frontiers | Frontiers in Malaria

TYPE Original Research
PUBLISHED 01 December 2025
DOI 10.3389/fmala.2025.1693543

Check for updates

OPEN ACCESS

EDITED BY
Louisa Alexandra Messenger,
University of Nevada, Las Vegas, United States

REVIEWED BY
Sanjay Tevatiya,
National Institute of Malaria Research (ICMR), India
Hemma Yulfi,
Universitas Sumatera Utara Departemen Parasitologi, Indonesia
Magnus Sichalwe,
Nantong University, China

*CORRESPONDENCE
Tegemeo Gavana
tgavana@ihi.or.tz

RECEIVED 27 August 2025
REVISED 10 November 2025
ACCEPTED 11 November 2025
PUBLISHED 01 December 2025

CITATION
Kihwele F, Gavana T, Kailembo D, Kasagama E, Mwalimu CD, Bernard J, Yoram B, Ndekuka L, Kajange S, Lazaro S, Kisoka N, Chaki P, Lengeler C and Dillip A (2025) Stakeholders' perceptions, acceptability, and sustainability of a larviciding intervention in Tanga Region, Tanzania. *Front. Malar.* 3:1693543. doi: 10.3389/fmala.2025.1693543

Stakeholders' perceptions, acceptability, and sustainability of a larviciding intervention in Tanga Region, Tanzania

Fadhila Kihwele[1], Tegemeo Gavana[1,2,3*], Denis Kailembo[2,3], Elizabeth Kasagama[2,3], Charles Dismas Mwalimu[4], Jubilate Bernard[4], Best Yoram[5], Leah Ndekuka[4], Stella Kajange[5], Samwel Lazaro[4], Noela Kisoka[2,3], Prosper Chaki[1], Christian Lengeler[2,3] and Angel Dillip[6]

[1]Environmental Health and Ecological Sciences, Ifakara Health Institute, Dar es Salaam, Tanzania, [2]Swiss Tropical and Public Health Institute, Allschwil, Switzerland, [3]University of Basel, Basel, Switzerland, [4]National Malaria Control Programme, Ministry of Health, Dodoma, Tanzania, [5]President Office, Regional Administration and Local Government, Dodoma, Tanzania, [6]Apotheker Health Access Initiative, Dar es Salaam, Tanzania

Background: In 2019, the Government of Tanzania endorsed the countrywide implementation of mosquito larviciding to complement insecticide-treated nets (ITNs) and indoor residual spraying (IRS) as vector control interventions. Between 2022 and 2024, a large-scale pilot project covering a population of over 1 million individuals was implemented in the Tanga Region, in the northeast of the country. The program was implemented entirely by the government system and made use of community-owned resource persons (CORPs). This manuscript presents the key results of a qualitative study assessing the perceptions and awareness of the stakeholders and the acceptability, facilitating factors, barriers, and sustainability of the intervention. Companion publications report on the operations, entomological and epidemiological impacts, and costs of the program.

Methodology: This cross-sectional qualitative study used in-depth interviews (IDIs) and focus group discussions (FGDs) to assess perceptions, acceptability, and sustainability regarding larviciding. A total of 44 IDIs were conducted with government officials who oversaw project implementation. In addition, 13 FGDs were held with 156 community participants(72 CORPs involved in larviciding activities and 84 other community members). Data were analyzed using framework analysis.

Results: The study findings showed that community-based larviciding was perceived as safe, acceptable, effective, feasible, and sustainable. However, several key challenges were identified, including the unpleasant smell of the larvicide, the CORP turnover, logistic problems, and discontinuous implementation.

Conclusion: The pilot larviciding intervention implemented in the Tanga Region was perceived as safe, effective, feasible, and sustainable, and was widely accepted by the community. However, addressing key operational challenges such as the unpleasant odor of the larvicide, high CORP turnover, logistical constraints, and discontinuous implementation will be essential to ensuring the effectiveness and sustainability of future large-scale rollouts.

KEYWORDS

larviciding, Bactivec®, Griselesf® perceptions, acceptability, sustainability

Background

Malaria remains a major public health and socioeconomic challenge despite decades of global efforts to control and eliminate the disease. It continues to cause an estimated 263 million cases and 597,000 deaths annually worldwide, with children under 5 years of age and pregnant women comprising the most vulnerable groups (World Health Organisation, 2024). Sub-Saharan Africa (SSA) accounts for approximately 95% of the global malaria cases and deaths (World Health Organisation, 2021a; World Health Organisation, 2024).

Vector control interventions, particularly the widespread use of insecticide-treated nets (ITNs) and indoor residual spraying (IRS), have been instrumental in reducing malaria transmission (World Health Organisation, 2021a; World Health Organisation, 2024; Weiss et al., 2025). However, these measures alone are insufficient to achieve malaria elimination. Among others, factors such as the behavioral and physiological adaptability of malaria vectors (Schmidt et al., 2018; Lindsay et al., 2021; Namias et al., 2021; van den Berg et al., 2021), the suboptimal intervention coverage (Koenker et al., 2014; Koenker and Yukich, 2017; Sherrard-Smith et al., 2022), and user compliance challenges (Krezanoski and Haberer, 2019; Rek et al., 2020) have reduced the effectiveness of these two core strategies (Sougoufara et al., 2017; Sougoufara et al., 2020). According to the Global Malaria Reports, global progress in malaria control has stalled since 2015 (World Health Organisation, 2016; World Health Organisation, 2017a; World Health Organisation, 2018; World Health Organisation, 2019; World Health Organisation, 2020; World Health Organisation, 2021b; World Health Organisation, 2022; World Health Organisation, 2023; World Health Organisation, 2024).

To address these challenges, the World Health Organization (WHO) recommends supplementing ITNs and IRS with complementary interventions, such as larval source management (LSM), particularly in areas where transmission persists despite optimal ITN and IRS coverage (World Health Organization, 2013; World Health Organisation, 2017b; World Health Organisation, 2021a). LSM may include environmental management, biological control, and larviciding (World Health Organization, 2013).

Larviciding refers to the application of chemical or biological agents called larvicides to aquatic habitats in order to eliminate mosquito larvae (World Health Organization, 2013; Choi et al., 2019). Evidence from multiple studies indicates that larviciding can effectively reduce mosquito populations and enhance the impact of ITNs and IRS (Shousha, 1948; Killeen et al., 2002a; Killeen et al., 2002b; Fillinger and Lindsay, 2006; Majambere et al., 2007; Fillinger et al., 2009; Majambere et al., 2010; Fillinger and Lindsay, 2011; Zhou et al., 2016; Obopile et al., 2018; Dambach et al., 2019; Dambach et al., 2020; Zhou et al., 2020). Historically, larviciding has contributed to the eradication of malaria vectors in regions such as Brazil (Killeen et al., 2002a), Egypt (Shousha, 1948), and the Zambian copper mining areas (Utzinger et al., 2002). In recent decades, several SSA countries, including Rwanda (Hakizimana et al., 2022), Kenya (Fillinger and Lindsay, 2006; Fillinger et al., 2009; Worrall and Fillinger, 2011), The Gambia (Majambere et al., 2010), Benin (Wafula et al., 2023), Burkina Faso (Dambach et al., 2018; Dambach et al., 2019; Dambach et al., 2020; Dambach et al., 2021), and Botswana (Obopile et al., 2018), have implemented larviciding, mostly on a small scale and primarily for research purposes.

Large-scale implementation has been constrained by operational challenges in locating numerous breeding sites and concerns about cost-effectiveness in areas with widely scattered habitats (Newman et al., 2013; Dambach et al., 2016; Antonio-Nkondjio et al., 2018; Newby et al., 2025; Okumu et al., 2025). Consequently, the WHO currently recommends larviciding as a supplementary intervention only, in areas where mosquito breeding habitats are few, fixed, and findable (World Health Organization, 2013). Nonetheless, recent advancements in geospatial mapping

Abbreviations: *Bti, Bacillus thuringiensis israelensis*; *Bs, Bacillus* sphaericus; CHMT, Council Health Management Team; CORPs, community-owned resource persons; DMFP, District Malaria Focal Person; DMO, District Medical Officer; DVCO, District Vector Control Officer; FGDs, focus group discussions; ICF, informed consent form; IDIs, in-depth interviews; IHI, Ifakara Health Institution; LSM, larval source management; NIMR, National Institute for Medical Research; NMCP, National Malaria Control Program; MEO, Mtaa Executive Officer; PO-RALG, President Office, Regional Administration and Local Government; RHMT, Council Health Management Team; RMFP, Regional Malaria Focal Person; TEMT, Towards Elimination of Malaria in Tanzania; VEO, Village Executive Officer; WEO, Ward Executive Officer; WaHO, Ward Health Officer; WHO, World Health Organization; Handeni DC, Handeni District Council; Tanga CC, Tanga City Council; Lushoto DC, Lushoto District Council.

and drone technologies (Carrasco-Escobar et al., 2019; Byrne et al., 2021; Carrasco-Escobar et al., 2022; Vigodny et al., 2023), along with the emergence of invasive vector species such as *Aedes aegypti* (Weetman et al., 2018; Abdulai et al., 2023; Love et al., 2023) and *Anopheles stephensi* (Sinka et al., 2020; Hemming-Schroeder and Ahmed, 2023; Taylor et al., 2024), which are less effectively controlled by ITNs or IRS, have renewed interest in larviciding as a complementary tool within the framework of integrated vector management (IVM) (Beier et al., 2008; Fillinger et al., 2009; Musoke et al., 2013).

Larvicides, particularly biological larvicides, have a different mode of action from the conventional insecticides used in ITNs and IRS, making larviciding a promising approach for addressing outdoor-biting mosquitoes and contributing to insecticide resistance management (Charles and Nielsen-LeRoux, 2000; Bravo et al., 2007; Ben-Dov, 2014; Choi et al., 2019). With widespread pyrethroid resistance threatening the sustainability of pyrethroid-based interventions (Kisinza et al., 2017; Matiya et al., 2019; Matowo et al., 2021; Tungu et al., 2023; Odero et al., 2024), larviciding offers a means to diversify the vector control arsenal and enhance its resilience (World Health Organisation, 2004; Beier et al., 2008; World Health Organisation, 2013; Chanda et al., 2015; Becker et al., 2022). Furthermore, larviciding can target multiple mosquito species, extending its benefits to the control of other vector-borne diseases (World Health Organisation, 2004; Beier et al., 2008; Becker et al., 2022).

In Tanzania, the National Malaria Control Program (NMCP) has adopted the WHO recommendations to introduce mosquito larviciding in areas where it is appropriate to complement high ITN and IRS coverage (Tanzania MoH, 2020; Tanzania MoH, 2023). In 2019, the Government of Tanzania (GoT) formally endorsed the countrywide community-based mosquito biolarviciding (Tanzania MoH, 2020). Evidence suggests that community-based larviciding can be more cost-effective, efficient, and sustainable than when the interventions are implemented solely by government agencies (Chaki et al., 2011; Maheu-Giroux and Castro, 2013; Ingabire et al., 2014; Diabaté et al., 2015; Afrane et al., 2016; Ingabire et al., 2017; Amazigo et al., 2021; Hakizimana et al., 2022; Mapua et al., 2024).

Although larviciding is not new to Tanzania, previous efforts have been limited in geographic scope and were inconsistently implemented. Historically, the only large-scale larviciding intervention occurred in Dar es Salaam and Tanga during the 1990s and 2000s as part of urban malaria control programs (UMCPs) (Caldas de Castro et al., 2004; Fillinger et al., 2008; Chaki et al., 2009; Geissbühler et al., 2009; Maheu-Giroux and Castro, 2013). Other efforts were generally small-scale and research-focused (Mboera et al., 2014; Rahman et al., 2016; Gowelo et al., 2020; Mapua et al., 2024), leaving limited evidence on the feasibility, sustainability, and impact of large-scale community-implemented larviciding.

To fill in this evidence gap and guide national scale-up, the Ministry of Health (MoH), through the NMCP and in collaboration with the President's Office–Regional Administration and Local Government (PO-RALG), launched a large-scale pilot larviciding project in the Tanga Region, northeastern Tanzania (Diarra et al., 2025; Gavana et al., 2025; Kailembo et al., 2025). The project operations were administered and supervised through the administrative structures of the local government authorities. National supervision was provided by the NMCP (Kailembo et al., 2025). This model was selected to develop an implementation modality that could be readily replicated if further upscaling was decided by the government (Diarra et al., 2025). The initiative was supported by the Towards Elimination of Malaria in Tanzania (TEMT) project of the Swiss Government and implemented by the Swiss Tropical and Public Health Institute (Swiss TPH).

The project was evaluated comprehensively by an independent research organization (the Ifakara Health Institute, IHI), which comprehensively assessed the implementation processes and impact. This study presents the findings from a qualitative study exploring the perceptions and awareness of stakeholders and the acceptability, facilitating, and hindering factors, and recommendations for the sustainability of the intervention. These insights are valuable to the MoH and the NMCP for refining operational plans, improving program efficiency, and guiding evidence-based decision-making for the potential nationwide scale-up of larviciding interventions. In addition, as more African countries adopt larviciding programs, the evidence from this study could inform the design of similar initiatives in comparable contexts.

Companion publications report quantitative findings on the outcomes (Gavana et al., unpublished), the entomological impact (Gavana et al., in press), and the epidemiological impact (Kailembo et al., 2025), and the costs of the program (Diarra et al., 2025). Given the complexity of the evaluation, multiple publications were necessary to address all components comprehensively.

Methods

Study design

In order to elicit the stakeholders' perceptions, awareness, and acceptability, identify factors that facilitate implementation and barriers, and obtain suggestions for ensuring the sustainability of the intervention, a purely qualitative approach was selected. A cross-sectional qualitative study was conducted using two methods: in-depth interviews (IDIs) and focus group discussions (FGDs). Participants were randomly selected to ensure representation across all three intervention councils, covering different roles and settings. The study was conducted in 2023, the second year of project implementation, when communities had already been exposed to the intervention for 1 year. The present work is part of a comprehensive evaluation of the program, with evaluations of the entomological and epidemiological impacts, along with a detailed costing analysis, being reported elsewhere.

Study setting

The study was conducted in the three intervention councils in the Tanga Region, representing three different malaria epidemiological risk strata, as defined in the National Malaria Strategic Plan (Tanzania MoH, 2020): high risk (Handeni DC), moderate risk (Tanga CC), and low risk (Lushoto DC) (Diarra et al., 2025). Tanzania is epidemiologically stratified into four malaria risk levels: high, moderate, low, and very low (Tanzania MoH, 2020; Thawer et al., 2020; Runge et al., 2022). At the same time, the selection included two rural (Handeni DC and Lushoto DC) and one urban setting (Tanga CC) (United Republic of Tanzania: NBS, 2022a). These councils were selected pragmatically by the NMCP and partners to represent three different malaria risk strata in the country. The populations of Handeni DC, Tanga CC, and Lushoto DC were 394,052, 403,361, and 359,821, respectively (United Republic of Tanzania: NBS, 2022a; United Republic of Tanzania: NBS, 2022b). Hence, the total population in the intervention area was 1,157,234. The intervention covered 91 villages in Handeni DC, 89 villages in Lushoto DC, and 181 streets in Tanga CC (Diarra et al., 2025; Kailembo et al., 2025).

The larviciding intervention

The pilot larviciding intervention was conducted between June 2022 and April 2024. It involved the application of two biolarvicide products: Bactivec®, containing spores of *Bacillus thuringiensis* var. *israelensis* (Bti) (Derua et al., 2022), and Griselesf®, containing spores of *Bacillus sphaericus* (Bs) (Lacey, 2007; Lai et al., 2023). The two biolarvicide products are manufactured in-country by Tanzania Biotech Products Limited (TBPL) (https://www.tanzaniabiotech.co.tz/). The TBPL is a wholly owned subsidiary of the government-owned National Development Corporation (NDC), created through a bilateral partnership between the Governments of Cuba and Tanzania. The factory was established in 2015.

The two bacteria-based larvicides produce toxins that are lethal to mosquito larvae when ingested (Bravo et al., 2007; Roh et al., 2007). The efficacy of both products lasts for up to 7 days, requiring weekly application. The two products specifically target mosquito larvae and are considered a safe and eco-friendly method for mosquito control (Roh et al., 2007). Studies conducted in both laboratory and semi-field systems have indicated that the two biolarvicide products are efficacious against multiple species of mosquitoes and are safe to humans and the environment (Derua et al., 2022; Gavana et al., 2025).

Larviciding operations

The larviciding operations in the Tanga Region involved the following three key aspects: 1) the identification of breeding habitats; 2) the weekly application of larvicides; and 3) an extensive monitoring system. The present study mainly looked into the second aspect, the actual larviciding operations. The operations were carried out through a community-based approach using community-owned resource persons (CORPs). Every village in the intervention councils had at least two CORPs in rural settings and at least two CORPs per ward in the urban setting. The CORPs were selected by the village leaders and were permanent residents in those areas. Using community members to identify and eliminate sources of mosquitoes can be cheaper, more effective, and more sustainable than when implemented by government agents (Diabaté et al., 2015; Elsinga et al., 2017; van den Berg et al., 2018; Gowelo et al., 2020; Phiri et al., 2021; Forsyth et al., 2022). This approach strengthens grassroots participation, reinforcing the core principle of decentralization and the simple truth that local actors are best positioned to understand and respond to their own health needs.

The project was entirely administered and supervised through the existing administrative structure of the local government authorities. At the village level, Village Executive Officers (VEOs) had direct supervisory responsibility over the CORPs. The VEOs were, in turn, overseen by Ward Executive Officers (WEOs) or Ward Health Officers (WaHOs). At the level of councils, members of the Council Health Management Teams (CHMTs), particularly the District Medical Officers (DMOs), the District Malaria Focal Persons (DMFPs), and the District Vector Control Officers (DVCOs), were responsible for the oversight of the larviciding activities. Oversight of the councils was provided by members of the Regional Health Management Teams (RHMTs). Overall coordination and supervision of the project were the responsibility of a national technical team, which comprised officials from the NMCP, the PO-RALG, the TEMT Project, and the National Institute for Medical Research (NIMR).

Data collection

IDIs were conducted with representatives of the authorities responsible for overseeing the implementation of the project at all levels, from the national level to the village level. On the other hand, FGDs were conducted with CORPs and other community members. The IDIs aimed to capture individual perceptions, while FGDs captured group opinions toward the intervention. The study questions were designed to explore mainly the participants' engagement and roles in the larviciding intervention and their perceptions of how the intervention was being implemented, including the facilitators and barriers to implementation. The study also investigated the acceptability of the intervention by the recipient communities, opinions on the achievements of the project, and thoughts on the sustainability of the intervention. Both the IDIs and FGDs were conducted at either participants' offices or homes, and interviews were conducted in Swahili, the national language in Tanzania. The FGDs were coordinated by a social scientist, assisted by a research assistant trained in administering tools for social science research. With respondent consent, the interviews were audio-recorded, each lasting approximately an hour. Data saturation determined the end of the data collection process (Saunders et al., 2018; Rahmani et al., 2022).

Data saturation was assessed iteratively during data collection and analysis. After each set of interviews and FGDs, the research team reviewed the emerging themes to determine whether new information was still arising. Data collection was concluded once no new themes or insights emerged, indicating that thematic saturation had been reached.

Data collection tools

For the FGDs and IDIs, data collection tool guides were developed specifically for this study. The guides were informed by a review of the existing literature on community-based larviciding interventions (Dambach et al., 2016; Dambach et al., 2021), malaria control programs, and implementation research frameworks, such as the Consolidated Framework for Implementation Research (CFIR) (Damschroder et al., 2022; Reardon et al., 2025). Initial drafts were reviewed by subject matter experts from the NMCP, the Swiss TPH TEMT project, and the IHI to ensure content relevance and contextual appropriateness. The tools were pre-tested in a non-study district (Rufiji District) with similar demographic characteristics. Minor revisions were made to improve the clarity, flow, and cultural sensitivity. Both the FGD and IDI guides included open-ended questions and probing prompts covering themes such as stakeholder awareness, perceptions, acceptability, facilitators and barriers to implementation, and recommendations for sustainability.

In-depth interviews

We conducted a total of 31 IDIs: 10 with village/street-level leaders (three from Lushoto DC, three from Tanga CC, and four from Handeni DC), nine with ward-level leaders (three from each of the three councils), nine with council-level leaders (three from each council), one with a regional-level officer, and two with national-level officials.

The villages and wards from which the IDI participants were obtained were randomly selected from a list of all villages and wards. For the IDIs that involved village leaders, the initial plan was to conduct three interviews per council. However, in Handeni DC, one additional IDI was conducted with a village leader from Msomera, which had been newly established to accommodate pastoralists relocated from the Arusha Region.

At the village level, the IDIs were conducted with VEOs. At the ward level, the WEOs or WaHOs were targeted. At the district level, the IDIs targeted DMOs, DMFPs, and DVCOs. At the regional level, one IDI was conducted with the only Regional Malaria Focal Person (RMFP). At the national level, two officials were targeted: one from NMCP and another from PO-RALG. At all these administrative levels, the participants for the IDIs were purposively selected due to their small numbers and specialized roles.

Focus group discussions

We initially aimed for a total of 12 FGDs: two FGDs with CORPs and two FGDs with community members in each council. In the end, 13 FGDs were conducted due to the addition of one more FGD from the Msomera village in Handeni DC, which was selected to explore the experience of the pastoralist community in the implementation of larviciding. Each FGD included 8–12 participants.

For the six FGDs with CORPs, we randomly selected two wards per council, covering all three intervention councils. On average, a ward consisted of six villages, and the FGDs were held with CORPs from villages within the same ward. Across the six FGDs with CORPs, a total of 72 CORPs participated.

For the FGDs targeting other (non-CORPs) community members, a total of seven FGDs were conducted: three in Handeni DC, two in Lushoto DC, and two in Tanga CC. The FGDs were held in randomly selected villages, except for Msomera Village, which was again purposively selected. Village leaders were involved in the selection of participants to foster a sense of ownership over project activities. Across the seven FGDs, a total of 84 community members participated.

Inclusion and exclusion criteria

For the FGDs involving CORPs, an individual was considered for recruitment if she/he: 1) was appointed by the village leadership and trained in larviciding activities; 2) had been carrying out the larviciding activities for at least one past month; and 3) was 18 years and above. The CORP was not considered for recruitment in the FGDs if: 1) she/he was just assisting to carry out the activities in the absence of a trained person, or 2) she/he had been absent from operations for one whole month of the two activity months (in each round of larvicide application).

For the FGDs involving community members to elicit their views on the acceptability of the intervention, only individuals above 18 years of age and living in their village for at least 6 months were considered. An individual was not considered for participation in the FGD if she/he: 1) holds any leadership position at any level or 2) had previously participated in the implementation of the project as a CORP.

The IDIs targeted local leaders within the three councils and representatives of the authorities, who were responsible for overseeing the implementation of the project at the council's regional and national levels. For the council level, an individual was considered for inclusion if she/he: 1) had been a leader at any level within the three intervention councils and responsible for overseeing the project implementation, and 2) had been actively involved in the project activities for the past 6 months. An individual was not to be included if she/he: 1) was assuming responsibilities in the absence of the officially assigned persons and 2) had been away or not involved in the larviciding operations for the past 6 months. At the regional level, the Regional Medical Officer (RMO) and the RMFP were targeted. At the national level, the NMCP manager, the LSM coordinator, the vector control coordinator, and one official from the PO-RALG were targeted. At the two levels, an individual was included in the study if she/he had assumed her/his position for a period covering at least two rounds of larvicide application.

Research team and reflexivity

The data collection for this study was carried out by the first author (FK) and the second author (TG). FK conducted all interviews, utilizing her training in sociology and public health and extensive experience to establish rapport with the participants. This ensured confidentiality, trust, and openness in sharing the respondents' perspectives and experiences of the intervention. TG supported participant recruitment, note-taking, obtaining informed consent, and preliminary data analysis. Both researchers received training prior to fieldwork in conducting interviews with communities, maintaining confidentiality, and managing research data.

Data management and analysis

Analysis of the data was based on a framework analysis approach. The framework analysis arranges codes and summarizes data in a matrix output, which makes it easier to arrange, identify, describe, and interpret the key patterns within and across cases and themes (Gale et al., 2013; Klingberg et al., 2024). The audio files from the IDIs and FGDs were transcribed verbatim immediately after collection. The transcriptions were read carefully to make sense of the collected data. Subsequently, the transcripts were imported into the NVivo software (version 12pro) for coding. An initial coding framework was developed inductively by two independent research assistants based on recurring concepts in the transcripts. The research team then discussed and refined these codes, resolving discrepancies through consensus. Where necessary, codes were merged, split, or redefined to accurately reflect the responses of the participants.

Once coding was complete, the data were organized into a matrix following the thematic framework analysis method, allowing the team to compare and contrast the responses within and across participant groups. Themes were derived by grouping related codes and interpreting patterns across the dataset. Emerging themes were discussed among the research team to ensure the credibility and confirmability of the findings. Representative participant quotations were selected to illustrate key themes, enhancing transparency and supporting the interpretation of the results. To ensure rigor, the analysis process involved triangulation (cross-checking across IDI and FGD findings), double coding, and regular team discussions to address potential biases. This systematic approach ensured that the findings were grounded in the data while remaining transparent and reproducible.

Results

The results are organized under seven main themes: perceptions of malaria, awareness of the larviciding intervention, perceptions of the larviciding intervention, acceptability, factors facilitating implementation, operational barriers, and perceptions of sustainability. These themes are elaborated below, and a summary linking the key findings to the study objectives is provided in Supplementary Table S1.

Perceptions of malaria

All respondents from the urban, peri-urban, and rural settings perceived malaria as a dangerous and severe disease affecting mostly children. Similarly, the majority of the respondents said that mosquitoes transmit the disease; however, very few mentioned specifically *Anopheles* mosquitoes as the vector of malaria transmission. Chikungunya and yellow fever were mentioned as other diseases transmitted by mosquitoes.

> "Malaria is a very dangerous disease, especially to young children, because their immunity against the disease is still weak." (FGD, Community member, Tanga CC)

Awareness of the larviciding intervention

The majority of the participants reported that they were aware of the implementation of larviciding in their settings. However, there were variations in the information they had, depending on the extent of their involvement in the implementation of the project and the dissemination of the information regarding the project. Village meetings were the main method of sensitization across the study area. Some respondents said they knew about the intervention after seeing the CORPs apply larvicides to mosquito-breeding sites surrounding their residential areas.

> "We were informed about the project by our street leaders at the meetings. They told us that CORPs will pass in our surroundings, spraying larvicide in the mosquito breeding habitats. We accepted and took it positively." (FGD, Community member, Lushoto DC)[SIC]

> "The village health volunteers have been visiting our premises, insisting that we should remove all water containers, which could be potential for mosquito breeding. They sprayed larvicide in standing water they find to prevent mosquito breeding". (FGD, Community member, Tanga CC) [SIC]

> "Larvicide is food sprayed in breeding habitats to kill mosquito larvae. Spraying in sewages, ponds, toilets and peddles can control mosquitoes' life cycle." (FGD, CORP, Tanga CC) [SIC]

> "This strategy aims to control mosquitoes' life cycle, preventing vectors to transmit a dangerous disease called malaria, which affects community members. Moreover, the national target is to have zero malaria by 2030." (IDI, District-level stakeholder, Handeni DC)

Perceptions of the larviciding intervention

This section aimed to explore the perceptions of stakeholders and community members of the larviciding intervention, with particular attention to their views on the safety of the larvicide and the approaches employed to foster community trust and confidence in its application. Almost all of the stakeholders said that the larviciding intervention was safe, and no adverse events were reported at village or ward offices across the study area. The only concern raised was the strong, unpleasant odor of the larvicide, which bothered some CORPs and community members. During the project rollout, people were initially worried about their safety when the CORPs started spraying, particularly when they sprayed into the water sources used for drinking and other domestic purposes. However, the situation improved as time passed due to the education provided by the CORPs and the village leaders, along with the fact that no adverse events were observed. At times, CORPs had to test the biolarvicides or drink the water from the wells that had been sprayed with biolarvicide in front of community members in order to prove to them that the biolarvicides are safe for human beings and animals.

> "I can confirm that the larvicides are safe, although, by their unpleasant smell, one may think it is poisonous. However, that is not the case; the larvicides are safe for human beings, livestock, and all other organisms living in water except mosquito larvae." (IDI, Village leader, Lushoto DC)

> "I tasted the larvicide in front of community members to show that it is safe. If it were harmful, I would not be here today." (FGD, CORP, Handeni DC)

> "it is something you can put in all water sources, even the water for human and livestock uses." (FGD, Community member, Handeni DC)

> "We used biological larvicides, meaning Bti and Bs. These are not insecticides, but bacteria that are selectively affecting only mosquito larvae, not fish or frogs. There is no harm to human beings or any other organisms in the ecosystem, including those available in the breeding sites." (IDI, National-level supervisor) [SIC]

Acceptability of the intervention

This part explored the views of stakeholders and community members on the acceptability of the larviciding interventions, focusing on their experiences with its implementation, the observed benefits, and the challenges that influenced community support and participation. The respondents mentioned that community members accepted and supported the intervention by helping CORPs to identify hidden breeding habitats or by notifying the supervisors whenever spraying activities were not conducted in their area.

> "Community members have accepted the intervention because it has reduced the perceived mosquito abundance in their settings. In 2019, there was a high abundance of mosquitoes, but since the implementation of this project started, there has been an improvement in the situation." (IDI, Village leader, Lushoto DC)

> "Community members have accepted the intervention, and education has led to cooperation, which has added value to attained achievement." (FGD, CORP, Handeni DC) [SIC]

A number of participants acknowledged the role of baseline interventions, such as ITNs, in preventing mosquito bites and contributing to reducing malaria cases.

> "We understand that the results we are seeing are not due to larviciding alone, because we have other interventions in place, such as the use of insecticide-treated nets, which remain our primary vector control tool." (IDI, National-level supervisor)

> "Let me just say that this larviciding intervention does not operate on its own; it goes hand in hand with other interventions, including the use of bed nets. Therefore, even if we say that the malaria levels have decreased, it is difficult to measure and attribute this solely to larviciding, because these interventions have been implemented together." (IDI, District-level supervisor, Lushoto DC)

Nevertheless, participants highlighted the unpleasant smell of the larvicide as a significant challenge, noting that the odor lingered on their clothing for an extended period. Initially, this unpleasant smell caused some community members to be suspicious of the biolarvicide, particularly when it was applied to sources of drinking water for humans, livestock, or fishponds. As a result, participants requested the manufacturers to explore ways to minimize the smell of the larvicide.

> "Larvicide has strong and unpleasant smell, which sticks on our clothes for long time after washing." (FGD, CORP, Tanga CC) [SIC]

Perceived facilitating factors

This part of the study explored the factors perceived by stakeholders and community members as facilitating the successful implementation of the larviciding intervention in the Tanga Region.

Training

All participants from the three councils stated that the training conducted before implementation was a foundation for the good performance of the CORPs during implementation. Moreover, they reported that the training enabled supervisors to ensure that CORPs adhered to the instructions.

> "Through training, they became aware of how the larvicide works and how you can spray it. Also, they have learned to determine breeding habitats and apply larvicides as per required dosage." (IDI, District-level supervisor, Lushoto DC)[SIC]

Supportive supervision

Supervision from the national to the council level was repeatedly cited as a key factor that enhanced the performance of both CORPs and supervisors. However, CORPs pointed out that inconsistencies in the instructions negatively impacted the proper implementation of the procedures. They recommended that supervisors should align their understanding of the guidelines on issues such as the identification of breeding habitats and spraying before disseminating the information to CORPs.

> "We are grateful for the supervision from the national and district level. There is cooperation, and they are making changes where we are doing wrong, and there is follow-up, which improves our performance." (IDI, District-level supervisor, Lushoto DC) [SIC]

Incentives

Respondents across all three councils cited the monthly financial incentive of 100,000 TZS (42 USD at a conversion rate of 2,400 TZS per USD) as a key motivator for improved performance and maintenance of consistency. However, some pointed out that the intensity of the work differed between urban and rural areas. Those in rural areas often had to walk long distances to locate breeding habitats and to cover much larger areas compared with their counterparts in town. They suggested that payment rates should reflect these differences rather than applying a flat rate.

> "Incentives are one of the biggest motivations that push them to work hard. They can buy vouchers and other things." (IDI, Supervisor, Tanga CC)

Availability of working equipment

All of the participants expressed appreciation for the availability of working equipment, including the biolarvicides. They said that, most of the time, they got the required equipment/larvicides whenever a stock-out was reported to the supervisors (i.e., the Malaria Focal Persons). However, a few participants, particularly those who joined the project later, reported not having received boots.

> "TEMT provided pumps and all requested equipment on time. The costs incurred during this project will serve as a basis for projections when planning implementation for scaling up. However, the government may not be able to provide the same level of support as seen in this project." (IDI, National-level supervisor)

Government policy

Respondents from the national level provided comprehensive insights into how policies and national strategies contributed to the success of the project. They highlighted that larviciding has been incorporated into Tanzania's Malaria Strategic Plan for 2021–2025 (Tanzania MoH, 2020), which facilitates resource generation from various stakeholders.

> "For a project to be implemented in the country, it must align with existing policies, strategies, and standards. Larviciding is specifically included in the Malaria Strategic Plan 2021-2025, which underscores its importance in the national approach to malaria control." (IDI, National-level supervisor)

Operational barriers

This section examined the factors perceived as barriers to the implementation of the larviciding project.

Low turnout of community members at the sensitization meetings

The leaders, including the VEOs, MEOs, and WEOs, reported a low turnout of community members to sensitization meetings. Sensitization meetings comprised the primary method of communication with community members in the villages and streets across the study area. This problem was more pronounced in urban settings (Tanga CC), where the majority of individuals reported being at work when sensitization meetings were conducted. A lack of community engagement and advertisements for the meetings was sometimes cited as a reason for the low turnout.

> "We did not incorporate community engagement and social behavior change components. That is why we had a low turn up to sensitization meetings. These elements are crucial for project implementation, as it is essential for people to be informed at every stage to ensure their participation and support. Moving forward, it is important to include these components, utilizing

> local radio, local artists, and public announcements, which would be vital for effective communication and engagement." (IDI, National-level supervisor) [SIC]

CORP turnover

Supervisors across the study area reported a high turnover among CORPs due to various factors, including the incentives perceived as being too low, lack of contracts or formal agreements, getting other jobs, and relocating to other areas due to family reasons, among others. They mentioned that, because of the high turnover, supervisors were required to regularly identify and train new CORPs in order to fill vacant positions, negatively affecting operations.

> "CORPs dropouts were a challenge that requires attention. I think in the future there is a need to have agreement forms signed by District Executive Directors to enforce their commitment to the work." (IDI, National-level supervisor) [SIC]

Insufficient number of CORPs

Repeatedly, the stakeholders in rural areas, and, less frequently, in urban settings, reported having too few CORPs compared with the high number of breeding sites, which forced CORPs to spend many hours on project activities, limiting the time spent on other income-generating activities. There are great disparities in the sizes of the villages and streets, while the number of CORPs remained constant per village/street due to budget constraints.

> "The current project implementation design calls for two CORPs per village; however, it has become evident that the number of CORPs should be adjusted based on the size and geographical characteristics of the area. Moving forward, the allocation of CORPs will be determined by these factors to ensure effective coverage." (IDI, National-level supervisor)

Breeding site sizes and distances

Similarly, the implementers in peri-urban and rural areas reported that the breeding habitats were far apart, resulting in long walking distances. Some of the habitats were also located in hard-to-reach areas, leading to inadequate spraying or no spraying at all.

> "Some breeding habitats are located far away, which leads to delays in spraying. Bicycles could serve as a better option to reduce the time spent walking to these sites, enabling more timely interventions." (FGD, CORP, Handeni DC).

Lack of means of transport

The lack of transportation options for CORPs was mentioned as one of the factors that negatively impacted their performance and the effectiveness of their work. CORPs from Tanga CC and Handeni DC expressed a need for bicycles to facilitate their activities. However, those in Lushoto DC indicated that bicycles would not be suitable in their case due to the hilly terrain. Instead, they proposed receiving financial support for transportation costs, as needed for project activities.

> "Some breeding habitats are located far away, which leads to delays in spraying. Bicycles could serve as a better option to reduce the time spent walking to these sites, enabling more timely interventions." (FGD, CORP, Handeni DC)

> "CORPs should have means of transport because of the long distances; some places are far away from the village. If they have motorcycles, it will be easy to reach places like Sendekuli, Nyangwelele, and Oromoti villages." (FGD, Community member, Handeni DC) [SIC]

> "providing bicycles will facilitate movement from point A to point B, enhancing the ability of CORPs to carry out their responsibilities efficiently across larger distances." (IDI, National-level supervisor) [SIC]

The rebound of mosquitoes during the months of no spraying

Although the implementers and supervisors across the study area expressed satisfaction with the reduction in mosquito abundance, they noted a rebound of the mosquito populations during the months when spraying was not conducted. Community members also reported observing an increase in mosquito presence during periods without spraying compared with periods when CORPs were spraying in their neighborhood.

> "By design, there were alternating rounds of two months with and without spraying. The data showed there was a rebound in population of mosquitoes during the months with no spraying across the study area. The advice is that spraying should be conducted throughout the year." (IDI, National-level supervisor)[SIC]

Lack of an environmental management component

The respondents mentioned that budget constraints limited the larviciding intervention, excluding the broader environmental management activities that were planned initially, such as filling ponds and permanently eliminating breeding sites. The respondents recommended that incorporating environmental management into larviciding activities would reduce the number of breeding habitats that required larvicide application, thereby improving operational effectiveness.

> "Not implementing environmental sanitation and management components may have hindered achieving a greater impact in the Tanga Region. While we believe that 80% success rate has been attained, the absence of these components may have contributed to the shortfall of 20%." (IDI, National-level supervisor) [SIC]

Sustainability of the intervention

This section explored the views of the participants on the sustainability of the larviciding intervention, focusing on the availability of resources, the ongoing community engagement, the institutional support, and the prospects for the long-term continuation of the intervention beyond the project period.

national-level supervisors recommended that councils incorporate larviciding resources into their Comprehensive Council Health Plans (CCHPs), the routine budgeting tool used by all councils in the country. Some supervisors also suggested making larvicides available commercially in smaller packages in shops in order to encourage individual purchases by community members. Moreover, the council's generated revenues, along with a strengthened multi-sectoral collaboration, were mentioned as strategies for sustaining the larviciding intervention.

> "If there will be larvicide packages in small volumes, we can sensitize and encourage community members to buy them and apply in their surroundings. If they apply the larvicides themselves, it will reduce the costs of paying CORPs because people will have their small bottles of half or one liter." (IDI, District-level supervisor, Lushoto DC) [SIC]

Discussion

The study findings showed that community-based larviciding was perceived as safe, acceptable, effective, feasible, and sustainable. However, several key challenges were identified, including the unpleasant smell of the larvicide, CORP turnover, logistical problems, and discontinuous implementation. There is ample evidence from many settings and for many health interventions that eliciting the views of the population on issues such as acceptability and ways to improve the implementation process contributes significantly to improving programs (Ingabire et al., 2014; Ingabire et al., 2017; Antonio-Nkondjio et al., 2018; Dambach et al., 2018; Gowelo et al., 2020; Dambach et al., 2021; Kihwele et al., 2025).

Regarding the stakeholders' perceptions of malaria, the findings revealed that respondents viewed malaria as a severe and dangerous disease, primarily affecting children. The majority of the respondents also demonstrated an awareness of the specific mosquito vector (genus) responsible for transmitting the disease. However, this awareness may have stemmed from the training provided at the beginning of the project. These results align with findings from other studies, which also reported high levels of awareness of malaria as an important problem among community members (Ingabire et al., 2014; Ingabire et al., 2017; Dambach et al., 2018; Matindo et al., 2021). The community perceptions of a disease as an important problem is one of the key drivers of its readiness to actively engage in preventive interventions (Allen et al., 2009; Nickel and von dem Knesebeck, 2020a; Nickel and von dem Knesebeck, 2020b).

Importantly, the findings indicate that the community members were aware of the larviciding intervention implemented in their area, expressing a positive opinion and acceptance of the intervention as being safe for humans and other living organisms. They also perceived it as being effective in reducing the mosquito populations. This study adds to the existing evidence derived from other studies in Africa that larviciding interventions are generally well-accepted as safe and effective in controlling mosquito-borne diseases (Mboera et al., 2014; Dambach et al., 2018; Gowelo et al., 2020; Stewart et al., 2020; Dambach et al., 2021; Ngadjeu et al., 2022). Together, these findings indicate that the implementation of larviciding in Africa is unlikely to face community acceptance challenges. However, significant concerns regarding the unpleasant smell of the larvicide were frequently voiced, which, if not addressed, could prevent complete community involvement.

With regard to the perceptions regarding the impact of the intervention, stakeholders at various levels reported a noticeable decrease in mosquito abundance and nuisance, along with a reduction in the malaria cases in their area, aligning with findings from other studies in Burkina Faso (Dambach et al., 2018), and Cameroon (Ngadjeu et al., 2022). However, the stakeholders in the current study also recognized that the reduction in mosquito abundance and malaria cases was partly influenced by other ongoing malaria control interventions in the same settings, such as ITNs and case management. Achieving the last mile in malaria elimination requires multiple effective interventions (Shiff, 2002; Beier et al., 2008; Benelli and Beier, 2017; Tia et al., 2024), recognition by stakeholders of the importance of combining interventions will be critical for the sustainability of disease control efforts.

Regarding the factors that appeared as facilitators or barriers to the implementation, the study showed that training, supportive supervision, financial incentives, availability of working equipment, and government policy were the key facilitating factors. Similar perceived facilitating factors were also reported in Burkina Faso (Dambach et al., 2016). These factors should be considered when scaling up larviciding projects in Tanzania and other parts of SSA.

The sustainability of health interventions plays a crucial role in achieving long-term improvements in public health. Previous studies have highlighted the prerequisites for sustainable health interventions in Africa (Iwelunmor et al., 2016; Moucheraud et al., 2017). The facilitators identified in this study, along with the sustainability plans outlined by stakeholders, contribute to a broader understanding of what is necessary for the successful and sustainable expansion of larviciding interventions.

Nevertheless, challenges such as an insufficient number of CORPs, the large size of some villages with a high number of breeding habitats, CORP turnover, lack of transportation, and the rebound of mosquitoes in months without larviciding were reported to have negatively impacted the intervention, despite the overall significant success reported across the study area. Therefore, the recommendation for continuous larviciding rather than a discontinuous implementation should be taken seriously. Addressing the challenges highlighted in this study, in addition to those reported by other studies in the region, will be invaluable for the successful implementation of larviciding in Africa (Mapua et al., 2021; Matindo et al., 2021; Ngadjeu et al., 2022).

Participants emphasized that sustaining the larviciding intervention would require adequate resources, community engagement, and institutional support beyond the project period. National-level supervisors suggested integrating larviciding into the CCHP program and making larvicides available in smaller commercial packages. For the latter, there is currently no documented experience with this approach in Africa, despite studies exploring community willingness to purchase larvicides (Mboera et al., 2014; Dambach et al., 2021; Matindo et al., 2021). The practicality and potential challenges of commercialization require careful consideration. Simply offering commercialized larvicide packages may not ensure proper use, as community members would need guidance on the correct dosages, timing, and safe handling. In addition, the economic feasibility of purchasing larvicides, the willingness of the community to buy, and consistent supply mechanisms need to be assessed.

The strength of this study lies in its robust qualitative methodology, which combined in-depth interviews of a large number of implementers at all levels of the government system with community-based FGDs to comprehensively explore community perceptions and the acceptability of the intervention. The purposive selection of districts, ensuring geographical representativeness across urban, peri-urban, and rural settings, allowed the understanding of contextual differences. The use of thematic analysis, conducted with the NVivo software and supported by double coding and considering data saturation, further reinforced the internal validity of the findings.

However, the interpretation of these study results also needs to consider some limitations. The selection of the participants for the FGDs through community leaders may have introduced convenience sampling and social exclusion biases, potentially limiting the diversity of the obtained perspectives. We acknowledge that our study may be subject to selection bias, particularly due to the lack of data from marginalized populations such as the elderly, ethnic minorities, and postpartum women. This gap may limit the generalizability of our findings and underscores the need for truly inclusive sampling strategies.

In addition, given the inherent nature of FGDs, the responses may have been influenced by group dynamics, including peer pressure or social desirability bias (Kitzinger, 1995; Powell and Single, 1996; Korstjens and Moser, 2017). These factors could have affected the expression of individual perspectives, potentially limiting the depth and breadth of the data collected. Consequently, the findings should be interpreted within the context of these methodological considerations, highlighting the importance of complementing FGDs with other data collection approaches to capture a broader range of views.

While the participants reported a perceived reduction in larval densities and adult mosquito populations following larviciding, such perceptions alone are insufficient to establish impact. Fortunately, these perceptions are supported by our entomological evaluation, which showed a significant reduction in adult mosquito populations in Tanga and Lushoto, but not in Handeni Council (Gavana et al., in press). Measuring an impact on malaria incidence is inherently more difficult, and in this study, the epidemiological investigation did not demonstrate a substantial health impact (Kailembo et al., 2025). It is important to note that the scope of this manuscript was not to evaluate the intervention's impact but rather to understand the perceptions of the implementers and the communities regarding malaria and the larviciding intervention, with the goal of informing potential scale-up plans.

Furthermore, this study was conducted in three councils within the Tanga Region, covering rural, peri-urban, and urban settings. While this provides valuable insights into stakeholder and community perceptions of the larviciding intervention, the findings may not fully capture the diversity of contexts across Tanzania. Consequently, the results should be interpreted with caution, and generalization to the entire country may not be appropriate. Future studies including multiple regions with varied ecological, socioeconomic, and cultural contexts are recommended to provide a more comprehensive understanding of the acceptability and sustainability of larviciding in Tanzania.

Conclusions

The larviciding intervention in the Tanga Region was perceived as safe and effective and was generally well accepted by the community. The key factors facilitating its success included training, incentives, equipment availability, and supportive supervision. On the other hand, challenges such as CORP turnover, transport limitations, discontinuous larviciding, and too large areas for CORPs to cover affected its reach and effectiveness. Successful and effective implementation of larviciding in SSA will have to take into account these challenges, in addition to those reported by other studies in the region.

Data availability statement

Data can be made available upon receipt of official, reasonable requests to the corresponding author and with approval from the TEMT project director and the Government of Tanzania. Requests to access the datasets should be directed to Samwel Lazaro: snhiga000@gmail.com and Noela Kisoka: noela.kisoka@netcell.org.

Ethics statement

The studies involving humans were approved by the Ifakara Health Institute and the National Institute for Medical Research in Tanzania. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

FK: Formal Analysis, Investigation, Writing – original draft. TG: Conceptualization, Formal Analysis, Investigation, Methodology, Supervision, Writing – review & editing. DK: Validation, Writing – review & editing. EK: Visualization, Writing – review & editing. CM: Writing – review & editing. JB: Writing – review & editing. BY: Writing – review & editing. LN: Writing – review & editing. SK: Writing – review & editing. SL: Writing – review & editing. NK: Funding acquisition, Writing – review & editing. PC: Conceptualization, Funding acquisition, Methodology, Project administration, Writing – review & editing. CL: Conceptualization, Funding acquisition, Supervision, Validation, Writing – review & editing. AD: Methodology, Supervision, Validation, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. This work was made possible by an unrestricted grant from the Swiss government through the Swiss Embassy in Dar es Salaam to the Swiss Tropical and Public Health Institute (Swiss TPH) in Basel, Switzerland (TEMT project). The donor had no influence on the design, implementation, analysis, and publication of this work.

Acknowledgments

The authors are indebted to the Regional and District Medical Officers in the three districts of Tanga Region (Tanga City, Lushoto, and Handeni) for approving this study and supporting the data collection process. Also, the authors appreciate the cooperation offered by wards and village leaders in selecting study participants and organizing focus group discussions conducted at village offices. Moreover, the authors are grateful to all the study participants for their time and contributions.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmala.2025.1693543/full#supplementary-material

References

Abdulai, A., Owusu-Asenso, C. M., Akosah-Brempong, G., Mohammed, A. R., Sraku, I. K., Attah, S. K., et al. (2023). Insecticide resistance status of Aedes aEgypti in southern and northern Ghana. *Parasites vectors.* 16, 135. doi: 10.1186/s13071-023-05752-x

Afrane, Y. A., Mweresa, N. G., Wanjala, C. L., Gilbreath Iii, T. M., Zhou, G., Lee, M. C., et al. (2016). Evaluation of long-lasting microbial larvicide for malaria vector control in Kenya. *Malaria J.* 15, 577. doi: 10.1186/s12936-016-1626-6

Allen, D., Gillen, E., and Rixson, L. (2009). The effectiveness of integrated care pathways for adults and children in health care settings: A systematic review. *JBI Libr Syst. Rev.* 7, 80–129. doi: 10.11124/01938924-200907030-00001

Amazigo, U. V., Leak, S. G. A., Zoure, H. G. M., Okoronkwo, C., Diop Ly, M., Isiyaku, S., et al. (2021). Community-directed distributors-The "foot soldiers" in the fight to control and eliminate neglected tropical diseases. *PloS Negl. Trop. Dis.* 15, e0009088. doi: 10.1371/journal.pntd.0009088

Antonio-Nkondjio, C., Sandjo, N. N., Awono-Ambene, P., and Wondji, C. S. (2018). Implementing a larviciding efficacy or effectiveness control intervention against malaria vectors: key parameters for success. *Parasites vectors.* 11, 57. doi: 10.1186/s13071-018-2627-9

Becker, N., Langentepe-Kong, S. M., Tokatlian Rodriguez, A., Oo, T. T., Reichle, D., Lühken, R., et al. (2022). Integrated control of Aedes albopictus in Southwest Germany supported by the Sterile Insect Technique. *Parasites vectors.* 15, 9. doi: 10.1186/s13071-021-05112-7

Beier, J. C., Keating, J., Githure, J. I., Macdonald, M. B., Impoinvil, D. E., and Novak, R. J. (2008). Integrated vector management for malaria control. *Malaria J.* 7 Suppl 1, S4. doi: 10.1186/1475-2875-7-s1-s4

Ben-Dov, E. (2014). Bacillus thuringiensis subsp. Israelensis and its dipteran-specific toxins. *Toxins (Basel).* 6, 1222–1243. doi: 10.3390/toxins6041222

Benelli, G., and Beier, J. C. (2017). Current vector control challenges in the fight against malaria. *Acta Trop.* 174, 91–96. doi: 10.1016/j.actatropica.2017.06.028

Bravo, A., Gill, S. S., and Soberón, M. (2007). Mode of action of Bacillus thuringiensis Cry and Cyt toxins and their potential for insect control. *Toxicon* 49, 423–435. doi: 10.1016/j.toxicon.2006.11.022

Byrne, I., Chan, K., Manrique, E., Lines, J., Wolie, R. Z., Trujillano, F., et al. (2021). Technical Workflow Development for Integrating Drone Surveys and Entomological Sampling to Characterise Aquatic Larval Habitats of Anopheles funestus in Agricultural Landscapes in Côte d'Ivoire. *J. Environ. Public Health* 2021, 3220244. doi: 10.1155/2021/3220244

Caldas de Castro, M., Yamagata, Y., Mtasiwa, D., Tanner, M., Utzinger, J., Keiser, J., et al. (2004). Integrated urban malaria control: a case study in dar es salaam, Tanzania. *Am. J. Trop. Med. Hyg.* 71, 103–117. doi: 10.4269/ajtmh.2004.71.103

Carrasco-Escobar, G., Manrique, E., Ruiz-Cabrejos, J., Saavedra, M., Alava, F., Bickersmith, S., et al. (2019). High-accuracy detection of malaria vector larval habitats using drone-based multispectral imagery. *PloS Negl. Trop. Dis.* 13, e0007105. doi: 10.1371/journal.pntd.0007105

Carrasco-Escobar, G., Moreno, M., Fornace, K., Herrera-Varela, M., Manrique, E., and Conn, J. E. (2022). The use of drones for mosquito surveillance and control. *Parasites vectors.* 15, 473. doi: 10.1186/s13071-022-05580-5

Chaki, P. P., Dongus, S., Fillinger, U., Kelly, A., and Killeen, G. F. (2011). Community-owned resource persons for malaria vector control: enabling factors and challenges in an operational programme in Dar es Salaam, United Republic of Tanzania. *Hum. Resour Health* 9, 21. doi: 10.1186/1478-4491-9-21

Chaki, P. P., Govella, N. J., Shoo, B., Hemed, A., Tanner, M., Fillinger, U., et al. (2009). Achieving high coverage of larval-stage mosquito surveillance: challenges for a community-based mosquito control programme in urban Dar es Salaam, Tanzania. *Malaria J.* 8, 311. doi: 10.1186/1475-2875-8-311

Chanda, E., Ameneshewa, B., Mihreteab, S., Berhane, A., Zehaie, A., Ghebrat, Y., et al. (2015). Consolidating strategic planning and operational frameworks for integrated vector management in Eritrea. *Malaria J.* 14, 488. doi: 10.1186/s12936-015-1022-7

Charles, J. F., and Nielsen-LeRoux, C. (2000). Mosquitocidal bacterial toxins: diversity, mode of action and resistance phenomena. *Mem Inst Oswaldo Cruz.* 95 Suppl 1, 201–206. doi: 10.1590/s0074-02762000000700034

Choi, L., Majambere, S., and Wilson, A. L. (2019). Larviciding to prevent malaria transmission. *Cochrane Database Syst. Rev.* 8, Cd012736. doi: 10.1002/14651858.CD012736.pub2

Dambach, P., Baernighausen, T., Traoré, I., Ouedraogo, S., Sié, A., Sauerborn, R., et al. (2019). Reduction of malaria vector mosquitoes in a large-scale intervention trial in rural Burkina Faso using Bti based larval source management. *Malaria J.* 18, 311. doi: 10.1186/s12936-019-2951-3

Dambach, P., Jorge, M. M., Traoré, I., Phalkey, R., Sawadogo, H., Zabré, P., et al. (2018). A qualitative study of community perception and acceptance of biological larviciding for malaria mosquito control in rural Burkina Faso. *BMC Public Health* 18, 399. doi: 10.1186/s12889-018-5299-7

Dambach, P., Traoré, I., Kaiser, A., Sié, A., Sauerborn, R., and Becker, N. (2016). Challenges of implementing a large scale larviciding campaign against malaria in rural Burkina Faso - lessons learned and recommendations derived from the EMIRA project. *BMC Public Health* 16, 1023. doi: 10.1186/s12889-016-3587-7

Dambach, P., Traoré, I., Sawadogo, H., Zabré, P., Shukla, S., Sauerborn, R., et al. (2021). Community acceptance of environmental larviciding against malaria with Bacillus thuringiensis Israelensis in rural Burkina Faso - A knowledge, attitudes and practices study. *Glob Health Action.* 14, 1988279. doi: 10.1080/16549716.2021.1988279

Dambach, P., Winkler, V., Bärnighausen, T., Traoré, I., Ouedraogo, S., Sié, A., et al. (2020). Biological larviciding against malaria vector mosquitoes with Bacillus thuringiensis Israelensis (Bti) - Long term observations and assessment of repeatability during an additional intervention year of a large-scale field trial in rural Burkina Faso. *Glob Health Action.* 13, 1829828. doi: 10.1080/16549716.2020.1829828

Damschroder, L. J., Reardon, C. M., Widerquist, M. A. O., and Lowery, J. (2022). The updated Consolidated Framework for Implementation Research based on user feedback. *Implementation science: IS.* 17, 75. doi: 10.1186/s13012-022-01245-0

Derua, Y. A., Tungu, P. K., Malima, R. C., Mwingira, V., Kimambo, A. G., Batengana, B. M., et al. (2022). Laboratory and semi-field evaluation of the efficacy of Bacillus thuringiensis var. Israelensis (Bactivec®) and Bacillus sphaericus (Griselesf®) for control of mosquito vectors in northeastern Tanzania. *Curr. Res. Parasitol. Vector Borne Dis.* 2, 100089. doi: 10.1016/j.crpvbd.2022.100089

Diabaté, S., Druetz, T., Millogo, T., Ly, A., Fregonese, F., Kouanda, S., et al. (2015). Domestic larval control practices and malaria prevalence among under-five children in Burkina Faso. *PloS One* 10, e0141784. doi: 10.1371/journal.pone.0141784

Diarra, S., Kailembo, D., Derua, Y., Gavana, T., Yoram, B., Kajange, S., et al. (2025). A costing analysis of an intermittent biolarviciding intervention with limited epidemiological effect in Tanga Region, Tanzania. *Malaria J.* 24, 352. doi: 10.1186/s12936-025-05553-w

Elsinga, J., van der Veen, H. T., Gerstenbluth, I., Burgerhof, J. G. M., Dijkstra, A., Grobusch, M. P., et al. (2017). Community participation in mosquito breeding site control: an interdisciplinary mixed methods study in Curaçao. *Parasites vectors.* 10, 434. doi: 10.1186/s13071-017-2371-6

Fillinger, U., Kannady, K., William, G., Vanek, M. J., Dongus, S., Nyika, D., et al. (2008). A tool box for operational mosquito larval control: preliminary results and early lessons from the Urban Malaria Control Programme in Dar es Salaam, Tanzania. *Malaria J.* 7, 20. doi: 10.1186/1475-2875-7-20

Fillinger, U., and Lindsay, S. W. (2006). Suppression of exposure to malaria vectors by an order of magnitude using microbial larvicides in rural Kenya. *Trop. Med. Int. Health* 11, 1629–1642. doi: 10.1111/j.1365-3156.2006.01733.x

Fillinger, U., and Lindsay, S. W. (2011). Larval source management for malaria control in Africa: myths and reality. *Malaria J.* 10, 353. doi: 10.1186/1475-2875-10-353

Fillinger, U., Ndenga, B., Githeko, A., and Lindsay, S. W. (2009). Integrated malaria vector control with microbial larvicides and insecticide-treated nets in western Kenya: a controlled trial. *Bull. World Health Organ.* 87, 655–665. doi: 10.2471/blt.08.055632

Forsyth, J. E., Kempinsky, A., Pitchik, H. O., Alberts, C. J., Mutuku, F. M., Kibe, L., et al. (2022). Larval source reduction with a purpose: Designing and evaluating a household- and school-based intervention in coastal Kenya. *PloS Negl. Trop. Dis.* 16, e0010199. doi: 10.1371/journal.pntd.0010199

Gale, N. K., Heath, G., Cameron, E., Rashid, S., and Redwood, S. (2013). Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC Med. Res. Methodol.* 13, 117. doi: 10.1186/1471-2288-13-117

Gavana, T., Kailembo, D., Machange, J., Michael, V., Swai, K., Odufuwa, O. G., et al. (2025). Laboratory efficacy of Bactivec® and Griselesf® biolarvicides used for large-scale larviciding in Tanzania. *Front. Malaria* 3. doi: 10.3389/fmala.2025.1614476

Geissbühler, Y., Kannady, K., Chaki, P. P., Emidi, B., Govella, N. J., Mayagaya, V., et al. (2009). Microbial larvicide application by a large-scale, community-based program reduces malaria infection prevalence in urban Dar es Salaam, Tanzania. *PloS One* 4, e5107. doi: 10.1371/journal.pone.0005107

Gowelo, S., McCann, R. S., Koenraadt, C. J. M., Takken, W., van den Berg, H., and Manda-Taylor, L. (2020). Community factors affecting participation in larval source management for malaria control in Chikwawa District, Southern Malawi. *Malaria J.* 19, 195. doi: 10.1186/s12936-020-03268-8

Hakizimana, E., Ingabire, C. M., Rulisa, A., Kateera, F., van den Borne, B., Muvunyi, C. M., et al. (2022). Community-Based Control of Malaria Vectors Using Bacillus thuringiensis var. Israelensis (Bti) in Rwanda. *Int. J. Environ. Res. Public Health* 19. doi: 10.3390/ijerph19116699

Hemming-Schroeder, E., and Ahmed, A. (2023). Anopheles stephensi in Africa: vector control opportunities for cobreeding An. stephensi and Aedes arbovirus vectors. *Trends Parasitol.* 39, 86–90. doi: 10.1016/j.pt.2022.11.011

Ingabire, C. M., Alaii, J., Hakizimana, E., Kateera, F., Muhimuzi, D., Nieuwold, I., et al. (2014). Community mobilization for malaria elimination: application of an open space methodology in Ruhuha sector, Rwanda. *Malaria J.* 13, 167. doi: 10.1186/1475-2875-13-167

Ingabire, C. M., Hakizimana, E., Rulisa, A., Kateera, F., Van Den Borne, B., Muvunyi, C. M., et al. (2017). Community-based biological control of malaria mosquitoes using Bacillus thuringiensis var. *Israelensis (Bti) Rwanda: Community awareness acceptance participation. Malaria J.* 16, 399. doi: 10.1186/s12936-017-2046-y

Iwelunmor, J., Blackstone, S., Veira, D., Nwaozuru, U., Airhihenbuwa, C., Munodawafa, D., et al. (2016). Toward the sustainability of health interventions implemented in sub-Saharan Africa: a systematic review and conceptual framework. *Implementation science: IS.* 11, 43. doi: 10.1186/s13012-016-0392-8

Kailembo, D., Gavana, T., Kasagama, E., Bernard, J., Molteni, F., Kisoka, N., et al. (2025). Large-scale intermittent larviciding intervention and associations with key malaria epidemiological parameters in Tanga Region, Tanzania. *Malaria J.* 24, 350. doi: 10.1186/s12936-025-05548-7

Kihwele, F., Odufuwa, O. G., Muganga, J. B., Mbuba, E., Philipo, R., Moore, J., et al. (2025). Community perceptions and acceptability of insecticide-treated screens for mosquito proofing of unimproved houses in Chalinze district, Tanzania: a mixed-methods study. *Fronteers in Malaria.* 3. doi: 10.3389/fmala.2025.1540184

Killeen, G. F., Fillinger, U., Kiche, I., Gouagna, L. C., and Knols, B. G. (2002a). Eradication of Anopheles Gambiae from Brazil: lessons for malaria control in Africa? *Lancet Infect. Dis.* 2, 618–627. doi: 10.1016/s1473-3099(02)00397-3

Killeen, G. F., Fillinger, U., and Knols, B. G. (2002b). Advantages of larval control for African malaria vectors: low mobility and behavioural responsiveness of immature mosquito stages allow high effective coverage. *Malaria J.* 1, 8. doi: 10.1186/1475-2875-1-8

Kisinza, W. N., Nkya, T. E., Kabula, B., Overgaard, H. J., Massue, D. J., Mageni, Z., et al. (2017). Multiple insecticide resistance in Anopheles Gambiae from Tanzania: a major concern for malaria vector control. *Malaria J.* 16, 439. doi: 10.1186/s12936-017-2087-2

Kitzinger, J. (1995). Qualitative research. Introducing focus groups. *BMJ (Clinical Res. ed).* 311, 299–302. doi: 10.1136/bmj.311.7000.299

Klingberg, S., Stalmeijer, R. E., and Varpio, L. (2024). Using framework analysis methods for qualitative research: AMEE Guide No. *164. Med. Teach.* 46, 603–610. doi: 10.1080/0142159x.2023.2259073

Koenker, H., Keating, J., Alilio, M., Acosta, A., Lynch, M., and Nafo-Traore, F. (2014). Strategic roles for behaviour change communication in a changing malaria landscape. *Malaria J.* 13, 1. doi: 10.1186/1475-2875-13-1

Koenker, H., and Yukich, J. O. (2017). Effect of user preferences on ITN use: a review of literature and data. *Malaria J.* 16, 233. doi: 10.1186/s12936-017-1879-8

Korstjens, I., and Moser, A. (2017). Series: Practical guidance to qualitative research. Part 2: Context, research questions and designs. *Eur. J. Gen. Pract.* 23, 274–279. doi: 10.1080/13814788.2017.1375090

Krezanoski, P., and Haberer, J. (2019). Objective monitoring of mosquito bednet usage and the ethical challenge of respecting study bystanders' privacy. *Clin. Trials.* 16, 466–468. doi: 10.1177/1740774519865525

Lacey, L. A. (2007). Bacillus thuringiensis serovariety Israelensis and Bacillus sphaericus for mosquito control. *J. Am. Mosq. Control Assoc.* 23, 133–163. doi: 10.2987/8756-971x(2007)23[133:btsiab]2.0.co;2

Lai, L., Villanueva, M., Muruzabal-Galarza, A., Fernández, A. B., Unzue, A., Toledo-Arana, A., et al. (2023). Bacillus thuringiensis Cyt Proteins as Enablers of Activity of Cry and Tpp Toxins against Aedes albopictus. *Toxins (Basel)* 15. doi: 10.3390/toxins15030211

Lindsay, S. W., Thomas, M. B., and Kleinschmidt, I. (2021). Threats to the effectiveness of insecticide-treated bednets for malaria control: thinking beyond insecticide resistance. *Lancet Glob Health* 9, e1325–e1e31. doi: 10.1016/s2214-109x(21)00216-3

Love, R. R., Sikder, J. R., Vivero, R. J., Matute, D. R., and Schrider, D. R. (2023). Strong positive selection in aedes aEgypti and the rapid evolution of insecticide resistance. *Mol. Biol. Evol.* 40. doi: 10.1093/molbev/msad072

Maheu-Giroux, M., and Castro, M. C. (2013). Impact of community-based larviciding on the prevalence of malaria infection in Dar es Salaam, Tanzania. *PloS One* 8, e71638. doi: 10.1371/journal.pone.0071638

Majambere, S., Lindsay, S. W., Green, C., Kandeh, B., and Fillinger, U. (2007). Microbial larvicides for malaria control in The Gambia. *Malaria J.* 6, 76. doi: 10.1186/1475-2875-6-76

Majambere, S., Pinder, M., Fillinger, U., Ameh, D., Conway, D. J., Green, C., et al. (2010). Is mosquito larval source management appropriate for reducing malaria in areas of extensive flooding in The Gambia? A cross-over intervention trial. *Am. J. Trop. Med. Hyg.* 82, 176–184. doi: 10.4269/ajtmh.2010.09-0373

Mapua, S. A., Finda, M. F., Nambunga, I. H., Msugupakulya, B. J., Ukio, K., Chaki, P. P., et al. (2021). Correction to: Addressing key gaps in implementation of mosquito larviciding to accelerate malaria vector control in southern Tanzania: results of a stakeholder engagement process in local district councils. *Malaria J.* 20, 258. doi: 10.1186/s12936-021-03778-z

Mapua, S. A., Limwagu, A. J., Kishkinev, D., Kifungo, K., Nambunga, I. H., Mziray, S., et al. (2024). Empowering rural communities for effective larval source management: A small-scale field evaluation of a community-led larviciding approach to control malaria in south-eastern Tanzania. *Parasite Epidemiol. Control.* 27, e00382. doi: 10.1016/j.parepi.2024.e00382

Matindo, A. Y., Kapalata, S. N., Katalambula, L. K., Meshi, E. B., and Munisi, D. Z. (2021). Biolarviciding for malaria vector control: Acceptance and associated factors in southern Tanzania. *Curr. Res. Parasitol. Vector Borne Dis.* 1, 100038. doi: 10.1016/j.crpvbd.2021.100038

Matiya, D. J., Philbert, A. B., Kidima, W., and Matowo, J. J. (2019). Dynamics and monitoring of insecticide resistance in malaria vectors across mainland Tanzania from 1997 to 2017: a systematic review. *Malaria J.* 18, 102. doi: 10.1186/s12936-019-2738-6

Matowo, N. S., Martin, J., Kulkarni, M. A., Mosha, J. F., Lukole, E., Isaya, G., et al. (2021). An increasing role of pyrethroid-resistant Anopheles funestus in malaria transmission in the Lake Zone, Tanzania. *Sci. Rep.* 11, 13457. doi: 10.1038/s41598-021-92741-8

Mboera, L. E., Kramer, R. A., Miranda, M. L., Kilima, S. P., Shayo, E. H., and Lesser, A. (2014). Community knowledge and acceptance of larviciding for malaria control in a rural district of east-central Tanzania. *Int. J. Environ. Res. Public Health* 11, 5137–5154. doi: 10.3390/ijerph110505137

Moucheraud, C., Schwitters, A., Boudreaux, C., Giles, D., Kilmarx, P. H., Ntolo, N., et al. (2017). Sustainability of health information systems: a three-country qualitative study in southern Africa. *BMC Health Serv. Res.* 17, 23. doi: 10.1186/s12913-016-1971-8

Musoke, D., Karani, G., Ssempebwa, J. C., and Musoke, M. B. (2013). Integrated approach to malaria prevention at household level in rural communities in Uganda: experiences from a pilot project. *Malaria J.* 12, 327. doi: 10.1186/1475-2875-12-327

Namias, A., Jobe, N. B., Paaijmans, K. P., and Huijben, S. (2021). The need for practical insecticide-resistance guidelines to effectively inform mosquito-borne disease control programs. *Elife* 10. doi: 10.7554/eLife.65655

Newby, G., Chaki, P., Latham, M., Marrenjo, D., Ochomo, E., Nimmo, D., et al. (2025). Larviciding for malaria control and elimination in Africa. *Malaria J.* 24, 16. doi: 10.1186/s12936-024-05236-y

Newman, R. D., Mnzava, A., and Szilagyi, Z. (2013). Mosquito larval source management: evaluating evidence in the context of practice and policy. *Cochrane Database Syst. Rev.* 2013, Ed000066. doi: 10.1002/14651858.Ed000066

Ngadjeu, C. S., Talipouo, A., Kekeunou, S., Doumbe-Belisse, P., Ngangue-Siewe, I. N., Djamouko-Djonkam, L., et al. (2022). Knowledge, practices and perceptions of communities during a malaria larviciding randomized trial in the city of Yaoundé, Cameroon. *PloS One* 17, e0276500. doi: 10.1371/journal.pone.0276500

Nickel, S., and von dem Knesebeck, O. (2020a). Effectiveness of community-based health promotion interventions in urban areas: A systematic review. *J. Community Health* 45, 419–434. doi: 10.1007/s10900-019-00733-7

Nickel, S., and von dem Knesebeck, O. (2020b). Do multiple community-based interventions on health promotion tackle health inequalities? *Int. J. Equity Health* 19, 157. doi: 10.1186/s12939-020-01271-8

Obopile, M., Segoea, G., Waniwa, K., Ntebela, D. S., Moakofhi, K., Motlaleng, M., et al. (2018). Did microbial larviciding contribute to a reduction in malaria cases in eastern Botswana in 2012-2013? *Public Health Action* 8. doi: 10.5588/pha.17.0012

Odero, J. O., Nambunga, I. H., Masalu, J. P., Mkandawile, G., Bwanary, H., Hape, E. E., et al. (2024). Genetic markers associated with the widespread insecticide resistance in malaria vector Anopheles funestus populations across Tanzania. *Parasites vectors.* 17, 230. doi: 10.1186/s13071-024-06315-4

Okumu, F., Moore, S. J., Selvaraj, P., Yafin, A. H., Juma, E. O., Shirima, G. G., et al. (2025). Elevating larval source management as a key strategy for controlling malaria and other vector-borne diseases in Africa. *Parasites vectors.* 18, 45. doi: 10.1186/s13071-024-06621-x

Phiri, M. D., McCann, R. S., Kabaghe, A. N., van den Berg, H., Malenga, T., Gowelo, S., et al. (2021). Cost of community-led larval source management and house improvement for malaria control: a cost analysis within a cluster-randomized trial in a rural district in Malawi. *Malaria J.* 20, 268. doi: 10.1186/s12936-021-03800-4

Powell, R. A., and Single, H. M. (1996). Focus groups. *Int. J. Qual. Health care: J. Int. Soc. Qual. Health Care* 8, 499–504. doi: 10.1093/intqhc/8.5.499

Rahman, R., Lesser, A., Mboera, L., and Kramer, R. (2016). Cost of microbial larviciding for malaria control in rural Tanzania. *Trop. Med. Int. Health* 21, 1468–1475. doi: 10.1111/tmi.12767

Rahmani, A. A., Susanna, D., and Febrian, T. (2022). The relationship between climate change and malaria in South-East Asia: A systematic review of the evidence. *F1000Res* 11, 1555. doi: 10.12688/f1000research.125294.2

Reardon, C. M., Damschroder, L. J., Ashcraft, L. E., Kerins, C., Bachrach, R. L., Nevedal, A. L., et al. (2025). The Consolidated Framework for Implementation Research (CFIR) User Guide: a five-step guide for conducting implementation research using the framework. *Implementation science: IS.* 20, 39. doi: 10.1186/s13012-025-01450-7

Rek, J., Musiime, A., Zedi, M., Otto, G., Kyagamba, P., Asiimwe Rwatooro, J., et al. (2020). Non-adherence to long-lasting insecticide treated bednet use following successful malaria control in Tororo, Uganda. *PloS One* 15, e0243303. doi: 10.1371/journal.pone.0243303

Roh, J. Y., Choi, J. Y., Li, M. S., Jin, B. R., and Je, Y. H. (2007). Bacillus thuringiensis as a specific, safe, and effective tool for insect pest control. *J. Microbiol. Biotechnol.* 17, 547–559.

Runge, M., Thawer, S. G., Molteni, F., Chacky, F., Mkude, S., Mandike, R., et al. (2022). Sub-national tailoring of malaria interventions in Mainland Tanzania: simulation of the impact of strata-specific intervention combinations using modelling. *Malaria J.* 21, 92. doi: 10.1186/s12936-022-04099-5

Saunders, B., Sim, J., Kingstone, T., Baker, S., Waterfield, J., Bartlam, B., et al. (2018). Saturation in qualitative research: exploring its conceptualization and operationalization. *Qual Quant.* 52, 1893–1907. doi: 10.1007/s11135-017-0574-8

Schmidt, M., Hrabcova, V., Jun, D., Kuca, K., and Musilek, K. (2018). Vector control and insecticidal resistance in the african malaria mosquito anopheles Gambiae. *Chem. Res. Toxicol.* 31, 534–547. doi: 10.1021/acs.chemrestox.7b00285

Sherrard-Smith, E., Winskill, P., Hamlet, A., Ngufor, C., N'Guessan, R., Guelbeogo, M. W., et al. (2022). Optimising the deployment of vector control tools against malaria: a data-informed modelling study. *Lancet Planet Health* 6, e100–e1e9. doi: 10.1016/s2542-5196(21)00296-5

Shiff, C. (2002). Integrated approach to malaria control. *Clin. Microbiol. Rev.* 15, 278–293. doi: 10.1128/cmr.15.2.278-293.2002

Shousha, A. T. (1948). Species-eradication: the eradication of anopheles gambioe from upper Egypt, 1942-1945. *Bull. World Health Organ.* 1, 309–352.

Sinka, M. E., Pironon, S., Massey, N. C., Longbottom, J., Hemingway, J., Moyes, C. L., et al. (2020). A new malaria vector in Africa: Predicting the expansion range of Anopheles stephensi and identifying the urban populations at risk. *Proc. Natl. Acad. Sci. U S A.* 117, 24900–24908. doi: 10.1073/pnas.2003976117

Sougoufara, S., Doucouré, S., Backé Sembéne, P. M., Harry, M., and Sokhna, C. (2017). Challenges for malaria vector control in sub-Saharan Africa: Resistance and behavioral adaptations in Anopheles populations. *J. Vector Borne Dis.* 54, 4–15. doi: 10.4103/0972-9062.203156

Sougoufara, S., Ottih, E. C., and Tripet, F. (2020). The need for new vector control approaches targeting outdoor biting Anopheline malaria vector communities. *Parasites vectors.* 13, 295. doi: 10.1186/s13071-020-04170-7

Stewart, A. T. M., Winter, N., Igiede, J., Hapairai, L. K., James, L. D., Feng, R. S., et al. (2020). Community acceptance of yeast interfering RNA larvicide technology for control of Aedes mosquitoes in Trinidad. *PloS One* 15, e0237675. doi: 10.1371/journal.pone.0237675

Tanzania MoH (2020). *National malaria strategic plan (NMSP) 2021-2025*. Available online at: http://api-hidlafyagotz/uploads/library-documents/1641210939-jH9mKCtzpdf (Accessed October 26, 2025).

Tanzania MoH (2023). *Integrated Vector Management Guidelines and Standard Operating Procedures*. Available online at: https://wwwnmcpgotz/storage/app/

uploads/public/64b/232/6dc/64b2326dc352e610711786pdf (Accessed October 26, 2025).

Taylor, R., Messenger, L. A., Abeku, T. A., Clarke, S. E., Yadav, R. S., and Lines, J. (2024). Invasive Anopheles stephensi in Africa: insights from Asia. *Trends Parasitol.* 40, 731–743. doi: 10.1016/j.pt.2024.06.008

Thawer, S. G., Chacky, F., Runge, M., Reaves, E., Mandike, R., Lazaro, S., et al. (2020). Sub-national stratification of malaria risk in mainland Tanzania: a simplified assembly of survey and routine data. *Malaria J.* 19, 177. doi: 10.1186/s12936-020-03250-4

Tia, J. B., Tchicaya, E. S. F., Zahouli, J. Z. B., Ouattara, A. F., Vavassori, L., Assamoi, J. B., et al. (2024). Combined use of long-lasting insecticidal nets and Bacillus thuringiensis Israelensis larviciding, a promising integrated approach against malaria transmission in northern Côte d'Ivoire. *Malaria J.* 23, 168. doi: 10.1186/s12936-024-04953-8

Tungu, P., Kabula, B., Nkya, T., Machafuko, P., Sambu, E., Batengana, B., et al. (2023). Trends of insecticide resistance monitoring in mainland Tanzania, 2004-2020. *Malaria J.* 22, 100. doi: 10.1186/s12936-023-04508-3

United Republic of Tanzania: NBS (2022a). *Administrative_units_Population_Distribution_Report_Tanzania_volume1a*. Available online at: https://wwwnbsgotz/nbs/takwimu/Census2022/Administrative_units_Population_Distribution_Report_Tanzania_volume1apd (Accessed October 26, 2025).

United Republic of Tanzania: NBS (2022b). *Age and Sex Distribution Report Tanzania Mainland*. Available online at: https://sensanbsgotz/publication/volume2bpdf (Accessed October 26, 2025).

Utzinger, J., Tozan, Y., Doumani, F., and Singer, B. H. (2002). The economic payoffs of integrated malaria control in the Zambian copperbelt between 1930 and 1950. *Trop. Med. Int. Health* 7, 657–677. doi: 10.1046/j.1365-3156.2002.00916.x

van den Berg, H., da Silva Bezerra, H. S., Al-Eryani, S., Chanda, E., Nagpal, B. N., Knox, T. B., et al. (2021). Recent trends in global insecticide use for disease vector control and potential implications for resistance management. *Sci. Rep.* 11, 23867. doi: 10.1038/s41598-021-03367-9

van den Berg, H., van Vugt, M., Kabaghe, A. N., Nkalapa, M., Kaotcha, R., Truwah, Z., et al. (2018). Community-based malaria control in southern Malawi: a description of experimental interventions of community workshops, house improvement and larval source management. *Malaria J.* 17, 266. doi: 10.1186/s12936-018-2415-1

Vigodny, A., Ben Aharon, M., Wharton-Smith, A., Fialkoff, Y., Houri-Yafin, A., Bragança, F., et al. (2023). Digitally managed larviciding as a cost-effective intervention for urban malaria: operational lessons from a pilot in São Tomé and Príncipe guided by the Zzapp system. *Malaria J.* 22, 114. doi: 10.1186/s12936-023-04543-0

Wafula, S. T., Habermann, T., Franke, M. A., May, J., Puradiredja, D. I., Lorenz, E., et al. (2023). What are the pathways between poverty and malaria in sub-Saharan Africa? A systematic review of mediation studies. *Infect. Dis. Poverty.* 12, 58. doi: 10.1186/s40249-023-01110-2

Weetman, D., Kamgang, B., Badolo, A., Moyes, C. L., Shearer, F. M., Coulibaly, M., et al. (2018). Aedes mosquitoes and aedes-borne arboviruses in africa: current and future threats. *Int. J. Environ. Res. Public Health* 15. doi: 10.3390/ijerph15020220

Weiss, D. J., Dzianach, P. A., Saddler, A., Lubinda, J., Browne, A., McPhail, M., et al. (2025). Mapping the global prevalence, incidence, and mortality of Plasmodium falciparum and Plasmodium vivax malaria, 2000-22: a spatial and temporal modelling study. *Lancet* 405, 979–990. doi: 10.1016/s0140-6736(25)00038-8

World Health Organisation (2004). *Global strategic framework for integrated vector management*. Available online at: https://wwwwhoint/publications/i/item/WHO-CDS-CPE-PVC-200410 (Accessed October 26, 2025).

World Health Organisation (2013). *Global plan for insecticide resistance management in malaria vectors*. Available online at: https://wwwwhoint/publications/i/item/WHO-HTM-GMP-20125 (Accessed October 26, 2025).

World Health Organisation (2016). *World malaria report 2016*. Available online at: https://wwwwhoint/teams/global-malaria-programme/reports/world-malaria-report-2016 (Accessed October 26, 2025).

World Health Organisation (2017a). *World malaria report 2017*. Available online at: https://wwwwhoint/teams/global-malaria-programme/reports/world-malaria-report-2017 (Accessed October 26, 2025).

World Health Organisation (2017b). *Global vector control response 2017–2030*. Available online at: https://iriswhoint/bitstream/handle/10665/259205/9789241512978-engpdf?sequence=1 (Accessed October 26, 2025).

World Health Organisation (2018). *World malaria report 2018*. Available online at: https://wwwwhoint/teams/global-malaria-programme/reports/world-malaria-report-2018 (Accessed October 26, 2025).

World Health Organisation (2019). *World malaria report 2019*. Available online at: https://wwwwhoint/teams/global-malaria-programme/reports/world-malaria-report-2019 (Accessed October 26, 2025).

World Health Organisation (2020). *World malaria report 2020*. Available online at: https://wwwwhoint/teams/global-malaria-programme/reports/world-malaria-report-2020 (Accessed October 26, 2025).

World Health Organisation (2021a). *Global technical strategy for malaria 2016–2030_2021*. Available online at: https://wwwwhoint/publications/i/item/9789240031357 (Accessed October 26, 2025).

World Health Organisation (2021b). *World malaria report 2021*. Available online at: https://wwwwhoint/teams/global-malaria-programme/reports/world-malaria-report-2021 (Accessed October 26, 2025).

World Health Organisation (2022). *World malaria report 2022*. Available online at: https://wwwwhoint/teams/global-malaria-programme/reports/world-malaria-report-2022 (Accessed October 26, 2025).

World Health Organisation (2023). *World malaria report 2023*. Available online at: https://wwwwhoint/teams/global-malaria-programme/reports/world-malaria-report-2023 (Accessed October 26, 2025).

World Health Organisation (2024). *World malaria report 2024*. Available online at: https://wwwwhoint/teams/global-malaria-programme/reports/world-malaria-report-2024 (Accessed October 26, 2025).

World Health Organization (2013). *Larval Source Management_ a supplementary measure for malaria vector control*. Available online at: https://wwwwhoint/publications/i/item/9789241505604 (Accessed October 26, 2025).

Worrall, E., and Fillinger, U. (2011). Large-scale use of mosquito larval source management for malaria control in Africa: a cost analysis. *Malaria J.* 10, 338. doi: 10.1186/1475-2875-10-338

Zhou, G., Lo, E., Githeko, A. K., Afrane, Y. A., and Yan, G. (2020). Long-lasting microbial larvicides for controlling insecticide resistant and outdoor transmitting vectors: a cost-effective supplement for malaria interventions. *Infect. Dis. Poverty.* 9, 162. doi: 10.1186/s40249-020-00767-3

Zhou, G., Wiseman, V., Atieli, H. E., Lee, M. C., Githeko, A. K., and Yan, G. (2016). The impact of long-lasting microbial larvicides in reducing malaria transmission and clinical malaria incidence: study protocol for a cluster randomized controlled trial. *Trials* 17, 423. doi: 10.1186/s13063-016-1545-4