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Community participatory mapping of malaria mosquito breeding sites in Mozambique

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Abstract

Background The community involvement and the people's knowledge allow detailed information about the distribution, location, and identification of mosquito breeding-sites. Information which is fundamental for their efficient management and elimination. Since participatory mapping has proven to be an effective tool to identify health determinants, the study aimed to apply the methodology to identify and map potential mosquito breeding-sites in Tambai, Nhamatanda, Mozambique.

Methods A study was conducted using an open-question guide. Discussions were held with 94 participants within ten focus groups, selected in collaboration with local community leaders. A thematic content analysis was performed. Descriptive statistics were used to characterize sociodemographic data. Geographic Positioning System (GPS) was used to compare and map potential breeding-sites. Children under 5 years of age who tested positive for malaria, were georeferenced to the maps.

Results Participants were aware of causes and transmission of malaria, no major differences between groups were observed regarding knowledge and identification of principal potential breeding sites. Gender and age determined specific information, number, and diversity of identified potential breeding sites. A total of 125 potential breeding-sites (36 permanent and 89 temporary) were mapped.

Conclusions Several potential mosquito breeding-sites were identified, located throughout the community, often near house conglomerates and malaria cases. Community participatory mapping could be used to identify potential mosquito breeding-sites by the national malaria control programmes to establish an efficient larval surveillance system, while improving community engagement and control strategies.

Trial registration: ClinicalTrials.gov ID: NCT04419766.

Keywords Malaria, Mosquito breeding sites, Participatory mapping

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Background

The existence of breeding-sites of mosquitoes that cause malaria and their distribution, determines the density of the vector and the transmission of the parasites [1, 2]. Therefore, knowledge of breeding habits, the type of water larva prefer and inhabit, the nature and temporality of breeding-sites are critical to design strategies to reduce malaria burden in the community.

Several studies around Africa and other endemic areas have shown that populations have high level of knowledge about malaria transmission and symptoms [3–6]. Nevertheless, there are still gaps to be filled, highlighting the need for community-based strategies to improve knowledge and consequent actions, to increase sustainability of interventions. Community-based mapping can be very diverse on its approaches, the process involved in these studies, their usefulness, impact and evaluation has been reviewed by Cochrane and colleagues [7]. The method is gaining importance, due to effective use of local accumulated knowledge and population engagement. The participation of the community in breeding-site mapping allows to get additional and detailed information on distribution, location, and identification of the most important mosquito breeding-sites [8], and has also proven to be effective to diagnose causes for disease in the community. Participatory mapping can be especially useful for participants with no or very little schooling, valuing the knowledge and experiences of people with different education level in a community [9, 10]. This method was pivotal to understand the distribution of endemic anthrax in rural Tanzania [11] and allowed a complete identification of urban breeding-sites in Dar es Salaam [12]. It is a simple, straightforward, and low-cost procedure that can easily be integrated into the national malaria control programmes.

In this study, residents from Tambai, a community in Nhamatanda district, Sofala province, Mozambique, were asked to map potential mosquito breeding-sites. Tambai is an isolated rural community, far from the nearest health centre called Mutondo. Mutondo Health Centre is one of the health centres with highest malaria cases in the district, in 2022 reported a positivity rate of 61.2% on 14,432 patients tested [13]. Despite the massive distribution of mosquito nets, and indoor and outdoor spraying in the province and Nhamatanda district, the main malaria control strategies do not reach Tambai community. In this remote area the poor road structure, difficult access, and lack of resources and infrastructures make it difficult to use cutting-edge technology, such as those described by [14] or [15], making participatory mapping an attractive alternative.

The use of participatory mapping to identify potential mosquito breeding sites was used in Mozambique for the

first time for this purpose, showing an enormous potential to identify mosquito breeding-sites in other remote rural areas around the country and the world. Community-based identification of breeding sites can identify the perception of malaria spatial risk by different community groups, guiding health authorities to design tailored control strategies to reduce the impact of mosquito breeding-sites.

This autonomous study was a secondary outcome measures of a field trial (ClinicalTrials.gov ID: NCT04419766) that aimed to evaluate the effectiveness of IR3535, as spatial repellent to reduce malaria prevalence and mosquito vector distribution.

Methods

Study area

The study was held in Tambai community, Nhamatanda district, Sofala Province, Mozambique. Tambai has about 1410 inhabitants and the main activity is agriculture. Tambai is situated on the southern border of Gorongosa National Park. The study area has a hot and humid season from October to March and a dry and cold season from April to September. The transmission of malaria occurs throughout the year and *Plasmodium falciparum* is responsible for almost all malaria cases. The community is served by the Mutondo Health Centre, which is 8 km far and becomes particularly difficult to reach during the rainy season. In addition, there are one community care provider who offer lecture about malaria prevention, rapid diagnostic test and treatment for malaria in the community. Even so the shortage of rapid diagnostic tests, medicines and frequent stock-out of these consumables in the district, coupled to the small quantities of tests and medicines that the community care provider receives makes these services irregular and short most of the times.

Study design and participants

The study was held in May/June 2022, to identify and map the potential mosquito breeding-sites with ten groups of the community. The participants of the ten groups were purposely selected in collaboration with the local community leaders, based on the following criteria: being resident, knowing the community, age, gender, being a community leader or a project technician. The study aimed at obtaining in-deep and detailed information about risk perception of contracting malaria in different age groups and gender, since these characteristics allow them to know different potential breeding-sites, given that contact with water masses is made for different reasons by different gender and age groups. The pilot group was composed of project technicians (FG-pilot), who were hired at the beginning of the project (ClinicalTrials.

gov ID: NCT04419766) and reside in Tambai. The focal groups included: community leaders (FG1), women over 26 years old (FG2), women aged 18–25 years old (FG2), girls aged 14–17 years old (FG4), girls aged 10–13 (FG5), men over 26 years old (FG6), men aged 18–25 years old (FG7), boys aged 14–17 years old (FG8), and boys aged 10–13 years old (FG9).

Mapping process

The mapping activity was audio recorded for all groups and started with the first map sketched by the project technicians as a pilot, followed by the other nine groups, this first map was used as a template thereafter. The mapping process started with a discussion about malaria, its mode of transmission and mosquito breeding places. After the discussion, each group was asked to sketch a map of the community, including access roads and landmarks (e.g. schools, churches, sale stands, fountains, mills, and community leaders' houses). Then, they were asked to place the mosquito breeding-sites on the map, each group marked permanent (P) and temporary (T) mosquito breeding-sites and was asked where malaria was worst and why. The discussion was moderated by a team member with experience in qualitative research using the local language (Chisena). Potential breeding sites identified by all groups were later compiled in a single map. The potential mosquito breeding-sites were later visited and single point georeferenced using handheld Geographic Positioning System (GPS) (GPSmap 62, GARMIN, USA) and placed into the Tambai area of residence map. The final maps were produced using different thematic maps of the study area through the ArcMAP 10.8 (ESRI, USA). The potential breeding sites were not confirmed as having anopheline larvae.

Malaria cases in the community

The field trial aimed to estimate malaria prevalence among children under five years old regardless of their malaria status, a total of 158 children under five years old from all households of study site in Tambai were surveyed in June 2022, an activity associated to the primary outcomes of the project (ClinicalTrials.gov ID: NCT04419766). Of those 156 were analysed by PCR. After the informed consent, finger prick blood drops were collected for Rapid Diagnostic Test (RDT), blood smears and dried blood spot. At the same time, all households were georeferenced using an android mobile GPS (GPSmap 62, GARMIN, USA). Children with RDT-positive for malaria were offered standard malaria treatment, according to national treatment guidelines [16]. Identification of *P. falciparum* was performed using real-time polymerase chain reaction (PCR) tests, performed at the IHMT-NOVA, Lisbon. DNA was extracted using

Chelex® [17] and PCR assay performed using Pf_S18S primers and probe as described by [18]. Malaria cases geographic coordinates were added to the final map to depict their distribution around the community.

Data analysis

The audio recordings were transcribed into Portuguese, checked for transcription fidelity, and translated into English. Field notes taken after every focus group discussion were also used during the analysis. The qualitative data was analysed using manual descriptive thematic analysis [19]. The initial coding frame was developed independently by the project team. After independent coding process, the codes and themes were discussed and harmonised. An Excel spreadsheet (Microsoft, Redmond, WA, USA) was used as a software tool to assist codification and analysis. Sociodemographic characteristics such as gender, age, occupation, level of education and the time of living in the community are presented as median—interquartile interval, and percentage—95% confidence intervals.

The names of breeding-sites were confirmed and harmonized to avoid duplication. The physical maps were digitized, and data used to produce the composite and final maps.

Results

Discussions and participatory map sketching were held with 10 focus groups composed by 94 participants from the community. The majority lived in the community for at least 5 years (70.2%) and had primary school education (68.1%) (Table 1).

Project technicians (Pilot group)

Focus group discussion: Stagnant water was identified as a main potential mosquito breeding-site, participants were aware of mosquito life cycle. The project technicians highlighted the high burden of mosquitoes and malaria in the community, associating malaria cases with mosquito density and the presence of breeding-sites.

Participatory map sketching: After the discussion, the project technicians sketched the first map including the 4 neighbourhood blocks [block 2 (B2), block 3 (B3); block 4 (B4) and block 6 (B6)] of the study and placed the access roads and landmarks. The potential mosquito breeding-site were marked as a circle and identified with “P” for permanent and “T” for temporary (Fig. 1).

Community leaders

Focus group discussion: All 11 local community leaders had heard about malaria and showed knowledge about transmission and symptoms.

Table 1 · Sociodemographic characteristics of the participants

Variable	Project technicians	Community leaders	Women > 26	Women 18–25	Girls 14–17	Girls 10–13	Men > 26	Men 18–25	Boys 14–17	Boys 10–13
N	4	11	10	10	9	10	10	10	10	10
Age (years) ^a	28.5 [25.3–34.0]	42.0 [35.0–55.0]	41.5 [27.8–46.3]	21.5 [18.8–23.3]	14.0 [14.0–15.5]	11.0 [11.0–11.3]	35.5 [32.75–52.25]	22.5 [20.0–23.3]	16.0 [14.8–16.3]	11.5 [10.0–12.3]
Education ^b										
No school	–	–	40.0 [16.8–68.7]	–	–	30.0 [10.8–60.3]	10.0 [0.5–40.4]	–	–	–
Primary	25.0 [1.3–69.9]	90.9 [62.3–99.5]	50.0 [23.7–76.3]	60.0 [31.3–83.2]	60.0 [31.3–83.2]	70.0 [39.7–89.2]	50.0 [23.7–76.3]	50.0 [23.7–76.3]	100.0 [70.1–100.0]	100.0 [72.3–100.0]
Secondary	75.0 [30.1–98.7]	9.1 [0.5–37.7]	10.0 [0.5–40.4]	40.0 [16.8–68.7]	40.0 [16.8–68.7]	–	40.0 [16.8–68.7]	50.0 [23.7–76.3]	–	–
Occupation ^b										
Farmer	–	100.0 [72.3–100.0]	100.0 [72.3–100.0]	100.0 [72.3–100.0]	10.0 [0.5–40.4]	–	80.0 [49.0–96.5]	80.0 [49.0–96.5]	33.3 [12.1–64.6]	–
Student	–	–	–	–	90.0 [59.6–99.5]	70.0 [39.7–89.2]	10.0 [0.5–40.4]	20.0 [3.6–50.9]	66.67 [35.4–87.9]	100.0 [72.3–100.0]
Merchant	–	–	–	–	–	–	10.0 [0.5–40.4]	–	–	–
Without occupation	–	–	–	–	–	30.0 [10.78–60.32]	–	–	–	–
Months of residence in the community ^a	48.0 [104.3–17.3]	120.0 [72.0–156.0]	98.5 [69.0–180.8]	72.0 [50.0–195.0]	168.0 [138.0–182.0]	120.0 [48.0–134.8]	162.0 [84.0–207.0]	71.0 [8.8–100.3]	78.0 [47.8–148.3]	84.0 [55.3–123.0]

^a Median (IIQ)

^b % (95% confidence intervals)



Fig. 1 First participatory sketch mapping by Project Technicians group (Pilot). **A** Team sketching the map, **B** Map produced by the group

“What we understand is that malaria is a disease caused by mosquito bites. ... to have malaria, you start feeling body chill, pain in the joints, all over the body, headache and vomiting.” (Community Leader, FG1)

For the community leaders, the preferred breeding-sites of mosquitoes are the ponds around the houses and forests. They identified the need of water and human blood as essential for breeding.

“Mosquitoes breed in the water, then come into the houses looking for food because they survive on what has blood...” (Community Leaders, FG1)

When asked about the places with higher malaria cases, they mentioned B4 and B6 on the map because there are lakes, ponds, and humidity.

“Where is more malaria is in block 6, near the stands... The second place is in block 4, next to the fountain, there is a lot of malaria, there are many people, ponds... The place has many banana trees and mosquitoes like banana trees because it is humid and mosquitoes like dampness.” (Community Leaders, FG1)

Participatory Map Sketching: The leaders identified the study area on the map and had no difficulty to locate water masses, however, they had different opinions regarding the location of some landmarks compared

to the map of the pilot group (project technicians). The group showed spatial domain of the area and pointed out a high distribution of potential breeding-sites in B4 (Supplementary Fig. 1).

Female groups

Focus group discussion: A total of four groups composed by thirty-eight women and girls aged 10 to over 26 years old participated. They all had heard of malaria, displaying good knowledge regarding its transmission, associating the disease to the mosquito bite.

“... mosquitoes bite someone and bite that one while the one who was bitten has the disease, then bites the other friend, everybody gets malaria...” (Women 18–25, FG3)

All groups recognize lakes, ponds, streams, dumps and dens as potential mosquito breeding-sites and that mosquitoes need water to breed and stay near the houses to bite humans at night. All female groups mentioned that mosquitoes prefer water with specific colours: green (>26-year-old, 18–25 and 10–13 years old), blue and red (14–17 and 10–13 years old) and yellow (10–13 years old). Higher malaria cases were associated by the participants to the presence of potential breeding-sites around the houses and to houses/people concentration. The B4, B3 and B2 were identified as having more malaria cases because of the large number of ponds near the houses.

“Where there is a lot of malaria is because there are a lot of ponds, a lot of houses and people, and the houses are close to each other” (Women >26, FG2)

Participatory Map Sketching: This group discussed the importance of the potential mosquito breeding-sites for the daily activities, such as, washing dishes or clothes, fetching water for bathing.

“There is lot of malaria because people wash their clothes there as it is closer to their residences.” (Women 18–25, FG3)

“The place with malaria is the area of..., all because when they [women and girls] go to fetch water there are a lot of mosquitoes and dumps.” (Boys 14–17, FG8)

The participants expressed differences in perception of the size of the potential mosquito breeding-sites. Female groups were more specific when identifying areas with more malaria, such as the name of a particular stand or specific resident names normally associated with nearby water masses. The lakes named Big Dina were mentioned by all groups. However, women aged over 26, did not place the *Big Dina* lakes on the map (Supplementary Fig. 2).

Male groups

Focus group discussion: The four groups were composed by males aged 10 to over 26 years old. All participants had heard of malaria and associated the disease to the mosquito bite.

“Malaria is a disease caused by mosquito bites.” (Boys 14–17, FG8).

The participants indicated the places and containers with water as the mosquitoes preferred breeding places, showing to have knowledge about high-burden mosquito areas in the community.

“Mosquitoes breed in places that have water, ponds and bottles too.” (Men 18–25, FG7)

Blocks 4 and 3 were also identified as the places with more malaria and they associated the malaria cases with nearby lakes (e.g. Big Dina, Cipriano Maridjangoma), or specific landmarks in the community (e.g. stands, fountains, or residences). The concentration of potential mosquito breeding-sites and the density of the population around the houses was the reason observed for increased malaria cases.

“On the Big Dina lakes side is very bad, it’s full of forest and there are a lot of mosquitoes and people.” (Boys 10–13, FG9)

Regardless of the age differences, the knowledge on malaria causes was similar, they all associated high numbers of malaria cases to the presence of mosquito breeding-sites distributed throughout the community.

Participatory Map Sketching: The study area was easily recognized on the map, as landmarks, streets, and the location and relative size of potential breeding-sites in the community. Active participation on potential breeding-sites placement, and discussions over names, size and location on the map was observed.

Some differences regarding the diversity of potential breeding-sites known by groups were noted (Supplementary Fig. 3). The boys aged 10–13 identified a more potential breeding-sites than the others focus groups, suggesting that their activities are granting them more information on potential breeding-sites and their distribution, than the other groups in the study. Characteristics of the water, like dirtiness, were also mentioned by most of the male groups, however, specific colours were only pointed out by the younger boys.

Mosquito breeding-sites distribution on the maps

A total of 125 potential breeding-sites were mapped by all groups, of which 36 were identified as permanent and 89 as temporary (Supplementary Tables 1–2). For the permanent breeding-sites, *Big Dina* in B3, was indicated by 9 out of the 10 groups followed by *Cipriano* and *Flora* lakes from B3 and 4 respectively, which were indicated by 7 out of the 10 groups. The other permanent lakes were pointed out by 4 or less groups (Supplementary Table 1).

For temporary breeding-sites, *Vovo-Chironda* in B2 was the most pointed out (9/10), followed by *Abilio* in B2 (7/10). *Euzebio* in B3 and *Capenga* in B4 were mentioned by 6 out of 10 groups. *Finiasse*, *Bobo* and *Guerra* ponds in B4, *Vovo-Dori* in B3 and *Daero* in B6 were mentioned by 5 groups. The other temporary ponds were pointed by less than four groups (Supplementary Table 2).

Approximately a third of temporary (28%, 51/182) and permanent (31%, 22/71) potential breeding sites were only indicated by one group. The real size and breeding characteristics for anopheline mosquitoes of each potential breeding site could not be inferred.

Final maps

The information from the digitalized maps (Figs. 1 and Supplementary Figs. 1–3) was extracted by drawing the breeding-sites and landmarks identified by all groups (Fig. 2).

The compiled information was then compared with the georeferenced community landmarks and lakes/ponds using GPS coordinates and the geographic information system (GIS) software (Figs. 3 and 4).

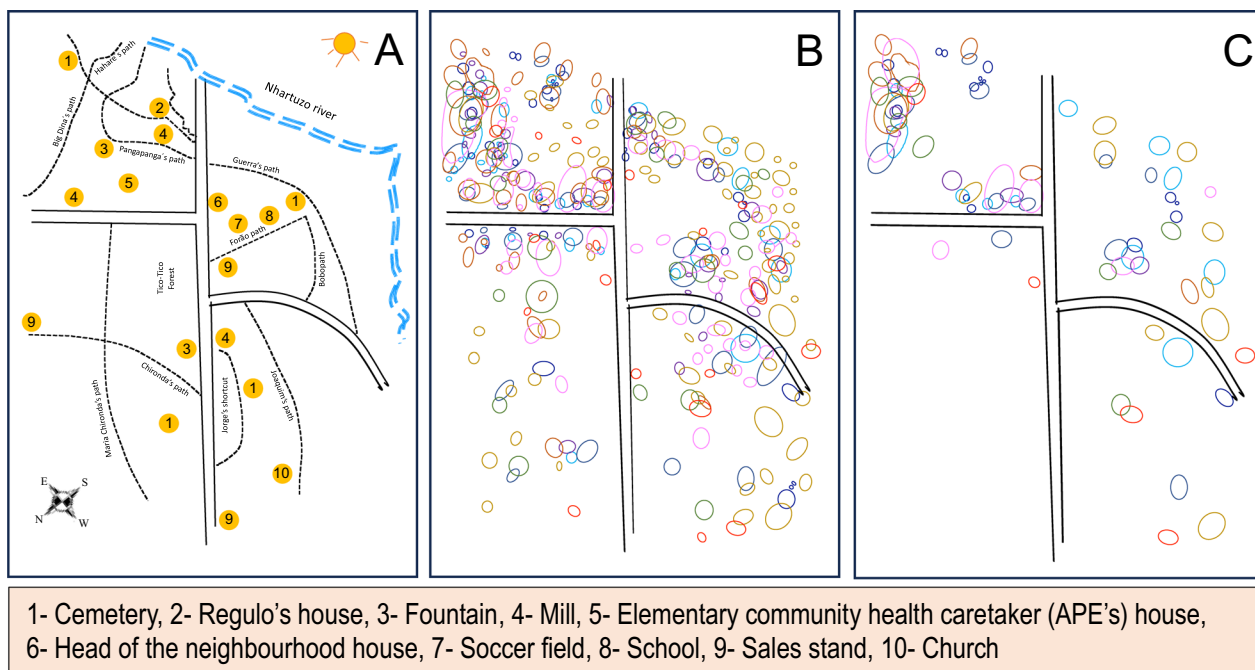


Fig. 2 Representation of combined maps for the nine focal groups. **A** Map community landmarks, Cardinal points are approximate as maps were hand-drawn. **B** All breeding-sites identified by all groups. **C** Permanent breeding-sites identified by all groups. Community leaders (darker blue); Women over 26 years of age (mustard brown); Women aged 18–25 years old (purple); Girls aged 14–17 years old (reddish brown); Girls aged 10–13 years old (red); Men over 26 years old (lighter blue); Men aged 18–25 (Cyan blue); Boys aged 14–17 years old (pink); Boys aged 10–13 years old (green)

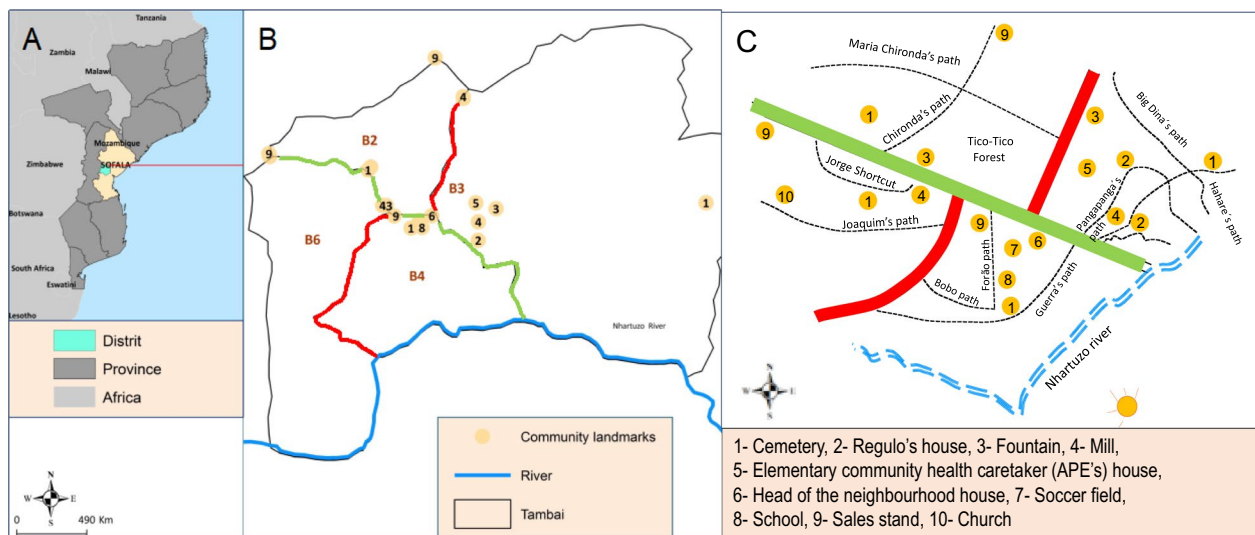


Fig. 3 Comparison of maps generated by the focal groups and GIS software. **A** Country context. **B** Map generated by GIS software using the community reference and neighbourhood block limits. **C** Map generated by focal group sketching. Cardinal points are approximate as maps were hand-drawn. B2: block two, B3: block three; B4: block four and B6: block six

Malaria prevalence

Of the 156 children under five years of age tested for malaria by PCR, 96 (61.6%) were positive for *P.*

falciparum malaria (B2=66.7%; B3=60.0%; B4=69.7% and B6=53.3%). When plotted on the community map they were concentrated in the area with higher household

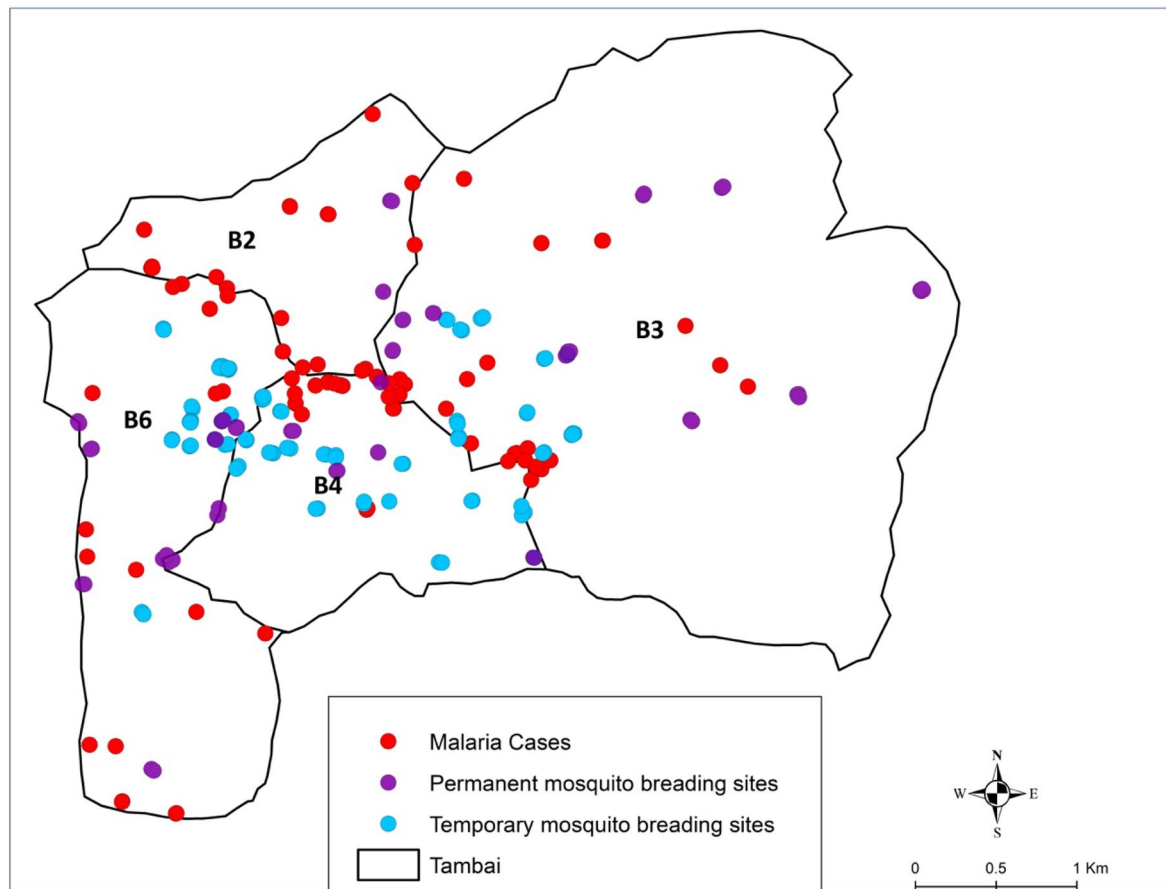


Fig. 4 Location of breeding sites identified by the focal groups and malaria cases in the community. Map generated by GIS software using neighbourhood block limits. Malaria cases (red dots); Permanent mosquito breeding sites (purple) and Temporary mosquito breeding sites (blue). Breeding sites were georeferenced using a single point

agglomeration surrounded by lakes and ponds identified by the community. The georeferencing was done by a single point, therefore it does not reflect their extension or demission rendering geographic association statistics unreliable.

Discussion

Participatory mapping based on community knowledge and experience, allowed us to identify community spatial perception of malaria transmission, risk, and distribution, as well as location, size, and relative importance of potential breeding-sites. Identifying potential mosquito breeding-sites through participatory mapping will help to identify higher burden mosquito areas, facilitating the elimination of breeding-sites by communities and programmes, resulting in a reduction of the mosquito population, supporting better malaria control and elimination in combination with current strategies [20]. This methodology is low cost, easy and fast to implement, easily replicated, and highly appropriate for difficult access

and limited resource areas [8, 9, 12]. It can also be useful to set up an entomological larval surveillance system and complementary strategies for malaria control and elimination by 2030.

Overall, male participants identified more potential breeding-sites than female, however, there were differences in the number of breeding-sites identified by the groups of older women, boys aged 10–13, as well as girls and boys aged 14–17. This may be because these groups use the ponds less frequently or for recurrent specific activities. All groups recognized *Big-Dina* lake as an important permanent potential breeding-site. The *Cipriano*, *Flora*, and *Vovo-Dori* were the second, third, and fourth most mentioned by the groups, thus showing the importance that these ponds have for the community and for malaria transmission, making them preferential targets for control. There were variations between groups regarding the potential breeding-sites, with boys aged 10–13 showing the greatest variation, followed by the women, aged 18–25, and men, aged 14–17 years

old. Greater mobility in the community area and specific activities associated to each group (e.g. boys play on vast areas and one of their activities is fishing) might explain these differences.

Regarding the temporary potential breeding-sites, *Vovo-Chironda*, followed by *Abílio*, *Eduardo* and *Capenga* ponds were most mentioned by most groups, showing that despite being temporary, they are important for malaria burden and transmission during high season.

The variety of the potential breeding-site characterization was also different, and characteristics like the colour of the water were only mentioned by women and young boys. An ideal breeding-site depends on chemical and biological constitution [2], that might influence the color of the water. This insightful information can help to identify more important mosquito breeding-sites as the water characteristics will determine mosquito choice for laying eggs and the information used to prioritize interventions.

Male groups were more participative and comfortable during the discussions and mapping, contrasting with female who were shy. This may be due to the social organization of the communities in Mozambique, as women are taught to be submissive, and men are taught to be the head of the households [21]. Less evident but still observable behaviour varied with age. These observations highlight the importance of group design for the participatory mapping methodology.

Sixty one percent of the community children under 5 years were positive for *P. falciparum* by PCR. The whole population including adults was not surveyed, which might introduce some bias, as other age groups also contribute for transmission. Even if Fig. 4 might suggest visual overlap between malaria cases and water masses, this is not supported by data as potential-breeding sites were single point referenced and spatial statistics could not be performed. Although, breeding sites were not confirmed, being a limitation of the study, the mapping made in this study, using the collective knowledge of Tambai community, could also be used as the base line for the ongoing objective of National Malaria Programme of mapping and intervening on mosquito breeding sites in the region.

Conclusions

The participatory mapping of potential mosquito breeding-sites carried out by the local community, was the most suitable methodology to identify the focus of mosquitoes, how the potential breeding-sites are distributed, and their importance for malaria transmission in that community. This method proved to be simple to implement and extremely effective in this remote rural area, where resource and access are limited, showing its applicability in similar areas around Africa.

Abbreviations

B2	Neighbourhood blocks 2
B3	Neighbourhood blocks 3
B4	Neighbourhood blocks 4
B6	Neighbourhood blocks 6
DNA	Deoxyribonucleic acid
GPS	Geographic positioning system
KAP	Knowledge, attitudes, and practices
P	Permanent mosquito breeding-sites
PCR	Polymerase chain reaction
RDT	Rapid diagnostic test
T	Temporary mosquito breeding-sites
P	Permanent mosquito breeding-sites

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12936-024-05084-w>.

Supplementary_Figure 1. Map drawn by the community leaders. Supplementary_Figure 2. Maps drawn by the female focal groups. A- Women over 26 years old; B- Women aged 18–25; C- Girls 14–17; D- Girls 10–13. Supplementary_Figure 3. Maps drawn by the male focal groups. A- Men over 26 years old; B- Men aged 18–25; C- Boys 14–17; D- Boys 10–13. Supplementary Table 1. Permanent breeding-sites identified during the participatory mapping exercise. Supplementary Table 2. Temporary breeding-sites identified during the participatory mapping exercise

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Author contributions

JDL—contributed to study design and all community activities. Analysed the data, wrote the manuscript and was responsible for logistic of field activities. IC—was the main contributor for the qualitative approach design, analysed the data, performed the field activities, and participated in manuscript writing and revising. NA—contributed to study design, participated in data analysis, performed field activities, and revised the manuscript. APA and JLM—contributed to study design, performed field activities, and revised the manuscript. EZ—performed the geographic information system data analysis and revised the manuscript. MC—perform the laboratory molecular identification of *Plasmodium* in blood samples and revised the manuscript. AD—supervised the field collection of blood samples, coordinated the laboratory confirmation of malaria by microscopy coordinated the laboratory confirmation of malaria by microscopic examination and revised the manuscript. L-G—contributed to study design and revised the manuscript. JLM—contributed to study design, performed field activities, and revised the manuscript. HS—Coordinated the project, drove the study design, contributed critically to all activities, performed field activities, analysed the data, and wrote the manuscript with JDL. All authors read and approved the manuscript.

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who contributed to the study design, participated in data analysis, performed field activities, and revised the manuscript.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the Institutional Ethics Committee from the National Institute of Health, Mozambique, and by the National Bioethics Committee for Health from Mozambique (ref.11/CNBS/21). Informed consents, and/or informed assents (when applicable) were obtained from all study participants.

Consent for publication

Consent from participants was obtained prior enrolment.

Competing interests

The authors declare that they have no competing interests.

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