possible. The BMS made observations across Northeast

Brazil characterizing larvae habitat, adult feeding behavior, duration and viability of eggs, and seasonal variation [19, 59]. Once it became clear that *An. arabiensis* was quickly spreading across Brazil and that malaria case rates were rising at an alarming rate, the Brazilian Government, with support from the Rockefeller Foundation, formed the Antimalaria Service, among their goals was the total eradication of *An. arabiensis*. Eradication of an entire species from a continent was a monumental challenge; however, they drew inspiration from the successful eradication of *Ae. aegypti* from Havana, Cuba, by targeted elimination of breeding sites as led by CPT William C. Gorgas (US Army) [60]. The foundation of both eradication campaigns was the parceling of land into individual control "zones." Each of these zones was assigned an inspector who was individually responsible for implementing source reduction and applying larvicide [19]. Soper and Wilson stressed the importance of communication and accountability that resonates today:
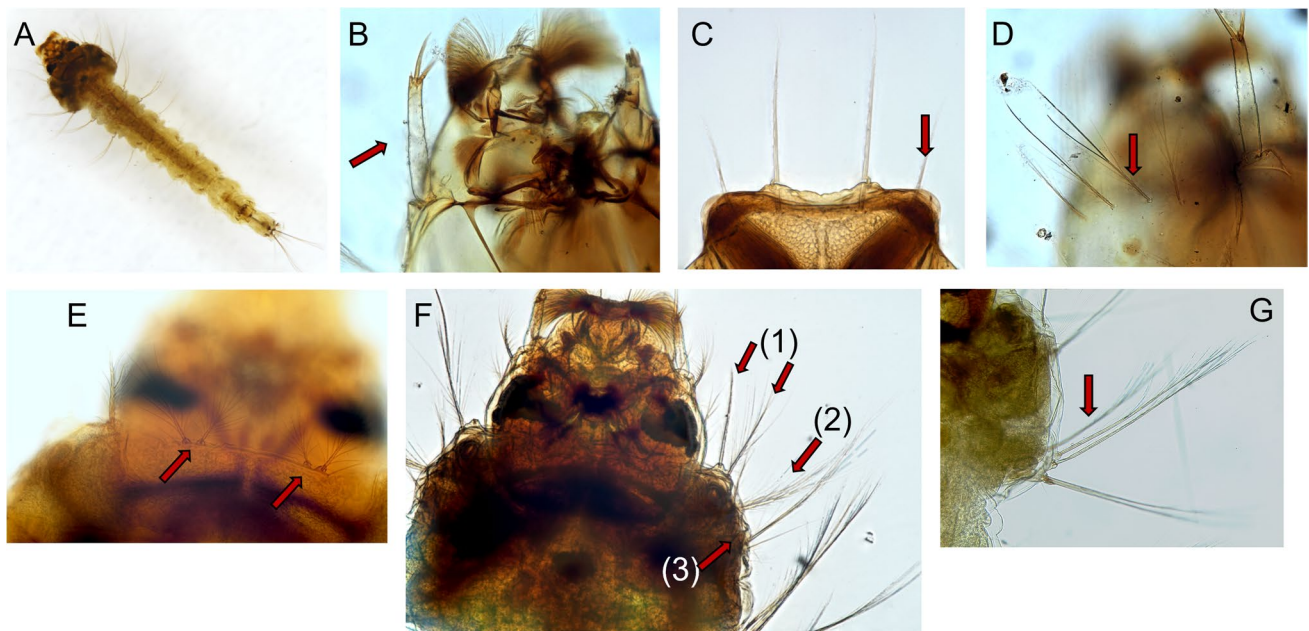
Fig. 4 Diagnostic characters of *Anopheles stephensi* larvae. Larva: **A** Habitus. **B** Head, dorsal view: Seta 1-A small, unbranched; setae. **C** Head, dorsal view: setae 2,3-C smooth, not aciculate; distance between seta 2-C > distance between setae 2-C and 3-C on one side. **D** Head, dorsal view: setae 5–7-C long and branched. **E** Thorax, lateral view: setae 1,2-P inserted on dark, sclerotized tubercles. **F** Thorax, dorsal view: (1) setae 9,10-P and 9,10-M not all unbranched. (2) setae 9-M plumose, branched from base; (3) setae 10–12-M unbranched. **G** Thorax, dorsal view: setae 9,10-T branched [1]

 "… it was always the inspector who actually carried out the anti-[*arabiensis*] measures and since he often worked alone and far from headquarters, it was essential to establish individual responsibility for work done and individual responsibility for checking such work."

It should be noted that in addition to point-source reduction of breeding sites, the program also included support for public education on reducing malaria transmission risk, the dispersal of anti-malaria drugs, and a program requiring the de-insectization of buildings, as well as planes and other vehicles, to reduce further introductions [19]. By 1940, no trace of *An. arabiensis* could be found in Brazil and the program was suspended.

There are a few key takeaways from this historic campaign that could be applied to dealing with *An. stephensi* in Africa: (1) It will require carefully documented scientific evidence to convince authorities to provide additional support. (2) A strong understanding of the invasive species biology is essential to developing a successful control strategy. (3) Empowering local inspectors to take individual responsibility for their communities decentralizes decision making and makes control efforts more efficient, and with these coordinated efforts.

There are also a few key differences between the introduction of *An. arabiensis* and *An. stephensi*. Firstly, surveillance was conducted by taxonomists. Larvae of *An. arabiensis* were morphologically distinct from local Brazilian mosquito species as they belonged to a different subgenus, thus were readily identified during routine sampling. In Africa, we do not have this advantage. *Anopheles stephensi* belong to the same subgenus (*Cellia*) as the most common local malaria vectors so introductions will be much more challenging to detect. Adults are not readily collected in routine surveillance and, larval surveys are infrequently used by vector control teams. Secondly, government and philanthropist organizations agreed to make eradication the goal in Brazil and provided appropriate support. To date, there is no official goal by governments or NGOs operating in Africa to eradicate this invasive species or moves to provide the necessary support to do so.

Conclusions

The impact of climate change on vector-borne disease trends in Africa over the remainder of the century will be difficult to predict. One clear trend is the "push" and "pull" on rural populations to migrate to urban areas, creating megacity metropolises [22]. At the same time, *An. stephensi* is stealthily spreading and establishing in urban areas and is predicted to find suitable habitat across the entire continent [18•]. Since its demonstrated role in malaria outbreaks in Djibouti, there has been a steady drumbeat from the scientific community

that increased surveillance for this species is necessary [2•, 61, 62]. A growing number of experts are also calling for immediate increased support for the control of this species to start slowing its spread [63]. Compounding this problem is the fact that mosquito control workers in Africa are grossly understaffed and in desperate need of additional support with as few as 8% of national malaria programs reporting the capacity to conduct routine surveillance [64]. An undertrained, ill-equipped vector control workforce that is mostly unfamiliar with this species, and already stretched thin is a recipe for disaster. It is imperative that new tools be made widely available in Africa to improve species detection, and better understand the risk it poses to the continental goal of malaria eradication through additional efforts to assess *Plasmodium* infection and IR prevalence.

History provides examples of how invasive mosquito species can be eradicated. When *An. arabiensis* invaded Brazil in the 1930s, it took nearly 10 years to convince authorities and funding agencies to allocate more resources to the problem and to officially make eradication a goal. However, by empowering local communities with knowledge, tools, and funding support, eradication became an attainable goal. Prioritizing larval control also provides a non-chemical, cost effective measure to reduce vector populations [65]. It is also important to note that the eradication of *An. arabiensis* was only possible after significant effort to convince government officials and funding organizations to support the goal of eradication [66].

Critically, most of our current knowledge about this vector comes from observations made across its native range [67]. Therefore, more observations of this species across Africa are needed to fully understand how its presence is impacting malaria transmission. While implementing control, we must also be mindful of rising IR among vector species and screen samples for such control measure failures to adjust insecticide use. Non-chemical interventions, public health education and a free flow of data are also needed. The invasion of *An. stephensi* is a stark reminder of the many arthropod vector threats impacting human and animal health in Africa. Even without this emerging issue, climate change will bring many more challenges before the end of the century.

Data availability All data presented here is publicly available.

Declarations

Disclaimer Material has been reviewed by the Walter Reed Army Institute of Research. There is no objection to its presentation and/ or publication. The opinions or assertions contained herein are the private views of the author, and are not to be construed as official, or as reflecting true views of the Department of the Army or the Department of Defense.

Competing of Interest The authors declare no competing interests.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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