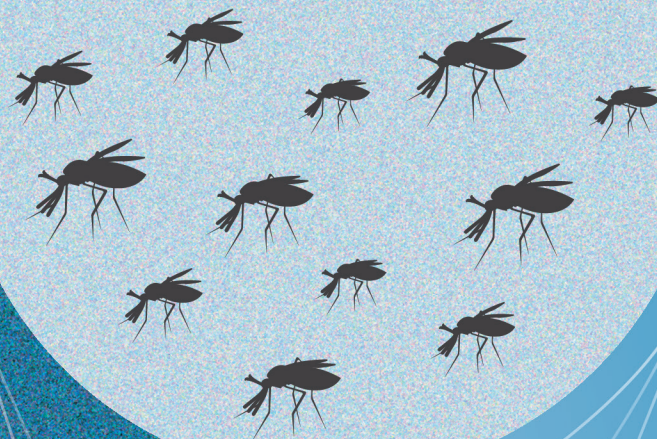# Surveillance and control of *Anopheles stephensi*

Country experiences

Surveillance and control of *Anopheles stephensi*

Country experiences

World Health Organization

Design and layout by Lushomo.

Contents

Foreword

In his foreword to the *World malaria report 2022*, the Director-General of the World Health Organization (WHO) Dr Tedros Adhanom Ghebreyesus noted the importance of resilience in the face of new risks to malaria control throughout the world. One of the named risks is the spread of *Anopheles stephensi* in Africa.

Anopheles stephensi is a highly competent vector of malaria parasites that was first detected on the African continent in Djibouti in 2012. With evidence emerging of the spread of *An. stephensi* to other African countries, WHO published a vector alert in 2019 recognizing the potential threat this vector poses to malaria control and elimination. An initiative was then launched in 2022 to address the spread of *An. stephensi* in Africa through a five-pronged approach: increasing collaboration, strengthening surveillance, improving information exchange, developing guidance and prioritizing research. It was deemed essential to build an evidence base to assess the feasibility of controlling *An. stephensi* in order to prevent its further spread and potentially eliminate it from areas that have been invaded.

This report provides case studies from selected countries to serve as examples of how to optimize the surveillance and control of *An. stephensi*. The aim is to voice experiences across different settings in order to generate a shared evidence base to inform the development of appropriate strategies in other countries. It is important to acknowledge that there are many efforts under way to control *An. stephensi*, including in the WHO African, Eastern Mediterranean and Western Pacific Regions. By no means have all of these been covered in this first edition. WHO plans for this initial document to serve as a template for establishing a collection of country case studies to optimize sharing and learning and, ultimately, expand appropriate surveillance and control activities to address *An. stephensi*.

WHO will continue to provide technical assistance to strengthen vector surveillance and control for malaria, including for *An. stephensi* in Africa, where this is an emerging challenge. Action at country level will be critical to addressing this threat in Africa, in order to realize the vision and targets set out in the *Global technical strategy for malaria 2016–2030*, national malaria plans and sustainable development plans. This will further drive progress towards achieving good health for all.

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Acknowledgements

Abbreviations

AMC	Anti Malaria Campaign
BMC	Brihanmumbai Municipal Corporation
DDI/DNA	Division of Data, Analytics and Delivery for Impact, Department of Data and Analytics
DDT	dichlorodiphenyltrichloroethane
ICMR	Indian Council of Medical Research
IRS	indoor residual spraying
LLIN	long-lasting insecticidal net
NCVBDC	National Center for Vector Borne Diseases Control
WHO	World Health Organization

1. Introduction

This collection of case studies was developed to address the need for further information on the successes and challenges encountered in the surveillance and control of the invasive and highly resilient malaria vector, *Anopheles stephensi*. The aim is to showcase how different countries outside of Africa – with different health systems and different challenges and facilitators in the control or elimination of malaria – have implemented surveillance and control of this vector species.

This document contains an initial set of three country case studies from India, the Islamic Republic of Iran and Sri Lanka. Experiences with *An. stephensi* in these countries range from many decades of ongoing surveillance and control to recent response to invasion of this species. These initial country case studies will form the basis of a repository of examples to facilitate sharing and learning on this threat to malaria control, in support of the *WHO initiative to stop the spread of* Anopheles stephensi *in Africa (1).*

The country case studies do not assess or evaluate implementation, but explore approaches taken and lessons learned during the implementation of surveillance and control. These experiences have been used to identify key findings and general programmatic considerations to inform actions to address *An. stephensi* in Africa.

2. Background

Anopheles stephensi is known to be an efficient vector of *Plasmodium falciparum* and *P. vivax* in some settings. This mosquito species has the capacity to thrive in urban environments and adapt to new habitats. It has been found to be resistant to many of the insecticides used in public health. These characteristics enable the species to invade new territories and pose a challenge to the effectiveness of the most commonly used malaria vector control tools.

Originally native to Asia with a range from the eastern part of the Arabian Peninsula to Thailand, *An. stephensi* was later detected in western Saudi Arabia (2004), Sri Lanka (2016) and Yemen (2021). On the African continent, it was first detected in Djibouti in 2012 and has since been reported in seven additional African countries (see Fig. 1). To date, there have been no reports of it spreading to the east from its original native area.

Awareness of and surveillance for *An. stephensi* have been limited in many areas. The current distribution of this vector species is therefore likely to be considerably wider than reported. In the absence of more information, it is difficult to ascertain when and where the vector may be spreading versus where it may already be established. This constrains the ability to implement informed containment and control activities.

Fig. 1. Years that *An. stephensi* was first detected in countries in the WHO African Region and the WHO Eastern Mediterranean Region
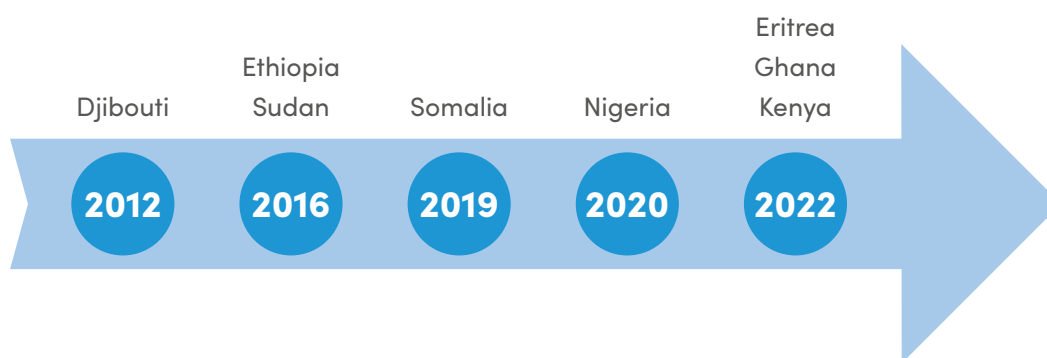
Note: As reported to WHO by 31 December 2023

Anopheles stephensi consists of three major biotypes: type, intermediate and mysorensis. These biotypes differ in their morphology, ecology, behaviour and mating characteristics. In India, the *An. stephensi* type form is considered the most important vector of malaria in urban areas. The intermediate form is a more common vector in rural areas. The mysorensis form is generally considered to be a poor vector of human malaria due to its preference for feeding on animals; however, it has been confirmed as a human malaria vector in some locations, such as in the Islamic Republic of Iran.

Anopheles stephensi is thought to have contributed to a resurgence of malaria in Djibouti City and at least one outbreak in Ethiopia *(2,3)*. However, the overall contribution of *An. stephensi* to malaria transmission in Africa is unclear. Nevertheless, the rapid growth of many African cities coupled with the invasion and spread of this highly adaptable species is of concern. Establishment of *An. stephensi* as an efficient malaria vector in urban areas of Africa could undermine malaria control on the continent *(4,5)*.

Recognizing the potential threat that *An. stephensi* may pose to achieving global malaria control and elimination targets, in 2022, WHO launched the *WHO initiative to stop the spread of* Anopheles stephensi *in Africa (1)*. This initiative recognizes the need to increase collaboration, strengthen surveillance, improve information exchange, develop more guidance and prioritize research, as summarized in Fig. 2. To support this, WHO has commenced the process of documenting country experiences in the surveillance and control of *An. stephensi*.

Fig. 2. Aims of the _WHO initiative to stop the spread of_ Anopheles stephensi _in Africa_
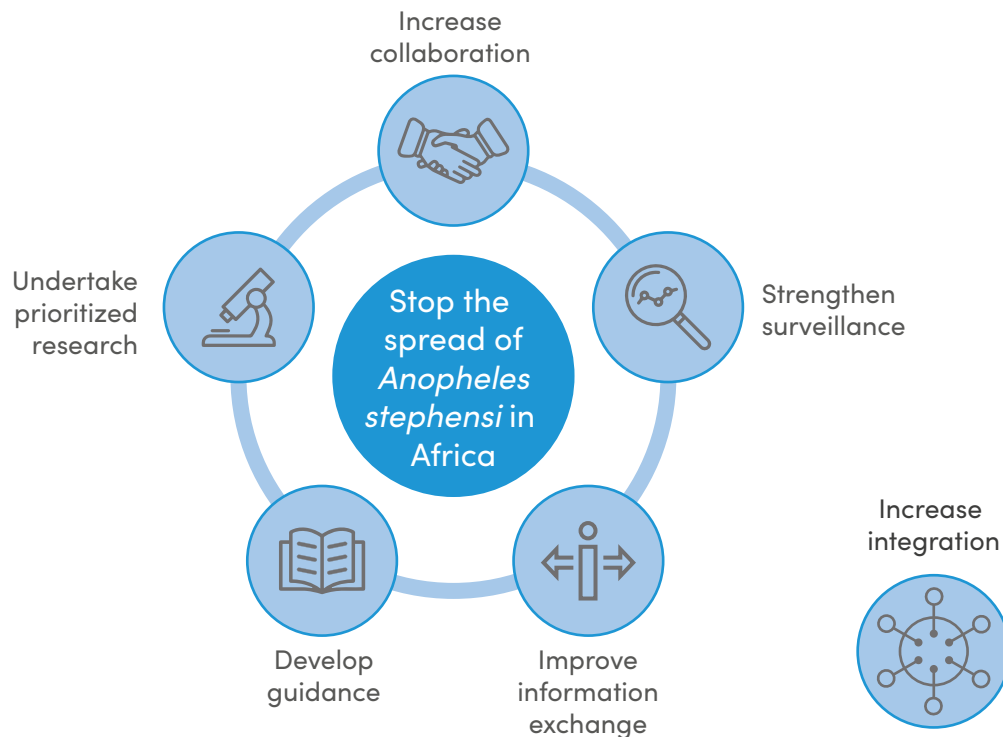
While increased integration is not an explicit aim of the initiative, this report highlights areas where the surveillance and control of _An. stephensi_ can be integrated with actions targeting other vectors of malaria or other vector-borne diseases.

2.1 Aim of this collection

The purpose of these country case studies is to document practices and experiences in _An. stephensi_ surveillance and control with the aim of encouraging national malaria control programmes – particularly in Africa – to learn from experiences elsewhere and adopt best practices, including through integrated programming and implementation.

The first edition of this collection offers a small snapshot of country and local experiences from India, the Islamic Republic of Iran and Sri Lanka to contribute to advancing the _WHO initiative to stop the spread of_ Anopheles stephensi _in Africa (1)_. The document includes an overview of common challenges and facilitators of implementation. General programmatic considerations also outline how WHO Member States may be able to continue progress in this area. The country case studies do not comprehensively evaluate programme implementation, efficiency or impact, but instead rely on country experience and expert opinion.

The intention is for these case studies to form the basis of a repository of implementation experience to inform the design and implementation of control activities in other WHO Member States affected or threatened by the invasion of _An. stephensi_, including those in the process of determining whether invasion has occurred or how to prevent it. This knowledge base can be extended to further facilitate sharing and learning on the surveillance and control of _An. stephensi_ and other potentially invasive vector species.

Lessons learned must be considered in the broader context of reducing malaria burden and threat, as articulated in country malaria strategic plans and guided by the WHO *Global technical strategy for malaria 2016–2030 (6)* and the *Global vector control response 2017–2030 (7)*. The intention is not to divert existing resources away from essential ongoing malaria vector control activities, but to identify extension activities that may be needed. This includes identifying and assessing options for integrating vector surveillance and control activities, facilitating inter- and intra-sectoral action, and fostering community engagement and mobilization. Underpinning these efforts will be the maintenance of sufficient capacity and capability to enhance vector control, as well as research and innovation to better inform action against *An. stephensi* and other malaria vectors. Research and innovation may also guide the mobilization of additional resources to address *An. stephensi*, where needed.

2.2 Target audience

This collection of case studies is intended for stakeholders working towards control and elimination of malaria in countries affected or threatened by the apparent spread of *An. stephensi* in Africa. These stakeholders include high-level decision makers responsible for setting policies, strategies and plans and for developing budgets for vector surveillance and control at national and subnational levels. More broadly, this collection is designed to support development partners that have an interest in or are working on malaria vector control in Africa, including academia, private sector, and bilateral and multilateral organizations.

2.3 Methodology

The countries for the initial case studies (India, Islamic Republic of Iran, Sri Lanka) were selected based on the availability of scientific literature and data on *An. stephensi* and in consultation with WHO regional focal points. Detailed desktop reviews were undertaken of relevant published and grey literature for each country to identify preliminary key findings, major knowledge gaps and potential key informants. A standard interview tool was developed with closed- and open-ended questions and adapted to each country based on the outcomes of the literature review. Semi-structured interviews with key informants were conducted online or in-person, either individually or in groups. A total of 31 people were interviewed for India, eight for the Islamic Republic of Iran and 42 for Sri Lanka (see Annex). Subsequent clarifications were sought from informants as needed. Key findings and programmatic considerations were drafted based on the literature review, interviews and discussions. These were reviewed by the key informants and regional advisors, with amendments made based on consensus.

3. Country case studies

This collection consolidates findings from case studies of three countries, highlighting key lessons learned and supporting the *WHO initiative to stop the spread of* Anopheles stephensi *in Africa (1)*.

3.1 India

Key lessons				
Improve information exchange	Increase collaboration	Strengthen surveillance	Undertake prioritized research	Develop guidance

3.1.1 Background

Malaria dynamics are complex and varied across India. Diverse environmental conditions, multiple species of vectors and parasites, varied human socioeconomic situations, and different cultural and behavioural practices complicate malaria control. Significant progress has been made in many states, but progress overall has been uneven. Nationwide, malaria burden declined by 72% between 2016 and 2022 – from 12.3 million cases to 3.4 million cases *(8)*. Over the same period, deaths due to malaria dropped by over 75%. Around one tenth of the total cases of malaria in India are reported in urban areas *(9)*.

There are six main malaria vectors in India (*An. culicifacies, An. stephensi, An. baimaii, An. fluviatilis, An. minimus* and *An. sundaicus*) and four secondary vectors (*An. annularis, An. varuna, An. nivipes* and *An. jeyporiensis*). *Anopheles culicifacies*, which is a sibling species complex, shows varied species composition and distribution across states, which influences regional transmission dynamics. *Anopheles stephensi* serves as the urban vector responsible for transmitting both *P. vivax* and *P. falciparum*, breeding prolifically in overhead tanks, wells, water used for curing concrete at construction sites, cement cisterns, ornamental fountains and a variety of other man-made habitats. *Anopheles stephensi* type form has been found more often and is more commonly associated with malaria transmission in urban settings than the mysorensis form, but there have been some exceptions in India, such as in Visakhapatnam *(10)* and the Deccan Plateau *(11)*.

The National Center for Vector Borne Diseases Control (NCVBDC) covers the prevention and control of malaria, dengue, chikungunya, Japanese encephalitis, kala-azar and lymphatic filariasis. The NCVBDC provides technical assistance and disburses funds and commodities to the states and union territories for implementing the programme. Malaria vector control in rural areas involves the deployment of indoor residual spraying (IRS) and long-lasting insecticidal nets (LLINs), with nets distributed at high coverage, particularly in north-eastern states and in forested areas of states in central and eastern India.

The Urban Malaria Scheme was initiated in 1971 under the National Malaria Eradication Programme (predecessor to the NCVBDC) in response to a rising trend in urban malaria, which contributed around 10–12% of total cases nationwide *(9)*. The main activities currently administered under the scheme are larval control using larvivorous fish and chemical or biological insecticides, and enforcement of by-laws aimed at preventing the proliferation of mosquitoes.

The accumulated experiences of surveillance and control of *An. stephensi* in India in heavily populated urban areas are likely to provide valuable lessons for other urban centres facing the threat of this species, such as in Africa. Four key lessons are presented below, although there are numerous other lessons from this wide and varied country, some of which are documented elsewhere (e.g. *(12,13)*).

3.1.2 Lessons learned

1. Urban construction activity can support the proliferation of *An. stephensi* and transmission of malaria.

Panaji, the capital city of Goa, suffered a severe outbreak of malaria, with an increase from around 10 cases per year in 1985 to over 5000 in 1988, in a population of around 43 000 people. Construction activity in Panaji had increased significantly in the previous decade, and the focus of malaria transmission seemed to originate from a major construction site before spreading further in the city. An epidemiological investigation noted certain features of the outbreak that were consistent with those reported in many other urban settings in India: most of the workers at the construction sites were migrants from other states of India. Large numbers of cases were found in these workers, with incidence rates 11- to 19-fold higher than in local residents *(14)*. Around three quarters of the workers reported visiting home at least once per year. Most of them (73%) were from Karnataka state, a malaria-endemic region in the south–west of India. This may have provided a source of domestic importation of malaria parasites into Panaji.

Significant levels of *An. stephensi* larvae were found at the construction sites and nearby housing occupied by migrant workers. Larval infestation rates varied throughout the year, ranging from 0.8% to 6.1% in masonry tanks and 0.6% to 9% in curing water and rainwater storage tanks; the highest positivity generally coincided with higher rainfall. Investigators concluded that vector control measures should be implemented in all construction sites to control *An. stephensi* larvae and reduce the risk of malaria transmission. Similarly, *An. stephensi* was subsequently found to be involved in many other outbreaks of malaria in Indian cities, often related to construction *(15,16)*.

Several changes were made to the Goa Public Health Act to prevent vector proliferation, with the imposition of fines if vector surveillance workers detected vectors in residential, commercial and construction sites. Deployment of multiple interventions, such as introduction of larvivorous fish, selective application of bio-larvicides and temephos, source reduction with minor engineering methods, compulsory installation of mosquito-proof overhead tanks, and free distribution of LLINs to construction workers, together with active and passive screening, diagnosis and treatment of malaria cases, have resulted in dramatic decreases in malaria in Goa, particularly over the past 10 years.

2. Greater focus on *An. stephensi* control is warranted where there is evidence of its involvement in urban malaria transmission.

IRS was scaled up in India from 1945, with further expansion following the launch of the National Malaria Eradication Programme in 1958 *(17)*. In rural areas, spraying with dichlorodiphenyltrichloroethane (DDT) insecticide was common. However, urban areas with over 40 000 inhabitants were excluded from DDT coverage, with larval control measures recommended instead *(18)*. While rural areas noted a dramatic decline in malaria cases during this time, the proportion of cases in some urban areas increased. This raised concerns given the ongoing rapid urbanization throughout India, leading to the convening of a special committee to make appropriate recommendations to address urban malaria.

The recommendations of this committee led to the establishment of the Urban Malaria Scheme, which was initiated to tackle malaria mainly transmitted by *An. stephensi*. This scheme was limited to towns or cities with a minimum population of 40 000 (since revised to 50 000) and with an annual parasite incidence of two or more *(18)*, with the additional condition that "the towns should promulgate and strictly implement the civic by-laws to prevent/eliminate domestic and peri-domestic breeding places".

The scheme focuses on larval source management through minor engineering or mosquito-proofing activities, enforcement of by-laws aimed at preventing mosquito breeding, and control of larvae through the application of larvicides or distribution of larvivorous fish. In addition, some space spraying is conducted in and around positive cases in outbreak conditions to kill infective mosquitoes. The national government provided the funds to states and municipalities for these activities until 1980, at which point the costs were shared equally between the national and state governments *(18)*. The scheme was initiated in 23 towns, but now covers 131 towns and 19 states and union territories.

One example of the implementation of urban malaria control can be seen in Chennai. Chennai city has historically contributed around 57–79% of the malaria cases recorded in Tamil Nadu state. A seven-point action plan was initiated in 1992 based on field demonstration of the bio-environmental control of malaria in six highly endemic corporation divisions of the city. The plan included application of lids, larvivorous fish or larvicidal oil to tanks, cisterns and wells as known habitats of *An. stephensi*; rigid implementation of municipal by-laws to prevent mosquito proliferation; construction requirements (including additional measures for high-risk sites) with clearance by the health department; coordination within and between corporations/municipalities and state health departments; and monitoring and reporting of implementation. Malaria cases in Chennai decreased from 9789 in 2010 to 585 in 2021 *(19)*, indicating that focused, multi-pronged control in urban areas where *An. stephensi* is the main vector can have a significant impact on the urban malaria burden.

While significant progress has been made against urban malaria under the Urban Malaria Scheme, the authors of the malaria programme review report in 2022 recommended a greater focus on urban malaria issues, along with better coordination, data reporting and data sharing *(20)*. The national strategic plan indicates that "intervention measures for Integrated Vector Management in urban areas must be developed in close coordination with Local Urban Bodies" *(13)*.

3. Urban legislation can prevent *An. stephensi* proliferation in private and public premises.

Mumbai is a mega-city of 12.5 million people on the west coast of India, with 23 million people in the 6328 km^2 greater metropolitan area. *Anopheles stephensi* is the major malaria vector in Mumbai, where it breeds primarily in overhead tanks, fountains, water used for curing concrete at construction sites and, in some areas, wells. Infrastructure projects and construction sites are key contributors to mosquito breeding, with an estimated 6000 development projects ongoing. Malaria cases are reported throughout the year, but spike in the monsoon season between June and September. The number of cases was reduced from 76 755 in 2010 to 7319 in 2023. However, there is some indication of an increase in recent years that may be associated with increases in construction and migrant workers and enhanced surveillance to include cases detected in the private sector.

The Brihanmumbai Municipal Corporation (BMC) has a wide remit that includes control of disease vectors and nuisance pests, including *Anopheles*, *Aedes* and *Culex* mosquitoes, flies, rodents, fleas and cockroaches. Vector surveillance and control are applied through an inspection-detection-action approach. Over 2000 staff of the insecticide branch conduct daily house surveys. Interventions follow NCVBDC guidelines and include source reduction, minor engineering such as applying screening to tanks, biological control by introducing *Gambusia affinis* or *Poecilia reticulata* fish, or – as a final option – chemical treatment with larvicides and adulticides.

Legislative action is strong in Mumbai and is governed primarily by the Mumbai Municipal Corporation Act 1888 *(21)*. Section 381 of this Act includes provisions to prohibit the collection of standing or flowing water in which mosquitoes breed or are likely to breed, unless this has been "so treated as effectively to prevent such breeding". BMC issues notices if provisions are contravened, when potential or actual mosquito breeding sites are identified. A statutory period is provided to address the issue, with follow-up inspections conducted. While compliance is reportedly high, if appropriate action has not been taken, then legal action is initiated by BMC. This includes fines of 2000–10 000 rupees (approximately US$ 24–120) for a first offence or 500 rupees (US$ 6) per day after conviction.

For government and municipal properties, BMC conducts annual surveys and compiles lists of all identified defects relevant to mosquito breeding. A Mosquito Abatement Committee meeting chaired by the Commissioner convenes three or more months prior to the onset of the monsoon season each year; the lists are presented to each of the 56 government authorities, along with a request for action to be taken to make the necessary fixes within a two-month period. Joint inspections are then held after this period to confirm that the work has been completed. In the case of non-compliance, a notice is issued to the relevant government authority and further action may be taken.

BMC also issues 10-point advisories for construction projects to prevent mosquito breeding and transmission of vector-borne diseases. These require, among other things, that workers are screened for malaria infections and provided with LLINs, as many migrants are from endemic areas and reside in unprotected worker huts at construction sites. BMC convenes meetings to sensitize safety officers and supervisors of construction sites to make them aware of the required measures, and monitors compliance to the 10 points. Stop-work notices have been used at construction sites under section 354(A) of the Act *(21)* until rules are complied with. Dilapidated properties are also inspected and treated by BMC, using novel methods such as drone application of insecticides in some situations.

BMC actively communicates with government authorities, owners of buildings and establishments, and housing societies on the requirements under the Act, and provides regular updates on vector-borne diseases, the number of mosquito breeding sites detected, and numbers of notices and fines issued. In 2023, the staff of the insecticide branch inspected 276 286 premises, with 10-point advisories issued to all construction sites. A total of 22 571 notices were issued, with 2230 cases launched for prosecution. The use of legislation to address mosquito breeding in Mumbai is considered a success attributable to a strong and enabling Act that is implemented effectively and consistently by BMC.

## 4. Research agenda co-development and priority setting involving key stakeholders can streamline knowledge generation on issues such as *An. stephensi*.

Previous malaria strategic plans of the NCVBDC have recognized the critical role of research in supporting and guiding malaria elimination efforts; this was reaffirmed in the most recent national strategic plan *(13)*. While there has been a long-standing

record of malaria research in India, mainly through the government-funded network of institutes that form the Indian Council of Medical Research (ICMR; see Fig. 3), deficiencies have been identified in the impact of this research. For instance, Rahi and colleagues *(22)* noted issues with stakeholder coordination, communication, harmonization, translation and shared learnings, which are likely to have led to duplication of efforts, contradictory or invalid results, lack of translation into action, and shortfalls in influence on policy and practice. Better engagement of policy-makers and implementers in prioritizing and defining the research agenda was noted as one key upstream measure to address these deficiencies.

Fig. 3. Location of institutes of ICMR working on malaria vector surveillance and control (November 2023)
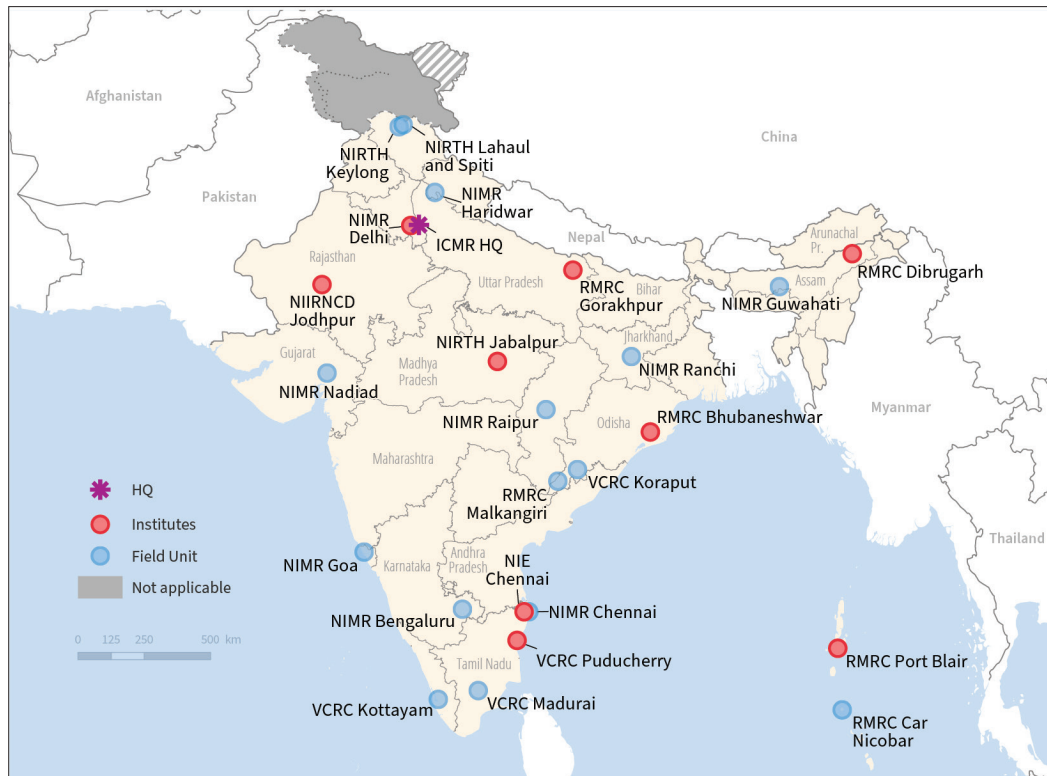
Source: WHO GIS Centre for Health, WHO Division of Data, Analytics and Delivery for Impact, Department of Data and Analytics (DDI/DNA), ICMR

One way in which NCVBDC influences the research agenda is by funding ICMR to conduct research on priority topics. For instance, from 2017 to 2019, ICMR was commissioned to coordinate a multi-centre study to assess insecticide susceptibility of primary and secondary malaria vectors across 328 villages in 79 districts of 15 states. The first formalized prioritized research agenda was developed in 2022, with co-design by the NCVBDC and institutes of the ICMR that contribute to research on vector surveillance and control. The process enabled the strategic identification of key operational research topics for NCVBDC to finance.

The Malaria Elimination Research Alliance India was also launched in 2019 to "identify, articulate, prioritize and respond to the research needs of the country to eliminate malaria from India by 2030" and to "facilitate trans-institutional coordination and collaboration around a shared-research agenda". Coordinated by ICMR, this Alliance includes NCVBDC, union and state health ministries, and other key technical and financing partners. Since its formation, ICMR has convened stakeholders to identify key informational needs, awarded funding to multi-centre projects, and developed common objectives, protocols and methodologies.

While India is unique in that the majority of research on malaria vector surveillance and control is conducted by ICMR, often with funding from NCVBDC, it does serve as an example of how a prioritized research agenda can be an efficient way to ensure coordination of research on programmatic options to improve surveillance and control of *An. stephensi*.

3.2 Islamic Republic of Iran

Key lessons		
Improve information exchange	Undertake prioritized research	Increase integration

3.2.1 Background

Malaria was previously an endemic, high-burden disease in the Islamic Republic of Iran. Prior to the spraying of DDT in the 1940s, the annual number of malaria cases was estimated at 3–4 million *(23)*. At that stage, the highest incidence was in the north near the Caspian Sea with *An. maculipennis* and *An. superpictus* as the main vectors, and in the south-eastern areas with *An. stephensi* and *An. culicifacies* as the main vectors. More recently, transmission has been the highest in the southern and south-eastern areas of the country (Fig. 4).

Fig. 4. Annual parasite incidence (per 1000 population) showing districts with malaria cases in the Islamic Republic of Iran in 2022
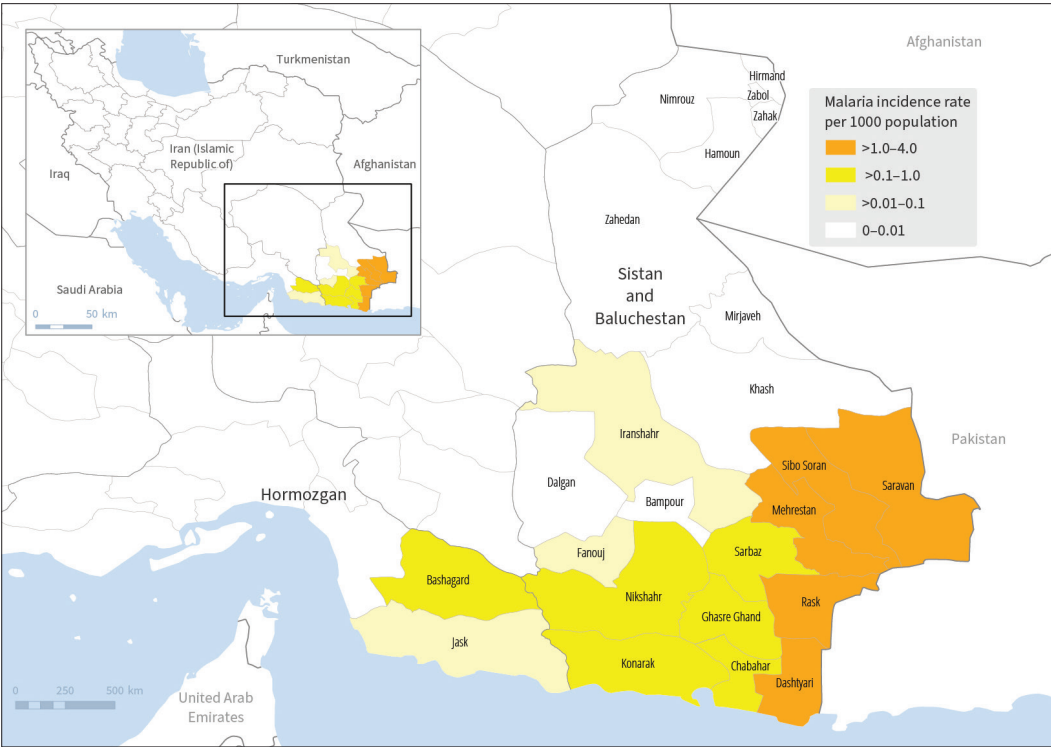
Source: WHO GIS Centre for Health, DDI/DNA, Islamic Republic of Iran National Malaria Elimination Programme

IRS as the main vector control intervention commenced in the country in the 1940s using DDT. Deployment was expanded, along with increased distribution of antimalarial

drugs in the 1940s and 1950s. These interventions had a high impact on malaria epidemiology throughout the country, especially in the north *(23)*. However, in 1961, resistance of *An. stephensi* to DDT was confirmed in Khuzestan, and spray operations were halted in the southern plains. Subsequently, different vector control strategies were used, such as IRS with malathion and oil or *G. affinis* introduced into larval habitats. Vector control measures continued to be scaled up in the 1970s, along with other efforts, such as the use of community health workers. When resistance to malathion was found in *An. stephensi* in 1975, the new insecticides propoxur and temephos were used instead for IRS and larviciding.

IRS with pyrethroids continued from 2003 to 2011, and from the early 2000s, pyrethroid-treated nets were also deployed under certain conditions and to special groups. Some larviciding was also undertaken. Other measures were piloted, such as installation of solid coverings over water storage containers to prevent *An. stephensi (24)*, but these were not widely deployed. By 2010, cases had dropped to 1847 annually, and by 2012, only 29 of the Islamic Republic of Iran's 1057 districts remained malaria transmission zones. From 2016, scale-back of malaria vector control was undertaken. Zero indigenous malaria cases were reported nationwide for four consecutive years between 2018 and 2021, and WHO evaluations were ongoing for certification of malaria elimination. However, in 2022, there was a five-fold increase in the number of imported cases to 4238 cases, with 1439 indigenous and introduced cases reported (Fig. 4) *(8)*. These changes were mainly attributed to an upsurge in cases in neighbouring Pakistan, especially in the border area where there is frequent movement of people, as well as to flooding, diversion of resources to address *Ae. aegypti* emergence and spread, insufficient funding and limited availability of malaria commodities due to international sanctions *(8)*.

The National Malaria Elimination Programme, under supervision of the Ministry of Health and Medical Education, coordinates malaria control efforts in the Islamic Republic of Iran. Vector surveillance is routinely conducted throughout the country through collaboration with medical universities in each province. There are sentinel sites where entomological surveillance is conducted every two weeks using multiple collection methods (e.g. pyrethrum spray catch, aspirator collection from inside houses, and larval sampling).

3.2.2 Lessons learned

1. A network of local institutes with capacity for operational research can assist in filling location-specific information gaps.

There is at least one University of Medical Sciences and Health Services in each of the 31 provinces of the Islamic Republic of Iran. Together, these universities function as an integral part of the health system. Initially administered by the Ministry of Science, they were moved under the newly formed Ministry of Health and Medical Education in 1985. The restructuring was to address the lack of personnel in the health system and to ensure that research and programmatic questions could be communicated effectively to institutions with the capacity to answer them. At that time, efficient answering of questions was considered an important requirement for successful implementation of malaria control in the Islamic Republic of Iran.

While the structural integration of health services with health education provides a conduit for improved communication and action, it does not guarantee it. A study assessing the integration found both positive and negative aspects, indicating that such integration does not automatically improve all facets of a programme, but may have certain costs and benefits *(25)*. Indeed, the National Malaria Elimination Programme continues to communicate its research needs both formally and informally within the Ministry.

While this structure has been maintained, with funds provided by the central ministry and augmented by the governors' offices in each province, as well as by private donors and international organizations in some provinces, overall funds and activities have decreased. Limited funds have needed to be divided between universities, which has undermined the conduct of multi-centre studies and comprehensive research throughout the country. This situation underlines that multiple avenues and funding sources should be maintained to ensure that informative operational research can continue and that results can be effectively communicated to improve vector control programming.

2. Initiatives to improve water and electricity services can impact *An. stephensi* and malaria transmission, and must be carefully managed.

By 2000, 98% of the overall population of the Islamic Republic of Iran had access to electricity *(26)*. However, access rates remained low in the south-east of the country, and less than one third of the population of Sistan and Baluchestan province had electricity in 2005 *(23)*. Exposure to night-biting mosquitoes – with *An. stephensi* recognized as the key malaria vector – was high in this province, as people often slept outside in the evening during the hot summer months. The province also received large numbers of people from neighbouring Pakistan. Malaria case burden was high, accounting for about 60% of cases in the country each year.

Electricity rates in the south-east increased from 30% in 2005 to over 90% in 2012 *(26)*. The improved supply of electricity allowed for more homes to have fans, desert air coolers or air-conditioning, which enabled dwellings to be kept shut at night, thereby preventing mosquito access and biting. Residents also slept outside less often during the summer months. The spread of electricity in the south-east correlated with a decrease in malaria cases *(27)*, which led to a saying that "when electricity comes, malaria goes" *(28)*.

Improved water supply in the Islamic Republic of Iran is also thought to have led to reductions in malaria incidence. Increased access to reliable and safe drinking water reduced the need for stored water, thereby reducing the availability of aquatic habitats for *An. stephensi*. In 2022, 94% of the Islamic Republic of Iran's population had access to drinking water that was accessible on the premises, available when needed and free from contamination *(29)*. Although water access rates may be lower in the south-east, the correlation with malaria transmission is difficult to ascertain due to the low numbers of cases.

These experiences from the Islamic Republic of Iran indicate that electricity and water infrastructure can play an important role in malaria control. However, while improved supply of electricity and water reduced the human–vector contact and the number of larval habitats, respectively, if not managed properly, infrastructure development can present risk factors for malaria transmission. For instance, breaks in water pipes can result in small pools that can be inhabited by *An. stephensi*. Furthermore, inconsistency in the piped water supply may increase water storage at the household level and provide additional habitats for *An. stephensi*, as has been the case elsewhere for *Ae. aegypti (30)*.

3. *An. stephensi* form is not a reliable predictor of malariogenic potential across all settings where the mysorensis form is involved in transmission

The different forms of *An. stephensi* have been widely reported to differ in their bionomics and relationship to disease. As noted earlier, research has generally found that the type form of *An. stephensi* is better adapted to urban settings, can more readily colonize habitats and plays a more important role as a vector than the mysorensis form. However, an exception to this is the involvement of *An. stephensi* mysorensis in malaria transmission in the Islamic Republic of Iran.

Several papers have reported *An. stephensi* mysorensis to be the primary form of *An. stephensi* in malarious areas of the Islamic Republic of Iran. It was the only form of *An. stephensi* present in Jiroft district, Kerman province *(31)* and was the most numerous form found in Jask district, Hormozgan province *(32)*. In 1962, naturally infected *An. stephensi* mysorensis mosquitoes were collected from Jadas village, near Kazeroun, with a sporozoite rate of 5.0% 14 days after collection *(33)*. A colony of mysorensis form established from collections in Iranshahr district in Sistan and Baluchestan province was also able to develop sporozoites *(34)*. While the involvement of the mysorensis form in transmission has mainly been noted in the Islamic Republic of Iran, there have been similar findings in India *(35)* and Pakistan *(36)*.

Involvement of the mysorensis form in transmission indicates that assumptions should not be made about its bionomics that preclude its role as an efficient malaria vector. Further work is needed to understand the distribution, genetics, bionomics and vector biology of the different forms of *An. stephensi* and to determine their involvement in malaria transmission. This will help to determine whether monitoring of *An. stephensi* form can be informative for programmatic decisions.

4. Changing threat or burden of other vector-borne diseases influences financial and human resources and political attention to vector control.

Aedes aegypti has recently been detected as an invasive species in the Islamic Republic of Iran *(37)*. Although all cases of *Aedes*-borne diseases have thus far been imported, the presence of this efficient vector of dengue, chikungunya, yellow fever and Zika virus disease poses a risk of local transmission.

Public and political attention to vector control for preventing further spread or establishment of *Ae. aegypti* has significantly increased, with malaria programme staff at both the central and provincial levels assigned tasks for *Aedes* surveillance and control. This has, to some extent, undermined the continuity of malaria activities, compounded by systemic shortages in malaria resources due to a progressive decline in partner allocations since 2016. In particular, at the national level, there has been insufficient technical staff to plan, prioritize and guide the entomological and vector control work of provincial teams.

At the implementation level, there are opportunities for integration of *Ae. aegypti* and *An. stephensi* surveillance and control. However, despite some overlap in larval habitats in the southern part of the country – such as used tires – the habitats of these two important vector species are not identical. Therefore, measures targeting *Ae. aegypti* are expected to have some but not full impact on *An. stephensi* populations.

There are some indications that political attention to the health threat posed by *Ae. aegypti* will result in additional resources being allocated for urban vector control. Response activities should capitalize on the technical expertise built through the malaria programme at the provincial level, although staff shortages persist. Many personnel have retired, with funding and contracting constraints preventing the recruitment of replacement staff.

This example from the Islamic Republic of Iran emphasizes the need for programmes to adapt to emerging threats, including other vector-borne diseases. A comprehensive vector control strategy that identifies options for integrated surveillance and control across disease vectors may optimize the use of available resources, as outlined in the *Global vector control response 2017–2030 (7)*.

3.3 Sri Lanka

Key lessons			
Increase collaboration	Strengthen surveillance	Undertake prioritized research	Increase integration

3.3.1 Background

The last two indigenous cases of malaria in Sri Lanka were reported in 2012, and the country was certified by WHO as malaria-free in 2016. Between 2016 and 2022, the number of imported cases reported annually ranged between 25 and 57. Most were local migrants returning from travel to malarious countries for United Nations peacekeeping missions, business, tourism or pilgrimage. There is a high level of receptivity to malaria across much of the country, especially in dry and intermediate climatic zones (see Fig. 5). The Anti Malaria Campaign (AMC) of the Sri Lanka Ministry of Health considers the primary malaria vector to be *An. culicifacies*, with *An. subpictus*, *An. annularis*, *An. varuna, An. vagus* and *An. tessellatus* as secondary vectors.

Fig. 5. Climatic zones of Sri Lanka and six districts in which *An. stephensi* was collected from 2017 to 2023
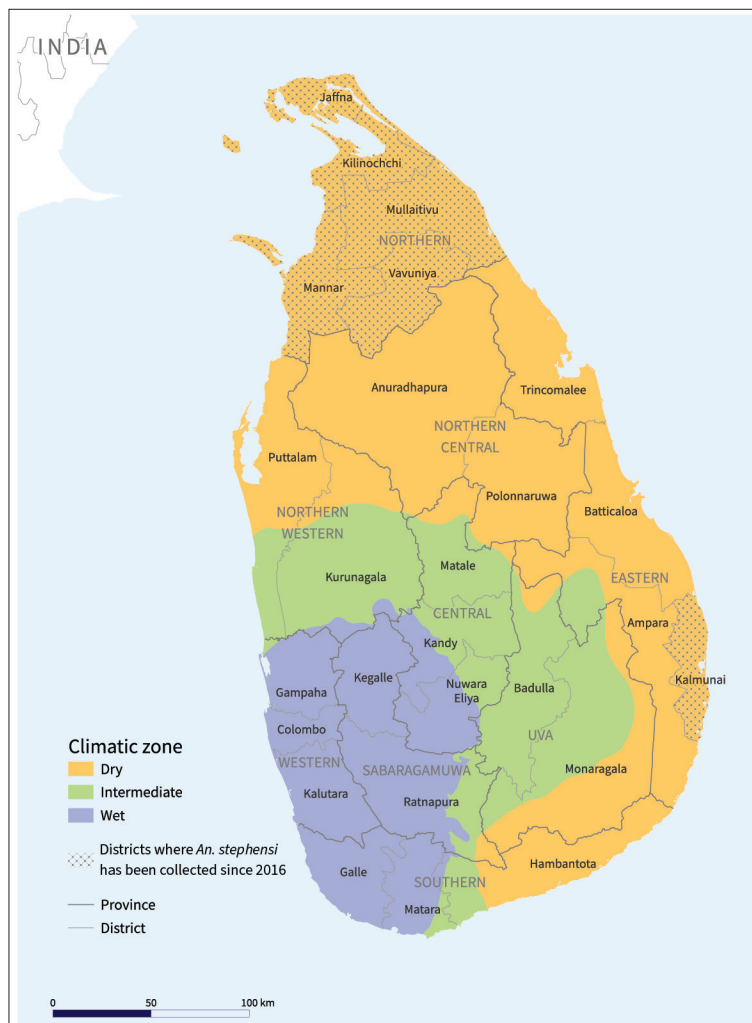
Source: WHO GIS Centre for Health, DNA/DDI, AMC

A surveillance system is in place to prevent the re-establishment of malaria, which includes routine, extended and spot entomological surveillance. Risk is determined for each region based on receptivity (as indicated by entomological data) and risk of importation *(38)*. Risk levels are regularly updated and used to prescribe surveillance and prevention activities. For imported malaria cases, entomological data collected around case locations determine the response approach. Activities are implemented by AMC regional malaria offices with the support of AMC headquarters in Colombo. Malaria entomological activities up to 2016 were focused on non-urban areas, and vector control interventions were mainly LLINs, IRS and space spraying.

In December 2016, *An. stephensi* was collected during larval sampling in the northern district of Mannar, which has close transport routes with southern India. Subsequent investigations found this species to be breeding abundantly in cemented wells and present in plastic water storage barrels in Mannar *(39)*. It was also collected in adult surveys using various techniques.

In response, AMC set out an initiative to eliminate the species from invaded areas. Entomological surveillance was intensified across all areas of the country, particularly in urban areas, transport hubs and legal points of entry into the country. *Anopheles stephensi* was detected in 2017 and 2018 at sites in four additional districts in Northern and Eastern provinces. Vector control was also intensified, primarily through the use of chemical larviciding and introduction of larvivorous fish into the main vector habitat of wells. In 2022–2023, *An. stephensi* was detected in only two of the six districts in which it had previously been found (see Fig. 6).

Fig. 6. Timeline of detection of *An. stephensi* in Sri Lanka

Province	District	2016	2017	2018	2019	2020	2021	2022	2023
Northern	Mannar	●	●	●	●	●	●		
	Vavuniya		●		●	●	●		
	Jaffna		●	●	●	●	●	●	●
	Mullativu		●	●					
	Kilinochchi		●	●					
Eastern	Kalmunai			●	●	●	●	●	●

3.3.2 Lessons learned

1. Routine entomological surveillance is needed to detect invasive species.

The presence of *An. stephensi* in Sri Lanka was detected through the routine entomological surveillance system of AMC. This system was first established in the 1930s and was run by AMC, with assistance provided by a private organization in some conflict-affected districts of Northern province (including Mannar) between 2008 and 2014. Few studies were conducted in the area during the time of war; however, in 2010–2012, a study on *Anopheles* species composition and breeding habitat diversity did not detect the presence of *An. stephensi (40)*.

In 2016, *An. stephensi* was not included in the Sri Lankan mosquito checklist and dichotomous key used by AMC *(41)*, or in its subsequent updates *(42)*, despite earlier predictions of geographical spread from India *(43)*. The species was only added to the AMC resources used for identification in 2017, following its detection and identification using other keys and confirmation by sequencing *(39)*. It is therefore not clear whether *An. stephensi* was present earlier but went undetected, or whether there have been one or more recent invasive events.

This experience from Sri Lanka emphasizes the importance of ensuring regular surveillance, even in settings preventing the re-establishment of malaria transmission. Moreover, it underscores that identification keys should include not only those species that have been confirmed to be present, but also those for which there is a high risk of invasion and establishment.

2. Maintaining an essential entomological workforce will enable rapid and targeted response to the detection of *An. stephensi.*

Intensified entomological surveillance from 2017 onwards enabled rapid detection of *An. stephensi* in the five additional districts of Northern and Eastern provinces. This extension of routine surveillance included larval surveys, as well as cattle-baited hut trapping, indoor and outdoor resting collections, and human landing collections, especially in urban and peri-urban areas. Based on the surveillance data, targeted responses were initiated that included introduction of temephos or the larvivorous fish species *P. reticulata* to wells. Populations returning from overseas were also provided with LLINs, although no widespread net distribution campaign was undertaken.

Re-programming of funds from both the central government and partners, such as the Global Fund to Fight AIDS, Tuberculosis and Malaria and WHO, enabled rapid response to the detection of *An. stephensi* through scaled up entomological surveillance and vector control. Sufficient staffing was already in place in AMC to adapt to the intensification of activities. Infrastructure, such as vehicles and breeding facilities for larvivorous fish, were already set up and could be quickly leveraged.

In 2022 and 2023, *An. stephensi* was detected in Jaffna and Kalmunai districts only. *Anopheles stephensi* was not detected in any of the 8353 wells checked in Mannar district or the 5477 wells checked in Vavuniya district in 2022. There were no detections in these districts in 2023 either. This reduction in the known distribution of *An. stephensi* is thought to have been mainly due to the rapid response mounted before the species could become well established in northern and eastern Sri Lanka and spread further. This underscores the importance of maintaining capacity for entomological surveillance and vector control response, even in elimination settings.

3. Closure of unused wells or introduction of larvivorous fish has the potential to control *An. stephensi,* but sustainability and cost-effectiveness need to be evaluated.

Through the AMC programme, a number of potential *Anopheles* spp. aquatic habitats are routinely examined for the presence of mosquito vectors, including *An. stephensi*. An example of the numbers of habitats checked and the numbers positive for *An. stephensi* in a single month is given in Fig. 7. Built cement wells used for domestic purposes have been identified as the key habitat for immature *An. stephensi* across all areas in which this species has been found in Sri Lanka. Other habitats include cement tanks and other containers (with overhead tanks not considered a common habitat).

Fig. 7. Potential and detected larval habitats of *An. stephensi* in four districts, showing data for October 2023
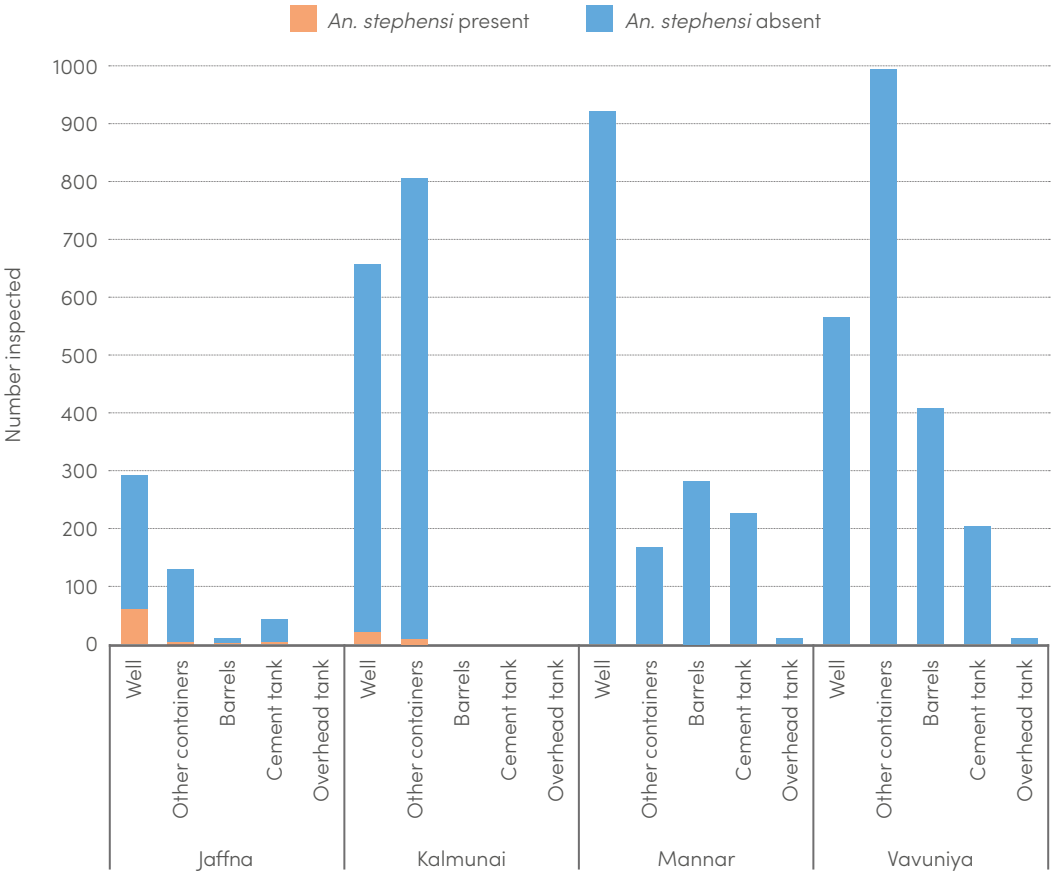
Wells are often found in former residences abandoned during the civil war period that have since remained vacant. AMC initiated a programme in Mannar, with the support of the town council, to fill these wells with sand to ensure that they cannot retain water or serve as larval habitats for *An. stephensi* (Fig. 8). The involvement of the town council was critical, as it supplied the heavy machinery and manpower needed to accomplish this work. In 2017, 215 unused wells were filled in Mannar. However, AMC reported that it had been unable to initiate a similar programme in other areas due to lack of support from the respective town councils.

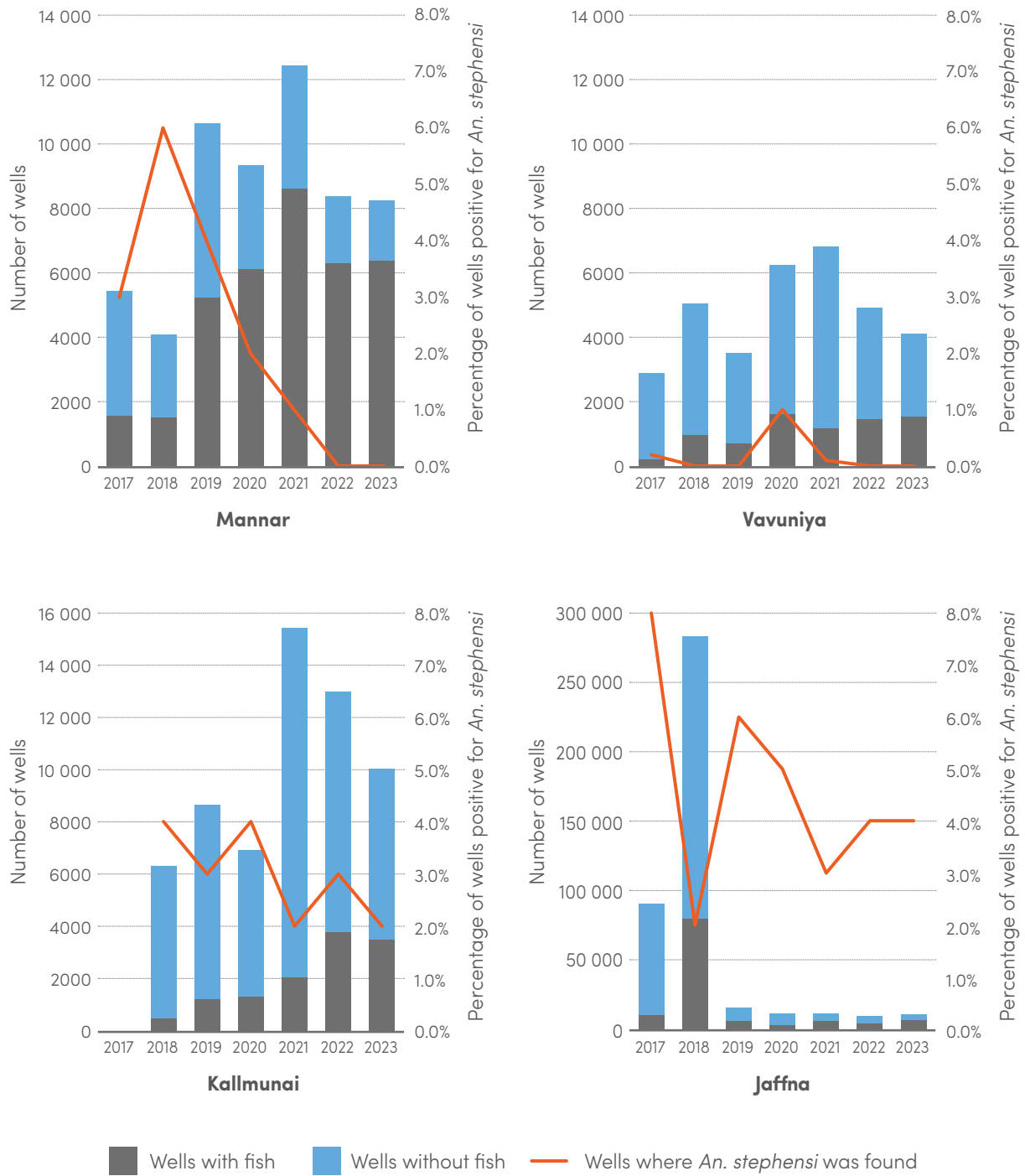**Fig. 8. Abandoned wells in Mannar district filled with sand**

Image credit: Seth Irish, 2023

For wells that are in use, the initial approach of AMC was to introduce temephos; however, residents were increasingly reluctant to allow this, especially once the threat of malaria transmission had been reduced. AMC therefore initiated a programme of introducing the larvivorous fish *P. reticulata* to wells used for domestic purposes and tracking the presence and absence of *An. stephensi* larvae and fish in these wells over time (Fig. 9).

The association between the presence of *P. reticulata* and the absence of *An. stephensi* in wells in Mannar, Jaffna and Vavuniya underscores the potential of this control tool, although there is no disease impact or cost-effectiveness information available for Sri Lanka. Variations in *P. reticulata* survival have been noted between districts, with monthly fish survival ranging from 29% to 94% (T. Fernando, personal communication, 2023). AMC indicated that householder practices and acceptance may limit the utility of this intervention in some areas. For instance, field teams have reported high levels of chlorination of domestic wells, particularly in areas such as Jaffna with high rates of water-borne diseases. While the health department recommends chlorination at a rate of 5 mg/L, which would be unlikely to induce mortality in *P. reticulata*, householder application rates are thought to exceed this amount, as chlorine is relatively cheap and readily available.

Fig. 9. Number of wells inspected in which *An. stephensi* immatures were detected or not detected

Mannar

Vavuniya

Kallmunai

Jaffna

Wells with fish   Wells without fish   Wells where *An. stephensi* was found

Regional differences in key habitats and community acceptance of interventions indicate the need for local assessment of suitability and the importance of community education and engagement to ensure optimal impact. Data to show sustainability and cost-effectiveness are needed. These will need to be gathered in other settings with ongoing malaria transmission, such as in Africa.

4. Integration of *An. stephensi* surveillance and control activities with other vector-borne disease programming can improve efficiency.

While malaria has been eliminated, the population of Sri Lanka is still at risk of other vector-borne diseases, including dengue, leishmaniasis and lymphatic filariasis. In Vavuniya, AMC supports public health activities related to other vector-borne diseases, as well as district-level disaster management. Staffing and operations are funded from the annual budget of the Regional Director of Health Services with activities guided by an integrated action plan for vector-borne diseases that includes:

- prevention of re-establishment of malaria
- dengue prevention and control
- leishmaniasis surveillance
- filariasis surveillance.

There are three entomological surveillance teams that consist of one health entomology officer, two or three field technicians and a driver. These teams carry out routine and extended surveys at sentinel sites and spot surveys at selected sites (see Table 1). Two teams conduct malaria and dengue surveys, and the third team conducts dengue and leishmaniasis surveys. Surveys are done monthly in urban areas and quarterly in non-urban sites. Spot checks are conducted in areas with confirmed dengue cases or imported malaria cases.

Malaria data are used to inform the risk index and responses as per the national strategy. For dengue, if the number of containers with *Aedes* larvae per 100 houses is more than one or the percentage of houses positive for *Aedes* larvae is more than 3%, immature habitats are monitored weekly for an additional 4–6 weeks. For leishmaniasis, entomological surveys are reactive in response to cases. No specific surveillance activities are currently conducted for vectors of lymphatic filariasis. Some vector sampling techniques used are applicable to more than one mosquito genus.

Table 1. Summary of entomological sampling techniques used

Stage	Sampling method	*Aedes*	*Anopheles* spp. – known primary and secondary malaria vectors	*An. stephensi*	Sand flies
Eggs	Ovitraps	X			
Immatures	Habitat inspections for larvae and pupae	X	X	X	
Adults	Indoor/outdoor hand collections		X	X	X
	Sticky traps				X
	Light traps				X
	Cattle-baited night traps		X	X	X
	Double net traps	X			X
	Human landing collections		X	X	

For vector control, an important intervention in Vavuniya is the introduction of larvivorous fish to confined water bodies, mainly wells. LLIN and IRS deployment is guided by the malaria risk stratification conducted at the national level. Supervision of entomological surveillance activities and larvivorous fish introductions is planned for once and twice per month, respectively. However, reduced funding has made this difficult to sustain. Environmental modification is conducted for sand fly control. Multiple vector control interventions are also used if necessary, e.g. IRS, LLINs. However, there is no specific stock of IRS chemicals and LLINs for sand fly control.

This integration of activities was instigated at the regional level to rationalize resources due to reduced funding following malaria elimination. While integrated programming in Vavuniya has supported more efficient use of limited resources, implementation is constrained by siloed programming at the national level. Disease-specific strategies and systems mean that field staff use multiple forms when conducting surveillance (e.g. one for *Aedes* and one for *Anopheles*), have multiple reporting lines to the central level, and must follow several strategies and adhere to different guidance. This may undermine optimal efficiency. The implications of adapting national structures to better support integrated operations warrant further examination in Sri Lanka and in countries affected by other vector-borne diseases.

4. Findings and programmatic considerations

The following general findings and programmatic considerations have emerged from this initial collection of country case studies.

Aim of initiative addressed	Key finding	Programmatic considerations for African countries
	Ongoing vector surveillance supported by sufficient resources and motivated personnel will increase the likelihood of successfully detecting and containing *An. stephensi*.	Where a potential invasive vector species such as *An. stephensi* is a threat to human health, core capacity and resources for routine vector surveillance should be maintained (including in low transmission settings).
	Accurate and timely identification of invasive vector species requires appropriate identification keys (and supporting molecular techniques).	*Anopheles* identification keys for adults and larvae should include *An. stephensi* and other potentially invasive vector species (e.g. *An. culicifacies*).
	The mysorensis form of *An. stephensi* has been shown to be a competent malaria vector in some settings. Therefore, current evidence indicates that *An. stephensi* form is not a reliable predictor of vectorial capacity.	*An. stephensi* control strategies should consider all forms to be competent vectors, unless there is specific and robust evidence to the contrary.
	Larvivorous fish have the potential to control *An. stephensi* in specific settings and situations, but householder practices and acceptance can limit utility. Sustainability and cost-effectiveness are not well documented.	Further research is required to determine the appropriateness of larvivorous fish for control of *An. stephensi* in settings in Africa. This should include evaluations of sustainability, cost-effectiveness, and community education and engagement strategies.
	Infrastructure development, e.g. to increase access to water and electricity, can affect *An. stephensi* population dynamics and human–vector contact, thereby influencing urban malaria epidemiology.	Planning and implementation of construction and infrastructure development projects must consider vector aspects, as further articulated in the *Global framework for the response to malaria in urban areas (44)*.
	Consistent enforcement of building standards and civic by-laws can prevent the proliferation of *An. stephensi*.	Current building standards and civic by-laws should be examined to determine whether these can be better enforced or amended to improve urban vector surveillance and control.
	Collaboration and information sharing across different areas and levels of the health system can improve efficiency and uptake of research outcomes and is essential for streamlining research on specific threats such as *An. stephensi*.	A prioritized research agenda that addresses operational issues crucial for *An. stephensi* detection, surveillance, containment and control should be developed, leveraging available institutional capacity and linkages. The agenda should identify or establish mechanisms for efficient sharing of information.

Aim of initiative addressed	Key finding	Programmatic considerations for African countries
	An integrated approach to urban vector surveillance and control that includes *Aedes* and *Anopheles* vectors can help to maintain capacity for detection or response to threats, such as invasive species or emerging vector-borne diseases. This is particularly important in low transmission settings, where resources, coordination and political motivation for malaria vector control may be dwindling.	Options for integrating *An. stephensi* surveillance and control activities into broader vector-borne disease control programmes should be identified, including opportunities for improved coordination, cross-sectoral engagement and resource use.
	In elimination settings, routine entomological surveillance is essential to ensure that changes in receptivity are detected, e.g. the arrival of new vector species such as *An. stephensi*.	Sufficient capacity should be maintained to enable essential vector surveillance and control activities as well as preparedness for response to any emerging threats.

Programmatic considerations will be refined or extended as subsequent findings from additional country case studies become available.

5. Conclusions

It is essential to develop knowledge and actions to optimize *An. stephensi* surveillance and control across countries facing invasion of this vector and potential increases in malaria transmission.

The five priority areas identified in the *WHO initiative to stop the spread of* Anopheles stephensi *in Africa (1)* were designed to provide a framework for advancing work that attends to the needs of Member States in the WHO African Region. This collection showcases brief examples from selected countries in the WHO South-East Asia and Eastern Mediterranean Regions with extensive experience in the surveillance and control of *An. stephensi.* This is intended to help inform the development and extension of priority activities in African countries currently faced with the threat of the invasion or establishment of this malaria vector.

Locally adapted and sustainable vector control is the hallmark of successes documented in these country examples, which aligns with the aim of the *Global vector control response 2017–2030 (7).* This adaptability is crucial to mitigate the threat posed by *An. stephensi* across the range of settings and situations in Africa – from high-burden to elimination countries.

Looking ahead, it is important to learn from these examples and for each programme to consider how best to address *An. stephensi*, through the refinement of national strategic plans where necessary. Additional country examples need to be documented to further support information and experience sharing towards optimized surveillance and control of *An. stephensi.*

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Annex. List of key informants

India

In India, the following people attended focus group meetings or were interviewed: P Elango, S Gopalakrishnan, Bhavna Gupta, Manju Rahi, A Daniel Reegan, A Sakthivel, AN Shriram, K Divya Teja and PT Vidhya (ICMR – Vector Control Research Centre); Ashwani Kumar (Saveetha University); Bhupinder Nagpal (retired); Aswin Asokan, Alex Eapen, V Nair Haritha, PK Kripa, L Mathiarasan, R Sangamithra, K Sushmitha, PS Thanzeen and K Tulasi (ICMR – National Institute of Malaria Research Field Unit Chennai); Manoj Mushekar (ICMR – National Institute of Epidemiology); Chetan V Choubal and Daksha Shah (BMC); RS Sharma (Absolute Human Care Foundation); Naveen Rai Tuli (Municipal Corporation of Delhi); Tanu Jain and Rinku Sharma (Ministry of Health and Family Welfare); Himmat Singh (ICMR – National Institute of Malaria Research); Roop Kumari (WHO Country Office); Susanta Ghosh (ICMR – National Institute of Malaria Research Bangalore); and Keshav Vaishnav (Surat Municipal Corporation).

Islamic Republic of Iran

In the Islamic Republic of Iran, the following people attended focus group meetings or were interviewed: Minoo Mashayekhi and Fatemeh Nikpour (Ministry of Health); Ghasem Zamani (WHO Regional Office for the Eastern Mediterranean); Nima Ghalekhani and Omid Zamani (WHO Country Office); Morteza Zaim (retired); Ahmadali Enayati (Mazandaran University of Medical Sciences); and Ahmad Ali Hanafi–Bojd (Tehran University of Medical Sciences).

Sri Lanka

In Sri Lanka, the following people attended focus group meetings or were interviewed: Kamini Mendis (University of Colombo); Champa Aluthweera, Kasuni Atapattu, Pubudu Chulasiri, Kumudu Gunasekera, Jeevanie Harischandra, Mihirini Hewavitharane, Samantha Jayasinghe, D Ion Maduranga, MAST Pernoucle, Krishani Pirahlathan, S Priyadasha, Shilanthi Seneviratne, Srimal Silva, Nethmini Thenuwan and Asanga Wickvamasignle (AMC Headquarters); S Arthiuan, T Eswaramotran, S Kokila, and Sinnathamby "Noble" Surendran (University of Jaffna); Alaka Singh and Preshila Somaraweera (WHO Sri Lanka Country Office); Ranjith de Alwis and Devika Perera (retired); Piyuma Kulathuga (AMC Kurunegala); P Antory, NH Jimson Ceelas, PK Mihiranga, SE Priyantharshan, RMBB Rathnayake, M Reginold Roche, M Suganthan Sosai and D Venoden (AMC Mannar); D Venoden (Health Department Mannar); R Kopinoj, K Sathiyendran, B Sinthujan and S Srishanth (AMC Jaffna); A Ketheeswaran (Health Department Jaffna); M Machedran (Health Department Vavuniya); and S Prasanth (AMC Vavuniya).

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