

RESEARCH

Open Access



Indoor residual spraying household visits as a platform for engaging pregnant women in malaria prevention on Bioko Island, Equatorial Guinea

David S. Galick^{1*}, Jeremías Nzamío Mba Eyono¹, Matilde Riloha Rivas², Wonder P. Phiri¹, Carlos A. Guerra³ and Guillermo A. García^{3*}

Abstract

Background Pregnant women are particularly vulnerable to many health conditions, including infectious diseases, which place them at elevated risk of severe outcomes. In particular, malaria poses a significant burden during pregnancy, and as such there has long been a strong focus on delivering malaria prevention interventions to pregnant women during antenatal care (ANC), including long-lasting insecticide-treated nets (LLINs) and intermittent preventive treatment in pregnancy (IPTp). However, outreach to drive uptake of these interventions presents some distinct challenges. For example, pregnant women may not attend ANC or may not do it in public health facilities, where these interventions are freely available, precluding access. In this study, an implementation of routine annual indoor residual spraying (IRS) on Bioko Island, Equatorial Guinea was leveraged to identify pregnant women and conduct follow-up visits focused on awareness and uptake of LLINs and IPTp.

Methods IRS campaign data was used to generate lists of households with pregnant women for follow-up visits, during which communication agents conducted an interview based on relevant sections of a malaria indicator survey to assess knowledge about malaria, LLINs and IPTp, and uptake of these interventions. Uptake was defined on an ordinal, three-category scale, and ordinal regression modeling was performed to assess the relationship between uptake and knowledge indicators.

Results In total, 1,567 households were visited, and 589 pregnant women identified. There was a high awareness about LLINs (76.9% cited LLINs as a malaria prevention method), but low awareness of IPTp (34.5% could cite any benefit and 37.1% were aware of availability in public health facilities). In line with awareness levels, regular use of LLINs (54.8% reported using every night) was higher than IPTp uptake (35.2% on track for three doses). Ordinal regression modelling confirmed that LLIN use on some or all nights was associated with awareness that LLINs prevent malaria, and IPTp uptake was associated with awareness of the number of doses required.

*Correspondence:

David S. Galick
dgalick@mcd.org
Guillermo A. García
ggarcia@mcd.org

Full list of author information is available at the end of the article



© The Author(s) 2025. **Open Access** This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by-nc-nd/4.0/>.

Conclusions This work demonstrated that complementary malaria control interventions can be leveraged to identify pregnant women for further outreach. The information collected provides a baseline to evaluate the impact of future activities on Bioko Island and suggests that increasing awareness of IPTp could improve coverage, while further increasing LLIN use will likely require identifying specific barriers to use.

Keywords Malaria prevention, Antenatal care, Intermittent preventative treatment in pregnancy (IPTp), Long-lasting insecticide-treated nets (LLIN), Program integration

Background

Malaria in pregnancy is a major contributor to the global burden of malaria, due to its risks for both mother and child. Many studies have demonstrated a relationship between malaria infection during pregnancy and poor birth outcomes, most notably low birth weight and neonatal and infant mortality [1–3]. Severe maternal anemia often mediates this relationship, and in malaria-endemic areas around 25% of severe maternal anemia has been estimated as attributable to malaria [4]. Anemia also predisposes pregnant women to greater risk of both wider morbidity outcomes and maternal mortality [5, 6]. The quantitative contribution of malaria to maternal mortality is not very well characterized, due in large part to a lack of high-quality data, but at least in some areas of endemic transmission malaria may cause as many as 10–15% of all maternal deaths [7, 8]. These epidemiological associations are concerning given that in 2023 an estimated 12.4 million pregnant women in sub-Saharan Africa were infected with malaria during their pregnancy [9].

Due to the significant burden of malaria in pregnancy, a large focus has been placed on protecting pregnant women, including by providing access to long-lasting insecticide-treated nets (LLINs) and preventive treatments, usually during antenatal care (ANC). When used by pregnant women, LLINs have been shown to decrease low birth weight, stillbirth and placental malaria [10]. Similarly, intermittent preventive treatment in pregnancy (IPTp) with sulfadoxine-pyrimethamine (SP) has been shown to improve birth outcomes, in large part but likely not exclusively due to the chemoprotection it provides against malaria [11–13]. In line with this evidence, the WHO recommends that all pregnant women in malaria endemic areas be protected by both LLINs and at least three doses of IPTp (IPTp-3) [14], but significant gaps in coverage remain [9].

Barriers to the uptake of malaria prevention in pregnancy are varied. Reviews of the literature have identified factors such as cost, distance to health facilities and ANC attendance as important barriers to LLIN ownership [15], while risk awareness, attitudes toward interventions, trust in their efficacy, and the discomfort of use were related to the use of nets where available [16]. Factors driving the gap in IPTp-3 coverage are similar, with the addition of the quality of care provided and (relatedly)

trust in the health system as additional important factors [16, 17]. In part due to the variation in barriers to uptake, strategies to improve coverage of malaria prevention in pregnancy continue to be investigated. Some studies have demonstrated that community-level deployment of interventions can increase LLIN and IPTp-3 coverage among pregnant women [18–20]. Likewise, analyses of cross-sectional data indicate that awareness of the risk malaria poses in pregnancy and of the available interventions, may be important factors increasing uptake of LLINs [21] and IPTp [22]. This suggests that information, education and communication (IEC) activities, whether coupled with community-level distribution of the intervention or not, could be an effective strategy to improve coverage, and in some cases such a strategy has improved IPTp uptake [23]. However, IEC campaigns targeting pregnant women face difficulties in how to reach an ever-changing population, especially in contexts where use of private health facilities for ANC is common, or ANC attendance overall is low.

Bioko Island is the largest island of Equatorial Guinea, located off the coast of Cameroon in the Bight of Biafra. Both the capital city, Malabo, and a substantial proportion of the national population (28% according to the most recent national census) are located on Bioko, where the population is mostly urban and concentrated in Malabo, although specific population estimates vary from around 270,000–335,000 [24–26]. Historically, Bioko has high, perennial malaria transmission, although intensive control efforts since 2004 have significantly reduced transmission intensity and the disease burden of malaria [27, 28]. Major malaria intervention activities include continuous distribution of LLINs, annual rounds of IRS, larval source management, particularly in urban areas, and free access to malaria testing and treatment in public health facilities. Activities targeted specifically to pregnant women include the distribution of LLINs and IPTp with SP free of charge at ANC in public health facilities.

In addition to public health facilities, the population of Bioko is served by private facilities, which due to ease of market entry and slow regulatory action greatly outnumber public facilities and vary vastly in quality of care provided (from well-equipped hospitals to basic clinics and pharmacies). Despite investments and improvements in the quality of care provided in the public sector, the convenience of private facilities, including shorter wait times

and close proximity due to the high number in residential areas, and the perception that they provide better quality of care may have contributed towards a trend of increasing private facility utilization on Bioko. Anecdotally, the perception of quality may be influenced by factors related to customer service and facility amenities, such as more comfortable waiting areas, rather than differences in clinical care quality itself. Indeed, while they may offer services similar to those in public facilities, including for malaria prevention in pregnancy, private facilities do not benefit from the same level of investment and oversight by the Ministry of Health, nor do their staff receive training from the National Malaria Control Program, so they may be more likely to vary in their adherence to national and international guidelines.

Despite significant reduction in overall malaria transmission over the past two decades, malaria in pregnancy remains a persistent public health challenge on Bioko, with 10.9% of pregnant women testing positive for *P. falciparum* malaria during the 2023 malaria indicator survey (MIS) [29]. However, even with substantial test positivity, and 80% use of public health facilities for ANC according to self-reported survey data [29], public health facilities on Bioko have reported only around 300–500 cases of malaria in pregnant women annually for the past several years (unpublished National Malaria Control Program database), suggesting a potential gap in population reached by health facility-based approaches. Furthermore, in 2023 LLIN use among pregnant women was low overall (34%), and suboptimal even in households owning a net (65%), but higher among households with at least one net for every two residents (84%). Similarly, while the coverage of a single dose of IPTp with SP was 86%, coverage of the recommended three doses was only 41% [29]. These data suggest that while access to LLINs and ANC attendance are important factors in determining uptake of the interventions, other considerations such as knowledge and perceptions likely play important roles in limiting population coverage on Bioko. Perhaps more importantly, existing communication activities conducted primarily in public health facilities do not appear to be having the desired effects, as key malaria prevention in pregnancy indicators (LLIN use and IPTp coverage) have plateaued from 2020 to 2023 [29].

To address these challenges, we developed an innovative outreach approach leveraging existing indoor residual spraying (IRS) on Bioko Island. IRS household visits provide unique opportunities for pregnant women outreach because the program generally reaches high community coverage [30], benefits from high community trust, and reaches women who seek ANC in the private sector, delay their first ANC until late in the pregnancy or who may not attend ANC at all. IRS household visits also present an opportunity to obtain an assessment of LLIN

use, IPTp-3 uptake, and knowledge about malaria and these interventions. Hence, the use of complementary interventions can ease the burden of identifying pregnant women, while the information gained can help inform future communication strategies. Specifically, this study aimed to: (1) evaluate the feasibility of using IRS visits to identify and reach pregnant women, (2) assess baseline knowledge and uptake of malaria prevention measures, and (3) identify key factors influencing intervention uptake to inform future communication strategies.

Methods

IRS campaign

On Bioko Island, IRS has been conducted annually with one or two rounds since 2004, with the 30th round conducted from March to early August 2023. The spatial decision support system (SDSS) and related data systems used in IRS campaigns on Bioko Island have been described in detail elsewhere [25, 30]. In brief, households are geolocated and assigned persistent unique codes based on a gridded mapping system, and field workers are assigned workloads based on 100 m x 100 m grid cells (map sectors). On their visit to a household, spray operators collected basic information about the household, including its unique code and the population protected (i.e. the number of residents), which included the number of resident children under the age of 5 years and pregnant women. Pregnant women were identified through self-reporting, with spray operators specifically trained to ask about pregnancy status in each sprayed household using standardized questions. These data were used to identify households (using their unique codes) with pregnant women for follow-up.

Follow-up visits to pregnant women

We identified 1,880 houses reporting pregnant women residents (see Fig. 1 for a flow of households and participants through the study). Follow-up visits were conducted in three phases, designed to allow for process refinement and gradual scale-up (Fig. 2). An initial pilot phase included houses in a single 1 km x 1 km grid cell (map area) sprayed from the beginning of the round until March 28 (140 houses). A scale-up phase included houses outside the pilot area sprayed from the beginning of the round until April 22 (920 houses), and a final phase included houses sprayed from April 23 through the end of June 2023 (820 houses). For logistical reasons, the selection of houses reported to have pregnant women was limited to those located in the greater Malabo area, and within this area several map areas were not targeted for follow-up because no pregnant women were reported in IRS campaign data. Hence, the households visited comprised a convenience cross-sectional sample, and no formal sample size calculations were performed.

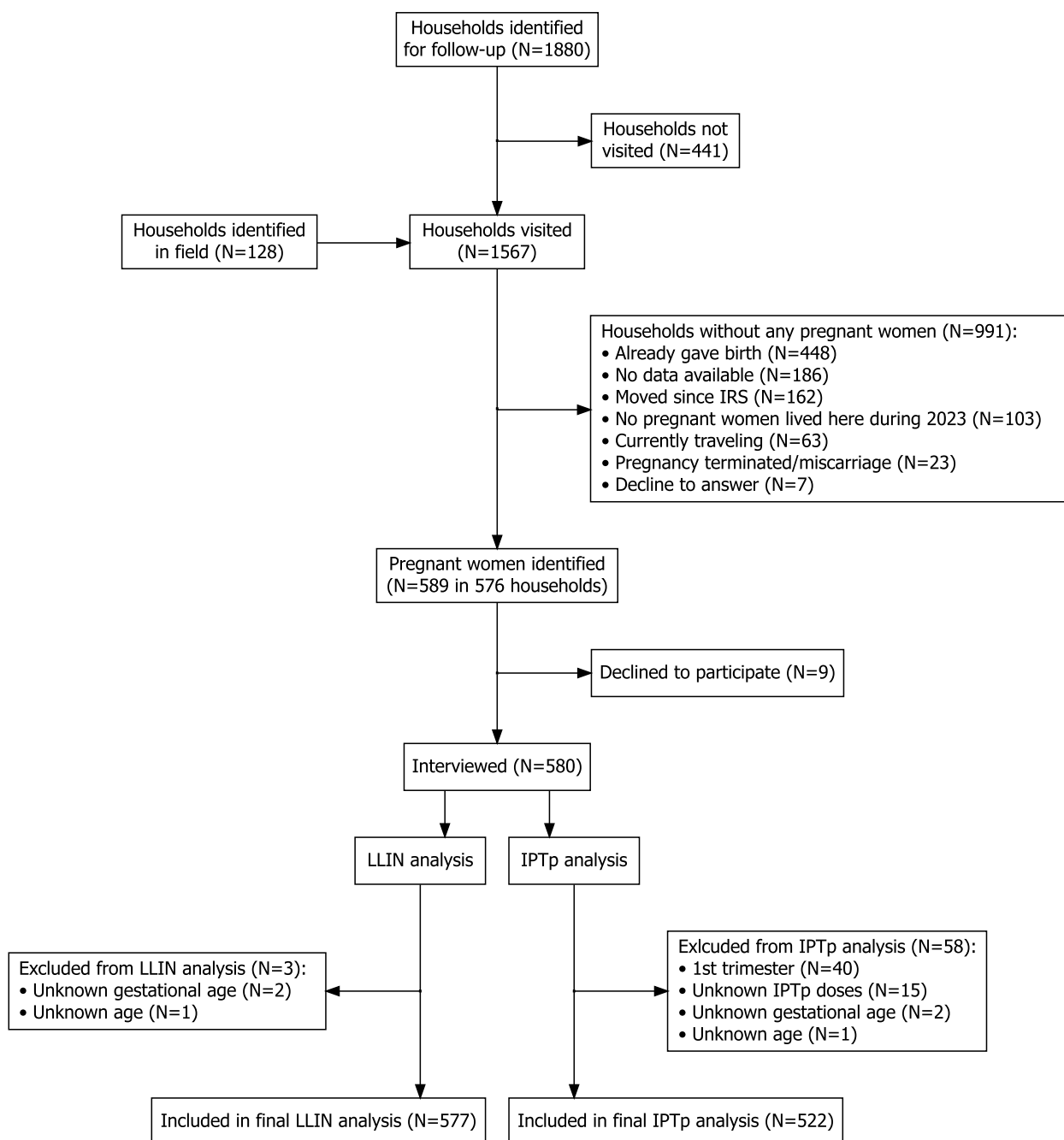


Fig. 1 Flow of households and participants through the study and analysis

Six members of the communications team used lists of selected households to conduct visits from April 25th to October 20th, 2023.

All follow-up visits were conducted with the following protocol. If no pregnant women resided in the household, this was registered along with the reason (e.g. had already given birth, moved, etc.). For houses with a pregnant woman present, verbal informed consent for participation was obtained, and the interview proceeded following a simple questionnaire. The questionnaire was

designed based on the MIS questionnaire used on Bioko Island and included questions about awareness of the availability and benefits of malaria prevention measures for pregnant women, namely ANC, IPTp, and LLINs, and uptake of these interventions (see Additional File 1 for full questionnaire). In addition, basic demographic information was collected, along with phone numbers for participants consenting to be contacted for further follow-up. Data were entered digitally on tablets, using the same data systems as were used in IRS, and shared

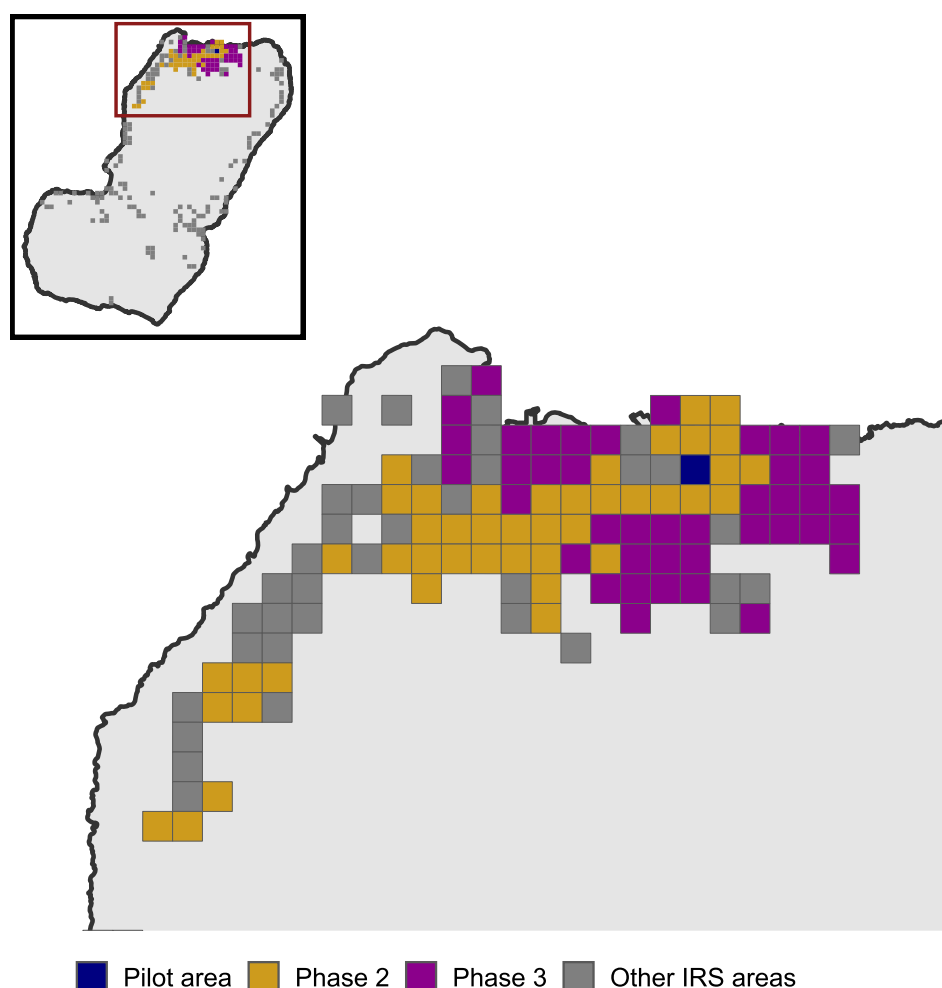


Fig. 2 Phased implementation approach. Pilot area (1 × 1 km) is shown in blue, and other 1 × 1 km map areas in yellow are those which were first targeted in phase 2, those in pink were first targeted in phase 3, and those in gray indicate other areas targeted by IRS but not for follow-up of pregnant women

internally to the field team via interactive, real-time dashboards [30]. Fieldworkers were trained in the use of the data collection instrument prior to starting fieldwork and were given supportive tools (e.g. scripts for obtaining consent and performing sensitization) to ensure uniformity in data collection.

Data analysis

To simplify reporting, for several knowledge indicators, we collapsed respondents unsure or reporting not knowing information and those reporting incorrect information into a single unaware category. This approach was taken for awareness that LLINs prevent malaria, of LLIN availability free of charge at ANC in public health facilities, and awareness of any IPTp benefit (where being unsure what SP is, or of its benefits, or reporting not knowing what SP is or not knowing any benefits were all collapsed into a single unaware category). Indicators of awareness and uptake of interventions were calculated by demographic breakdowns, trimester of pregnancy, and

place of ANC (at a public or private facility). Additionally, LLIN use and IPTp uptake were computed by awareness status of these interventions. Associations between demographic and awareness covariates and LLIN use and IPTp uptake were assessed by chi-squared tests.

To analyze IPTp uptake, we defined pregnant women as on schedule to complete the total of three recommended doses during their pregnancy if: she was in her 4th –5th month of pregnancy and had taken at least one dose; she was in her 6th –7th month and had taken at least two doses; or she was in her 8th –9th month and had taken at least three doses. Behind schedule was defined as having taken at least one dose, but less than the number of doses required to be determined as on schedule. These definitions were necessary, since guidance establishes the total minimum number of doses during pregnancy necessary for protection (at least three), but all survey respondents had not yet completed their pregnancy. While simpler endpoints could have been analyzed (e.g. the number of doses received by the time of interview), these would

not be comparable across gestational ages with respect to clinical guidance. For example, a woman in her second trimester who has received one dose of IPTp may be likely to finish the recommended minimum of three, but one already in her third trimester with only one dose likely will not. Pregnant women in their first trimester were excluded from analyses of IPTp uptake, since guidance recommends initiating IPTp in the second trimester, as were women with an unknown number of IPTp doses. Thus, the denominator for IPTp uptake was women in their second or third trimester with a known number of IPTp doses taken, also referred to here as women with known number of IPTp doses.

To quantify the possible association between knowledge and practice, we conducted a partial proportional odds ordinal regression analysis. This is a method which recognizes the ordered nature of response variables (here, where each level in the LLIN use and IPTp categorical variables indicates increased uptake), assuming that some but not all of the covariates have equivalent effects in all contrasts (endpoints built on a comparison across a single split in the ordinal variable) on the log-odds scale [31]. Two models were constructed, one for LLIN use where the contrasts were (1) use of LLIN on some or all nights versus no use, and (2) use of LLINs on all nights versus use on no or some nights; and another for IPTp uptake where the contrasts were (1) having started IPTp (i.e. behind schedule or on track) versus not having started IPTp, and (2) on track for IPTp3 versus no IPTp or behind schedule. First, proportional odds models were fit using demographic variables (age, education level, trimester of pregnancy and ANC facility type, i.e. public versus private) and knowledge indicators related to LLINs and IPTp as covariates. For the LLIN use model, a covariate indicating whether the respondent reported having received an LLIN during ANC was additionally included. Covariates selected were included based on their availability in the dataset and possible relationship to endpoints, and in the case of ANC facility type based on interest in identifying differences in uptake by this variable; exploratory analysis for covariate selection was not performed, but correlation coefficients between covariates included in each model were examined for multicollinearity and in all cases had absolute value less than 0.85. Then the proportional odds assumption was examined with a likelihood ratio test (LRT) to identify variables which may violate this assumption. Finally, a partial proportional odds model was fit with the same covariates but allowing those with an LRT p -value < 0.2 to have non-proportional odds. This selected one variable in the LLIN model (having received an LLIN at ANC) and two in the IPT model (trimester of pregnancy and the reported number of IPTp doses required) to have non-proportional odds. Results are presented only for

the final, partial proportional odds models, as odds ratios (OR), with their corresponding 95% confidence interval (CI) and p -value for each contrast separately. However, OR for variables assumed to have proportional odds are (by definition) equal across contrasts and have been included in only one hypothesis test. Model goodness of fit was assessed using McFadden pseudo- R^2 , for which values of 0.2–0.4 indicate a very good fit [32]. Analyses were conducted in R (Version 4.4.2), using the packages *ordinal* and *VGAM* for proportional and partial proportional odds modeling, respectively [33, 34].

Results

Population reached

Of the 1,880 households identified through IRS data, 1,439 households (76.5%) were successfully visited, in addition to 128 households identified in the community and therefore not linked to IRS records, for a total of 1,567 households visited (Fig. 1). Overall, a median of 121 households with pregnant women were identified per week of spraying across all areas targeted for follow up (range 20–171). Individual team members performed a median of 25 follow-up visits per week (range 2–87), identifying a median of 8 pregnant women (range 1–33), meaning the team of six should have been able to visit around 150 households per week. Among households visited and linked to IRS records, follow-up visits were conducted a median of 82 days (range 20–173 days) after the initial IRS visit.

Follow-up visits resulted in identification of 589 pregnant women from 576 households (13 households had multiple pregnant residents). Given a high number of houses without any pregnant women found during the first month of fieldwork, the questionnaire was updated to collect information on the reasons no pregnant women were found (households without pregnant women visited prior to this addition are labelled with the exclusion reason “No data available” in Fig. 1). The most common reasons identified were that the pregnant woman had already given birth (448 households, 45.2%) or had moved (162 households, 16.3%). Notably, in 103 houses (10.4%), residents indicated no pregnant women had lived there in 2023, despite IRS data indicating otherwise. These households were most likely suggestive of data quality issues, in data either from IRS or follow-up visits, possibly due to reporting bias.

Among the pregnant women identified, participation was high, with 98.5% (580/589) agreeing to be surveyed and 98.3% of these (570/580) providing contact information for future follow-up (Fig. 1). The age distribution of surveyed women was representative of typical pregnancy demographics in the country [35], with most aged 20–39 (85.7%, 497/580). The majority were in their second (32.1%, 186/580) or third (60.7%, 352/580) trimester,

25.3% (147/580) attended ANC at a private health facility, and 11.6% (67/580) had not attended ANC during the current pregnancy.

Knowledge, awareness and uptake of interventions

Overall, the respondents reported high awareness of the importance and availability of LLINs, but low IPTp awareness (Table 1). More than 75% cited LLINs as a malaria prevention measure, although this was somewhat lower in women under age 20 (62.5%). Nearly all women were aware that LLINs are available free of charge for pregnant women attending ANC in public health facilities (overall 93.3%), and this was true across most demographic breakdowns. On the other hand, only 34.5% were able to cite at least one benefit of IPTp, and the majority were unsure about the month when IPTp should be initiated and how many doses should be taken throughout the pregnancy (62.6% and 66.4%, respectively). There was a correspondingly low awareness (overall 37.1%) that IPTp is available free of charge in public health facilities on Bioko Island.

Despite high awareness of the importance and availability of LLINs, use was lower (Table 2). More than one third of women reported never using a LLIN (38.1%), while 54.8% reported using one every night and 7.1% on

some but not all nights. Never-use was higher among women attending private facilities (46.3%) or who hadn't attended ANC (50.0%), compared to those attending public hospitals (33.2%) or other public facilities (31.7%). As shown in Table 3, IPTp uptake was lower than LLIN use: among 522 women included in IPTp analysis, only 35.2% were on track to complete the recommended three doses. Those non-compliant with recommendations mostly consisted of women in the second trimester who had not received any doses (56.3% of those in the second trimester), and in the third trimester who had received at least one dose, but not sufficient to be on schedule (43.7% of those in the third trimester).

Relationship between awareness and uptake

An analysis of knowledge and practice relationships indicated potentially important associations between awareness and intervention uptake. As shown in Fig. 3, respondents with increased awareness of LLINs and IPTp had an overall higher uptake of these interventions. LLIN use was much higher among respondents aware that LLINs prevent malaria (with 64.6% and 8.1% of those aware reporting LLIN use all and some nights, respectively, versus 22.4% and 4.5% in those unaware), and those who reported receiving an LLIN had higher overall

Table 1. Awareness and knowledge related to malaria among pregnant women surveyed, according to demographic factors. Note that the overall category includes women with unknown age and trimester (one woman each). Cells for columns corresponding to a correct piece of information are shaded according to level of awareness (ranging from dark blue for high awareness to dark orange for low awareness)

	Pregnant women	Aware LLIN prevent malaria	Aware of any IPTp benefit	Reported month when IPTp should be started:				Reported doses IPTp required:			Aware public facilities provide free LLIN at ANC	Aware public facilities provide free IPTp at ANC
				1st Trimester	Month 4	Months 5-9	Don't know	1-2 doses	3+ doses	Don't know		
Age												
15-19	64	62.5%	6.2%	3.1%	3.1%	3.1%	90.6%	0.0%	7.8%	92.2%	89.1%	7.8%
20-29	300	76.7%	30.3%	12.7%	12.3%	8.0%	67.0%	5.0%	23.7%	71.3%	93.3%	30.7%
30-39	197	82.2%	49.7%	19.3%	25.9%	8.1%	46.7%	12.7%	36.0%	51.3%	94.9%	55.3%
40+	18	72.2%	38.9%	16.7%	11.1%	11.1%	61.1%	27.8%	16.7%	55.6%	88.9%	50.0%
Education level												
At most primary	60	71.7%	20.0%	11.7%	6.7%	1.7%	80.0%	5.0%	16.7%	78.3%	83.3%	23.3%
Secondary	437	78.7%	34.3%	13.7%	15.6%	8.2%	62.5%	7.1%	25.9%	67.0%	95.4%	37.8%
Post-secondary	72	75.0%	48.6%	19.4%	25.0%	6.9%	48.6%	13.9%	34.7%	51.4%	93.1%	44.4%
Unknown	11	45.5%	27.3%	0.0%	18.2%	18.2%	63.6%	9.1%	18.2%	72.7%	63.6%	36.4%
Trimester of pregnancy												
1st	40	75.0%	25.0%	17.5%	10.0%	5.0%	67.5%	2.5%	20.0%	77.5%	87.5%	22.5%
2nd	186	75.3%	31.2%	13.4%	10.8%	4.8%	71.0%	7.5%	18.3%	74.2%	89.8%	30.1%
3rd	352	77.8%	37.5%	13.9%	19.0%	9.4%	57.7%	8.5%	30.4%	61.1%	95.7%	42.3%
Location of ANC												
Public hospital	217	76.0%	30.0%	12.0%	15.7%	5.1%	67.3%	8.3%	20.7%	71.0%	95.9%	35.5%
Other public facility	147	81.0%	34.7%	15.0%	13.6%	8.8%	62.6%	6.8%	24.5%	68.7%	98.0%	45.6%
Private clinic	147	74.8%	43.5%	15.6%	21.1%	10.2%	53.1%	8.2%	38.1%	53.7%	87.8%	35.4%
No ANC/ Other	69	76.0%	30.0%	12.0%	15.7%	5.1%	67.3%	8.3%	20.7%	71.0%	95.9%	35.5%
Overall												
	580	76.9%	34.5%	14.0%	15.9%	7.6%	62.6%	7.8%	25.9%	66.4%	93.3%	37.1%

Table 2 Reported uptake of long-lasting insecticide-treated Nets (LLIN) among pregnant women surveyed and included in LLIN analysis, according to demographic factors. P value column reports the result of a chi-squared test of independence with the categorical response (LLIN use)

	Pregnant women	Attended ANC	ANC: Received LLIN	Use LLIN: Never	Use LLIN: Some nights	Use LLIN: All nights	P value (χ^2 test)
Age							
15–19	64	89.1%	63.2%	39.1%	12.5%	48.4%	0.4
20–29	299	88.0%	58.6%	35.8%	6.7%	57.5%	
30–39	196	89.8%	46.6%	40.3%	6.6%	53.1%	
40+	18	83.3%	46.7%	50.0%	0.0%	50.0%	
Education level							
At most primary	59	84.7%	46.0%	37.3%	10.2%	52.5%	0.6
Secondary	435	88.3%	59.6%	36.8%	6.4%	56.8%	
Post-secondary	72	94.4%	35.3%	45.8%	8.3%	45.8%	
Unknown	11	81.8%	33.3%	45.5%	9.1%	45.5%	
Trimester							
1st	40	22.5%	33.3%	45.0%	7.5%	47.5%	0.5
2nd	186	82.3%	54.9%	39.8%	4.8%	55.4%	
3rd	351	99.4%	55.0%	36.5%	8.3%	55.3%	
Location of ANC							
Public hospital	217	100.0%	65.9%	33.2%	6.9%	59.9%	0.03 *
Other public facility	145	100.0%	86.2%	31.7%	7.6%	60.7%	
Private clinic	147	100.0%	6.8%	46.3%	8.2%	45.6%	
No ANC/Other	68	2.9%	50.0%	50.0%	4.4%	45.6%	
Overall	577	88.6%	54.6%	38.1%	7.1%	54.8%	

Table 3 Reported uptake of antenatal care (ANC) and intermittent preventive treatment (IPTp) among pregnant women surveyed and included in IPTp analysis, according to demographic factors. P value column reports the result of a chi-squared test of independence with the categorical response (IPTp uptake)

	Pregnant women	Attended ANC	IPTp uptake: None	IPTp uptake: Behind schedule	IPTp uptake: On schedule	P value (χ^2 test)
Age						
15–19	60	90.0%	38.3%	35.0%	26.7%	0.1
20–29	268	92.9%	34.7%	32.8%	32.5%	
30–39	179	95.0%	25.1%	31.8%	43.0%	
40+	15	93.3%	26.7%	46.7%	26.7%	
Education level						
At most primary	56	87.5%	39.3%	26.8%	33.9%	0.3
Secondary	393	93.6%	32.3%	33.6%	34.1%	
Post-secondary	65	98.5%	20.0%	38.5%	41.5%	
Unknown	8	75.0%	37.5%	12.5%	50.0%	
Trimester						
2nd	183	82.0%	56.3%	13.7%	30.1%	<0.001 ***
3rd	339	99.4%	18.3%	43.7%	38.1%	
Location of ANC						
Public hospital	205	100.0%	31.7%	34.6%	33.7%	<0.001 ***
Other public facility	140	100.0%	20.0%	37.9%	42.1%	
Private clinic	140	100.0%	26.4%	34.3%	39.3%	
No ANC/Other	37	5.4%	94.6%	2.7%	2.7%	
Overall	522	93.3%	31.6%	33.1%	35.2%	

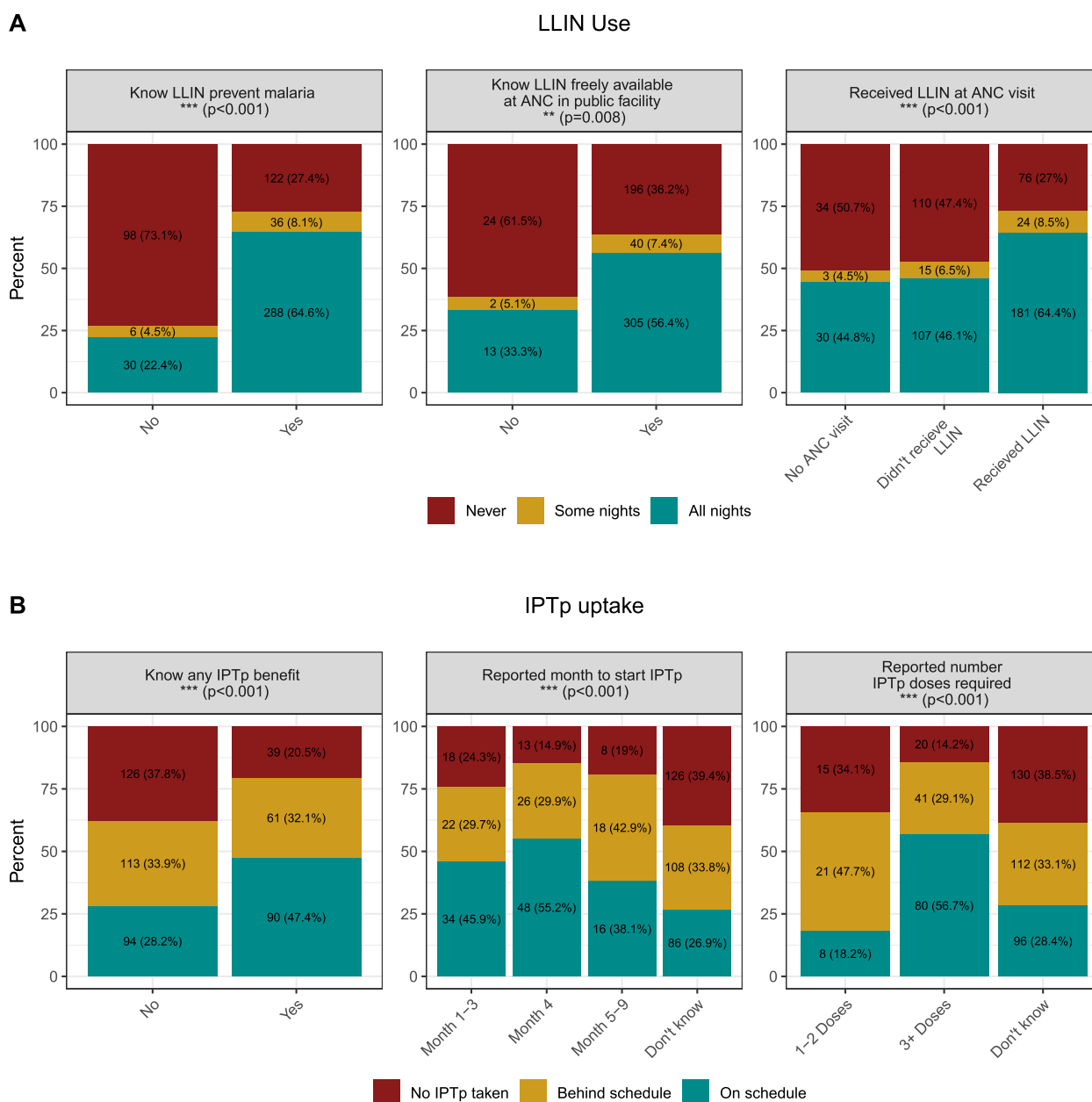


Fig. 3 Association between knowledge and uptake of LLINs and IPTp. Proportion of respondents by LLIN use category according to awareness that LLINs prevent malaria, awareness of their availability free of charge at ANC in public facilities, and whether the respondent reported receiving an LLIN at ANC (A); and proportion of respondents by IPTp uptake category, according to awareness of any IPTp benefit, and of the timing and number of doses required (B). Significance levels and p-values indicate results of chi-squared tests

use. Chi-squared tests indicated that the relationships between these variables and LLIN use was statistically significant (Fig. 3A). Similarly, awareness of the benefits, timing and dosing of IPTp was associated with IPTp uptake (Fig. 3B). Indeed, among women who reported knowing that three IPTp doses were needed, 56.7% were on schedule compared to 28.4% of those unsure of the doses required and 18.2% of those believing only 1–2 doses were required. All IPTp awareness indicators were

found to have a statistically significant relationship with IPTp uptake (Fig. 3B).

Multiple partial proportional odds ordinal regression modeling partially confirmed these associations. LLIN use on some or all nights was found to be significantly associated with awareness of LLINs as a malaria prevention measure (adjusted OR 7.03, 95% CI 4.48–11.04, Table 4) and receiving LLIN at ANC (adjusted OR 2.09, 95% CI 1.26–3.46), and use on every night was similarly associated. For IPTp compliance, knowledge that three

Table 4 Partial proportional odds ordinal regression results for LLIN use for two different contrasts (use of LLIN on some or all nights, on left, and on all nights, on right). Proportional odds were assumed for all coefficients except the intercept, received LLIN at ANC and aware LLIN prevent malaria, where coefficients for each contrast were allowed to vary. The odds ratio (OR), 95% confidence interval (CI) and p-value are reported for each variable and contrast, and bolded where the p-value < 0.05. For categorical variables, reference levels are indicated as REF. Pseudo R^2 is the McFadden Pseudo R^2

Pseudo- R^2 : 0.11	Use LLIN some or all nights			Use LLIN every night		
	OR	95% CI	P value	OR	95% CI	P value
Intercept	0.75	(0.2–2.89)	0.7	0.12	(0.02–0.54)	0.006 **
Age						
15–19	REF			REF		
20–29	1.1	(0.61–2)	0.7	1.1	(0.61–2)	0.7
30–39	0.88	(0.47–1.64)	0.7	0.88	(0.47–1.64)	0.7
40+	0.74	(0.24–2.28)	0.6	0.74	(0.24–2.28)	0.6
Education level						
At most primary	REF			REF		
Secondary	0.87	(0.48–1.6)	0.7	0.87	(0.48–1.6)	0.7
Post-secondary	0.65	(0.3–1.4)	0.3	0.65	(0.3–1.4)	0.3
Unknown	1.52	(0.37–6.34)	0.6	1.52	(0.37–6.34)	0.6
Trimester of pregnancy						
1st	REF			REF		
2nd	0.85	(0.36–1.98)	0.7	0.85	(0.36–1.98)	0.7
3rd	0.77	(0.32–1.88)	0.6	0.77	(0.32–1.88)	0.6
Location of ANC						
Public hospital	REF			REF		
Other public facility	0.84	(0.52–1.33)	0.4	0.84	(0.52–1.33)	0.4
Private clinic	0.82	(0.48–1.41)	0.5	0.82	(0.48–1.41)	0.5
No ANC/Other	0.63	(0.29–1.35)	0.2	0.63	(0.29–1.35)	0.2
Received LLIN at ANC	2.09	(1.26–3.46)	0.004 **	1.78	(1.09–2.9)	0.02 *
Aware LLIN prevent malaria	7.03	(4.48–11.04)	<0.001 ***	7.03	(4.48–11.04)	<0.001 ***
Aware LLIN free at public HF	1.2	(0.55–2.61)	0.6	1.2	(0.55–2.61)	0.6

or more doses are recommended was significantly correlated with both having started IPTp (adjusted OR 3.38 compared to those believing 1–2 doses were necessary, 95% CI 1.39–8.24, Table 5) and being on track for three doses (adjusted OR 6.62, 95% CI 2.74–16.00). Intriguingly, being unsure about the number of required doses was significantly associated with being on track for three IPTp doses (adjusted OR 3.15 compared to those who reported that only 1–2 doses were necessary, 95% CI 1.22–8.10). Women in their third trimester were also more likely to have started IPTp than those in their second trimester (adjusted OR 3.79, 95% CI 2.43–5.90), but not significantly more (or less) likely to be on track to complete three doses, indicating a tendency towards delayed initiation of IPTp with unclear implications for non-compliance. Women who attended ANC in public facilities that were not hospitals were also somewhat more likely to have higher IPTp uptake. Despite apparent trends (Fig. 3), awareness that LLIN are available free of charge at ANC in public facilities and awareness of IPTp benefits and timing were not found to be significantly associated with LLIN use and IPTp compliance in regression modeling.

Discussion

Summary of key findings

This study demonstrates that household-level outreach through IRS visits can serve as a feasible platform for identifying and engaging pregnant women for malaria prevention, especially those missed by routine ANC-based strategies. Awareness of the utility of LLINs and their availability for pregnant women was much higher than that of IPTp, and for both interventions, awareness was associated with higher uptake. Despite the relatively high awareness of LLINs, use was only moderate, and IPTp-3 coverage was low compared to targets set in Equatorial Guinea's National Health Development Plan [36]. These findings suggest a need for further work to understand and provide solutions for specific barriers to LLIN use and IPTp uptake among pregnant women.

Operational feasibility and challenges

Follow-up visits to households identified in IRS was an effective method to reach pregnant women, with 79.4% of targeted households reached and 98.5% of identified pregnant women participating. The primary barrier to visiting all households targeted from IRS data was a difficulty in finding residents at home and thus the necessity

Table 5 Partial proportional odds ordinal regression results for IPTp compliance for two different contrasts (any IPTp taken, on left, and on track to complete 3 doses of IPTp, on right). Proportional odds were assumed for all coefficients except the intercept, trimester of pregnancy, and reported number of IPTp doses required, where coefficients for each contrast were allowed to vary. The odds ratio (OR), 95% confidence interval (CI) and p-value are reported for each variable and contrast, and bolded where the p-value < 0.05. For categorical variables, reference levels are indicated as REF. Pseudo R² is the McFadden Pseudo R²

Pseudo-R ² : 0.17	Any IPTp			On track for IPTp3		
	OR	95% CI	P value	OR	95% CI	P value
Intercept	0.61	(0.17–2.14)	0.4	0.16	(0.04–0.6)	0.006 **
Age						
15–19	REF			REF		
20–29	0.93	(0.53–1.64)	0.8	0.93	(0.53–1.64)	0.8
30–39	1.2	(0.65–2.23)	0.6	1.2	(0.65–2.23)	0.6
40+	0.88	(0.27–2.8)	0.8	0.88	(0.27–2.8)	0.8
Education level						
At most primary	REF			REF		
Secondary	0.82	(0.46–1.47)	0.5	0.82	(0.46–1.47)	0.5
Post-secondary	1.05	(0.5–2.21)	0.9	1.05	(0.5–2.21)	0.9
Unknown	2.12	(0.39–11.56)	0.4	2.12	(0.39–11.56)	0.4
Trimester of pregnancy						
2nd	REF			REF		
3rd	3.79	(2.43–5.9)	< 0.001 ***	0.89	(0.58–1.36)	0.6
Location of ANC						
Public hospital	REF			REF		
Other public facility	1.66	(1.09–2.54)	0.02 *	1.66	(1.09–2.54)	0.02 *
Private clinic	0.98	(0.63–1.51)	> 0.9	0.98	(0.63–1.51)	> 0.9
No ANC/Other	0.04	(0.01–0.19)	< 0.001 ***	0.04	(0.01–0.19)	< 0.001 ***
Reported month when IPTp should be started						
1st trimester	REF			REF		
Month 4	1.67	(0.88–3.18)	0.1	1.67	(0.88–3.18)	0.1
Months 5–9	0.77	(0.36–1.66)	0.5	0.77	(0.36–1.66)	0.5
Don't know	0.84	(0.42–1.67)	0.6	0.84	(0.42–1.67)	0.6
Reported number of IPTp doses required						
1–2 doses	REF			REF		
3+ doses	3.38	(1.39–8.24)	0.007 **	6.62	(2.74–16)	< 0.001 ***
Don't know	1.65	(0.69–3.96)	0.3	3.15	(1.22–8.1)	0.02 *
Aware of IPTp benefit	1.37	(0.77–2.42)	0.3	1.37	(0.77–2.42)	0.3

of performing multiple re-visits to reach the population. Despite this difficulty, this approach offers a promising opportunity to achieve high population coverage, but the effectiveness remains to be evaluated. On Bioko, much of the outreach to pregnant women for malaria prevention has historically been conducted via public health facilities, but as shown here this approach is likely to fail to reach many women who either attend ANC only in private facilities, or do not attend ANC. Our findings showed that 25.3% of the women were accessing ANC care outside of public health facilities and 11.6% were not attending ANC at all, confirming a crucial gap in traditional outreach methods. Household IRS visits provided access to a cross-section of the population, enabling identification of pregnant women not usually reached by the public health system.

The only additional costs of the IRS-based strategy are the costs of follow-up visits to already identified

households, offering a cost-efficient approach that requires only marginal increases in resources compared to establishing new outreach programs. While we have applied this approach for outreach to pregnant women regarding malaria, it could similarly be applied for outreach to pregnant women on other aspects of health, or for outreach to other groups, such as to identify children under 5, for follow-up on a range of health topics, such as nutritional screening, immunization status checks, and maternal health education. Success of such strategies could be measured through indicators such as intervention coverage rates and health outcome improvements. The approach could potentially be adapted to eliminate the need for in-person household visits, if IRS teams were to collect contact information and consent to be contacted for households meeting inclusion criteria.

One of the major challenges of this study was the lack of timely follow-up visits, in most cases several months

after an initial IRS visit. The data showed that 45.3% of follow-up visits found women had already given birth, which highlights the critical importance of timing to increase the effectiveness of the outreach. Delays between initial IRS and follow-up visits were caused in part by the phased implementation approach. The team could have potentially covered the weekly number of households identified in the target area (median 121 identified per week, with a team member able to visit a median of 25 per week and six team members). However, the phased approach and initial implementation nearly two months after the beginning of IRS meant that the follow-up team began visiting households with a significant delay after spraying and the delay increased with each phase. The root cause of these delays were the operational considerations that prevented finalization of the protocol and training of the follow-up team until well after IRS began. This was inherent to the pilot nature of the outreach but, in the future, could be improved by better planning. For example, creating weekly lists of households targeted for follow-up from the beginning of the IRS round could allow achieving more timely follow-up visits even if fewer houses were targeted and visited. If the outreach were to be scaled up, however, it would require a larger follow-up team or a sampling approach (whereby not all households with pregnant women according to IRS data would be targeted). A systematic sampling approach, potentially stratified, for example, by geographic area, could help prioritize visits and optimize resource allocation for such a scale-up. Any approach would benefit from a robust real-time SDSS such as the one used on Bioko island, which was critical for the coordination between IRS teams, follow-up staff and data managers [30].

Implications for LLIN and IPTp uptake

The survey results reported here serve both as a baseline for potential future evaluations of outreach activities, as well as a source of information to effectively plan and target such activities. However, as previous work has demonstrated there is a complex cognitive process which ultimately results in decisions about LLIN use [37–39] and IPTp uptake [40, 41], while only a relatively limited set of awareness indicators concerning the benefits and availability of LLIN and IPTp were considered here. In the nomenclature of the commonly applied Health Belief Model (HBM) [42, 43], these indicators provided some insight into perceived benefits and barriers, but the questionnaire did not incorporate other key HBM beliefs such as perceived susceptibility, severity, or self-efficacy, and may not have sufficiently characterized perceived benefits or barriers. This incomplete coverage of relevant beliefs is an important consideration when interpreting findings, especially as it concerns improving communication and outreach activities to drive uptake. Despite these caveats,

this study did find strong associations between awareness and uptake of LLINs and IPTp, pointing towards the potential benefits of properly designed communication and outreach activities.

The association between the perceived benefit of LLIN use and actual use was particularly strong (adjusted OR 7.03). Despite the magnitude of this finding, the overall high level of perceived benefit (>70% of women reported LLINs as protective against malaria) suggests that in many cases the balance between perceived benefits and barriers is unlikely to be a primary driver of non-use. Rather, a lack of perceived threat (i.e. perceived susceptibility or severity) may drive a lack of resolve to act. However, as noted above the questionnaire used in this study was not designed to investigate such perceptions. The large proportion of women reporting never using nets (38.1%) indicates the importance of understanding and providing solutions for drivers of non-use, whether related to perception of susceptibility and severity, continued barriers to use or other factors. If properly designed and targeted, taking into account aspects beyond knowledge including perceptions, convenience of use and sleeping arrangements, additional communication activities could have substantial effects.

In contrast to LLIN awareness, the very low understanding of the benefits and timing of IPTp presents a clear opportunity for targeted communication strategies among women of reproductive age. On the other hand, the lack of a statistically significant association between awareness of benefits and uptake is an indication that awareness of IPTp benefit may not be the main barrier to increasing coverage. Regression modeling found that among covariates considered knowledge about the number of doses was most highly correlated with uptake, which could be an indication that cues to action (a HBM component, see [43] for more detail) are a limiting factor towards uptake rather than perceived threats, benefits or barriers. This interpretation would also suggest that late start of IPTp should be a challenge in this population, which was consistent with findings (since women in the third trimester were significantly more likely to have started IPTp than those in the second trimester). Thus, even though it was not significantly associated with compliance in this analysis, raising awareness about the recommended timing to begin IPTp may also contribute towards improved coverage of IPTp-3. More generally, if the primary challenge to IPTp uptake is a lack of cues to action, a simple SMS reminder of upcoming ANC visits and corresponding IPTp doses, which has been shown to be highly effective in at least one similar context [44], could be an effective strategy for Bioko Island. Of course the effects of such a system would also depend on factors such as trust in the health system.

Programmatic integration and scalability

Beyond its findings specific to malaria, this study demonstrates the importance of integrating different types of health promotion activities. Malaria programs often operate mostly in isolation from other health programs, and, even within national malaria control programs, vector control activities are often disconnected (at least in implementation) from case management or communication activities [45]. However, as we have shown here, there are significant benefits of improving coordination of activities into a broader, coherent health promotion strategy. This integration can maximize impact while optimizing resource use. Just as we have shown that vector control presents opportunities to reinforce community outreach, there are surely many other opportunities to support health-related activities with one another. To date, most such work has been focused mostly on leveraging existing implementations to deliver new interventions or collect additional data. In malaria, prime examples are the inclusion of intermittent preventive treatment of infants (IPTi) in routine immunization schedules [46, 47] or the use of ANC for monitoring malaria prevalence [48–50]. The approach taken here is distinct in that it involves passing information between functional teams in real time, requiring close coordination between previously separated activities. If the (possibly substantial) logistical difficulties can be overcome, this can improve the efficiency of both activities while providing a model for integrated service delivery in resource-limited settings.

In this exercise, the integration of activities was made possible by the existence of a robust SDSS where data from virtually every malaria control intervention live [25, 30]. Prior work on Bioko has similarly utilized these tools to conduct household visits with communication activities focused on antimalarial drug adherence following implementation of an annual MIS [51]. In both cases, the triangulation of spatial and demographic data represented a critical first step to identify and reach out to the target population (here, pregnant women) in the community. Without this system, IRS teams would not have been able to provide actionable information to the communications team. The same system can be used in the future to tailor communication strategies to the at-risk group in order to promote better uptake of malaria prevention.

Finally, it should be noted that currently Bioko Island does not have active community health workers (CHW). In other contexts where CHW are active, the benefit of leveraging data from complementary activities could be substantially lesser, given that the CHW are likely to already be aware of the key populations in their areas of responsibility, and indeed community-level delivery of interventions may be a more effective approach [18–20]. Nevertheless, where such community-level activities are

not possible, leveraging other household-level activities such as vector control can be a useful approach for improving maternal health interventions in malaria-endemic settings. Moreover, as Equatorial Guinea explores implementation and activation of CHW on Bioko and throughout the country, this exercise provides important information about a key population and will be useful in enabling CHW to more quickly and effectively ramp up outreach to pregnant women.

Limitations and future directions

The main limitation of this study was its dependence on a non-systematic, convenience sample of pregnant women in households which had been sprayed in the IRS campaign. Hence, it was not possible to identify individuals living in areas not targeted by IRS, or in households which were not sprayed (possibly due to refusal). This is arguably a small issue, since outright refusals are relatively rare on Bioko (e.g. less than 3,000 recorded in the 2023 IRS round, compared to more than 30,000 houses sprayed), and difficulty in locating a resident at home, particularly in higher-income neighborhoods, is a larger barrier to IRS coverage. Given these patterns, an IRS-based outreach approach could bias against identifying higher income pregnant women, or those living alone or working. Additionally, this study used only self-report to identify pregnant women, and only in urban areas, meaning stigmatized pregnancies (e.g. among young girls) and those among rural populations may be underrepresented. These gaps highlight the need for complementary strategies to reach all pregnant women, including those leveraging technology (e.g. social media). The exclusive use of self-reported outcomes (LLIN use and IPTp uptake) is also a limitation but approaches which can more objectively measure these outcomes are likely to have a smaller reach in the population of interest. Since both tests of independence between covariates and the outcome and regression were performed, there may be some risk of Type I error. Finally, as this was the first implementation of its kind for pregnant women on Bioko, there is not yet information available to evaluate if this type of outreach will improve uptake of interventions, highlighting the need for longer-term impact evaluation.

While this study demonstrated the utility of its outreach approach and provided useful baseline information about knowledge and uptake of LLINs and IPTp, it also suggests further work is necessary to inform the promotion of malaria prevention in pregnancy on Bioko. Associations between knowledge and uptake were observed here, but the questionnaire measured awareness only on a small, well-defined set of indicators. Future work investigating aspects beyond awareness, such as perceptions of malaria and related interventions, social norms, influence and trust in the health system will be essential

in designing effective strategies to increase the coverage of malaria prevention among pregnant women. Furthermore, the present study did not assess the effectiveness of its outreach method to make sustained changes in the uptake of malaria prevention measures. Such an evaluation will require investigation in future studies, either focused exclusively on pregnant women or as part of larger population studies.

Conclusion

This study demonstrated that data collected from household-level vector control campaigns can be leveraged to support other health promotion activities, particularly for reaching populations that may not access traditional or public health services. We focused on using IRS data to reinforce outreach to pregnant women about malaria prevention, achieving high household coverage and identifying a large gap between LLIN awareness and use, very low IPTp awareness, and gaps in public health facility ANC attendance. Similar approaches could strengthen outreach for various health interventions across different target populations. This underscores the importance of working towards better integrated health programs and adaptive management strategies that maximize existing resources from complementary activities or programs. Implementing such cross-cutting integrations will require investment in robust information management systems and program management to overcome the logistical and technical challenges they present, but as shown here can provide avenues for innovative health promotion (or interventional) activities complementary to traditional approaches.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12884-025-08257-w>.

Supplementary Material 1.

Acknowledgements

The authors would like to acknowledge the Ministry of Health and Social Welfare of Equatorial Guinea, the Bioko Island Malaria Elimination Project (BIMEP) staff, district health authorities and community leaders for their continued support in the implementation of malaria control activities on Bioko Island, and thank the pregnant women reached during this activity for their collaboration during follow-up visits.

Authors' contributions

DSG, GAG and CAG conceptualized the study and drafted the manuscript; DSG, JNME, MRR and WPP oversaw fieldwork; DSG and JNME compiled data; DSG conducted data analyses, and prepared figures and tables; MRR, WPP and GAG supervised and supported coordination between different functional teams; all authors reviewed and approved the final manuscript.

Funding

This work was supported by a public-private partnership between the Government of Equatorial Guinea and a consortium of companies including Marathon Oil (a ConocoPhillips company) and its partners, Noble Energy (a Chevron Company), SONAGAS, and GEPetrol, under the Bioko Island Malaria

Elimination Project (BIMEP). The funders had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Data availability

Anonymized data from follow-up visits are available at DOI: [10.6084/m9.figshare.28581074](https://doi.org/10.6084/m9.figshare.28581074).

Declarations

Ethics approval and consent to participate

This work was conducted as part of programmatic malaria control activities, and as such was reviewed and received approval from the Technical and Ethics Committee of the Ministry of Health and Social Welfare of Equatorial Guinea as part of the standard operational procedures and annual work plan for the National Malaria Control Program. All pregnant women participating (or their legal guardians) provided verbal informed consent. The study was conducted in accordance with the principles outlined in the Declaration of Helsinki.

Competing interests

The authors declare no competing interests.

Author details

¹MCD Global Health, Malabo, Equatorial Guinea

²Ministry of Health and Social Welfare, Malabo, Equatorial Guinea

³MCD Global Health, Silver Spring, MD, USA

Received: 21 March 2025 / Accepted: 19 September 2025

Published online: 26 November 2025

References

1. Steketee RW, Nahlen BL, Parise ME, Menendez C. The burden of malaria in pregnancy in malaria-endemic areas. *Intolerable Burden Malaria New Look Numbers Am J Trop Med Hyg*. 2001;64(Suppl 1):28–35.
2. Desai M, Ter Kuile FO, Nosten F, McGready R, Asamoah K, Brabin B, et al. Epidemiology and burden of malaria in pregnancy. *Lancet Infect Dis*. 2007;7(2):93–104.
3. Guyatt HL, Snow RW. Malaria in pregnancy as an indirect cause of infant mortality in sub-Saharan Africa. *Trans R Soc Trop Med Hyg*. 2001;95(6):569–76.
4. Das JK, Lakhani S, Rahman AR, Siddiqui F, Padhani ZA, Rashid Z, et al. Malaria in pregnancy: meta-analyses of prevalence and associated complications. *Epidemiol Infect*. 2024;152:e39.
5. Harrison RK, Lauhon SR, Colvin ZA, McIntosh JJ. Maternal anemia and severe maternal morbidity in a US cohort. *American Journal of Obstetrics & Gynecology MFM*. 2021;3(5):100395.
6. Brabin BJ, Hakimi M, Pelletier D. An analysis of anemia and pregnancy-related maternal mortality. *J Nutr*. 2001;131(2):S604–15.
7. Granja AC, Machungo F, Gomes A, Bergström S, Brabin B. Malaria-related maternal mortality in urban Mozambique. *Ann Trop Med Parasitol*. 1998;92(3):257–63.
8. Menéndez C, Romagosa C, Ismail MR, Carrilho C, Saute F, Osman N, et al. An autopsy study of maternal mortality in Mozambique: the contribution of infectious diseases. *PLoS Med*. 2008;5(2):e44.
9. World Health Organization. World malaria report 2024: addressing inequity in the global malaria response. 2024. <https://www.who.int/teams/global-malaria-programme/reports/world-malaria-report-2024>.
10. Gamble C, Ekwari PJ, Garner P, ter Kuile FO. Insecticide-treated nets for the prevention of malaria in pregnancy: a systematic review of randomised controlled trials. *PLoS Med*. 2007;4(3):e107.
11. ter Kuile O, van Eijk F, Filler AM. Effect of sulfadoxine-pyrimethamine resistance on the efficacy of intermittent preventive therapy for malaria control during pregnancy: a systematic review. *JAMA*. 2007;297(23):2603–16.
12. Eisele TP, Larsen DA, Anglewicz PA, Keating J, Yukich J, Bennett A, et al. Malaria prevention in pregnancy, birthweight, and neonatal mortality: a meta-analysis of 32 National cross-sectional datasets in Africa. *Lancet Infect Dis*. 2012;12(12):942–9.
13. Waltmann A, McQuade ETR, Chinkhumba J, Operario DJ, Mzembe E, Itoh M, et al. The positive effect of malaria IPTp-SP on birthweight is mediated by gestational weight gain but modifiable by maternal carriage of enteric

- pathogens. *eBioMedicine*. 2022. <https://doi.org/10.1016/j.ebiom.2022.103871>.
14. World Health Organization. WHO guidelines for malaria [Internet]. 2024 [cited 2024 Dec 10]. Available from: <https://app.magicapp.org/#/guideline/8100>
 15. Singh M, Brown G, Rogerson SJ. Ownership and use of insecticide-treated nets during pregnancy in sub-Saharan Africa: a review. *Malar J*. 2013;12(1):268.
 16. Pell C, Straus L, Andrew EVW, Meñaca A, Pool R. Social and cultural factors affecting uptake of interventions for malaria in pregnancy in Africa: a systematic review of the qualitative research. *PLoS ONE*. 2011;6(7):e22452.
 17. Roman E, Andrejko K, Wolf K, Henry M, Youll S, Florey L, et al. Determinants of uptake of intermittent preventive treatment during pregnancy: a review. *Malar J*. 2019;18(1):372.
 18. Mbonye AK, Bygbjerg I, Magnussen P. Intermittent preventive treatment of malaria in pregnancy: evaluation of a new delivery approach and the policy implications for malaria control in Uganda. *Health Policy*. 2007;81(2):228–41.
 19. Hassan SEDH, Malik EM, Okoued SI, Eltayeb EM. Retention and efficacy of long-lasting insecticide-treated nets distributed in Eastern Sudan: a two-step community-based study. *Malar J*. 2008;7(1):85.
 20. Gutman JR, Stephens DK, Tiendrebeogo J, Badolo O, Dodo M, Burke D, et al. A cluster randomized trial of delivery of intermittent preventive treatment of malaria in pregnancy at the community level in Burkina Faso. *Malar J*. 2020;19(1):282.
 21. Nganda RY, Drakeley C, Reyburn H, Marchant T. Knowledge of malaria influences the use of insecticide treated nets but not intermittent presumptive treatment by pregnant women in Tanzania. *Malar J*. 2004;3(1):42.
 22. Mchwampaka WM, Tarimo D, Chacky F, Mohamed A, Kishimba R, Samwel A. Factors affecting uptake of ≥ 3 doses of Sulfadoxine-pyrimethamine for malaria prevention in pregnancy in selected health facilities, Arusha region, Tanzania. *BMC Pregnancy Childbirth*. 2019;19(1):440.
 23. Gies S, Coulibaly SO, Ky C, Ouattara FT, Brabin BJ, D'Alessandro U. Community-based promotional campaign to improve uptake of intermittent preventive antimalarial treatment in pregnancy in Burkina Faso. *Am J Trop Med Hyg*. 2009;80(3):460–9.
 24. República de Guinea Ecuatorial Censo de Población 2015 [Internet]. Gobierno de Guinea Ecuatorial. 2016. Available from: <https://inege.org/wp-content/uploads/2024/07/RESULTADOS-DEFINITIVOS-DEL-IV-CENSO-GENERAL-DE-P OBLACION-Y-VIVIENDAS-2015.pdf>
 25. García GA, Hergott DEB, Phiri WP, Perry M, Smith J, Osa Nfumu JO, et al. Mapping and enumerating houses and households to support malaria control interventions on Bioko Island. *Malar J*. 2019;18(1):283.
 26. Fries B, Guerra CA, García GA, Wu SL, Smith JM, Oyono JNM, et al. Measuring the accuracy of gridded human population density surfaces: a case study in Bioko Island, Equatorial Guinea. *PLoS ONE*. 2021;16(9):e0248646.
 27. Kleinschmidt I, Schwabe C, Benavente L, Torrez M, Ridl FC, Segura JL, et al. Marked increase in child survival after four years of intensive malaria control. *Am J Trop Med Hyg*. 2009;80(6):882–8.
 28. Cook J, Hergott D, Phiri W, Rivas MR, Bradley J, Segura L, et al. Trends in parasite prevalence following 13 years of malaria interventions on Bioko island, Equatorial Guinea: 2004–2016. *Malar J*. 2018;17(1):62.
 29. National Malaria Control Program of Equatorial Guinea. MCD Global Health. Bioko Island Malaria Indicator Survey 2023. 2024. https://mcd.org/docs/BIME P%20MIS_report_2023-FINAL.pdf.
 30. García GA, Atkinson B, Donfack OT, Hilton ER, Smith JM, Eyono JNM, et al. Real-time, spatial decision support to optimize malaria vector control: the case of indoor residual spraying on Bioko Island, Equatorial Guinea. *PLoS Digit Health*. 2022;1(5):e0000025.
 31. Peterson B, Harrell FE. Partial proportional odds models for ordinal response variables. *Appl Stat*. 1990;39(2):205.
 32. Louviere JJ, Hensher DA, Swait JD. Stated choice methods: analysis and applications. Cambridge University Press. 2000. <https://doi.org/10.1017/CBO9780511753831>.
 33. Christensen RHB. ordinal—Regression Models for Ordinal Data. 2023. Available from: <https://CRAN.R-project.org/package=ordinal>
 34. Yee TW. Vector generalized linear and additive models: with an implementation in R. New York, USA: Springer; 2015.
 35. Ministerio de Sanidad y Bienestar Social de Guinea Ecuatorial, de Economía M. Planificación e Inversiones Públicas de Guinea Ecuatorial, ICF International. Guinea Ecuatorial Encuesta Demográfica y de Salud (EDSGE-I) 2011 [Internet]. Calverton, Maryland, USA: Ministerio de Sanidad y Bienestar Social, Ministerio de Economía, Planificación e Inversiones Públicas/Guinea Ecuatorial and ICF International; 2012. Available from: <http://dhsprogram.com/pubs/pdf/FR271/FR271.pdf>
 36. Ministerio de Sanidad y Bienestar Social de Guinea Ecuatorial. Plan Nacional de Desarrollo Sanitario (2021–2025). Malabo; 2020. https://p4h.world/app/uploads/2022/08/Plan_Nacional_Desarrollo_Sanitario_Guinea_Ecuatorial.x91912.pdf.
 37. Okoh OM, Olapeju B, Oyedokun-Adebago F, Inyang U, McCartney-Melstad A, Tweedie I, et al. The role of ideation on the effect of an SBC intervention on consistent bed net use among caregivers of children under 5 years in Nigeria: a multilevel mediation analysis. *BMC Public Health*. 2021;21(1):1660.
 38. Kumoji E, Kuor, Awantang GN, Toso M, Kamara D, Bleu T, Lahai W, et al. Ideational factors associated with net care behaviour: a multi-country analysis. *Malar J*. 2022;21(1):53.
 39. Babalola S, Kumoji K, Awantang GN, Oyenubi OA, Toso M, Tsang S, et al. Ideational factors associated with consistent use of insecticide-treated nets: a multi-country, multilevel analysis. *Malar J*. 2022;21(1):374.
 40. Welty JC. Exploring the Ideational and Sociodemographic Characteristics that Influence Uptake of Intermittent Preventative Treatment of Malaria in Pregnant Women in Northwest Nigeria [Internet] [DrPH dissertation]. [New Orleans, LA]: Tulane University; 2023 [cited 2024 Dec 29]. Available from: <http://www.proquest.com/openview/a042681915a7eac82df5e8d8d20dcaab/1?pq-origsite=gscholar&cbl=18750&diss=y>
 41. Namusoke F, Lugaajju A, Buwembo W, Kiwuuwa MS, Kaddumukasa M. Perspectives of postpartum women on intermittent presumptive treatment in Uganda: implications for malaria prevention: a qualitative study. *Malar J*. 2024;23(1):331.
 42. Rosenstock IM. The health belief model and preventive health behavior. *Health Educ Monogr*. 1974;2(4):354–86.
 43. Champion VL, Skinner CS. The health belief model. In: Glanz K, Rimer BK, Viswanath K, editors. *Health behavior and health education: Theory, research, and practice*. 4th ed. San Francisco: Jossey-Bass; 2008. p. 45–65.
 44. Flueckiger RM, Thierno DM, Colaço R, Guilavogui T, Bangoura L, Reithinger R, et al. Using short message service alerts to increase antenatal care and malaria prevention: findings from implementation research pilot in Guinea. *Am J Trop Med Hyg*. 2019;101(4):806–8.
 45. The Global Health Group. Program management issues in implementation of elimination strategies. UCSF Global Health Sciences. 2014. <https://shrinkingthemap.org/sites/default/files/resources/mei-program-management-issues-in-implementation-of-elimination-strategies.pdf>.
 46. Macete E, Aide P, Aponte JJ, Sanz S, Mandomando I, Espasa M, et al. Intermittent preventive treatment for malaria control administered at the time of routine vaccinations in Mozambican infants: a randomized, placebo-controlled trial. *J Infect Dis*. 2006;194(3):276–85.
 47. Manzi F, Hutton G, Schellenberg J, Tanner M, Alonso P, Mshinda H, et al. From strategy development to routine implementation: the cost of intermittent preventive treatment in infants for malaria control. *BMC Health Serv Res*. 2008;8(1):165.
 48. Willilo RA, Molteni F, Mandike R, Mugalura FE, Mutafungwa A, Thadeo A, et al. Pregnant women and infants as sentinel populations to monitor prevalence of malaria: results of pilot study in lake zone of Tanzania. *Malar J*. 2016;15(1):392.
 49. Brunner NC, Chacky F, Mandike R, Mohamed A, Runge M, Thawer SG, et al. The potential of pregnant women as a sentinel population for malaria surveillance. *Malar J*. 2019;18(1):370.
 50. Kitojo C, Gutman JR, Chacky F, Kigadye E, Mkude S, Mandike R, et al. Estimating malaria burden among pregnant women using data from antenatal care centres in tanzania: a population-based study. *Lancet Glob Health*. 2019;7(12):e1695–705.
 51. Galick DS, Donfack OT, Mifumu TAO, Onvogo CNO, Dougan TB, Mikue MIAA, et al. Adapting malaria indicator surveys to investigate treatment adherence: a pilot study on Bioko Island, Equatorial Guinea. *Malar J*. 2024;23(1):1–12.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.