NJE Vol. 41(2): 31-47, 2025
Nigerian Journal of Entomology
Published by the Entomological Soc. of Nig.
www.esnjournal.com.ng
DOI.10.36108/NJE/5202/14.0230

IDENTIFYING THE CURRENT GAPS IN MALARIA VECTOR CONTROL IN ORUK ANAM LGA, AKWA IBOM STATE, NIGERIA

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Abstract

Malaria presents a persistent public problem in Oruk Anam Local Government Area (LGA), Akwa Ibom State, Nigeria, despite various vector control interventions. The study's aim was to evaluate the current gaps in malaria vector control, evaluating existing strategies, and exploring potential improvements. Data were collected from September to November, 2024 using focus group discussions, structured questionnaires, and Pyrethrum Spray Catch (PSC) to examine socio-economic characteristics, intervention methods, and mosquito vector populations respectively. Results showed that *Aedes* mosquitoes were the most prevalent species (43 individuals), followed by *Anopheles* (16) and *Culex* (8). Socio-economic analysis revealed that most respondents were aged 18–30 years (27%), predominantly male (54%), and married (54.5%), with 46.5% living in households of 4–6 members. Common vector control practices included insecticide use (89%), bush clearing (60.5%), and sleeping under mosquito nets (46.5%). Effectiveness ratings highlighted insecticide use (mean = 2.45) and stagnant water drainage (mean = 2.55) as the most effective strategies, while closing windows (mean = 1.85) was rated low. Key barriers noticed in this study included vector breeding sites (75%), environmental factors (70%), and resource constraints (65%). Proposed solutions included ecological management programs (90%), improved health infrastructure (85%), and integrated vector management (80%). The findings reveals the necessity of enhanced community education, targeted environmental sanitation, improved health infrastructure, and innovative vector management strategies to address gaps and effectively bring down the burden of malaria in the region.

Keywords: Malaria, *Anopheles, Culex,* Key barriers, community education.

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INTRODUCTION

Malaria continually presents a major worldwide challenge in the health sector, as the World Health Organization (WHO) documented about 249 million incidences in 2022, showing some increase from 244 million cases reported in 2021. This rise in cases is particularly concerning as it exceeds pre-COVID-19 pandemic levels (Venkatesan, 2023; WHO, 2024). The disease is predominantly concentrated within the sub-Saharan African region, which accounted for about 94% of malaria cases as well as 95% of malaria deaths globally within the same year (WHO, 2023a; WHO, 2023b). In terms of mortality rates, malaria caused approximately 608,000 deaths in 2022, 80% of which were amongst children under five years old (Liu *et al.*, 2021; WHO, 2023). Malaria creates great threat in the public health sectors within the world's subtropical and tropical regions. It accounts for approximately 2.6% of the entire burden of disease in the world, making it a very important health challenge worldwide (Venkatesan, 2023; Shi *et al.*, 2023). It significantly impacts economic development due to healthcare costs and lost productivity. In Africa, malaria is responsible for about 10% of the overall disease burden, severely affecting more susceptible members of the population, such as pregnant women and young children, who are disproportionately affected by its severe consequences (Liu *et al.*, 2021; Venkatesan, 2023).

Malaria is majorly transmitted by *Anopheles* mosquitoes (Ubong *et al.*, 2024), which act as vectors for the Plasmodium parasites responsible for the disease. Environmental factors such as temperature, rainfall and humidity significantly influence mosquito behavior and survival rates (WHO, 2023; WHO, 2024). Unfortunately, the highest global burden of malaria lies within Nigeria, which contributes an estimated 27% of malaria cases and 31% of deaths resulting from malaria all over the world in the year 2022. This translates to approximately 68 million cases and about 200,000 deaths every year within the country (WHO, 2023).

Furthermore, the incidence rate remains high at around 306 cases per 1,000 population at risk, with rural populations experiencing a prevalence nearly 2.4 times higher than their urban counterparts (WHO, 2023). Moreover, it is estimated that malaria contributes to one tenth of maternal deaths and a quarter of deaths among infants and children under five (Nwaneli *et al.*, 2020). Malaria remains a major public health challenge in Akwa Ibom State, Nigeria, where it is endemic and accounts for a substantial burden of disease. The state has reported that malaria contributes to over 70% of all outpatient visits, with an estimated 246,362 verified cases of mild malaria and 2,863 complicated cases documented in 2016 alone (Effah *et al.*, 2019).

The prevailing high records of malaria in Akwa Ibom contribute to alarming rates of sickness and deaths, especially among the most susceptible members of the population (Okeibunor *et al.*, 2011). Environmental and climatic factors contribute importantly to the transmission dynamics of malaria in Akwa Ibom State. The tropical climate pattern, combined with high humidity and temperatures of between 23°C to 31°C, creates suitable environment for the breeding of *Anopheles* mosquitoes (Okeibunor *et al.*, 2011). Additionally, proximity to water bodies, bad drainage systems, and improper waste disposal supports increased mosquito breeding sites, further exacerbating the malaria burden in the area (Ugwu and Zewotir, 2020). Oruk Anam L.G.A. is situated within Akwa Ibom State. The geographical and demographic profile reveals a predominantly rural population that faces unique challenges in malaria control. Oruk Anam is characterized by a mix of agricultural activities and rapid urbanization due to migration driven by economic opportunities related to oil extraction. The population density and settlement patterns influence malaria transmission dynamics, as many residents live near stagnant water bodies that facilitate mosquito breeding (Ugwu and

Zewotir, 2020). Specific challenges related to malaria control in rural areas like Oruk Anam include poor access to healthcare facilities as well as inadequate implementation of measures aimed at prevention. Many residents do not consistently use insecticide-treated nets (ITNs) or engage in other preventive practices due to a lack of awareness or resources. Furthermore, the surveillance systems in place are often insufficiently equipped to monitor and respond effectively to malaria cases, leading to underreporting and delayed interventions (Udofia *et al*., 2021). The combination of these factors makes it difficult to achieve significant progress in controlling malaria transmission in the region.

Malaria vector control remains pivotal in the worldwide war against malaria, with strategies primarily focused on reducing the transmission potential of these vectors. The World Health Organization (WHO) endorses several key interventions, such as ITNs, indoor residual spraying (IRS), and larval source management (LSM). ITNs are designed to protect against mosquito bites during the night when transmission is most likely, while IRS involves spraying surfaces within the house where mosquitoes rest. LSM goes after the larval stages of mosquitoes by managing their breeding sites (WHO, 2023; NAID, 2023). The effectiveness of these interventions varies based on local vector behaviors and environmental conditions. For instance, ITNs have in the past significantly led to the reduction of malaria cases in areas where mosquitoes predominantly feed indoors at night. However, challenges arose with the outbreak of insecticide resistance, majorly within the pyrethroid class primarily used for both ITNs and IRS. Studies indicate that resistance can diminish the effectiveness of these tools, leading to increased malaria transmission rates despite high coverage levels of ITNs and IRS (Lobo *et al*., 2018; Burkot *et al*., 2019; Rodriguez, 2021). Furthermore, LSM requires comprehensive planning and local adaptation to be effective, as its success hinges on the specific ecological contexts of vector breeding sites (Lobo *et al*., 2018). Implementing these strategies in rural areas presents unique challenges. Limited healthcare infrastructure often hampers the distribution and maintenance of ITNs and IRS programs. Additionally, socioeconomic factors such as poverty can restrict access to these preventive measures, while cultural practices may influence their acceptance and usage (Sherrard-Smith *et al*., 2022; Rodriguez, 2021). Significant gaps persist in malaria vector control efforts that hinder effective implementation and utilization of available tools. Accessibility issues are prevalent; many communities lack sufficient access to ITNs and IRS due to logistical challenges and inadequate healthcare outreach. This situation is exacerbated by socioeconomic disparities that limit financial resources for purchasing or maintaining these protective measures (Burkot *et al*., 2019; Rodriguez, 2021).

Cultural barriers further contribute vitally to the under-utilization of vector control tools. In some regions, there may inadequate knowledge regarding the need to use ITNs or being part of IRS programs. Additionally, traditional practices may conflict with modern health recommendations, leading to resistance against adopting new interventions (Sherrard-Smith *et al*., 2022; Lobo *et al*., 2018). Emerging challenges such as insecticide resistance further complicate vector control efforts. Resistance not only affects the efficacy of existing insecticides but also necessitates ongoing research into alternative insecticides and innovative control strategies tailored to local vector populations (Ranson *et al*., 2011; Burkot *et al*., 2019; Rodriguez, 2021). Absence of an elaborate and consistent evaluation and monitoring system makes it difficult to accurately assess the effect of ongoing interventions. Without systematic data collection on vector populations and resistance patterns, malaria control programs cannot adapt quickly to changing epidemiological landscapes or optimize resource allocation (Lobo *et al.*, 2018; Sherrard-Smith *et al.*, 2022). Unfortunately, malaria continues to pose a significant health and socioeconomic burden in Nigeria, with rural areas like Oruk Anam LGA in Akwa Ibom State disproportionately affected due to environmental, cultural, and infrastructural challenges. While various vector control strategies like ITNs and IRS have been promoted, their effectiveness in rural communities is hindered by gaps in accessibility, adherence, and sustainability. Identifying these gaps is crucial for tailoring control programmes to address the unique peculiarities of these communities. Our study provides critical insights into the specific challenges and seeks to identify and analyze the current gaps of malaria vector control in Oruk Anam LGA, offering actionable recommendations to improve the effectiveness of existing programs while contributing to the broader vision of Malaria elimination within Nigeria.

MATERIALS AND METHODS

Study area

Oruk Anam (4°49′0″N latitude and 7°39′0″E longitude) L.G.A. is located in Akwa Ibom State, Nigeria, primarily inhabited by Annang ethnic group. It is one of the largest LG.As in the state, with a population of approximately 219,300 as of the latest census projections (Figure 1). The area's economy is predominantly agrarian, with many residents engaged in farming, craftsmanship, and civil service. Geographically, Oruk Anam features a tropical monsoon climate characterized by high rainfall from March to November, with humidity levels often exceeding 60% and temperatures range of 18°C to 32°C, creating suitable environment for malaria transmission. The topography includes flat lands and water bodies that provide suitable sites for mosquito breeding, particularly *Anopheles* mosquitoes.

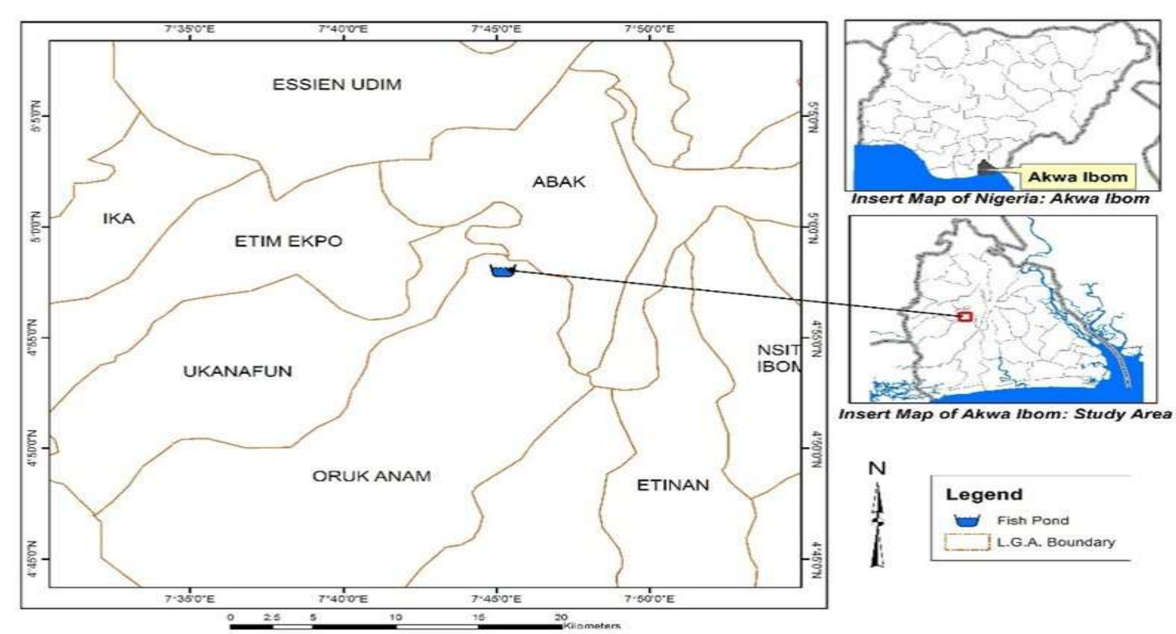

Figure 1: Map showing Oruk Anam L.G.A., Akwaibom state

Study Design

This study utilized a survey-based design to evaluate malaria vector control measures in Oruk Anam LGA, Akwa Ibom State, and was carried out from September to November, 2024. Stratified random sampling was employed to ensure household representative coverage across the L.G.A., considering variations in geographic, socioeconomic, and environmental factors. Specific sites were picked in relation to the prevalence of cases of malaria and proximity to mosquito breeding sites, ensuring that both areas with high-risk and low-risk were included for comprehensive data collection.

Data collection

A combination of data collection methods such as focus group discussions (FGDs) and structured questionnaires was used to gather information on malaria vector control strategies in Oruk Anam LGA. FGDs were conducted with community members, health workers, and local leaders to explore practices, perceptions, and challenges related to vector control. Two hundred (200) structured questionnaires were administered to households to collect data on the usage of various malaria vector control methods.

Pyrethrum Spray Catch (PSC) Method

The Pyrethrum Spray Catch (PSC) was conducted for 3 months in 14 households across the L.G.A. to assess indoor resting mosquitoes. Each morning (6 am to 7:30 am), selected households were sprayed with a ToPrank insecticide. Prior to spraying, white sheets were spread on the floor to collect mosquitoes that fell after spraying. After about 5 minutes of spraying all mosquitoes that fell on the sheets were picked with forceps and preserved in eppendorff tubes for identification. The collected mosquitoes were then identified and counted to ascertain density and composition of vector species. Standard entomological protocols were followed to ensure consistency and accuracy in the data collection process.

Data Analysis

Descriptive and inferential statistical methods were employed in analyzing the resulting data. Frequencies and percentages, were used to summarize demographic characteristics, and usage of vector control measures like ITNs and insecticides. Inferential analysis, including chi-square tests, was performed to identify associations.

RESULTS

Pyrethrum Spray Catch (PSC)

Result from the Pyrethrum Spray Catch (PSC), as shown in Table 1, shows that *Aedes* mosquitoes were the most frequently caught genus, accounting for 43 individuals over 14 nights. This was followed by *Anopheles* mosquitoes, with a total of 16 individuals, and *Culex* mosquitoes, with 8 individuals.

Table 1: **Pyrethrum Spray Catch (PSC)**

Night	No. of mosquitoes caught	Genus
1	5	*Aedes*
2	6	*Aedes*
3	4	*Culex*
4	6	*Aedes*
5	7	*Aedes*
6	4	*Anopheles*
7	5	*Aedes*
8	2	*Culex*
9	5	*Aedes*
10	8	*Anopheles*
11	4	*Aedes*
12	2	*Culex*
13	5	*Aedes*
14	4	*Anopheles*

The Socio-economic characteristics of the respondents

Results of the socio-economic characteristics respondents on display in in Table 2, revealed that more of the respondents were aged 18–30 years (27%), followed by ages 31–40 years and 41–50 years, each representing 24.5% of the sample. Respondents aged 51–60 years accounted for 14%, while those aged 61–69 years constituted the smallest group at 10%. Regarding gender, males represented a slightly higher proportion (54%) compared to females (46%). Majority of respondents were married (54.5%), with singles making up 27.5%, widows 12.5%, and divorced 5.5%. In terms of household size, the most common size was 4–6 members (46.5%), followed by 1–3 members (38.5%). Households with 7–10 members accounted for 11%, while those with 11–13 and 14–16 members constituted 3% and 1%, respectively.

Table 2: Socio-economic characteristics of the respondents

Variables	Frequency	Percentage (%)
Age (years)		
18 – 30	54	27.00
31 – 40	49	24.50
41 – 50	49	24.50
51 – 60	28	14.00
61 – 69	20	10.00
Total	**200**	**100**
Gender		
Male	108	54.00
Female	92	46.00
Total	**200**	**100**
Marital Status		
Married	109	54.50
Single	55	27.50
Divorced	11	5.50
Widowed	25	12.50
Total	**200**	**100**
Household size		
1-3	77	38.50
4-6	93	46.50
7-10	22	11.00
11-13	6	3.00
14-16	2	1.00
Total	**200**	**100**

The Malaria vector control intervention currently in place in Oruk Anam L.G.A, Akwa Ibom State, Nigeria

The result of malaria vector control interventions currently in place in Oruk Anam L.G.A, expressed on Table 3, revealed that the most commonly practiced intervention is the use of insecticides (89%), followed by covering the body with clothes (61%) and cutting bushes and grasses around the home (60.5%). Sleeping under mosquito nets and burning coils or grass as repellents are practiced by 46.5% and 46% of respondents, respectively, while clearing gutters is also reported by 46%. Draining stagnant water is practiced by 35% of respondents, and sleeping with windows closed is reported by 34.5%. Fewer respondents reported rubbing repellent cream on the body (9%).

Table 3: Malaria vector control intervention currently in place in ORUK Anam L.G.A, Akwa Ibom State, Nigeria

Interventions	Frequency	%
Use of insecticides	178	89.00
Sleeping under the mosquito net	93	46.50
Sleeping with windows closed	69	34.50
Burning a coil/grass as repellents	92	46.00
Cutting bushes and grass around the home	121	60.50
Draining stagnant water	70	35.00
Clearing gutters	92	46.00
Covering the body with clothes	122	61.00
Rub repellent cream on the body	18	9.00
Covering the body with clothes	90	45.00

Source: Field survey, 2024. Multiple responses recorded

The potential and efficiency of the interventions

The result of the potentials and efficiency of the interventions, as shown in Table 4, reveals that the use of insecticides (mean = 2.45), sleeping under mosquito nets (mean = 2.15), burning coils or grass as repellents (mean = 2.40), cutting bushes and grasses around the home (mean = 2.00), draining stagnant water (mean = 2.55), clearing gutters (mean = 2.20), covering the body with clothes (mean = 2.30), and rubbing repellent cream on the body (mean = 2.19) are considered highly effective. Sleeping with windows closed (mean = 1.85) is rated as having low effectiveness.

Table 4: Potentials and efficiency of the interventions **N = 200**

Variables	**Highly Effective (3)**	**Moderately Effective (2)**	**Low Effectiveness (1)**	**Mean**	**Decision**
Use of insecticides	120(360)	50(100)	30 (30)	2.45	HE
Sleeping under mosquito net	70(210)	90(180)	40 (40)	2.15	HE
Sleeping with windows closed	40(120)	90(180)	70 (70)	1.85	LE
Burning a coil/grass as repellents	110(330)	60(120)	30 (30)	2.40	HE
Cutting bushes and grasses around the home	60(180)	80(160)	60 (60)	2.00	HE
Draining stagnant water	130(390)	50(100)	20 (20)	2.55	HE
Clearing gutters	90(270)	60(120)	50 (50)	2.20	HE
Covering the body with clothes	97(291)	66(132)	37(37)	2.30	HE
Rub repellent cream on the body	78(234)	81(162)	41(41)	2.19	HE

Source: Field survey, 2024, Decision rule: Mean > 2.00 = Highly effective (HE), Mean ≤2.00 = Low effectiveness (LE)

Table 5: Human and vector drivers of gaps in protection

Interventions	**Frequency**	**%**
Low Community Awareness	120	60.00
Behavioral Non-compliance	80	40.00
Socioeconomic Barriers	90	45.00
Cultural Beliefs	70	35.00
Vector Resistance to Insecticides	110	55.00
Vector Breeding Sites	150	75.00
Adaptability of Vectors	100	50.00
Resource Constraints	130	65.00
Health Infrastructure Limitations	115	57.50
Environmental Factors	140	70.00

Source: Field survey, 2024, multiple responses recorded

The new interventions that could cover the gap in protection

The result of new interventions that could cover the gap in protection, as shown in Table 6, reveals that the most reported intervention is environmental management programs (90%), followed by improved health infrastructure (85%) and integrated vector management (80%). Enhanced community education programs are reported by 75%, while new insecticide formulations account for 70%. Social and financial support is mentioned by 65%, strengthened surveillance systems by 60%, and biological larval control by 50%.

Table 6: New interventions that could cover the gap in protection

Interventions	Frequency	%
Enhanced Community Education Programmes	150	75.00
Social and Financial Support	130	65.00
New Insecticide Formulations	140	70.00
Biological Larval Control	100	50.00
Environmental Management Programs	180	90.00
Integrated Vector Management (IVM)	160	80.00
Strengthened Surveillance Systems	120	60.00
Improved Health Infrastructure	170	85.00

Source: Field survey, 2024. Multiple responses recorded

DISCUSSION

The PSC result highlights the presence of multiple mosquito genera in the area, with *Aedes* being dominant, which may reflect breeding patterns or local environmental conditions conducive to their proliferation (Udofia *et al.*, 2021; Akpan *et al.*, 2025). The detection of *Anopheles* underscores the risk of an ongoing transmission of malaria within study area (Okorie *et al.*, 2011).

Socio-economic characteristics from respondents provide essential insights into the demographic patterns and their potential influence on the prevalence and prevention strategies for malaria. Age distribution showed that more respondents were within an economically active group (18–30 years, 27%), with declining representation among older age brackets. This pattern aligns with observations by the DHS Program (2021) that malaria prevalence is highest among younger individuals in regions with high malaria endemicity, such as Nigeria. This demographic is often more mobile and may have increased exposure to mosquito bites, especially in poorly protected outdoor environments. The gender distribution showed a slight male predominance (54%), which is corroborates with findings from Effah *et al*. (2019), indicating that men often engage in activities that expose them to mosquito habitats, such as farming and outdoor labor. However, females, particularly pregnant women, remain the most vulnerable group due to immunological changes during pregnancy, as highlighted by WHO (2023).

The predominance of married respondents (54.5%) and moderate household sizes (4–6 members, 46.5%) underscores socio-economic dynamics that can affect malaria control. Larger households may face challenges in accessing adequate malaria vector control tools, like ITNs, as noted by Nwanosike *et al*. (2015). In contrast, smaller households may have better resource allocation for malaria prevention measures.

The findings of the Malaria Vector Control Interventions in Oruk Anam L.G.A, Akwa Ibom State highlight that insecticide use is the predominant malaria control measure, aligning with global trends where insecticide-based strategies, such as IRS and ITNs, are central to the prevention of malaria (WHO, 2024). The reliance on insecticides in Oruk Anam is consistent with trends observed in Akwa Ibom State, where insecticide spraying was used by 77.2% of respondents (Paul *et al*., 2020). However, the relatively low ITN usage in Oruk Anam mirrors broader challenges in Nigeria, where less than 30% of the population regularly sleeps under nets (NMEP, 2014). While WHO advocates for widespread ITN usage, only 46.5% of respondents reported using mosquito nets, indicating suboptimal adherence despite their proven efficacy in reducing malaria incidence by approximately 20% (Nikolaeva *et al*., 2015). Other methods like bush cutting, covering the body with clothes, and clearing gutters are reflective of environmental management approaches. These strategies are consistent with whose recommendation to eliminate mosquito breeding sites, a sustainable intervention also supported by Lindsay *et al*. (2004). However, the relatively lower adoption of draining stagnant water and sleeping with windows closed suggests gaps in awareness or accessibility. Interestingly, the low utilization of repellent creams might reflect either cultural preferences or limited access to such products. This contrasts with findings from studies in other regions where repellents are more commonly used due to their portability and ease of application (Paul *et al*., 2020).

The effectiveness of interventions in Oruk Anam L.G.A. aligns with established literature. Insecticides and draining stagnant water were rated highly effective, corroborating their recognized role in malaria vector control (WHO, 2024). Draining stagnant water, in particular, addresses larval habitats, reducing mosquito populations. However, its limited practice indicates a need for enhanced community engagement. The moderate efficacy of cutting bushes and clearing gutters suggests their supportive role in environmental management, but not as standalone solutions. The slightly lower effectiveness of sleeping under mosquito nets compared to insecticides might result from improper use or damaged nets, as documented in Akwa Ibom's low ITN utilization rates (Paul *et al*., 2020). While burning coils is moderately practiced in Oruk Anam, its mean efficiency aligns with its effectiveness in repelling mosquitoes but not eliminating them. Similar findings from Akwa Ibom emphasize the need for a holistic approach, combining repellent methods with long-term solutions like ITNs and IRS (Effah *et al*., 2019). Sleeping with windows closed was rated less effective, possibly due to the structural inadequacies of homes in rural Nigeria, where many windows lack protective screens (Effah *et al*., 2019). This emphasizes the need of combining physical barriers with chemical methods for optimal outcomes. The results also align with global findings on the efficacy of integrated vector management. The WHO highlights that combining number of interventions like larviciding and environmental management, enhances overall malaria control effectiveness (WHO, 2021).

The findings on the gaps in malaria protection arise from a combination of human-related, vector-related, and structural/environmental drivers, aligning with the literature review and other studies on the subject. The result that low community awareness (60%) and behavioral non-compliance (40%) are significant gaps aligns with findings from Nwaneri *et al*. (2016), who reported a disconnect between ITN ownership (42%) and regular use (23%). This highlights a persistent issue of poor adherence to recommended malaria prevention practices despite widespread awareness campaigns. Similarly, socioeconomic barriers (45%) reflect the findings of Tesfazghi *et al*. (2016) as well as that of Nwaneri *et al*. (2016), where cultural beliefs and financial constraints limited the adoption of ITNs and IRS. Behavioural factors like cultural beliefs (35%) also resonate with Flatie and Munshea (2021) who revealed preferences for traditional remedies over scientifically proven methods in Bauchi State. The significant impact of vector breeding sites (75%), resistance to insecticides (55%), and vector adaptability (50%) is consistent with reports by Yusuf *et al*. (2021) and Muhammad *et al*. (2021). Resistance to pyrethroids and DDT among *Anopheles gambiae* and *An. coluzzii*, coupled with genetic adaptations like the kdr gene, has drastically reduced the effectiveness of traditional interventions. Behavioral changes in vectors, such as altered biting times to evade ITNs, exacerbate these challenges (Yusuf *et al*., 2021). This aligns with global trends where resistance and behavioral adaptability significantly undermine vector control strategies (Ononamadu *et al*., 2020). Environmental factors (70%) and resource constraints (65%) are critical drivers identified in the study, consistent with findings by Ugwu and Zewotir (2020) and Castro (2017). Poor infrastructure, such as inadequate drainage and waste management, contributes to mosquito breeding. Additionally, geographic disparities in malaria prevalence, as highlighted by Villena *et al*. (2024), emphasize the importance of localized interventions designed for specific environmental conditions. Climate change, as described by Nikolaeva *et al*. (2015), further amplifies these challenges, with altered rainfall patterns and flooding creating new breeding grounds, consistent with this study’s emphasis on environmental drivers. The finding that health infrastructure limitations (57.5%) contribute to gaps in protection mirrors Ugwu and Zewotir's (2020) observation of poor access to health services in rural areas. Limited entomological surveillance and monitoring capacity (Oduola *et al.*, 2018; Maduka, 2018) further exacerbates these gaps. The President's Malaria Initiative (PMI, 2024) also noted that the lack of trained personnel and weak integration of malaria surveillance into broader health systems hampers the timely response to evolving vector behaviors and resistance patterns.

The results showing the new intervention that could cover the gap underscore the importance of adopting innovative and multifaceted interventions to bridge existing gaps in malaria protection. Environmental management programs were the most reported (90%), which aligns with findings emphasizing their effectiveness in reducing mosquito breeding sites and lowering malaria incidence when implemented at a community level (Asale *et al*., 2019). This aligns with studies on community-based integrated vector management (CBIVM), where education and local participation in environmental cleanup have shown significant reductions in malaria cases (Asale *et al*., 2019; Nwaneri, 2023). Improved health infrastructure (85%) and integrated vector management (80%) were also highly prioritized. Strengthening health infrastructure ensures timely diagnosis and treatment, while integrated vector management combines tools like ITNs, IRS, and LSM for comprehensive protection. For example, CBIVM approaches involving ITNs and environmental management, as highlighted in the PMI VectorLink project, have proven sustainable and effective (PMI VectorLink, 2024). Community education programs (75%) also play a vital role in enhancing adherence to malaria prevention strategies. Studies have shown that proper education about ITNs significantly improves their use and maintenance, leading to better malaria prevention outcomes (Ekedo *et al*., 2024). This is consistent with the report highlighting the effectiveness of community-based education in reducing the incidence of malaria (Asale *et al*., 2019). Notably, new insecticide formulations (70%) represent a crucial response to insecticide resistance. For instance, insecticides like indoxacarb have demonstrated high efficacy against resistant *Anopheles gambiae*, with potential integration into current vector control strategies (Oxborough *et al*., 2015). Innovations in ITNs with multi-insecticide formulations further reinforce the need to address resistance mechanisms (Ekedo *et al*., 2024; Sogoba, 2024). The report also highlights strengthened surveillance systems (60%) and biological larval control (50%) as essential strategies. These measures align with WHO recommendations for effective monitoring and targeting of mosquito populations, complemented by the use of biological agents like Bacillus thuringiensis to control larvae in water bodies (WHO, 2021). Generally, these interventions address critical gaps in malaria protection through an integrated and community-driven approach. Compared to traditional methods, such as standalone IRS or ITNs, the combination of innovative tools like genetically modified mosquitoes and improved insecticides demonstrates a higher potential for sustainable malaria control (Dunning, 2024; Naidoo and Oliver, 2024). The emphasis on community involvement ensures local relevance and sustainability, key to closing gaps in malaria control efforts.

CONCLUSION

This study reveals significant gaps in malaria vector control in Oruk Anam LGA, Akwa Ibom State, highlighting the need for comprehensive and innovative approaches. Key challenges include limited implementation of environmental management programs, inadequate health infrastructure, and weak surveillance systems, which hinder effective vector control and disease monitoring. Existing interventions, such as ITNs and IRS, are compromised by growing insecticide resistance, poor adherence, and insufficient community education and participation. Furthermore, promising innovations like genetically modified mosquitoes, new insecticide formulations, and biological larval control remain underutilized, leaving residual transmission unaddressed. Bridging these gaps requires integrating innovative tools with robust health systems, enhanced engagement in communities, and improved surveillance for sustainable control of malaria.

It also recommends a multifaceted approach to addressing the gaps in malaria vector control in Oruk Anam LGA. Priority should be given to scaling up environmental management programs and improving health infrastructure to enhance the accessibility and effectiveness of interventions. Integrated vector management (IVM) strategies, incorporating genetically modified mosquitoes, innovative insecticide formulations, and biological larval control, should be explored to tackle insecticide resistance and residual transmission. Community education and engagement must be intensified to promote adherence to preventive measures like ITNs and environmental hygiene practices. Additionally, strengthening surveillance systems and fostering collaborations between government, NGOs, and communities are important for maintaining efforts put into malaria control. Emphasis should also be placed on research and field trials of emerging technologies to ensure context-specific and evidence-based solutions.

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