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Community acceptance of a novel malaria intervention, Attractive Targeted Sugar Baits, in the Zambia phase III trial

Erica Orange[1*], Annie Arnzen[1*], Chuma Muluma[2], Situmbeko Akalalambili[2], Titus Tobolo[2], Frank Ndalama[2], Chama Chishya[2], Kochelani Saili[2,3], Ruth A. Ashton[4], Thomas P. Eisele[4], Joshua Yukich[4], Irene Kyomuhangi[4,5], John Miller[6], Kafula Silumbe[6], Javan Chanda[6], Busiku Hamainza[7], Joseph Wagman[8], Laurence Slutsker[9], Thomas R. Burkot[10] and Megan Littrell[8]

Abstract

Background Community acceptance is an important criterion to assess in community trials, particularly for new tools that require high coverage and use by a target population. Installed on exterior walls of household structures, the attractive targeted sugar bait (ATSB) is a new vector control tool designed to attract and kill mosquitoes. ATSBs were evaluated in Western Zambia during a two-year cluster randomized controlled trial to assess the efficacy of ATSBs in reducing malaria transmission. Community acceptance of ATSBs was critical for successful trial implementation.

Methods A community engagement strategy outlined activities and key messages to promote acceptance. Annual cross-sectional surveys, conducted during the peak transmission period, assessed households for presence of ATSBs as well as perceived benefits, concerns, and willingness to use ATSBs. Sixteen focus group discussions and 16 in-depth interviews, conducted at the end of each ATSB station deployment period, obtained a range of perceptions and household experiences with ATSB stations, as well as ITN use in the context of ATSB deployment.

Results Methods used during the study to promote acceptance and continued use of ATSBs were effective in achieving greater than 90% coverage, a high (greater than 70%) level of perceived benefits, and fewer than 10% of households reporting safety concerns. Common facilitators of acceptance included the desire for protection against malaria and reduction of mosquitoes, trust in health initiatives, and understanding of the product. Common barriers to acceptance included misconceptions of product impact on mosquitoes, continued cases of malaria, association with satanism, and damage to household structures.

Discussion Future use of the ATSB intervention will likely require activities that foster community acceptance before, during, and after the intervention is introduced. Additional research may be needed to understand the impact of different levels of community engagement on ATSB station coverage, ATSB station perception, and ITN use.

*Correspondence:
Erica Orange
eorange@path.org
Annie Arnzen
aarnzen@path.org
Full list of author information is available at the end of the article

Conclusion There was high acceptance of ATSB stations during the trial in Western Zambia. Continuous and intense community engagement efforts contributed to sustained ATSB coverage and trust in the product. Acceptance of ATSBs during programmatic delivery requires further research.

Keywords Malaria, Community acceptance, Attractive targeted sugar bait

Background

Community acceptance is an important aspect to consider when assessing new tools for vector control, particularly for new tools that require coverage and use by a target population [1–7]. Community acceptance, defined as willingness to use an intervention and attitudes, perceptions, and behavioural responses related to an intervention, is increasingly acknowledged when designing and evaluating community trials. Acceptance is evaluated in community trials using coverage as the primary indicator [1, 8]. Additional factors commonly explored include reported willingness to accept the intervention again in the future, and qualitative exploration of the sociocultural barriers and enablers of successful implementation [1, 2, 9]. Inadequate consideration of community acceptance can undermine successful implementation or lead to unintended, negative consequences for new interventions [10].

Acceptance is also an important indicator of the feasibility to scale-up a new tool or intervention and the effort required to engage community members for the intervention to be successful. The World Health Organization (WHO) includes acceptance as a criterion that should be considered when moving from evidence to recommendation in the WHO guidelines development process [11].

The attractive targeted sugar bait (ATSB) is a new tool designed for vector control. Installed on exterior walls of household structures, the Westham ATSB Sarabi version 1.2 stations were designed to attract and kill mosquitoes using a sugar bait laced with an ingestion toxicant [12, 13]. Previous studies, including studies conducted in Western Zambia, have shown that mosquitoes, including those that transmit the parasite that causes malaria, are attracted to and will feed from prototype attractive sugar bait (ASB) stations [14]. While it was hypothesized that ATSBs would be efficacious in reducing the average lifespan of female *Anophelines*, thereby potentially reducing and interrupting malaria transmission; the ATSB intervention is not designed to fully eliminate mosquitoes in intervention areas.

ATSB stations were evaluated in Western province, Zambia during a Phase III cluster randomized controlled trial (cRCT) to assess the efficacy of the ATSB station to reduce malaria incidence and prevalence [15]. Community acceptance was particularly important in the ATSB trial as high levels of ATSB station coverage were required for successful implementation of an efficacy trial on top of background vector control. ATSB station coverage was dependent on community member willingness to allow ATSB station installation on household structures for the duration of the malaria transmission season (approximately 7 months). Community engagement activities to promote acceptance of the ATSB station and continued acceptance of standard malaria vector control were conducted throughout the trial.

This paper examines ATSB station acceptance during the trial through household ATSB station coverage at the time of annual cross-sectional surveys. Additionally, this paper explores the facilitators of and barriers to ATSB station acceptance through qualitative data collection.

Methods

A Phase III cRCT to assess the efficacy of the ATSB station was conducted in three independent trial sites; Zambia, Kenya, and Mali. Details of the Zambia trial design are reported elsewhere [3], a description of the Zambia study site is reported by Arnzen et al. [16], and the ATSB intervention is described in detail by Orange et al. [17]. Briefly, the cRCT in Zambia deployed ATSB stations in 35 intervention clusters and compared outcomes in these clusters to a set of 35 control clusters. Trial clusters consisted of a minimum of 250 households, with a mean of 335 households per cluster. In the ATSB trial in Western province, Zambia, ATSB stations were deployed seasonally during the period of high transmission from November to June in 2021–2022 and November to June 2022–2023. Following initial installation, ATSB stations were routinely monitored for damage and replaced as needed. Epidemiological and entomological outcomes were measured during the ATSB deployment period. The trial was approved by the University of Zambia Biomedical Research Ethics Committee (Ref # 1197-2020), PATH REC (Ref # 1460046-5) and Tulane University (Ref # 2019-595).

ATSB trial community engagement strategy

The community engagement strategy was centered around achieving continuous high coverage with both ATSB stations and ITNs in order to contribute to reductions in malaria incidence and prevalence. An initial conceptual framework was refined after a baseline round of qualitative data collection was conducted with

community members in June 2021 (Fig. 1). The framework identifies potential factors that could affect ATSB station and ITN use (Fig. 1 blue boxes with red-dotted borders). The framework was used to design a comprehensive community engagement strategy to promote the acceptance of the ATSB trial, monitor for ATSB station coverage and acceptance, and continued use of ITNs in the Zambia trial site.

The community engagement strategy included key messages to drive early acceptance of the ATSB station (i.e., consent to install ATSB stations on the exterior walls of household structures) and ongoing acceptance (i.e., accepting continuous installation for the duration of the deployment period). Initial key messages were developed based on baseline qualitative study findings and included explaining how the ATSB stations work, describing and showing the contents of the ATSB station, explaining the distance at which a mosquito will be attracted to visit an ATSB station, and providing guidance to ensure safety (i.e., avoid tampering with the stations, restrict access of animals or children to the ATSB stations). In addition, key messages promoted the continued use of insecticide-treated nets (ITNs) across study communities. Key messages were added throughout the trial as more was learned about community acceptance, or lack thereof, of ATSB stations.

The community engagement strategy outlined two sets of activities for delivering key messages: routine activities and response activities. Routine activities were designed to foster and monitor ATSB acceptance throughout the trial and included community meetings at least twice a year (i.e., large sensitization meetings prior to ATSB installation and following ATSB removal), accompanying research teams monthly to share key messages and address questions in the community, and regular check-ins with health facilities in the study area to inquire about study related concerns. Response activities were designed to address emerging issues with community acceptance. These activities were implemented following direct reports of community concerns; when results from

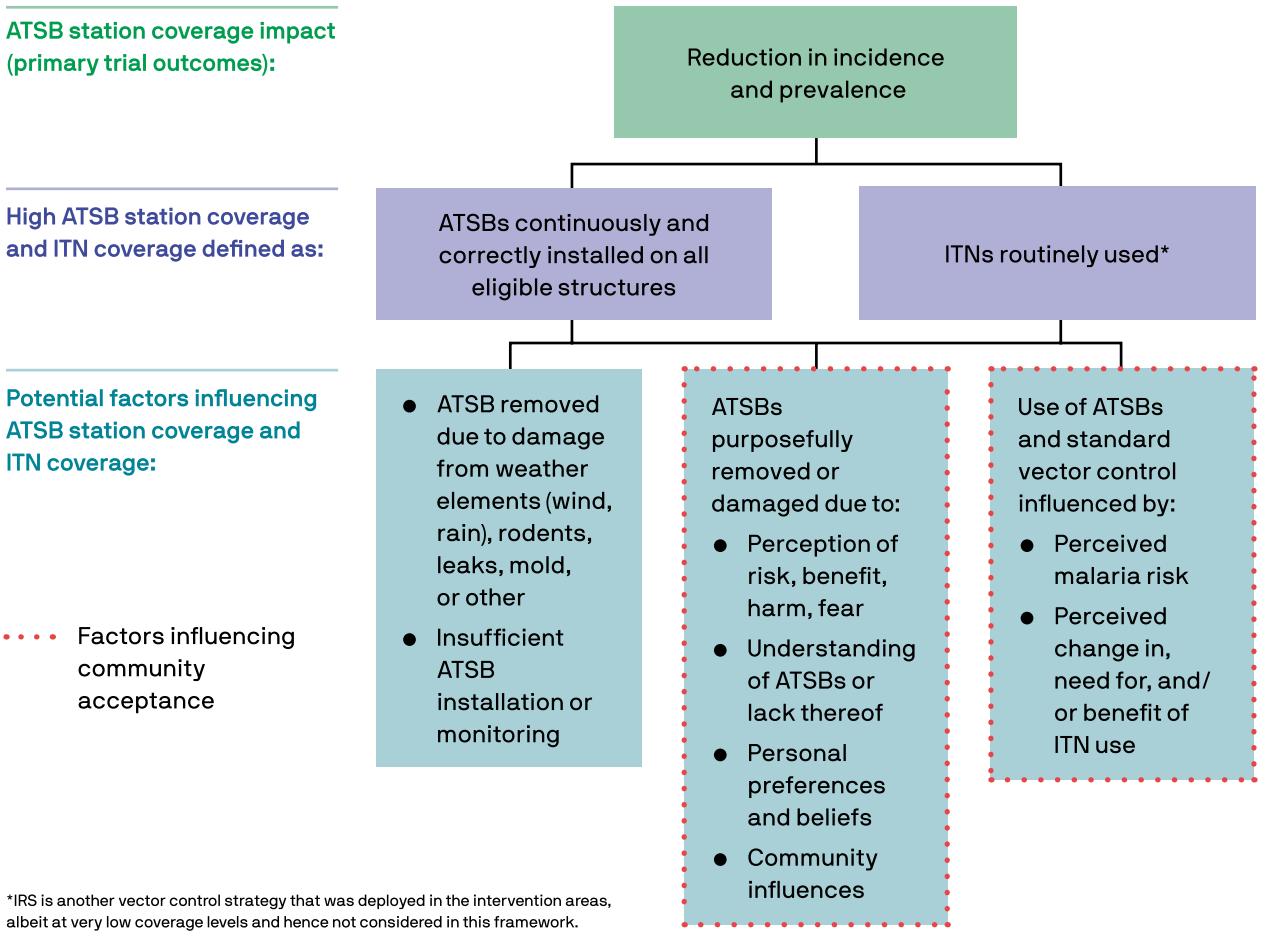

Fig. 1 Conceptual framework of potential factors influencing ATSB station and ITN use

routine data monitoring indicated study refusals, dropouts, ATSB station removals; and upon learning about rumours and misperceptions about ATSB stations or trial activities from research teams. The type of community engagement response activity depended on the scale and scope of the concern and included activities such as household visits accompanied by local leaders and/or health facility staff, additional community meetings, targeted activities to respond to concerns, or updates to communication materials to address a particular concern.

The oversight and implementation of the activities in the community engagement strategy were led by a team of three full-time Community Engagement Officers. The officers were responsible for managing a team of approximately 150 community-based community health workers (CHWs) that were recruited, trained, and supervised to conduct community engagement activities specific to the ATSB trial in their trial cluster. Two to four CHWs were recruited in each of the 70 study clusters for each year of the study. CHWs were expected to report community concerns to the officers if/as they arose.

Cross-sectional household surveys

Annual cross-sectional household surveys were conducted during peak malaria transmission season in April–May 2021 (baseline), March–April 2022 (Year 1), and March–April 2023 (Year 2). Participating households were selected in each cluster, each year, by simple random sample from a sampling frame of geolocated enumerated households. Each household survey included an inspection of household structures to assess for ATSB station presence and condition (not measured at baseline), and for ITN presence and condition. The household survey included an administered questionnaire with the head of household on perceived ATSB station benefits, ATSB station concerns, and willingness to accept and recommend ATSB stations in the future. ATSB station coverage was defined as 'high' coverage if greater than 90% of eligible structures had greater than or equal to two ATSB stations in any condition. Full household survey procedures are described in detail elsewhere (Ashton et al., pers. commun.).

Focus group discussions and in-depth interviews

Focus group discussions (FGDs) and in-depth interviews (IDIs) were conducted at the end of each ATSB station deployment period in June 2022 and June 2023. Sixteen FGDs (8 FGDs in June 2022 and 8 FGDs in June 2023) were conducted with a total of 144 participants divided into groups of 6–10 individuals. FGD participants were purposefully selected by the research team to obtain a range of perceptions, beliefs, and attitudes towards ATSB stations. Participants were identified through routine community engagement reports as individuals who had knowledge of and could represent their communities. Participants included community leaders and members residing in ATSB intervention clusters, CHWs from intervention clusters, and community-based ATSB monitors responsible for monitoring the ATSB intervention. FGD participants included residents and CHWs associated with 28 of the 35 ATSB intervention clusters. Participants ranged in age from 18–89 years old, and 41% were female. The FGD semi-structured interview guide included questions to facilitate group discussion around facilitating factors and barriers to ATSB station acceptance among community members.

Sixteen IDIs (8 IDIs in June 2022 and 8 IDIs in June 2023) were conducted with a total of 16 households. IDI participants were purposively selected by the research team to obtain a range of household experiences with ATSB stations. IDI participants were identified through routine community engagement reports and included residents from 16 of the 35 ATSB intervention clusters. Participants ranged in age from 31 to 68 years old, and 50% were female. The IDI semi-structured interview guide included questions to explore household experiences with ATSB stations with a focus on understanding household decisions regarding acceptance, refusal, or removal of ATSB stations at different points during the trial and reasons for acceptance, refusal, or removal.

FGDs and IDIs were facilitated and audio-recorded in local languages that included Silozi, Mbunda, and Nkoya. Audio recordings were transcribed into local language, translated into English, and reviewed for translation accuracy.

Thematic analysis

Inductive and deductive codes were developed based on the conceptual framework in Fig. 1, resulting in a codebook of nine parent codes and accompanying sub-codes. Codes were generated by one researcher and confirmed by the interview team. Interview transcripts were coded using Dedoose software (Los Angeles, CA: SocioCultural Research Consultants, LLC). Codes were analysed within and across transcripts based on the assigned parent code. Analytical findings were reviewed and validated by the community engagement team.

Results

Household survey results for ATSB acceptance

Findings from the cross-sectional household surveys demonstrated high coverage of ATSB stations was achieved across Year 1 and Year 2 of ATSB station deployment, with 93.1% of eligible household structures having greater than or equal to 2 ATSB stations in any

condition (Table 1). ATSB station coverage indicates high levels of ATSB station acceptance during the ATSB trial.

In addition to achieving high ATSB station coverage, more than 93% of heads of households with ATSB stations in Year 1 and Year 2 would choose to install ATSB stations on their household structures again in the future and would recommend their use to friends and family, indicating high levels of future ATSB acceptance (Table 2). A high percentage of households reported seeing benefits of ATSB installation (71.5% in Year 1 and 77.9% in Year 2). Over 70% of households reported perceiving that ATSB stations decrease mosquito numbers (71.8% in Year 1 and 79.8% in Year 2), while a relatively small percentage of households reported that ATSB stations increase mosquito numbers (14.5% in Year 1, 9.7% in Year 2). Overall, concerns about ATSB safety were low (8.8% in Year 1 and 4.2% in Year 2).

Qualitative study results for ATSB acceptance

Thematic analysis of the FGDs and IDIs identified four themes: (1) common facilitators of ATSB station acceptance (Table 3); (2) common barriers to ATSB station acceptance (Table 3); (3) other factors influencing acceptance, such as safety; and (4) ATSB station impact on ITN use. Each theme is explored in further detail below. There was no identifiable difference in responses between female and male respondents. There was minimal difference in responses between Year 1 and Year 2 of the qualitative study. Where applicable, any differences between years are noted in the findings below. With the exception of discussions on ITN use, qualitative results supported the quantitative results from the household surveys.

Key facilitators of ATSB station acceptance

Study participants indicated that community residents generally accepted having ATSB stations installed on their structures at the time of ATSB station installation. FGD and IDI participants cited the following as the main reasons for accepting ATSB stations at the time of installation: desire for protection against malaria; desire for the reduction of mosquitoes; trust in Ministry of Health initiatives; and key messaging about the ATSB station that was delivered to them by a trusted individual such as health facility staff, local leader, community members.

> *"What motivated us were the lessons we used to receive [about the ATSB intervention] and how effective it was at malaria prevention and how useful it was to have on our home."*

Results suggest that most community residents continued to keep ATSB stations installed on their structures throughout the duration of ATSB station deployment,

Table 1 ATSB station coverage

	Year 1 (Mar–Apr 2022) % (95% CI) n = 981	Year 2 (Mar–Apr 2023) % (95% CI) n = 1400	Y1 & Y2 combined n = 2381
Among eligible structures assessed, % with ≥ 2 ATSB stations in any condition	98.3 (97.5–99.0)	89.5 (87.1–91.9)	93.1 (91.6–94.7)

Table 2 Household survey respondent reports of ATSB perceptions

	Y1 (March–April 2022) % (95% CI) N = 592	Y2 (March–April 2023) % (95% CI) N = 648
Among heads of households reporting to have an ATSB station, % that would choose to install bait stations again in the future	93.6 (90.6–96.6)	94.6 (91.4–97.8)
Among heads of households reporting to have an ATSB station, % that would recommend that their friends or family use bait stations for their own dwellings	93.4 (89.9–96.9)	93.4 (90.0–96.8)
Among heads of households reporting to have an ATSB station, % see any benefits with bait station	71.5 (65.5–77.4)	77.9 (73.5–82.4)
Among heads of households reporting to have an ATSB station, % have any concerns about the safety of the bait stations	8.8 (5.5–12.1)	4.2 (2.3–6.0)
Among heads of households reporting to have an ATSB station, since bait stations installed, % noticed change in the numbers of mosquitoes around and inside the house (as mentioned below)		
Increase	14.5 (8.9–20.2)	9.7 (6.3–13.2)
Decrease	71.8 (64.4–79.1)	79.8 (75.5–84.1)
No change	12.8 (8.7–17.0)	9.3 (0.0–2.0)
Don't know	0.8 (0.0–1.7)	1.2 (0.3–2.1)

Table 3 Common facilitators of and barriers to ATSB station acceptance

ATSB station acceptance

COMMON FACILITATORS	COMMON BARRIERS
• Desire for protection against malaria	• Lack of understanding of and exposure to the product
• Desire for the reduction of mosquitos	• Association of the product with satanism
• Trust in Ministry of Health initiatives	• General mistrust in individuals associated with intervention activities
• Key messaging delivered by a trusted individual	• Misconception about product impact on mosquitos
• Lack of negative experience with the product	• Continued experience with cases of malaria
• Good understanding of purpose, function, and contents of product	• Perceptions that ATSB stations were "attracting" mosquitos
	• Frustration with product damage to household structures

citing the following as the main reasons for continued acceptance of ATSB stations: perceived reduction in malaria cases; perceived reduction in mosquitoes and/or the belief that mosquitoes had stopped biting them; lack of negative experiences with ATSB stations which disproved rumours about ATSB stations; and having a good understanding of purpose, function, and contents of the ATSB stations. The same reasons were mentioned for willingness to accept ATSB stations again in the future.

> *"Since the time they [ATSBs] were installed, malaria cases in my family have gone down. We have concluded that they are truly working."*
> *"It kills mosquitoes and we have seen the benefits because mosquitoes have reduced."*

Key barriers to ATSB station acceptance

Participants noted the following as the main reasons for lack of initial ATSB station acceptance: lack of understanding of and exposure to the product; fears that the ATSB stations would cause new illnesses; association of the ATSB station with satanism through the belief that the ATSB stations were filled with human blood to attract mosquitoes; and general mistrust in individuals conducting community sensitization or ATSB station installation activities.

> *"I was not prepared for them, so I refused because I did not understand what they were. Later on, I enquired and that is when I heard that those things were for protection against mosquitoes, so I agreed."*

Participants noted that in some cases, community members initially accepted ATSB station installation, however later removed the ATSB stations from their household structures. The following reasons were noted for ATSB station removal: insufficient understanding of how the intervention works—including the misconception that all mosquitoes would be eradicated, the misconception that there would be piles of dead mosquitoes below the ATSB stations, and the misconception that mosquitoes would not enter the household; continued experience with cases of malaria and no longer perceiving benefit in the intervention; negative perceptions that ATSB stations were "attracting" mosquitoes and increasing the density of mosquitoes around the household putting them at greater risk for malaria; and frustration with the damage ATSB stations were causing to their household structures through either bait leaking from stations onto their walls, mold growth from the stations onto their walls, or nails used to secure stations to their walls and causing undesired holes. While some participants raised the issue of ATSB damages such as leakages, many noted community appreciation for the speed at which ATSB stations were replaced after becoming damaged.

> *"When they were first installed, the bait stations attracted mosquitoes and that's the reason why we would remove them."*
> *"We had concerns that bait stations were destroying our walls which is why we removed them."*

Participants noted that some community members intentionally took the ATSB stations down for a short period of time, defined as anywhere from a few days up to a few weeks, because the ATSB stations were at risk to be tampered with. To prevent children, community members under the influence of drugs or alcohol, community members with mental health illnesses, and/or livestock from tampering with the ATSB station, the head of household would intentionally remove the ATSB station while they

perceived the exposure to these individuals and animals as a concern, and would only re-install them after they no longer felt there was a concern to these individuals and animals.

Participants noted that initial refusal of ATSB station installation or intentional removal after installation was generally followed by accepting ATSB stations to be installed/re-installed at a later date. Participants cited the following as main reasons for later acceptance: new knowledge and/or being directly educated by the ATSB study team on how ATSB stations are designed to work; demonstrations of cutting open an ATSB station to confirm the contents; and seeing benefit from neighbors and/or not observing harm to other community members who had accepted ATSB stations.

Influencing factor: perceived safety considerations for ATSBs

Results from IDIs and FGDs indicate that a key factor influencing the overall perception of ATSBs was perceived safety considerations. Participants readily discussed potential safety considerations surrounding ATSB stations. Community safety considerations described by participants included: awareness that ATSB stations are potentially dangerous due to the inclusion of an insecticide, the deployment practice of installing stations at a sufficient height to keep them away from children and animals, and the deployment and monitoring practice of using gloves; associated concerns about what would happen if the ATSB station contents were accessed by children or animals; instruction not to touch the ATSB stations and observation that they are only handled with gloves; and lack of clarity on why the ATSB stations are collected back after several months. No concerns were reported when asked directly about environmental safety.

> *"The only fear that was there was that as they leak maybe a child can touch them and access the chemical. We see those that installed them usually put on gloves, so what would happen to our children without gloves. That was the fear of people in this village."*

Despite the safety considerations highlighted by FGD and IDI participants, it was noted that these perceptions generally did not lead to widespread ATSB station refusals or other challenges with ATSB coverage. Safety perceptions were key to address, and once addressed generally facilitated adherence to guidance from the study team to refrain from tampering with stations and preventing access to stations for children and animals.

> *"[ATSB stations] were hung very far, where children could not reach or play with them. We also cautioned our children from playing with those things to keep them safe. We really paid attention to the rules they give us."*

Impact of ATSB deployment on ITN use

During the two-year study, two supplemental ITN distributions were implemented by the study team within the study clusters. The first was in February 2022 and was implemented to address high community demand for ITNs in the context of perceived increase in mosquitoes. During this distribution ITNs were distributed with a strategy of one ITN per household across the trial site. The second distribution was in September 2022 to the 48 clusters that were not fully covered by National Malaria Elimination Centre (NMEC)-led IRS campaigns. During this distribution, one ITN was provided for every two residents in the household per the national strategy. Additional detail on ITN campaigns in the trial site are available elsewhere [16]. During the first year of the trial, about one-third of households in the study area had universal ITN access defined as owning at least one ITN per two people, including 37.4% of households in ATSB intervention areas. During the second year of the trial, more than half of households had universal ITN access, including 55.9% of households in ATSB intervention areas. ITN use among people in households with universal ITN access was generally high. In ATSB intervention areas, the percentage of people that reported not sleeping under an ITN the previous night was only 11.3% in Year 1 and 13.1% in Year 2, similar to net use in control households with universal access (Table 4). FGD and IDI participants described ways in which ATSB deployment was associated with community shifts in perceptions around mosquitoes, malaria risk, and ITN use. The impact of ATSB deployment on IRS uptake was not explored given the limited intervention overlap in study clusters and time between NMEC IRS campaigns and qualitative data collection.

Participants noted that at the time of ATSB station installation, particularly during the first year of the trial, some community members perceived an associated increase in mosquitoes due to ATSB stations, and noted that this led to an increased demand for and use of ITNs. Over time, particularly during the second year of the trial, participants noted that there was a community perception of a decrease in the mosquito population which may have made some community members feel comfortable to decrease their ITN use. The perception of an increase or decrease in mosquitoes was discussed in the context of the presence of ATSB stations, and not perceived to be associated with environmental or other context specific factors.

> *"Before they [ATSB stations] were installed, mosquitoes used to trouble us, but when I came back from the farm I found that there were no mosquitoes anymore. Though the children continued sleeping in the*

Table 4 Household ITN coverage and usage

	Baseline (March–April 2021)	Y1 (March–April 2022)		Y2 (March–April 2023)	
		ATSB	Control	ATSB	Control
n = Households	**% (95% CI) n = 1605**	**% (95% CI) n = 615**	**% (95% CI) n = 630**	**% (95% CI) n = 658**	**% (95% CI) n = 678**
% of households that report owning at least 1 ITN per 2 people	38.5 (33.6–43.5)	37.4 (31.7–43.1)	35.7 (30.2–41.2)	55.9 (47.8–64.0)	63.6 (56.8–70.4)
n = People in households	**% (95% CI) n = 1882**	**% (95% CI) n = 802**	**% (95% CI) n = 829**	**% (95% CI) n = 2155**	**% (95% CI) n = 1683**
% of people that reported not using a net the previous night among those in household with at least 1 net per 2 people	7.9 (5.7–10.1)	11.3 (8.2–14.5)	9.9 (7.5—12.3)	13.1 (9.9–16.2)	14.7 (11.5–17.9)

mosquito nets, from the time I came back I just sleep like that. Even now I don't sleep in the mosquito net because I really wanted to prove if these things [ATSB stations] are really effective."

Although promoted by the study team as a complementary vector control tool and not a replacement vector control tool, when asked specifically whether individuals would accept ATSB stations in the future without receiving a mosquito net, differing viewpoints were expressed by study participants. Approximately half of qualitative study participants noted they would accept ATSB stations without receiving ITNs due to benefit of protection against malaria, while the other half of the participants noted that ATSB stations would not be accepted without having sufficient ITNs in the household.

"Not all mosquitoes will die from the bait station, others might still enter the house. If we aren't given a net then it will be a problem because we shall be bitten by the mosquitoes."

Similarly, although promoted by the study team as a complementary vector control tool, when asked specifically whether there was a community preference for ITNs versus ATSB stations to protect against malaria, there were differing viewpoints expressed by qualitative study participants. Several participants noted that ITNs were preferred because they provide protection from other insects/snakes, can travel with the family (e.g., between the farm and home), and can be used for a long time. Other participants noted that ATSB stations are preferred because ATSB stations protect more people, people spend more time outdoors near the ATSB station as compared to indoors under a net, and ATSB stations are perceived as a good alternative to negative perceptions surrounding ITNs (e.g., ITNs are hot, suffocating, and develop large holes).

"The goodness of mosquito nets is that unlike the bait station you can go with it everywhere. But when it comes to protecting the whole family, the net is powerless. That is why we need both."

Discussion

High levels of community acceptance of ATSBs were observed in the context of a tightly-controlled deployment with dedicated community engagement as part of the Western Province, Zambia ATSB cRCT. ATSB structure coverage was greater than 90% in Year 1 and Year 2 combined, with the majority of community residents (>70%) reporting perceived benefits of the ATSB stations. Although residents expressed some safety considerations regarding the ATSB stations, ATSB stations were generally perceived as safe with fewer than 10% of households reporting concerns.

Key facilitators contributing to ATSB station acceptance during the ATSB trial included the desire for protection against malaria and reduction of mosquitoes, trust in the initiative and personnel, and having a good understanding of the product. These key facilitators are also known to influence the acceptance of other vector control interventions, mainly ITNs and IRS. In particular, the perceived reduction of mosquitoes and protection from nuisance biting that was noted during the ATSB trial is also cited as a strong facilitator in the literature on IRS and ITN acceptance [18–20]. This perceived benefit is strengthened by the perception that the intervention is mitigating malaria [21, 22]. This study found that awareness of the intervention and association of the intervention with the government and/or trusted community members were important in facilitating ATSB acceptance. These have been identified as best practices for acceptance of new malaria interventions in the literature [21].

Key barriers to ATSB station acceptance identified in this study were misconceptions of the intervention impact on mosquitoes, perceived negative effects of the product on personal property and home, inadequate understanding of the product or trial, and fear about safety and potential side effects. These have been identified as barriers to uptake of other malaria interventions, most notably IRS [18, 20, 21].

Many of the initial reasons for refusal surrounding ATSB stations were particularly salient at the start of the trial but decreased over time. Despite baseline qualitative work to inform initial routine community engagement activities and key messages, a number of concerns and misperceptions about ATSBs arose. These included beliefs that ATSB stations were attracting more mosquitoes from outside of the community, that the ATSB stations were associated with satanic practices, and that ATSB stations destroyed household structures. These initial barriers do not appear to have affected overall community acceptance, which is likely a direct result of intensive routine and responsive community engagement activities implemented during the ATSB trial to address community concerns and misperceptions.

Community engagement activities allowed for clear, timely, and frequent delivery of key messages. Key messages were continually revised and adapted as more was learned about the reasons individuals refused or removed ATSB stations and what motivated them to accept the product. Future introduction and scale-up of the ATSB intervention will likely require supporting interventions aimed at fostering community acceptance. The factors that influence acceptance are likely context-specific and require initial investigation and ongoing monitoring and community engagement to address potential community acceptance issues [23].

Additional research may be needed to understand the impact of less intensive community engagement and ATSB station monitoring on ATSB station coverage, ATSB station perception, and ITN use, as would be likely during routine programmatic use. The Zambia trial included a robust ATSB monitoring component whereby community-based ATSB monitors routinely visited stations, assessed them for damage, and replaced them as needed. ATSB monitors were also available at any time to address community member questions or concerns regarding ATSB stations installed at their households [17]. The monitoring system and/or prompt removal and replacement of damaged stations may have contributed to the high levels of acceptance observed in this study.

Results from this study suggest that there is need for future ATSB deployments to incorporate monitoring of potential reductions in ITN use. Although ITN use among those with ITN access reported during household surveys remained high during the Zambia ATSB trial, qualitative study results suggest that there was a degree of reduced perceived risk for malaria as well as reduced perceived need to use ITNs in the context of ATSB deployment. Household surveys captured reported ITN use the night before the survey, but did not measure consistent ITN use. It is therefore not known if consistent ITN use was present in the context of ATSB deployment.

ATSB station acceptance results may be limited by the acceptance and overlap of other ATSB trial components. During the ATSB trial, many community members were employed by the study to implement various trial components, including CHWs, ATSB monitors, entomology collectors, epidemiology data collectors and received a monthly wage. Additionally, several members of the community benefitted from the implementation of other ATSB trial components, such as through malaria testing and treatment, cohort study participation payments, and meals provided during community meetings. This level of community involvement and employment during the trial may have influenced the high levels of ATSB acceptance. General acceptance of the ATSB trial, including employment and community benefits, are difficult to separate from acceptance of the ATSB station product.

Conclusion

There was high acceptance of ATSB stations during the ATSB Phase III trial in Western Province, Zambia. This was achieved in the context of a robust community engagement strategy, continuous monitoring of ATSB coverage, replacement of ATSBs when necessary, and key messaging. Community engagement efforts were most important at the time of ATSB station installation to explain the product and address individual's questions and concerns. Once installed, there were minimal acceptance challenges that impacted continuous ATSB coverage and the need for response activities decreased as community awareness and trust in the product increased. Government support of ATSB stations and the trial activities was also a key facilitator of acceptance in this context. Acceptance of ATSBs during future programmatic delivery requires further research and will need to consider strategies to effectively introduce, build, and sustain trust in and knowledge of ATSBs.

Abbreviations

ATSBs	Attractive targeted sugar baits
CHW	Community health worker
cRCT	Cluster Randomized Control Trial
FGDs	Focus group discussions
IDIs	In-depth interviews
IRS	Indoor residual spraying
ITN	Insecticide-treated net
NMEC	National Malaria Elimination Centre
WHO	World Health Organization

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Author contributions
Designed the study: ML, EO, TE, RA, JY, JM, JC, KS, LS, and TB. Acquisition of the household survey data: CC, FN, TT, KS, AA, and EO. Acquisition of the qualitative data: CM, SA, TT, and EO. Analysed the primary household survey data: RA, TE, IK and JY. Analysed the qualitative data: EO. Wrote the first draft: EO and AA. All other authors reviewed and approved the final document.

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Availability of data and materials
De-identified data and transcripts are available from the corresponding author on reasonable request. Following publication of forthcoming secondary analyses of trial data, the deidentified trial dataset will be posted on a public repository.

Declarations

Ethics approval and consent to participate
Ethical approval was obtained from the National Health Research Ethics Board (NHREB) at the University Teaching Hospital (ethical institution of record) in Zambia (Ref # 1197-2020), the PATH Research Ethics Committee (Ref # 1460046-5), and the Institutional Review Board at Tulane University (Ref # 2019-595).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]PATH, Seattle, WA, USA. [2]PATH, Kaoma, Zambia. [3]Present Address: Macha Research Trust, Choma, Zambia. [4]Centre for Applied Malaria Research and Evaluation, Tulane School of Public Health and Tropical Medicine, New Orleans, LA, USA. [5]Present Address: Centre for Health Informatics Computing and Statistics, Lancaster University, Lancaster, UK. [6]PATH, Lusaka, Zambia. [7]National Malaria Elimination Centre, Lusaka, Zambia. [8]PATH, Washington DC, WA, USA. [9]Independent Consultant, Atlanta, GA, USA. [10]Australian Institute of Tropical Health and Medicine, James Cook University, Cairns, QLD, Australia.

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