Current Research in Parasitology & Vector-Borne Diseases 1 (2021) 100038

Contents lists available at ScienceDirect

Current Research in Parasitology & Vector-Borne Diseases

journal homepage: www.editorialmanager.com/crpvbd/default.aspx

Biolarviciding for malaria vector control: Acceptance and associated factors in southern Tanzania

Athuman Yusuph Matindo [a], Secilia Ng'weshemi Kapalata [b], Leonard Kamanga Katalambula [c], Eugene Benjamin Meshi [b], David Zadock Munisi [d,*]

[a] Department of Health, Liwale District Council, Liwale, Tanzania
[b] Department of Community Medicine, School of Medicine and Dentistry, University of Dodoma, Dodoma, Tanzania
[c] Department of Public Health, School of Nursing and Public Health, University of Dodoma, Dodoma, Tanzania
[d] Department of Microbiology and Parasitology, School of Medicine and Dentistry, University of Dodoma, Dodoma, Tanzania

ARTICLE INFO

Keywords:
Biolarviciding
Malaria
Mosquitoes
Community acceptance
Southern Tanzania

ABSTRACT

In the struggle towards malaria elimination, the government of Tanzania scaled up nationwide biolarviciding to supplement existing vector control measures. As with any community-based intervention, success of biolarviciding depends on acceptability to the community. This study sought to ascertain acceptance of biolarviciding among communities in southern Tanzania. A mixed-method study involved administration of questionnaires to 400 community members, with 32 key informant interviews and five in-depth interviews also held in selected councils of southern Tanzania. A multistage sampling method was employed in selecting community members, with purposive sampling used in selecting key informant and in-depth interviewees. The study found high community acceptance (80.3%) despite very low (19.3%) knowledge on biolarviciding. Community perception that biolarvicide is effective in reducing malaria infection was found to be a significant predictor of community acceptance to biolarviciding: those who perceived biolarvicide as effective in reducing malaria were five times more likely to accept biolarviciding compared to those with a negative perception (odds ratio = 4.67, 95% CI: 1.89–11.50, $P = 0.001$). We conclude that biolarviciding received high acceptance among community members in southern Tanzania and therefore the implementation is likely to get strong support from community members. To enhance and make community acceptance sustainable, heath education to enhance the level of community knowledge on biolarviciding is recommended.

1. Introduction

Malaria remains endemic in at least 87 countries in the world, including Tanzania (National Bureau of Statistics of Tanzania, 2018; WHO, 2019). Strategies to control the disease involve adoption of integrated vector control methods that mainly involve the use of techniques that target adult mosquitoes such as long-lasting insecticide-treated bed nets and indoor residual spraying (Musoke et al., 2018). However, these methods are challenged by mosquito development of resistance to the commonly used insecticides and changes in biting behaviors (Corbel et al., 2012; Walker et al., 2016; Choi and Furnival-Adams, 2019). The WHO recommends countries to engage in additional control techniques that avoid use of insecticides, or those used for adult control, such as environmental modification, manipulation and biological control, e.g. biolarviciding, depending on suitability in local contexts (WHO, 2013). Biolarviciding, which is the regular application of biological insecticides to waterbodies, has been observed to be effective in controlling malaria mosquito populations, and is considered safe for humans with limited adverse environmental impact (WHO, 2013; Choi et al., 2019).

In 2017 Tanzania scaled up a nationwide biolarviciding implementation that involved all mainland urban and rural areas (National Audit Office, 2018; President's Office Regional Administration and Local Government, 2018). The implementation adopted a community-based approach in which community members are tasked with breeding site identification, application of biolarvicides, and collaborating in monitoring the programme progress (National Malaria Control Programme, 2016b). Such an approach requires community acceptance, approval for interventions to be implemented in their environment, and for them to share opinions and take part in its implementation (Dambach et al., 2018).

* Corresponding author.
E-mail addresses: david.munisi@udom.ac.tz, massugii@gmail.com (D.Z. Munisi).

https://doi.org/10.1016/j.crpvbd.2021.100038
Received 10 March 2021; Received in revised form 23 May 2021; Accepted 15 June 2021

As with any novel intervention, the acceptability of biolarviciding may be influenced by community knowledge and attitude towards its effectiveness and safety (Gücin and Berk, 2015; Dambach et al., 2018; Rubin et al., 2020). Anecdotal reports indicated that there has been a low level of implementation of biolarviciding in some regions in the country with low community acceptance as one of the contributing factors (Mboera et al., 2014; President's Malaria Initiative [Tanzania], 2018). There is therefore a need to establish the levels of community acceptance for biolarviciding, and enhancing or limiting factors, to identify necessary actions to enhance acceptance and levels of implementation. This study aimed to address these questions in the councils of Lindi and Mtwara in southern Tanzania.

2. Materials and methods

2.1. Study area and design

The study was conducted in four councils of southern Tanzania, two from Lindi region (Lindi Municipal Council and Nachingwea District Council) and two from Mtwara region (Mtwara Mc and Nanyamba Town Council). According to the 2012 population census, 864,652 people live in Lindi region and 1,270,854 in Mtwara region (National Bureau of Statistics of Tanzania, 2013). The study employed a mixed-method cross-sectional design to assess the acceptability of community to biolarviciding, which across Tanzania involves the application of microbial biolarvicides, *Bacillus thuringiensis israelensis* (Bti) and *Bacillus sphaericus* (Bs), to waterbodies surrounding human habitats (National Malaria Control Programme, 2016a).

2.2. Sample size and sampling procedure

Quantitative data were collected by administering questionnaires to 400 community members, 100 from each council. A multistage sampling procedure was employed. This involved purposive selection of Mtwara and Lindi regions based on a report showing the regions are among the areas where biolarviciding implementation was low (President's Office Regional Administration and Local Government, 2018). After purposive selection of regions, two District Councils (DC) were randomly selected from each region, then from each DC, wards were randomly sampled. From each selected ward, ten cell leader units were randomly selected, followed by households in which one member of the family was selected.

Qualitative data were collected by conducting 32 key informant interviews from community leaders; which included village chairpersons and members of village health committees, and 5 in-depth interviews with vector control coordinators. The interviewees were purposively selected based on the position they hold in the respective study areas.

2.3. Data collection procedures

A structured questionnaire was administered by the researchers to community members. The questionnaire was prepared in English and translated into Kiswahili. Respondents were asked about their knowledge on biolarviciding, perception of biolarvicide safety, perception of biolarvicide effectiveness in reducing mosquitoes, and perception of biolarvicide effectiveness in reducing malaria; finally, they were asked to indicate the likelihood they would accept biolarvicide application in their surrounding environment, both on their property and in public places.

Qualitative data were collected through recorded interviews and an interview guide prepared in English and translated into Kiswahili. The interview guide was adapted from a recommended tool for conducting scaling up case studies developed by the WHO in collaboration with Expand Net and Management System International (WHO, Expand Net & Management Systems International, 2007) and used in a previous study (Quintero et al., 2017).

2.4. Data processing and analysis

Quantitative data were entered into IBM SPSS version 20.0 (IBM SPSS Statistics for Windows, Version 20.0. IBM Corp., Armonk, NY, USA) for management and analysis. Participants were stratified by age into 4 groups (15–24 years, 25–54 years, 55–64 years, and $>$ 65 years) based on labour working group classifications (ILO, 2012). Stratification of occupation and education level was based on existing reports on socio-economic profiles (Planning Commission & Regional Commissioner's Office Mtwara, 1997; National Bureau of Statistics of Tanzania, 2017). Continuous variables were reported as means and standard deviations, categorical variables were reported as frequencies and percentages. Univariable logistic regression analysis was performed to analyse the effect of the explanatory variables (knowledge on biolarvicides, perception of biolarvicide safety, perception of biolarvicide effectiveness in reducing mosquito and perception of biolarvicide effectiveness in reducing malaria) on the outcome variable (whether or not community member would accept biolarvicide application in their environment). Variables with a *P*-value of ≤ 0.2 were then entered into a multivariable logistic regression analysis, which adjusted for identified confounders (age, gender, marital status and education level).

Qualitative data from key informant interviews and in-depth interviews audio records were transcribed verbatim by the researchers who conducted the sessions. The transcript was then translated into English by a linguist at The University of Dodoma. Translated transcripts were entered into ATLS.ti version 8 for data management and analysis (ATLAS.ti Scientific Software Development GmbH. Qualitative Data Analysis, Version 8.0). Thematic analysis was perfomed using guidance for framework of analysis (Gale et al., 2013) in which transcripts were interpreted into codes, that were generated inductively by three interdependent coders, then grouped into categories which were merged to generate themes based on similarities of their meaning. All participants' explanations were carefully reviewed and the significant statements that were directly related to the study questions were extracted and reported.

3. Results

3.1. Quantitative data

A total of 400 community members were recruited to participate in the study (Table 1). The age of the participants ranged from 18 to 82 years with a mean of 41 (standard deviation = 15.4). Of all the respondents, 80.3% expressed acceptance to biolarviciding. Chi-square test results revealed none of these factors had a significant relationship with community acceptance (Table 2). Of all the respondents 19.3% had knowledge on biolarviciding. Chi-square test results revealed that

Table 1
Socio-demographic characteristics of community member respondents

Variable	Category	*n*	Percent
Age (years)	15–24	46	11.5
	25–54	277	69.3
	55–64	39	9.8
	65+	38	9.5
Gender	Male	185	46.2
	Female	215	53.8
Marital status	Married	211	52.8
	Unmarried	189	47.2
Education	No formal education	41	10.2
	Primary education	221	55.3
	Secondary and beyond	138	34.5
Occupation	Small-scale farmers	249	62.3
	Formal employed	26	6.5
	Other	125	31.2
Council	Lindi MC	100	25.0
	Nachingwea DC	100	25.0
	Mtwara Mc	100	25.0
	Nanyamba TC	100	25.0

Table 2
Community acceptance of biolarviciding across demographic characteristics

Variable	Category	Community acceptance		*df*	Chi-square (*P*-value)
		No, *n* (%)	Yes, *n* (%)		
Age (years)	15–24	5 (10.9)	41 (89.1)	3	6.95 (0.073)
	25–54	59 (21.3)	218 (78.7)		
	55–64	4 (10.3)	35 (89.7)		
	65+	11 (29.0)	27 (71.0)		
Gender	Male	43 (23.2)	142 (76.8)	1	2.65 (0.104)
	Female	36 (16.7)	179 (83.3)		
Marital status	Married	48 (22.8)	163 (77.2)	1	2.53 (0.111)
	Unmarried	31 (16.4)	158 (83.6)		
Education	No formal education	10 (24.4)	31 (75.6)	2	4.77 (0.092)
	Primary education	35 (15.8)	186 (84.2)		
	Secondary and beyond	34 (24.6)	104 (75.4)		
Occupation	Small-scale farmers	46 (18.5)	203 (81.5)	2	0.81 (0.666)
	Formal employed	5 (19.2)	21 (80.8)		
	Other	28 (22.4)	97 (77.6)		
Council	Lindi MC	20 (20.0)	80 (80.0)	3	1.56 (0.668)
	Nachingwea DC	16 (16.00)	84 (84.0)		
	Mtwara Mc	23 (23.00)	77 (77.0)		
	Nanyamba TC	20 (20.00)	80 (80.0)		
Total		79 (19.8)	321 (80.3)		

Abbreviation: df, degrees of freedom.

education and council of residence had a statistically significant association with knowledge on biolarviciding (Table 3). Of all the respondents 30.8% perceived biolarvicides as safe to human health and the environment. Chi-square test results revealed that only council of residence had a statistically significant association with perception of biolarvicide safety to human health (Table 4). Of all the respondents 49.3% perceived biolarvicides to be effective at reducing mosquito abundance. Chi-square test results revealed that only level of education and council of residence had a statistically significant association with perception of biolarvicide effectiveness at reducing mosquito abundance (Table 5).

Table 3
Community knowledge of biolarviciding for mosquito control

Variable	Category	Community knowledge		*df*	Chi-square (*P*-value)
		No, *n* (%)	Yes, *n* (%)		
Age (years)	15–24	33 (71.7)	13 (28.3)	3	7.29 (0.063)
	25–54	222 (80.1)	55 (19.9)		
	55–64	32 (82.0)	7 (18.0)		
	65+	36 (94.7)	2 (5.3)		
Gender	Male	142 (76.8)	43 (23.2)	1	3.53 (0.060)
	Female	181 (84.2)	34 (15.8)		
Marital status	Married	168 (79.6)	43 (20.4)	1	0.37 (0.545)
	Unmarried	155 (82.0)	34 (18.0)		
Education	No formal education	39 (95.1)	2 (4.9)	2	6.83 (0.033)[a]
	Primary education	178 (80.5)	43 (19.5)		
	Secondary and beyond	106 (76.8)	32 (23.2)		
Occupation	Small-scale farmers	199 (79.9)	50 (20.1)	2	0.33 (0.848)
	Formal employed	21 (80.8)	5 (19.2)		
	Other	103 (82.4)	22 (17.6)		
Council	Lindi MC	79 (79.0)	21 (21.0)	3	12.14 (0.007)[a]
	Nachingwea DC	71 (71.0)	29 (29.0)		
	Mtwara Mc	83 (83.0)	17 (17.0)		
	Nanyamba TC	90 (90.0)	10 (10.0)		
Total		323 (80.7)	77 (19.3)		

Abbreviation: df, degrees of freedom.
[a] Statistically significant ($P < 0.05$).

Table 4
Community perception of biolarvicide safety to humans and environment

Variable	Category	Safe to environment?		*df*	Chi-square (*P*-value)
		No, *n* (%)	Yes, *n* (%)		
Age (years)	15–24	30 (65.2)	16 (34.8)	3	3.50 (0.321)
	25–54	187 (67.5)	90 (32.5)		
	55–64	30 (76.9)	9 (23.1)		
	65+	30 (79.0)	8 (21.0)		
Gender	Male	128 (69.2)	57 (30.8)	1	0.00 (0.980)
	Female	149 (69.3)	66 (30.7)		
Marital status	Married	156 (73.9)	55 (26.1)	1	4.60 (0.320)
	Unmarried	121 (64.0)	68 (36.0)		
Education	No formal education	34 (82.9)	7 (17.1)	2	5.63 (0.060)
	Primary education	155 (70.0)	66 (30.0)		
	Secondary and beyond	88 (63.8)	50 (36.2)		
Occupation	Small-scale farmers	180 (72.3)	69 (27.7)	2	4.45 (0.108)
	Formal employed	14 (53.9)	12 (46.1)		
	Other	83 (66.4)	42 (33.6)		
Council	Lindi MC	65 (65.0)	35 (35.0)	3	19.01 (<0.001)[a]
	Nachingwea DC	55 (55.0)	45 (45.0)		
	Mtwara Mc	81 (81.0)	19 (19.0)		
	Nanyamba TC	76 (76.0)	24 (24.0)		
Total		277 (69.2)	123 (30.8)		

Abbreviation: df, degrees of freedom.
[a] Statistically significant ($P < 0.05$).

Chi-square test results revealed that only level of education and council of residence had a statistically significant association with perception of biolarvicide effectiveness in reducing malaria prevalence (Table 6).

Univariable logistic regression analysis was performed to determine factors showing possible association with community acceptance (using a

Table 5
Community perception of biolarvicide effectiveness in reducing mosquito abundance

Variable	Category	Effective?		*df*	Chi-square (*P*-value)
		No, *n* (%)	Yes, *n* (%)		
Age (years)	15–24	17 (37.0)	29 (63.0)	3	4.45 (0.217)
	25–54	144 (52.0)	133 (48.0)		
	55–64	20 (51.3)	19 (48.7)		
	65+	22 (57.9)	16 (42.1)		
Gender	Male	99 (53.5)	86 (46.5)	1	1.05 (0.305)
	Female	104 (48.4)	111 (51.6)		
Marital status	Married	107 (50.7)	104 (49.3)	1	0.00 (0.987)
	Unmarried	96 (50.8)	93 (49.2)		
Education	No formal education	31 (75.6)	10 (24.4)	2	11.30 (0.004)[a]
	Primary education	106 (48.0)	115 (52.0)		
	Secondary and beyond	66 (47.8)	72 (52.2)		
Occupation	Small-scale farmers	132 (53.0)	117 (47.0)	2	3.28 (0.194)
	Formal employed	9 (34.6)	17 (65.4)		
	Other	62 (49.6)	63 (50.4)		
Council	Lindi MC	32 (32.0)	68 (68.0)	3	50.52 (<0.001)[a]
	Nachingwea DC	34 (34.0)	66 (66.0)		
	Mtwara Mc	69 (69.0)	31 (31.0)		
	Nanyamba TC	68 (68.0)	32 (32.0)		
Total		203 (50.7)	197 (49.3)		

Abbreviation: df, degrees of freedom.
[a] Statistically significant ($P < 0.05$).

Table 6
Community perception of biolarviciding effectiveness in reducing malaria prevalence

Variable	Category	Effective at reducing malaria prevalence?		*df*	Chi-square (*P*-value)
		No, *n* (%)	Yes, *n* (%)		
Age (years)	15–24	33 (71.7)	13 (28.3)	3	6.58 (0.086)
	25–54	222 (80.1)	55 (19.9)		
	55–64	32 (82.1)	7 (17.9)		
	65+	36 (94.7)	2 (5.3)		
Gender	Male	142 (76.8)	43 (23.2)	1	2.16 (0.141)
	Female	181 (84.2)	34 (15.8)		
Marital status	Married	168 (79.6)	43 (20.4)	1	0.27 (0.602)
	Unmarried	155 (82.0)	34 (18.0)		
Education	No formal education	39 (95.1)	2 (4.9)	2	6.88 (0.032)[a]
	Primary education	178 (80.5)	43 (19.5)		
	Secondary and beyond	106 (76.8)	32 (23.2)		
Occupation	Small-scale farmers	199 (79.9)	50 (20.1)	2	1.56 (0.459)
	Formal employed	21 (80.8)	5 (19.2)		
	Other	103 (82.4)	22 (17.6)		
Council	Lindi MC	79 (79.0)	21 (21.0)	3	42.39 (<0.001)[a]
	Nachingwea DC	71 (71.0)	29 (29.0)		
	Mtwara Mc	83 (83.0)	17 (17.0)		
	Nanyamba TC	90 (90.0)	10 (10.0)		
Total		323 (80.7)	77 (19.3)		

Abbreviation: df, degrees of freedom.
[a] Statistically significant ($P < 0.05$).

threshold of *P*-value ≤ 0.2 for any factor level *vs* the reference group, for inclusion in subsequent multivariable logistic regression analysis. Despite retention of most factors from the univariable analysis, only two were significant in the multivariable analysis, marital status and most notably perception of malaria reduction (Table 7). The odds of accepting biolarviciding in those who had positive perception that biolarvicide is effective in reducing malaria were more than 4 times higher (AOR = 4.67, 95% CI = 1.89–11.50, $P = 0.001$) than in those who had negative perception. Neither knowledge of biolarviciding, nor perception of biolarviciding as safe were significant predictors for community acceptance of biolarviciding (Table 7).

3.2. Qualitative data

3.2.1. Key informant interviews

3.2.1.1. Acceptance of biolarviciding among community leaders. All 32 (100%) community leaders showed acceptance of biolarviciding. They believed that the government is doing the right thing to reduce mosquito bites, as illustrated by the following responses:

- *"I should say that I am one of the people who said that the government has made the right decision. This is because there are a lot of mosquitoes in our area where larviciding is required to a great extent."* (KI 15, male, community leader).
- *"When it was announced, I am one of the people who said that the government has made a good decision. There are many areas with standing water here which have become mosquito breeding sites. We would be happy if the activity was done as it was announced here. It would be an important decision if the government will help its people to fight against mosquitoes."* (KI 14, male, community leader).

Table 7
Logistic regression analysis to identify predictors of community acceptance

Variable	Univariable analysis			Multivariable analysis		
	OR	95% CI	*P*-value	AOR	95% CI	*P*-value
Age (years)						
15–24	1					
25–54	0.45	0.17–1.19	0.108	0.65	0.23–1.84	0.416
55–64	1.07	0.26–4.28	0.927	1.25	0.28–5.60	0.771
65+	0.30	0.09–0.96	0.042	0.38	0.10–1.39	0.145
Gender						
Male	1					
Female	1.51	0.92–2.47	0.115	1.16	0.67–2.00	0.593
Marital status						
Married	1					
Unmarried	1.50	0.91–2.48	0.113	2.01	1.11–3.64	0.022
Education						
No formal education	1					
Primary education	1.71	0.77–3.81	0.186	1.33	0.55–3.23	0.534
Secondary and beyond	0.99	0.44–2.22	0.974	0.62	0.24–1.63	0.334
Knowledge						
Low	1					
High	1.26	0.66–2.43	0.48			
Perception of safety						
Negative	1					
Positive	1.97	1.09–3.57	0.026	0.82	0.39–1.72	0.593
Perception of mosquito reduction						
Negative	1					
Positive	3.63	2.09–6.30	<0.001	1.20	0.47–3.12	0.703
Perception of malaria reduction						
Negative	1					
Positive	5.04	2.93–8.68	<0.001	4.67	1.89–11.50	0.001

Abbreviations: 1, reference; CI, confidence interval; OR, odds ratio; AOR, adjusted odds ratio.

3.2.1.2. Knowledge of biolarviciding among community leaders. Of 32 interviewees, 11 (34.4%) interviewees knew that biolarviciding is one of the methods used for control of mosquito abundance. When asked "What is biolarviciding?" one interviewee responded that:

- *"In my understanding, this is a process of killing insects in standing water to destroy breeding of insects; the insects which if we don't kill will spread fever."* (KI 03, male, community leader).

Although some interviewees were not aware of biolarviciding being implemented in their area, some had past experience which demonstrated their knowledge, for example:

- *"I remember it was in the 1980s. I remember they were biolarviciding in houses, in toilets. Honestly, it was a good activity. It reduced mosquitoes here. I have never seen it these days. I have never seen it since when I became a leader."* (KI 06, male, community leader).
- *"I have heard of that. It was in a different region. There was this exercise where they were spraying chemicals; outside and inside to kill insects."* (KI 21, male, community leader).

One interviewee reported to have received education on biolarviciding from the health expert:

- *"About larviciding, we have been educated by the officials from our town council. We were told that there will be larvicide that will be brought here from Kibaha, we were told that it will be sprayed on vegetables, in forests, and in areas where there are standing waters and on grasses because they are breeding areas."* (KI 16, male, community leader).

However, the majority (65.6%) of interviewees had no knowledge of biolarviciding. When asked to mention methods used to control mosquitoes in the area, one interviewee responded that:

- *"The only methods I know to be used are self-protection methods; one may have a mosquito net, or if you can buy some mosquito pests. Only that!"* (KI 05, female, community leader).

Other interviewees showed to have no knowledge that biolarviciding is one of the methods for mosquito control as they responded to have never heard about it before.

- *"There are chemicals that we buy from shops for repelling mosquitoes, but I know nothing about biolarvicide."* (KI 11, male, community leader).
- *"If that [biolarviciding] is happening, may be for individual family or person, but not something communal. What I know there was spraying of chemicals in that pond in previous years but not in recent years."* (KI 20, male, community leader).

One (in-depth) interviewee highlighted that the challenge in gathering together community members was a reason why some community members are not aware of biolarviciding:

- *"This is because we do sit with them [community members] in meetings, particularly ward meetings, street meetings and we tell them something will be done and it will be done on a particular day and time. Many citizens don't attend meetings when we call, you may find only ten people attending a meeting … We talk to the ten people because we can't easily get 30 or 40 people to attend meetings here. We do tell those who attend meetings to inform their neighbours that the exercise will be done on a certain date."* (IDI 03, male, vector control coordinator).

3.2.1.3. Perception of biolarvicide safety among community leaders. Although all interviewees showed acceptance to biolarviciding, 53.1% of interviewees' responses suggested trust in biolarvicide safety. This was based on experience or knowledge they had on biolarviciding or trust in the government.

- *"In my understanding and having done this work for a long time, it does not harm, I can confirm that it is safe. I would be the first person to be affected if it was not safe."* (KI 3, male, community leader).
- *"We don't have doubt, because I believe the government will not bring something harmful to its people."* (KI 31, male, community leader).

About 18.7% expressed distrust in biolarvicide safety; they regarded biolarvicide as a poisonous chemical like other chemicals used to treat insects:

- *"Basically, if they kill mosquito, they might be not safe … The community needs to be informed that we have to apply biolarvicide in small water collections in this area, and they should be told of the effects the larvicide may have, especially because children play in the areas."* (KI 17, male, community leader).

Others (28.0%) were uncertain whether it is harmful or not. They reported to have no information regarding the safety and requested community education on biolarviciding:

- *"I can't say for sure. They had to tell us that we prohibit from using this water because it is harmful or not."* (KI 28, male, community leader).

3.2.1.4. Perception of biolarvicide effectiveness among community leaders. Community leaders showed trust in the biolarvicide effectiveness to reduce mosquitoes and malaria. When asked whether biolarvicide can be helpful in reducing mosquitoes, one interviewee shared his past experience and stated that:

- *"Yes! Because years back; 1970s, there were council employee[s] who were doing an activity like this. They would clean the environment and spray chemicals in toilets, streams of water and bushes. At that time there was a lot of mosquitoes in our area; but it dramatically reduced."* (KI 23, male, community leader).

However, one interviewee showed distrust in biolarvicide ability to control mosquitoes based on her reported past experience in the area:

- *"I remember they applied biolarvicide in standing water, in garbage areas and the toilets. But I think the chemical was fake! Or how come it didn't kill [mosquitoes]. They applied biolarvicide but the mosquitoes were still there and, as a street leader, I was getting complaints [from community members]. They said, "chairperson, you brought us people to apply biolarvicide but mosquitoes are still there."* (KI 4, female, community leader).

One of the interviewees who expressed trust in biolarvicide ability to reduce malaria, stated that:

- *"When they apply biolarvicide in the breeding sites, mosquitoes will be reduced. We will benefit from it by reducing the chances of getting malaria."* (KI 02, male, community leader).

3.2.2. In-depth interviews

Five in-depth interviews were conducted, four involving Vector Control Coordinators and one involving a Community Own Resource Person. The interview focused on (i) community acceptance of biolarviciding, and (ii) provision of health education to community members.

All four interviewees affirmed that biolarviciding was being implemented in their councils at different scales and that they provide education to community members.

- *"This activity started in our council in 2018. Larvicides were brought in our council, and we started making awareness campaigns around the community through the community/ward leaders. Then we explained how the activity will be done in the area. Thereafter, we identified the breeding sites … Having identified the area, we started larviciding according to the ways we planned."* (IDI 2, female, Vector Control Coordinator).

Another interviewee reported that biolarviciding had received high acceptance among the community members.

- *"We have been getting feedback from the residents whose areas were applied biolarvicide. They say that they don't see mosquitoes after we applied biolarvicide! So, we can tell its effectiveness from the feedback we get from these people who either report to the Ward offices or directly inform the health department asking for the exercise to be done for the second or the third time and sorts of things like that. With this feedback, we believe that this is one of the interventions that helps to decrease malaria infections."* (IDI 01, male, Vector Control Coordinator).

4. Discussion

Information regarding community acceptance, or reasons for not accepting an intervention, can guide the development of proper educational messages aiming at improving programme performance (WHO, 2015). This study was conducted to determine the level of

community acceptance to biolarviciding for malaria vector control in southern Tanzania. Generally, the study found that the level of acceptance of biolarviciding for malaria vector control among community members in southern Tanzania was reasonably high, with over 80% expressing acceptance of biolarviciding in their living environment. However, the acceptability of biolarviciding found in this study is slightly lower than in earlier reports from east-central Tanzania (92.9%; Mboera et al., 2014) and from north-eastern Tanzania (97%; Wambui, 2016).

Previous studies have shown that the acceptability of an intervention is influenced by, among other things, knowledge, confidence in safety and benefits of the intervention (Mboera et al., 2014; Gücin and Berk, 2015; Dambach et al., 2016). Our study found a low level of knowledge on biolarviciding as a mosquito control method, despite application in the study areas. This observation is likely to be due to lack of adequate community sensitization and expert education on biolarviciding. Lack of knowledge among community members was also found in the study by Mboera et al. (2014). However, we also found that knowledge of biolarviciding did not have any relationship with acceptance of the intervention. Lack of association between community knowledge on an intervention and its acceptance has also been reported in another study carried out in counties in the Seattle area, USA (Dempsey et al., 2006). Nevertheless, this does not downplay the importance of providing health education on the benefit of an intervention, but it does highlight the importance of uncovering other factors more influential in acceptance of the intervention.

This study found respondents' perception of biolarvicide effectiveness to reduce malaria was a significant predictor for community biolarvicide acceptance (Table 7). This factor could explain the difference in acceptance rate between the present and previous studies. In the present study, only 58.5% of respondents had confidence that biolarvicide can reduce malaria, much lower than the 91.2% reported elsewhere (Mboera et al., 2014). Difference in acceptability could also be explained by different study areas; whereas in the previous study respondents were small-scale farmers living near rice fields where water bodies are available throughout the year. In the present study, most respondents would experience seasonal breeding sites which could have influenced their perception of the risk for malaria, a factor that is strongly associated with acceptance of biolarviciding.

The study found that only a third of community members and half of community leaders interviewed trusted in biolarvicide safety. This could be due to lack of knowledge on biolarvicides, where two thirds of the interviewed community leaders had no knowledge on biolarviciding as a method for malaria control. The observed level of trust in this study was much lower than the 73.4% found in the study by Mboera et al. (2014). Nonetheless, trust in biolarvicide safety had little effect on acceptance of biolarviciding, this is likely to have been influenced by trust that people have in the government as observed when one key informant interviewee said "*We don't have doubt, because I believe the government will not bring something harmful to its people.*"

Employing a mixed-method that allowed the use of more than one method to collect data from the study population is a strength of this study as this has been observed to enhance the study validity (Creswell and Plano Clark, 2006). We, however, acknowledge that the study was limited in some ways. These include the use of convenience-based selection of study participants at household levels which was likely to cause selection bias, and the difference in time between the study and biolarvicide application: participants' attitudes during the time of implementation could have been different to that at the time when this study was conducted.

5. Conclusions and recommendations

The results of this study revealed that biolarviciding receives high acceptance among community members in the area of southern Tanzania investigated despite a low knowledge level. However, a high level of acceptance among community members with very low knowledge on biolarviciding does not assure sustained acceptance. Therefore, public health education on biolarviciding through advocacy and community sensitization to improve the level of community knowledge is highly recommended. The education should focus on the benefits and safety of biolarviciding which may help win the acceptance and support of the intervention among community members. Special consideration should be given to small-scale farmers as they account for a majority of the population and expressed least trust in its safety. It is thus important to provide community education on benefits of biolarviciding in malaria reduction together with regular application of biolarviciding at a level that can reduce malaria, which in turn will attract more acceptance on biolarviciding.

Funding

No funding was available for this study.

Ethical approval

Ethical clearance for study and publication was granted from the University of Dodoma Institutional Research Review Committee. All participants gave a verbal consent to participate.

CRediT author statement

Athumani y. Matindo and David Z. Munisi: Conceptualisation, Methodology, Data Curation, Formal analysis, Writing - Original Draft, Review & Editing. David Z. Munisi: Supervision. Eugene B. Meshi, Leonard K. Katalambula and Secilia N. Kapalata: Review & Editing. All authors read and approved the final manuscript.

Declaration of competing interests

The authors confirm that there are no known conflicts of interest associated with this publication and that there has been no significant financial support for this work that could have influenced its outcome.

Acknowledgements

We express our sincere gratitude to the Department of Public Health, University of Dodoma, Tanzania, to which this work was submitted in partial fulfilment of the requirements for the degree of Master of Science in Public Health.

References

Choi, L., Furnival-Adams, J., 2019. Indoor residual spraying for preventing malaria (Protocol). Cochrane Database Syst. Rev. 3, CD013300. https://doi.org/10.1002/14651858.CD013300.

Choi, L., Pryce, J., Richardson, M., Lutje, V., Walshe, D., Garner, P., 2019. Guidelines for malaria vector control. World Health Organization, Geneva. https://www.sciencedirect.com/science/article/pii/S0305750X19303420.

Corbel, V., Akogbeto, M., Damien, G.B., Djenontin, A., Chandre, F., Rogier, C., Henry, M.C., 2012. Combination of malaria vector control interventions in pyrethroid resistance area in Benin: a cluster randomised controlled trial. Lancet Infect. Dis. 12, 617–626. https://doi.org/10.1016/S1473-3099(12)70081-6.

Creswell, J.W., Plano Clark, V.L., 2006. Designing and Conducting Mixed Method Research. Sage Publications Inc., Thousand Oaks, USA, pp. 58–89.

Dambach, P., Traoré, I., Kaiser, A., Sié, A., Sauerborn, R., 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 Publ. Health 16, 1023. https://doi.org/10.1186/s12889-016-3587-7.

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

Dempsey, A.F., Zimet, G.D., Davis, R.L., Koutsky, L., 2006. Factors that are associated with parental acceptance of human papillomavirus vaccines: a randomized intervention study of written information about HPV. Pediatrics 117, 1486–1493. https://doi.org/10.1542/peds.2005-1381.

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

Gücin, N.Ö., Berk, Ö.S., 2015. Technology acceptance in health care: an integrative review of predictive factors and intervention programs. Proc. Soc. Behav. Sci. 195, 1698–1704. https://doi.org/10.1016/j.sbspro.2015.06.263.

ILO, 2012. ILO Estimates of the Economically Active Population: 1990–2010, sixth ed., vol. 2010. International Labour Organization, Geneva https://www.ilo.org/empelm/pubs/WCMS_205815/lang–en/index.htm.

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

Musoke, D., Karani, G., Morris, K., Ndejjo, R., Atusingwize, E., Guwatudde, D., Musoke, M.B., 2018. Integrated approach to malaria prevention at household level in rural communities in Wakiso district, Uganda: impact evaluation of a pilot project. Afr. Health Sci. 18, 1144–1156. https://doi.org/10.4314/ahs.v18i4.35.

National Audit Office, 2018. Annual General Report of the Controller and Auditor General on the Audit of Public Authorities and Other Bodies for the Financial Year 2016/2017, vol. 143. Dar es Salaam,Tanzania. https://www.nao.go.tz.Fuploads.FPUBLIC-AUTHORITIES-OTHER-BODIES-GENERAL-REPORTS-2017-2018.pdf&usg=AOvVaw2te2uA_lIIL_CMIFKOgwH4.

National Bureau of Statistics of Tanzania, 2013. Tanzania 2012 Population and Housing Census. Dar Es Salaam, Tanzania. http://www.tzdpg.or.tz/fileadmin/documents/dpg_internal/dpg_working_groups_clusters/cluster_2/water/WSDP/Background_information/2012_Census_General_Report.pdf.

National Bureau of Statistics of Tanzania, 2017. Women & Men in Tanzania: Facts and Figures 2017. https://www.nbs.go.tz/nbs/takwimu/WomenAndMen/women_and_men_booklet.pdf.

National Bureau of Statistics of Tanzania, 2018. Tanzania Malaria Indicator Survey 2017. https://dhsprogram.com/pubs/pdf/MIS31/MIS31.pdf.

National Malaria Control Programme, 2016a. National Guidelines for Integrated Malaria Vector Control. Ministry of Health Community Development Gender Elderly and Children, Dar es Salaam, Tanzania. https://www.nao.go.tz.Fuploads.FPUBLIC-AUTHORITIES-OTHER-BODIES-GENERAL-REPORTS-2017-2018.pdf&usg=AOvVaw2te2uA_lIIL_CMIFKOgwH4.

National Malaria Control Programme, 2016b. Standard Operating Procedure for Mosquito Larviciding. Dar es Salaam, Tanzania.

Planning Commission & Regional Commissioner's Office Mtwara, 1997. Mtwara Region: Socio-Economic Profile. Dar Es Salaam: Tanzania. www.tzonline/org/mtwara/socio-economic/profile.

President's Malaria Initiative [Tanzania], 2018. Malaria Operational Plan FY 2018. Dar Es Salaam, Tanzania. https://www.pmi.gov/docs/default-source/default-document-library/malaria-operational-plans/fy-2018/fy-2018-tanzania-malaria-operational-plan.

President's Office Regional Administration and Local Government, 2018. Implementation of larviciding for killing malaria mosquito larva. Government of Tanzania, Dar Es Salaam, Tanzania. http://hssrc.tamisemi.go.tz/storage/app/uploads/public/5b8/7d9/9e2/5b87d99e28b3e080525154.pdf.

Quintero, J., García-Betancourt, T., Caprara, A., Basso, C., Garcia da Rosa, E., Manrique-Saide, P., et al., 2017. Taking innovative vector control interventions in urban Latin America to scale: lessons learnt from multi-country implementation research. Pathog. Glob. Health 111, 306–316. https://doi.org/10.1080/20477724.2017.1361563.

Rubin, N.B., Mboera, L.E.G., Lesser, A., Miranda, M.L., Kramer, R., 2020. Process evaluation of a community-based microbial larviciding intervention for malaria control in rural Tanzania. Int. J. Environ. Res. Publ. Health 17, 7309.

Walker, P.G.T., Griffin, J.T., Ferguson, N.M., Ghani, A.C., 2016. Estimating the most efficient allocation of interventions to achieve reductions in *Plasmodium falciparum* malaria burden and transmission in Africa: a modelling study. Lancet Glob. Health 4, e474–e484. https://doi.org/10.1016/S2214-109X(16)30073-0.

Wambui, D., 2016. Knowledge, attitudes, and perceptions towards microbial larviciding in malaria vector control, Lower Moshi Tanzania: a mixed methods study. MSc Thesis, Duke University, Durham, USA. https://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/13449/Wambui_duke_0066N_13792.pdf?sequence=1.

WHO, 2013. Larval source management: a supplementary measure for malaria vector control. World Health Oganization, Geneva.

WHO, 2015. Indoor residual spraying: an operational manual for indoor residual spraying (IRS) for malaria transmission control and elimination. World Health Organization, Geneva. https://www.who.int/home/cms-decommissioning.

WHO, 2019. Malaria Fact Sheet 2019. World Health Organization, Geneva. https://www.who.int/en/news-room/fact-sheets/detail/malaria.

WHO, Expand Net & Management Systems International, 2007. Questions for scaling up case study. Expandnet/WHO/MSI. World Health Organization, Geneva. https://expandnet.net/PDFs/MSI-ExpandNet-IBP%20Case%20Study%2020%20case%20study%20questions.pdf.