FINAL REPORT
After 36 months follow-up
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Durability Monitoring of LLINs in **Nigeria**

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VECTOR WORKS
Scaling Up Vector Control for Malaria Prevention

JOHNS HOPKINS
Center for Communication Programs

TROPICAL HEALTH

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1 Abstract

Background: Malaria prevention with long-lasting insecticidal mosquito nets (LLINs) has seen a tremendous scale-up in sub-Saharan Africa in recent years; however, studies have suggested that the physical durability of the same or similar LLINs may vary significantly. These differences are largely driven by environmental and behavioral factors, and country programs should regularly monitor LLIN durability. Following guidance from the U..S President's Malaria Initiative (PMI), durability monitoring of one brand of LLIN (DAWA Plus 2.0, polyester treated with deltamethrin)— distributed during the 2015/16 mass distribution campaign in Nigeria—was set up in local government areas (LGAs) of three ecologically different states: Zamfara, Ebonyi, and Oyo. The activity was carried out by the National and State Malaria Elimination Programs and the principal investigators of the adjacent entomological surveillance sites, with support from the VectorWorks project and PMI.

Results: The demographic characteristics of the populations were comparable across sites and did not change significantly over time. The Ebonyi and Zamfara sites were both rural and predominantly agricultural, while the Oyo site had more peri-urban characteristics and was economically better off than the other two sites. In Zamfara, 91% of households had agricultural land and some livestock as an economic resource, compared to 69% in Ebonyi, with another 26% of households having either livestock or agricultural land. In Oyo, 25% of households had non-agricultural income sources. Ownership of household assets—such as mobile and smart phones, television, refrigerator, etc.—were significantly more common in Oyo, and house structures were constructed of better materials.

From the risk factors suspected to be linked to net damage, Zamfara had the lowest risk, particularly due to a very positive net care attitude of households; 96% of households showed a very positive composite attitude score in at least two surveys and 55% in all four surveys. In contrast, 39% of households in Oyo never reached the "very positive" level, 22% had a very positive score at least twice, and 3% in all three surveys. In Ebonyi, 58% of households never registered a very positive score, only 6% twice, and no household more than twice. Storing food in sleeping rooms was common in Zamfara, but no household ever cooked in these rooms. In contrast, in Ebonyi, 30% sometimes cooked in sleeping rooms, while the proportion storing food decreased from 82% to around 30% during the study. In Oyo, about one-third stored food and 10% sometimes cooked in the sleeping rooms. Washing of nets was similar in Ebonyi and Oyo with about two washes every six months, but was higher in Zamfara with four washes. In Ebonyi, only bar soap was used, while in Oyo at least one-quarter of households used detergents. In Zamfara, reported detergent use was high initially (40%–66%), but then fell to just 9%.

At baseline, a considerable number of campaign nets were found not yet hanging: 58% Ebonyi, 22% Zamfara, and 80% Oyo. This was significantly improved by the 12-month survey: 27% Ebonyi, 9% Zamfara, and 51% Oyo and, thereafter, essentially all cohort nets were hanging and being used in Ebonyi (99%) and Zamfara (94%). However, in Oyo, the rate of cohort net hanging the previous night only reached 65% after 24 months. Initially, between 30% and 69% of households also owned nets from other sources, but most of these were gone 12 months later. The influx of new nets during the study was very limited and mainly from routine health facility distribution or from family or friends. In Zamfara, all older nets were discarded and the new campaign nets were immediately put into use. In Ebonyi, initially, the older nets were prioritized until they were considered too old and, only then, were the new campaign nets used. In Oyo, there was a 50-50 mix of using old and newer nets across follow-up points.

All-cause attrition was highest in Oyo, with 47% after 24 months compared to 37% in Ebonyi and 14% in Zamfara at the same time. All-cause attrition in Ebonyi then increased to 53% at the final survey and reached

28% in Zamfara. The proportion of losses due to wear and tear among all losses was very small at baseline (0% Ebonyi, 7% Zamfara, and 2% Oyo) meaning that almost all losses were due to nets being given away. The proportion gradually increased and, at the final survey, 38% of attrition was due to wear and tear in Ebonyi, 44% in Zamfara, and 22% in Oyo (24 months only). Overall, only 1% of all campaign nets were used for other purposes, mostly in Oyo and, to a smaller extent, in Ebonyi. Covering windows and doors was the most common other use, followed by protection of crops. No other uses were reported.

The proportion of cohort nets in serviceable condition, therefore, was best in Zamfara (90%), followed by Ebonyi (78%) and Oyo (89% after 24 months). This translates to an estimate for survival in serviceable condition of the campaign nets of 80%, 55%, and 75%, respectively, and an estimated median survival of 5.3 years in Zamfara, 3.3 years in Ebonyi, and 3.2 years in Oyo. The difference between Zamfara and Ebonyi and Oyo was statistically significant (p=0.005). The survival estimate did not differ by gender or head of household (71% for males and 70% for females), but did improve with increasing positive net care and repair attitude of the households. Across the sites, survival in households—which never had a very positive attitude score in any of the surveys—was 54%, increasing to 69% if a household had a very positive score at least once and 81% if two or more times (p=0.0003). Net survival was also found to differ between villages, but was more homogenous within each village.

The 24- and 36-month samples taken for insecticidal effectiveness testing (bio-assay) from all three sites showed a relatively low knockdown rate of 50% to 69%, but 24-hour mortality was above 95% for all samples, resulting in 100% optimal performance in Ebonyi and Oyo and 97% in Zamfara. None of the samples failed the minimal criteria, suggesting that insecticidal effectiveness of the campaign nets was sufficient.

Conclusions: Physical durability of the campaign nets was within the expected range, but showed some differences in performance for the same LLIN brand in different locations. Zamfara performed significantly above expectations, with an estimated median survival of 5.3 years compared to 3.3 and 3.2 for Ebonyi and Oyo. All campaign net samples showed sufficient insecticidal effectiveness.

Contents

3 Acknowledgments

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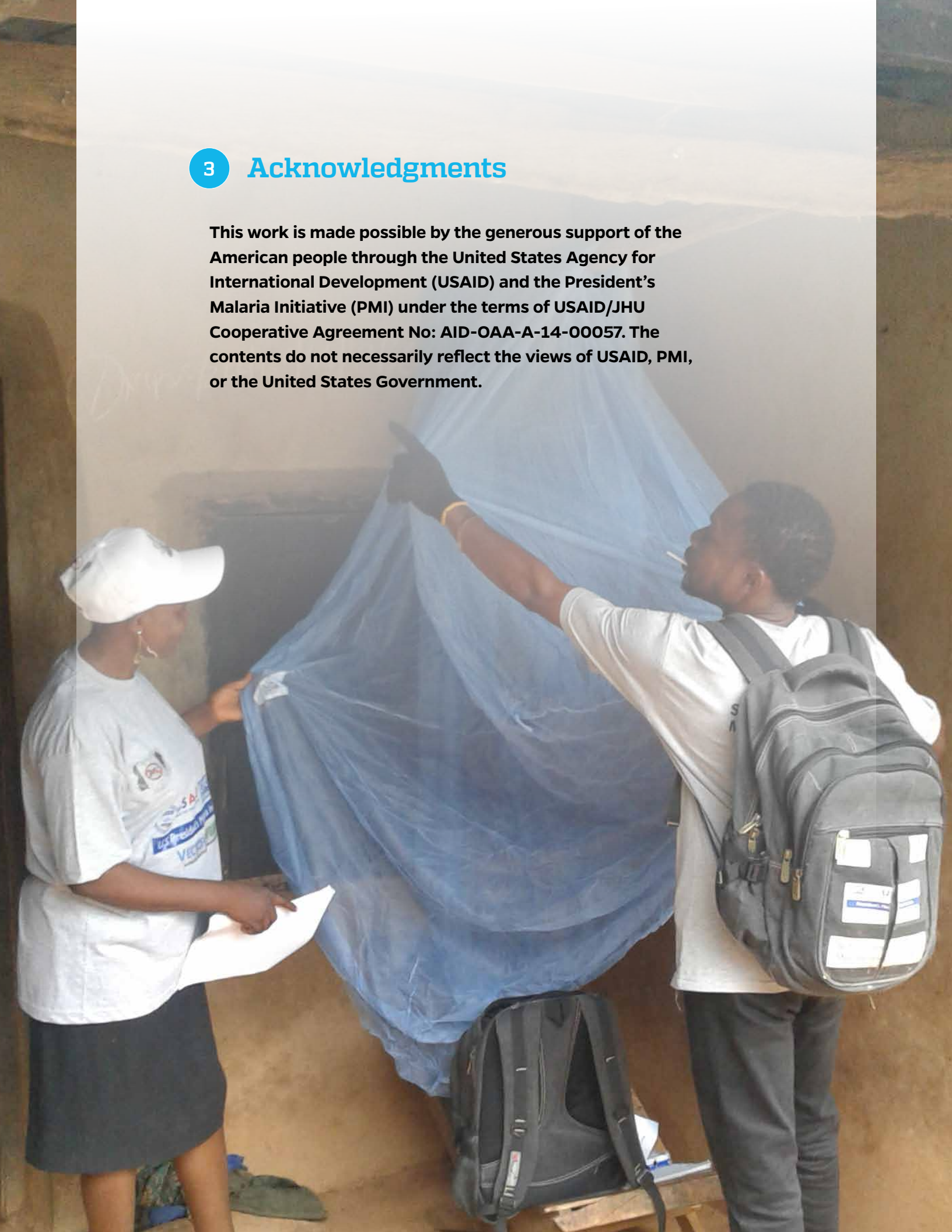

4 Background

Malaria prevention with long-lasting insecticidal-treated mosquito nets (LLINs) has seen a tremendous scale-up in sub-Saharan Africa in recent years. Many countries have achieved high ownership coverage with LLINs and are approaching the universal coverage target of one net for every two people for the population at risk, as recommended by the World Health Organization (WHO). A critical question now is how these successes can be sustained. In this context, it is important to understand how long distributed LLINs remain in the households and continue to protect net users. This information is needed to decide when the LLINs need to be replaced and, also, to select the best product for a specific environment.

Net durability has two components: the physical durability and the insecticidal durability or effectiveness. Physical durability, in turn, includes the loss of nets due to wear and tear and the physical integrity of surviving nets. Over the last five years, the methodology regarding how to measure such net durability has made significant progress and now comprehensive guidance is available from WHO. It resulted in the recommendation that malaria control programs that distribute LLINs should also routinely monitor net durability. Other donors and implementation partners, such as the President's Malaria Initiative (PMI), have taken up this recommendation and recommend routine monitoring of LLIN durability in the countries they support.

To-date, few studies have been published that use the new methodology to measure the field performance of specific LLIN brands, compare different products in the same area, or compare the same product in different environments. In western Uganda, the polyester LLIN brand Interceptor was followed up for 3.5 years, with 20% of nets lost during the study period, 87% of surviving nets still in acceptable or serviceable condition, and 71% with optimal insecticidal effectiveness[1]. The study concluded that this LLIN had a median functional survival of three and a half years.

Monitoring of LLIN durability started in Nigeria in 2012 in the context of the PMI-funded NetWorks project (the predecessor of VectorWorks). In three different eco-geographical zones, researchers carried out a three-year, retrospective study monitoring the physical survival of campaign nets (100-denier polyester LLINs). Sites were located in Zamfara, Nasarawa, and Cross River states. The study showed a significant variation in median survival between the sites, between 3.0 and 4.7 years, which were driven mainly by differences in attitudes and behavior of the households[2]. The study found that, in retrospective durability monitoring, a significant recall bias can exist that overestimates LLIN survival unless it is adjusted for and, thereby, contributed to the current PMI recommendation of prospective study designs, wherever possible.

These results suggest that the physical durability of the same or similar products may vary significantly between less than two and four, or more years, and differences are largely driven by environmental and behavioral factors and not as much by the product type. This has been further confirmed by a study in Nigeria where behavior change communication was able to significantly improve household attitudes toward care and repair, which resulted in better physical condition of nets in these households and an estimated nine-month extension of net survival[3]. This means that data on durability from one site or product cannot necessarily be applied to another, and each national malaria program should undertake its own durability monitoring.

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1 Kilian A, Byamukama W, Pigeon O, Gimnig J, Atieli F, Koekemoer L, Protopopoff N: "Evidence for a useful life of more than three years for a polyester-based long-lasting insecticidal mosquito net in Western Uganda." *Malar J* 2011, 10:299.

2 Kilian A, Koenker H, Obi E, Selby RA, Fotheringham M, Lynch M: "Field durability of the same type of long-lasting insecticidal net varies between regions in Nigeria due to differences in household behaviour and living conditions." *Malar J*, 2015,14:1

3 Koenker H, Kilian A, Hunter G, Acosta A, Scandurra L, Fagbemi B, Onyefunafoa EO, Fotheringham M, Lynch M: "Impact of a behaviour change intervention on long-lasting insecticidal net care and repair behaviour and net condition in Nasarawa State, Nigeria." *Malar J*, 2015,14:18.

5 Methods

5.1 Sites

Three sites were selected for Nigeria—representing different parts of the country with differing ecological and socio-demographic environments—but, they each received the same brand of LLIN during the campaign and, also, had an entomological surveillance site nearby so that durability data could be compared with vector behavior and resistance data. In each of the selected states, one rural local government area (LGA) was purposively selected as the study site, in collaboration with the National and State Malaria Elimination Programs. The locations are shown in Figure 1 and are described briefly, as follows:

Zamfara (Bakura LGA) is in the north-west geo-political zone and belongs to the Sudan savannah ecological zone. Climate is tropically warm, with temperatures rising up to 38°C and above between March and May. The rainy season starts in late May to September, while the "cold" season, known as Harmattan, lasts from December to February. This results in highly seasonal malaria transmission with meso- to hyperendemicity during the rainy season. Zamfara state is mainly populated by Hausa and Fulani people.

Oyo state (Akinyele LGA) is in the south-west geo-political zone and belongs to the Guinea savannah ecological zone. The climate is equatorial, with dry and wet seasons and relatively high humidity. The dry season lasts from November to March, while the wet season starts from April and ends in October. Average daily temperature ranges between 25°C and 35°C, throughout most of the year. Malaria transmission is essentially perennial at meso-endemic levels. Oyo state is predominantly occupied by Yoruba people.

Ebonyi (Ishielu LGA) is in the south-east geo-political zone and belongs to the Guinea savannah ecological zone. The climate is similar to that of Oyo state but slightly more tropical and humid and malaria transmission is perennial. Ebonyi state is inhabited and populated primarily by the Igbo people.

Table 1 summarizes some of the key malariometric indicators for the three states from the most recent Malaria Indicator Survey (MIS), undertaken during the rainy season of 2015.

Table 1: Socio-demographic and malaria situation in the study areas (2015); HH=household

Province	Under 5s with Fever Receiving Malaria Test*	Under 5s Positive for Malaria (microscopy)	Febrile Children Treated with ACT*	HH with at Least One LLIN	Population Access to LLIN	Population using LLIN Last Night
Ebonyi	11%	30%	47%	88%	77%	49%
Zamfara	10%	63%	36%	89%	69%	56%
Oyo	29%	19%	35%	51%	44%	31%

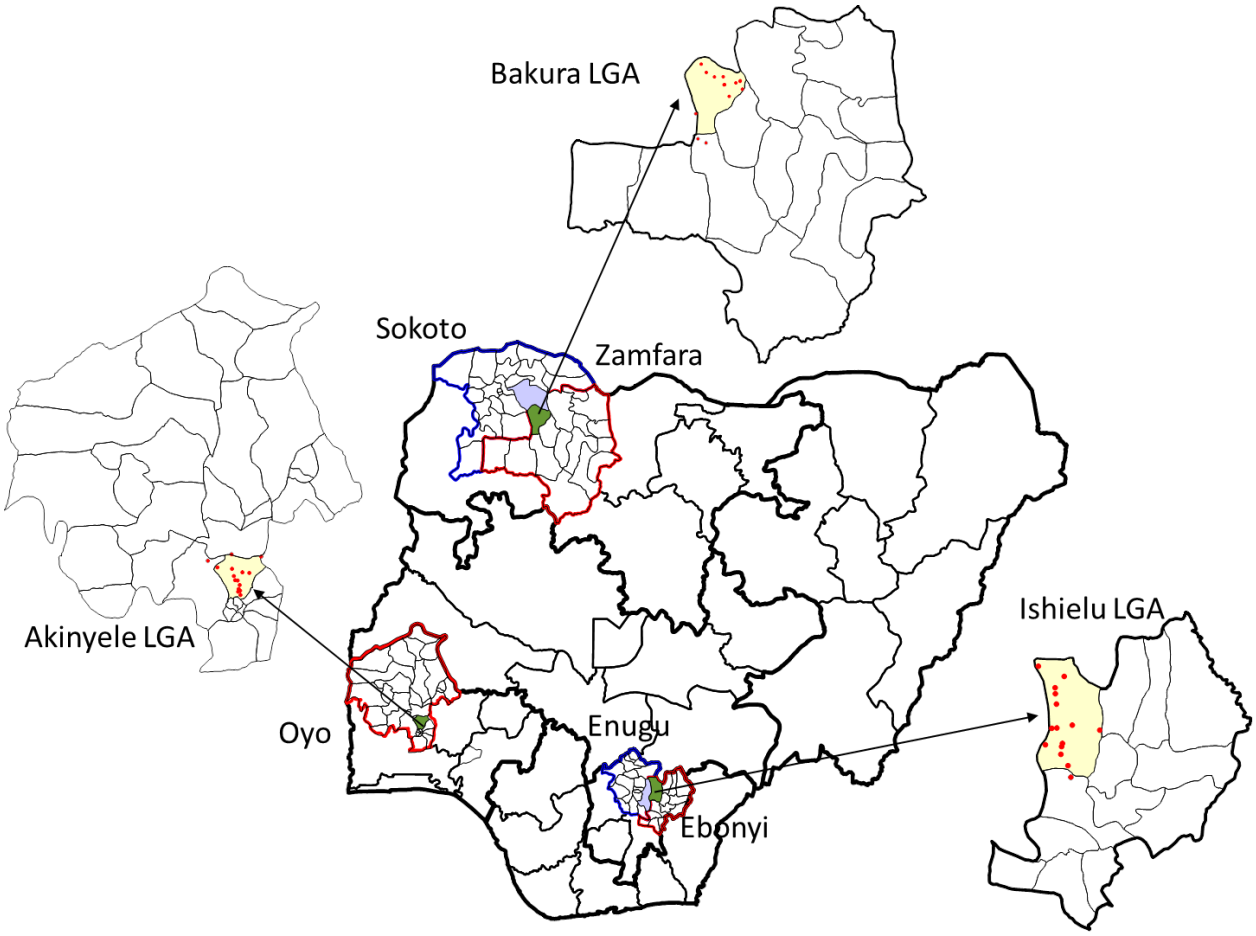
* From regional data as no data reported by state

Based on the 2016 and 2017 reports from entomological surveillance at or close to the study sites, the entomological situation can be described as follows: the major vector at all three sites is *Anopheles gambiae sensu latu;* only in Ebonyi was a small presence of *Anopheles funestus* found. Within the gambiae complex about 30% was arabiensis in the north (Sokoto) and the rest were *sensu stricto.* In contrast, almost no arabiensis were found in Oyo. Instead, there was a higher proportion of Anopheles gambiae s.s with some *Anopheles coluzzii* (formerly known as M form of An. gambiae s.s.). In Ebonyi, coluzzii was the dominant species, followed by *arabiensis* and *sensu stricto.*

In all three sites, most biting occurred indoors, but the proportion was highest in Ebonyi, with over 80%; while in Sokoto and Oyo, indoor biting was 52% and 64%. Peak biting times were as expected, between 23:00 and 5:00, but some early evening biting was observed in Sokoto. Intensity of transmission has fluctuated in recent years, but, overall, was highest in Ebonyi, with an entomological inoculation rate of 15–30 infective bites, per person, per year, followed by Sokoto with 20–28 and Oyo with 5–22.

Resistance of *Anopheles gambiae* s.l. against deltamethrin was found at all three sites, but was most pronounced in Sokoto, where over 90% of tests showed resistance. The level of resistance was moderate with an average mortality of 78%. In Oyo, two-thirds of the tests showed resistance, with an average mortality of only about 50%; in Ebonyi, slightly less than half the tests showed resistance, with an average mortality of around 70%.

Figure 1: Site map with GPS points of selected clusters



5.2 Brands monitored

The brand of LLINs being monitored is the DAWA Plus 2.0, a 100-denier polyester LLIN in either a white or blue color. This LLIN uses the coating technology with a loading dose of 80 mg/m^2 of deltamethrin. DAWA Plus 2.0 received an interim WHO Pesticide Evaluation Scheme (WHOPES) recommendation in July 2009 (13th WHOPES Report).

5.2.1 Pre-shipment testing

All LLINs procured with public funds from the major donors—The Global Fund, PMI, UNICEF, etc.—undergo a pre-shipment quality control. This includes all parameters defined in the specifications issued by the WHOPES, namely textile features (grams per square meter, bursting strength) and insecticide content. Pre-shipment quality assurance data is available from the procurer from September 2015 (document references

PUP-2194 and PUP 2190). At this point, chemical content of the Dawa Plus samples was according to specifications. We are not certain that these were the nets used in the Zamfara and Ebonyi campaigns. Pre-shipment data for the Oyo campaign is currently being obtained.

5.3 Design summary

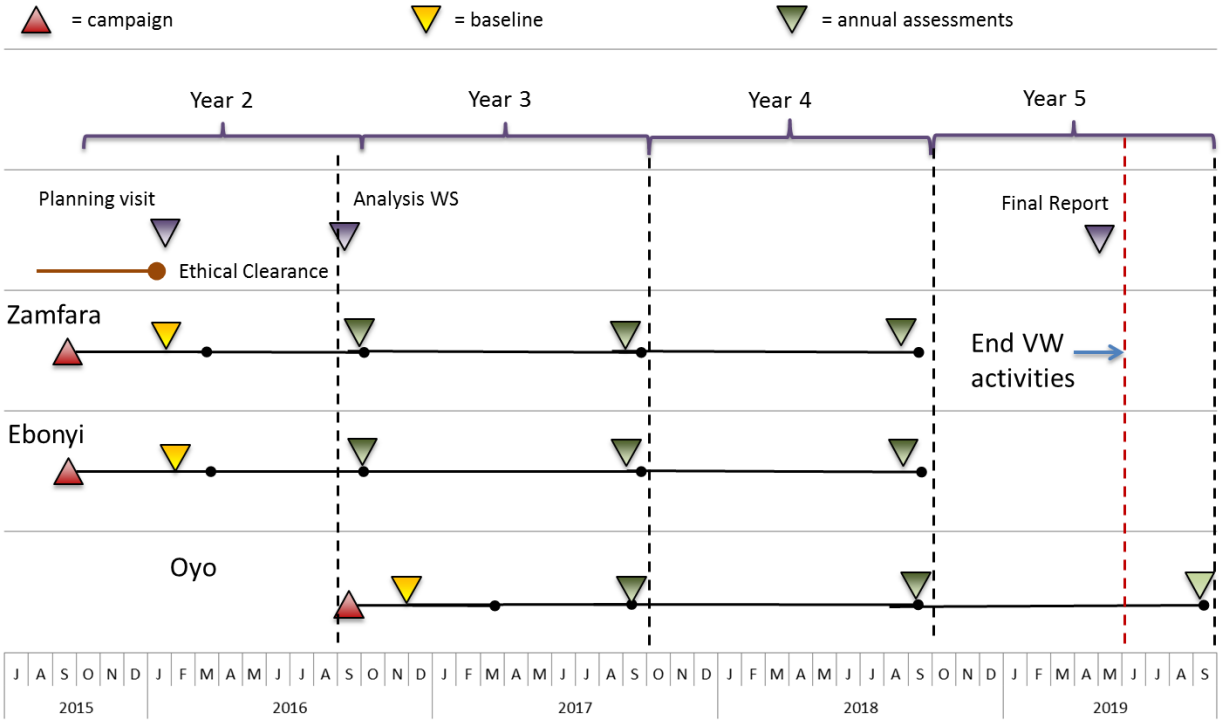
This is a prospective study of a cohort of LLINs from the 2015/6 mass distribution campaigns that was followed up over three years (two years in Oyo state). The design follows guidance from PMI for LLIN durability monitoring (see www.durabilitymonitoring.org). Within six months following the mass distribution campaign a representative cohort of campaign LLINs were sampled and labeled in each selected site and then followed up after 12, 24, and 36 months. At each time point, measures of physical durability were assessed (attrition and integrity). For all data points after the baseline, samples were taken to assess the insecticidal effectiveness (bio-assay) and analyzed at the entomology laboratory of the Nigeria Institute of Medical Research (NIMR) in Lagos. At the 12- and 24-month surveys, the samples were taken from households that are not part of the cohort (nearest neighbor) and nets were taken from the cohort at 36 months. In Nigeria, three sites with the same type of LLIN brand were selected, so this durability study compares the same brand between areas with different ecological and/or behavioral characteristics.

The sample size followed the recommendation from PMI guidance, with 150 households per site (15 clusters with 10 households each) and an expected number of 345 campaign nets labeled for follow-up. This sample size is targeted at detecting a deviation of 18% from the expected 50% survival after three years, comparing the best and the poorest performing site. Using the standard formula for sample size for comparing proportions in two groups with the above outlined settings resulted in a sample of 147 LLINs per study site after three years. After applying the expected design effect of 2.0 and loss to follow-up of households of 5%, the required sample after three years was 279 LLINs per site. Taking into account the expected attrition rates, a sample of 345 LLINs had to be taken at baseline; based on the expected number of LLIN distributed per household, 150 households needed to be sampled per site.

At baseline, the LLIN cohort in each district was established by selecting a representative sample of clusters (communities), based on probability proportionate to size and households using simple random sampling from household lists established on the day of the survey. As soon as clusters were sampled, the local authorities and chiefs were informed of the purpose and expected time of the survey, and their support sought. Communities were then sensitized and mobilized to obtain maximum cooperation for the surveys. All LLINs received from the National Malaria Control Program campaign by the selected households were identified and marked with a unique ID number. The physical condition of the campaign nets was measured through a hole assessment and a corresponding household interview was administered.

The LLIN mass distribution campaign took place in September 2015 in Ebonyi and Zamfara states and in August 2016 for Oyo state. In Ebonyi, a baseline assessment took place March 7–15, 2016; the 12-month survey from September 26–October 3, 2016; the 24-month assessment September 23–30, 2017; and

the final 36-month survey from October 5–10, 2018. In Zamfara, the baseline was March 21–29, 2016; 12-month follow-up from September 26 to October 4, 2016; 24-month follow-up October 9–17, 2017; and the 36-month survey from September 29 to October 6, 2018. The Oyo baseline was done December 5–13, 2016; the 12-month follow-up October 2–10, 2017; and the 24-month survey for Oyo from October 12–19, 2018.



5.4 Field work

An implementation team of nine individuals was established, per site, with one overall site coordinator and two field teams each consisting of one supervisor and three interviewers. Activities in the field were overseen by staff of state and national malaria elimination programs. Interviewers and supervisors were carefully selected to ensure they were culturally acceptable, had good knowledge of the local languages, and had experience in conducting household surveys.

Prior to the fieldwork, a five-day training was held at baseline and a three-day refresher training before each follow-up survey, which included the following components:

- understanding the study design and sampling procedures
- taking a general approach to ethics of field work (consent and interview)
- participating in a detailed study of interview with role play
- introducing and practicing with the data entry device, including the mapping software to track households
- physically assessing the holes and repairs in LLINs with practical exercises
- collecting sample campaign LLINs for bio-assays and issuing replacement LLINs.

The training for each site took place immediately before the field work.

5.5 Data management

For data collection, tablets PCs (Samsung Galaxy Tab 5) were used and installed with the data collection software, Open Data Kit (ODK), a free and open-source mobile data collection tool. Each field team was provided with a tablet for the household interviews and net hole counting; data from each interviewer was collected and directly uploaded to a Dropbox folder (if internet was available) or collected on a local storage device (laptop) by the supervisor until it could be transferred. Data were then checked and verified before being deleted from the tablets, and any inconsistencies followed up the following day. From the data, four types of data files were created and updated after each assessment round:

- household files
- household member files (baseline and final)
- campaign (cohort) net files
- files for other nets owned by the households.

5.6 Analysis

Data were converted from the ODK system to comma-delimited data files (*.csv format) using the ODK briefcase tool for daily inspection of incoming data. After the survey was complete, data sets were transferred to Stata version 14.0 (Stata, Texas, USA) for further aggregation, consistency checks, and preparation for analysis. Stata do-files (macros), developed by the VectorWorks project, were applied and adjusted, as needed (see www.durabilitymonitoring.org).

For continuous variables, arithmetic means were used to describe the central tendency and the t-test for comparison of groups for normally distributed data. Otherwise, median and non-parametric tests were used. Proportions were compared by contingency tables and the Chi-squared test was used to test for differences in proportions. For calculation of confidence intervals around estimates, the intra- and between-cluster correlation was taken into account.

Overall, household attitudes toward nets and care and repair were measured using a set of Likert score questions where a statement is read to the respondent and the level of agreement recorded. These are analyzed by recoding the four-level Likert scale score to have a value of -2 for "strongly disagree," -1 for "disagree," +1 for "agree," and +2 for "strongly agree." These attitude scores for each respondent were then summed and divided by the number of statements to calculate an overall attitude score for which zero (0) represents a neutral result and positive values a positive result. For each site, the proportion of households with a score above 1 (very positive attitude) were calculated. Two attitude scores were used, one for general attitude toward net use and one specifically for care and repair.

A wealth index was calculated for the baseline data set using the basic household assets and using a principal component analysis, with the first component used as the index. Households were then grouped into tertiles. The full household data collection will be repeated at the 36-month survey. However, at 12- and 24 months, no specific household or member data were collected.

The primary outcome measure was the physical net survival, which was defined as:

The proportion of nets received from the LLIN distribution not given away for use by others that are still present and in serviceable physical condition (definition provided below).

It is calculated for each time point as follows:

$$\text{\% surviving to time x} = \frac{\text{\# of LN present and "serviceable" at time x}}{\text{\# of LN originally received and not given away at time x}} \times 100$$

For the calculation of this outcome, two interim outcomes will be calculated, as follows:

Net attrition rate due to wear and tear: Defined as the proportion of originally received nets that were lost to wear and tear (thrown away, destroyed, or used for other purposes) at the time of the assessment. Nets received, but given away for use by others or stolen, are excluded from the denominator. Similarly, nets with unknown outcome are not considered.

Net integrity: Measured first by the proportionate Hole Index (pHI), as recommended by WHO. Holes in the LLINs of the cohort will be categorized into four different sizes: size 1: 0.5–2 cm, size 2: 2–10 cm, size 3: 10–25 cm, and size 4: larger than 25 cm in diameter. The pHI for each net will be calculated in the following way:

$$\text{pHI} = \text{\# size 1 holes} + (\text{\# size 2 holes} \times 23) + (\text{\# size 3 holes} \times 196) + (\text{\# size 4 holes} \times 576)$$

Based on the pHI, each net is then categorized as "good," "serviceable," or "torn," as follows:

Good:	**total hole surface area <0.01 m^2 or pHI<64**
Serviceable:	**total hole surface area ≤0.1 m^2 or pHI≤642**
Torn:	**total hole surface area >0.1 m^2 or pHI>642**

To be able to compare the physical survival measured at different time points (surveys were not always done exactly 12, 24, or 36 months after distribution) the outcome of **median net survival** was estimated defined as:

The time in years until 50% of the originally distributed LLINs were no longer serviceable.

Two approaches were used to estimate median survival. At each time point, the proportion surviving in serviceable condition were plotted against the hypothetical survival curves with defined median survival; the median survival was taken as the relative position of the data point on a horizontal line between the two adjacent median survival curves.

At the end of monitoring, median net survival was calculated from the last two time points, the lowest below 85%, using the following formula:

$$tm = t1 + \frac{(t2 - t1) * (p1 - 50)}{(p1 - p2)}$$

...where tm is the median survival time, t1 and t2 the first and second time points in years, and p1 and p2 the proportion surviving to first and second time point, respectively, in a percentage. Confidence intervals for this estimate was calculated by projecting the 95% CI from the survival estimates in the same way as described above. If one of the values for calculating the median survival was above 85%, the final value was derived from the graph as the proportionate horizontal distance between the two nearest hypothetical year lines, the 95% CI range calculated as described above, and applied to the estimate.

The secondary outcomes of insecticidal effectiveness were based on the bio-assay results using the standard WHO cone test, carried out at the Nigerian Institute of Medical Research in Lagos. A pyrethroid-sensitive Kisumu strain of *Anopheles gambiae s.s.* was used with five mosquitoes per cone, five sites tested on each net (4 sides and roof), and two replicates per location (10 cone tests with 50 mosquitoes per net in total). Recoded were 60-minute knockdown (KD60) and 24-hour mortality. The two variables from these tests—KD60 rate and 24-hour mortality rate—were combined into the following outcome measures:

Optimal effectiveness: KD60 ≥ 95% or functional mortality ≥ 80%
Minimal effectiveness: KD60 ≥ 75% or functional mortality ≥ 50%.

5.7 Ethical Clearance

Ethical clearance was obtained from the Institutional Review Board of the Johns Hopkins University, Baltimore, USA (IRB No.: 6852) and the National Health Research Ethics Committee of Nigeria (NHREC/01/01/2007-01/01/2016).

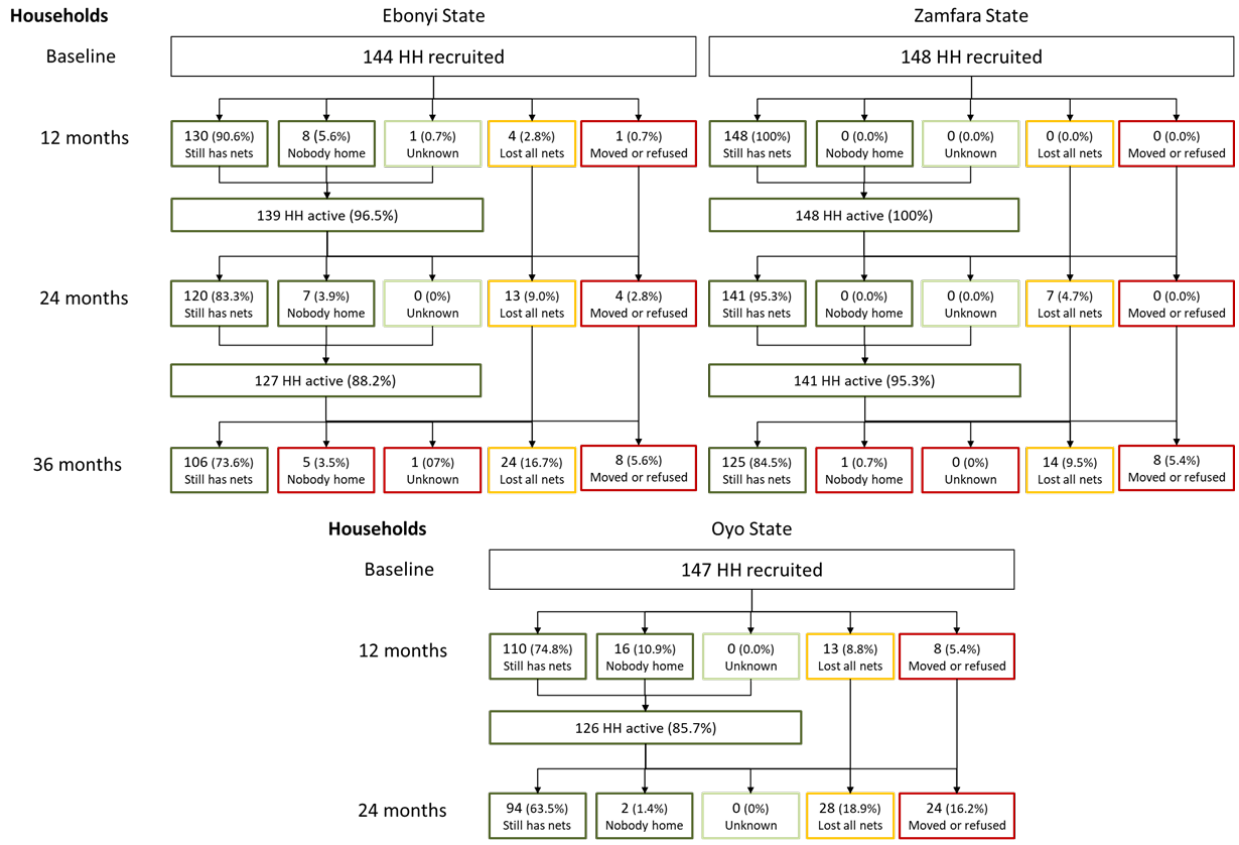
6 Results

6.1 Sample

At baseline, a total of 439 households were recruited, representing 98% of the target and 1,096 campaign nets labeled for follow-up (106% of target). Figure 2 provides a detailed summary of the recruited households and their follow-up in all three sites. Households dropped out of the study for three reasons: the most important being the loss of all their campaign nets so no further follow-up was needed. After three years, this applied to 17% of the 144 recruited households in Ebonyi; 10% of the 148 recruited households in Zamfara; and, after only 24 months follow-up, 19% of the 147 recruited households in Oyo. The second reason for loss to follow-up was households moving away to other communities. This was most common in Oyo, applying to 16% of the households after 24 months; migration was lower in Ebonyi (8%) and Zamfara (5%), even though the follow-up at these sites was 36 months. Some within-village migration (i.e., households shifted to new homes within the village) was noted, but only for 4% of households each in Zamfara and Oyo, but not in Ebonyi. These households were, however, kept in the study and the new location was recorded. The third reason for dropping out was refusal to continue participation in the study, but this was very rare, with only one refusal in Oyo.

Thanks to the excellent mobilization by the state and LGA teams, very few households were missing on the day of the survey, especially for the final round, when only eight (2%) of 394 still active households could not be interviewed.

Figure 2: Follow-up status of households recruited at baseline



6.2 Socio-demographic characteristics

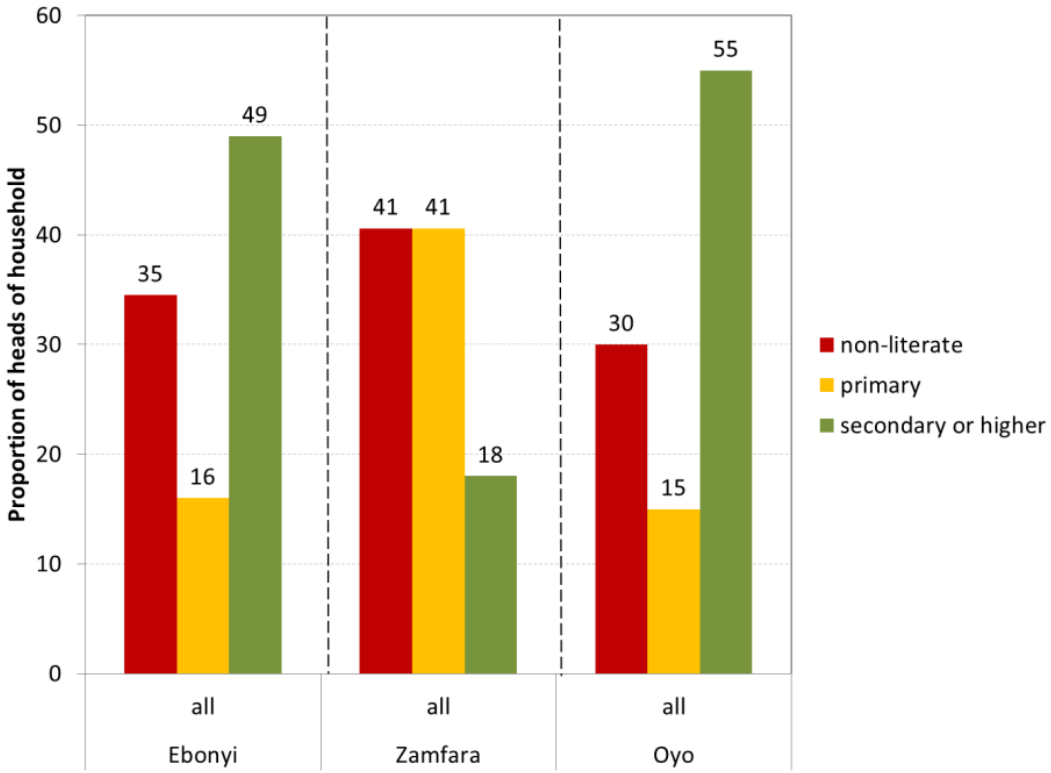
By comparing the households that participated in the baseline and final surveys (N=358), the data were explored for any demographic or socio-economic changes during the three years of the study.

In Ebonyi and Zamfara, the mean number of *de jure* household members decreased significantly between the first and last surveys: from 5.9 to 4.1 in Ebonyi ($p<0.05$) and 6.5 to 4.6 in Zamfara ($p<0.05$). In Oyo, the number of household members remained the same: 4.5 and 4.4. It is difficult to say from the available data why the numbers declined and whether it was an actual decline of the household population or an issue of over-reporting and/or under-reporting. The proportion of household members absent on the survey day was below 1% at all time points, for all sites. The proportion of children under 5-years-old was below the expected in Ebonyi (13%) and Zamfara (10%), while a bit high in Oyo (22%), but nothing changed between the surveys.

The proportion of female-headed households did not vary statistically over time; it was very low in Zamfara (2%), followed by Ebonyi (8%), and Oyo (19%). The mean age of the heads of households was 41 years in Zamfara and around 50 years in Ebonyi (51) and Oyo (50, $p<0.05$). In Oyo, the mean age between male and female heads was the same.

See Figure 2a for the educational status of the male heads of households. It demonstrates a statistically significant difference between Zamfara and the two southern locations ($p<0.001$), with a higher proportion of non-literates and a significantly lower proportion of secondary education. For female heads, reliable data is only available for Oyo; here the educational status of the female head was lower than that for males—49% non-literate, 27% primary, and 24% secondary level. However, due to the small number of female-headed households, the difference did not quite reach statistical significance ($p=0.08$).

Figure 2a: Educational status of male heads of household by site



For socio-economic indicators, very little changed in the three years of the durability monitoring for the households that were included in the baseline, as well as the final surveys. Some household assets were reported less in the final survey in Ebonyi and Zamfara, namely television ($p<0.03$) and electric fans ($p=0.01$). In Zamfara, reported ownership of bicycles increased ($p=0.008$) and cars in Oyo decreased ($p=0.02$). All other assets remained similar and the observed changes are not enough to interpret them as a significant change in socio-economic status, over time.

On the other hand, the three sites had clear differences in the socio-economic profiles. Where both Zamfara and Ebonyi sites were agricultural rural communities—Zamfara somewhat poorer than Ebonyi—the Oyo site was more peri-urban and more affluent than the other two. Household assets in Zamfara were scarce and essentially limited to radios, owned by 67% of households and mobile phones (66%). In Ebonyi, 93% of households owned a radio, but only 49% a mobile phone because areas in the LGA are without coverage. In addition, 41% owned a television; between 6% and 16% owned a refrigerator, electric iron, or fan. In contrast, household assets were quite frequent in Ebonyi: 88% owned a radio, 61% a TV, 55% a fan, 41% an electric iron, and 40% a refrigerator. Not only did 84% of households own some kind of mobile phone, 31% also owned a smart phone—which was not true in Zamfara and Ebonyi—and 2% owned a computer.

The situation around transport also reflects the different types of environments. In Ebonyi, 80% of households owned any type of transport and 72% in Zamfara; and, in both cases, these were bicycles and motorcycles. In Oyo, only 41% owned means of transport and these were motorcycles and cars.

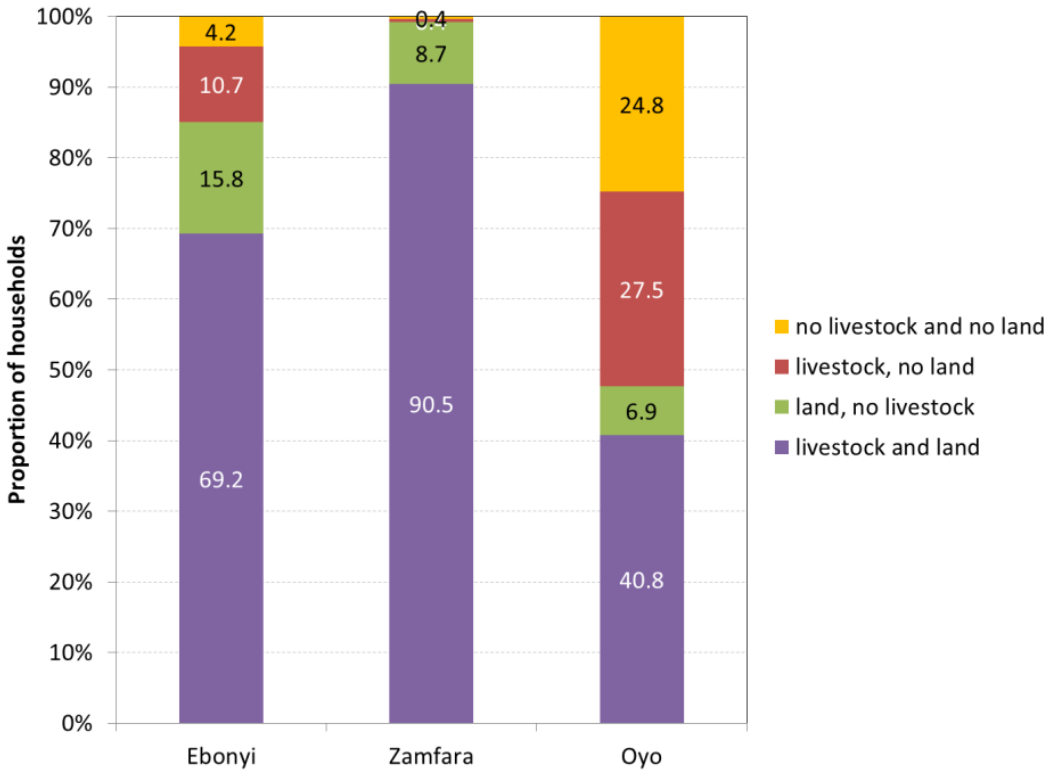
See Figure 2b for the differences in the economic resources. In Zamfara, 91% of households had both land and livestock and less than 1% had neither. In Ebonyi, 85% of households were active in agriculture and 80% had livestock. But, in Oyo, less than half the

households owned agricultural land and 68% owned livestock, mainly chickens and goats ($p<0.001$ for site comparison).

Other indicators confirm the differences between the sites. In Oyo, 93% of households had access to safe drinking water, including 6% of households that used bottled water or water sachets. Safe water access was also very high in Zamfara (97%); however, in Ebonyi, 86% of households used surface water from rivers or creeks. Improved pit latrines or flush toilets were common in Oyo, with 40%, but essentially absent in Zamfara and Ebonyi. All households in Zamfara had access to a pit latrine, while 34% of households in Ebonyi and 33% in Oyo said they had no access and they used the bush.

Very simple housing structures were found in Zamfara: grass or thatch roofs, mud walls and soil, or clay floors. In Ebonyi, house materials were similar, but somewhat better, with 40% of walls plastered and 37% of floors made from tiles or cement. In contrast, house walls in Oyo were predominantly plastered (73%) and 75% of floors were made from tiles, cement, or wood.

Figure 2b: Economic resources of households by site at 36-month survey



6.3 Determinants of durability

Factors previously shown to be associated with LLIN durability were explored. They can be divided into environmental factors, LLIN handling, type of sleeping place, and knowledge and attitudes toward LLINs and their care and repair. See Table 2 and Figure 3 for the factors immediately involving the sleeping place environment. Overall, the situation remained similar throughout the three years in Zamfara and Oyo. Fluctuations were primarily due to the changing sample size as a direct comparison of only households that attended all surveys, but did not show any significant trends in most of the indicators. In Ebonyi, however, the proportion of households reporting storing food in sleeping rooms significantly decreased over time, from 82% to 39%, even after limiting the sample to the 107 households that participated in all four

surveys ($p<0.001$). In Oyo, slightly more than half the households stored food in sleeping rooms, while almost all households did so in Zamfara. By contrast, cooking in sleeping rooms was essentially not found in Zamfara, it was rare in Oyo with around 10%, but was reported by one in five households in Ebonyi.

Table 2: Household risk factors

Variable and Site	Baseline	12 months	24 months	36 months
Ebonyi	N=143	N=133	N=129	N= 117
Ever store food in sleeping room	81.8%	59.4%	24.8%	39.2%
Cook in sleeping room				
never	79.9%	81.2%	95.4%	68.4%
sometimes	20.1%	18.1%	4.7%	29.9%
always	0%	0%	0%	1.7%
Rodents observed (last 6 months)	98.6%	72.2%	76.0%	89.7%
Zamfara	N=148	N=148	N=148	N=132
Ever store food in sleeping room	97.3%	89.9%	91.2%	99.2%
Cook in sleeping room				
never	98.7%	99.3%	100%	100%
sometimes	1.3%	0%	0%	0%
always	0%	0.7%	0%	0%
Rodents observed (last 6 months)	94.6%	98.0%	99.3%	100%
Oyo	N=147	N=122	N=109	
Ever store food in sleeping room	73.0%	53.3%	56.9%	
Cook in sleeping room				
never	98.0%	86.0%	89.9%	
sometimes	2.0%	12.4%	9.2%	
always	0%	1.7%	0.9%	
Rodents observed (last 6 months)	89.7%	95.1%	96.3%	

The type of sleeping place over which the campaign nets were hanging was similar; more than 80% were bed frames but, in Ebonyi, two-thirds were unfinished sticks. The situation was reversed in Zamfara where-two thirds had finished bed frames. In Oyo, foam mattresses without a bed frame were the most common sleeping place, with slightly more than 50%, while one-quarter of the cohort nets were used over bed frames, half of them finished.

Figure 3: Main type of sleeping place for campaign nets if used

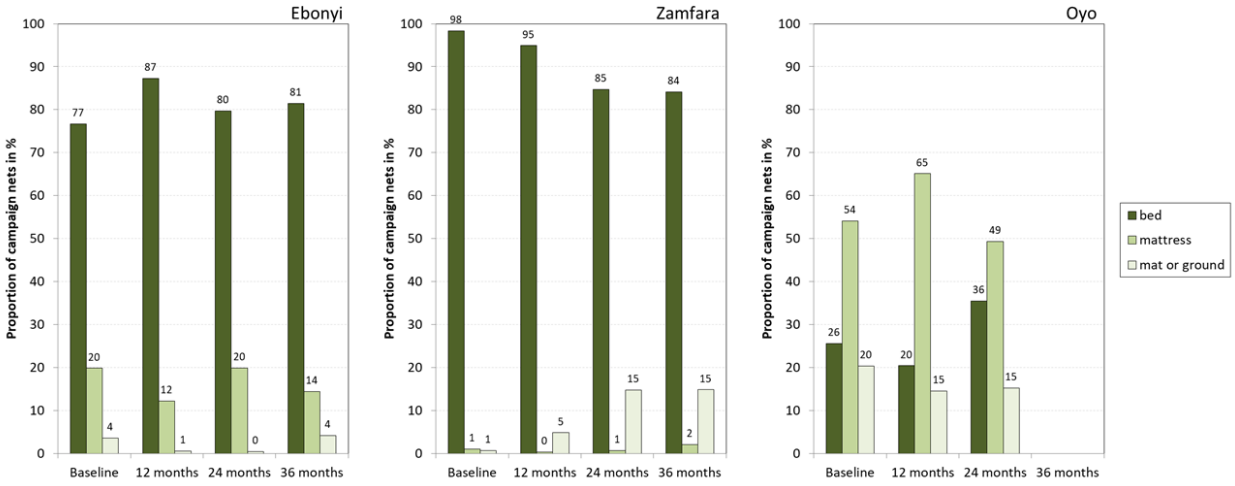


Table 3: Handling of campaign nets (Inter-Quartile-Range [IQR])

Variable and Site	Baseline	12 months	24 months	36 months
Ebonyi				
Hanging nets NOT folded or tied	52.6%	39.2%	15.7%	10.6%
Net dried on fence or bush	0%	0%	0%	0.9%
Net ever washed	2.2%	36.5%	53.5%	61.1%
Median washed last 6 months (IQR)	1.0 (1.0–2.0)	2.0 (2.0–3.0)	2.0 (2.0–2.0)	2.0 (2.0–2.0)
Used detergent/bleach for wash	12.5%	0%	0%	0.9%
Zamfara				
Hanging nets NOT folded or tied	14.7%	40.3%	52.9%	50.7%
Net dried on fence or bush	27.6%	48.4%	4.6%	36.5%
Net ever washed	28.9%	86.7%	91.3%	91.1%
Median washed last 6 months (IQR)	2.0 (1.0–3.0)	2.0 (2.0–3.0)	3.0 (3.0–5.0)	4.0 (3.0–8.0)
Used detergent/bleach for wash	39.1%	66.7%	17.4%	8.5%
Oyo				
Hanging nets NOT folded or tied	40.5%	56.2%	41.2%	
Net dried on fence or bush	12.0%	8.5%	41.7%	
Net ever washed	6.9%	49.1%	71.0%	
Median washed last 6 months (IQR)	1.0 (1.0–2.0)	2.0 (1.0–3.0)	2.0 (2.0–3.0)	
Used detergent/bleach for wash	24.0%	55.5%	22.9%	

See Table 3 for durability risk factors associated with LLIN handling. The proportion of cohort LLINs that were hanging loose over the sleeping place and not folded up or tied during the day (when they were found hanging) also showed a significant improvement in Ebonyi (p=0.004)—nets hanging loose decreased from 53% to only 11% at the final survey. These trends were not seen in Zamfara or Oyo, where about half the nets hung loose, except for the baseline finding in Zamfara where this rate was only 14%. However, there was no statistically significant trend, over time, in Zamfara for this indicator (p=0.06).

Drying nets on bushes or fences was not practiced at all in Ebonyi, but it was reported by about one-third of households in Zamfara. In Oyo, this rate seemed to increase over time (p=0.006) when only nets from households participating in all surveys were considered and it reached 41% at the final survey. As expected, the proportion of nets ever washed increased over time at all three sites, but washing was clearly more frequent in Zamfara (p<0.001); already, 87% of all campaign nets had ever been washed after 12 months, increasing to over 90% in the last two surveys. By contrast, in Ebonyi, only 61% of campaign nets had ever been washed after 36 months; in Oyo, the rate was 71% after 24 months. Although this lower washing rate can be explained, in part, by lower net use rates in Oyo (see Table 7), there was also a difference when the number of washes in the last six months were considered—with a median of four washes in Zamfara at the final survey compared to only two in Ebonyi and Oyo (p<0.001). In Ebonyi, washes were made with bar soap and almost no detergents or bleach. In Zamfara, the use of detergent decreased over time, from an initial 39% to only 9% at the final survey (p<0.001); in Oyo, it fluctuated between 24% and 56%.

Table 4: Exposure to messages on nets in the last six months

Variable and Site	Baseline	12 months	24 months	36 months
Ebonyi				
Any exposure last 6 months	46.2%	56.4%	75.2%	62.4%
Mean info sources (if exposed)	1.1	8.2	6.0	2.6
Type of media				
media only	0%	0%	2.1%	4.1%
both	0%	89.3%	72.3%	38.4%
IPC only	100%	10.7%	25.8%	57.5%
Zamfara				
Any exposure last 6 months	60.2%	95.3%	99.3%	75.7%
Mean info sources (if exposed)	1.8	2.0	1.4	1.7
Type of media				
media only	3.4%	0%	1.4%	26.0%
both	3.4%	27.7%	25.5%	26.0%
IPC only	93.2%	72.3%	73.1%	48.0%
Oyo				
Any exposure last 6 months	85.1%	82.0%	62.4%	
Mean info sources (if exposed)	2.1	2.9	2.3	
Type of media				
media only	1.6%	8.1%	17.7%	
both	15.9%	66.7%	54.4%	
IPC only	82.5%	25.2%	27.9%	

Exposure to net care–related messages fluctuated somewhat over time, but was generally high in all three sites (see Table 4). Exposure to net messages was highest in Zamfara with, on average, 82% of households participating in all surveys exposed), followed by Oyo (78%) and Ebonyi (67%), but the differences did not reach statistical significance levels (p=0.09). Also, a shift was visible in all three sites from predominantly inter-personal communication through health workers, community agents, or local leaders to a higher proportion of exposure to the media, namely radio messages. This trend was most evident in Ebonyi.

Table 5 shows recall of specific messages in combining exposure and the recall, if exposed. This also shows a better recall in Zamfara and, generally, a better recall of messages on net use and lower recall of messages for repair. The overall "care and repair attitude" score (see methods for details) was significantly higher in Zamfara, followed by Oyo, and was lowest in Ebonyi. Since the rates presented in Table 5 showed some fluctuations in the way these questions were asked, responses can be expected to vary over time. The data were analyzed across all surveys. This showed that, in Zamfara, 96% of households had a very positive attitude score in at least two surveys and 55% in all four surveys. By contrast, 39% in Oyo never reached the "very positive" level, 22% had a very positive score at least twice, and 3% in all three surveys. In Ebonyi, the situation was worse, with 58% of households never registering a "very positive" score, only 6% twice, and no household more than twice.

Table 5: Recall of messages and attitude toward net care and repair (based on all surveyed households)

Variable and site	Baseline	12 months	24 months	36 months
Ebonyi				
Recalled "use net (every) night"	43.8%	56.4%	75.2%	62.4%
Recalled "nets prevent malaria"	27.8%	54.9%	70.5%	53.0%
Recalled "care for net"	36.8%	56.4%	75.2%	59.8%
Recalled "repair net"	11.8%	52.3%	66.7%	52.1%
Attitude score care and repair mean (95% CI) % with score >1.0	 0.8 (0.7–0.8) 11.9%	 0.7 (0.6–0.8) 5.3%	 0.9 (0.8–1.0) 34.1%	 0.5 (0.4–0.6) 1.7%
Zamfara				
Recalled "use net (every) night"	58.1%	94.6%	98.7%	75.7%
Recalled "nets prevent malaria"	54.7%	89.9%	98.0%	74.2%
Recalled "care for net"	56.1%	93.9%	98.0%	75.0%
Recalled "repair net"	54.7%	87.8%	96.0%	72.7%
Attitude score care and repair mean (95% CI) % with score >1.0	 1.3 (1.2–1.4) 86.4%	 1.3 (1.3–1.4) 93.2%	 1.4 (1.3–1.4) 95.2%	 1.2 (1.1–1.3) 72.3%
Oyo				
Recalled "use net (every) night"	83.1%	79.5%	62.4%	
Recalled "nets prevent malaria"	43.2%	67.2%	52.3%	
Recalled "care for net"	75.7%	75.1%	62.4%	
Recalled "repair net"	20.3%	27.1%	22.9%	
Attitude score care and repair mean (95% CI) % with score >1.0	 0.9 (0.7–1.0) 40.5%	 0.8 (0.6–1.0) 39.3%	 0.7 (0.5–0.9) 22.9%	

The final step in the risk factor review looks at households' experiences with holes and net repair (Table 6). As expected, the proportion of households experiencing any holes in their nets increased significantly over time, reaching 85% and 97% after three years in Ebonyi and Zamfara, respectively. In contrast, it plateaued at about one-third after 24 months in Oyo, which can be explained, in part, by the lower net utilization rates at this site (see Table 7). In Ebonyi and Zamfara, a high proportion of households that said they had holes in their nets also reported having made repairs, but this did not match the actually observed repairs, especially in Zamfara where only 14% of damaged nets had signs of repairs. It must be taken into account, however, that the level of damage in Zamfara was less than at the other two sites (see Table 13). Actual repairs were highest in Ebonyi, with 47% of damaged nets, followed by Oyo with 21%. Female-headed households tended to have a higher rate of repair if the net had any damage (40% versus 30%), but due to the small number of female-headed households, this difference was not statistically significant (p=0.3).

If repairs were made, it was almost exclusively by household members in Ebonyi and Zamfara, while 20% of households in Oyo that had any repairs said they had used a tailor. Stitching the holes up was the most common way of repair, reported by 88% of repairing households, followed by knotting up the holes (31%), while patching was used only by 4% (multiple responses were possible).

Table 6: Household experience with care and repair of any nets and actual repairs made in damaged campaign nets (n.a. =not applicable)

Variable and Site	Baseline	12 months	24 months	36 months
Ebonyi				
Ever experienced holes in net	16.8%	36.1%	71.3%	86.3%
Ever discussed care and repair	20.3%	51.1%	82.2%	64.1%
Ever repaired (if had holes)	4.4%	62.5%	64.1%	65.3%
Damaged campaign nets repaired	n.a.	11.2%	47.1%	46.8%
Zamfara				
Ever experienced holes in net	12.8%	36.5%	80.4%	97.7%
Ever discussed care and repair	57.2%	66.2%	66.2%	52.3%
Ever repaired (if had holes)	57.8%	20.4%	58.0%	62.0%
Damaged campaign nets repaired	n.a.	1.8%	7.5%	13.7%
Oyo				
Ever experienced holes in net	13.5%	36.9%	33.9%	
Ever discussed care and repair	68.2%	65.6%	71.5%	
Ever repaired (if had holes)	35.0%	26.7%	32.4%	
Damaged campaign nets repaired	n.a.	21.7%	20.6%	

The assessment in Zamfara showed better performance with respect to risk factors for durability (to the extent that risk factors are understood to-date) compared to the other two sites, and this assessment still holds, although the difference between Zamfara and Ebonyi continued to be less over the course of the study. Oyo can be assessed as similar or slightly poorer performance with respect to risk factors than Ebonyi.

6.4 Net use and ownership

This section looks at the use and ownership of the campaign nets, as well as other nets in the sampled households, including where they were obtained and used, who used them, and what the level of ownership coverage was among the study sample.

The initial concern of cohort nets not being used in Ebonyi was completely relieved because, at 12 months, 73% were hanging and more than 90% in the last two surveys; none were found in the package (Table 7). In Zamfara, a high proportion of campaign nets (78%) was already hanging at baseline and, by the 12-month survey and until the final survey, the hanging rate of campaign nets still in the households exceeded 90%. In Oyo, the proportion of cohort nets hanging at baseline was particularly low, with only 20%, which may have been supported by a certain oversupply during the campaign (see also baseline report). Cohort nets hanging improved to 49% at 12 months and 65% at 24 months, but this was still lower than the other two sites at that time. Nets in the package were not an issue in Oyo because nets were given out, primarily, without a package.

Table 7: Hanging and use of campaign nets from cohort

Variable	Baseline	12 months	24 months	36 months
Ebonyi	N=368	N=296	N=232	N=175
Hanging	41.7%	73.3%	98.7%	92.0%
Taken down or stored	30.5%	24.7%	1.3%	7.4%
Still in package	27.8%	2.0%	0%	0%
Used last night	41.0%	66.9%	84.9%	79.4%
Used every night (last week)	19.8%	43.6%	37.6%	11.4%
Zamfara	N=363	N=353	N=309	N=246
Hanging	77.6%	90.7%	93.5%	91.5%
Taken down or stored	4.4%	1.7%	1.3%	2.8%
Still in package	17.4%	4.5%	1.9%	0%
Used last night	73.6%	88.4%	91.3%	90.7%
Used every night (last week)	69.7%	82.6%	74.5%	72.0%
Oyo	N=372	N=216	N=169	
Hanging	19.9%	48.6%	64.5%	
Taken down or stored	76.7%	46.1%	28.4%	
Still in package	3.8%	2.3%	3.6%	
Used last night	28.8%	56.1%	61.5%	
Used every night (last week)	24.5%	37.4%	30.6%	

Use of cohort nets the previous night usually closely followed the hanging rate (i.e., if a net was hung, it was also used). In Oyo, the use rate was even higher than the hanging rate, suggesting that some nets taken down during the day were also used; this agrees with the high use of mattresses in Oyo, which allow for a more flexible arrangement of sleeping places. Regular use during the past week, as reported by the household respondent, was quite high in Zamfara, with 70% or higher at all time points; but it must be taken into account that all surveys were conducted either at the beginning (baseline) or toward the end of the rains. Interestingly, 95% of household respondents in

Zamfara also consistently reported using nets equally in the rainy and dry season. This is somewhat suspicious as data from MIS and Demographic and Health Surveys suggests that northern Nigeria has a considerable seasonality in ITN use if people have access and, it is possible that a "social desirability bias" was at work here. As is typical for the southern parts of Nigeria, the regular use of the cohort nets was far less in Ebonyi and Oyo, with only half or less of the nets were reported used every day of the previous week. While in Oyo, more than 90% claimed to be equally used nets in the dry and rainy season, there was in increasing number of households in Ebonyi that admitted they used the nets mainly during the rains: 2% at 12 months, 21% at 24 months, and 70% at 36 months.

Initially, nets from other sources were found at all three sites, varying between 30% of households with any non-cohort nets in Ebonyi, 46% in Oyo, and 69% in Zamfara; these nets represented 17%, 20%, and 35% of all nets owned by the households, respectively (Table 9, Figure 3a). At the 12-month assessment, most of these nets had disappeared. This was most pronounced in Zamfara where the number went from 192 to just three (this went along with a very low attrition rate of the cohort nets). Sixteen households in Zamfara reported receiving any nets from other sources, which totaled 19 at the final survey. These were mostly from antenatal care (ANC) or Expanded Programme on Immunization services at health facilities, with some also received from family and friends and a few from the markets. In Ebonyi, only seven households received any additional nets and only six were present at the final survey, all from the public sector. An influx of new nets was significantly higher in Oyo, where 16% reported having received new nets, half from routine distributions, and half from informal sources: family and friends.
As shown in Table 8, the other nets were used initially more than the campaign nets, but then in roughly equal percentages.

Table 8: Hanging and use of non-cohort nets

Variable	Baseline	12 months	24 months	36 months
Ebonyi	N=72	N=4	N=1	N=6
Hanging	90.3%	n.a.	n.a.	n.a.
Taken down or stored	6.9%	n.a.	n.a.	n.a.
Still in package	2.8%	n.a.	n.a.	n.a.
Used last night	86.1%	n.a.	n.a.	n.a.
Used every night (last week)	30.6%	n.a.	n.a.	n.a.
Zamfara	N=192	N=3	N=17	N=19
Hanging	59.4%	n.a.	58.8%	84.2%
Taken down or stored	40.1%	n.a.	42.2%	10.5%
Still in package	0%	n.a.	0%	5.2%
Used last night	60.4%	n.a.	70.6%	84.2%
Used every night (last week)	47.9%	n.a.	70.6%	84.2%
Oyo	N=92	N=29	N=41	
Hanging	62.0%	41.4%	41.5%	
Taken down or stored	21.7%	44.8%	43.9%	
Still in package	6.5%	0%	2.4%	
Used last night	64.8%	44.8%	46.2%	
Used every night (last week)	56.5%	37.9%	36.6%	

Figure 3a: Proportion of non-cohort nets among all owned nets in surveyed households

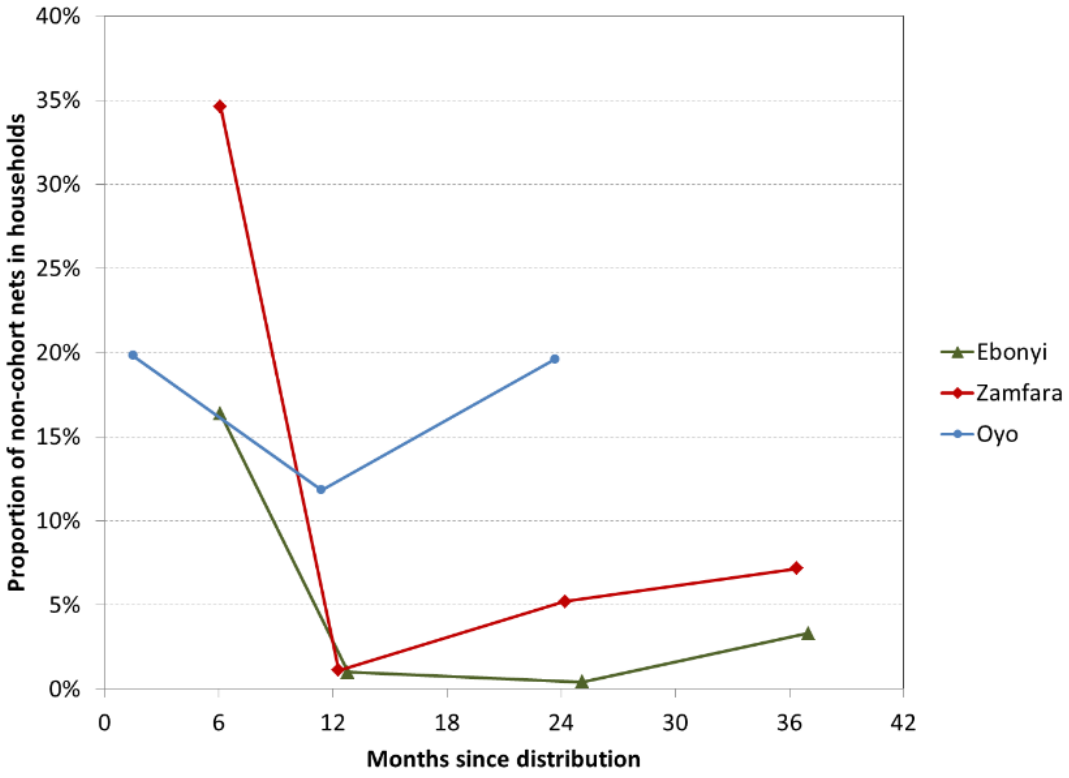


Table 9: Ownership of any non-cohort nets by households and source for these nets
HF=health facility; n.a. =not applicable

Variable	Baseline	12 months	24 months	36 months
Ebonyi	N=72	N=4	N=1	N=6
Household has any other nets	29.5%	1.5%	0.8%	3.9%
Source public sector	76.4%	n.a.	n.a.	n.a.
Source other campaign*	34.7%	n.a.	n.a.	n.a.
Source ANC, HF	41.6%	n.a.	n.a.	n.a.
Source private sector	12.5%	n.a.	n.a.	n.a.
Source family/friends, NGO, other	6.9%	n.a.	n.a.	n.a.
Zamfara	N=192	N=3	N=17	N=19
Household has any other nets	68.9%	1.4%	6.5%	10.6%
Source public sector	88.0%	n.a.	52.9%	84.2%
Source other campaign*	82.8%	n.a.	0%	0%
Source ANC, HF	5.1%	n.a.	47.1%	84.2%
Source private sector	9.9%	n.a.	11.8%	5.3%
Source family/friends, NGO, other	1.5%	n.a.	35.3%	10.5%
Oyo	N=92	N=29	N=41	
Household has any other nets	46.0%	18.0%	27.6%	
Source public sector	57.6%	65.5%	56.1%	
Source other campaign*	21.7%	13.8%	7.3%	
Source ANC, HF	31.5%	37.9%	46.4%	
Source private sector	20.7%	24.1%	4.9%	
Source family/friends, NGO, other	21.7%	10.3%	36.5%	

*Previous or subsequent to cohort campaign

Given that households that had lost all their cohort nets were dropped from the monitoring, and all sites received additional free nets from campaigns or routine distributions, it is not surprising that 92% of households in Ebonyi, 95% in Zamfara, and 92% in Oyo still owned any LLINs at the final survey. The proportion of households with enough nets for all household members (one LLIN for every two people) at the final survey was 38% in Ebonyi, and 52% in Zamfara after 36 months, and 52% in Oyo after 24 months. Population access to an ITN was still acceptable in Ebonyi with 67%, excellent in Zamfara with 71%, and good in Oyo with 70% (24 months). It must be kept in mind, however, that this survey was designed to monitor LLIN durability and is not necessarily representative of post-campaign LLIN ownership coverage, because households that had lost all their nets had been dropped from the cohort.

The use pattern of cohort nets from the campaign (Table 10) did not change significantly over time and was similar between sites. Due to a small number of available nets, use patterns of non-cohort nets could not be assessed with certainty (Table 11).

Table 10: Net users of campaign cohort nets

Variable	Baseline	12 months	24 months	36 months
Ebonyi				
Children only*	5.3%	12.1%	7.1%	15.1%
Children + adults**	53.6%	59.6%	58.4%	39.6%
Adults only**	41.1%	28.3%	34.5%	45.3%
Zamfara				
Children only*	3.4%	4.8%	4.3%	7.6%
Children + adults**	52.1%	66.0%	67.0%	61.0%
Adults only**	44.5%	29.2%	28.7%	31.4%
Oyo				
Children only*	3.8%	12.4%	3.8%	
Children + adults**	23.4%	36.4%	36.5%	
Adults only**	72.9%	51.2%	59.6%	

*Age 0–9 years; **includes adolescents 10–19

Table 11: Net users of non-cohort nets (n.a. =not applicable)

Variable	Baseline	12 months	24 months	36 months
Ebonyi	N=72	N=4	N=0	N=5
Children only*	4.8%	n.a.	n.a.	n.a.
Children + adults**	56.5%	n.a.	n.a.	n.a.
Adults only**	38.7%	n.a.	n.a.	n.a.
Zamfara	N=192	N=3	N=12	N=16
Children only*	15.5%	n.a.	16.7%	12.5%
Children + adults**	27.6%	n.a.	33.3%	25.0%
Adults only**	56.9%	n.a.	50.0%	62.5%
Oyo	N=92	N=13	N=19	
Children only*	6.8%	23.1%	5.2%	
Children + adults**	20.3%	38.5%	21.1%	
Adults only**	72.9%	38.5%	73.7%	

*Age 0–9 years; **includes adolescents 10–19

6.5 Durability of campaign nets

The status of the campaign nets for the durability cohort throughout the study is shown in Figures 4–6. Of the 367 nets labeled in Ebonyi, 175 (48%) were still present at the 36-month survey. The proportion discarded reached 20%, those given away 19%, while 4% were lost because households had moved. For 25 of the original cohort nets, the reasons for loss could not be determined; for another 8%, the fate remained unknown because the households were not available at the final survey.

In Zamfara, the major reason for loss to follow-up was giving nets away (15%), with only 8% discarded and another 5% moved away with their households. Two nets (1%) were used by the households in another location and 69% of the cohort nets were still present after 36 months.

In Oyo, only 169 or 45% of the originally recruited 372 cohort nets were present after 24 months, with a high proportion (18%) given away, 8% discarded, 6% used elsewhere,15% were moved with their households, and 4% had unknown outcome.

Figure 4: Status of cohort nets recruited at baseline in Ebonyi state

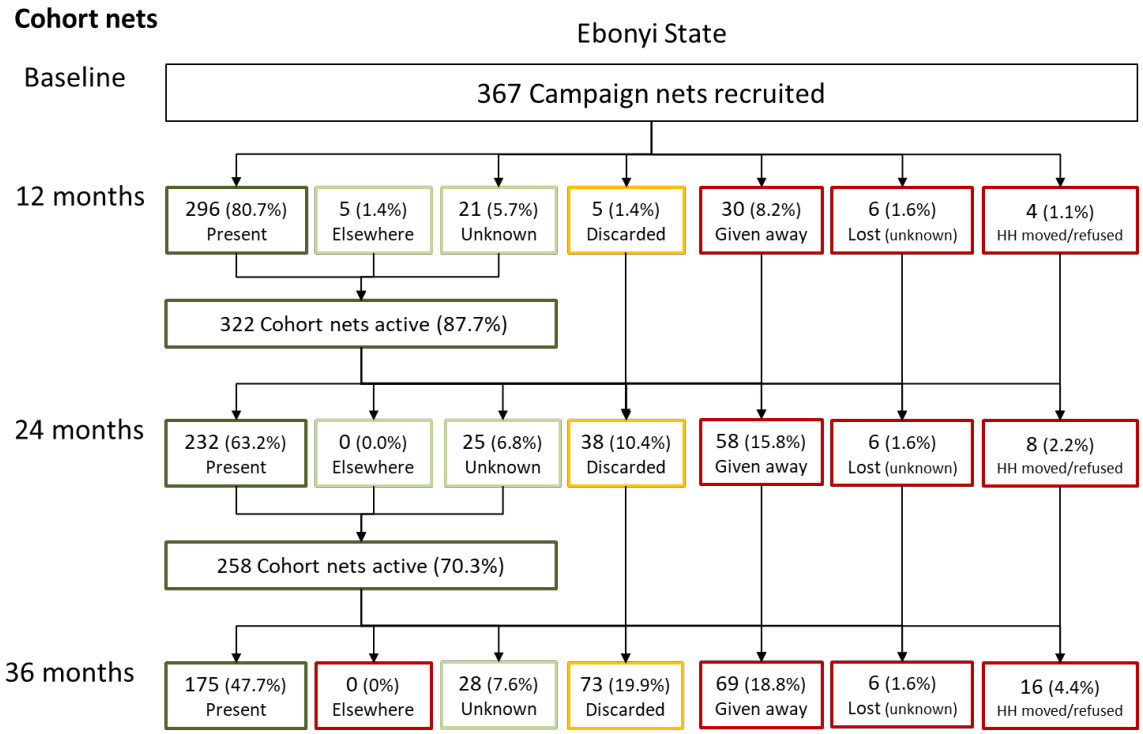


Figure 5: Status of cohort nets recruited at baseline in Zamfara state

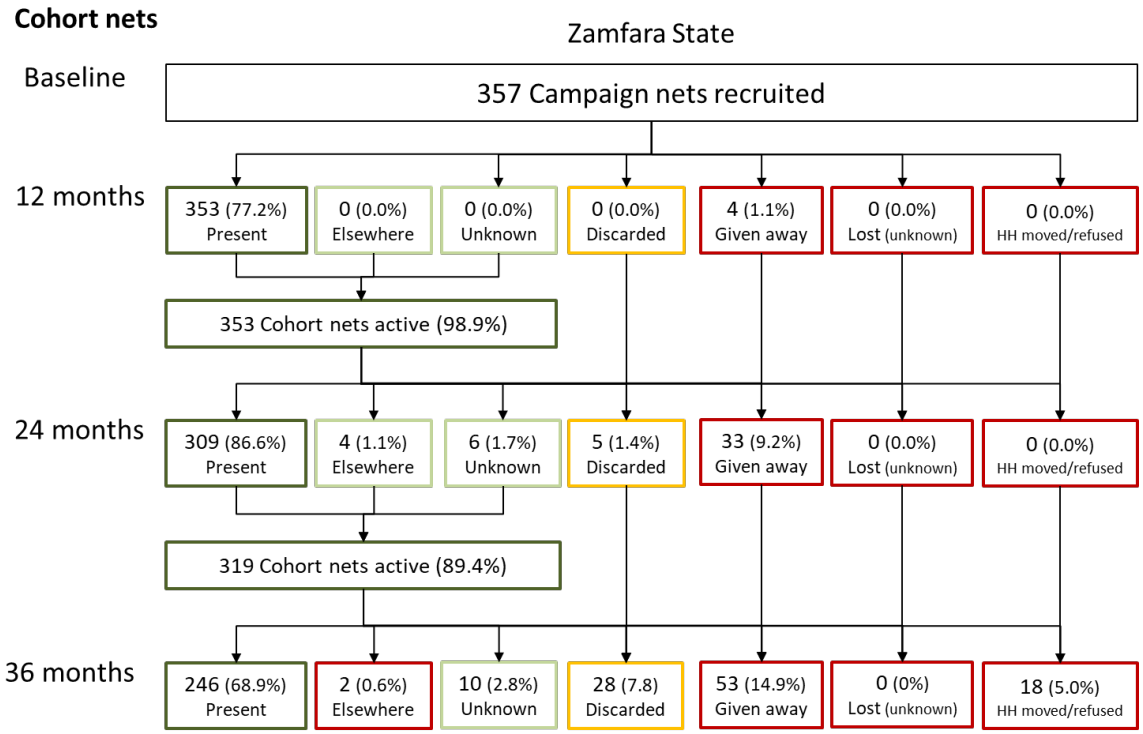


Figure 6: Status of cohort nets recruited at baseline in Oyo state

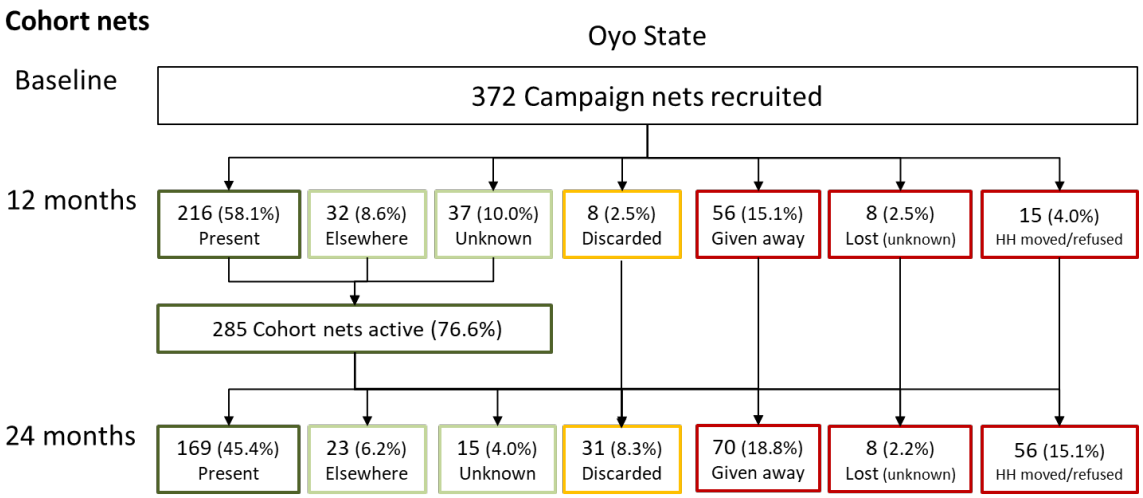


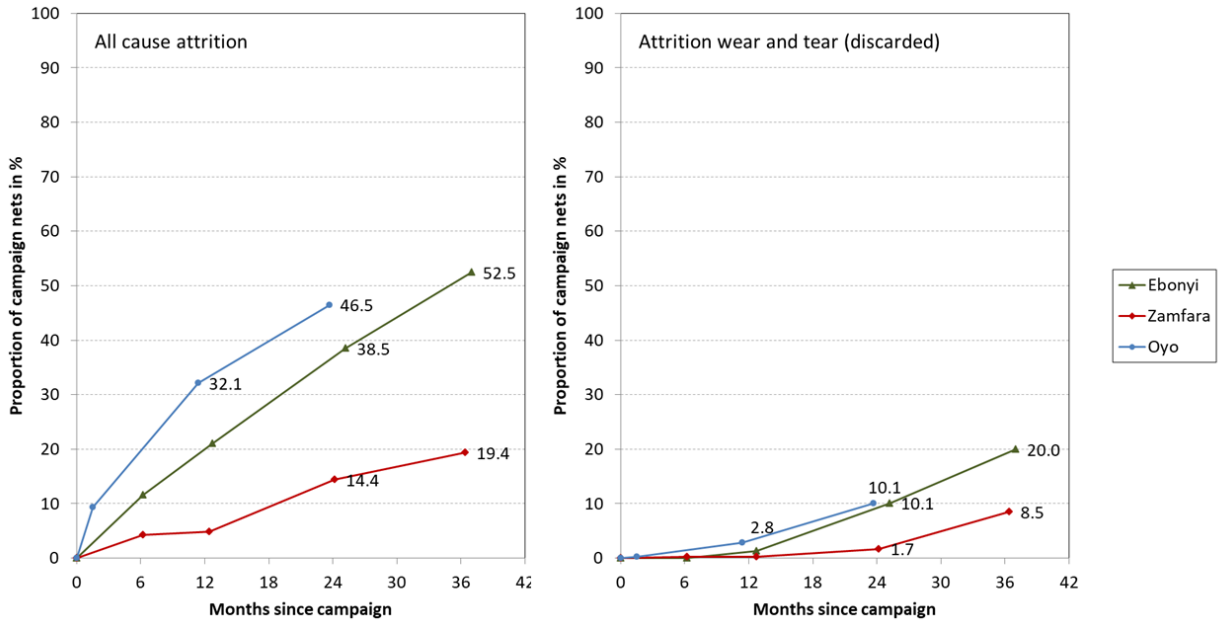
Table 12: Attrition (including nets lost between campaign and baseline)

Variable	Campaign – baseline	Campaign – 12 months	Campaign – 24 months	Campaign – 36 months
Ebonyi	N=415	N=390	N=377	N=366
Given away	10.6%	19.0%	27.1%	30.8%
Discarded (wear & tear)	0%	1.3%	10.1%	20.0%
Unknown	1.0%	1.5%	1.4%	1.4%
Total	**11.6%**	**21.8%**	**38.5%**	**52.5%**
Zamfara	N=373	N=373	N=361	N=341
Given away	3.5%	4.7%	12.7%	19.4%
Discarded (wear & tear)	0.3%	0.3%	1.7%	8.5%
Unknown	0.3%	0.3%	0%	0%
Total	**4.1%**	**5.3%**	**14.4%**	**27.9%**
Oyo	N=410	N=318	N=316	
Given away	9.0%	29.3%	33.9%	
Discarded (wear & tear)	0.2%	2.8%	10.1%	
Unknown	0%	0%	2.5%	
Total	**9.2%**	**32.1%**	**46.5%**	

See Table 12 and Figure 7 for the resulting all-cause attrition rates and losses due to wear and tear since the campaign. These figures differ slightly from the follow-up figures because they also include campaign nets that were reported lost between campaign and baseline survey, but exclude nets with unknown outcome. In Oyo, loss for any reason was highest, with almost half of the nets (47%) gone after 24 months, compared to 53% in Ebonyi after 36 months, and only 28% lost after 36 months in Zamfara. Losses due to wear and tear were similar, over time, in Ebonyi and Oyo reaching 20% and 10%, respectively, in the final surveys. In contrast, losses due to wear and tear were only 9% in Zamfara after 36 months.

The proportion of losses due to wear and tear among all losses was very small at baseline (0% Ebonyi, 7% Zamfara, and 2% Oyo) meaning that almost all losses were due to nets being given away. The proportion gradually increased and, at the final survey, 38% of attrition was due to wear and tear in Ebonyi, 44% in Zamfara, and 22% in Oyo (24 months only). The outcome for the old nets differed between sites (p=0.003). In Ebonyi, 86% of discarded nets were thrown away, 12% destroyed, and 2% used for other purposes (window and door cover). In Zamfara, 59% were destroyed, 41% thrown away, and none used for other purposes. In Oyo, the major way of discarding was also destroying them (58%), but only 18% were thrown away and 24% were used for other purposes (87% window and door covers, 13% protection of crops). However, repurposing nets occurred for only 2.5% of all campaign nets distributed; a definite outcome was available in Oyo, 0.5% in Ebonyi, and none at all in Zamfara.

Figure 7: Trends in all-cause attrition and wear and tear (discarded nets) as a function of time since distribution



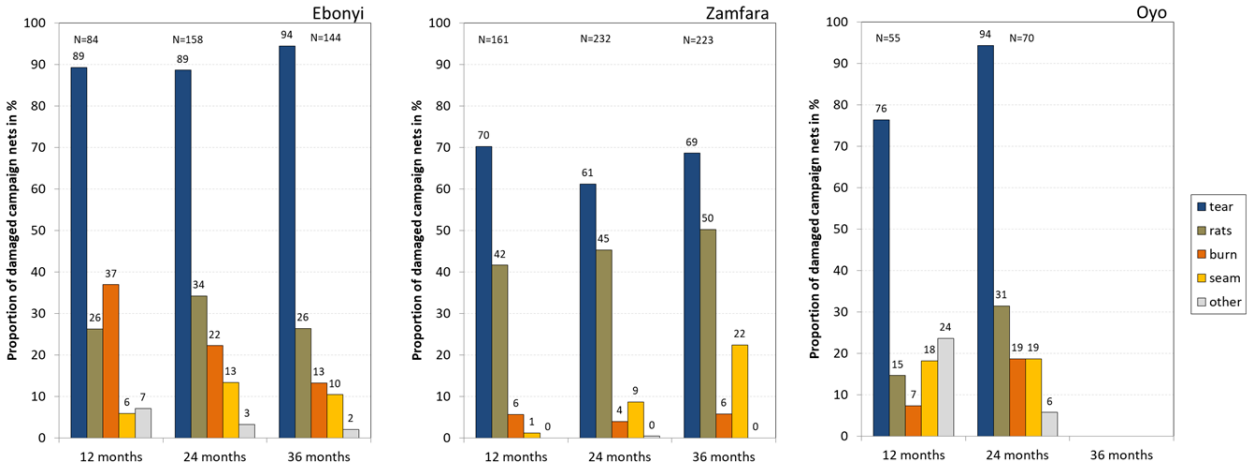
As expected, the proportion of nets still present in the surveyed households with any sign of damage increased continuously, over time, reaching 89% in Ebonyi and Zamfara after 36 months. In Oyo, the rate was somewhat lower, with 40% after 24 months, which probably is due to the lower use rate there. This is also reflected in the relatively high proportion of nets in good condition after 24 months, which was 77% in Oyo, compared to 64% in Zamfara, and 55% in Ebonyi, at the same time point. However, the nets in Oyo with any damage had more damage than at the other sites, with 11% torn and a median pHI of 189. Even after 36 months, only 10% were torn and the median pHI was 129. After 36 months, 78% of cohort nets still present in Ebonyi were serviceable compared to 90% in Zamfara and 89% in Oyo after 24 months.

Table 13: Physical condition (integrity) of surviving cohort nets (proportionate Hole Index [pHI])

Variable	Baseline	12 months	24 months	36 months
Ebonyi	N=367	N=296	N=232	N=175
Any holes	12.8%	33.1%	73.3%	89.1%
Median pHI (if any hole)	24	33	103.5	213
Good (pHI <64)	96.2%	87.2%	55.2%	36.0%
Too torn (pHI >642)	0.3%	2.4%	11.2%	22.3%
Serviceable (pHI ≤642)	**99.7%**	**97.6%**	**88.8%**	**77.7%**
Zamfara	N=357	N=353	N=309	N=246
Any holes	14.1%	47.0%	73.8%	89.0%
Median pHI (if any hole)	29	28	58	129
Good (pHI <64)	97.8%	87.0%	64.1%	44.7%
Too torn (pHI >642)	0.0%	2.0%	6.5%	10.2%
Serviceable (pHI ≤642)	**100%**	**98.0%**	**93.5%**	**89.8%**
Oyo	N=372	N=216		
Any holes	1.6%	27.8%	40.2%	
Median pHI (if any hole)	12	133	186	
Good (pHI <64)	99.5%	85.2%	76.9%	
Too torn (pHI >642)	0.0%	4.2%	11.2%	
Serviceable (pHI ≤642)	**100%**	**95.8%**	**88.8%**	

See Figure 8 for damage mechanisms reported by the households for each campaign net with any holes. Across all three sites mechanical damage was consistently the most common mechanisms, but more so in Ebonyi, which had a lower rate of reported rodent damage than Zamfara but a higher rate of burns than Zamfara or Oyo. The reported damage pattern at the surveys was very similar, if not identical, at all three sites, suggesting that these results are reasonably robust.

Figure 8: Type of damage mechanisms reported for damaged campaign nets (multiple responses)



Overall physical survival in serviceable condition (i.e., the combination of attrition due to wear and tear) and the integrity of the still existing nets, was 55% in Ebonyi and 80% in Zamfara after 36 months (Table 14) and this difference was statistically significant (p=0.005). Survival in Oyo was 75% after 24 months (i.e., almost the same as Oyo) after 24 months. When only nets that had ever been used were considered, the rates dropped by less than 1% point, because most nets had been in use by the end of the study. The survival estimate did not differ by gender of head of household (71% males; 70% females), but it did improve with increasing positive net care and repair attitude of the households. Across the sites, survival in households that never had a very positive attitude score in any of the surveys was 54%, increasing to 69% if a household had a very positive score at least once, and 81% if two or more times (p=0.0003).

Survival of the campaign nets also showed a strong intra-cluster correlation, meaning that within a village it was more consistent than between villages or, in other words, net care and repair behavior was similar within communities, but some were better than others. This can be inferred from the higher than expected statistical "design effect" of LLIN survival, which was 4.3 in Ebonyi, 3.1 in Zamfara, and 4.2 in Oyo, compared to the expected 2.0.

Table 14: Nets surviving in serviceable condition (including nets discarded before baseline)

Variable	Baseline	12 months	24 months	36 months
Ebonyi	N=367	N=301	N=270	N=248
Survival estimate	99.7%	96.0%	76.3%	54.8%
95% CI	98.0–100	92.5–97.9	67.9–83.1	41.4–67.6
Only nets ever used	N=166	N=231	N=265	N=243
Survival estimate	99.4%	95.7%	75.9%	54.7%
95% CI	96.1–99.9	90.8–98.0	67.3–82.7	41.3–67.2
Zamfara	N=357	N=354	N=315	N=275
Survival estimate	99.3%	97.7%	91.8%	80.4%
95% CI	97.9–99.8	95.7–98.8	84.1–95.9	72.7–86.3
Only nets ever used	N=284	N=332	N=299	N=261
Survival estimate	99.1%	97.6%	91.3%	80.1%
95% CI	96.8–99.9	95.4–98.8	83.5–95.6	72.7–85.9
Oyo	N=372	N=225	N=201	
Survival estimate	100%	92.0%	74.6%	
95% CI	-.-	86.0–95.6	60.2–85.1	
Only nets ever used	N=124	N= 220	N=197	
Survival estimate	100%	91.8%	74.1%	
95% CI	**-.-**	85.7–95.4	59.6–84.8	

When these results are plotted against the hypothetical survival curves with defined median survival (Figure 9), it can be seen that survival roughly follows the same line in Zamfara with an estimated survival at 36 months of 5.3 years[4] (previous estimate was 5.6). In Ebonyi, the median survival estimate dropped somewhat, from around 4 years after 12 months to 3.3 years at 24 months, and again 3.3 years after 36 months. Median survival estimate was lowest in Oyo, but slightly increased from a median survival of 2.7 years after 12 months to 3.2 years after 24

[4] To obtain the figure, estimate the relative position of the 12-month data point on a horizontal line between the two adjacent median survival curves.

months. Table 14a shows the median survival estimates obtained by different methods. However, for Zamfara and Oyo, the "last two points" calculation did not give reliable results because the first point was still above 85%. In these instances, only the confidence interval was calculated and applied to the estimate from the graphic method.

Figure 9: Estimated net survival in serviceable condition with 95% confidence intervals (error bars) plotted against hypothetical survival curves with defined median survival.

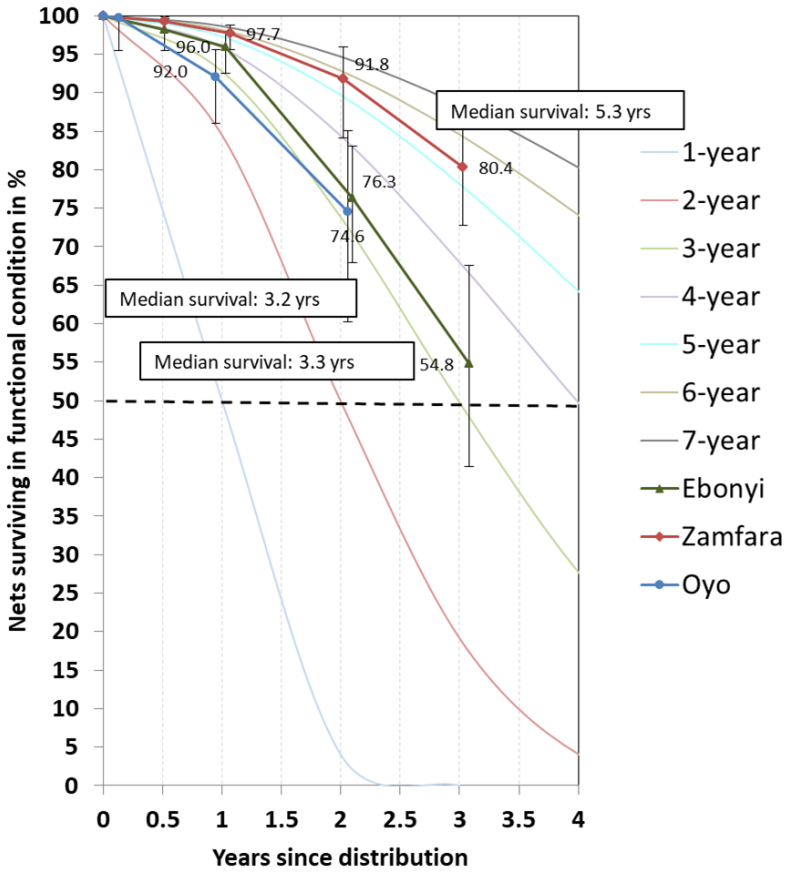


Table 14a: Estimated median survival of LLINs in years using different methods

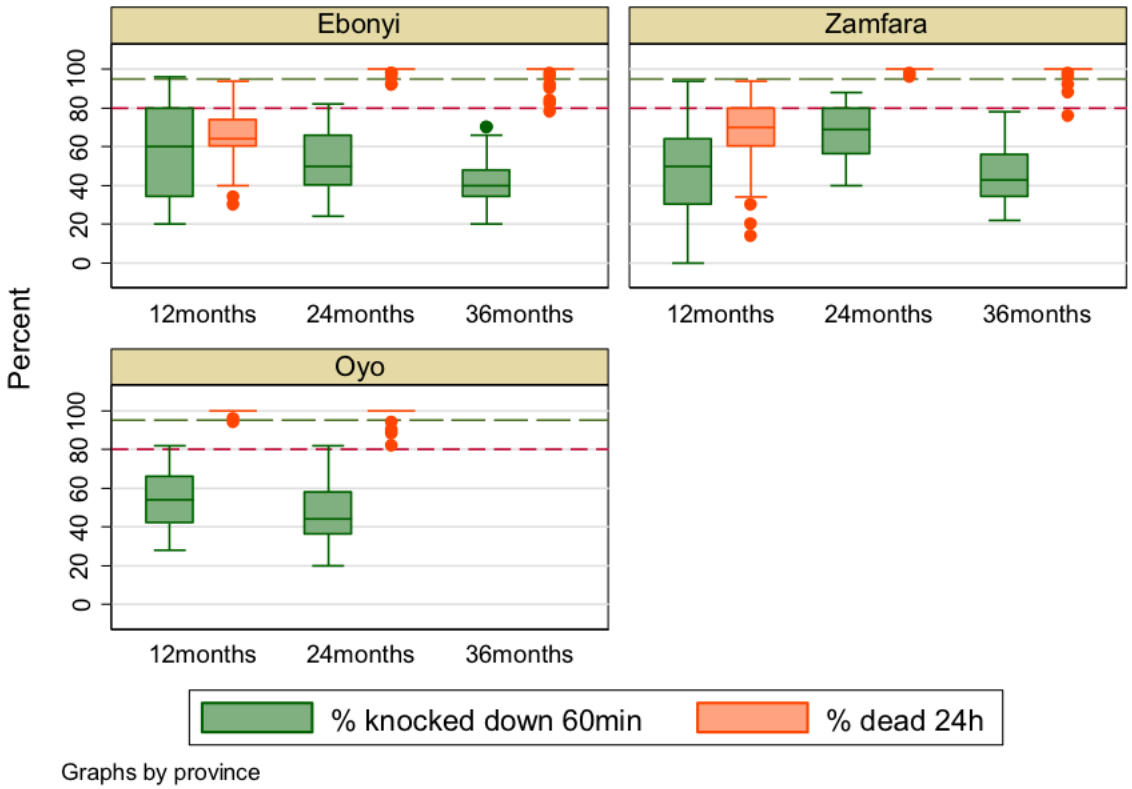
Variable	12 months	24 months	36 months
Ebonyi			
Estimated from Figure 9[1]	4.1	3.3	**3.3**
Calculated from last two data points (95% CI)	-.-	-.-	**3.3 (2.8–4.2)**
Zamfara			
Estimated from Figure 9	5.8	5.6	**5.3**
Calculated from last two data points (95% CI)	-.-	-.-	**5.3 (4.6–6.4)**
Oyo			
Estimated from Figure 9	2.7	3.2	
Calculated from last two data points (95% CI)	-.-	**3.2 (2.1–5.3)**	

6.6 Insecticidal effectiveness of campaign nets

See Table 15 and Figure 10 for the results from bio-assays of the 30 campaign nets sampled at each site and time point. The samples collected at 12 months at Ebonyi and Zamfara showed very poor results, with only 16% and 30%, respectively, showing optimal insecticidal performance based on WHO criteria. However, results from the 24- and 36-month samples did not confirm these results. While the 60KD rates slightly declined over time, median 24-hour mortality remained near 100%, resulting in optimal performance in 97% of samples in Ebonyi and 98% in Zamfara. All the samples showed at least minimum effectiveness. The results from the Oyo samples, which were different batches of DAWA Plus 2.0, were very similar to the 24-month results of the other two sites—with a median knockdown rate of 44% and median mortality of 100% corresponding to 100% optimal performance.

Negative and positive controls were within expected, 0% and 100% mortality, respectively. Results from chemical residue testing from a sub-sample of the 12-month sample from Ebonyi and Zamfara showed a deltamethrin content of 1.08 g/kg and 0.83 g/kg, respectively, corresponding to 44 mg/m^2 and 37 mg/m2, respectively. This corresponds to 55% of the initial loading dose remaining in Ebonyi and 46% in Zamfara. This is lower than expected, but still sufficient because all except one sample had at least 15 mg/m2 deltamethrin and that sample (1.5 mg/m2) was from Zamfara. The r-isomer of deltamethrin, which tends to increase after intensive UV light exposure, was only found in three of the 10 samples; and, in only one, was it slightly elevated—with 21%—while the other two samples had 1% and 3%. These results do not suggest significant damage of the insecticide due to storage.

Figure 10: Results from WHO cone bio-assays: the box plot shows the median (horizontal line), Inter-Quartile-Range (box), adjacent values5 (whiskers), and outliers (circles)



[5] Adjacent values: +/- 1.5* ITR

Table 15: Results from bio-assays

Variable	12 months	24 months	36 months
Ebonyi	N=30	N=30	N=30
Knock down 60 minutes			
Mean (95% CI)	58.3% (50.7–65.9)	52.0% (46.2–57.8)	42.3% (37.4–47.1)
Median (IQR)	60.0% (34.0–80.0)	50.0% (40.0–66.0)	40.0% (34.0–48.0)
Mortality 24 hours			
Mean (95% CI)	65.0% (60.3–69.7)	99.2% (98.4–99.9)	97.3% (95.2–99.5)
Median (IQR)	64.0% (60.0–74.0)	100% (100–100)	100% (100–100)
Optimal effectiveness			
Estimate (95% CI)	16.7% (7.3–33.6)	100% (-.-)	96.7% (77.7–99.6)
Minimal effectiveness			
Estimate (95% CI)	90.0% (72.7–96.8)	100% (-.-)	100% (-.-)
Zamfara	N=30	N=30	N=30
Knock down 60 minutes			
Mean (95% CI)	46.8% (39.5–54.1)	66.1% (60.0–72.3)	45.2% (40.9–49.6)
Median (IQR)	50.0% (35.0–64.0)	69.0% (56.0–80.0)	43.0% (34.0–56.0)
Mortality 24 hours			
Mean (95% CI)	64.4% (57.8–71.2)	99.6% (99.5–100)	98.3% (96.6–100)
Median (IQR)	70.0% (60.0–80.0)	100% (100–100)	100% (100–100)
Optimal effectiveness			
Estimate (95% CI)	30.0% (16.2–48.7)	100% (-.-)	96.7% (77.7–99.6)
Minimal effectiveness			
Estimate (95% CI)	80.0% (63.4–90.2)	100% (-.-)	100% (-.-)
Oyo	N=30	N=30	
Knock down 60 minutes			
Mean (95% CI)	53.4% (47.9–58.9)	47.5% (41.3–53.6)	
Median (IQR)	54.0% (42.0–66.0)	44.0% (36.0–58.0)	
Mortality 24 hours			
Mean (95% CI)	99.7% (99.2–100)	98.5% (97.0–99.9)	
Median (IQR)	100% (100–100)	100% (100–100)	
Optimal effectiveness			
Estimate (95% CI)	100% (-.-)	100% (-.-)	
Minimal effectiveness			
Estimate (95% CI)	100% (-.-)	100% (-.-)	

Tables 16–18 then show the details of handling and use of the sampled bio-assay nets. For the final samples, these were extracted from the cohort net database. All nets had been hung the previous night in Ebonyi and Zamfara, but 8 out of 30 samples at the final survey in Oyo had not been hung, and 12 nets had not been used the previous night (but still had been ever used). As seen for the cohort nets, washing frequency was slightly higher in Zamfara, with 3.0 average washes in the last six months, compared to 2.0 in Ebonyi after 24 months and 1.0 in Oyo after 12 months. Overall, the results for the bio-assay nets are comparable to those for the cohort nets, suggesting that the bio-assay samples were a good representation of the campaign nets under study. Analysis of the bio-assay results by nets hung or soap used did not show any differences in the proportion, with optimal insecticidal performance when the 12-month results from Ebonyi and Zamfara were excluded.

Table 16: Variables related to handling of bio-assay test LLINs

Variable	12 months	24 months	36 months
Ebonyi	N=30	N=30	N=30
Location found			
hanging loose	53%	20%	13%
hanging folded/tied	47%	80%	80%
not hung	0%	0%	7%
Type of sleeping place			
bed	77%	87%	93%
mattress	10%	13%	7%
mat/ground	13%	0%	0%
Net users			
young child only	10%	64%	15%
young child + adult	50%	0%	44%
older child, adult only	40%	36%	41%
Zamfara	N=30	N=30	N=30
Location found			
hanging loose	60%	40%	54%
hanging folded/tied	40%	57%	46%
not hung	0%	3%	0%
Type of sleeping place			
bed	90%	83%	96%
mattress	0%	3%	0%
mat/ground	10%	13%	4%
Net users			
young child only	3%	47%	7%
young child + adult	52%	0%	46%
older child, adult only	45%	53%	47%
Oyo	N=30	N=30	
Location found			
hanging loose	30%	32%	
hanging folded/tied	23%	40%	
not hung	47%	28%	
Type of sleeping place			
bed	17%	40%	
mattress	53%	50%	
mat/ground	30%	10%	
Net users			
young child only	39%	0%	
young child + adult	0%	25%	
older child, adult only	61%	75%	

Table 17: Variables related to use of bio-assay test nets

Variable	12 months	24 months	36 months
Ebonyi	N=30	N=30	N=30
Used last night	100%	100%	90%
Use last week			
every night	70%	43%	20%
most nights (5–6)	20%	40%	60%
some nights (1–4)	0%	17%	13%
not used	3%	0%	3%
don't know	7%	0%	3%
Seasonal use			
equally rain and dry	83%	43%	30%
mainly rain	17%	57%	70%
rain only	0%	0%	0%
Zamfara	N=30	N=30	N=30
Used last night	97%	100%	100%
Use last week			
every night	94%	70%	100%
most nights (5–6)	0%	23%	0%
some nights (1–4)	3%	7%	0%
not used	3%	0%	0%
don't know	0%	0%	0%
Seasonal use			
equally rain and dry	97%	67%	100%
mainly rain	0%	27%	0%
rain only	3%	7%	0%
Oyo	N=30	N=30	
Used last night	63%	64%	
Use last week			
every night	43%	48%	
most nights (5–6)	17%	16%	
some nights (1–4)	10%	12%	
not used	30%	24%	
don't know	0%	0%	
Seasonal use			
equally rain and dry	73%	60%	
mainly rain	17%	37%	
rain only	10%	3%	

Table 18: Variables related to washing of bio-assay test nets

Variable	12 months	24 months	36 months
Ebonyi	N=30	N=30	N=30
Ever washed	40%	63%	67%
Washes last 6 months (all)			
Mean	0.5	1.2	2.0
Median	0.0	1.0	2.0
Washes last 6 months (if washed)			
Mean	1.3	1.9	2.0
Median	1.0	2.0	2.0
Soap used			
country soap bar	25%	79%	95%
detergent or bleach	75%	21%	5%
mix	0%	0%	0%
Zamfara	N=30	N=30	N=30
Ever washed	100%	100%	96%
Washes last 6 months (all)			
Mean	2.9	3.2	5.9
Median	2.0	3.0	4.0
Washes last 6 months (if washed)	2.9	3.2	5.9
Mean	2.0	3.0	4.0
Median			
Soap used			
country soap bar	50%	40%	96%
detergent or bleach	50%	60%	4%
mix	0%	0%	0%
Oyo	N=30	N=30	
Ever washed	80%	72%	
Washes last 6 months (all)			
Mean	1.4	2.4	
Median	1.0	2.0	
Washes last 6 months (if washed)			
Mean	1.9	2.5	
Median	1.0	2.0	
Soap used			
country soap bar	46%	89%	
detergent or bleach	54%	11%	
mix	0%	0%	

Summary and Conclusion

This report presents the findings of a three-year durability monitoring study of LLINs (DAWA Plus 2.0) distributed through mass campaigns in three locations with different ecological, demographic, and behavioral environments in Nigeria: Ebonyi state (Ishielu LGA) in the southeast, Zamfara state (Bakura LGA) in the northwest, and Oyo state (Akinyele LGA) in the southwest. At baseline, between one and six months after the mass campaign, a cohort of households that represented the selected LGA was recruited and all their nets obtained from the campaign were labeled as cohort nets. These households and cohort nets were then followed up approximately 12, 24, and 36 months after distribution. Because the Oyo campaign took place one year after the one in Ebonyi and Zamfara, the results for Oyo represent the data collection only up to the 24-month time point.

Sample and follow-up

The target to recruit 450 households, 150 households per site (15 clusters with 10 households each), and 1,035 campaign nets (345 per site) into the study cohort were reached with 439 households enrolled (98%) and 1,096 campaign nets labeled for follow-up (106%).

During the three-year follow-up (two years for Oyo), a definite outcome could be determined for 928 cohort nets (85%), but this rate differed between sites, with the best outcome found in Zamfara (92%), followed by Ebonyi (88%), and Oyo (75%). The lower follow-up rate in Oyo was due to the populations' high mobility, as 16% of the sampled households moved away from the study communities—representing 15% of the cohort nets. A second major reason for loss to follow- up was cohort nets used by the households in different locations (school, farm, or second home) and this was also most common in Oyo, applying to 6% of the cohort nets. The final reason was households not being available for interview on survey day, which was highest in Ebonyi (8% of cohort nets), followed by Oyo (4%). Only one household (0.2%) refused participation during the study and this was in Oyo.

Demographic and socio-economic characteristic

The mean household size was 5.0 in Ebonyi, 5.5 in Zamfara, and 4.4 in Oyo, although in Ebonyi and Zamfara the registered household members in the final survey were lower than at baseline. Very few households were headed by women, 2% in Zamfara, 8% in Ebonyi, and 19% in Oyo.

Educational status of male heads of households was poorest in Zamfara, with 41% non-literate and only 18% attending any secondary education; followed by Ebonyi, with 35% and 49%, respectively, and best in Oyo with 30% and 55%, respectively.

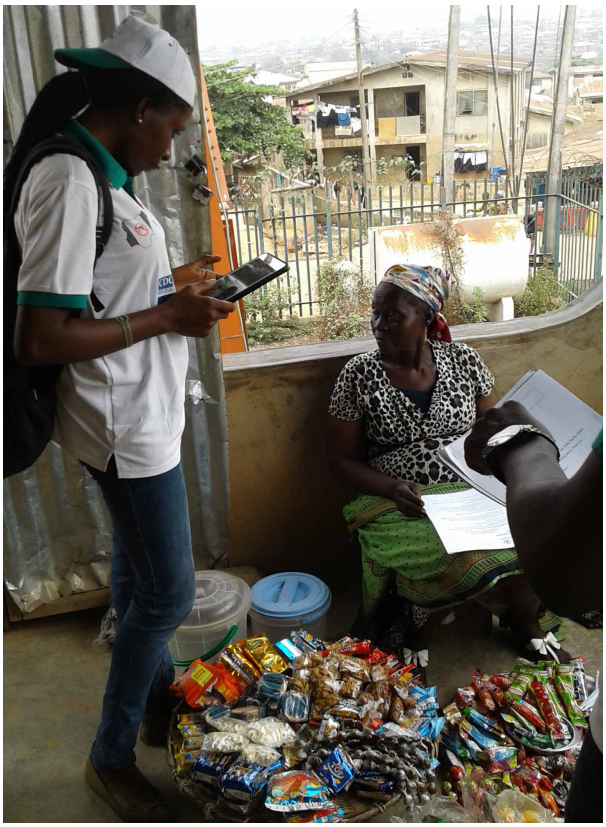
The Ebonyi and Zamfara sites were both rural and predominantly agricultural, while the Oyo site had more peri-urban characteristics and was economically better off than the other two sites. In Zamfara, 91% of households had agricultural land and some livestock as an economic resource; in Ebonyi, this rate was 69%, with another 26% of households having one or the other; while, in Oyo 25% of households had non-agricultural income sources. Ownership of household assets representative of wealth—such as mobile and smart phones, television, refrigerator, etc.—were significantly more common in Oyo and house structures were better.

Durability risk factors

A number of behavioral factors that are known, or thought to be associated with damaged nets, were monitored and divided into four groups: factors of the net use environment in the household, net handling, type of sleeping place, and knowledge and attitudes toward net care and repair. The assessment in Zamfara showed better performance with respect to risk factors for durability compared to the other two sites, although the difference between Zamfara and Ebonyi became less during the study. Oyo can be assessed as similar or slightly poorer performance with respect to risk factors than Ebonyi.

With respect to net use environment, all three sites had a high presence of rodents. In Zamfara, households frequently (>90%) stored food in their sleeping rooms and this correlated with a relatively high damage rate from rodents (42%–50% of damaged nets). But, on the other hand, they never cooked in the same room they slept in resulting in low rates of burn damage. In Oyo, people rarely cooked in their sleeping rooms and about one-third stored food there. The situation in Ebonyi was fluid as the proportion of households reporting storage of food in sleeping rooms was high initially (82%), but then gradually decreased to around 30%. However, a significant proportion (30%) cooked in their sleeping rooms, at least sometimes.

Over time, net handling also improved in Ebonyi; initially, 53% of hanging nets were not folded up or tied but hung loose. During the final survey, this rate was gradually reduced to just 11%. In Zamfara and Oyo, about half of all hanging nets were hanging loose during the day. Drying nets on fences or bushes was only relevant in Zamfara (around 30%) and in Oyo where the rate increased over time reaching 41% in the final survey. Washing of nets was similar in Ebonyi and Oyo with about two washes every six months, but was higher in Zamfara with four washes per six months. In Ebonyi, only bar soap was used, while in Oyo at least 25% of households used detergents. In Zamfara, reported detergent use was high initially (40%–66%), but then fell to just 9%.



At all three sites exposure to behavior change communication messages on nets was relatively high and there was a gradual increase in media exposure (radio) compared to interpersonal communication through health workers or community agents. The biggest differences between sites were seen in the resulting net care and repair attitude. In Zamfara, 96% of households had a very positive attitude score in at least two surveys and 55% in all four surveys. By contrast, 39% in Oyo never reached the “very positive” level, 22% had a very positive score at least twice, and 3% in all three surveys. In Ebonyi, the situation was even worse, with 58% of households never registering a very positive score, only 6% twice, and no household more than twice.

Net use and ownership

At baseline, there had been some concerns that a significant number of campaign cohort nets were not found hanging: 58% Ebonyi, 22% Zamfara, and 80% Oyo. This had significantly improved by the 12-month survey—27% Ebonyi, 9% Zamfara, and 51% Oyo—and, thereafter, essentially all cohort nets were hanging and being used in Ebonyi (99%) and Zamfara (94%). However, in Oyo the rate of cohort nets hanging the previous night only reached 65% after 24 months. A significant proportion of households at all three sites owned additional nets in addition to those from the campaign: 30% Ebonyi, 69% Zamfara, and 46% Oyo. However, these were almost all gone by the 12-month assessment and very few nets were obtained in Ebonyi, resulting in less than 1% of households with non-cohort nets at 24 months and only 4% at 36 months. In Oyo and Zamfara, around 6% of households had obtained new nets, mainly from health facilities (including ANC) and some nets were obtained from relatives or friends, resulting in 7% with additional nets in Zamfara after 24 months and 11% at 36 months. In Oyo, at 12 months, 18% owned other nets and at 24 months 28% owned them. These results suggest a different behavior at sites regarding replacing old with new nets. In Zamfara, all older nets were discarded and the new campaign nets immediately put into use. In Ebonyi, initially, the older nets were prioritized until they were considered too old and only then were the new campaign nets used. Oyo had a near 50-50 mix of using old and newer nets.

Physical durability outcomes

All-cause attrition was highest in Oyo, with 47% after 24 months compared to 37% in Ebonyi and 14% in Zamfara at the same time. All-cause attrition in Ebonyi then increased to 53% during the final survey and 28% in Zamfara. The proportion of losses due to wear and tear among all losses was very small at baseline (0% Ebonyi, 7% Zamfara, and 2% Oyo) meaning that almost all losses were due to nets given away. The proportion gradually increased and, at the final survey, 38% of attrition was due to wear and tear in Ebonyi, 44% in Zamfara and 22% in Oyo (24 months only). In Ebonyi, 86% of the discarded nets were thrown away while in Zamfara and Oyo the majority were destroyed (58%). Overall, only 1% of all campaign nets were used for other purposes, mostly in Oyo and to a smaller extent in Ebonyi. Covering windows and doors was the most common use followed by protection of crops. No other uses were reported.

After 36 months, 89% of the cohort nets still present in Ebonyi and Zamfara had any holes, but the level of damage was higher in Ebonyi with 22% “too torn” compared to 10% in Zamfara. In Oyo, only 40% of the cohort nets had any holes after 24 months, but those that were damaged had significant damage with 11% “too torn” and a pHI of 186 compared to 104 and 58 in Ebonyi and Zamfara at the same time point. Repairs were highest in Ebonyi, with 47% of damaged nets followed by Oyo with 21%. Female-headed households tended to have a higher rate of repair if the net had

any damage (40% versus 30%), but due to the small number of female-headed households this difference was not statistically significant (p=0.3). If repairs were made, it was almost exclusively by household members in Ebonyi and Zamfara, while 20% of households in Oyo who reported repairs said they had used a tailor. Stitching the holes up was the most common way of repair reported by 88% of repairing households, followed by knotting up the holes (31%); only 4% used patching (multiple responses were possible).

Therefore, the proportion of cohort nets in serviceable condition was best in Zamfara (90%), followed by Ebonyi (78%), and Oyo (89%) after 12 months. This translates to an estimate for survival in serviceable condition of the campaign nets of 80%, 55%, and 75%, respectively; and an estimated median survival of 5.3 years in Zamfara, 3.3 years in Ebonyi, and 3.2 years in Oyo. The difference between Zamfara and Ebonyi and Oyo was statistically significant (p=0.005). The survival estimate did not differ by gender of head of household (71% males, 70% females) but, it did improve with increasing positive net care and repair attitude of the households. Across the sites, survival of nets in households that never had a very positive attitude score in any of the surveys was 54%, increasing to 69%, if a household had a very positive score at least once and 81% if two or more times (p=0.0003). Net survival was also found to differ between villages, but it was more homogenous within each village.

Insecticidal effectiveness outcomes

The 12-month bio-assay results from Ebonyi and Zamfara were lower than expected, with only 16% and 30%, respectively, showing optimal insecticidal performance. Results from the pre-shipment testing had shown normal insecticide content and this was confirmed by the manufacturer re-testing samples of the concerned batches. These factory samples also showed high bio-assay results, suggesting that either there had been some insecticide loss between arrival at the port in Nigeria and the testing, or there was a problem with the testing. The 24- and 36-month samples from all three sites showed a relatively low knockdown rate of 50% to 69%, but vector 24-hour mortality was above 95% for all samples, resulting in a 100% optimal performance in Ebonyi and Oyo and 97% in Zamfara. None of the samples failed the minimal criteria, suggesting that insecticidal effectiveness of the campaign nets was sufficient. Results from chemical

residue testing from a sub-sample (n=10) of the 12-month samples from Ebonyi and Zamfara showed a deltamethrin content of 1.08 g/kg and 0.83 g/kg, respectively, corresponding to 44 mg/m^2 and 37 mg/m2, respectively. The r-isomer of deltamethrin, which tends to increase after intensive UV light exposure, was only found in three of the 10 samples; in only one was it slightly elevated with 21%, while the other two samples had 1% and 3%. These results do not suggest significant damage of the insecticide during storage.

Limitations

Some of the durability risk factor, such as net care and repair attitude, as well as some of the outcomes—such as reason for net losses—were based on the answers of the household members interviewed and, therefore, are prone to recall or social desirability biases. Furthermore, while the sample of the campaign net cohort was representative for the selected districts within each province, the district selection was purposive and some caution is required when generalizing the findings to the states or even Nigeria as a whole.

Conclusion

In conclusion, it can be said that the durability monitoring of representative cohorts of campaign nets in Ebonyi, Zamfara, and Oyo was successful, and the results for the physical durability were within the expected range, but showing some differences in performance of the same LLIN brand in different locations. Zamfara performed significantly above expectations, with an estimated median survival of 5.3 years, compared to 3.3 and 3.2 for Ebonyi and Oyo. All campaign net samples showed sufficient insecticidal effectiveness.