

**FINAL REPORT
AFTER 36 MONTHS
SEPTEMBER 2020**



DURABILITY

MONITORING OF LLIN IN BENIN



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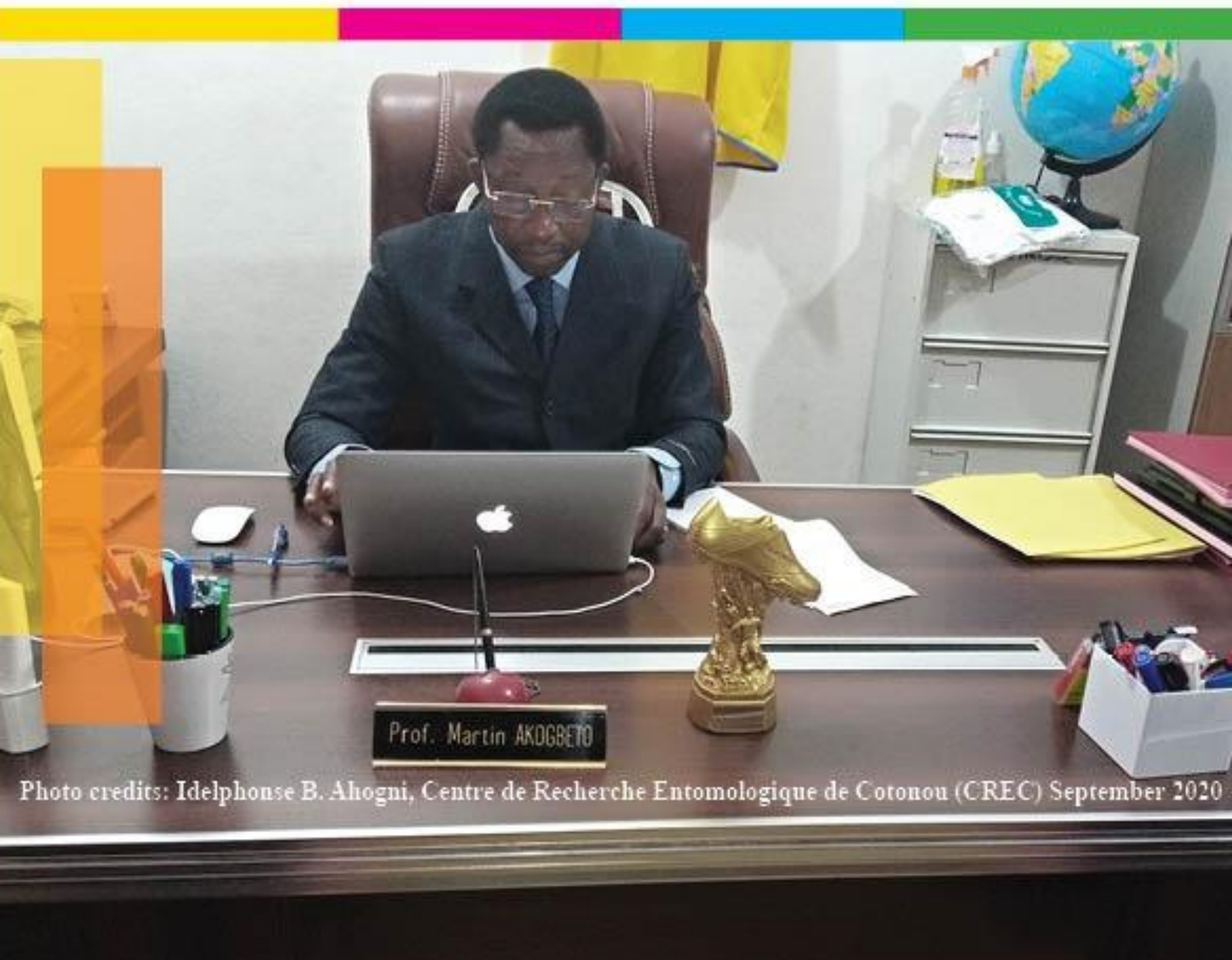


Photo credits: Idelphonse B. Ahogni, Centre de Recherche Entomologique de Cotonou (CREC) September 2020

1 Abstract

Background

Long-lasting insecticide-treated mosquito nets (LLINs) are an essential tool in malaria control. Prevention using this tool has improved considerably in Africa south of the Sahara in recent years. However, the physical and insecticidal durability of this tool varies greatly from country to country according to several studies. The differences observed are largely due to behavioral and environmental factors, but could also depend on the quality of fibers used by the different brands of LLINs. This leads the national malaria control programs to include in their control strategy, regular monitoring of the durability of LLINs after each mass distribution campaign. In accordance with the recommendations of the Presidential Malaria Control Initiative (PMI) of the United States, monitoring the sustainability of three brands of LLINs (with different characteristics) and distributed during the mass distribution of LLINs in Benin from July to October 2017, was set up for three years in three malaria-endemic health zones with different ecological profiles: Dogbo (in the south), Djougou (in the north) and Kétou (towards the center). Physical integrity, sustainability and bio-efficiency are key variables in the effectiveness of LLINs. This study was entrusted to the Cotonou Entomological Research Center (CREC) and which received support from the National Malaria Control Program (NMCP) and the PMI.

Methods

This prospective study was carried out in a setting where samples of representative households from two districts in each municipality were enrolled at the start of the study and at every six-month interval (the first year) and three months in the following years. . Five hundred LLINs per municipality at a rate of 250 / district from the distribution and present in these households were selected, labeled and followed for 36 months. A total of 1,500 households or 1,500 LLINs were included in the study. Precise results could be established for 8.8% of the mosquito nets of the cohort in Dogbo, 6.6% in Djougou and 5.8% in Kétou. To assess the physical durability of LLINs, the criteria used included losses (losses from all causes and losses due to natural wear and tear) and physical integrity, assessed using the proportional hole index (pHI), used to identify mosquito nets in the cohort deemed repairable (pHI <643). These criteria were then combined to obtain the 'proportion of nets remaining and repairable' at each stage of follow-up and the median survival in years (the time elapsed until 50% of the nets in the cohort with known status failed. are more repairable). A survival analysis was also performed in correlation with the NetCalc model, to analyze the determinants of LLIN survival. The durability of the

insecticide was measured by bioassays (World Health Organization (WHO) cone test) using sub-samples of mosquito nets from the distribution campaign. The result was the proportion of nets with optimal insecticidal efficacy (24 hour mortality $\geq 80\%$ or shock effect $\geq 95\%$ after 60 minutes). At each stage of the follow-up, a structured questionnaire also made it possible to assess demographic, socioeconomic and behavioral aspects.

Results

The demographic profile of the population of the three sites is comparable and representative of rural African populations. This profile has not changed significantly over time. On all three sites, the construction of the houses is similar and very simple. There are about 55.7% of roofs made with sheet metal, 37.9% of walls built with mud clay and 5.1% of soil or clay. Almost all households use firewood for cooking, have access to simple pit latrines and drink surface water from unprotected rivers and collective wells. The economic situation of the three sites is also very similar. Mobile telephony is the best means of communication, although it varies from community to community. Most of the risk factors for sustainability are very similar across the three sites, with some minor differences.

After 36 months, the loss from all causes was 90% across all sites. Overall, very few nets were used for other purposes at each site. In the different sites, the mosquito nets were recycled to protect the doors and windows, and other mosquito nets from the distribution campaign were used for fishing, animal husbandry and even sale.

Although significant differences were observed in the rejection rate of used and torn nets between the three sites, the physical condition of the remaining nets was very similar. During the last survey (36 months after distribution), 17.2% (Ketou), 20.5% (Dogbo) and 0% (Djougou) of the mosquito nets were torn and impossible to repair, but still used. The level of deterioration of the mosquito nets with holes was significant at the three sites, but even more in the commune of Dogbo (72.7%) ($p < 0.0001$), which suggests that the nets were not rejected prematurely, but only when they were badly damaged.

During the last survey, the overall rate of remaining and repairable mosquito nets was 17.2% in Ketou, 31.8% in Dogbo and 18.2% in Djougou. Median survival was 1.9 years for DawaPlus 2.0 in Ketou, 2 years for PermaNet 2.0 in Dogbo, and 1.10 years for Yorkool, three results well below the expected median 3-years survival. Survival analysis with the NetCalc model confirmed this result.

We haven't done any testing after 36 months. The results of bioassays are those obtained after 2 years of follow-up. Most brands of LLINs maintained optimal efficacy during two years of study, the insecticidal efficacy of brands of LLINs only remained optimal until the 18th month data point, before gradually falling, with a rate median shock effect around 82% and a similar median vector mortality rate. About 20% of the samples showed optimal insecticidal efficacy against almost 90% minimum efficacy. Few LLINs failed the tests.

Conclusion

After 33 months of follow-up in the communes of Ketou, Dogbo and Djougou, the PermaNet 2.0 LLIN in 100 denier polyester displayed a higher median survival than that of the DawaPlus 2.0 and Yorkkool LLIN (in 100 denier polyester) as well. The three nets are nevertheless very far from the expected median survival of three years. It may be advisable to consider a distribution strategy with campaigns every two years or an ongoing distribution strategy with a communication plan to minimize the risk of loss and tear. Insecticidal efficacy was relatively acceptable by WHO standards after two years of use.



3 Acknowledgments

This work was made possible by the generous support of the American people, through the United States Agency for International Development (USAID) and the Presidential Malaria Initiative (PMI), in under the Cooperation Agreement between USAID and the Entomological Research Center of Cotonou (CREC). The contents of this document do not necessarily reflect the views of USAID, PMI, or the United States government.



4 Context

Malaria prevention using long-lasting insecticidal nets (LLINs), a highly effective and cost-effective intervention, has grown significantly in sub-Saharan Africa in recent years. As many countries have now achieved high LLIN coverage and are moving closer to the WHO goal of universal coverage of one mosquito net for every two people in the population at risk, the question of how these successes can be sustained is raised. The subject of debate. Benin is not behind on this objective because 80% of households have a LLIN for two people (Malaria Indicators Survey (MIS) 2017). However, the importance of the durability of nets and their "average useful life" is increasingly recognized as a critical factor in the design of malaria control programs, as it is they who determine the frequency of mosquito nets, screen replacement and the type of screen to purchase. This is reflected in the WHO guidelines for field surveillance of LLINs, which recommend countries to regularly monitor the durability of nets. In this context, it is imperative to understand how long distributed LLINs remain in households and continue to protect net users. Several reports indicate a rapid decline in mosquito net survival in Benin. This underscores the need to set up net monitoring activities in order to justify, quantify and prioritize future replacement needs. There are two parameters that go into the durability of mosquito nets: physical durability and durability or effectiveness of the insecticide. Physical durability includes loss of nets due to natural wear and tear and the physical integrity of the remaining nets. In recent years, the methodology for assessing the durability of nets has evolved considerably, and WHO has issued detailed recommendations. It is now recommended that all malaria control programs that distribute LLINs also regularly monitor the durability of the nets. Donors, such as the Presidential Malaria Initiative (PMI) and operational partners, have followed these recommendations and are also encouraging the countries they support to put in place regular monitoring of the sustainability of LLINs.

Currently, very few published studies are based on the new methodology used to assess the actual effectiveness of brands of LLINs.

In the Republic of Benin, a few previous field study reports suggest that the average survival of LLINs in real conditions could be less than three years. To date, two studies have taken place in different regions (Gnanguenon et al, Azondekon et al, published studies and Ahogni et al, in publication).

These studies were carried out in 2011 and 2014 in six different communes, with a prospective design for aspects relating to the survival of LLINs and a cross-sectional design for aspects

relating to the use of long-lasting insecticide-treated mosquito nets. action (LLIN) in households. The study looked at both casualties and physical integrity. The results show each time that the survival of the DawaPlus 2.0, DuraNet, Olyset and PermaNet 2.0 nets was less than 2 years according to the NetCalc model.

In 2017, the National Malaria Control Program (PNLP) of Benin launched, with the support of its partners, a massive distribution campaign throughout the country, in order to maintain universal LLIN coverage in places where brands of LLINs are distributed. With this sustainability monitoring exercise, the PNLPP intends to better understand the respective performance of brands in regions with different ecological and socio-demographic conditions.

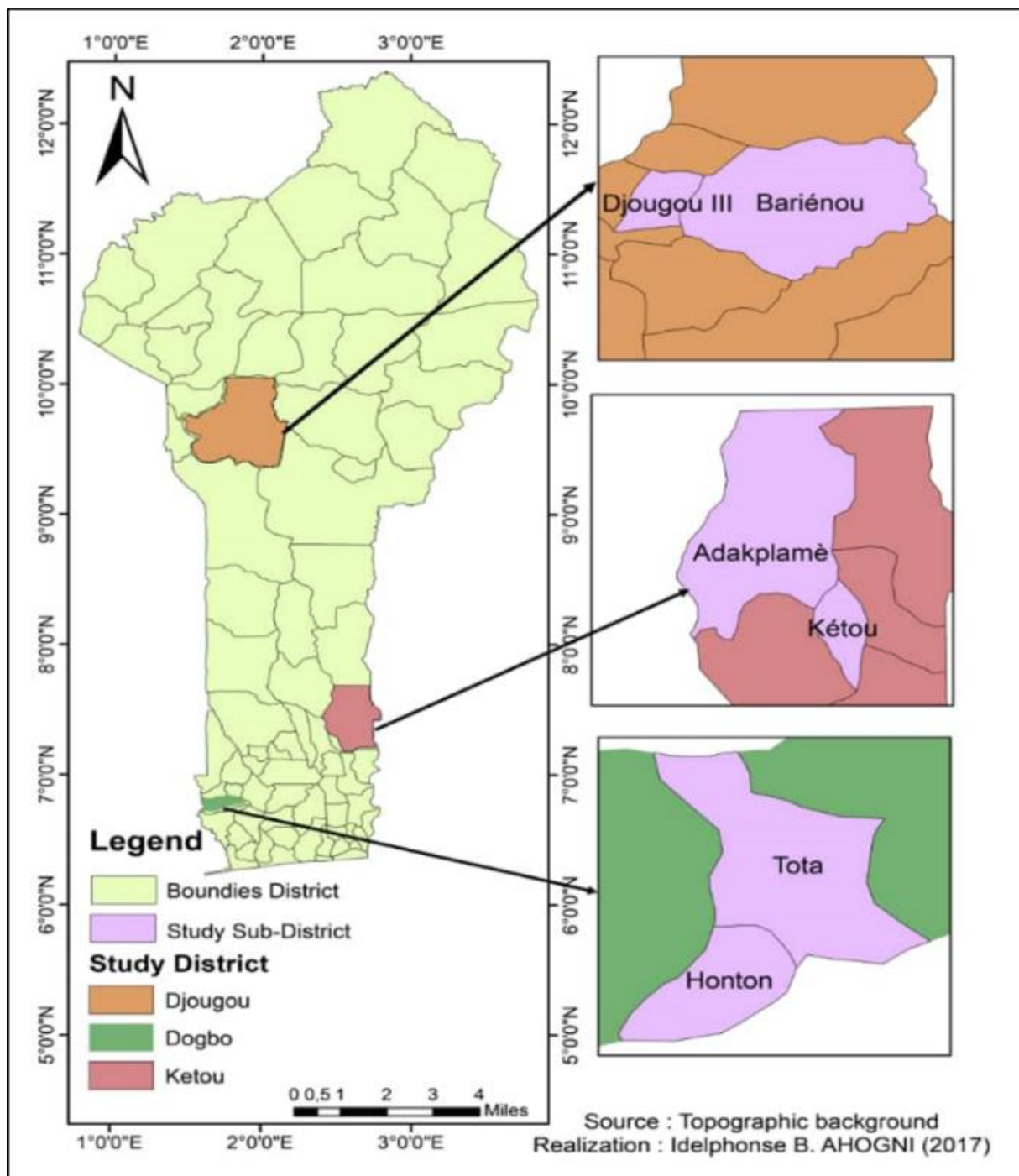
5 Methodologies

This activity was entrusted to the Entomological Research Center in Cotonou, which received support from the PMI.

5.1 Sites

This study followed a cohort model and was implemented in three municipalities that obtained mosquito nets through a mass distribution campaign in July and October 2017. Immediately after LLIN distribution during the mass campaign (the first month following), a representative sample of 1,500 field nets from the study sites was identified through a cluster household survey, with all nets from consenting households forming the study cohort. The marking and labeling of these nets was then carried out using a unique identifier (code). Their presence and physical condition at home were assessed in all series of surveys, as well as household characteristics, use, maintenance and behavior. At each stage of the assessment (6, 12, 24 and 36 months), sub-samples of field nets were selected for insecticide efficacy testing. The study was conducted in six sub-districts: The inhabitants of Kétou received *DawaPlus®2.0* LLINs, those of Dogbo received *PermaNet®2.0* and those of Djougou received *Yorkool®*. In each community, a rural area and an urban area were randomly selected. There are differences between the sites.

Figure 1: Map of study site



The selection of the three municipalities for the study, although random, took into account their socio-ecological and epidemiological profiles of malaria. These municipalities represent areas with different malaria transmission potential and very different climatic or socio-demographic characteristics. The household was the sampling unit and, in each household, only one net was selected from those found in each household, which ensured that it was one of the brands distributed in the household. of the mass campaign (Table 1).

Table 1: Summary of the study sites and the sampling

Transmission zone	Brand net	Sub-district	Campaign net period	Data collection period
Long transmission	<i>DawaPlus</i> ®2.0	Adakplame	October	Baseline 12, 24 and 36 months
Long transmission	<i>DawaPlus</i> ®2.0	Ketou	October	Baseline 12, 24 and 36 months
Long transmission	<i>PermaNet</i> ®2.0	Honton	October	Baseline 12, 24 and 36 months
Long transmission	<i>PermaNet</i> ®2.0	Tota	October	Baseline 12, 24 and 36 months
Seasonal transmission	<i>Yorkool</i> ®	Barienou	July	Baseline 12, 24 and 36 months
Seasonal transmission	<i>Yorkool</i> ®	Djougou	July	Baseline 12, 24 and 3 months

For the Barienou and Djougou III sites, the distribution of the mass campaign took place in July, slightly different from that of the 4 other sites with *PermaNet*®2.0 and *DawaPlus*®2.0. The data collection cycles were implemented respectively at the beginning, and semi-annually the first year and quarterly the following years after the campaign for all LLINs.

5.2 Brands monitored

The three brands of LLIN being monitored are

***DawaPlus*®2.0**, 100 denier polyester MILD, white color. This LLIN is made with impregnation technology and an initial dose of 80 mg / m² deltamethrin. *DawaPlus*®2.0 received interim recommendation from the World Health Organization's (WHOPES) Pesticide Rating System (WHOPES) in July 2009 (13th WHOPES report).

***PermaNet*®2.0**, made of 100% polyester, the netting fibers are 75 or 100 denier. The mesh size is a minimum of 25 holes / cm² with deltamethrin incorporated (55 mg ai / m²).

***Yorkool*®LN**, made of 100% polyester, the fibers of the net are 75 or 100 denier. The mesh size of the net is 24-26 holes / cm², coated with deltamethrin (55 mg ai/m²).

5.3 Design summary

The study design follows the PMI guidelines for monitoring the sustainability of LLINs ([see www.durabilitymonitoring.org](http://www.durabilitymonitoring.org)) overall. During the six months following the mass distribution campaign, a representative cohort of LLINs from the campaign is sampled and labeled at each selected site, for semi-annual monitoring in the first year and quarterly in subsequent years. At each stage of monitoring, the physical durability (losses and integrity) as well as the biological durability of the nets are assessed. Samples are taken from households that are not part of the cohort (nearest neighbor) for chemical testing. All mosquito nets collected for bioassays are replaced by new LLINs. In Benin, three different sites using two different brands of LLINs

were selected. This sustainability study aims to compare three brands in regions with a very divergent ecological and / or behavioral profile.

The size of the sample conforms and even more to the recommendations of the PMI: 250 households per district (500 / municipality) and a target of 1,500 mosquito nets from the distribution campaign labeled for monitoring. The purpose of this sample size is to identify an 18 percentage point deviation from the expected 50% survival at three years, by comparing the site or brand with the best results and the site or brand with the worst. results.

At the start of the study, the LLIN cohort of each commune was defined by selecting a representative sample of clusters (communities), according to the probability proportional to the size, after removing inaccessible communities from the sampling frame and sampling. simple random number of households from the lists drawn up for the survey. As soon as the clusters were sampled, local authorities and chiefs were informed of the objectives and timing of the survey; their support was requested. In order for them to cooperate optimally with the surveys, the communities were sensitized and mobilized. Only one of the LLINs distributed to households selected as part of the PNLP campaign was identified and received a unique identification number. The physical condition of the mosquito nets from the distribution campaign was assessed through a hole assessment, and household interviews were conducted.



The massive LLIN distribution campaign, implemented by the United Nations Children's Fund and funded by PMI, the global fund, took place throughout the country, implemented by the Center de Recherche Entomologique de Cotonou and funded by the Global Fund. The current investigation took place later than planned to avoid serious threats from COVID-19.

5.4 Field work

Three teams made up of three investigators and a community intermediary carried out field activities per site under the supervision of a global site coordinator. Field activities were

supervised by CREC staff. The selection of interviewers and supervisors was made with care so that they have a good knowledge of local languages, experience in conducting household surveys and above all that they are culturally acceptable. To this end, a 5-day training session was organized before the start of the study and systematic retraining was carried out for 2 days before each follow-up survey. A key point was made on the standardized process for assessing physical damage. The questionnaire was subdivided into three main modules: the first for the household respondent, the second for the nets of the cohort campaign (including the nets lost in the baseline study and the campaign) and the last module for other household mosquito nets at each follow-up. In addition, a list of household members and their assets was obtained during the baseline study and the final study. GPS coordinates were recorded during the baseline survey and used to track households during monitoring. If the households moved within the clusters, the new dwellings were identified; if they moved outside the cluster, they were considered lost for follow-up. The mass distribution campaign took place in October 2017 at the three sites. Baseline assessment was carried out six months after the campaign, data collection followed every 6 months for a follow-up of 36 months each time.



5.5 Data management

The data for our study were collected using tablets (Samsung Galaxy Tab 4 and Tecno P04) on which the Open Data Kit (ODK) software for the questionnaire was installed. Data from each field team was collected daily and directly uploaded to a secure database if internet was available or collected on a local storage device by the coordinator until it could be transferred. The data was converted to comma-delimited data files using the Dropbox Briefcase Tool for Incoming Data Inspection and daily data quality feedback was provided to the teams. For each survey cycle, updated lists were compiled from the household and cohort network master files and preloaded on the ODK system, including all household and cohort networks for which no precise results were available. available today. After the surveys were completed, the datasets were transferred to Stata version 14.2 (Stata, TX 77845, USA) and R software for further aggregation, consistency checks, and preparation for analysis. Our Stata do files (macros) have been applied and adjusted as needed. For the final analysis, the survey data sets were merged.



5.6 Analysis

With regard to continuous variables, the description of the central tendency was made using the arithmetic means and the comparison of the groups for the data normally distributed with the T test. For the other cases, tests of the medians and the tests non-parametric were used. Contingency tables were used to compare proportions and the chi-square test was used to assess differences in proportions. For the calculation of the confidence interval of the estimates, the intra-cluster and inter-cluster correlation was taken into account. In addition to a descriptive single-variable analysis, linear and logistic regression models were used, where possible, to assess the factors determining physical durability.

The main outcome to be assessed is the physical survival of the nets, i.e. the proportion of nets received as part of the distribution of LLINs that have not been passed on to other people and are still present in the net. cleaning and repairable (definition below). At each evaluation, this result is calculated according to the following formula:

To calculate this result, we calculate two intermediate results, as follows:

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

The net rate of loss (attrition) due to wear, which was defined as the proportion of nets initially received that were lost due to wear and tear (discarded, destroyed or used for other purposes) at the time of the "evaluation". Nets received but given for use by others or stolen were excluded from the denominator. Likewise, mosquito nets with an unknown outcome are excluded.

The physical integrity of the LLINs was measured by the proportional hole index (pHI), as recommended by the WHO. In the LLINs of the study, it was counted and grouped into four different sizes, the holes encountered: size 1: 0.5-2 cm, size 2: 2-10 cm, size 3: 10-25 cm and size 4: more than 25 cm in diameter. The proportional pHI of each fillet was then calculated by multiplying the number of holes counted by the weight of the size categories, as suggested by the WHO. Each LLIN was then classified on the basis of pHI, as "good", "damaged", "usable" or "torn" as follows:

Good: total hole surface area <0.01 m² or pHI <64

Damaged: total hole surface area 0.01-0.1 m² or pHI 65-642

Torn: total hole surface area > 0.1 m² or pHI > 642

Serviceable: total hole surface area ≤ 0.1 m² or pHI ≤ 642 (good or damaged)

In order to be able to compare physical survival measured at different time points, the median net survival outcome was estimated as the time in years until 50% of the LLINs originally distributed were no longer usable. Two approaches were used to estimate median survival. At each time point, the proportion of people surviving in a service state was plotted against follow-up time and compared to hypothetical survival curves with defined median survival. The estimate of median survival was taken as the interpolated position of the data point on a horizontal line between the two adjacent median survival curves. After the final survey, the median net survival was calculated from the last two data points provided they were both less than 85% (when the hypothetical curves are linear), using the following formula where t_m is the median survival time, t_1 and t_2 the first and time points in years and p_1 and p_2 the proportion surviving the first and second time points respectively in percentage. Confidence intervals for this estimate were calculated by projecting the 95% CI from the survival estimates in the same manner as described above.

Biological Efficiency Assessments

The evaluation of the chemical efficacy of LLINs was carried out using biological cone tests in accordance with WHO guidelines, at the start and at each follow-up until the 30th month after the two mosquito net distribution campaigns. At each follow-up, 50 LLINs of each type were randomly selected and removed from the different study areas for use in testing. New nets were given to owners to replace those removed for testing and farms were not included for bioassays in the future. Each of the removed LLINs was cut in 5 different places (the 4 sides plus the roof) into pieces (30×30 cm) according to the WHOPES sampling plan. A sensitive laboratory strain (*An. Gambiae* Kisumu) was used to perform the standard bioassay according to WHOPES recommendations. For this test, five non-engorged females, aged 2 to 5 days and belonging to this strain sensitive to pyrethroids were used. These mosquitoes were introduced simultaneously into the WHO cone and 10 cones are applied simultaneously to the mosquito net sample (2 per side). Mosquito exposure to LLINs lasted three minutes. After exposure, the females are grouped into groups of 5 in 200 ml transparent plastic cups, covered with a mosquito net and kept at $28^\circ \text{C} \pm 2^\circ \text{C}$ and at a relative humidity of $80\% \pm 10\%$ with a 10% sugar solution. We therefore use a total of 50 mosquitoes per net. Each test day, four cones, each with 10 *An. Gambiae* Kisumu were exposed on an untreated net as a negative control. The proportion of mosquitoes falling on their backs was measured 60 minutes after exposure and mortality was assessed after 24 hours. If the mortality in the control was $>5\%$ for a given day, the data was fitted with Abbott's formula. If the control mortality was greater than 10%, all tests for that day were repeated. The standard protocol recommends using a mixed result, i.e. $\geq 80\%$ mortality or

$\geq 95\%$ KD to consider LLIN effective. Mortality corrected with Abbott's formula was no longer required to be applied to the data. The number of mosquitoes that have fallen on their backs ("knock-down", KD) is recorded at 5-minute intervals for 60 minutes, which makes it possible to calculate the level of KD at 60 minutes (KD 60). The percentage of mortality is calculated at 24 hours according to the immediate and delayed mortality defined in the WHO recommendations. This endpoint was combined according to the optimal efficacy of the insecticide (KD60 $\geq 95\%$ or mortality $\geq 80\%$), minimum effectiveness (KD60 $\geq 75\%$ or mortality $\geq 50\%$) or failure (do not meet the minimum efficiency criteria).



5.7 Ethical Clearance

This study received the ethical approval (favourable ethical opinion No. 05 of November 07, 2017) from the Institutional Ethics Committee of the CREC (IECC). All heads of households 18 years of age or older who have received *the DawaPlus®2.0, PermaNet®2.0 and Yorkool®LN* nets under evaluation are voluntarily included in the study after signing the consent form and may withdraw if they wish without fear of reprisal.

6 Results

6.1 Sample

In total, 1,500 households, or 500 per district, were recruited at the start of the study. The total number of mosquito nets from the distribution campaign labeled for monitoring amounts to 1,500, at the rate of one LLIN sampled per household. Figure 2 presents a detailed summary of the households recruited and their monitoring at the three sites. Households dropped out of the study for three reasons, the main one being the loss of all their mosquito nets from the distribution campaign, which made follow-up difficult. After 36 months, this situation concerned 94% of the 500 households recruited in the Plateau, 93.4% in the Donga and 91.2% in the Couffo. The second reason for discontinuing monitoring: households that have moved to other communities. This situation was the main reason and more similar in the three communes and concerned 73.6% of households at 36 months of study in Ketou. 33.8% in Djougou and 73% in Dogbo. We also noted a few cases of intra-municipal migration (households having changed houses in the same village) but which were not reported here. These households, however, continued the study and their new address was registered. Finally, the third reason for discontinuing follow-up was refusal to continue the study, a situation which, however, rarely occurred. Overall, follow-up was quite weak in all municipalities for all surveys. Due to frequent absences, from the new distribution of LLINs, we were confronted with the abandonment or with the abandonment of the old LLINs against the new ones received by the population after 36 months of use.



Figure 2a: Follow-up status of households recruited at baseline at DawaPlus 2.0 Site

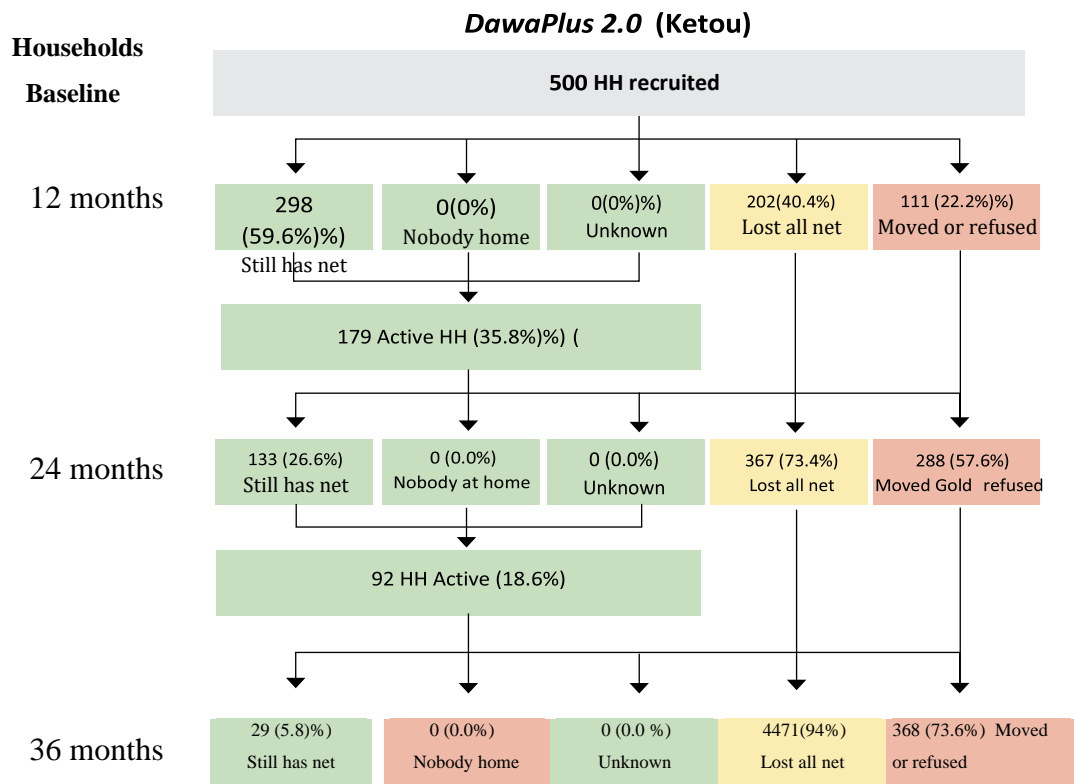


Figure 2b: Follow-up status of households recruited at baseline at Yorkool Site

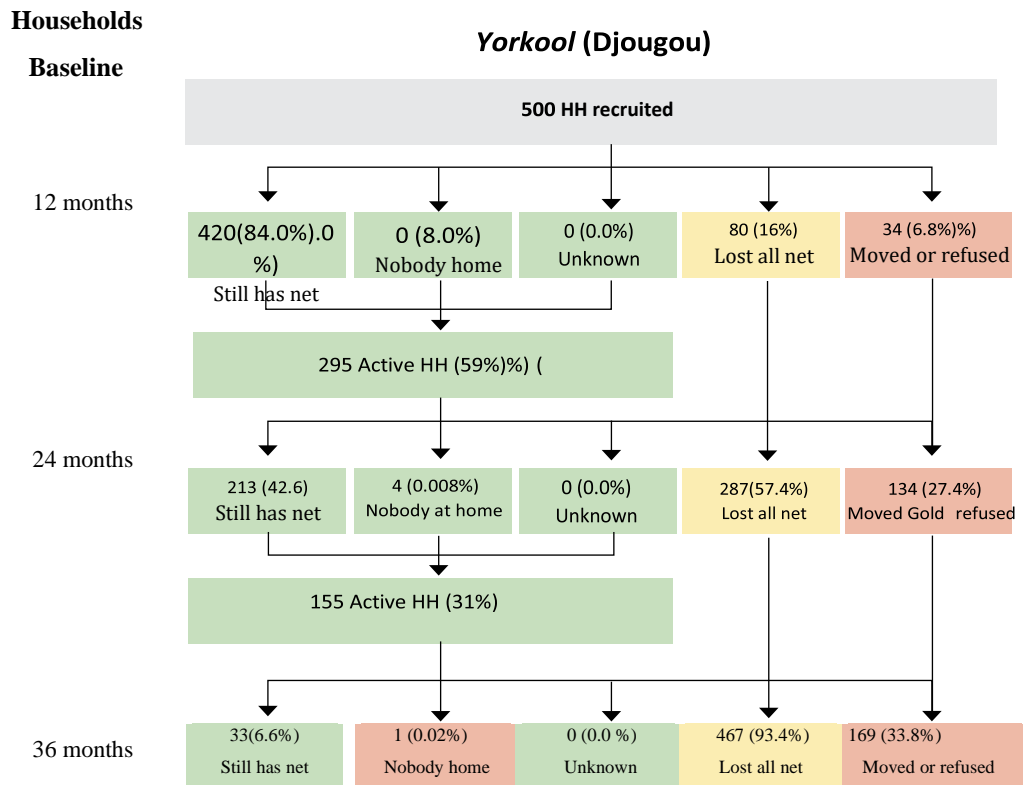
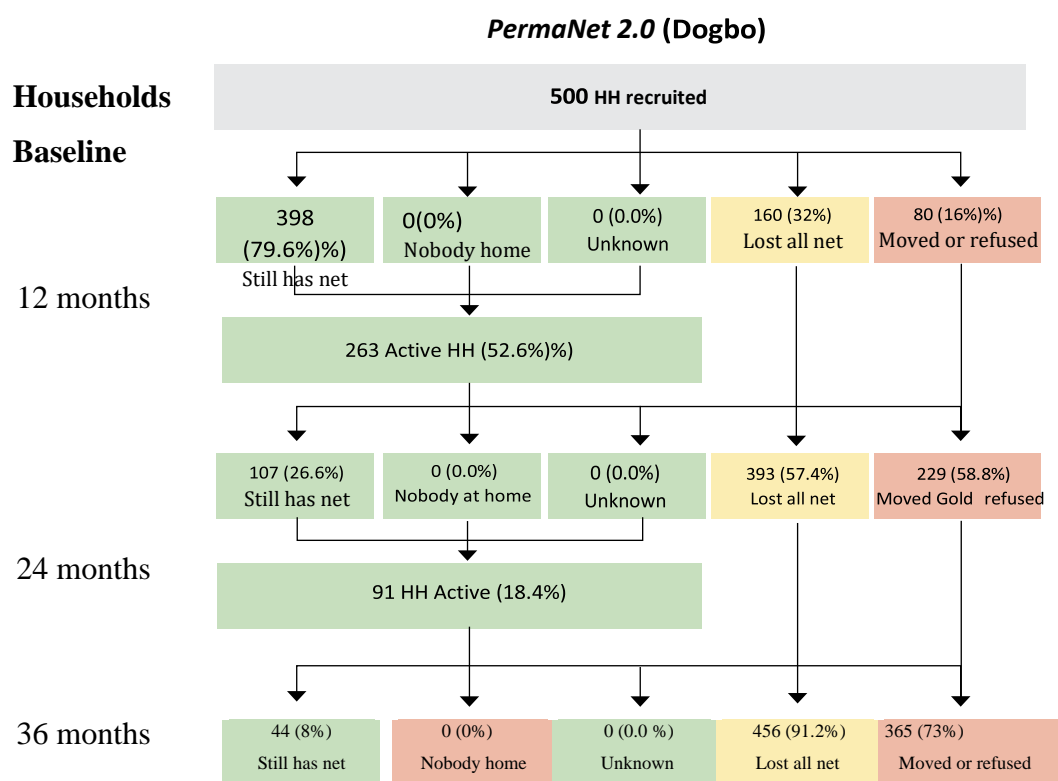


Figure 2c: Follow-up status of households recruited at baseline at PermaNet 2.0 Site



6.2 Socio-Demographic characteristics

Data on the households that participated in the survey were collected to identify demographic or socioeconomic changes that occurred during the 36 months of the study.

By comparing households that participated in the baseline survey and the 36-month survey, we explored the data to detect any demographic or socio-economic changes after the survey. As expected, the average age of household heads increased by about three years over the course of the study. The education level of the household head also did not change over time. However, more women than men heads of household were illiterate in all three sites. Very few women reached secondary school and none reached university. (Figure 3a).

Among the three sites, all indicators of household socioeconomic status in PermaNet 2.0 and DawaPlus 2.0 and Yorkool were similar. Livestock ownership and access to land for horticulture or agriculture (Figure 3b) best illustrate this situation.

A noticeable change was observed during the 36 months of sustainability monitoring for households that were included in the baseline, as well as during the survey (Table 2).

Figure 3a: Educational status of heads of household by gender and site after 3 years

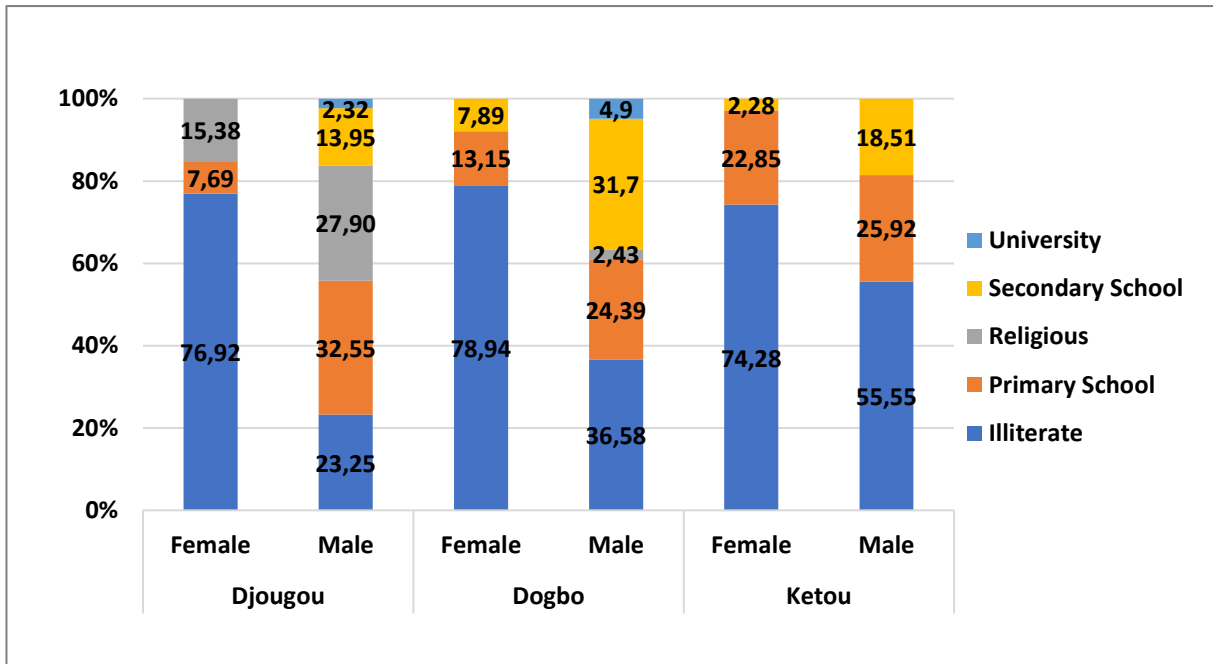


Figure 3b: Economic resources of households by site at 36 months survey

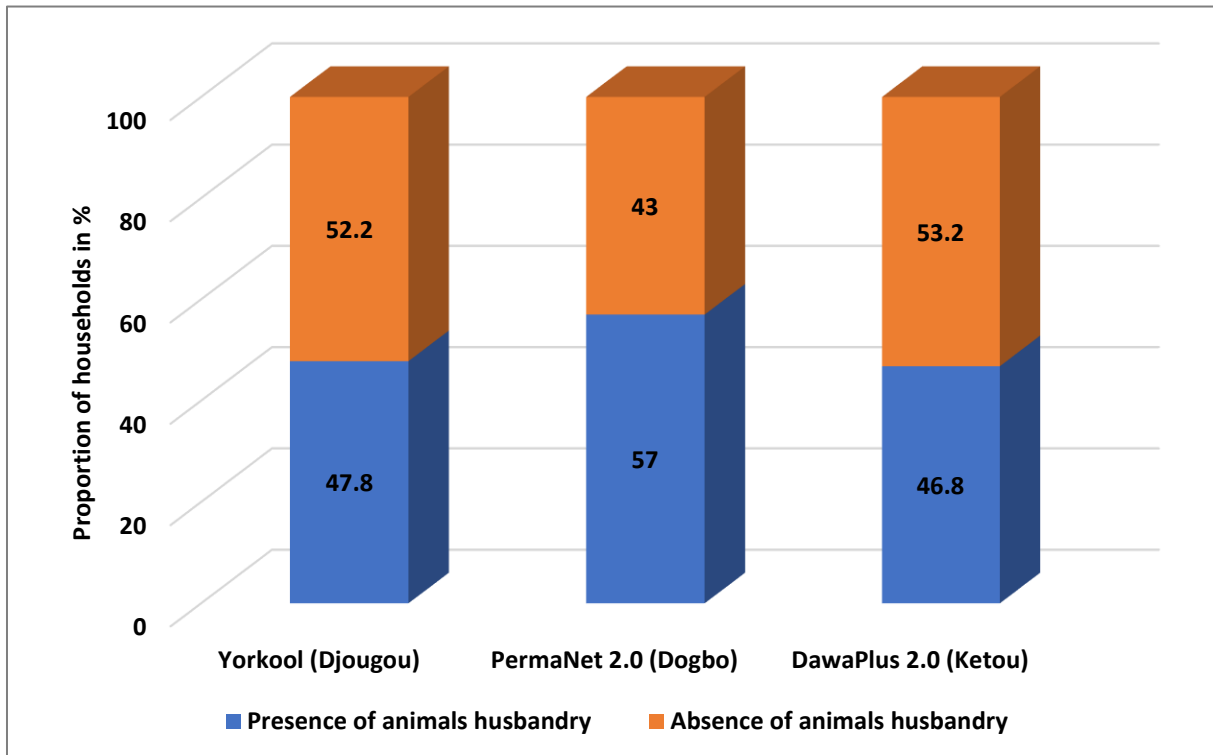


Table 2: Household characteristics and assets

Variable and site	Baseline	36 months
PermaNet 2.0 (Dogbo)	No.385	No.44
Roof (sheets/tile)	91.2	55.69
Cooking fuel (freewood)	81.0	44.30
Access to safe water	97.9	16.45
Access to latrine	82.1	43.03
Radio	8.6	5.06
Mobile phone	32.5	11.39
Any transport	15.6	15.18
Clay or laterite wall	64.9	37.97
Clay or laterite soil	41.6	5.06
Yorkool (Djougou)	No.469	No.33
Roof (sheets/tile)	100.0	47.82
Cooking fuel (freewood)	68.7	31.88
Access to safe water	71.2	10.14
Access to latrine	50.1	24.63
Radio	10.7	15.94
Mobile phone	74.0	26.08
Any transport	36.0	24.63
Clay or laterite wall	78.7	40.57
Clay or laterite soil	11.1	8.69
DawaPlus 2.0 (Ketou)	No.455	No.29
Roof (sheets/tile)	99.1	46.77
Cooking fuel (freewood)	85.9	43.54
Access to safe water	99.8	27.41
Access to latrine	61.8	32.25
Radio	4.2	6.45
Mobile phone	73.8	25.80
Any transport	100.0	29.03
Clay or laterite wall	84.4	30.64
Clay or laterite soil	40.7	9.67
Total	No. 1309	No.106
Roof (sheets/tile)	97.1	50.47
Cooking fuel (firewood)	78.3	40.00
Access to safe water	89.0	17.61
Access to latrine	63.6	32.38
Radio	7.8	9.04
Mobile phone	61.7	20.00

Any transport	52.3	22.38
Clay or laterite wall	76.6	36.66
Clay or laterite soil	30.3	7.61

6.3 Determinants of Durability

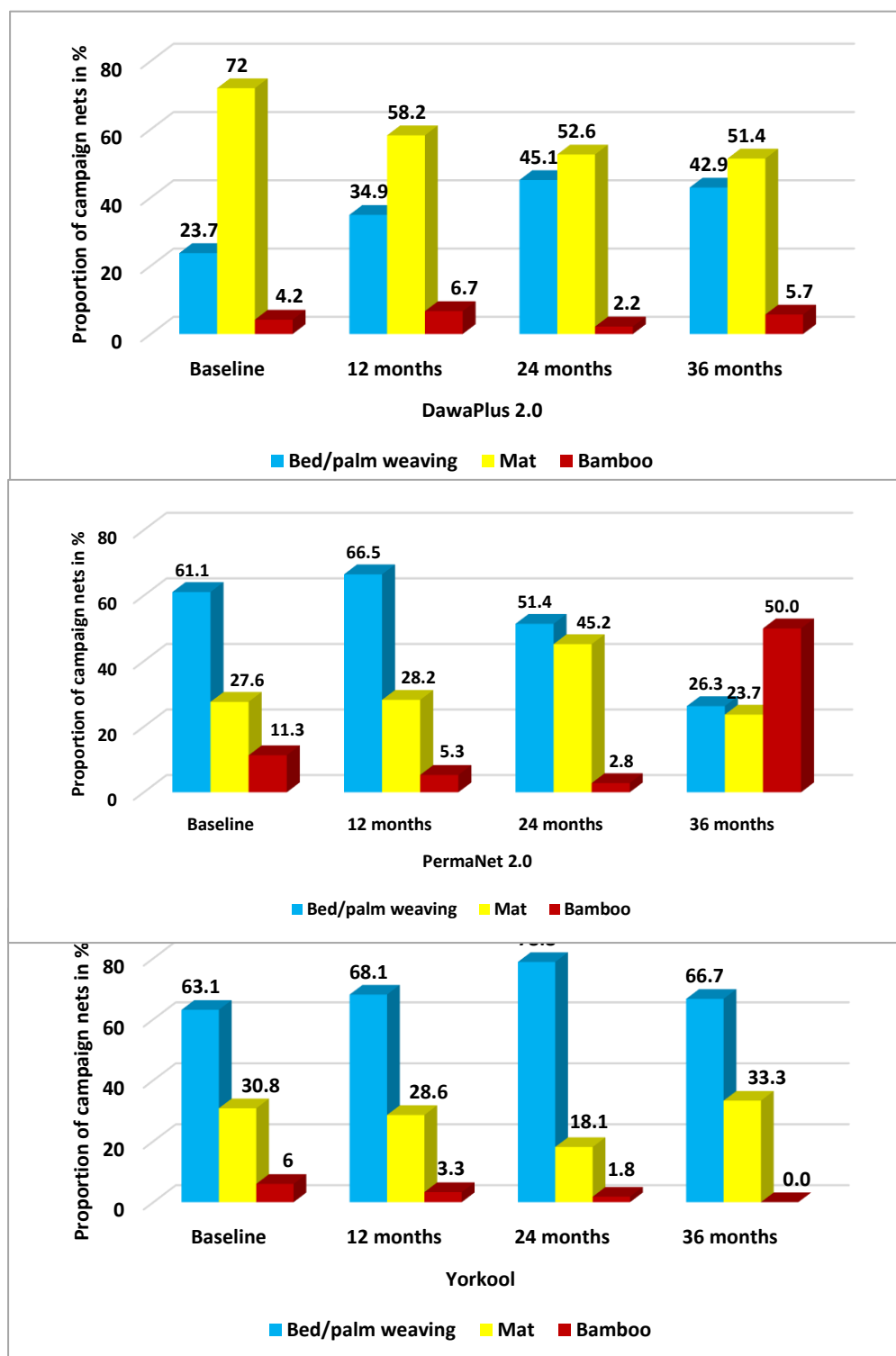
Several factors associated with the durability of LLINs have been studied. These include the following environmental factors: LLIN handling, type of sleeping space, and knowledge and attitudes about LLINs and their care. Factors that directly implicate the sleeping space environment are shown in table 2 and figure 4. Overall, the situation has not changed after 36 months of the study. Most of the fluctuations are due to variations in sample size, as direct comparison of households present for all surveys did not reveal any significant trend for most indicators. The number of households reporting the presence of rodents is very high at all sites. Cooking and possibly storing food in a room used for sleeping is believed to attract rodents, which increases the risk of mosquito damage. About 20% of households at the three sites reported storing food inside households used for sleeping. Cooking in a room where mosquito nets are hung poses a fire hazard, particularly if cooking with firewood, which was common at all three sites.

Table 3: Household risk factors

Variable and site		Baseline	12 months	24 months	36 months
PermaNet 2.0		No. 434 (95% CI)	No. 398 (95% CI)	No. 143 (95% CI)	NO.48 (95% CI)
Location of the kitchen	Outside	88.2 (84.8-91.1)	69.6 (64.8-74.1)	90.6 (86.6-93.7)	81.6 (75.49-86.44)
	Inside	11.8 (8.9-15.1)	30.4 (29.5-33.4)	9.4 (8.3-11.5)	18.4 (13.55-24.50)
Rodents observed (last 6 m)		99.2	99.4	98.1	73.7
Yorkkool		No. 480 (95% CI)	No. 460 (95% CI)	NO.345 (95% CI)	No.37
Location of the kitchen	Outside	97.0 (95.1-98.4)	91.1 (88.1-93.5)	78.5 (73.9-82.7)	96.9 (93.25-98.64)
	Inside	3.0 (1.6-4.8)	8.9 (6.5-11.9)	21.5 (17.4-26.0)	3.0 (1.35-6.74)
Rodents observed (last 6 m)		86.8	98.3	97.7	100
DawaPlus 2.0		No. 475 (95% CI)	No. 413 (95% CI)	No.174 (95% CI)	No.31
Location of the kitchen	Outside	94.5 (92.0-96.4)	80.6 (76.5-84.3)	61.9 (55.6-67.8)	94.3 (90.23-97.01)
	Inside	5.5 (3.6-7.9)	19.4 (15.6-23.5)	38.1 (32.1-44.3)	5.7 (2.98-9.76)
Rodents observed (last 6 m)		95.4	100	99.2	94.3

Total LLIN		No. 1389 (95% CI)	No. 1271 (95% CI)	NO.662 (95% CI)	No.116
Location of the kitchen	Outside	93.4 (92.0-94.7)	80.9 (78.7-83.1)	77.6 (74.8-80.3)	90.9 (84.7-95.78)
	Inside	6.6 (5.3-7.9)	19.1 (16.9-21.3)	22.4 (19.6-25.1)	9.0 (4.2-15.28)
Rodents observed (last 6 m)		93.4	99.1	98.2	89.3

Figure 4: Main type of sleeping place for campaign nets if used



For sustainability risk factors associated with handling LLINs, see Table 4. Throughout the study, almost all of the nets were found loosely suspended above the sleeping space. during the day (if suspended), which increases the risk of deterioration. The same observation was made on the three sites. On the other hand, the risk of deterioration of mosquito nets due to drying outside in the sun or in the shade was no less important and concerned between 5% and 405% of the mosquito nets washed in Djougou, 2% and 33% of the mosquito nets washed in Ketou and between 1% and 31% of mosquito nets washed in Dogbo.

Table 4: Handling of campaign net

Variables	Baseline	12 months	24 months	36 months
Yorkool (DJOUGOU)				
Hanging nets NOT folded or tied	84.20%	80.8% %	76.8% %	52.2%
Net dried on fence or bush	3.60%	39.80%	22%	47.8%
Median washed last 6 m	4(4-4)	4(1-4)	4(1-4)	4(4-4)
Used detergent/bleach for wash	4.80%	23.20%	41.60%	10.1%
DawaPlus 2.0 (KETOOU)				
Hanging nets NOT folded or tied	64.60%	68.2% %	81.9% %	53.2%
Net dried on fence or bush	33.40%	22.20%	3.60%	46.8%
Median washed last 6 m	4(2-4)	1(1-4)	4(4-4)	4(4-4)
Used detergent/bleach for wash	30%	23%	26.20%	1.6%
PermaNet 2.0 (DOGBO)				
Hanging nets NOT folded or tied	50.80%	82.7% %	81.3% %	49.4%
Net dried on fence or bush	31.80%	30.60%	8.4% %	50.6%
Median washed last 6 m	4(4-4)	1(1-4)	4(4-4)	3(1-4)
Used detergent/bleach for wash	11%	16.80%	21.40%	10.1%

6.4 Net Use and Ownership

This part deals with the use and possession of LLINs from the distribution campaign and other mosquito nets present in the households of the sample: their source, the place where they are used, the people who use them and the rate. possession at the time of the study.

From the start of the study, two months after distribution, the proportion of mosquito nets from the distribution campaign suspended in households was very high and similar in the three sites ($p > 0.05$). The proportion of mosquito nets hung varied regularly during the study, but the difference between the periods was not remarkable after 36 months, (74-90%) on average (all LLINs combined) against 76.7% of mosquito nets hung at the start of the study. study ($p > 0.05$).

A large number of mosquito nets from the distribution campaign had also been unhooked or folded, more in the commune of Ketou (17.1%). Typically, if a mosquito net was hung, it was also used and had been used regularly during the previous week. This fact was confirmed in the last survey, for which the rate of daily use of the previous week was found to be higher and even very sometimes as in previous surveys. This finding does not apply to other household mosquito nets and is probably explained by the poor condition of the nets, and not by a general reluctance to use nets.

Table 5: Suspension and use of campaign nets from the cohort

	Baseline	12 months	24 months	36 months
DawaPlus 2.0				
Hanging	73.5	68.5	79.7	74.3
Taken down or stored	19.8	11.1	16.5	17.1
Still in package	6.7	20.5	3.8	8.6
Used every night (last week)	95.16	61.6	29.3	75.9
PermaNet 2.0				
Hanging	66.4	83.5	80.4	81.8
Taken down or stored	8.4	10.0	7.5	2.6
Still in package	25.2	6.5	12.1	15.6
Used every night (last week)	66.14	83.5	55.1	84.1
Yorkool				
Hanging	90.2	81.0	76.5	90.0
Taken down or stored	8.3	15.2	20.7	6.1
Still in package	1.5	3.8	2.8	3.0
Used every night (last week)	95.41	90.5	85.4	100

The source of the mosquito nets presents a similar dynamic: at 12 months, a significant part of the mosquito nets outside the cohort came from public sources (92% to 100% in the three communes). Private sector nets played a minimal role in all three communities, and the relative contribution of this source has remained constant over time. Although we did not take it into account, the finding is that there was a high rate of suspension and use of non-cohort nets throughout the study.

Table 6: Possession of mosquito nets other than those in the countryside and source of these nets

Variable and site	Baseline	12 months	24 months	36 months
Yorkkool (DJOUGOU)				
Household has any other net	54.55%	60.00%	51.52%	72.5%
Public sector source	100%	95.83%	98.53%	100%
Source private sector	0%	4.17%	1.47%	0%
Source family, friends, NGO	0%	0%	0%	0%
DawaPlus 2.0 (KETOU)				
Household has any other net	75.00%	66.09%	65.85%	82.3%
Public sector source	100%	100%	96.30%	100%
Source private sector	0%	0%	3.70%	0%
Source family, friends, NGO	0%	0%	0%	0%
PermaNet 2.0 (DOGBO)				
Household has any other net	81.63%	98.28%	75.00%	92.4%
Public sector source	97.50%	100%	92.59	100%
Source private sector	2.50%	0%	7.41	0%
Source family, friends, NGO	0%	0%	0%	0%

The mode of use of the cohort's LLINs, and non-cohort nets, did not change much over time, as shown in Tables 7. The modes of use were similar at the three sites, the majority of the nets being used only by adults and children at a time. No significant difference was observed between the mode of use of the cohort nets and that of non-cohort nets.

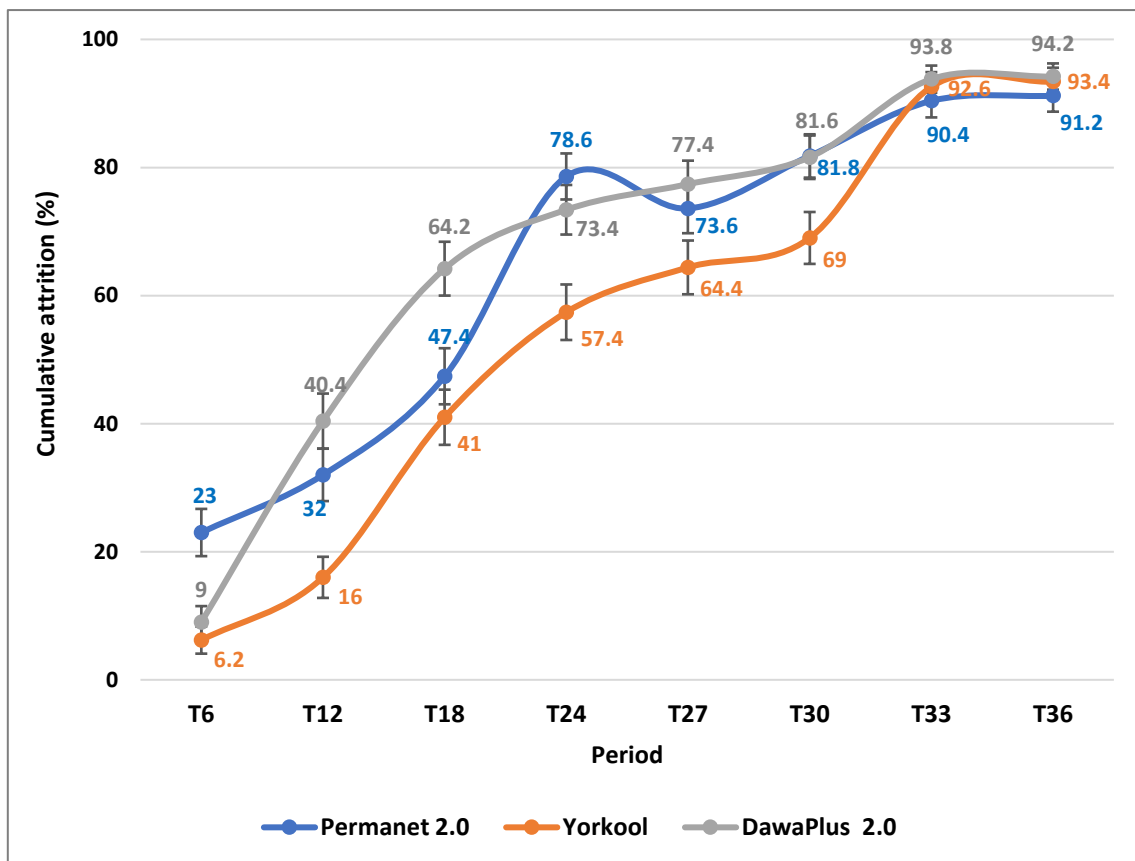
Table 7: Net users of Campaign net cohort

Variables	Baseline	12 months	24 months	36 months
Yorkkool (DJOUGOU)				
Children only	0.64%	2.64%	13.74%	9.1%
Children - adults	61.83%	47.49%	48.90%	66.7%
Adults only	37.53%	49.87%	37.36%	24.2%
DawaPlus 2.0 (KETOU)				
Children only	0.44%	3.33%	17.95%	2.9%
Children - adults	88.35%	72.22%	35.90%	77.1%
Adults only	11.21%	24.44%	46.15%	20.0%
PermaNet 2.0 (DOGBO)				
Children only	2.08	0.72%	5.08%	2.6%
Children - adults	58.70%	65.23%	33.90%	50.0%
Adults only	39.22	34.05%	61.02%	47.4%

6.5 Durability of campaign LLINs

See figure 5 for the all-cause loss rate. These figures only include nets whose status is known with certainty. The rate of losses from all causes was very high after 36 months of follow-up in all the sites with no difference between the LLINs ($p > 0.05$).

figure 5: Losses from distribution (including nets lost between the campaign and the start of the study)



As might be expected, the proportion of LLINs still present in the households surveyed and showing signs of deterioration initially increased rapidly, and exponentially, with the number of old discarded nets increasing (Table 8). As previously indicated, the rate of mosquito nets showing deterioration was systematically higher in the plateau ($p < 0.05$) compared to Djougou and Dogbo. The level of deterioration of the nets with holes, but not yet rejected, was however similar in the three sites regardless of the follow-up period ($p > 0.05$). The decrease in the proportion of mosquito nets in good condition was just as similar at the three sites ($p > 0.05$), but with the highest rate of mosquito nets in good condition in Djougou.

Table 8: Physical condition (integrity) of surviving cohort nets (proportionate Hole Index pHI)

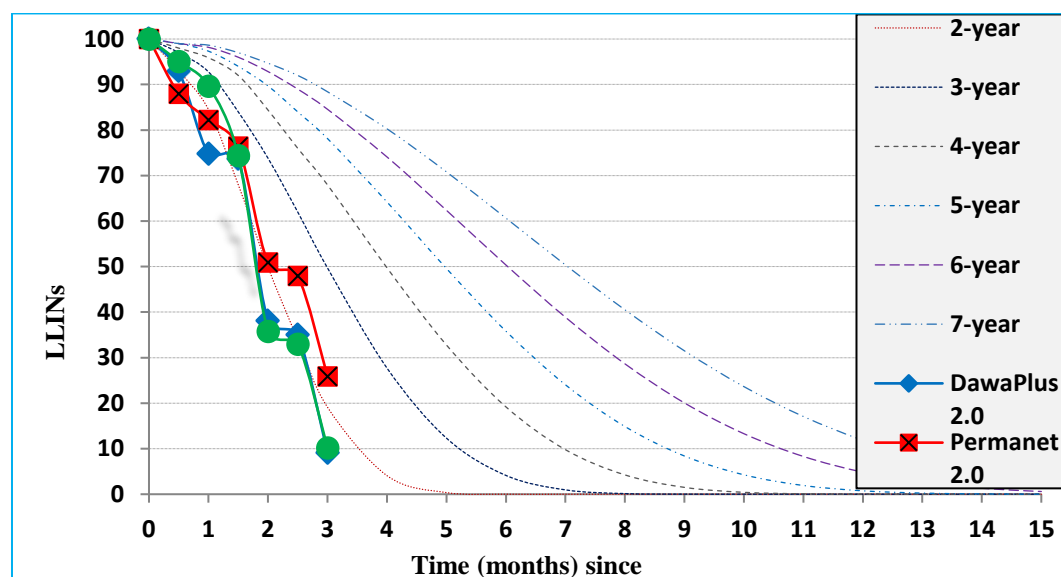
Different Brands		6 months	12 months	24 months	36 months
DawaPlus 2.0		No.475	No.413	No.174	No.72
		% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)
Net has any hole		2.9(1.6-4.9)	9.2(6.6-12.4)	39.0(31.8-46.7)	37.9(20.7-57.7)
Physical condition (pHI)	Good (0-64)	97.3(95.4-98.5)	95.6(93.2-97.4)	72.9(3.6-11.7)	65.5(45.7-82.1)
	Damaged (65-642)	2.1(1.0-3.8)	3.3(1.8-5.6)	16.6(11.1-23.0)	17.2(5.8-35.8)
	Torn (642)	0.6(0.1-1.8)	0.9(0.2-2.4)	10.3(6.2-15.8)	17.2(5.8-35.8)
	Serviceable (0-642)	99.4(98.5-99.8)	99.0(97.5-99.7)	89.6(84.1-93.7)	82.8(64.2-94.2)
Median pHI if any hole (IQR)		578(196-611)	48(7-284)	219.5(49-700)	318.0(147.0-1030.0)
PermaNet 2.0		No.434	No.398	No.143	No.89
		% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)
Net has any hole		1.8(0.7-3.5)	6.0(3.9-8.8)	19.5(13.4-27.0)	72.7(57.2-85)
Physical condition (pHI)	Good (0-64)	98.4(96.7-99.3)	97.7(95.7-98.9)	87.4(80.8-92.4)	47.7(32.5-63.3)
	Damaged (65-642)	0.9(0.2-2.3)	1.7(0.7-3.6)	9.7(5.4-15.8)	31.8(18.6-47.6)
	Torn (642)	0.6(0.1-2.0)	0.5(0.0-1.8)	2.7(0.7-7.0)	20.5(9.8-35.3)
	Serviceable (0-642)	99.3(97.9-99.8)	99.4 (96.5-100)	97.2(92.9-99.2)	79.5(64.7-90.2)
Median pHI if any hole (IQR)		578(398.5-767)	42.5(14.5-215)	243(46-463.5)	196.5(49.5-684)
Yorkool		No.480	No.460	No.345	No.80
		% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)
Net has any hole		1.0(0.3-2.4)	5.4(3.5-7.9)	13.9(10.4-18.0)	33.3(18-51.8)
Physical condition (pHI)	Good (0-64) (152)	99.1(97.8-99.7)	97.3(95.5-98.6)	92.1(88.8-94.7)	81.8(64.5-93)
	Damaged (65-642)	0.2(0.0-1.1)	2.1(1.0-3.9)	6.0(3.8-9.1)	18.2(7-35.5)
	Torn (642)	0.6(0.1-1.8)	0.4(0.0-1.6)	1.7(6.4-3.7)	0(0-10.6)
	Serviceable (0-642)	99.3(98.1-99.8)	99.5(98.4-99.9)	98.3(96.2-99.3)	100(89.4-100)
Median pHI if any hole (IQR)		843(392-854)	48(23-219)	74.5(25-323.5)	62.5(46.0-330)
Total LLIN		No. 1389	No. 1271	No.662	No.241
		% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)
Net has any hole		1.9(1.3-2.8)	6.8(5.5-8.3)	21.7(18.6-25.0)	47.9(32.1-63.5)
Physical condition (pHI)	Good (0-64)	98.3(97.4-98.8)	9.6(8.1-11.4)	86.1(83.2-88.6)	65(45.0-82.1)
	Damaged (65-642)	1.0(0.6-1.7)	2.4(1.6-3.4)	9(7.5-12.1)	22.4 (8.5-32.2)
	Torn (642)	0.6(0.2-1.2)	0.6(0.2-1.2)	4.2(2.8-6.0)	12.7 (8.5-17.5)
	Serviceable (0-642)	99.3(98.7-99.7)	99.4(98.7-99.7)	95.7(93.9-97.2)	87.5 (82.3-97.4)
Median pHI if any hole (IQR)		578(219-843)	46(23-225)	196(46-524.5)	197.0(49.0-666.0)

(pHI - proportional hole index)



In all communities, survival rates declined exponentially over time, with the most dramatic decline occurring after 3 years (Figure 5). In Ketou, the survival rate increased from 92.9% [95% CI (90.3-95.1)] at baseline to 9.1% [95% CI (4.1-15.3)] after 36 months for DawaPlus 2.0. Likewise, the survival rate decreased at Dogbo from 88.0% [95% CI (84.7-90.8)] at month 6 to 25.9% [95% CI (18.8-34.2)] after 36 months for PermaNet 2.0 LLINs. In Djougou, Yorkool LLINs had a survival rate of 95.1% [95% CI (92.2-96.8)] at the 6th month against 10.2% [95% CI (7.1-14)] after 3 years (figure 5).

Figure 5: Survivorship of the three types of LLINs at 6, 12, 18, 24, 30 and 36 months according to the NetCalc model



In addition to the estimate of median survival at each time point in Figure 5, survival was also calculated from the last two data points (see "Methodologies") and the results are shown in Table 9.

The calculated median survival was 1.9 years in Ketou (DawaPlus 2.0 LLIN), 2 years in Dogbo (PermaNet 2.0) and 1.10 years in Djougou (Yorkool LLIN). The estimates in Figure 5 were very similar to those calculated in the last survey, but they also show that, in this context, the previous figure estimates at 12 and 24 months were comparable to the final estimates. Taking into account the confidence intervals for median survival, the LLINs tested at all three sites are clearly below the three-year mark.

Table 9: Estimated median survival of LLIN in years using different methods

Variable	12 months	24 months	36 months
(DawaPlus 2.0) Ketou			
Estimated from Figure 5	1.8	1.8	1.9
Calculated from last two data points (95% CI)			1.9 (1.6-2.3)
(PermaNet 2.0) Dogbo			
Estimated from Figure 5	2.7	2	2
Calculated from last two data points (95% CI)			2 (1.9-2.5)
(Yorkool) Djougou			
Estimated from Figure 5	4.7	1.8	1.10
Calculated from last two data points (95% CI)			1.10 (1.7-2.3)

Relationship between pHI and factors contributing to the appearance of holes

Table 10 shows some factors that contribute to the appearance of holes. It was found that the Energy used for cooking, LLIN maintenance, LLIN user did not have a significant impact during the 36 month assessment ($p > 0.05$). In contrast, the frequency of washing and the frequency of use are factors that have a direct impact on the appearance of holes in the LLINs ($p < 0.05$). Figure 6 illustrates pHI as a function of each LLIN over time.

Table 10: Relationship between pHI and some factors after 36 months

Modalities	PermaNet 2.0		DawaPlus 2.0		Yorkkool	
	Mean pHI	Groups	Mean pHI	Groups	Mean pHI	Groups
Charcoal	446.5556	a	0.00000	a	115.27273	a
Wood	255.4571	a	283.74074	a	45.36364	a
Never	526.6875	a	722.14286	a	16.61538	a
2-5 time	410.0000	ab	163.00000	b	49.00000	a
One time	142.8077	b	81.33333	b	105.31579	a
Dirty	308.5714	a	333.41176	a	61.44000	a
Clean	0.0000	a	166.08333	a	91.25000	a
Not at all	1153.2000	a	1939.00000	a	-	-
Often	292.0000	b	313.20000	b	-	-
Every night	178.6486	b	100.77273	b	-	-
Children only	550.0000	a			139.00000	a
Children/Adults	344.0952	a	306.44000	a	56.27273	a
Adults	220.6667	a	0.00000	a	76.37500	a

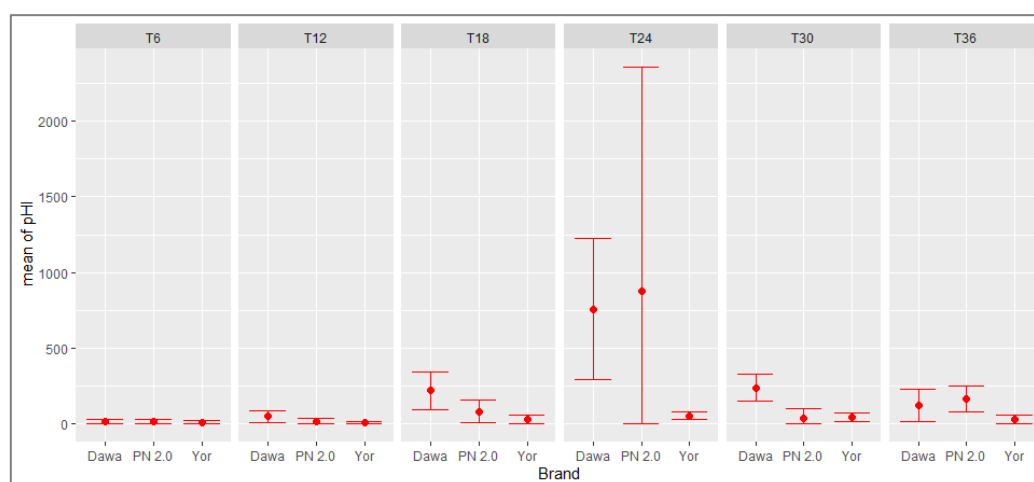


Figure 6: Physical integrity of LLINs during follow-up

6.6 Insecticidal effectiveness of net

The target of sampling 50 mosquito nets from the distribution campaign per site for bio-testing was achieved for each survey (see Table 13). No LLIN brand maintained optimal efficacy during two years of study, the insecticidal efficacy of LLIN brands only remained optimal until the 18th month data point, before dropping considerably, with a median shock effect rate around 82% and a similar median vector mortality rate. About 20% of the samples showed optimal insecticidal efficacy compared to almost 90% minimum efficacy. Few LLINs failed the tests with the lowest criteria.

Table 13: Results from bio-assays

Variable	Baseline	6 months	12 months	24 months
PermaNet 2.0				
	No.50	No.50	No.50	No.50
KD 60min (CI-95%)	98.5% (97.6-99.3%)	98.9% (98-99.7%)	97.9% (96.7-99%)	84.6% (81.8-87.3%)
Median IQR	100% (100-97.6%)	100% (100-98.5%)	100% (100-96.9%)	82.1% (93.2-78%)
Mortality 24h (CI-95%)	95.6% (94.5-96.7%)	94.2% (93.1-95.4%)	92% (89.7-94.3%)	82.2% (80.2-84.2%)
Median IQR	96.3% (98.1-92.7%)	94.4% (96.6-91.8%)	93.8% (100-87.2%)	83.3% (87.8-75.3%)
Optimal effectiveness	89.8% (77.8-96.6%)	93.5% (82.1-98.6%)	72.3% (57.4-84.4%)	17.6% (8.4-30.9%)
Minimal effectiveness	100% (92.7-100%)	100% (92.3-100%)	100% (92.5-100%)	88.2% (76.1-95.6%)
Yorkkool				
KD 60min (CI-95%)	98.1% (96.8-99.4%)	96.5% (95.2-97.9%)	97.1% (96.5-97.8%)	82.5% (78.3-86.7%)
Median IQR	100% (100-97.4%)	97.7% (100-95.2%)	97.1% (100-95.6%)	82.2% (95.2-73.2%)
Mortality 24h (CI-95%)	93.1% (91-95.2%)	95.6% (94.3-96.8%)	83% (81.9-84.1%)	88.9% (86.7-91%)
Median IQR	95.7% (98-91.2%)	97.5% (97.8-94.4%)	82.2% (86-79.4%)	90.4% (94.6-85.3%)
Optimal effectiveness	84.8% (71.1-93.7%)	75% (60.4-86.4%)	60% (45.2-73.6%)	13.6% (5.2-27.4%)
Minimal effectiveness	100% (92.3-100%)	100% (92.6-100%)	100% (92.9-100%)	63.6% (47.8-77.6%)
DawaPlus 2.0				
KD 60min (CI-95%)	99.1% (98.6-99.6%)	99.3% (98.6-100.1%)	92.6% (91.2-94%)	85.5% (83.7-87.4%)

	100% (100-97.9%)	100% (100-100%)	93.1% (96.9-89.6%)	84.1% (90.2-80.4%)
Mortality 24h (CI-95%)	96% (95.1-96.9%)	98.1% (97.2-99%)	97.9% (97-98.7%)	91.4% (89-93.8%)
Median IQR	95.5% (98-93.3%)	100% (100-97.2%)	98.4% (100-96.5%)	93.4% (98.3-85.7%)
Optimal effectiveness	100% (92.6-100%)	93.8% (82.8-98.7%)	34% (20.9-49.3%)	11.8% (4.4-23.9%)
Minimal effectiveness	100% (92.6-100%)	100% (92.6-100%)	100% (92.5-100%)	96.1% (86.5-99.5%)

7 Summary and conclusion

This report presents the findings of a 36-month sustainability tracking study that compared three brands of LLINs (DawaPlus 2.0, PermaNet 2.0 and Yorkool). These mosquito nets were distributed as part of mass distribution campaigns, in different regions with different ecological and demographic profiles throughout Benin's territory. The towns of Ketou (Department of Plateau), Dogbo (Department of Couffo) and Djougou (Department of Donga) were randomly selected to serve as the study site. At the start of the study, 3 months after the massive distribution campaign of 2017, a cohort of households representative of the selected areas was recruited and a net from the campaign belonging to these households (the mosquito nets of the cohort) were labeled. These households and the mosquito nets in the cohort were then monitored semi-annually in the first year and quarterly in subsequent years after distribution. This report presents the baseline and 12, 24 and 36 month results.

Sample and follow-up

For each site, the objective was to recruit 250 households per arrondissement in each commune and a cohort of 500 mosquito nets / commune, from the distribution campaign, the household being the sampling unit. The goal in terms of mosquito nets has been reached.

During the three follow-up surveys, the status of 29 nets of the cohort out of 500 could be established in Ketou (5.8%); 62% of the nets were lost to follow-up because the households had moved, the rest because the households were absent at the time of the survey or did not know where the nets were. In Djougou, the proportion of mosquito nets in the cohort whose status could be established with certainty was 6.6%, or 33 mosquito nets out of 500. The finding was not better in Dogbo where we had only 8% or 44 out of 500 LLINs present to be evaluated. The status of some mosquito net could not be established because households had moved for several other reasons.

Demographic and socio-economics characteristics

In order to compare the sustainability of the three brands of LLINs, it was necessary that the other factors that could influence sustainability be constant and that the demographic and socio-economic characteristics of the chosen sites were very similar. The results confirm that the three sites were very similar and that any differences were unlikely to significantly affect sustainability.

At all three sites, the construction of the houses was similar and very simple. There were about 57.7% of roofs made with, 37.9% of walls built with clay-based mud and about 5.1% of earth or clay soils. Almost all households use firewood for cooking (31.8-44.3), have access to simple pit latrines, and drink surface water from rivers and streams or from collective unprotected wells.

The socioeconomic situation of the three sites was also very similar. Household goods were limited to radios (9%) and cell phones. Means of transport included bicycles and motorbikes (15%) in Dogbo and more than 29 and 24% in Ketou and Djougou Household income came mainly from agriculture and livestock.

Durability risk factors

Several behavioral factors that are known or suspected to be related to the deterioration of nets have been monitored. These factors include four categories: the environment in which the nets are used in households, the handling of the nets, the type of sleeping space, and the knowledge and attitudes about net care and repair. For the first category, no difference was observed: very few households at each site stored food in a room used for sleeping, more than 89% reported traces of rodents and very few cooked in the rooms used for the bed itself ($p>0.05$). The pattern of mosquito net use was very similar at all three sites, with a low proportion of mosquito nets (around: 2-9%) used exclusively by children. Handling of the mosquito nets was also very similar: almost all households never folded up hanging mosquito nets and few households dried their mosquito nets on shrubs.

Net hanging and use

The suspension and use of nets from the sustainability monitoring cohort cannot be interpreted without taking into account the presence of nets from other sources in households. From the start, and throughout the study, households had a considerable number of other nets in their possession. New mosquito nets were constantly arriving in households, so much so that, in the

last survey, 72.5% of households in Djougou, 82.3% of those in Ketou and 92.5% of those in Dogbo had non-cohort nets.

Immediately after distribution, a considerable proportion of the mosquito nets in the cohort were hung up (74% in Ketou, 66% in Dogbo, and 90% in Djougou), but at this point the rate of use of other nets was likely high. After 12 months, the situation had changed and the cohort nets were now used more often (69%, 84% and 81%) than the non-cohort nets. However, as the nets from the distribution campaign began to deteriorate and the lot of nets decreased, the suspension and use of all three types of nets became more common. Throughout the study, suspension and use rates were high at all sites, but no seasonal net use was observed.

Physical durability outcomes

After 36 months, the loss from all causes was 90% all sites. This figure are exceptional, as lower rates (56% and 74%) were observed in another study supported by the VectorWorks project in Mozambique. In the different sites, the mosquito nets were recycled to protect the doors and windows, and other mosquito nets from the distribution campaign were used for fishing, animal husbandry and even sale.

Although significant differences were observed in the rejection rate of used and torn nets between the three sites, the physical condition of the remaining nets was very similar. During the last survey (36 months after distribution), 17.2% (Ketou), 20.5% (Dogbo) and 0% (Djougou) of the mosquito nets were torn and impossible to repair, but still used. The level of deterioration of the mosquito nets with holes was significant at the three sites, but even more in the commune of Dogbo (72.5%) ($p < 0.0001$), which suggests that the nets were not rejected prematurely, but only when 'they were badly damaged.

During the last survey, the overall rate of remaining and repairable mosquito nets was 17.2% in Ketou, 31.8% in Dogbo and 18.2% in Djougou. Median survival was 1.9 years for DawaPlus 2.0 in Ketou, 2 years for PermaNet 2.0 in Dogbo, and 1.10 years for Yorkool, three results well below the expected median 3-year survival. Survival analysis with the NetCalc model confirmed this result (Figure 5).

Insecticidal durability outcomes

We haven't done any testing here after 33 months. The results of bioassays are those obtained after 2 years of follow-up. No brand of LLINs maintained optimal efficacy during two years of study, the insecticidal efficacy of brands of LLINs remained optimal only up to the 18th month

data point, before dropping considerably, with a rate of median shock effect around 82% and a similar median vector mortality rate. About 20% of the samples showed optimal insecticidal efficacy against almost 90% minimum efficacy. Few LLINs failed the tests with the lowest criteria.

Limitations

Some of the risk factors for sustainability, such as attitude towards net maintenance and repair, as well as some findings, such as the reason for net losses, were based on responses from household members interviewed and therefore subject to recall or social desirability biases. Furthermore, even though the sample of the net cohort from the campaign was representative of the health zones selected in each province, the health zones were chosen by means of directed sampling and therefore caution should be exercised before generalizing the findings across the country.

Conclusion

After 36 months of follow-up in the communes of Ketou, Dogbo and Djougou, the PermaNet 2.0 LLIN in 100 denier polyester displayed a higher median survival than that of the DawaPlus 2.0 and Yorkool LLIN (in 100 denier polyester) as well. The three nets are nevertheless very far from the expected median survival of three years. It may be advisable to consider a distribution strategy with campaigns every two years or an ongoing distribution strategy with a communication plan to minimize the risk of loss and tear. Insecticidal efficacy was relatively acceptable by WHO standards after two years of use.