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Exploring community perspectives and experiences of larviciding for malaria control in Papua New Guinea

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Abstract

Background

A resurgence of malaria in Papua New Guinea (PNG) has prompted exploration of additional vector control tools that can complement insecticide treated nets, including larviciding, a type of larval source management. Understanding determinants of community acceptability of additional approaches such as larviciding is vital to inform future implementation strategies. This study aims to understand community-level perceptions, enablers and barriers related to larvicide use in water bodies in a rural village in Madang province, PNG.

Methods

Four focus group discussions (FGDs) and eleven semi-structured interviews (SSIs) were conducted with community members in a rural village along the south coast of Madang Province, PNG. FGDs were conducted with a combination of participants who did and did not have their water bodies treated with larvicides. Qualitative data analysis software NVivo 14 was used to thematically code transcripts inductively, using a coding framework to identify themes and sub-themes as they emerged.

Results

Enablers to acceptability included attendance at awareness sessions and knowledge that larviciding is safe for humans and the environment, building positive relationships and trusted partnerships with local community leaders and stakeholders, and recognising the importance of traditional approaches to malaria prevention and care. Barriers to acceptability included fears of unknown side effects and toxicity of larviciding to humans, animals and ecosystems, perception that larviciding is unnecessary and ineffective, and poor attendance at larviciding awareness sessions. Participants expressed willingness to purchase larvicides for between 5–50 PGK, preferably from trusted sources such as health clinics or government groups who can provide accurate information on how to apply them safely.

Conclusions

Using a community-based approach to engage, educate and address community concerns surrounding larviciding should be prioritised. Culturally tailored implementation strategies that respect and incorporate local knowledge and emphasise the safety to humans, animals and ecosystems are more likely to foster acceptability.

Background

Papua New Guinea (PNG) accounts for the vast majority of malaria cases reported in the Western Pacific region. In 2024, PNG reported over 1.5 million cases of malaria, accounting for 65.6% of malaria cases and 78.2% of deaths in the Western Pacific region[1]. Insecticide treated nets (ITNs) are the only programmatically implemented vector control tool in PNG, distributed throughout the country at no cost to community members by PNG's National Malaria and Vector Borne Disease Control Program. In addition to ITNs, a combination of traditional and biomedical approaches are used to avoid mosquito bites, including making fires, swatting and burning mosquito coils[2].

Malaria burden in PNG reduced significantly in the years following introduction of nation-wide ITNs, parasitological diagnosis and artemisinin-based combination therapy, however has increased since 2015[3,4]. The observed increase is likely due to a combination of factors including reduced bioefficacy of ITNs distributed between 2013 and 2019[5] and reduced funding for and implementation of behaviour change campaigns for malaria prevention. Coupled with the additional challenges of outdoor transmission[2,6] and possible emerging resistance to insecticides[7], these factors have prompted consideration of alternative approaches, including larval source management (LSM).

LSM includes habitat modification and manipulation, environmental management, biological control (including larvivorous fish) and larviciding[8]. Larvicides are used in larval habitats targeting mosquito aquatic stages to reduce adult mosquito vector populations and thereby reduce malaria transmission[8].

With extensive evidence of its efficacy in reducing mosquito larvae and mosquito borne disease[9–15], the substantial potential for LSM approaches to be integrated within national malaria control programs is becoming increasingly recognised[16]. However, some structural barriers limit the feasibility of implementing large-scale LSM programs, such as poor global technical support, donor hesitancy, and a lack of robust guidelines, policy recommendations and funding[16,17]. This has fuelled calls to re-evaluate the role of LSM for malaria control, create strong guidelines, and boost the public health resourcing required to implement widespread, local-level workforces targeting mosquito vectors[16,17].

Larviciding has been used for decades in higher income countries such as the USA and Australia, via both ground and aerial application as the primary method to reduce nuisance and potential vector mosquito populations[18–20]. Larviciding is increasingly used in Africa as an effective tool for reducing mosquito larvae and against the challenges of outdoor malaria transmission and insecticide resistance management[9,10,12–14,21]. Larviciding has also been successful in parts of Asia[22] and South America[23]. In PNG, larviciding is being used by the mining industry to treat bodies of water in mine-impacted zones[24]. However, elsewhere in the country, larval source management—including the use of larvicides—is not routinely implemented as part of mosquito control programmes. Furthermore, limited qualitative evidence exists surrounding community experiences and perspectives of larviciding for malaria control in Melanesia and the Western Pacific region.

Recognising the need to explore implementation feasibility and community perspectives on additional mosquito control tools, the Newly Adapted Tools and Network Against Mosquito Borne Disease Transmission - NATNAT project implemented a pilot field study in Madang Province in 2023 to assess the feasibility and acceptability of larviciding in a village setting.

Several similar studies have been conducted in Africa, which have demonstrated high levels of acceptability, whilst also highlighting potential barriers to acceptance including concerns about health risks and safety of water, heavy rain impacting efficacy, financial barriers and perceptions that larvicides were ineffective[25–27].

Geographical, ecological, social and cultural differences between Africa and PNG necessitate context-specific research to be conducted on community-level acceptance of larviciding. To address this, key understanding of local-level community leadership structures, belief systems, ways of working, existing community activities and opinions on implementation approaches is required to inform acceptable and culturally tailored implementation strategies for larviciding in PNG.

We used the theoretical framework of acceptability tool to guide the evaluation of community-level acceptability of a larviciding implementation research program conducted in a rural village of PNG[28]. Using this framework, we applied key constructs designed to capture dimensions of acceptability, assessing both prospective and retrospective experiences of larviciding in community recipients.

Methods

Author positionality statement: The data collection was undertaken by KM and AA. KM (male) and AA (female) are Papua New Guinean qualitative research assistants based in Madang province, PNG with backgrounds in social science. KM and AA have strong understanding of culture and community life in PNG, however, are not from the study village. AA and GS co-analysed the data together. GS is a female Australian research assistant based in Melbourne, Australia with experience in public health research. All researchers hold relevant degrees and have experience in social science, health management, qualitative research, and public health. Collaborative reflexivity was regular given ongoing, trusted relationships were established between researchers.

Data Collection

We undertook a qualitative exploratory study to provide evidence on the acceptability of larviciding at the community level. Data collection occurred at two timepoints, pre-implementation of larvicides and post deployment of larvicides. The pre-implementation data collection occurred from the 14th – 16th March 2023. The post deployment data collection occurred from the 14th – 20th of December 2023. This study used two data collection methodologies; focus group discussions (FGDs) and semi structured interviews (SSIs), to gather a broad range of perspectives, as well as in-depth opinions. FGDs and SSIs were conducted in Tok Pisin, by a member of the qualitative research team. FGDs were conducted in a shared

area in the community that was deemed as safe for participants, offering audio privacy, and at a time convenient to participants. SSIs were conducted in both private homes and shared community spaces depending on participant preference. A question guide was developed for both SSIs and FGDs to explore specific themes.

Recruitment

The study was conducted in a small rural village located along the South Coast of Madang Province. This coastal village consists of 2 major clans that are guided by well-respected community leaders. The village depends on fishing and agriculture of taro, yams and bananas for both subsistence and their livelihoods. Many households are heavily reliant on betelnut for income, and in some cases it is the only cash crop grown. Purposive sampling was used to recruit total of 11 participants for SSIs including people in decision-making roles such as clan leaders, church elders and volunteers from the village who were engaged by the entomology team for the larval survey. KM and AA discussed the project with community leaders to seek guidance on participants that may be interested in being involved. The community leader approached participants at their house and asked them if they were interested in being interviewed by the qualitative research team. SSIs were between 32 minutes – 1 hour 8 minutes in duration. Convenience sampling was used to recruit total of 32 participants for 4 FGDs including male and female community members who refused and accepted larviciding in their water sources. The community leader assisted KM and AA in identifying these participants from the community and jointly approached them at their house a day prior to the FGD. Male and female FGDs were conducted separately. FGD were between 1 hour 11 minutes – 2 hours 17 minutes in duration.

Table 1
Pre-Implementation: Distribution of Participants by Data Collection Method

Data collection method	Gender		Total No. Of interviews	Total No. Of participants	Age
	Male	Female			
Focus group discussion	**8**	**11**	**2**	**19**	**NA**
Semi structured interview	**5**	**1**	**6**	**6**	**36–50 yrs old**

Table 1 summarises the number of participants, interviews and focus groups conducted in the community during the pre-implementation data collection.

Table 2
Post-Deployment: Distribution of Participants by Data Collection Method

Data collection method	Gender		Total No. Of interviews	Total No. Of participants	Age
	Male	Female			
Focus group discussion	5	7	2	12	NA
Semi structured interview	3	2	5	5	35–73 yrs old

Table 2 summarises the number of participants, interviews and focus groups conducted in the community post-deployment of larvicides in water sources.

Consent and Data Management:

Following an explanation provided by the research team about the study, participants were given the opportunity to ask questions before agreeing to participate. Written informed consent was obtained from all the participants prior to the SSIs and FGDs. SSIs and FGDs were audio recorded and supplemented by detailed interview notes. At the end of each day, the audio recordings were uploaded onto a secure shared drive. The voice-recorded audio files were transcribed verbatim in Tok Pisin, which were then translated by KM into English using MS Word. Quality checks on these files were completed by ZK, a Papua New Guinean qualitative researcher, to ensure data validity.

Analysis:

Qualitative data was analysed by 2 researchers, GS and AA. SSIs and FGDs were thematically analysed using qualitative data analysis software NVivo 14, following the Braun & Clarke system for thematic analysis[29]. Inductive coding was used to identify high level thematic categories and sub-categories as they emerged, forming a reflexive analysis. A coding framework was collaboratively produced to structure themes and trends within the data. Code development was also informed by reflexivity sessions and notes from data collection. High level themes included: understanding of larviciding, enablers to acceptability of larviciding, barriers to acceptability of larviciding and feasibility of implementation of larviciding in the PNG context.

Pilot larviciding study:

A pilot larviciding study was conducted in a coastal village in Madang Province, where larviciding had not previously been implemented. After pre-implementation *Anopheles* larval habitat surveys, selected sites were allocated to treatment or untreated control habitats and included ground wells, ponds, forest swamp pools, and transient puddles. Reported habitat uses were water for washing (bathing), washing

clothes, fishing, or no specific use. Drinking water sources were not treated in this study. The larvicides applied were a granular spinosad product, an (S)-methoprene product and a pyroproxifen product. These larvicides were selected for use in the study based on their relatively long effective duration and were applied once following manufacturers' instructions. Application of larvicides was conducted by trained study staff, with the assistance of local community volunteers. Habitats were monitored for 10 weeks post treatment.

Ethical Approval:

This NATNAT study has been approved by the PNG IMR Institutional Review Board (#2005), the Medical Research Advisory Committee in PNG (#20.19) and Alfred Hospital Ethics Committee (#67898) in Melbourne, Australia.

Results

The findings highlight several key aspects that influence community acceptability of larviciding, including knowledge transfer, community hierarchy structures and pre-existing approaches to malaria control. These findings will inform appropriate implementation strategies for future larviciding programs in PNG.

Community context in PNG

Important aspects of community culture, beliefs and practices surrounding malaria control are central to determining acceptance of village-based interventions such as larviciding. Individual and communal beliefs around home remedies and herbal preparations mean that they are regularly used as the first-line approach for malaria treatment and control and are often prioritised over programmatically implemented medical approaches. Recognising the importance of existing traditional approaches to malaria control is vital to successful implementation of new vector control tools in PNG.

"This tree skin is for when you are sick, the evil spirits must not come. So, that is why [elderly people] will chew [tree skin] and spit to get rid of those sicknesses [caused by evil spirits]. Most people use this tree skin" ***- Female focus group member***

Whilst the majority of participants explained that religion did not act as a barrier to their acceptability of larviciding, the intricacies of religious belief systems and perspectives in rural PNG are diverse and differ between individuals. The clan leader raised religious questions regarding the impact of larviciding on natural processes and ecosystems, explaining that nature will always prevail and therefore any success of the larviciding will be short lived.

"God himself created [mosquitoes] that we want to change and want to go, [but they] will not, still [mosquitoes] will come back again. It's nature, it's in the hands of the great God. [Mosquitoes] will go but will come back, we will be strong, we will spend a lot of money, we will put a lot of our knowledge on how to prevent this from happening but [mosquitoes] will come back again" ***- Paul, male 46, clan leader***

Existing structures and systems of communal activities within the village were highlighted by participants. Community-led 'work parade' activities were mentioned as a successful model currently used for maintaining community tidiness and environmental management that reduces larval habitats. Every Tuesday community members participate in clean-up activities around their homes and community, as directed by community leaders.

"at the community meeting, the committee will allocate areas for the people to work, and we also have committees for each catchment. But every Tuesday we used to do general work parade inside the community or at our own yard to make the area or yard look nice or attractive" ***– Male focus group member***

Facilitators of acceptability of larviciding

Understanding of larviciding

Prior to this small study of larviciding, community members were largely unfamiliar with larviciding as a method of mosquito control. During initial community awareness sessions, there was strong engagement and question/answer sessions between community members and the research team that enabled an understanding about larviciding and the study. Following this, several pre-deployment SSI participants explained that most of the community would be supportive of the larviciding as a tool to reduce the impact of mosquitos and malaria in their village. A female, focus group member noted that she was *"happy for the research team to apply the insecticide in [her] well water. So, in case [mosquitoes] breed there, reduce some of them."*

Several participants anecdotally reported a reduction in the malaria burden following larviciding activities. As Olivia, female 23, community member, noted, *"Yeah, I think [malaria] has reduced a bit. But after the team have visited and went back, there was no malaria and now it is 3 months for us."*

Larviciding education and awareness dissemination

Participants explained that clear and culturally accessible awareness dissemination would aid the community in engaging with and supporting the implementation of larviciding. A female, focus group member noted that *"if [larviciding] is very clear for the lens of the people, many people are aware of it, and it will be rolled out."*

Attendance at community information sessions with the research team reduced uncertainty and improved willingness to engage with larviciding.

"They wanted to treat the water, so we gathered there and allowed them to come, and I have asked one question. I said, "The insecticide that will be used, will it affect us or not?" So, it was made clear [that larviciding would not impact people], and we understood, and we accepted, and the treatment started" ***- Victor, Male, 72, Church leader***

To improve the sustainability and longevity of larviciding acceptability if implemented in the future, several participants suggested a whole-community approach to training and teaching. Participants expressed willingness to adopt larviciding, however emphasised that clear information that is accessible to everyone in the community surrounding the purpose of larviciding and how to use larvicides would be beneficial. A female, focus group member noted that *"In [her] opinion, if the team trains [them], [she] can do it at [her] well water to help."*

One participant suggested the distribution of a physical instruction guide on how to use larvicides would be helpful.

"*Put the information inside the paper and someone can come and explain the information and the dosage of the insecticide required and the frequency of applying it."* ***- Victor, male 72, Church leader***

Positive relationships with community leaders and trust building

The respect and trust placed in community leaders, including clan and church leaders in PNG was emphasised by several participants. Acceptance of larviciding by community leaders was a key determinant of community acceptability, due to the power that leaders have in their communities. It was explained that in many cases, the community follows and supports decisions made by community leaders, demonstrating their influence in community acceptability of new public health interventions such as larviciding. Leaders suggested that prospective implementors should engage with, and understand the hierarchal structures and power dynamics of target populations to improve acceptability.

"So, when I say anything, the whole community, they agree to what I say, and they would follow what I say and they were happy to work with me." ***- Chris, male 50, previous community chairman, father***

A local Church leader explained his active leadership in reassuring people who had concerns about larviciding. He explained how community members often turn to leaders for guidance in uncertain situations, and emphasised the need for clear and logical explanations surrounding unfamiliar strategies such as larviciding to gain the support of the community.

"We have treated it, that well water is on the other side that we used to drink, and I am referring to it. I said, to the [community members], do you feel it, are the research team lying to us or is it true? Alright we tested it, and nothing happened. It helped and there was no effect from the treated water that we used." ***- Victor, male 72, Church leader***

Individualised approach to culturally tailored implementation

Complex intricacies and sociocultural nuances differ between communities in PNG, leading to differences in community operation, leadership hierarchy, the role of religion and willingness to engage with public health interventions. Participants explained that individualised approaches to community engagement and trust building are needed prior to, and during larviciding activities. They reiterated that

dedicated time and support is required to understand the community context, emphasising that larviciding should be community-led and guided by those it is designed to serve.

"We are not same as other communities. When a government service arrives, the people in the community decides [if they will engage with the service] or not. We assess to see if the specific service will be good and will help us and if so, we look after it." - ***Victor, male 72, Church leader***

"*When you come through the leader before you come into the community, there is no problem, no ups and downs, agreement would be there."* ***Chris, male 50, previous community chairman, father***

Barriers to acceptability

Fears of toxicity and side effects of larviciding

Some participants shared their reasons for not participating in or supporting the larviciding activities. This included fears about toxicity and potential side effects of larviciding, such as poisoning fish, ruining drinking and bathing water, causing skin irritations and potentially causing death and illness. Some fears of toxicity originated from a perception that previous instances of washing insecticide treated bed nets in water sources impacted aquatic life and water safety. These fears resulted in one family removing identification tags from their water source so that it would not be treated with larvicides.

"It was a mother that asked them, she thought about her well water so she said, "If you put this insecticide to kill the mosquito, this insecticide might kill fish and destroy my water to drink." - ***Female focus group member***

A recurring barrier to community acceptability was the perception that the larviciding was causing itchy skin and skin sores. Several participants mentioned the presence of skin irritations following deployment, suggesting that larviciding was the cause, and that this perspective had been widely discussed throughout the community. A female focus group member noted that *"[they] bathed in the well water which was treated with insecticide and felt itchy skin"*

However, some participants identified that itchy skin was already prevalent amongst the community prior to the larviciding, suggesting that the skin irritations and larviciding were unrelated. A female focus group member noted that *"[Itchy skin] was here [for a] long time, so in case [anyone] blame[s] this insecticide for causing itchy skin, it was here before the treatment was done."*

Beliefs that larviciding is unnecessary and ineffective

One participant refused to participate based on a perceived understanding that their water source is not where the adult mosquitoes were coming from.

"No, because my well water does not breed mosquitoes. There are also fish, and all other things are inside as well. That is the truth I am telling you. No mosquitoes are breeding inside, the water is clean and clear." ***- Female focus group member***

In addition, some participants questioned the efficacy of the intervention after noticing the persistence of larvae in treated water sources.

"After 3 days or 4 days we went and noticed mosquito larvae were there inside the water that had insecticide. The question we had was is the insecticide killing the mosquitoes or not?" ***- Female focus group member***

Poor attendance at community awareness sessions

Finding appropriate timings for information sessions remains a key challenge for public health teams. Participants highlighted that some people were unable to attend study awareness sessions due to employment, community commitments or changing schedules, contributing towards a lack of initial understanding of larviciding.

"Like for us we have attended the awareness, so we know, what was the reason for the research team for treating the water with insecticide. I think a lot of the well waters inside the community were not treated. Maybe, because the owners of these well waters did no turn up during the awareness. If all the people attend the awareness, then all the well waters should have been treated" ***- Olivia, female 23, community member***

Implementation and financing of larviciding in the PNG context

Several delivery and implementation models were described by participants. These included distribution through public health programs, local store purchasing options and hybrid models that utilise health facilities as outlets.

Some participants suggested that larvicides could be distributed free of charge alongside ITN distribution programs. A male, focus group member noted that *"It can be brought here during the distribution of bed nets and inform [people] the clear information so [they] will get that as well."*

Some community members suggested that local shops would be a suitable place for larvicides to be purchased. However, several participants highlighted the potential for spread of misinformation if larvicides were to be sold at local shops, as shopkeepers may not have in-depth knowledge and understanding about larvicides. Several community members therefore suggested that larvicides should be distributed or sold at health facilities or pharmacies to ensure that accurate information about the larvicides could be provided to consumers by a health professional.

"Some shop workers know about the use of the insecticide and others do not know about it. They will give the wrong instruction to the people who will buy the insecticide. That is from my opinion so I think it will be best to be at the health facility." ***- Olivia, female 23, community member***

Many participants recognised the value of larvicides after positive experiences of having their water treated without side effects and would therefore be happy to pay for larvicides in the future. Financial

strain was raised as a potential barrier to purchasing ability, and it was also highlighted that willingness to pay may not be shared by all community members, particularly those who had not used larvicides before. A female, focus group member noted that *"Okay, yes if they sell the insecticide, [people] will buy it. [People] will be stressed to pay but [they] will."* ***- Female focus group member***

"I think the people who had their water source treated and they have used this water, and nothing happened to them, they maybe will be willing. For the people who did not have their well water treated, I think they will not be willing to pay." ***- Olivia, female 23, community member***

Between K5 – K50 was suggested by participants as an acceptable price if larvicides were to be available to purchase at local outlets. Some participants mentioned that the price should depend on the quantity in each pack, duration of protection and dosage required. Tracey, a female community member explained that *"About K20 will do. It will depend on the quantity of the insecticide inside the container."* - *Tracey, female, supermarket cashier*

Discussion

Integrating additional vector control strategies into existing approaches and systems

Religion and spirituality are deeply woven into the foundational values of communities throughout PNG[30], and our study highlights the religious and cultural significance of traditional approaches in rural communities. The use of traditional malaria control methods has been demonstrated throughout Southeast Asia and the Western Pacific, with traditional approaches often preferred over biomedical or programmatically implemented strategies to avoid mosquito bites[31]. Our findings support the development of implementation strategies that recognise traditional approaches as long-standing, central aspects of malaria control in PNG.

Community-based approaches to larviciding have been demonstrated in Africa, highlighting that locally-led models can empower communities, create a sense of ownership and foster acceptability[21,32]. In our study, community 'work parades' were mentioned by participants as an existing form of environmental management and mosquito habitat removal. Work parades provide a possible model to engage community-based groups and encourage local leadership, which are vital elements of successful malaria control interventions[33]. Similarly, Indonesia and Malaysia's 'gotong royong' program demonstrates a successful approach to community-led malaria prevention through a shared practice of improving environmental cleanliness[34]. Implementation planning in PNG should leverage existing models of community mobilisation and could consider integrating larviciding with community work parades or similar initiatives.

Understanding of malaria and larviciding

Larviciding and malaria understanding is key to enabling greater community acceptability of larviciding[25,27,35]. Reduced participation in larviciding activities can also be the result of misconceptions

about the connection between larval habitats and malaria transmission[36]. In our study, clear understanding of larvicide application, and that they are safe for humans, animals and the environment increased willingness to participate and support the intervention. This trend mirrored a study in Vanuatu which found that people who acknowledged the threat of malaria were more intrinsically motivated to participate in malaria control practices and empower others to also do so[37]. Region-specific literature also suggests that inconsistencies and gaps in malaria knowledge exist on a broader scale beyond PNG[31]. Implementation of larviciding programs in PNG should therefore be coupled with an extensive and thorough community-based education package that emphasises key aspects of malaria and the role of larviciding in reducing transmission. Interestingly, through experiences of larviciding programs in Cameroon and Burkina Faso, community members were significantly more likely to understand malaria transmission and know about mosquito breeding habitats[38,39]. Although acceptability is linked with knowledge and understanding, it also relies on how interventions are introduced, demonstrating that the intervention package needed for successful implementation must be context specific.

The presence of health concerns and fears for humans and animals that use water bodies treated with larvicide have been identified in several larviciding studies globally[26,27,39,40]. Some participants raised questions and concerns about the toxicity of larvicides, fearing that using them may poison fish or animals living in water sources, ruin drinking and bathing water, cause illness or even death. Several participants also raised concerns about larviciding being linked to skin irritations. A Cambodian study that trialled larvivore fish and pyriproxifen larvicide to address dengue found that most participants supported larviciding in their water bodies, and any initial concerns of water contamination or toxicity were alleviated following positive experiences of larviciding and explanation from volunteers[41]. Emphasising larvicide safety during implementation and delivery of larvicide awareness is recommended to foster greater acceptance of larviciding in PNG. It should also be considered that acceptability is highly dependent on the ethicality of larviciding as an intervention in alignment with local practices, views and environmental stewardship. Implementers should therefore prioritise understanding the culture, daily practices and values that underpin community perspectives and acceptance in PNG.

Community engagement, awareness and education about larviciding

Community engagement and capacity building within delivery of malaria control programs has had positive impact globally[21,33,34,36]. Key aspects of community engagement identified in a scoping review of African larviciding programs were reflected in our study, including desire for community participation in planning and implementation, involvement of local leaders and stakeholders to foster improved community acceptance, and conducting sustainable and accessible education, training and awareness[36].

Attendance at community awareness sessions was a prominent enabler of acceptability, however timings for information sessions remains a key challenge. Some participants were unable to attend awareness sessions for various reasons such as daily activities or employment commitments, reducing information dissemination. Diverse channels and timing of awareness sessions, and use of local

languages or Tok Pisin (the widely spoken language in PNG), should be prioritised to maximise attendance rates and engagement. Alternative approaches to vector control information dissemination such as house-to-house distribution of written materials and radio were highlighted in a Puerto Rican study[42], and could be explored to suit communities in PNG.

Sociocultural diversity across PNG necessitates individualised approaches to be prioritised when designing and upscaling programs. Evidence from Melanesian settings similarly cautions against the transfer of implementation "blueprints" across settings[43]. Indo-pacific health systems research, Torres Strait vector control and malaria programs in Vanuatu all demonstrated greater acceptability when implementation aligns with local organizational structures[37,44,45]. Our findings echoed this concept, with participants reinforcing the need for tailored approaches that are appropriate for each community. Desire for hands-on participatory approaches to implementation involving local stakeholders was also highlighted, and is reinforced by findings of an African scoping review linking the success of larviciding programs to participatory approaches and greater ownership[36].

Fostering strong and trusting partnerships with local leaders in malaria prevention programs is crucial for community acceptability[33,36], and is a well-documented attribute of successful implementation research in PNG[46]. Leaders who participated in the study explained that they should be engaged prior to larviciding activities to provide consent and collaborate on implementation strategies. Allowing space for religious and local leaders to champion public health implementation has been emphasised as an important act of respect to local communities in PNG[47]. Our findings, situated amongst several other examples from PNG, demonstrate the necessity of trust building, and creating a partnership environment with local stakeholders that is conducive to open communication, collaboration and inclusivity[46]. The positive impact of local leaders' involvement in educating, supporting and participating in larviciding programs has also been demonstrated in several African settings[26,27,35,36].

Implementation and financing of larviciding in the PNG context

Our findings highlighted several implementation and financing options for larvicides in PNG. In a setting where ITNs are nationally distributed free of charge to communities, financial incentives to purchase additional vector control tools including larvicides may be reduced. Our findings also suggested that limited pre-existing experience and knowledge of larviciding may hinder community motivation to use and purchase larvicides in PNG.

Local store purchasing options for larvicide distribution were explored and supported by some, however financial barriers could limit purchasing power for disadvantaged groups and those facing financial hardship, further driving inequity gaps. In Cambodia, a larviciding trial found that participants were willing to purchase larvicides if available at local markets, reporting reasons such as positive larviciding experiences, a lack of smell and lack of impact on water quality, however expressed some fears that larvicides may become too expensive at local markets due to poor price regulation[41]. Willingness to pay for larvicides was also reported in larviciding acceptability studies in rural Burkina Faso[25,39] and

Tanzania, where significant associations were identified between willingness to pay and wealth, education and trust in the safety of larvicides[27]. Interestingly, studies from Kenya and Tanzania found that community members were willing to pool financial and labour resources to support larviciding campaigns[27,48], however some concerns were raised about corruption and the correct use of money[27]. Embedding community-based mechanisms such as resource pooling could promote widespread, more equitable and cost-effective pathways for larviciding.

Hybrid models that utilise health facilities as distribution outlets were suggested by some participants as a solution to concerns about purchasing from local stores. These concerns were centred around poor regulation of stores and beliefs that local store attendants would not have sufficient capacity to provide accurate information about larvicides. PNG's decentralised health system may suit distribution models that utilise health facilities, however accessibility barriers and varying community motivation may limit widespread uptake. Provincial and District-level support for community empowered malaria control that addresses equity concerns, the risks associated with privatising, and includes education for community members should therefore be considered to foster acceptability and uptake of larviciding in PNG.

Study limitations

Our study had some limitations. As data was only collected in a small number of participants, the views expressed may not be representative of the whole community. Additionally, data was only collected in one village, so the findings may not be generalisable to other settings, as communities across PNG are highly diverse. However, several key findings have been highlighted in relevant literature from other settings, suggesting that this research has value to inform malaria control beyond this specific village. These include the importance of community engagement, collaboration with community leaders, as well as thorough and culturally appropriate education dissemination that addresses community misconceptions and misinformation. In the SSIs, the purposive sampling strategy was used to recruit decision makers within the community, given the important role they have in influencing community opinion and determining acceptability of new interventions in PNG. The patriarchal structure of the study village means that males likely occupy decision making and leadership roles such as community leader, church leader and head of households. This contributed to more SSI participants being male. However, this study still ensured female perspectives were prioritised by conducting female FGDs, and where possible, including females in SSIs.

Conclusion

This study demonstrates support for larviciding in rural PNG. Acceptance was linked to considered and thorough community engagement that focused on embedding in-person community education and awareness, fostering understanding of how larviciding works, and knowledge that correct use of larvicides is safe for humans and the general environment. Our findings confirmed that introducing unfamiliar malaria control approaches such as larviciding can be met with barriers, including willingness to engage, fears of toxicity and unknown side effects, association of skin irritations with larviciding and

beliefs that larviciding is ineffective. Community members expressed a desire for larvicides to be more readily available through trusted services such as health facilities. Future implementation planning for larviciding in PNG should prioritise strong community engagement processes that empower and encourage local ownership of larviciding interventions. Extensive education and awareness dissemination that is co-created with local stakeholders was also emphasised as a key element needed for successful implementation and acceptability of larviciding in PNG.

Abbreviations

PNG Papua New Guinea

NATNAT Newly Adopted Tools Network Against mosquito borne disease Transmission

LSM Larval Source Management

FGD Focus Group Discussion

SSI Semi Structured Interview

Declarations

Ethics approval and consent to participate

Research protocol for this study has been approved by the PNG IMR Institutional Review Board (#2005), the Medical Research Advisory Committee in PNG (#20.19) and Alfred Hospital Ethics Committee (#67898) in Melbourne, Australia.

Consent for publication

Authors agreed for publication

Availability of data and materials

The research data are confidential and are not publicly available. Excerpts of selected transcripts have been made available within the paper. Access to the de-identified minimal dataset can be provided on reasonable request. Please contact Burnet

Institutes Research Governance Office on: research.governance@burnet.edu.au

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

Alma Auwun; Investigation, Formal Analysis, Writing – original draft, Giselle Stogdale; Formal Analysis, Writing – original draft, Rachael Farquhar; Methodology, Investigation, Formal Analysis, Writing – Review & Editing, Zebedee Kerry; Methodology, Investigation, Writing – Review & Editing, Kilon Manuv; Methodology, Investigation, Writing – Review & Editing, Elias Omera; Writing – Review & Editing, Petrina Johnson; Conceptualisation, Supervision, Writing – Review & Editing, Paul Daly; Conceptualisation, Supervision, Writing – Review & Editing, Project administration, Michael Macdonald; Conceptualisation, Writing – Review & Editing, , Maria Ome Kaius; Conceptualisation, Supervision, Writing – Review & Editing, Stephan Karl; Conceptualisation, Supervision, Writing – Review & Editing, Funding acquisition, Moses Laman; Conceptualisation, Supervision, Writing – Review & Editing, Funding acquisition, Leanne Robinson; Conceptualisation, Supervision, Writing – Review & Editing, Funding acquisition.

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References

1. World Health Organization. World malaria report 2025: Addressing the threat of antimalarial drug resistance. 2025. Accessed July 22, 2025. https://www.who.int/teams/global-malaria-programme/reports/world-malaria-report-2025
2. Rodriguez-Rodriguez D, Katusele M, Auwun A, et al. Human Behavior, Livelihood, and Malaria Transmission in Two Sites of Papua New Guinea. J Infect Dis Apr. 2021;27(12 Suppl 2):S171–86. 10.1093/infdis/jiaa402.
3. Hetzel MW, Pulford J, Ura Y, et al. Insecticide-treated nets and malaria prevalence, papua new guinea, 2008–2014. Bull World Health Organ. 2017;95(10). 10.2471/BLT.16.189902.
4. Hetzel MW, Saweri OPM, Kuadima JJ et al. *Papua New Guinea Malaria Indicator Survey 2016–2017: Malaria Prevention, Infection, and Treatment*. 2018. Accessed August 15, 2025. https://www.pngimr.org.pg/wp-content/uploads/2023/02/PNGIMR-2018-PNG-MIS-2016-17_Final-Report.pdf

5. Vinit R, Timinao L, Bubun N, et al. Decreased bioefficacy of long-lasting insecticidal nets and the resurgence of malaria in Papua New Guinea. Nat Commun Jul. 2020;20(1):3646. 10.1038/s41467-020-17456-2.
6. Keven JB, Katusele M, Vinit R, et al. Vector composition, abundance, biting patterns and malaria transmission intensity in Madang, Papua New Guinea: assessment after 7 years of an LLIN-based malaria control programme. Malar J Jan. 2022;5(1):7. 10.1186/s12936-021-04030-4.
7. Katusele M, Lagur S, Endersby-Harshman N, et al. Insecticide resistance in malaria and arbovirus vectors in Papua New Guinea, 2017–2022. Parasit Vectors Nov. 2022;14(1):426. 10.1186/s13071-022-05493-3.
8. World Health Organization. Larval Source Management: A supplementary measure for malaria vector control: an operational manual. 2013. Accessed July 25, 2025. https://iris.who.int/server/api/core/bitstreams/b4afe447-30f5-494f-a63e-adfe77f57df0/content
9. Geissbuhler Y, Kannady K, Chaki PP, et al. Microbial larvicide application by a large-scale, community-based program reduces malaria infection prevalence in urban Dar es Salaam, Tanzania. PLoS ONE. 2009;4(3):e5107. 10.1371/journal.pone.0005107.
10. Mpofu M, Becker P, Mudambo K, de Jager C. Field effectiveness of microbial larvicides on mosquito larvae in malaria areas of Botswana and Zimbabwe. Malar J Dec. 2016;6(1):586. 10.1186/s12936-016-1642-6.
11. Fillinger U, Lindsay SW. Larval source management for malaria control in Africa: myths and reality. Malar J Dec. 2011;13:10:353. 10.1186/1475-2875-10-353.
12. Fillinger U, Ndenga B, Githeko A, Lindsay SW. Integrated malaria vector control with microbial larvicides and insecticide-treated nets in western Kenya: a controlled trial. Bull World Health Organ Sep. 2009;87(9):655–65. 10.2471/blt.08.055632.
13. Maheu-Giroux M, Castro MC. Impact of community-based larviciding on the prevalence of malaria infection in Dar es Salaam, Tanzania. PLoS ONE. 2013;8(8):e71638. 10.1371/journal.pone.0071638.
14. Antonio-Nkondjio C, Doumbe-Belisse P, Djamouko-Djonkam L, et al. High efficacy of microbial larvicides for malaria vectors control in the city of Yaounde Cameroon following a cluster randomized trial. Sci Rep Aug. 2021;24(1):17101. 10.1038/s41598-021-96362-z.
15. Choi L, Majambere S, Wilson AL. Larviciding to prevent malaria transmission. Cochrane Database Syst Rev Aug. 2019;14(8):CD012736. 10.1002/14651858.CD012736.pub2.
16. Okumu F, Moore SJ, Selvaraj P, et al. Elevating larval source management as a key strategy for controlling malaria and other vector-borne diseases in Africa. Parasit Vectors Feb. 2025;7(1):45. 10.1186/s13071-024-06621-x.
17. Newby G, Chaki P, Latham M, et al. Larviciding for malaria control and elimination in Africa. Malar J Jan. 2025;15(1):16. 10.1186/s12936-024-05236-y.
18. United States Environmental Protection A. Bti for Mosquito Control. 2025.
19. Government of Western Australia Department of H. Aerial application of mosquito larvicide. 2021.

20. Tomerini DM, Dale PE, Sipe N. Does mosquito control have an effect on mosquito-borne disease? The case of Ross River virus disease and mosquito management in Queensland, Australia. J Am Mosq Control Assoc. Mar 2011;27(1):39–44. 10.2987/10-6038.1.
21. Mapua SA, Limwagu AJ, Kishkinev D, et al. 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 Nov. 2024;27:e00382. 10.1016/j.parepi.2024.e00382.
22. Lamaningao P, Kanda S, Shimono T, Inthavongsack S, Xaypangna T, Nishiyama T. Aedes mosquito surveillance and the use of a larvicide for vector control in a rural area of the Lao People's Democratic Republic. Trop Med Health. 2020;48:54. 10.1186/s41182-020-00242-7.
23. Fontoura PS, Silva MF, da Costa AS, et al. Monthly biological larviciding associated with a tenfold decrease in larval density in fish farming ponds and reduced community-wide malaria incidence in northwestern Brazil. Parasit Vectors Sep. 2021;3(1):445. 10.1186/s13071-021-04964-3.
24. Millat-Martinez P, Baro B, Kasian B, et al. A cross-sectional study to ascertain malaria prevalence among asymptomatic travellers arriving on the Lihir Group of Islands, Papua New Guinea: implications for elimination efforts. Malar J Nov. 2023;29(1):364. 10.1186/s12936-023-04804-y.
25. Dambach P, Jorge MM, Traore I, et al. A qualitative study of community perception and acceptance of biological larviciding for malaria mosquito control in rural Burkina Faso. BMC Public Health Mar. 2018;23(1):399. 10.1186/s12889-018-5299-7.
26. Gowelo S, McCann RS, Koenraadt CJM, Takken W, van den Berg H, Manda-Taylor L. Community factors affecting participation in larval source management for malaria control in Chikwawa District, Southern Malawi. Malar J Jun. 2020;2(1):195. 10.1186/s12936-020-03268-8.
27. Mboera LE, Kramer RA, Miranda ML, Kilima SP, Shayo EH, Lesser A. Community knowledge and acceptance of larviciding for malaria control in a rural district of east-central Tanzania. Int J Environ Res Public Health May. 2014;14(5):5137–54. 10.3390/ijerph110505137.
28. Sekhon M, Cartwright M, Francis JJ. Acceptability of healthcare interventions: an overview of reviews and development of a theoretical framework. BMC Health Serv Res Jan. 2017;26(1):88. 10.1186/s12913-017-2031-8.
29. Braun V, Clarke V. Using thematic analysis in psychology. *Qualitative Research in Psychology*. 2006/01/01 2006;3(2):77–101. 10.1191/1478088706qp063oa
30. Laka RP. The role of religion in development communication in Madang, Papua New Guinea. Media Asia. 2015;42(1–2). 10.1080/01296612.2015.1072352.
31. Naserrudin NA, Adhikari B, Culleton R, et al. Knowledge, compliance, and challenges in anti-malarial products usage: a systematic review of at-risk communities for zoonotic malaria. BMC Public Health Jan. 2024;29(1):317. 10.1186/s12889-024-17792-8.
32. van den Berg H, van Vugt M, Kabaghe AN, et al. Community-based malaria control in southern Malawi: a description of experimental interventions of community workshops, house improvement and larval source management. Malar J Jul. 2018;16(1):266. 10.1186/s12936-018-2415-1.

33. Awasthi KR, Jancey J, Clements ACA, Rai R, Leavy JE. Community engagement approaches for malaria prevention, control and elimination: a scoping review. BMJ Open Feb. 2024;15(2):e081982. 10.1136/bmjopen-2023-081982.
34. Kasjono HS, Yamtana, Sugianto, Sintawati RE. Community Engagement Approach to Successful Malaria Elimination in Kulon Progo District. Kemas. 2025;21(1). 10.15294/kemas.v21i1.24999.
35. Ingabire CM, Hakizimana E, Rulisa A, et al. Community-based biological control of malaria mosquitoes using Bacillus thuringiensis var. israelensis (Bti) in Rwanda: community awareness, acceptance and participation. Malar J Oct. 2017;3(1):399. 10.1186/s12936-017-2046-y.
36. Shirima G, Masserey T, Gervas H, Chitnis N, Kiware S, Mirau S. Assessing the role of community involvement and capacity building in larviciding applications for malaria control in Africa: A scoping review. Curr Res Parasitol Vector Borne Dis. 2025;8:100307. 10.1016/j.crpvbd.2025.100307.
37. Watanabe N, Kaneko A, Yamar S, et al. A prescription for sustaining community engagement in malaria elimination on Aneityum Island, Vanuatu: an application of Health Empowerment Theory. Malar J Jul. 2015;31:14:291. 10.1186/s12936-015-0779-z.
38. Ngadjeu CS, Talipouo A, Kekeunou S, et al. Knowledge, practices and perceptions of communities during a malaria larviciding randomized trial in the city of Yaounde, Cameroon. PLoS ONE. 2022;17(11):e0276500. 10.1371/journal.pone.0276500.
39. Dambach P, Traore I, Sawadogo H, et al. Community acceptance of environmental larviciding against malaria with Bacillus thuringiensis israelensis in rural Burkina Faso - A knowledge, attitudes and practices study. Glob Health Action Jan. 2021;1(1):1988279. 10.1080/16549716.2021.1988279.
40. Kahamba NF, Tarimo FS, Kifungo K, et al. Societal uses of the main water bodies inhabited by malaria vectors and implications for larval source management. Malar J Nov. 2024;9(1):336. 10.1186/s12936-024-05154-z.
41. Shafique M, Lopes S, Doum D, et al. Implementation of guppy fish (Poecilia reticulata), and a novel larvicide (Pyriproxyfen) product (Sumilarv 2MR) for dengue control in Cambodia: A qualitative study of acceptability, sustainability and community engagement. PLoS Negl Trop Dis Nov. 2019;13(11):e0007907. 10.1371/journal.pntd.0007907.
42. Perez-Guerra CL, Rosado-Santiago C, Ramos SA, et al. Acceptability of emergent Aedes aegypti vector control methods in Ponce, Puerto Rico: A qualitative assessment. PLOS Glob Public Health. 2024;4(3):e0002744. 10.1371/journal.pgph.0002744.
43. Aswani S, Albert S, Love M. One size does not fit all: Critical insights for effective community-based resource management in Melanesia. Mar Policy. 2017;81:381–91. 10.1016/j.marpol.2017.03.041. 2017/07/01/.
44. Allen T, Crouch A, Russell TL, Topp SM. Factors influencing the community participation approaches used in Aedes mosquito management in the Torres Strait, Australia. BMC Public Health Oct. 2023;12(1):1993. 10.1186/s12889-023-16942-8.
45. Naing C, Htet NH, Tung WS, Aung HH, Whittaker MA. Facilitators and barriers to engaging communities in health service research on dengue control in Indo-Pacific region: a systematic

review. BMC Public Health Oct. 2023;5(1):1924. 10.1186/s12889-023-16845-8.

46. Dori A, Farquhar R, Kelebi T, et al. Partnership-Based Approach to Infectious Disease Research in Papua New Guinea. In: Stewart Ibarra A, LaBeaud AD, editors. Transforming Global Health Partnerships: Critical Reflections and Visions of Equity at the Research-Practice Interface. Springer Nature Switzerland; 2024. pp. 133–46.
47. Farquhar R, Dori A, MacCana S, et al. STRIVE PNG: using a partnership-based approach in implementation research to strengthen surveillance and health systems in Papua New Guinea. Health Res Policy Syst Apr. 2022;2(1):35. 10.1186/s12961-022-00840-3.
48. Diiro GM, Kassie M, Muriithi BW, et al. Are individuals willing to pay for community-based eco-friendly malaria vector control strategies? A case of mosquito larviciding using plant-based biopesticides in Kenya. Sustain (Switzerland). 2020;12(20). 10.3390/su12208552.