Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

From Risk Perception to Prevention: Malaria and Mosquito Control in Jigjiga, Ethiopia

Biniyam Bogale

blenbini@gmail.com

Jigjiga University

Solomon Yared

Jigjiga University

Dorian Michael Jackson

Emory University

Kim Awbrey

Emory University

Sharmarke Jama

Jigjiga University

Gonzalo Vazquez Prokopec

Emory University

Idowu Ajibade

Emory University

Research Article

Keywords:

Posted Date: November 25th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11857211/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

From Risk Perception to Prevention: Malaria and Mosquito Control in Jigjiga, Ethiopia

Biniyam Bogale[1], Solomon Yared[2], Dorian Michael Jackson[3], Kim Awbrey[3], Sharmarke Jama[1], Gonzalo Vazquez Prokopec[3], Idowu Ajibade[3]

1. Jigjiga University, Department of Sociology
2. Jigjiga University, Department of Biology
3. Emory University, Department of Environmental Sciences

Abstract

Background**:** *Malaria remains a major public health concern in Ethiopia, with over 2.9 million cases reported in 2024. While historically considered a rural disease, the invasion of the urban-adapted vector Anopheles stephensi, which breeds in artificial water-storage containers, is reshaping malaria epidemiology in Ethiopian cities. Jigjiga, a rapidly urbanizing, water-scarce city in the Somali Region, exemplifies this shift, yet social and behavioral research on community risk perception and prevention practices remains scarce.*

Objective: *To investigate perceptions of malaria risk and mosquito prevention practices among households in Jigjiga city, focusing on water management, gender roles, and malaria experience.*

Methods: *A community-based, cross-sectional mixed-methods study was conducted across six clusters of Jigjiga city. Data were collected through a structured household survey 357 of respondents, five key informant interviews, and observational checklists. Participants were selected using multistage sampling. Quantitative data sources were analyzed descriptively, while qualitative data were analyzed thematically. Findings from both data sources were triangulated to provide an integrated understanding of malaria risk perceptions and mosquitos' prevention practices.*

Results: *Out of 357 respondents, most of them (87%) had heard of malaria, and 81% correctly identified mosquito bites as the transmission route, though misconceptions persisted. Despite*

this, most households perceived their malaria risk as low, and only 3% reported a household case in the past two years. Water insecurity drove reliance on donkey carts, barrels, jerrycans, and birkas for storage, often uncovered despite self-reports of covering. Women take primary responsibility for water management and mosquito prevention (75% and 96%, respectively). Few households (8%) reported taking measures to prevent larval breeding in stored water, although most households (96%) were willing to accept larval source management interventions.

Conclusion: *Households in Jigjiga possess good knowledge of malaria but underestimated their individual risk, while conditions for the proliferation of An. Stephensi appear favorable. Enhancing surveillance, gender-focused health educational approach on malaria and breeding control methods in households including Larval Source Management are recommended.*

Background

Malaria remains a major global health challenge, with an estimated 282 million cases and 610, 000 deaths reported across 80 malaria endemic countries in 2024 (WHO, 2025a). The global burden also increased substantially between 2023 and 2024, with Ethiopia (+2.9 million cases), Madagascar (+1.9 million cases) and Yemen (+378 000 cases) accounting for 58% of the estimated increase in malaria cases(WHO, 2025a).

In Ethiopia, malaria remains an endemic public health problem, even though there has been steady progress in the reduction of malaria in Ethiopia as of April 2025, the country reported a total of 1.9 million cases and 77 deaths (Reliefweb, 2025b). Historically, malaria transmission in Ethiopia, as in much of Africa, has been considered primarily a rural phenomenon, driven by *Anopheles arabiensis* and other vectors that breed in natural water bodies away from dense human settlement. However, the epidemiology of the disease is rapidly changing in the country's urban centers following the invasion and establishment of the highly adaptable vector *Anopheles stephensi*, which breeds preferentially in artificial, human-made water-holding containers rather than natural pools (Yared et al., 2024; Merga et al., 2024; Gebresilassie et al., 2025).

The recent detection of the South Asian malaria vector *Anopheles stephensi*, an urban-adapted malaria vector in Ethiopia and other regions in the Horn of Africa has raised significant concerns

about its potential impact on malaria transmission as well as malaria control and elimination efforts particularly in the urban and peri-urban settings (Merga et al., 2024).

Anopheles stephensi was first detected in 2016 in Kebridahar (Somali Region) (Carter et al., 2018) and subsequently confirmed to have been found across diverse regions of Ethiopia, including the Northeast and Eastern Ethiopia (Balkew et al., 2020; Yared et al., 2020; Gebresillasie et al., 2025).

It is commonly believed that economic development in urban areas leads to better living conditions, such as improved housing, drainage systems, and environmental changes, making urban areas less conducive to breeding of malaria vectors. Studies on malaria in urban settings have been overlooked for centuries (Merga et al., 2024; File et al., 2019). Even though there is increasing evidence which suggests that rapid urbanization of Africa's human population is contributing to a reduction in malaria burden (Yared et al., 2023), the past two decades of Ethiopia's malaria control programme have witnessed the renewed threat from the spread of *Anopheles stephensi* into urban centers- a vector which breeds in household water-storage containers rather than natural water bodies and thus fundamentally changes who is exposed, when, and how (Merga et al., 2024).

The World Health Organization and UN-Habitat (2022) indicated that by 2050 nearly 7 out of 10 people globally will live in cities and urban settings. While urban life provides people with some benefits, such as access to education, health care, employment, transportation, and social services (Florio et al., 2023; Vearey et al., 2019), rapid and unplanned urbanization can also have negative health, social, and environmental impacts (NCD-RisC 2023). Unplanned growth of urbanization and the spread of the invasive malaria vector *Anopheles stephensi* is making malaria control difficult in urban areas (Sinka et al., 2020; Hamlet et al., 2022) and to address this problem the World Health Organization (2022) has developed a Global Framework for the Response to Malaria in Urban areas. Hence the use of this framework provides guidance to countries on undertaking a comprehensive malaria response in urban areas, recognizing the fact that malaria response in urban areas requires data unique to urban ecosystems. This is typical to Jigjiga city, Ethiopia.

Jigjiga city is among the urban settings in Eastern Ethiopia where this shift is unfolding alongside chronic water scarcity (Gobe et al., 2024). Jigjiga, the capital of the Somali Regional State, is situated in a semi-arid area characterized by erratic rainfall and chronic water scarcity, where households must store water in open or poorly covered containers for extended periods, and in turn, structurally predisposes them to generate the container habitats that sustain malaria vector (Gobe et al., 2024). At the same time, malaria prevention programming in Ethiopia has historically been designed around rural transmission dynamics and may not adequately address the realities of urban households, gendered water-management roles, or locally held beliefs about malaria causation and prevention.

Therefore, it is imperative to know that despite a growing body of entomological and case-control evidence on biological and environmental determinants of *Anopheles stephensi*, urban malaria in Eastern Ethiopia (Carter et al., 2018; Yared et al., 2020; Yared et al., 2023; Gobe et al., 2024; Merga et al., 2018; Yared et al., 2025; Geresilassie et al., 2025; Negesse et al., 2026) there is a notable scarcity of social-science and behavioral research examining how Jigjiga residents themselves understand their malaria risk, how household water management and gender roles interact to shape exposure, and what prevention practices households adopt. The objective of this study was to assess the perceptions of malaria risk and mosquito prevention practices among households in Jigjiga city, Ethiopia, with particular attention to water management, gender roles, and malaria experience.

Methods

Study Area

The study was conducted in Jigjiga city, the capital of the Somali Regional State in Eastern Ethiopia, with an estimated population of 800,000. Jigjiga is a rapidly growing urban center, expanding at a rate of 9.9% per year (Barow et al., 2019) and located in a semi-arid, water-scarce environment. *An. stephensi* has been documented in neighboring towns such as Dire Dawa and surrounding districts including Gursum (Gobe et al., 2024; Negesse et al., 2026). Jigjiga was selected because of its rapid urbanization, large population, connectivity to other malaria endemic regions and the port of Berbera in Somaliland. Data collection was conducted over approximately four months, spanning the malaria transmission season.

Study Design

A community-based, cross-sectional study design was used, combining a structured quantitative household survey with a complementary qualitative component (key informant interviews and observation) to provide explanatory depth to the quantitative findings, consistent with a mixed methods approach.

Study Population

The study population comprised household heads aged 20 years and above residing in selected clusters of Jigjiga City, along with concerned representatives from relevant Somali Regional Bureaus. Household participants were drawn from randomly selected blocks within the study clusters and included only those who consented to participate.

Sampling Technique and Procedure

A multistage sampling technique was employed. The study area was divided into six clusters. First, the number of blocks within Jigjiga city clusters was selected randomly using simple random sampling (lottery method). Second, households within each selected block were sampled proportional to block population size using systematic random sampling from household lists obtained from block administration. Within each selected household, one eligible household respondent was interviewed. Efforts were made to achieve balanced representation of men and women in the sample; however, gender parity was not attained.

Sample Size Determination

The sample size for the quantitative household survey was determined using (Yamane, 1973), sample size determination formula. To obtain the maximum required sample size, a 95% confidence level and a level of precision of 5% was used. This yields an initial sample size of 324 households. The addition of 10% contingency made the sample size 357.

$$N = \frac{N}{1 + N(e^2} \qquad \frac{1732}{1 + 1732\ (0.05 \times 0.05)} = \textbf{324 (Premises + 10\%=357)}$$

Where,

n: is sample Size

N: is the population size (Total number of premises with Households), and

e: is level of precision

10% addition to the total sample for contingency

For the qualitative data, five key informant interviews (with Regional Health Bureau, Regional Environmental Protection Agency, Community Leaders from two clusters, and Jigjiga City Water-supply Office) were conducted, with the exact number guided by data saturation.

Data Collection Tools and Procedures

A structured questionnaire (quantitative) was used to collect the data covering socio-demographics, malaria risk perception, water practices, gender roles, malaria experience, and prevention practices.

Key informant interviews (KIIs) were conducted with Regional Health Bureau, Regional Environmental Protection Agency, and Community Leaders from two clusters, and Jigjiga City Water-supply Office to contextualize the quantitative findings and identify programmatic gaps. *Observation* through check list was also made to objectively record household water-storage container types, water storage cover status, housing condition, breeding-sites, and presence of bed nets, reducing reliance on self-reporting alone.

Data Quality Assurance

Data collectors and supervisors with prior survey experience and fluency in Somali and Amharic language were recruited and trained for two days on the quantitative tool and research ethics. The questionnaire was pre-tested and refined before the actual data collection. Daily supervision and review of completed questionnaires were conducted by field supervisors and the principal investigator throughout the data collection process.

Data Processing and Analysis

The quantitative data were coded, entered, and cleaned using a secure, web-based software platform (ReDCap), and it was exported into statistical analysis formats. Descriptive statistics (frequencies, percentages, means, and medians) were used to summarize the socio-demographic characteristics, risk perception, water practices, and prevention practices. The qualitative data from the KIIs and observations were audio-recorded (with consent), transcribed, translated, and

analyzed thematically, with findings triangulated against the quantitative results during interpretation.

Ethical Considerations

Ethical clearance was obtained from Jigjiga University Institutional Review Board (Research Ethics Committee) before data collection. Written and verbal informed consent (as culturally appropriate) was obtained from all participants following explaining the purpose, risks, benefits, voluntary nature, and confidentiality of the study. Respondents were also assured to be free and withdraw at any stage of the interview without penalty. Finally, written permission was also sought from the Somali Regional Health Bureau.

Results

A total of 357 household interviews were performed in this study, with the sample selected from all six study clusters in Jigjiga city. Only one interview was missing from the 357 cases; thus, 99.7% of completed study response was attained.

Socio-demographic Characteristics of Respondents

The largest proportions of respondents were between 31 and 40 years of age (173, 49%). Most of the respondents were female (277, 78%), while males accounted for 78 (22%). Regarding occupation, the majority of respondents were housewives (227, 64%) (Table.1).

With respect to average monthly household income, most households reported a monthly income exceeding ETB 10,000 (236, 67%). It is only very small number of households have expressed that their average monthly income is below 5000 birr. Concerning the level of education, most of the respondents reported having no formal education (216, 62%) (Table.1).

Table 1. Characteristics of Study Participants

	n	%n
Gender	355	
Male	78	22
Female	277	78
Age group	352	
20-30	91	25.9
31-40	173	49.1

41-50	78	22.2
51+	10	2.8
Level of Education	356	
No formal schooling	216	60.7
Primary (grades 1-8)	44	12.4
Secondary (grades 9-12)	37	10.4
Vocational Training Certificate	0	0
Diploma	9	2.5
College	49	13.8
Other	1	0.3
Occupation	357	
Housewife	277	63.6
Trader	58	16.2
Government Employee	36	10.1
NGO Employee	2	0.6
Unemployed	23	6.4
Other	11	3.1
Monthly income	354	
Less than 5000 Birr	40	11.3
5000-10,000 Birr	78	22
Above 10,000 Birr	236	66.7

Perception of Mosquito-borne disease

Most respondents (306, 86%) had previously heard of malaria, whereas 51 (14%) had not. When respondents were asked about the cause of malaria, the majority of respondents identified that mosquito bites were the primary cause (224, 73%), followed by drinking dirty water (70, 23%), and eating contaminated food (3, 1%). A small fraction of respondents (10, 3%) did not know the cause of malaria (Table.2 and Figure S8).

Similarly, when respondents were asked about malaria transmission, most of the respondents (247, 81%) correctly stated that malaria is transmitted through the bite of an infected mosquito and 38 respondents (12%) reported that they did not know how malaria is transmitted. From this finding, a considerable number of (16%) respondents interviewed still hold misconceptions

regarding the cause and transmission of malaria in general (Table.2 and Figure S9). Likewise, basic malaria symptoms, reported were fever (275, 90%) and headache (257, 84%), followed by chills (123, 40%) and vomiting (118, 39%). A very small number of respondents (10, 3%) did not know the common symptoms of malaria at all (Table.2 and Figure S10).

Many households (126, 41%) perceived their risk of malaria as low risk, followed by moderate risk (99, 32%) and very low risk (43, 14%). More than 12% of them mentioned their households are at very high risk (Figure S11). Consistent with these perceptions, 296 respondents (97%) reported that no household member had experienced malaria during the past two years, whereas only nine respondents (3%) reported at least one malaria case during that period (Table.2 and Figure S12). Equally, an interview held with an official from the Somali Regional Health Bureau shared that malaria is currently not considered as a significant public health problem in Jigjiga city.

Among the nine respondents who reported that at least one household member had experienced malaria during the previous two years, the majority of the respondents indicated that first the person seek help from the health center (4, 44%), followed by from private clinic (2, 22%), from referral hospital (1, 11%), and traditional healers (1, 11%) and from other healthcare providers (1**,** 11%). Respondents were also asked how frequently have malaria cases occurred in their household over the past year and most of them reported that cases occurred very rarely (6, 67%) followed by those who said it occurred quarterly (3, 33%) (Figure S13 and Figure S14).

Regarding the age groups most affected by malaria, respondents who reported malaria cases in their households indicated that children were the most affected groups (3, 33%) while two respondents (22%) stated that all age groups were equally affected (Table.2 and Figure S15). A key informant interview held with an official from the Somali Regional Health Bureau indicated that since much of the Somali Region is malaria-prone, all population groups remain vulnerable to infection.

When respondents were asked about the time of day when mosquitoes most commonly bite, the majority of the respondents identified night time (273, 77%), followed by the early evening time (67, 19%). A very small proportion (1%) reported that they did not know (Table.2 and Figure S17).

Regarding the locations where mosquitoes are usually observed, most of the respondents reported seeing mosquitos inside the house (297, 83%), followed by nearer to stored water (138, 39%) and near birkas (72, 20%) (Table.2 and Figure S18). Respondents were also asked about their level of concern regarding mosquitoes in their households or neighborhoods and the larger proportion of the respondents reported that they are slightly concerned (137, 39%), while (86, 24%) were not concerned at all (Table.2 and Figure S19).

When respondents were asked how concerned their household is about mosquito-related illnesses, most of the respondents indicated that they are slightly concerned (132, 37%), while (103, 29%) of them stated not concerned at all (Table.2 and Figure S20).

Respondents identified water storage in open containers (312, 87%) and standing water, such as puddles and drains (240, 67%), as contributing factors to mosquito presence. Other commonly reported sources included construction pits or debris (75, 21%) and private *birkas* or water reservoirs (51, 14%). Few respondents identified drought conditions (11, 3%), flooding (11, 3%), or human migration and population movement (4, 1%) as important contributing factors. In addition, 60 respondents (17%) reported other factors that contributed to mosquito breeding within their communities (Table.2 and Figure S21).

Table 2: Overview of Knowledge and Perceptions of Malaria and Mosquitos: most common responses

Domain	Indicator	Most Common Response	n		n%
Knowledge of Malaria	Has heard of malaria	Yes	357	306	85.7
	Cause of malaria	Mosquito bites	307	224	73
	Mode of transmission	Bite of infected mosquito	306	247	80.7
	Symptoms recognized	Fever	306	275	89.9
Risk Perception	Perceived household malaria risk	Low	306	126	41.2
	Household malaria case in the past 2 years	No	306	296	97
	Most affected age group in those homes	Children	9	3	33.3
	Most affected gender in those homes	Female	9	6	66.6
Knowledge of mosquito behavior and ecology	Time of day when mosquitos bite	Night	357	273	76.5
	Where mosquitos are commonly observed	Inside house	357	297	83.2
	Main source of mosquito breeding	Water storage	357	312	87.4
Attitudes: Level of Concern					
Level of Concern	Concern about mosquitoes	Slightly concerned	356	137	38.5
	Concern about mosquito borne illness	Slightly concerned	357	132	37
Openness to larval source treatment by officials	Open to water treatment by health officials	Yes	354	343	96.3
		No	354	11	3.1

Water Sources, Uses, and Storage

Regarding the primary sources of drinking water, nearly half of the respondents reported that donkey carts were their main source of water (176, 49%), followed by municipal piped water (97, 27%), tanker trucks (59, 17%), and other sources (17, 4.8%). Respondents who selected "other" sources reported collecting rainwater stored from previous rainy seasons or using water from stagnant pools and residual floodwater (Table.3 and Fig.1). These alternative sources were used for drinking, cooking, and washing, particularly by households located in the peri-urban parts of the city. The key informant from Jigjiga city Water office shared that the maximum water amount we can supply through pipeline, provided that we do not face electricity disruption is 15,000 meter cube a day.

Although only a small proportion of respondents in Table.3 and Fig.1, reported obtaining water directly from unprotected wells (6, 3%) or unprotected boreholes (2, 0.6%), these sources remain important because much of the water distributed by donkey carts is reportedly collected from unprotected wells and boreholes according to our observations.

Respondents were also asked about the purposes for which water obtained from different sources was used. As of Fig.1, below among households that relied on donkey carts as their primary water source, almost all reported using the water for cooking (178, 99%), washing (177, 99%), and drinking purposes (170, 95%).

Similarly, respondents whose primary source of water was the municipal piped supply reported using the water mainly for cooking (101, 99%), drinking (100, 98%), and washing purposes (99, 97%). Among households relying on tanker trucks, water was primarily used for washing (58, 98%), cooking (58, 98%), and drinking (53, 90%) (Table.3).

Households using unprotected wells reported that the water was mainly used for washing (18, 100.0%), drinking (15, 83%), and cooking (15, 83%), whereas fewer respondents reported using it for livestock (3, 17%) or construction purposes (2, 11%). Likewise, respondents obtaining water from unprotected boreholes reported using it primarily for washing (3, 60%) and construction purposes (3, 60%), while only one respondent (20%) reported using it for drinking and cooking (Table.3).

Also interviewed community leaders explained that the supply of water to the city through municipality pipes was unfeasible and inconceivable due to many factors. Above all, they say, the city is growing at a fastest rate from year to year and its population is also increasing alarmingly due to the higher number of rural-urban migration to the city. Hence they say the situation is prompting the city's residents to take recourse to wells and boreholes whose water was never treated and that too it was being distributed through donkey carts and trucks for all purposes.

Respondents were further asked where household water was stored and whether storage containers were covered. As of Figure S29, nearly half of them reported storing water in containers located outside the kitchen (170, 48%), while 146 respondents (41%) stored water in containers inside the kitchen. The most commonly used water storage containers were barrels (272, 76%) and jerrycans (271, 76%), followed by *birkas* (44, 12%) (Figure S30). In the same token most of the respondents stated that their water storage containers were always covered (225, 63%), whereas 118 (33%) reported covering them only sometimes and 12 (3%) reported never covering them at all (Table.5). However, field observations made during the data collection revealed that many storage containers were left uncovered and were cleaned infrequently.

Among households with *birkas*, when asked about when the *birka* was built most respondents reported that the structures had been constructed within the previous 8-12 months (27, 63%), while nine respondents (21%) were unable to recall when their *birka* had been constructed. Most respondents reported that their *birka* was intended for permanent use (40, 91%), while only four (9%) indicated that it was temporary (Figure S31 and Figure s32).



Figure 1: A: Permanent *Birka*, B: Temporary *Birka*

When respondents were asked whether mosquitoes were commonly observed around *birkas*, 30 of the respondents reported that mosquitos were observed (68%) whereas (14, 32%) did not observe mosquitoes around at all (Figure S34). Field observations by the research team also independently identified several *birkas* as probable or certain mosquito breeding habitats.

Regarding the frequency of cleaning water storage containers, including *birkas*, most respondents reported cleaning them weekly (167, 47%), followed by monthly (61, 17%) and daily (45, 13%). However, 72 respondents (20%) reported cleaning their containers less frequently, while 12 (3%) reported rarely or never cleaning them at all (Table.5b and Figure S36). Despite these self-reported practices, field observations revealed that many water storage containers, including *birkas*, were left uncovered and contained algae, leaves, and other organic debris.

Table 3: Water Sources and Uses

Water Source			**Water used for:**				
	Primary Water Sources	Respondents using multiple sources	Drink n (%)	Wash n (%)	Cook n (%)	Animal n (%)	Construction n (%)
Unprotected well water	6	18	15 (83.3)	18 (100)	15 (83.3)	3 (16.7)	2 (11.1)
Unprotected borehole water	2	5	1 (20.0)	3 (60.0)	1 (20.0)	0 (0.0)	3 (60)
Water delivered by tanker truck	59	59	53 (89.8)	58 (98.3)	58 (98.3)	5 (8.5)	3 (5.1)
Water delivered by donkey cart	176	179	170 (95.0)	177 (98.9)	178 (99.4)	12 (6.7)	2 (1.1)
Water from city pipe	97	102	100 (98.0)	99 (97.1)	101 (99.0)	12 (11.8)	9 (8.8)
Other	17	24	21 (87.5)	21 (87.5)	19 (79.2)	4 (16.7)	0 (0.0)
	357						

Gender and Water Management

Water scarcity in Jigjiga city compels many households to store water in barrels, jerrycans, *birkas*, and other containers for extended periods. An interview held with community leaders revealed that most of the time in the Somali households, the responsibility for fetching, storing, covering, and managing household water rests primarily with women and girls.

In Table.4a below, respondents were asked who was primarily responsible for cleaning household water storage containers. The majority identified women as the primary persons responsible (262, 74%), for cleaning containers than men (57, 16%).

Likewise, respondents were also asked who was mainly responsible for preventing mosquitoes within the household. Nearly all respondents identified the mother as the principal responsible person for mosquito prevention (27, 96%). (Table.4b). In the same token, an interview held with the officials of the Somali Regional Health Bureau indicated that women (mother) are the front line actors involved in community health education program related to the use of insecticide bed nets and the indoor residual spraying.

Besides their responsibilities for household water management and mosquito prevention, respondents who reported malaria cases within their households were also asked which sex was more commonly affected by the disease. Most respondents indicated that females were more frequently affected (6, 67%), than males (33%) (Table.2).

Table 4a: Who is responsible for cleaning water containers? (n=356)

	n	%
Male	57	16
Female	262	73.6
Both	37	10.4
no one	0	0

Table 4b. Who is responsible for preventing mosquitoes? (n=28)*

	n	%
Mother	27	96.4
Father	4	14.3
Youngsters	5	17.9
Other	0	0

*From households reporting malaria cases

Mosquito Control Strategies and Practices

Regarding mosquito control strategies and practices, respondents were asked about the measures they currently use to reduce mosquito bites within their households. The most commonly reported method was the use of smoke (239, 67%), followed by aerosol-sprays (73, 20%), oil

(62, 17%), insecticide-treated bed nets (60, 17%), and untreated bed nets (45, 13%). A smaller proportion reported using insecticides (14, 4%) or other methods (42, 12%), including body creams, electronic mosquito repellents, and rechargeable mosquito traps (Table.5b). An interview held with the community leaders revealed that the locally available materials such as insane gums, olive tree wood and leaves and perfume resins were commonly burned to generate smoke for repelling mosquitoes at home. In an interview, an official from the Somali Region Environmental Protection Authority stated that due to the porous nature of the border of the region nearer to Somalia and Somaliland, many different types of insecticide aerosol-sprays and untreated mosquito bed nets are entering to Jigjiga city through contraband, and their chemical side effects are unknown.

Likewise, respondents were also asked whether they used any measures to reduce mosquitoes breeding in household water storage containers and the majority of them (325, 92%) reported taking no action to prevent mosquito breeding (Table.5a).

Among households implementing preventive measures, the reported practices included adding ash, oil, fuel residues, or burnt fuel waste to stored water. Some respondents also reported regularly cleaning water storage containers and maintaining a clean household compound to reduce mosquito breeding sites. Consistently, those who reported implementing mosquito control measures were further asked to assess their effectiveness and most of them considered the methods to be very effective (11, 39%) (Table.5b).

Regarding the availability and affordability of mosquito control measures, most respondents reported that the methods they considered most effective were readily available (20, 69%). Similarly, 19 respondents (66%) considered these measures were affordable (Table.5b). Some respondents explained that obtaining fuel and burnt fuel residues had become increasingly difficult because of rising fuel prices and periodic fuel shortages nationally.

Households were also asked whether national, regional, or local health authorities had ever provided mosquito larval control interventions in their communities and nearly all of the respondents (350, 98%) reported that no such support had been provided (Table.5a). Equally important the officials from the Somali Region Health Bureau confirmed that due to budget

limitation and the belief that malaria is uncommon in Jigjiga; interventions related to larval source control are very rare.

Notwithstanding the limited implementation of larval source management (LSM), the overwhelming majority of the respondents (343, 96%) expressed willingness to accept larvicide added to the household water containers if it is used to prevent mosquito breeding and if such interventions were introduced by the Ministry of Health or the Somali Region Health Bureau (Table.2). Here the majority of the respondents clearly expressed that their reason to accept the LSM intervention is to get relief from the noises and bites of mosquito and to have good sleep especially for children. Whereas few of the respondents who refused to accept the intervention reasoned that we fear the negative health consequences and we don't want to take the health risks it may cause on others.

Table 5a: Household mosquito prevention strategies

Do you currently do anything to reduce mosquitoes breeding in water at your household? (n=353)			
	Yes	28	7.9
	No	325	92.1
Have national, regional or local health authorities ever provided mosquito larvae control support in your area? (n=357)			
	Yes	7	2
	No	350	98

Table 5b: Household mosquito prevention practices and perceived efficacy

Bite Prevention (n=357)		n	%
	Treated bed net	60	16.8
	Untreated bed net	45	12.6
	Sprays	73	20.4
	Insecticides	14	3.9
	Smoke	239	66.9
	Oil	62	17.4
	Other	42	11.8
Practices reported conducted related to breeding reduction: cleaning and covering (n=357)			
	Clean storage containers always	225	63.4
	Clean storage container sometimes	118	33.2
	Never clean storage container	12	3.4
	Always cover container with lid	225	63.4
	Sometimes cover	118	33.2

	Never cover with lid	12	3.4
Perceived effectiveness of current control practice (n=28)			
	Not at all	2	7.1
	Slightly	8	28.6
	Moderately	7	25
	Very	11	39.3
	Extremely	0	0
Affordability and availability: is your most effective control mechanism affordable and available to you? (n=29)			
	Affordable	20	69
	Not affordable	9	31
	Available	19	65.5
	Not available	10	34.5

Discussion

This household survey of 357 respondents across six clusters of Jigjiga city offers one of the earliest community-level accounts of malaria risk perception, mosquito-prevention practice, household water management, and gender roles in a Somali-region urban center that is officially classified as malaria-free but sits inside a rapidly expanding zone of *Anopheles stephensi* invasion. The survey also informs our understanding of the general community knowledge, perceptions, water management behavior and mosquito protection strategies among residents in the city of Jigjiga, a newly recognized setting for the invasion of urban *Anopheles stephensi* which puts at risk for the advent of urban malaria. Understanding community perceptions and household level practices is essential for designing integrated vector management strategies that combine environmental management, larval source management, community engagement, and health education.

The socio-demographic profile of the respondents demonstrates that women constituted the majority (78%) of study participants while males accounted for (22%). The predominance of female respondents is attributed to the household survey being conducted during daytime hours, when many men were away from home because of work and business activities. Consequently, women were more readily available for interview. Similar respondent distributions have been reported in household-based Knowledge, Attitude, and Practice (KAP) studies conducted in

Ethiopia and other African countries, where women are more likely to be available during household surveys and are primarily responsible for domestic water management and child care (Deressa et al., 2023; Fuge et al., 2015).

Likewise, the occupational status of the respondents reveals that the majority of them were housewives (64%). The high proportion of female respondents (housewives) reflects the traditional gender roles within the Somali community, where women are more likely to remain at home to undertake domestic responsibilities and childcare, while men are commonly engaged in employment or business activities outside the home (Alagbe and Jimoh, 2021). Furthermore, the predominance of respondents without formal education, despite widespread attendance at informal Qur'anic education (61%) may partly explain some misconceptions observed regarding malaria transmission and prevention, as educational attainment has consistently been associated with improved malaria knowledge and adoption of preventive measures (Ayele et al., 2012; Tesfay et al., 2019).

Respondent's awareness of malaria (86%) is encouraging, and closer to (73%) of them correctly identified mosquito bites as the cause of malaria, while (81%) recognized transmission through bites of infected mosquitoes. These findings are comparable to national malaria indicator surveys in Ethiopia, which have reported generally high awareness of malaria but persistent misconceptions regarding disease causation and transmission (Ethiopian Public Health Institute (Kassa et al., 2005). However, approximately one-quarter of the respondents incorrectly attributed malaria to dirty water or contaminated food, while 12.4% were unable to explain how malaria is transmitted. Similar misconceptions have been documented in several Ethiopian and sub-Saharan African settings, where incomplete knowledge continues to hinder effective malaria prevention despite decades of health education campaigns (Deressa et al., 2023).

Respondent's recognition of malaria symptoms was generally satisfactory. The majority of the respondents properly identified fever (90%) and headache (84%) as major symptoms, consistent with findings reported from northwestern Ethiopia (Ayele et al., 2012)and systematic reviews conducted across Africa (Mboera et al., 2007). Early recognition of symptoms is an important determinant of timely healthcare seeking, which contributes to reduced malaria morbidity and mortality.

Interestingly, most households placed themselves at low or moderate malaria risk and only 3% reported experiencing malaria cases during the previous two years, consistent with the Regional Health Bureau's position that malaria is uncommon in Jigjiga city. However, this perception contrasts with the growing entomological evidence demonstrating that *Anopheles stephensi* is now well established in Jigjiga, Kebridehar and other towns within the Somali Region (Balkew et al., 2021; Yared et al., 2023). Likewise, a 2025 dry-season entomological survey of water-holding habitats across Jigjiga, Semera, and Logiya, explicitly noted that while malaria does not occur locally in Jigjiga, seasonal transmission occurs in lowland rural areas only about 25 kilometers away from the city, a distance easily bridged by human movement and by the mosquito's demonstrated ability to establish in artificial water containers (Gebresilassie et al., 2025). The apparent discrepancy between community perceptions and entomological findings may be explained by relatively low clinical incidence, incomplete surveillance, and under-reporting particularly the incomplete integration of data from both public and private health facilities.

Again, this mismatch between perceived disease risk and actual vector establishment has important implications for malaria prevention in urban areas. Risk perception strongly influences the adoption of protective behaviors. Households that perceive malaria as a minor threat are generally less likely to use insecticide-treated nets consistently, eliminate mosquito breeding sites, or participate actively in community vector control programmes. Here, (Merga et al., 2024) states that due to the widespread belief that malaria is more frequently seen as a problem of the rural poor, the illness has been less considered in urban settings for a long time.

The finding that children were perceived as the most affected group by malaria agrees with established epidemiological evidence from Ethiopia and elsewhere in sub-Saharan Africa. Children under five years remain particularly vulnerable because of their fragile immunity system and greater susceptibility to severe disease (WHO, 2025b). Recent Ethiopian studies similarly report disproportionately high malaria prevalence among young children living in endemic areas (Biset et al., 2022; Merga et al., 2024). Nevertheless, key informants from the Somali Regional Health Bureau correctly emphasized that all age groups remain vulnerable in areas where malaria transmission occurs.

Interestingly, among households reporting malaria, women were perceived to be more frequently affected than men. Although the small number of reported malaria cases limits firm conclusions, this perception may reflect gendered patterns of exposure rather than biological susceptibility. Women in Jigjiga spend considerably more time around household compounds, water storage containers, cooking areas, and domestic environments where *An. stephensi* commonly breeds and rests. Consequently, women may experience greater exposure to mosquitoes during routine household activities. Similar gender-related differences in exposure have been described in studies of household vector ecology and urban malaria conducted in Ethiopia and South Asia, where domestic water management influences mosquito-human contact (Balkew et al., 2021).

Respondents demonstrated a relatively good understanding of mosquito biting behavior, with over three-quarters identifying nighttime as the principal biting period. This finding aligns with the behavior of most African malaria vectors, including *Anopheles arabiensis*. However, *Anopheles stephensi* exhibits greater ecological flexibility and may also feed during the early evening and utilize both indoor and outdoor resting sites (Sinka et al., 2020). Consequently, reliance solely on nighttime protection may provide insufficient protection against this invasive vector.

Remarkably, the slight concern of respondents about mosquito-related illnesses and mosquitoes in their household deserves particular attention from the side of the regional health bureau as far as the establishment of *Anopheles stephensi* in Jigjiga city (Yared et al., 2023) has raised concerns regarding the potential emergence of urban malaria transmission.

One of the most important findings of this study relates to household water management practices. Most of the respondents' reliance on donkey carts and municipal pipes for water, and use of barrels and jerrycans for storage, is consistent with the broader water-insecurity context of Jigjiga. An official from the city Water Office shared that the maximum water we can supply through pipeline, provided that we do not face electricity disruption was 15,000 meter cube a day. These findings reflect the chronic urban water shortages previously documented in Jigjiga (Gobe et al., 2024). Similarly, (Dispatch et al., 2026) stated that across 38 African countries, water supply ranks as the third-most-important problem that citizens want their government to address, and one in four citizens report frequent shortages of clean water.

Because water availability is unreliable in Jigjiga, households commonly store large quantities of water in barrels, jerrycans, and underground cisterns (*birkas*) for prolonged periods and this finding contradicts with the 2024-2025 Ethiopian Demographic Health Survey, which reveals that roughly 97% of an overall urban community has got improved drinking water coverage(ESS and ICF, 2024). Such water storage practices create ideal breeding habitats for *Anopheles stephensi*, which preferentially breeds in artificial water containers commonly found in urban environments (WHO, 2022; Balkew et al., 2021). Consequently, urban water insecurity indirectly increases malaria risk because households must store water for prolonged periods, and then inadvertently provide permanent larval habitats throughout the year.

Although most respondents reported that water containers were always covered, direct field observations contradicted these reports, revealing numerous uncovered containers containing algae, organic matter, and mosquito larvae. Similar inconsistencies have been documented in urban Ethiopia, Kenya, and India, where households frequently over-report recommended environmental sanitation practices while direct observations demonstrate substantial opportunities for mosquito breeding (Carter et al., 2018).

The observation that mosquito presence was common around household *birkas* further supports growing evidence that urban water storage systems constitute major breeding habitats for *Anopheles stephensi*. Numerous studies conducted in Ethiopia, Djibouti, Sudan, India, and Pakistan have consistently identified domestic water storage containers as the principal larval habitats of this invasive vector (Sinka et al., 2020; Balkew et al., 2021; WHO, 2022). Consequently, improving household water storage practices represents one of the most promising interventions for preventing urban malaria transmission in Jigjiga.

In this study, the role of gender in urban households' water management, mosquito prevention practices, and malaria risk perception deserves particular attention. Women were overwhelmingly responsible for cleaning water containers (74%) %), while nearly all respondents (96%) indicated that mothers were principally responsible for preventing mosquito breeding around the household, and this is consistent with the regional health official description of women (mothers) as the front line actors in community health education program related to the use of insecticide bed nets and indoor residual spraying. These findings are consistent with

previous research among Somali pastoralist communities, where women and girls bear primary responsibility for water collection, storage, household sanitation, and childcare (OXFAM-Somali Water, 2008; Wardhere & Mahamed, 2026). Because women directly manage household water storage, they represent a critical target group for future community-based vector control interventions, health education campaigns, and larval source management (LSM) programs.

Although these responsibilities increase women's workload, it also position women as the principal decision-makers regarding household environmental management and therefore as essential partners in urban malaria prevention programmes. Likewise, earlier studies conducted across sub-Saharan Africa have consistently revealed that women are more likely than men to participate in community health education programmes and to adopt recommended preventive practices when adequate information and resources are available (Deressa et al., 2023; pulford et al., 2011). Studies further show that women who possess better malaria knowledge are more likely to encourage household members to use mosquito nets correctly and participate in environmental sanitation activities as well (Tassew et al., 2017). Consequently, interventions targeting women often generate broader household-level behavioral changes than programmes directed exclusively toward household heads or male decision-makers.

In the context of the establishment of *Anopheles stephensi* in urban areas like Jigjiga (Yared et al., 2023) the predominance role of women in household water management is particularly relevant. Unlike traditional rural malaria vectors, *An. stephensi* exploits artificial water storage containers that are maintained almost entirely within domestic environments. Subsequently, the daily decisions made by women regarding covering water containers, cleaning storage facilities, replacing stored water, and keeping household compounds clean directly influence the availability of mosquito breeding habitats. Comparable observations have been reported from India, Pakistan, Djibouti and Ethiopia, where the ecology of *An. stephensi* is closely linked to household water management practices rather than natural aquatic habitats (Carter et al., 2018; Balkew et al., 2021).

Despite respondents recognizing mosquitoes as a nuisance, preventive practices remained relatively limited. Traditional smoke was by far the most commonly used mosquito control method, whereas ownership or use of insecticide-treated nets was comparatively low. Locally

available materials such as insane gums, olive tree wood, leaves and perfume resins were commonly burned to generate smoke for repelling mosquitoes at home, however the smoke is actually targeting adult mosquito annoyance rather than larval breeding. Even more concerning, over 92% of households reported taking no action to prevent mosquito breeding within stored water. Similar practices have been documented throughout eastern Africa and the Horn of Africa. The wider community use of repellent plants has the potential to complement existing malaria control measures, such as ITNs (Insecticide treated mosquito nets) but not to take as primary malaria prevention strategy (Wendimu & Tekalign, 2021). This substantial gap between awareness and preventive behavior has been reported in numerous malaria KAP studies throughout sub-Saharan Africa (Deressa et al., 2023; Ayele et al., 2012). Behavioral barriers may include limited awareness of larval ecology, inadequate public health messaging regarding *Anopheles stephensi*, and the absence of organized community vector control programs.

The other noteworthy part of this study was almost the complete absence of government-supported larval source management. Nevertheless, the community willingness to accept larvicide interventions was remarkably high, with more than 96% expressing willingness to allow treatment of household water sources. This finding contrast with concerns occasionally expressed regarding potential community resistance to larviciding programmes (Yared et al., 2025). Rather, this finding suggests a strong community readiness for integrated vector management despite limited previous experience with LSM. A key informant interviews with officials from the Somali Regional Health Bureau similarly suggested that community acceptance is unlikely to constitute a major barrier to the future implementation of LSM programmes in Jigjiga city. Previous WHO guidance emphasizes that community participation and acceptance are essential prerequisites for successful urban larval source management programs (Tusting, 2014). Therefore, the high level of public acceptance observed in this study represents a valuable opportunity for implementing sustainable urban vector control strategies before *Anopheles stephensi* becomes firmly established.

Despite many strengths of this study, limitations should also be acknowledged. First interviews were conducted during daytime, resulting in a predominance of female respondents, while male perspective was underrepresented since they are out during the day at work. Second, the study relied on self-reported information, which is subject to recall and social desirability biases and

this may have influenced responses concerning water container cleaning and covering practices. Finally, since data were collected during a single period, seasonal variation in household water management practices may not be fully captured. Overall, the above limitations have not affected the outcomes of the study at all.

Conclusion

Overall, the findings of this study suggest that households in Jigjiga city possess relatively good general knowledge regarding malaria transmission and mosquito breeding. They perceive their personal malaria risk to be low despite widespread environmental conditions favorable for vector proliferation. Since the mosquito breeding in Jigjiga is closely linked to critical and unreliable urban water supplies, rapid urban expansion and domestic water storage practices, as well as the documented establishment of *Anopheles stephensi*, effective prevention requires coordinated action beyond the health sector through involving municipal water authorities, urban and construction bureau, environmental protection agencies and local administrations. The near-unanimous community willingness to accept a government-led larval control intervention, combined with the entomological evidence already available from Jigjiga and neighboring Somali-region towns, suggests that acceptability is not the barrier to a larval source management program in this city; the barrier is more likely the absence of routine surveillance data connecting clinical case reporting to entomological reality, and the resulting policy assumption that Jigjiga is not a malaria risk area at all. Therefore, strengthening community awareness on urban malaria ecology and urban malaria surveillance, expanding gender sensitive health education, improving household water management and implementing gender inclusive larval source management should be taken as the top priorities for malaria prevention in Jigjiga city.

Abbreviations

EPHI-Ethiopian Public Health Institute

ESS-Ethiopian Statistical Service

ETB-Ethiopian Birr

ITN-Insecticide Treated Nets

JJU- Jigjiga University

KAP-Knowledge Attitude and Practices

KII-Key Informant Interview

LSM-Larva Source Management

REDCap-Research Electronic Data Capture

WHO-World Health Organization

Supplementary Information is attached with this article

Acknowledgement

We sincerely extend our gratitude to Jigjiga city communities for their willingness to participate in the study through providing valuable information and sharing their experiences. We appreciate the support of community leaders, Somali Regional Bureaus and data collectors for their cooperation during the research process. We also acknowledge the financial and material support provided by Emory University and Gates Foundation (INV-080534) which made this study possible.

Author Contributions: Designed research: BB, SY, DJ, KA, IA, GVP. Performed research: BB, SY, DJ, SJ, GVP. Analyzed data: BB, KA, DJ, SJ. Wrote the paper: BB, SY, GVP, IA.

Funding

This study was financially supported by Emory University and Gates Foundation (INV-080534).

Declarations

We declare that this research is our original work and has been prepared in accordance with academic and ethical standards where IRB clearance was obtained from Jigjiga University (Reg.No.JJU-RERC/007/2025). Both verbal and written consent was obtained from households. All sources of information used have been appropriately acknowledged. This study has not been submitted previously for any academic award or publication. We also take full responsibility for the accuracy, integrity, and originality of the research.

References

Alagbe, E.A, Jimoh, S.O, and Jimoh, B. . (2021). *African multidisciplinary journal of development (amjd) vol.10, issue 3, 2021*. *10*(3), 59–69.

Ayele, D. G., Zewotir, T. T., & Mwambi, H. G. (2012). Prevalence and risk factors of malaria in Ethiopia. *Malaria Journal*, *11*, 1–9. https://doi.org/10.1186/1475-2875-11-195

Balkew, M., Mumba, P., Dengela, D., Yohannes, G., Getachew, D., Yared, S., Chibsa, S., Murphy, M., George, K., Lopez, K., Janies, D., Choi, S. H., Spear, J., Irish, S. R., & Carter, T. E. (2020). Geographical distribution of Anopheles stephensi in eastern Ethiopia. *Parasites and Vectors*, *13*(1), 1–8. https://doi.org/10.1186/s13071-020-3904-y

Balkew, M., Mumba, P., Yohannes, G., Abiy, E., Getachew, D., Yared, S., Worku, A., Gebresilassie, A., Tadesse, F. G., Gadisa, E., Esayas, E., Ashine, T., Yewhalaw, D., Chibsa, S., Teka, H., Murphy, M., Yoshimizu, M., Dengela, D., Zohdy, S., & Irish, S. (2021). An update on the distribution, bionomics, and insecticide susceptibility of Anopheles stephensi in Ethiopia, 2018–2020. *Malaria Journal*, *20*(1), 1–13. https://doi.org/10.1186/s12936-021-03801-3

Barow, I., Megenta, M., & Megento, T. (2019). Spatiotemporal analysis of urban expansion using GIS and remote sensing in Jigjiga town of Ethiopia. *Applied Geomatics*, *11*(2), 121–127. https://doi.org/10.1007/s12518-018-0245-z

Biset, G., Tadess, A. W., Tegegne, K. D., Tilahun, L., & Atnafu, N. (2022). Malaria among under - five children in Ethiopia : a systematic review and meta - analysis. *Malaria Journal*, 1–13. https://doi.org/10.1186/s12936-022-04370-9

Carter, T. E., Yared, S., Gebresilassie, A., Bonnell, V., Damodaran, L., Lopez, K., Ibrahim, M., Mohammed, S., & Janies, D. (2018). First detection of Anopheles stephensi Liston, 1901 (Diptera: culicidae) in Ethiopia using molecular and morphological approaches. *Acta Tropica*, *188*(September), 180–186. https://doi.org/10.1016/j.actatropica.2018.09.001

Deressa, A., Gamachu, M., Birhanu, A., Ayana, G. M., Raru, T. B., Negash, B., Merga, B. T., Regassa, L. D., & Ababulgu, F. A. (2023). Malaria Risk Perception and Preventive Behaviors Among Elementary School Students, Southwest Ethiopia. Generalized Structural Equation Model. *Infection and Drug Resistance*, *16*(June), 4579–4592. https://doi.org/10.2147/IDR.S415376

Dispatch, A., Stephen, N., Wyk-khosa, S. Van, & Chibwili, E. (2026). *Water supply high on Africa ns ' policy agenda amid persistent access and service gaps*. (1153), 1–24.

File, T., Dinka, H., & Golassa, L. (2019). A retrospective analysis on the transmission of Plasmodium falciparum and Plasmodium vivax: The case of Adama City, East Shoa Zone, Oromia, Ethiopia. *Malaria Journal*, *18*(1), 1–6. https://doi.org/10.1186/s12936-019-2827-6

Florio, P., Freire, S., & Melchiorri, M. (2023). Estimating Geographic Access to Healthcare Facilities in Sub-Saharan Africa by Degree of Urbanisation. *Applied Geography*, *160*, 103118.

Fuge, T. G., Ayanto, S. Y., & Gurmamo, F. L. (2015). Assessment of knowledge, attitude and practice about malaria and ITNs utilization among pregnant women in Shashogo District, Southern Ethiopia. *Malaria Journal*, *14*(1), 1–9. https://doi.org/10.1186/s12936-015-0755-7

Gebresilassie, A., Aklilu, E., Yared, S., Abdulahi, E., Darasa, K. A., habib, A. A., Witka, W. nore, Ahmed, H., Hagezom, D., Kassa, T., Jackson, D., & Vazquez-Prokopec, G. M. (2025). Habitat heterogeneity and green filamentous algae influence the larval ecology of Anopheles stephensi during the dry season in Eastern Ethiopia. *Parasites and Vectors* , *18*(1), 1–15. https://doi.org/10.1186/s13071-025-07100-7

Gobe, D. E., Mohammed, A., Adem, A., Deribe, K., Chernet, A., & Yared, S. (2024). Determinants of malaria infection among under five children in Gursum district of Somali region, Eastern Ethiopia. *Malaria Journal* , *23*(1), 1–16. https://doi.org/10.1186/s12936-024-05206-4

Hamlet, A., Dengela, D., Tongren, J. E., Tadesse, F. G., Bousema, T., Sinka, M., Seyoum, A., Irish, S. R., Armistead, J. S., & Churcher, T. (2022). The potential impact of Anopheles stephensi establishment on the transmission of Plasmodium falciparum in Ethiopia and prospective control measures. *BMC Medicine*, *20*(1), 1–10. https://doi.org/10.1186/s12916-022-02324-1

Kassa, M., Sileshi, M., Mohammed, H., Taye, G., & Asfaw, M. (2005). Development of resistance by Plasmodium falciparum to sulfadoxine/ pyrimethamine in Amhara Region, Northwestern Ethiopia. *Ethiopian Medical Journal*, *43*(3), 181–187.

Mboera, L. E. G., Makundi, E. A., & Kitua, A. Y. (2007). Uncertainty in malaria control in Tanzania: Crossroads and challenges for future interventions. *American Journal of Tropical Medicine and Hygiene*, *77*(SUPPL. 6), 112–118. https://doi.org/10.4269/ajtmh.2007.77.112

Merga, H., Degefa, T., Birhanu, Z., Abiy, E., Lee, M. C., Yan, G., & Yewhalaw, D. (2024).

Urban malaria and its determinants in Eastern Ethiopia: the role of Anopheles stephensi and urbanization. *Malaria Journal* , *23*(1). https://doi.org/10.1186/s12936-024-05126-3

NCD Risk Factor Collaboration (NCD-RisC). (2023). Diminishing benefits of urban living for children and adolescents' growth and development. *Nature, 615*, 874–883. https://doi.org/10.1038/s41586-023-05772-8

Negesse, A., Medhin, G., Aklilu, E., & Animut, A. (2026). Composition, blood meal sources, and entomological inoculation rates of Anopheles mosquitoes in an urban setting, central Ethiopia. *Malaria Journal* , *25*(1). https://doi.org/10.1186/s12936-026-05874-4

OXFAM-somali water 2008.

Pulford, J., Hetzel, M. W., Bryant, M., Siba, P. M., & Mueller, I. (2011). Reported reasons for not using a mosquito net when one is available: A review of the published literature. *Malaria Journal*, *10*, 1–10. https://doi.org/10.1186/1475-2875-10-83

Sinka, M. E., Pironon, S., Massey, N. C., Longbottom, J., Hemingway, J., Moyes, C. L., & Willis, K. J. (2020). A new malaria vector in Africa: Predicting the expansion range of Anopheles stephensi and identifying the urban populations at risk. *Proceedings of the National Academy of Sciences of the United States of America*, *117*(40), 24900–24908. https://doi.org/10.1073/pnas.2003976117

Tassew, A., Hopkins, R., & Deressa, W. (2017). Factors influencing the ownership and utilization of long-lasting insecticidal nets for malaria prevention in Ethiopia. *Malaria Journal*, *16*(1), 1–9. https://doi.org/10.1186/s12936-017-1907-8

Tesfay, K., Yohannes, M., Mardu, F., Berhe, B., & Negash, H. (2019). Assessment of community knowledge, practice, and determinants of malaria case households in the rural area of Raya Azebo district, Northern Ethiopia, 2017. *PLoS ONE*, *14*(10), 1–14. https://doi.org/10.1371/journal.pone.0222427

Tusting, L. S. (2014). Larval source management: A supplementary measure for malaria control. *Outlooks on Pest Management*, *25*(1), 41–43. https://doi.org/10.1564/v25_feb_13

Vearey, J., Luginaah, I., Magitta, N. W. F., Shilla, D. J., & Oni, T. (2019). Urban health in Africa: a critical global public health priority. *BMC public health*, *19*(1), 340.

Wardhere, M. A. H., & Mahamed, M. A. S. (2026). Impact of meteorological drought on pastoralist livelihood assets in the Southwest of Somalia. *Discover Sustainability*, *7*(1). https://doi.org/10.1007/s43621-026-02616-z

Wendimu, A., & Tekalign, W. (2021). Field efficacy of ethnomedicinal plant smoke repellency against Anopheles arabiensis and Aedes aegypti. *Heliyon*, *7*(7). https://doi.org/10.1016/j.heliyon.2021.e07373

WHO. (2025a). *Annexes: World malaria report 2025*. https://www.who.int/publications/m/item/annexes-world-malaria-report-2025?utm_source=chatgpt.com

WHO. (2025b). World malaria World malaria report report 2025. In *World Health: WHO/HTM/GM* (Number December).

World Health Organization. (2025, April). *Ethiopia Health Cluster bulletin: April 2025*. ReliefWeb. https://reliefweb.int/report/ethiopia/ethiopia-health-cluster-bulletin-april-2025

World Health Organization. (2022). Global Framework for the Response to Malaria in Urban areas. In *World Health Organization*. https://www.who.int/publications/i/item/9789240061781%0Ahttps://www.who.int/publications/i/item/guidelines-for-malaria

Yared, S., Dengela, D., Mumba, P., Chibsa, S., Zohdy, S., Irish, S. R., Yoshimizu, M., Balkew, M., Akuno, A., Perkins, T. A., & Vazquez-Prokopec, G. M. (2025). Anopheles stephensi larval habitat superproductivity and its relevance for larval source management in Ethiopia. *Malaria Journal* , *24*(1). https://doi.org/10.1186/s12936-025-05589-y

Yared, S., Gebresilassie, A., Aklilu, E., Abdulahi, E., Kirstein, O. D., Gonzalez-Olvera, G., Che-Mendoza, A., Bibiano-Marin, W., Waymire, E., Lines, J., Lenhart, A., Kitron, U., Carter, T., Manrique-Saide, P., & Vazquez-Prokopec, G. M. (2023). Building the vector in: construction practices and the invasion and persistence of Anopheles stephensi in Jigjiga, Ethiopia. *The Lancet Planetary Health*, *7*(12), e999–e1005. https://doi.org/10.1016/S2542-5196(23)00250-4

Yared, S., Gebressielasie, A., Damodaran, L., Bonnell, V., Lopez, K., Janies, D., & Carter, T. E. (2020). Insecticide resistance in Anopheles stephensi in Somali Region, eastern Ethiopia.

Malaria Journal, *19*(1), 1–7. https://doi.org/10.1186/s12936-020-03252-2

Yamane, Taro. (1973): Statistics: An Introductory Analysis, 3rd ed., New York: Harper and Row.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- BiniyamBogaleSupplementeryInformation.docx