FINAL REPORT AFTER
36 MONTHS FOLLOW UP
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Durability Monitoring of LLINs in **Democratic Republic of Congo**

JOHNS HOPKINS
Center for Communication Programs

VECTOR WORKS
Scaling Up Vector Control for Malaria Prevention

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1 Abstract

Background: Malaria prevention with long-lasting insecticidal-treated nets (LLINs) has seen a tremendous scale-up in sub-Sahara Africa in recent years; however, studies have suggested that the physical durability between LLINs may vary significantly. These differences are largely driven by environmental and behavioral factors, but may also be driven by differences in the textile qualities of the LLIN brand. Country programs should implement regular monitoring of LLIN durability. Following guidance from the U.S. President's Malaria Initiative (PMI), durability monitoring of two brands of LLINs—each with different specifications, distributed in the 2016 mass distribution campaign in the Democratic Republic of Congo (DRC) during three years—was set up in two ecologically similar health zones in neighboring provinces: Sud Ubangi and Mongala.

The National Malaria Control Program and the Kinshasa School of Public Health carried out this activity, with support from the VectorWorks project and PMI.

Methods: During this prospective cohort study, representative samples of households from each district were recruited at baseline, one to six months after the mass campaign. All campaign nets in these households were labeled and followed up during 33–36 months. A total of 240 households (80% of target) and 754 campaign nets (109%) were included in the study. Definite outcomes could be determined for 67% of the cohort nets in Sud Ubangi and 82% in Mongala. Outcomes measured for physical durability were attrition (all-cause attrition and attrition due to wear and tear) and physical integrity, based the proportionate Hole Index (pHI) and subsequent categorization of cohort nets as serviceable (pHI<643). They were then combined to provide the "proportion of nets surviving in serviceable condition" at each time point of follow up and the median survival in years (the time until 50% of cohort nets with known outcomes were no longer serviceable). In addition, a survival analysis was undertaken using a Cox proportionate hazard model to analyze determinants of LLIN survival. The outcome for insecticidal durability was determined by bio-assay (World Health Organization [WHO] cone test) from subsamples of the campaign nets; it was defined as the proportion of nets that showed optimal insecticidal effectiveness (24-hour mortality of ≥80% or 60-minute knockdown of ≥95%). In addition, demographic, socio-economic, and behavioral aspects were recorded through a structured questionnaire at each time point.

The demographic characteristics of the populations were comparable between sites, which are typical for rural African populations; it did not change significantly over time. House construction at both sites was similar and very simple, with around 80% of roofs made from grass or thatch, 80–90% of walls made from mud, and 90% of floors made from earth or clay. Almost all households used firewood for cooking, had access to a pit latrine, but also used surface water from rivers and creeks for drinking. The economic situation was also very similar, with a slight advantage for Mongala, mainly due to a higher mobile phone coverage that, generally, varied because of low-to-poor provider coverage.

Most durability risk factors were very similar between the two sites, with some minor differences, such as higher instances of cooking in the sleeping rooms in Sud Ubangi, higher use of finished bed frames in Sud Ubangi, but more foam mattresses in Mongala. The main difference was the much more positive attitude toward net care in Sud Ubangi, in spite of similarly low behavior change communication message exposure at both sites. This did not necessarily translate into actual repair of nets, but did impact the LLINs' physical durability.

While, overall, all-cause attrition of campaign nets (loss for any reason) was high—with 57% in Sud Ubangi and 76% in Mongala—the main observation was an exceptionally high rate of discarding nets because they were too old or were torn. This was statistically significantly higher in Mongala (48%) than Sud Ubangi (26%). In contrast, the physical condition of nets still found in the households was similar at both sites, with 23% of surviving nets in Sud Ubangi and 30% in Mongala being too torn to use.

Overall survival in serviceable condition during the last survey was 37% in Sud Ubangi and just 17% in Mongala; this difference was statistically and programmatically significant (p=0.003). Estimated median survival was 1.6 years for the Dawa Plus 2.0 in Mongala (95% CI 1.3–1.9) and 2.2 years for the DuraNet in Sud Ubangi (95% CI 2.0–2.4), both of which were well below the assumed three-year median survival. Results from survival analysis of the data confirmed the magnitude of median survival (1.7 years in Mongala and 2.6 years in Sud Ubangi). It was also established in a Cox proportionate hazard model that the difference in median survival was mainly due to the LLIN brand and not to other factors, such as positive net care attitude, type of sleeping place, or dominant use by children only, all of which showed some positive or negative impact on the outcome in the Cox models.

A bio-assay using the WHO cone tests showed optimal insecticidal performance up to the final survey for the DuraNet LLIN brand, but the Dawa Plus 2.0 LLIN brand only had optimal performance at >80% only, up to the 24-month data point; 53% of samples at the final survey failed, even the minimal effectiveness criteria. This suggests that insecticidal content was lower or was lost faster than expected. Whether this is relevant for vector control considerations in this case is questionable because the physical durability in this setting was only 1.6 years on average.

Conclusion: After three years of follow-up among neighboring, rural populations in the provinces of Sud Ubangi and Mongala, the 150 denier polyethylene LLIN DuraNet showed significant differences in median physical survival compared to the 100 denier polyester LLIN Dawa Plus 2.0; however, both remained well under the three-year expected median survival. The difference could be attributed mostly to the differences in the brand, because a Cox proportionate hazard model adjusting for other risk factors confirmed the brand as the strongest driver of the difference. This means that in environments like DRC, it will be preferable to distribute a more durable LLIN, such as the DuraNet or similar brands, but also to consider a distribution strategy with campaigns every two years or, alternatively, a continuous distribution strategy. Insecticidal performance was optimal for the DuraNet in Sud Ubangi, but for the Dawa Plus in Mongala optimal performance lasted only up to 24 months and it failed at 36 months. However, by this time, most of the cohort nets were already lost.

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3 Acknowledgements

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4 Background

Malaria prevention with LLINs has seen a tremendous scale-up in sub-Saharan Africa in recent years. Many countries have achieved high ownership coverage with insecticide-treated nets (ITNs) and they are approaching the universal coverage target of one net for every two people of 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 ITNs remain in the households and continue to protect the net users. This information is needed to decide when the ITN needs 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 comprises the loss of nets due to wear and tear and the physical integrity of the surviving nets. During the last five years, the methodology on how to measure net durability has made significant progress and now comprehensive guidance is available from WHO. This resulted in the recommendation that all malaria control programs that distribute ITN should also routinely monitor net durability. Donors, such as the President's Malaria Initiative (PMI) and implementing partners, have taken up this recommendation and they also encourage routine monitoring of ITN durability in the countries they support.

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

In Democratic Republic of Congo (DRC), some anecdotal reports from the field have suggested that the average survival of ITNs under operational conditions may be less than three years. To-date, only one study has been conducted in this area (Mansiangi et al., unpublished). The study was done in 2015 in eight provinces, using both a retrospective design for the survival aspects of ITNs and a cross-sectional one for aspects related to the use of long-lasting insecticidal-treated nets (LLINs) in households. The time elapsed since the distribution of nets (mainly Permanet 2.0) was between 5 and 44 months. Attrition and physical integrity were both measured. The results suggest that in only two of the eight provinces, median survival of the Permanet 2.0 in serviceable conditions was between 2.5 and 3.0 years, while for the other provinces it was between 1.5 and 2.0 years. However, the sample included only households with children under 5 years of age and this may have caused a slight underestimation of survival. Indeed, previous studies have shown that, in some cultural environments, the durability of nets is low in households with young children[2].

In 2015/16 the DRC's National Malaria Control Program (NMCP), with the support of its partners, launched a mass campaign in the northern provinces as part of the ongoing "rolling" system of provincial LLIN distributions to maintain universal coverage with ITNs in places where multiple brands of ITNs were distributed. With the current durability monitoring exercise, the NMCP would like to better understand the performance comparison of two of these brands in areas with similar ecologic and socio-demographic conditions.

[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 behavior and living conditions." *Malar J, 2015*,14:123

5 Methods

The NMCP and the School of Public Health, University of Kinshasa, with support from the VectorWorks project and PMI, carried out the activity.

5.1 Site

Two neighboring sites, Sud Ubangi and Mongala provinces, were selected. They are in the former Equateur province, which is in the rainforest zone in northwest DRC. One health zone (HZ) in each was selected: Ndage HZ for Sud Ubangi and Binga HZ for Mongala. The locations are shown in Figure 1 and briefly described as follows:

The climate is equatorial (warm and humid), with a bimodal rain pattern. The rainy season usually last nine months—from March to November. The dry season is from December to March, and three weeks in July. Vegetation is dominated by the equatorial forest with clay-sandy soil. The hydrography of the area comprises three large rivers: the Congo, the Mongala, and the Sambo. The tributaries of these rivers intersect the HZs, making access difficult for some places, especially during the rainy season.

In general, agriculture, hunting, fishing, and small trade are the main occupations. Livestock production is common, mainly small livestock and poultry. In addition, a number of large agricultural companies are active, such as the *Société des Cultures au Congo*, which is the main employer in the Binga HZ. It specializes in the production of palm oil, rubber, and cocoa. It employs about 30% of the labor force available in this HZ. It is thanks to the presence of this company that the HZ has telecommunication coverage, at least in some areas.

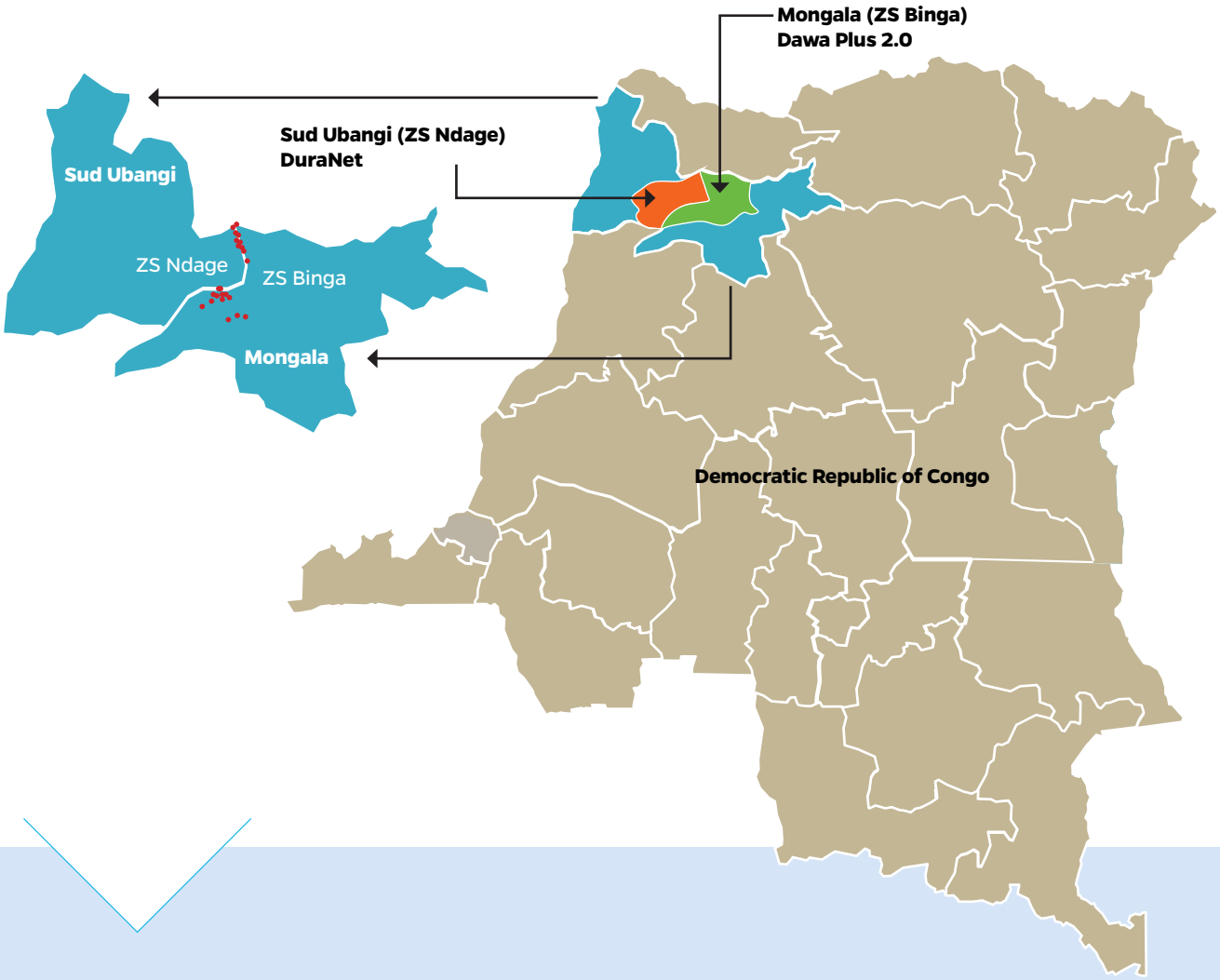
Malaria is the most dominant disease in terms of morbidity and mortality, with perennial transmission and hyper- to holoendemic endemicity. Based on estimates from the Malaria in Africa project, *Plasmodium falciparum* prevalence among children 2–10 years is around 60%. Other diseases with high morbidity are waterborne diseases, acute respiratory infections, and protein-energy malnutrition. Table 1 presents some of the key indicators from the 2013–14 Demographic and Health Survey (DHS).

Table 1: Socio-demographic and malaria situation in the study areas (2013/14); HH=household

Province	Under-5s with Fever Receiving Diagnostic Test	Under-5s with Positive Malaria RDT	Febrile Children Treated with Antimalarial	HH with at Least One LLIN	Population Using ITN Last Night
Sud Ubangi	15%	25%	35%	89%	63%
Mongala	7%	24%	25%	88%	66%

The main ethnic group in the area is the Ngombe and the main spoken languages are Lingala and Lingombe.

The Binga HZ is divided into 30 health areas (HAs); 28 are accessible by roads that are in very bad condition and two are accessible only by river. The Ndage HZ is subdivided into 18 HAs.



5.2 Brands monitored

The two brands of ITN being monitored are:

Dawa Plus 2.0, 100 denier polyester ITN in a white color. The ITN uses coating technology with a loading dose of 80 mg/m2 of deltamethrin. Dawa Plus 2.0 received interim World Health Organization/Pesticide Evaluation Scheme (WHOPES) recommendation in July 2009 (13th WHOPES Report).

DuraNet, a 150 denier polyethylene ITN in a blue color uses incorporation technology with a loading dose of 260 mg/m2 of alphacypermethrin. DuraNet received full WHOPES recommendation in July 2013 (16th WHOPES Report).

5.3 Design summary

The design follows, in general, the guidance of PMI for ITN durability monitoring (see www.durabilitymonitoring.org). Within six months following the mass distribution campaign, a representative cohort of campaign ITNs are 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 are assessed (attrition and integrity). Except at baseline, samples are taken for an assessment of insecticidal effectiveness (bio-assay) and analyzed at the entomology laboratory of the Institute of Bio-Medical Research (INRB) in Kinshasa (12 and 24 months) or the Centre de Recherche Entomologique de Cotonou (36 months). At the 12- and 24-month surveys, the samples are taken from households that are not part of the cohort (nearest neighbor) and from the cohort at 36-month follow-up; all nets collected for bio-assay were replaced with new LLINs. In DRC, two similar sites, with two different types of ITN brands, were selected. This durability study compares two brands in areas with very similar ecological and/or behavioral characteristics.

The sample size follows 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% points from the expected 50% survival after three years, comparing the best and the poorest performing site or brand. Using the standard formula for sample size calculations for comparing proportions in two groups with the above outlined settings results in a sample of 147 ITNs 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 is 279 per site. Taking into account that the expected attrition rates in a sample of 345 ITNs has to be taken at baseline, and based on the expected number of ITNs distributed per household, 150 households needed to be sampled per site.

At baseline, the ITN cohort in each HZ was established by selecting a representative sample of clusters (communities), based on probability proportionate to size, after inaccessible communities were eliminated from the sampling frame and households used simple random sampling from household lists established on the day of the survey. As soon as the clusters

were sampled, the local authorities and chiefs were informed of the purpose and expected time of the survey and their support was requested. To obtain maximum cooperation for the surveys, communities were sensitized and mobilized . All ITNs received from the NMCP campaign by the selected households were identified and marked with a unique ID number. Using a hole assessment, the physical condition of the campaign nets was measured and a household interview was undertaken.

The ITN mass distribution campaigns took place August 12–16, 2016, in Sud Ubangi—the United Nations Children's Fund implemented it and PMI funded it. Mongala's was on August 25–28, 2016, and PSI, with Global Fund funding, implemented it. Baseline assessments took place on October 19–24, 2016, in Sud Ubangi and October 27–31, 2016, for Mongala. The 12-month data collection was carried out August 12–17, and August 22–27, 2017, respectively. The 24-month data collection took place May 18–26, 2018, in Sud Ubangi and May 21–27, 2018, in Mongala. The final survey took place March 11–18, 2019, in Sud Ubangi and March 14–20, 2019, in Mongala. The earlier dates for the last two surveys were chosen to avoid the heavy rains and also considered the pending close-out of the VectorWorks project.

5.4 Field work

An implementation team of nine individuals was established, per site, for each of the survey rounds; including one overall site coordinator and two field teams, each with one supervisor and three interviewers. Staff of the Kinshasa School of Public Health oversaw the activities in the field, in cooperation with the NMCP staff. 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 three-day refresher training was held, which included the following components:

- understanding the study design and sampling procedures
- taking a general approach to ethics of field work (consent and interview)
- studying (detailed) an interview with role play
- introducing and practicing using the data entry device
- labeling the campaign cohort nets
- physically assessing holes and repairs in nets with practical exercises
- collecting sample campaign nets for bio-assays and issuing replacement nets.

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

5.5 Data management

Tablet PCs (Samsung Galaxy Tab 4) were used for data collection, which had the data collection software, Open Data Kit (ODK), a free and open-source mobile data collection tool [10] installed. Each field team received a tablet for the household interviews and LLIN 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 site coordinator until it could be transferred. Data were then checked and verified before it were deleted from the tablets, and any inconsistencies were 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 (only baseline and m36 surveys)
- campaign (cohort) LLIN 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 completed, datasets were transferred to Stata version 14.0 (Stata, Texas, USA) for further aggregation, consistency checks, and preparation for analysis. Stata do-files (macros) were created for partners to repeat the steps on their own copy of the data set.

For continuous variables, arithmetic means were used to describe the central tendency and t-tests were used to compare 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. In addition to descriptive univariable analysis, multi-variable analysis was performed to assess determinants of physical durability. For this purpose, linear and logistic regression models were used, where applicable.

Overall, household attitudes toward nets and care and repair were measured using a set of Likert score questions—a statement is read to the respondent and the level of agreement is 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: 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 and 36-month data sets using the basic household assets and a principal component analysis with the first component were used as the index. Households were then grouped into tertiles. At the 12- and 24-month surveys, no specific household or member data were collected.

The primary outcome measure was the physical net survival and was defined as—The proportion of nets received from the LLIN distribution, and 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:

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

To calculate this outcome, two interim outcomes will be calculated as follows:

Net attrition rate due to wear and tear: The proportion of originally received nets that have been lost due 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 outcomes are not considered.

Net integrity: Will be measured first by the proportionate Hole Index (pHI), as recommended by WHO **[Error! Reference source not found.]**. Holes in the LLIN of the cohort will be counted and 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:

pHI= # size 1 holes + (# size 2 holes x 23) + (# size 3 holes x 196) + (# size 4 holes x 576)

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

Good: total hole surface area <0.01 + 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 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 the defined median survival and the median survival 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, the median net survival was calculated; beginning at the last two time points, the lowest is 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 the first and second time point, respectively, in a percentage. Confidence intervals for this estimate were calculated by projecting the 95% CI from the survival estimates, as described above.

Finally, data were set up for a survival analysis to estimate median survival and determinant of outcome based on a Cox proportionate hazard model.

The secondary outcomes of insecticidal effectiveness were based on the bio-assay results using the standard WHO cone test tests for the 12- and 24-month samples, which were done at the Kinshasa National Institute for Biomedical Research. Those for the 36-month samples were done at the Centre for Entomological Research in Cotonou, Benin. A pyrethroid-susceptible strain of *Anopheles gambiae s.l.* was used, with 10 mosquitoes per cone, five sites tested on each net (four sides and roof), and two replicates per location (10 cone tests with 100 mosquitoes per net). Recorded were 60-minute knockdown and 24-hour mortality. The two variables from these tests—60-minute knockdown 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.: 7184) and the Ethics Committee of The School of Public Health, University of Kinshasa, DRC (ESP/CE/059/2016).

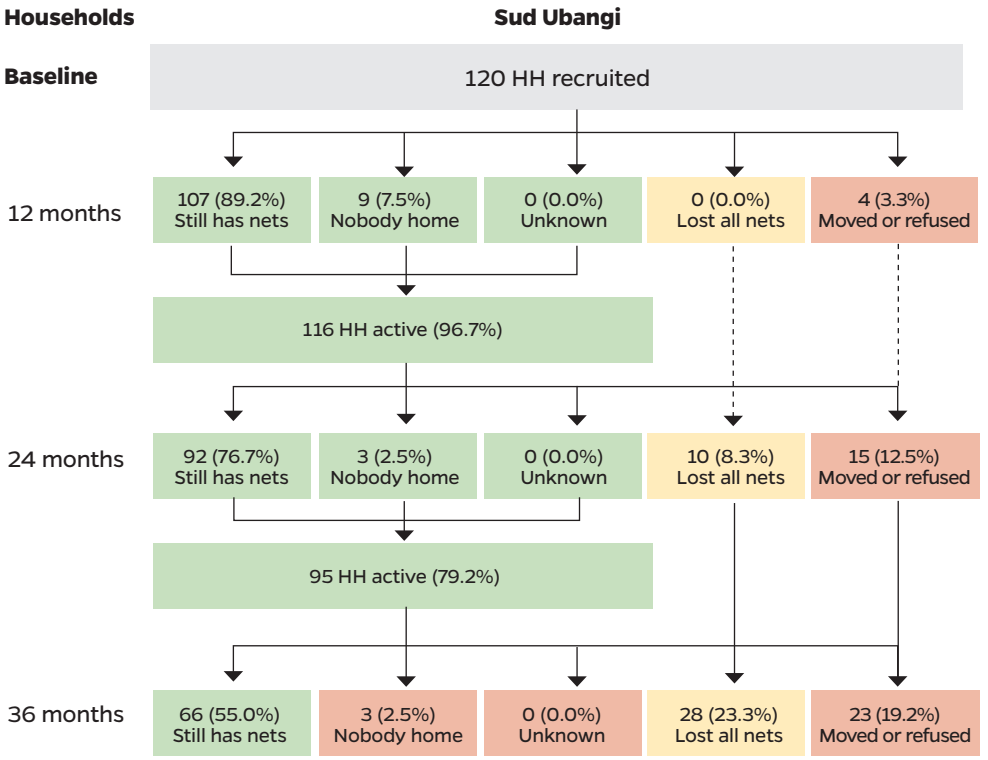
6 Results

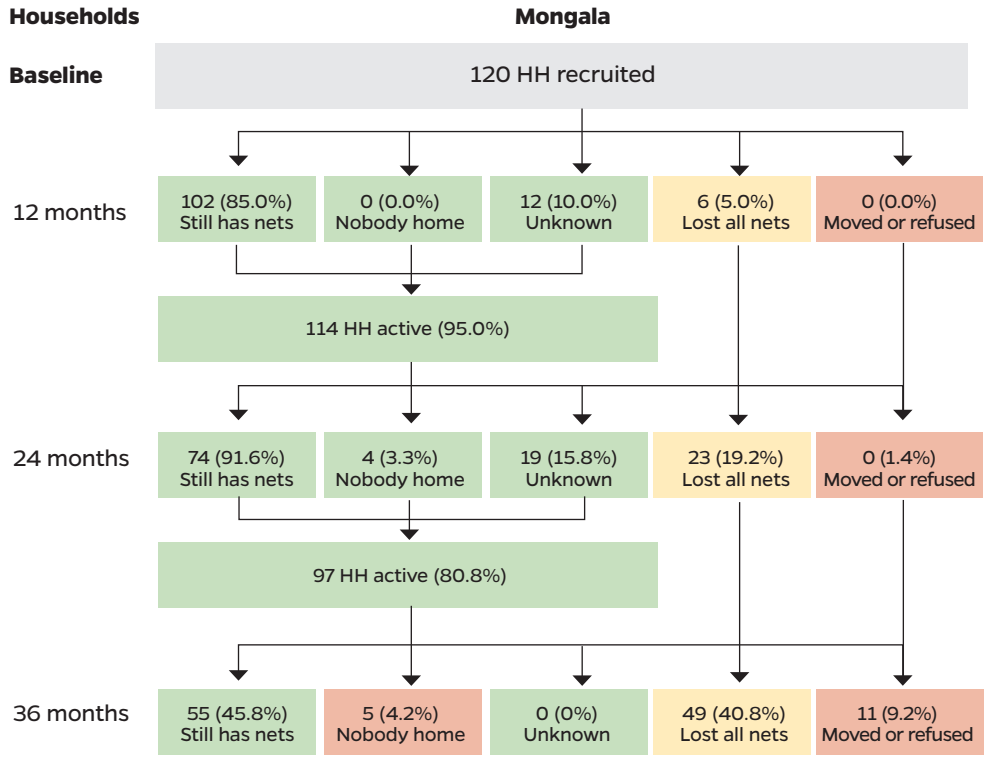
6.1 Sample

Out of the targeted 300 households from 30 clusters, a total of 240 from 24 clusters were recruited (80%), while the total number of campaign nets labeled for follow up was 754 or 109% of target. The lower number of households and clusters was due to a higher than expected number of campaign nets found in the households—the average household size was significantly above the assumed five persons. Therefore, the barcodes to label the cohort nets were not enough to cover 15 clusters per site; three clusters in each site were dropped. Figure 2 is 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 additional follow up was not needed. After three years, this applied to 23% of the 120 recruited households in Sud Ubangi and 41% of the 120 recruited households in Mongala. The second reason for loss to follow up was households moving to other communities. This was most common in Sud Ubangi and applied to 17% of the households at the end of the study; migration was lower in Mongala (9%). There was also some within-village migration (i.e., households shifted to new homes within the village: 5% in Sud Ubangi and 7.5% in Mongala). 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 these were rare: none in Mongala and only 2.5% in Sud Ubangi.

Overall, the follow up was quite good in Sud Ubangi, with 66% of the recruited households available at all four surveys. Due to the frequent absence of households in Mongala, only 57% of recruited households were included in all four surveys. However, 67% of the households in Mongala were seen at least at the baseline and 36-month surveys, compared to 70% in Sud Ubangi.

Figure 2: Cumulative follow-up status after 36 months of households recruited at baseline





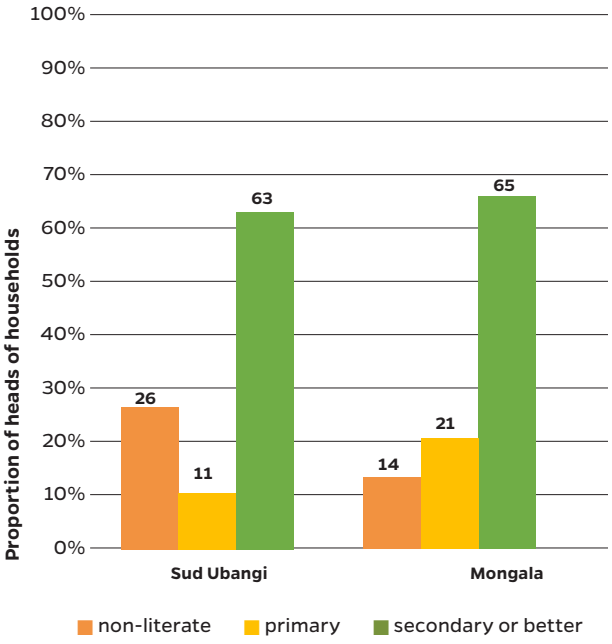
6.2 Socio-Demographic characteristics

Comparing those households that participated in the baseline and 36-month surveys (N=165), the data was explored for any demographic or socio-economic changes during the three years of the study.

The average number of household members decreased slightly in Sud Ubangi (from 7.6 to 7.0) and Mongala (6.8 to 5.7) and, overall, the decline was statistically significant (p=0.008). The proportion of households headed by females fluctuated in a non-significant manner and was 11% in Sud Ubangi and 7% in Mongala. The mean age was 44 years in Sud Ubangi and 43 years in Mongala. In both sites, the mean age of female heads of household was between one to two years older than that of the male heads of household. Population structure, measured by the proportion of children less than five years of age, also did not change over time, but it was slightly higher in Sud Ubangi, with 22% compared to 17% in Mongala (p=0.04).

The educational status of the head of household did not change over time and it was very similar between the two sites, with a high proportion (>60%) of at least some secondary education (Figure 2a). The educational level of female heads of household was significantly lower than that for males, with 65% non-literate, 15% primary, and 20% secondary education, (p<0.0001); however, the numbers were too small (n=20) to have separate estimates for each site.

Figure 2a: Educational status of heads of household by gender and site

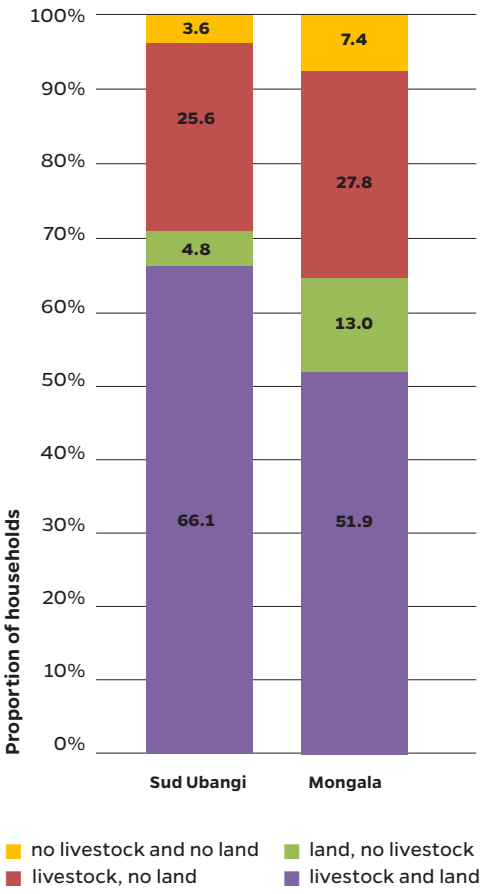


For socio-economic indicators, there was no evidence that the situation had changed in the three years of the durability monitoring for those households that were included in the baseline and 36-month surveys. Both sites were very similar, with a slightly better socio-economic situation in Mongala. Household assets were very limited and comprised mainly radios (42% in Sud Ubangi and 54% in Mongala, p=0.2), a few televisions (0.6% and 7.4%, p=0.007), and mobile phones (8% and 22%, p=0.03). The latter being generally limited by very poor provider coverage that was, however, somewhat better in Mongala. Means of transport were limited to bicycles (44% in Sud Ubangi and 48% in Mongala, p=0.7), a few motorbikes (10% and 17%, p=0.3), and boats (3% and 1%, p=0.4).

House characteristics were very basic, but similar in both sites. Most roofs were grass or thatch (85% in Sud Ubangi and 79% in Mongala, p=0.6), walls were made from mud (95% and 81%, p=0.2), and floors from sand or clay (98% and 87%, p=0.003). Fuel for cooking was almost exclusively firewood in both sites (97%). Most households used surface water from rivers and creeks (100% in Sud Ubangi and 82% in Mongala, p=0.07); and 99% of households in both sites had access to simple pit latrines.

The economic situation is summarized in Figure 2b and shows only minor differences between sites, which were not statistically significant. Only 4% of households in Sud Ubangi and 7% in Mongala did not have either land to farm or livestock, while the majority (66% in Sud Ubangi and 52% in Mongala) had both. Livestock consisted mainly of chickens (82% in Sud Ubangi and 77% in Mongala) with similar proportions also owning ducks (23% and 19%), goats (37% and 24%), or pigs (21% and 15%). Only two households in Sud Ubangi owned cows.

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



6.3 Determinants of Durability

Factors that have previously been shown to be associated with LLIN durability were explored. These can be divided into environmental factors: LLIN handling, type of sleeping place, and knowledge and attitude toward LLINs and their care and repair. Factors immediately involving the sleeping place environment are shown in Table 2 and Figure 3. Overall, the situation remained similar throughout the three years. Most of the fluctuations were due to the changing sample size because a direct comparison of only households present for all surveys did not show any significant trends for most of the indicators.

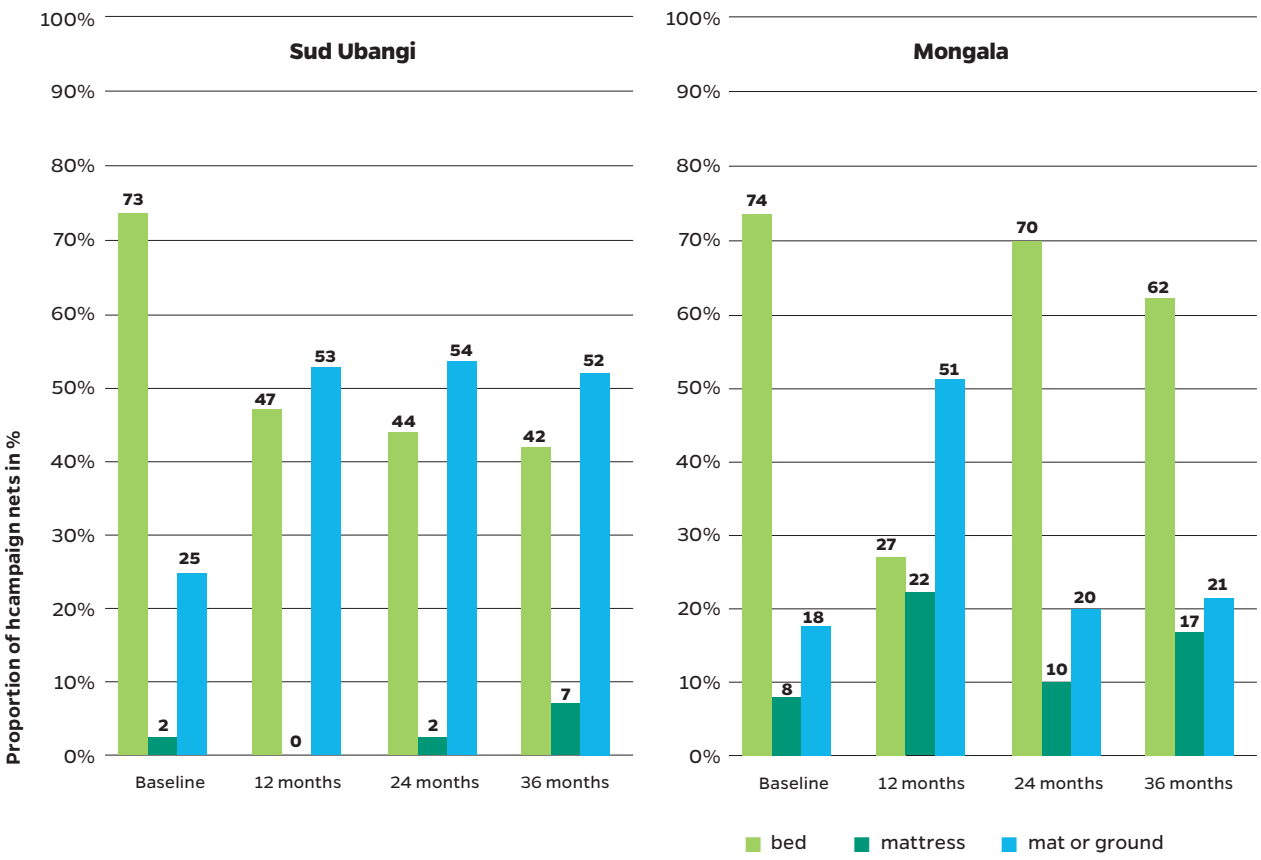
The perceived presence of rodents was generally very high and slightly higher in Mongala. Storing food in the sleeping room is thought to attract rodents, which increases the potential damage of nets by rodents. This practice was reported by approximately half the households in both sites. Cooking in the same room where nets are hanging can potentially cause a fire, especially if the cooking fuel is firewood, as was typical at both sites. This practice was more common in Sud Ubangi where around 15% said they always used firewood and the same proportion at least sometimes. In Mongala, these proportions were 0% and 16–20%, respectively (p=0.03).

The type of sleeping place over which the nets were used was mainly bedframes in Mongala (Figure 3) and 40% were finished bedframes. In contrast, reed mats and simple bed frames were similarly common in Sud Ubangi.

Table 2: Household risk factors

Variable and site	Baseline	12 months	24 months	36 months
Sud Ubangi	**N=120**	**N=107**	**N=102**	**N=84**
Ever store food in sleeping room	34.2%	54.2%	41.2%	58.3%
Cook in sleeping room				
· never	74.2%	53.3%	72.6%	52.4%
· sometimes	13.3%	19.6%	13.7%	28.6%
· always	12.5%	27.1%	13.7%	19.1%
Rodents observed (last 6 m)	85.8%	87.9%	81.4%	84.5%
Mongala	**N=120**	**N=108**	**N=91**	**N=81**
Ever store food in sleeping room	39.2%	58.3%	38.5%	40.7%
Cook in sleeping room				
· never	79.2%	82.4%	82.4%	80.6%
· sometimes	20.8%	16.7%	17.6%	19.8%
· always	0%	1.0%	0%	0%
Rodents observed (last 6 m)	93.3%	90.7%	94.5%	92.6%

Figure 3: Main type of sleeping place for campaign LLINs found hanging (for denominator, see Table 7)



See Table 3 for the durability risk factors associated with LLIN handling. Throughout the study period, almost all nets were found hanging loose over the sleeping place during the day—if they were hanging—exposing them to an increased risk of damage. This was the case in both sites. In contrast, the risk of damaging nets by drying them over bushes or fences was low, with less than 5% of washed nets in Sud Ubangi, and varying between 2% and 25% of washed nets in Mongala. But, there was a major difference between sites: consistently throughout the study, nets in Sud Ubangi were predominantly dried inside (85%), while in Mongala about 90% were always dried outside with slightly higher drying on bushes during the drier season (baseline and 36-month survey) and more on lines during the rainy season.

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

Variable and site	Baseline	12 months	24 months	36 months
Sud Ubangi				
Hanging nets NOT folded or tied	95.6%	100%	100%	100%
Net dried on fence or bush	0%	3.1%	4.8%	0.9%
Net ever washed	7.2%	71.0%	82.6%	96.7%
Median washed last 6 m (IQR)	1.0 (1.0–2.0)	2.0 (1.0–3.0)	2.0 (1.0–2.0)	2.0 (2.0–3.0)
Used detergent/bleach for wash	14.8%	21.4%	21.8%	5.2%
Mongala				
Hanging nets NOT folded or tied	99.0%	92.4%	100%	100%
Net dried on fence or bush	18.8%	5.3%	2.4%	25.8%
Net ever washed	4.2%	50.2%	75.5%	87.3%
Median washed last 6 m (IQR)	1.0 (1.0-1.0)	2.0 (1.0–3.0)	3.0 (2.0–3.0)	2.0 (1.0–3.0)
Used detergent/bleach for wash	0%	22.6%	43.3%	17.7%

As expected, the proportion of cohort LLINs ever washed started out low and increased over time, reaching 71% in Sud Ubangi and 50% in Mongala after 12 months, increasing to 97% and 87%, respectively, at the final survey. However, the difference between the sites was not statistically or programmatically significant. The washing frequency showed little variation; it was about two washes every six months at both sites and 12 washes, on average, during the three years. The proportion of households reporting washes with a detergent was generally low: 20% or less in Sud Ubangi and between 20% and 43% in Mongala.

Table 4: Exposure to messages on nets in the last six months (n.a. = not applicable due to small sample)

Variable and site	Baseline	12 months	24 months	36 months
Sud Ubangi				
Any exposure last 6m	64.2%	46.7%	7.8%	10.7%
Mean info sources (if exposed)	3.3 (1.9–4.6)	1.5 (1.2–1.7)	1.0 (1.0–1.0)	n.a.
Type of media · media only · both · IPC only	 0% 2.6% 97.4%	 0% 0% 100%	 0% 0% 100%	n.a.
Mongala				
Any exposure last 6m	64.2%	49.1%	13.2%	1.2%
Mean info sources (if exposed)	1.4 (1.2–1.6)	1.6 (1.3–2.0)	1.4 (1.1–	n.a.
Type of media · media only · both · IPC only	 32.9% 17.1% 50.0%	 1.9% 17.3% 80.8%	 0% 16.7% 83.3%	n.a.

See Tables 5 and 6 for the exposure to LLIN-related messages, message recall, and the resulting household attitude toward care and repair. In Sud Ubangi, as well as Mongala, the highest exposure to net-related messages was at baseline, just two months after the campaign. Exposure then dramatically declined at both sites, suggesting there was very little ongoing behavior change communication activity. Messages in Sud Ubangi were exclusively transmitted through interpersonal communication, mainly through community health workers (86%), faith-based organizations (40%), and health workers at facilities (36%). In Mongala, some exposure was also through media (17%), mainly radio. Interpersonal communication was also conducted through community health workers and health facilities, but faith-based organizations did not play a role.

Looking at the actual recall of messages and household care and repair attitudes calculated from a series of questions (Table 5) reflects the low exposure rates and shows that messages about "repair" are recalled consistently less than any other. Net care and repair attitude was, however, surprisingly high in Sud Ubangi and even increased over time—from 51% of households with a very positive attitude score at baseline to over 80% in the last two surveys. In contrast, the net care and repair attitude in Mongala was always lower than in Sud Ubangi (p=0.0001) and it never exceeded 48%. This is one of the most significant differences between the two sites; it is further emphasized by the finding that among households that were seen at all four surveys, 96% in Sud Ubangi had a score above 1.0 (very positive attitude) at least once, while Mongala's rate was only 78% (p=0.006).

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
Sud Ubangi				
Recalled "use net (every) night"	64.2%	41.2%	5.9%	9.5%
Recalled "nets prevent malaria"	64.2%	29.9%	1.0%	1.2%
Recalled "care for net"	64.2%	43.9%	5.9%	7.1%
Recalled "repair net"	56.7%	33.6%	3.9%	4.8%
Attitude score nets · mean · %with score >1 (95% CI)	 1.1 (0.9–1.3) 50.8%	 1.2 (1.0–1.3) 69.2%	 1.2 (1.1–1.4) 85.3%	 1.3 (1.2–1.4) 89.3%
Mongala				
Recalled "use net (every) night"	35.0%	35.2%	11.0%	1.2%
Recalled "nets prevent malaria"	23.3%	9.3%	3.3%	0%
Recalled "care for net"	20.8%	28.7%	6.6%	1.2%
Recalled "repair net"	0.8%	1.9%	2.2%	0%
Attitude score nets · mean (95% CI) · % with score > 1.0	 0.7 (0.5–0.8) 17.5%	 0.7 (0.5–0.9) 27.8%	 0.9 (0.8–1.1) 48.4%	 1.0 (0.9–1.1) 45.7%

The final step was to look at the actual experiences with holes and their repair. As expected, with increasing time since distribution, the proportion of households experiencing any holes in their campaign LLINs increased over time, reaching 94% in Sud Ubangi and 80% in Mongala. Actual repairs remained low, even with increasing damage. But, surprisingly, they were more common in Mongala, with around 30% of damaged nets showing any repair compared to Sud Ubangi with a maximum of only 16% (p=0.002), suggesting this behavior did not necessarily result from the net care and repair attitude. It must be remembered, however, that repairing holes is only one aspect of net care—preventive behaviors are at least equally, if not more, important.

The dominant way to repair holes in Mongala was stitching, with 88% of LLINs reported as repaired, compared to 22% by knotting (some nets received both methods of repair). In Sud Ubangi it was 55% and 59%, respectively. Patching was not used in either site and repairs were exclusively done by family members, relatives, or friends. Households with hole experience who said they had never repaired holes were asked why they did not repair the net. Among those that replied, 27% said they did not know how or lacked materials for repair, 20% stated they had no time, and 19% felt it was not necessary or possible to repair, with no difference between sites. Interestingly, owners modified a small amount of the campaign nets (8 in Sud Ubangi and 16 in Mongala, p=0.003) and this was mainly changing the shape into a conical design.

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

Variable and site	Baseline	12 months	24 months	36 months
Sud Ubangi				
Ever experienced holes in net	19.2%	82.2%	91.2%	94.1%
Ever discussed care and repair	58.3%	57.0%	60.8%	51.2%
Ever repaired (if had holes)	0%	8.0%	22.6%	22.8%
Damaged campaign nets repaired (observed)	n.a.	4.2%	8.2%	15.8%
Mongala				
Ever experienced holes in net	35.8%	72.2%	80.2%	77.8%
Ever discussed care and repair	46.7%	52.8%	38.5%	40.7%
Ever repaired (if had holes)	16.7%	15.4%	26.0%	30.2%
Damaged campaign nets repaired (observed)	n.a.	17.9%	31.9%	29.1%

6.4 Net Use and Ownership

This section looks at the use and ownership of the campaign LLINs, 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.

Already at baseline—two months after distribution—the proportion of campaign nets found hanging was significantly higher in Sud Ubangi than in Mongala (p=0.004). The proportion hanging steadily increased during the study, but the difference between the sites remained with 84% and 69%, respectively, found hanging at the last survey (p=0.03).

Table 7: Hanging and use of campaign nets from cohort

Variable and site	Baseline	12 months	24 months	36 months
Sud Ubangi	N=377	N=269	N=184	N=122
Hanging	54.4%	78.1%	82.1%	84.4%
Taken down or stored	2.9%	8.2%	15.7%	14.8%
Still in package	42.7%	13.8%	2.1%	0.8%
Used last night	53.6%	74.4%	80.4%	82.0%
Used every night (last week)	53.3%	71.4%	80.4%	41.2%
Mongala	N=377	N=231	N=106	N=71
Hanging	26.0%	45.5%	68.9%	69.0%
Taken down or stored	3.2%	21.6%	14.2%	26.8%
Still in package	70.8%	32.9%	17.0%	4.2%
Used last night	25.5%	45.9%	67.0%	69.6%
Used every night (last week)	25.5%	45.9%	63.2%	29.1%

While only one campaign net was found still in the package during the final survey in Sud Ubangi (1% of nets still there), three (4%) were found in Mongala. Also, a significant number of campaign nets were taken down or stored—more nets were found in Mongala than in Sud Ubangi. Generally, if a net was hanging, it was also being used and this was mostly true for regular use the previous week. The only exception was the last survey, which reported use every day of the past week, and was lower than in previous survey rounds. Because this did not apply to the other nets in the household (see below), it is probably because of the poor condition of these nets and not general unwillingness to use nets.

See Table 8 for the hanging and use of the non-cohort nets found during each survey; interpret Table 8 with the nets availability shown in Table 9 and Figure 3a. From the beginning, and throughout the study, households owned many other nets and new ones kept coming in. The proportion of households with any other nets increased, over time: in Sud Ubangi, from 23% to 64%. At the end, approximately one-third of nets owned were from sources other than the 2016 campaign. In Mongala, the proportion of households owning any other nets fluctuated around 40%, but the proportion of these nets among all nets owned was always higher than

in Sud Ubangi, reaching 44% at the last survey (Figure 3a). In line with this development, we see high hanging and use of the non-cohort nets at baseline (>80%) when the campaign nets were still in the package, then a sharp drop to 50–60% of non-cohort LLIN hanging at 12 months when the campaign net use increased. Then, higher rates of use returned for non-cohort LLINs (>80%) during the final survey when the campaign nets were old and many were torn and newer nets were preferred. Seasonal variation was not seen in net use; at both sites, >85% of respondents said they used the nets equally during the rainy and the "dry" season.

Table 8: Hanging and use of non-cohort nets

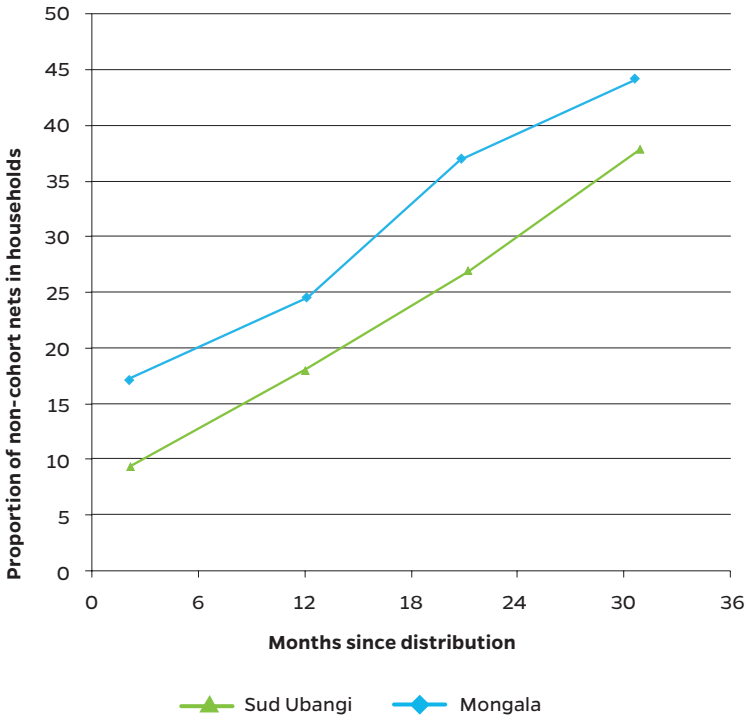
Variable and site	Baseline	12 months	24 months	36 months
Sud Ubangi	N=39	N=59	N=79	N=92
Hanging	82.1%	52.5%	68.4%	81.5%
Taken down or stored	2.6%	6.8%	2.6%	5.4%
Still in package	15.4%	39.0%	26.9%	13.0%
Used last night	76.9%	52.5%	68.0%	77.2%
Used every night (last week)	76.9%	52.5%	68.4%	70.7%
Mongala	N=78	N=75	N=71	N=68
Hanging	80.8%	62.7%	77.5%	80.9%
Taken down or stored	0%	6.7%	4.3%	11.8%
Still in package	2.6%	16.0%	8.6%	7.4%
Used last night	79.5%	62.7%	76.1%	77.9%
Used every night (last week)	79.5%	61.3%	69.0%	75.0%

The source of nets shows a similar dynamic: at 12 months, a significant part of non-cohort nets were from friends and family (44% Sud Ubangi and 29% Mongala), and these were most likely campaign nets not needed by other households. Nets from the private sector played a minor role in Sud Ubangi, although the relative contribution of this source increased over time. They played a more significant role in Mongala where, at the end of the study, 41% of the non-cohort nets were reported to be from the private sector. In both sites, the majority of nets from the private sector were identified as an LLIN (88% in Sud Ubangi and 75% in Mongala, p=0.3). Most common brands from the private sector were DuraNet (45%); Permanet (36%) and Dawa Plus (14%) in Sud Ubangi; and Permanet (35%), Dawa Plus (31%), and DuraNet (25%) in Mongala.

Table 9: Ownership of non-campaign nets and source of these nets

Variable and site	Baseline	12 months	24 months	36 months
Sud Ubangi				
Household has any other nets	22.5%	41.1%	50.0%	64.2%
Source public sector	87.2%	49.2%	55.1%	60.8%
Source ANC/HF	20.5%	47.5%	35.9%	25.0%
Source private sector	2.6%	3.4%	11.5%	14.1%
Source family or friends	10.3%	44.1%	19.2%	25.0%
Mongala				
Household has any other nets	39.2%	42.9%	38.5%	45.4%
Source public sector	74.4%	52.0%	66.1%	48.5%
Source ANC/HF	19.2%	30.6%	19.7%	16.1%
Source private sector	20.5%	13.3%	14.5%	41.2%
Source family or friends	5.1%	29.3%	12.7%	10.3%

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



Because households that had lost all their cohort nets were dropped from the monitoring and both sites received additional free nets through routine distribution, it is not surprising that between 96% (Sud Ubangi) and 81% (Mongala) of households still owned any ITN at the final survey. The proportion of households with enough nets for all household members (one LLIN for every two people) dropped significantly. It was only 30% at the final survey at both sites, down from a baseline value of 52% in Sud Ubangi and 67% in Mongala. Population access to an ITN within the household showed similar trends; it was down to 68% in Sud Ubangi from 81% at baseline and 53% in Mongala, down from a baseline 89%. It must be kept in mind, however, that this survey monitored LLIN durability and is not representative of post-campaign LLIN ownership coverage, which this survey will over-estimate.

The use pattern of cohort LLINs, as well as non-cohort nets, did not change dramatically over time, as shown in Tables 10 and 11. Use patterns were similar at both sites, with the largest proportion of nets used by adults only. No significant differences in use patterns were observed between the cohort and non-cohort nets.

Table 10: Net users of campaign cohort nets if net used

Variable and site	Baseline	12 months	24 months	36 months
Sud Ubangi	N=202	N=200	N=148	N=100
Children only*	7.4%	8.0%	8.1%	7.0%
Children + adults**	59.4%	55.0%	50.7%	51.0%
Adults only**	33.2%	37.0%	41.2%	42.0%
Mongala	N=102	N=106	N=71	N=48
Children only*	10.8%	15.1%	9.9%	16.7%
Children + adults**	32.4%	57.61%	54.9%	54.2%
Adults only**	56.9%	27.4%	35.2%	29.2%

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

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

Variable and site	Baseline	12 months	24 months	36 months
Sud Ubangi	N=30	N=31	N=53	N=71
Children only*	16.7%	12.9%	1.9%	12.7%
Children + adults**	50.0%	54.9%	69.8%	53.5%
Adults only**	33.3%	32.3%	28.3%	33.8%
Mongala	N=65	N=47	N=54	N=53
Children only*	15.4%	4.3%	9.3%	5.7%
Children + adults**	23.1%	55.3%	55.6%	50.9%
Adults only**	61.5%	40.4%	35.2%	43.3%

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

6.5 Durability of campaign LLINs

See Figures 4 and 5 for the status of the campaign LLINs for the durability cohort after the final survey. Of the 377 LLINs labeled in Sud Ubangi, a definite outcome for the durability measurement could be established for 254 (67%). Namely, 122 (32%) were found to be present, 73 (19%) were discarded, 51 (14%) given away, and 8 (2%) were lost. Among those with unknown outcome were 30 (9%) LLINs, the status was unknown because the household could not be interviewed during the survey or the respondent could not recall what happened to the net—62 (16%) were taken when the family moved, and 29 (8%) nets were used by families elsewhere (their status was also unknown).

In Mongala, 308 of the 377 (82%) labeled campaign nets had a definite outcome. But, only 71 (19%) were still present after 33 months and the highest proportion were discarded—with 142 (38%) followed by 43 (11%) given away, and 24 (6%) definitely lost. Among cohort nets with unknown outcome, those whose whereabouts could not be recalled were most frequent (14%), followed by moving away (7%), and using the net elsewhere (4%).

Figure 4: Status of cohort LLIN recruited at baseline in Sud Ubangi province

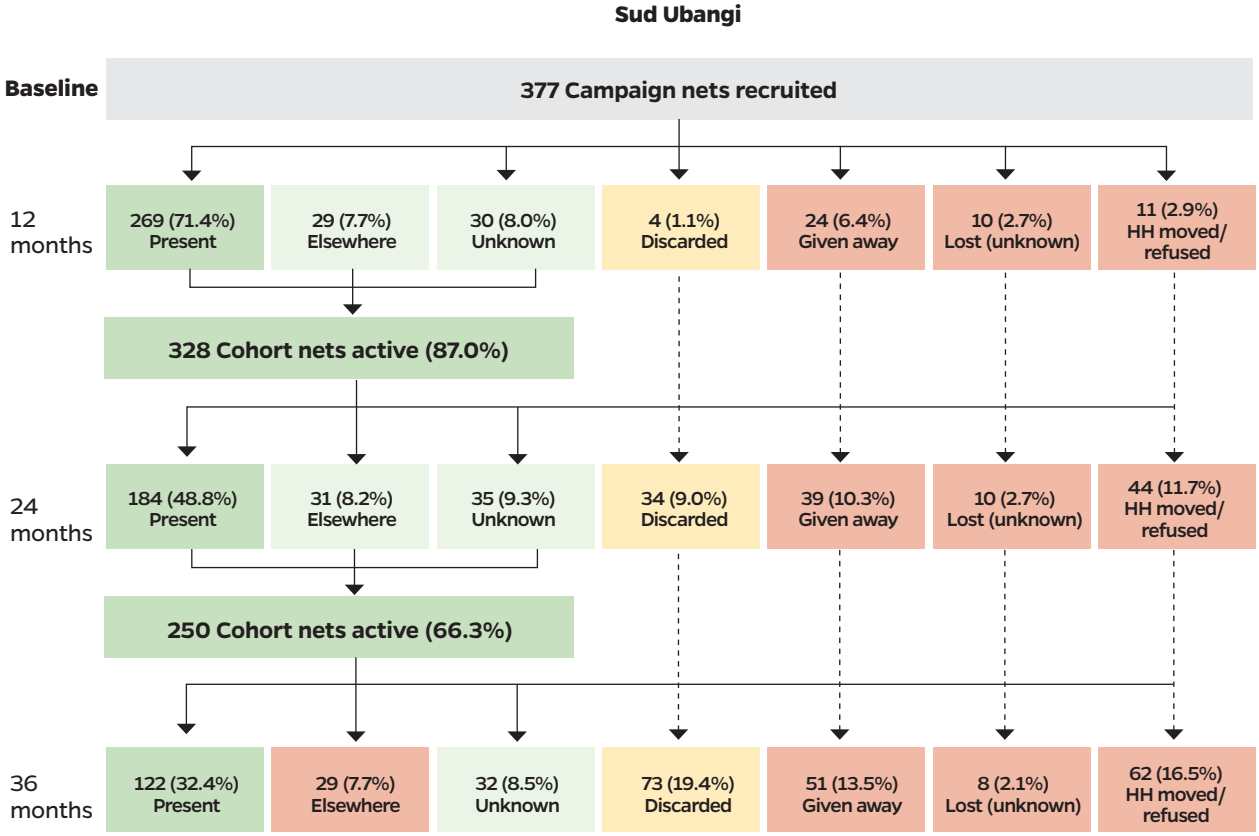
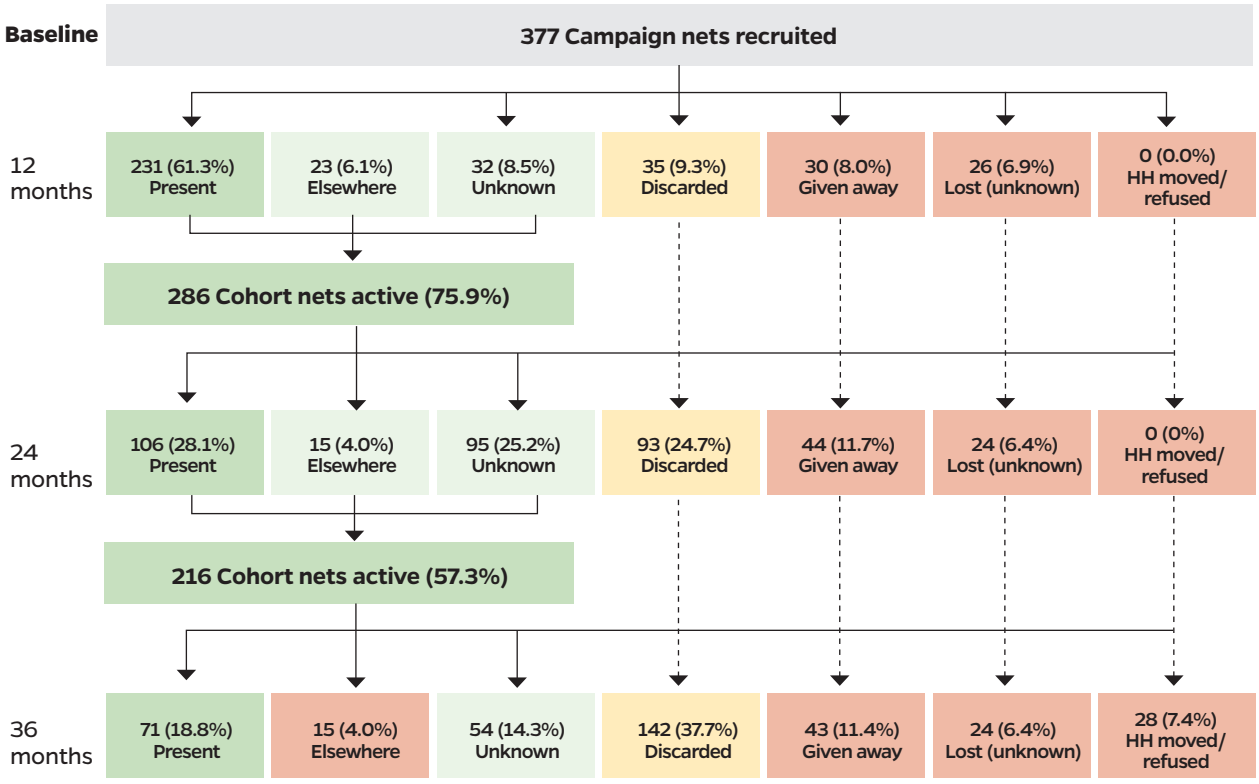


Figure 5: Status of cohort LLIN recruited at baseline in Mongala province

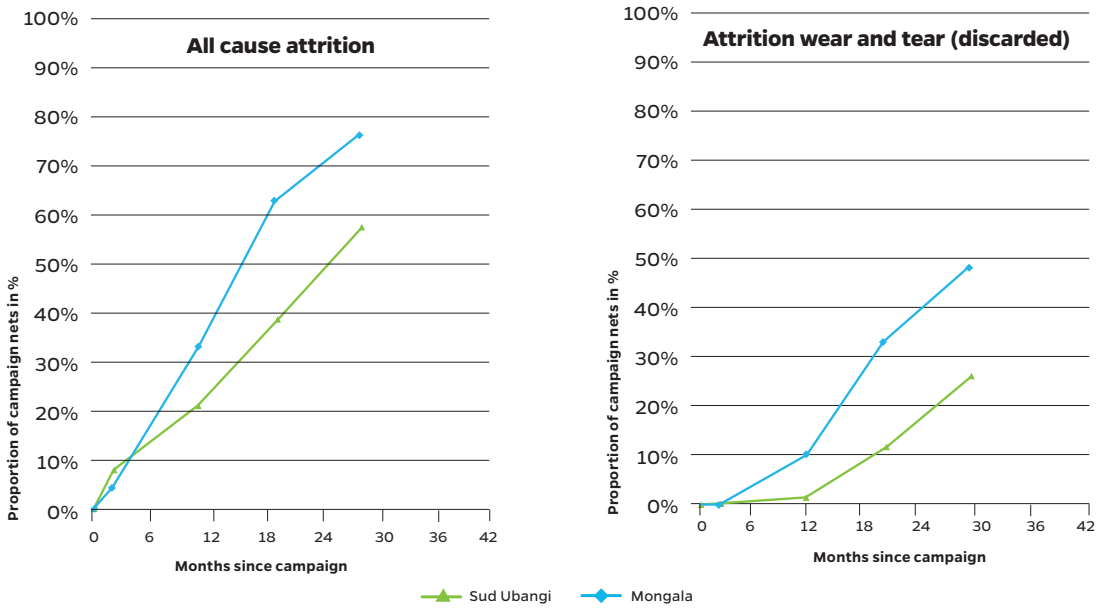


See Table 12 for the resulting all-cause attrition rates and losses due to wear and tear since the campaign, including LLINs that were reported to have been lost between the 2016 campaign and the baseline survey. These include only those nets with a definitive outcome. The highest all-cause attrition was seen in Mongala, with 76% compared to 57% in Sud Ubangi (p=0.005). The proportion of losses due to wear and tear among all-cause attrition increased gradually and, at the final survey, these losses comprised 45% in Sud Ubangi, but 63% in Mongala. This resulted in an attrition rate due to wear and tear in Mongala of 48%, almost as high as the all-cause attrition rate in Sud Ubangi, where the attrition caused by discarding was 26% (p=0.0009).

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

Variable	Campaign – Baseline	Campaign – 12 months	Campaign – 24 months	Campaign – 36 months
Sud Ubangi	N=409	N=340	N=299	N=286
Given away	7.6%	16.2%	23.4%	28.7%
Discarded (wear & tear)	0.2%	1.5%	11.7%	25.9%
Unknown*	0.0%	3.2%	3.3%	2.8%
Total	**7.8%**	**20.9%**	**38.5%**	**57.3%**
Mongala	N=394	N=345	N=284	N=297
Given away	4.3%	13.6%	21.5%	20.2%
Discarded (wear & tear)	0.0%	10.1%	32.8%	47.8%
Unknown*	0.0%	9.3%	8.5%	8.1%
Total	**4.3%**	**33.0%**	**62.7%**	**76.1%**

Figure 6: Trends in all cause attrition and wear and tear (discarded LLINs) as a function of time since distribution



The reasons for loss among the discarded nets differed slightly between the sites (p=0.018); more discarded nets (36%) were destroyed in Sud Ubangi or used for other purposes (10%) and the remainder (54%) were thrown away. In contrast, only 11% of discarded nets in Mongala were destroyed and 2% used for other purposes, while the bulk (87%) were thrown away. When calculated over all campaign nets with known outcome, the rate of alternative use was only 2% in Sud Ubangi and 1% in Mongala or 10 total nets. All seven in Sud Ubangi were used as window or door curtains, while two in Mongala were reportedly used for fishing and one to cover crops.

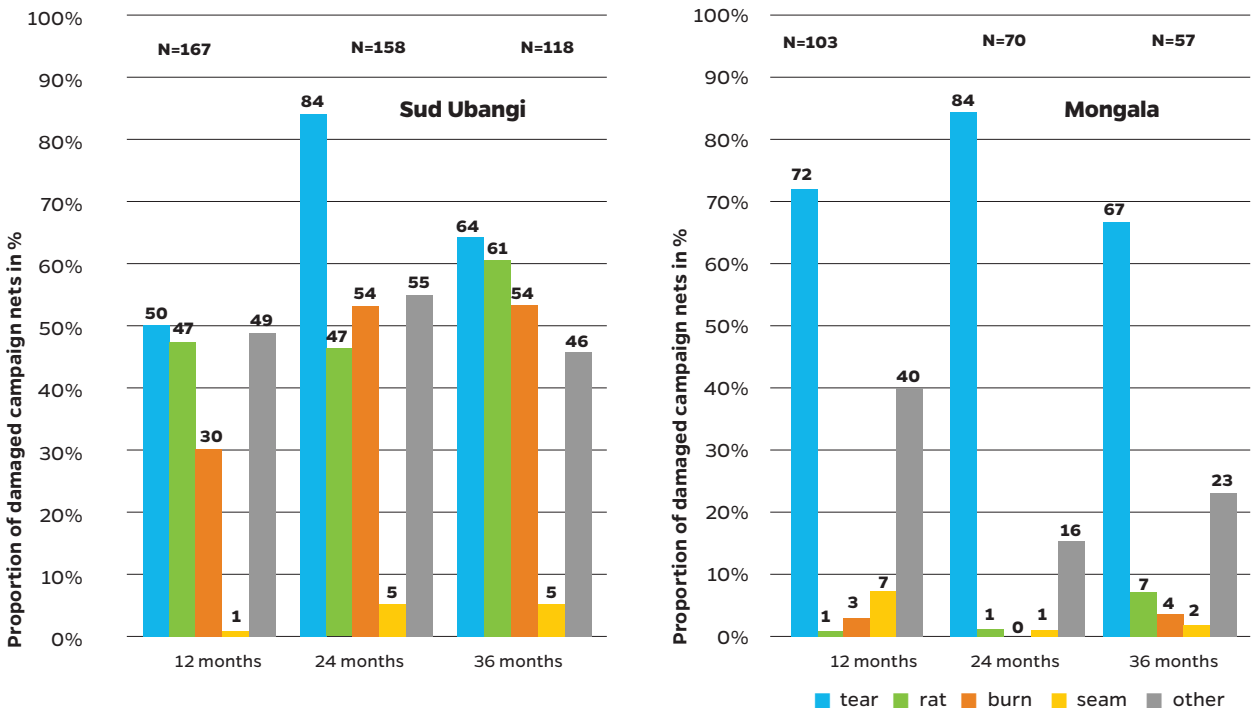
As expected, the proportion of LLINs still present in the surveyed households with any sign of damage initially increased rapidly, but then leveled off a bit, as older nets were increasingly discarded (Table 13). As mentioned earlier, the rate of nets with any damage was consistently higher in Sud Ubangi than in Mongala (p=0.01), which is consistent with the lower hanging and use rates there. However, the level of damage to the nets with any holes not yet discarded was significantly higher in Mongala at all times (p<0.0001). Nonetheless, the decline of the proportion of nets in serviceable condition was similar in both sites (p=0.1), caused by the higher discard rate in Mongala.

Table 13: Physical condition (integrity) of surviving cohort nets

Variable and site	Baseline	12 months	24 months	36 months
Sud Ubangi	N=377	N=269	N=184	N=122
Any holes	9.3%	61.3%	85.9%	93.4%
Median PHI (if any hole)	23	49	251	438
Good (pHI<64)	98.9%	72.9%	37.0%	23.0%
Too torn (pHI>642)	0%	9.7%	33.2%	41.0%
Serviceable (pHI≤642)	**100%**	**90.3%**	**66.9%**	**59.0%**
Mongala	N=377	N=231	N=106	N=71
Any holes	10.6%	45.9%	65.1%	77.5%
Median pHI (if any hole)	48	466	929	1184
Good (pHI<64)	96.3%	66.2%	46.2%	29.6%
Too torn (pHI>642)	1.1%	19.9%	37.7%	47.9%
Serviceable (pHI≤642)	**98.9%**	**80.1%**	**62.3%**	**52.1%**

(pHI=proportionate Hole Index)

Figure 7: Type of damage mechanisms reported for damaged campaign LLINs (multiple responses)



See Figure 8 for the type of damage mechanisms reported by the households for each campaign LLIN with any holes. The general damage pattern was dominated by mechanical damage and was similar within each site, but differed between the sites. In Sud Ubangi, high levels of rodent and burn damage were reported, but they were absent or minimal in Mongala. This is probably a difference in perception rather than actual damage mechanisms.

Overall, the physical survival of LLINs in serviceable condition after 30 months of follow up at the final survey (i.e., the combination of attrition due to wear and tear and the integrity of the still existing LLINs) was 37% in Sud Ubangi and only 17% in Mongala—this difference between the sites was statistically significantly different (p=0.003). When only those cohort LLINs that had been used at all (taken out of the package) were considered, the survival estimates were reduced only minimally by 3 or 4 percentage points in Sud Ubangi and Mongala, respectively, and the difference remained statistically significant.

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

Variable and site	Baseline	12 months	24 months	36 months
Sud Ubangi	N=377	N=274	N=219	N=196
Survival estimate	100%	88.7%	56.2%	36.7%
95% CI	-	84.8–91.7	45.7–66.1	29.4–44.7
Only nets ever used	N=340	N=237	N=251	N=172
Survival estimate	100%	86.9%	55.4%	33.2%
95% CI	-	82.4–90.4	45.3–65.1	26.4–42.0
Dawa Plus 2.0	N=377	N=266	N=199	N=213
Survival estimate	98.9%	69.6%	33.2%	17.4%
95% CI	96.7–99.7	59.5–78.1	23.5–44.4	10.7–26.9
Only nets ever used	N=301	N=190	N=181	N=167
Survival estimate	98.7%	57.4%	26.5%	13.2%
95% CI	96.1–99.6	49.1–65.3	18.9–35.9	7.9–21.1

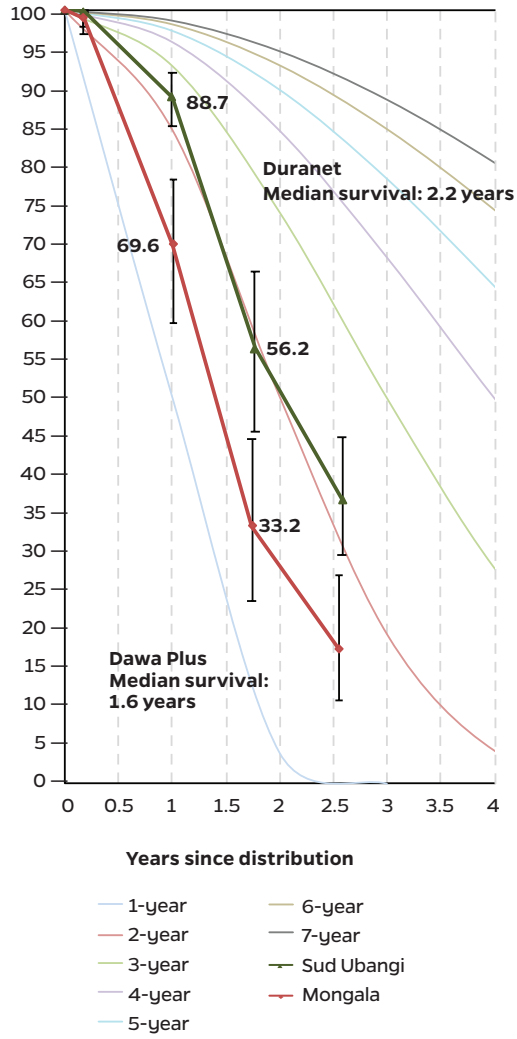
To standardize the analysis and facilitate comparisons with other durability data, the results were plotted against the hypothetical survival curves with defined median survival (Figure 9). The survival estimates roughly follow the hypothetical curves and the relationship between the two sites was the same throughout the follow up.

In addition to estimating the median survival at each time point from the graph[3], it was also calculated from the final two data points (see methods), and results are shown in Table 14a.

Calculated median survival was 1.6 years in Sud Ubangi (Dawa Plus 2.0 LLIN) and 2.2 years in Mongala (DuraNet LLIN). Estimates from the graph were very similar to the calculated ones at the final survey, but they also show that, in this setting, earlier estimates from the graph at 12 and 24 months were comparable to the final estimate. Considering the confidence intervals around the median survival, both sites performance of the tested LLIN was clearly below the three-year mark and, in Sud Ubangi, also below the two-year mark. This was confirmed by the survival analysis—the estimated median survival in Sud Ubangi at 2.6 years (95% CI 2.2-2.7) and 1.7 year for Mongala (95% CI 1.6-1.8).

The Cox proportionate hazard models showed that some determinants significantly contributed to explaining the outcome, but also confirmed that the difference of brands was the most important one (hazard ratio Dawa Plus to DuraNet 3.1, p<0.0001). Other factors with a positive explanatory power were a positive net care attitude (HR 0.68, p=0.02), using a finished bed frame or foam mattress as sleeping place (HR 0.59, p=<0.001), and marginal households being headed by a female (HR 0.62, p=0.09). A negative impact among cohort nets was found for those that had ever been reported as used by children only (HR 1.9, p= 0.001).

Figure 8: Estimated LLIN survival in serviceable condition with 95% confidence intervals (error bars) plotted against hypothetical survival curves with defined median survival.



[3]To calculate this figure, estimate the relative position of the data point on a horizontal line between the two adjacent median survival curves.

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

Variable	12 months	24 months	36 months
Sud Ubangi			
Esimated from Figure 9[1]	2.4	1.9%	2.2
Calculated from last two data points (95% CI)			2.2 (2.0-2.4)
Mongala			
Esimated from Figure 9	1.5	1.4	1.6
Calculated from last two data points (95% CI)			1.6 (1.3-1.9)

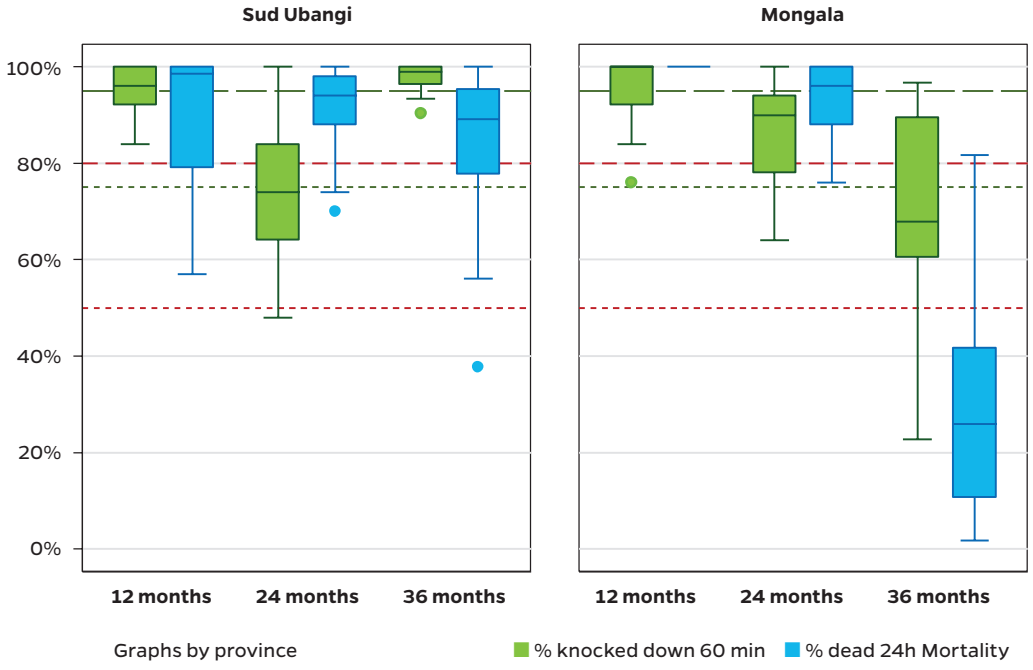
6.6 Insecticidal effectiveness of campaign LLINs

The target of sampling 30 campaign nets at each site with bio-assay testing was achieved at each of the survey points and results (see Table 15 and Figure 10). While the DuraNet LLIN brand maintained optimal performance throughout the three years of the study, the insecticidal effectiveness of the Dawa Plus 2.0 LLIN brand only maintained high performance up to the 24-month data point and then dropped considerably, with a median knockdown rate of 68% and median vector mortality of 26%. Only 10% of the samples showed optimal insecticidal performance, 47% minimal effectiveness, and 53% failed even the minimal criteria.

Table 15: Results from bio-assays

Variable	12 months	24 months	36 months
Sud Ubangi—DuraNet	**N=30**	**N=30**	**N=30**
Knock down 60 minutes · Mean (95% CI) · Median (IQR)	 95.6% (93.5–97.6) 96.0% (92.0–100)	 75.0% (67.3–82.7) 74.0% (64.0–84.0)	 97.8% (96.5–99.1) 99.0% (96.3–100)
Mortality 24 hours · Mean (95% CI) · Median (IQR)	 89.6% (82.9–96.3) 98.5% (79.0–100)	 92.2% (87.2–97.2) 94.0% (88.0–98.0)	 84.8% (77.7–2.0) 89.1% (77.7–5.4)
Optimal effectiveness · Estimate (95% CI)	83.3% (63.4–93.5)	86.7% (52.1–97.5)	100% (-.-)
Minimal effectiveness · Estimate (95% CI)	100% (-.-)	100% (-.-)	100% (-.-)
Mongala—Dawa Plus 2.0	**N=30**	**N=30**	**N=30**
Knock down 60 minutes · Mean (95% CI) · Median (IQR)	 95.5% (92.7–98.2) 100% (92.0–100)	 86.6% (81.1–92.0) 90.0% (78.0–94.0)	 69.9% (61.0–-8.8) 67.9% (60.5–9.5)
Mortality 24 hours · Mean (95% CI) · Median (IQR)	 100% (-.-) 100% (-.-)	 92.6% (88.8–96.4) 96.0% (88.0–100)	 28.5% (21.1–5.8) 25.9% (10.7–1.7)
Optimal effectiveness · Estimate (95% CI)	100% (-.-)	90.0% (72.3–96.9)	0.0% (2.9–28.9)
Minimal effectiveness · Estimate (95% CI)	100% (-.-)	100% (-.-)	46.7% (30.9–3.1)

Figure 9: Results from WHO cone bio-assays: the box plot shows the median (horizontal line), Inter-Quartile-Range (box), adjacent values[4] (whiskers) and outliers (circles); lines represent cut-offs for optimal and minimal insecticidal effectiveness



See Tables 16–18 for the details of the net handling and use of the nets sampled for the bio-assay. The results show that, overall, the final sample of nets taken from the cohort was not different from the previous samples taken from neighbor's houses. Hanging and use rates were slightly lower, but this was most likely because these nets were now torn; all had been washed, implying they had been used.

[4] Adjacent values: +/- 1.5 * Inter-Quartile-Range

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

Variable	12 months	24 months	36 months
Sud Ubangi	**N=30**	**N=30**	**N=30**
Location found			
· hanging loose	97%	97%	83%
· hanging folded/tied	3%	0%	7%
· not hanging	0%	3%	10%
Type of sleeping place			
· bed	53%	58%	43%
· mattress	3%	2%	7%
· mat/ground	43%	40%	50%
Net users*			
· young child only	20%	18%	10%
· young child + adult	37%	37%	29%
· older child, adolescent	43%	45%	61%
Mongala	**N=30**	**N=30**	**N=30**
Location found			
· hanging loose	87%	92%	77%
· hanging folded/tied	13%	0%	7%
· not hanging	0%	8%	16%
Type of sleeping place			
· bed	57%	67%	59%
· mattress	17%	12%	14%
· mat/ground	27%	22%	27%
Net users			
· young child only	17%	22%	14%
· young child + adult	27%	20%	23%
· older child, adolescent	57%	58%	63%

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

Variable	12 months	24 months	36 months
Sud Ubangi	**N=30**	**N=30**	**N=30**
Used last night	93%	88%	80%
Use last week			
· every night	93%	90%	80%
· most nights (5-6)	0%	5%	0%
· some nights (1-4)	0%	2%	0%
· not used	3%	2%	20%
· don't know	3%	1%	0%
Seasonal use			
· equally rain and dry	100%	98%	97%
· mainly rain	0%	2%	0%
· rain only	0%	0%	3%
Mongala	**N=30**	**N=30**	**N=30**
Used last night	87%	87%	73%
Use last week			
· every night	83%	83%	67%
· most nights (5-6)	3%	5%	7%
· some nights (1-4)	3%	3%	7%
· not used	10%	9%	16%
· don't know	0%	0%	3%
Seasonal use			
· equally rain and dry	93%	95%	87%
· mainly rain	7%	3%	7%
· rain only	0%	2%	6%

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

Variable	12 months	24 months	36 months
Sud Ubangi	**N=30**	**N=30**	**N=30**
Ever washed	93%	95%	100%
Washes last 6 month (all) · Mean · Median	 2.0 (1.3–2.6) 2.0 (1.0–3.0)	 2.0 (1.6–2.5) 2.0 (1.0–3.0)	 2.7 (2.2–3.3) 2.5 (2.0–4.0)
Washes last 6 month (if washed) · Mean · Median	 2.1 (1.6–2.7) 2.0 (1.0–3.0)	 2.2 (1.8–2.6) 2.0 (1.0–3.0)	 2.7 (2.2–3.3) 2.5 (2.0–4.0)
Soap used · country soap bar · detergent or bleach · mix · none	 72% 21% 7% 0%	 68% 11% 18% 3%	 97% 0% 3% 0%
Mongala	**N=30**	**N=30**	**N=30**
Ever washed	87%	93%	97%
Washes last 6 month (all) · Mean · Median	 1.8 (1.2–2.3) 2.0 (1.0–2.0)	 2.4 (1.8–2.9) 2.0 (1.0–3.0)	 2.2 (1.6–2.7) 2.0 (1.0–3.0)
Washes last 6 month (if washed) · Mean · Median	 2.0 (1.5–2.5) 2.0 (1.0–2.0)	 2.5 (1.9–3.2) 2.0 (1.0–3.0)	 2.2 (1.6–2.7) 2.0 (1.0–3.0)
Soap used · country soap bar · detergent or bleach · mix · none	 53% 30% 17% 0%	 48% 20% 22% 10%	 79% 7% 14% 0%

7 Summary and Conclusion

This report presents the findings of a three-year durability monitoring study that compared two LLIN brands (DuraNet and Dawa Plus). They were distributed during mass campaigns in neighboring locations in DRC with similar ecological and demographic environments: Sud Ubangi province (Ndage Health Zone) and Mongala province (Binga health zone). At baseline, two months after the 2016 mass campaign, a cohort of household representatives for the selected health zones 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.

Sample and follow up

The target for each site was to recruit 150 households (15 communities and 10 households each) and 345 cohort nets from the campaign at each of the sites. While the target for the cohort nets was well achieved, with 377 nets recruited at each site (109% of target), the number of households was smaller, with only 120 per site. This was because the household size at both sites was higher than expected and the field teams ran out of barcode labels to tag the campaign nets—therefore, the two clusters per site were dropped.

During the three follow-up surveys, the durability outcome for 254 out of 377 cohort nets in Sud Ubangi (67%) could be determined, while 16% were lost to follow up because the households moved away; 9% were lost because household members were not available at the time of the survey or could not recall the location of the net, and 8% were used by family members elsewhere. In Mongala, the proportion of cohort nets with a definite outcome was higher with 82% (308 out of 377), and reasons for unknown outcome where the location of the net could not be recalled (14%), followed by moving away (7%) and using the net elsewhere (4%).

Demographic and socio-economic characteristic

The study design of comparing the durability performance of two LLIN brands assumes that other factors that could influence durability are constant and that demographic and socio-economic characteristics of the selected sites are very similar. Results confirm that the two sites were very similar and any differences are unlikely to significantly impact durability. Average household size was between six and seven persons, with a rate of about 10% of female-headed households and 20% of the population being under 5 years of age.

The educational status of male heads of households was quite high, with more than 60% having had at least some secondary school education; only 26% in Sud Ubangi and 14% in Mongala were non-literate. This was quite different from the female heads of households, of whom 65% were non-literate and only 20% had any secondary education.

House construction at both sites was similar and very simple, with around 80% of roofs made from grass or thatch, 80–90% of walls made from mud, and 90% of floors were made from earth or clay. Almost all households used firewood for cooking, had access to a pit latrine, but also used surface water from rivers and creeks for drinking.

The economic situation was also very similar, with a slightly better socio-economic situation found in Mongala. Household assets were limited to radios (40–50%), a few televisions (1% Sud Ubangi and 7% Mongala), and mobile phones (9% Sud Ubangi and 22% Mongala). Transport included bicycles (45%), a few motorbikes (10% Sud Ubangi and 16% Mongala), and boats (2%). Income generation was mainly from farming, with about 95% of households having either land for agriculture, livestock, or both (66% in Sud Ubangi and 52% in Mongala). Around 80% of households owned chickens and 20–30% owned ducks, goats, or pigs.

Durability risk factors

A number of behavioral factors that are known or thought to be associated with damage of nets were monitored. They include 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. For the first category, no differences were seen: about half the households in each site stored food in the sleeping rooms, over 80% reported traces of rodents, and very few cooked inside sleeping rooms—although here the rate was higher in Sud Ubangi (16% always cooking inside the room) than Mongala (0%, p=0.03). The use pattern of nets was very similar in both sites, with a small proportion of nets (around 10%) used only by children. Net handling was also very similar; almost none of the households ever folded up the nets when they were hanging and few dried them on bushes. The rate for drying washed nets on bushes was slightly higher, with more variance in Mongala than in Sud Ubangi (2% to 20% versus 5%). In both sites, bed frames comprised about half to two-thirds of the sleeping places, with slightly more finished bed frames in Sud Ubangi. But, there were also more reed mats being used in Sud Ubangi than Mongala (50% versus about 25%). Care and repair attitude was the only category with a significant difference found between sites. Although exposure to net-related messages and recall was similar in both sites, with a dramatic decline of any message after the campaign. The positive attitude toward net care expressed by households in Sud Ubangi was significantly higher: more than 80% of households had a very positive attitude score, at least twice as high, during the four surveys in Sud Ubangi, compared to only 40% in Mongala (p=0.006).

Net hanging and use

Hanging and use of the durability cohort nets cannot be interpreted without considering the household net ownership from other sources. From the very beginning, and throughout the study, households owned a considerable number of other nets. New ones kept coming into the household, so that at the final survey, 64% of households in Sud Ubangi and 45% in Mongala had non-cohort nets, which represented 44% and 38% of all nets owned, respectively. However, population access to an ITN within the sampled population decreased sharply at both sites, from 81% to 68% in Sud Ubangi and from 89% to 53% in Mongala.

Immediately following the distribution, only a small proportion of cohort nets were found hanging (54% in Sud Ubangi and 26% in Mongala) but, at this time, the other nets were used at a rate of >80%. After 12 months, the situation had changed and now the cohort nets were used more often (78% and 45%, respectively) than the non-cohort nets (52% and 63%, respectively). But, as the campaign nets started to show damage and the overall net crop reduced, both types of nets were hung and used more regularly: >80% in Sud Ubangi and around 70% in Mongala. Throughout the study, hanging and use rates were lower in Mongala than Sud Ubangi (p=0.03), but seasonal net use was not seen.

Physical durability outcomes

After three years, the all-cause attrition (i.e., losses for any reason) varied between 57% in Sud Ubangi and 76% in Mongala. These rates are high, but not exceptionally high, with similar rates of 56% and 74% also seen in the VectorWorks–supported study in Mozambique. An increasing proportion of losses was due to discarding nets (destroying, throwing away, or alternative uses), which reached 48% in Mongala at the final survey and 26% in Sud Ubangi, suggesting a much higher loss due to wear and tear in Mongala. Nets discarded were mostly thrown away in Mongala (87%); but, in Sud Ubangi, 36% of the nets were destroyed and 10% used for other purposes. Overall, less than 2% of nets in either site were used for other purposes. While these were for window and door screening in Sud Ubangi, two out of 377 campaign nets were reportedly used for fishing.

While significant differences in the discarding rate of old and torn nets were seen between the sites, the physical condition of the ones still found in the households was very similar. At the final survey (30 months after distribution), 23% (Sud Ubangi) and 30% (Mongala) were torn and no longer serviceable, although they were still in use. The level of damage among nets with any holes was high at both sites, but higher in Mongala (p<0.0001). This suggests that nets were not discarded prematurely but only when they were badly damaged.

Overall survival in serviceable condition at the last survey was 37% in Sud Ubangi and just 17% in Mongala, and this difference was statistically and programmatically significant (p=0.003). Estimated median survival was 1.6 years for the Dawa Plus 2.0 in Mongala (95% CI 1.3–1.9) and 2.2 years for the DuraNet

in Sud Ubangi (95% CI 2.0–2-4), both significantly below the assumed three-year median survival. Results from the survival analysis of the data confirmed the magnitude of median survival (1.7 years in Mongala and 2.6 years in Sud Ubangi). It was also established in a Cox proportionate hazard model that the difference in median survival was mainly due to the LLIN brand and not to other factors—such as positive net care attitude, type of sleeping place, or dominant use by children only—all of which showed some positive or negative impact on the outcome in the Cox models.

Insecticidal durability outcomes

The bio-assay using the WHO cone tests showed optimal insecticidal performance up to the final survey for the DuraNet LLIN brand, but the Dawa Plus 2.0 LLIN brand only had optimal performance: >80% only up to the 24-month data point and 53% of samples at the final survey failed, even the minimal effectiveness criteria. This suggests that insecticidal content was lower or lost faster than expected. Whether this is relevant for vector control considerations in this case is questionable because the physical durability in this setting was only 1.6 years, on average.

Limitations

Some of the durability risk factors, 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 health zones within each province, the health zone selection was purposive and some caution is required when generalizing the findings to the province or even DRC as a whole.

Conclusion

After three years of follow up among neighboring, rural populations in the provinces of Sud Ubangi and Mongala, the 150 denier polyethylene LLIN DuraNet showed a significant difference in median physical survival compared to the 100 denier polyester LLIN Dawa Plus 2.0, but both remained well under the three-year expected median survival. The difference could be attributed mostly to the differences in the brand. A Cox proportionate hazard model, adjusting for other risk factors, confirmed the brand as the strongest driver of the difference. This means that, in harsh environments like DRC, it will be preferable to distribute a more durable LLIN, such as the DuraNet or similar brands, but also to consider a distribution strategy with mass campaigns every two years or, alternatively, a continuous distribution strategy. Insecticidal performance was optimal for DuraNet in Sud Ubangi, but for the Dawa Plus in Mongala, optimal performance lasted only up to 24 months and then failed at 36 months. However, at this time, most of the cohort nets were already lost.