FINAL REPORT
After 36 months follow-up
JUNE 2019

Durability Monitoring of LLINs in **Zanzibar, Tanzania**

USAID FROM THE AMERICAN PEOPLE

CDC CENTERS FOR DISEASE CONTROL AND PREVENTION

U.S. President's Malaria Initiative

VECTORWORKS
Scaling Up Vector Control for Malaria Prevention

KITENGO CHA KUMALIZA MALARIA ZANZIBAR

JOHNS HOPKINS Center for Communication Programs

TROPICAL HEALTH

Photo credits: Kanuth Dimoso and Hannah Koenker, PMI VectorWorks Project 2018.

1 Abstract

Background: Malaria prevention with long-lasting insecticidal mosquito nets (LLIN) has seen a tremendous scale-up in sub-Saharan 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 they 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 LLIN with different specifications, were distributed in the 2016 mass distribution campaign in Zanzibar, over three years. They were set up in two ecologically similar districts in Unguja and Pemba, Zanzibar. The Zanzibar Malaria Elimination Programme, with support from the VectorWorks project and PMI, carried out the activity.

Methods: This prospective cohort study had representative samples of households from each district, which 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 299 households (99% of target) and 834 campaign nets (121%) were included in the study. Definite outcomes could be determined for 86% of the cohort nets in Unguja and 89% in Pemba. Outcome measures for physical durability were attrition (all-cause attrition and attrition from wear and tear) and physical integrity, based on the proportionate Hole Index (pHI) and subsequent categorization of cohort nets as serviceable (pHI<643). These 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 (time until 50% of cohort nets with known outcomes were no longer serviceable). In addition, 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 and tunnel tests) from sub-samples of campaign nets; it is defined as the proportion of nets that showed optimal insecticidal effectiveness (24-hour mortality of ≥80% or 60-minute knockdown of ≥95% for cone test and >80% mortality or >90% feeding inhibition for tunnel test). In addition, demographic, socio-economic, and behavioral aspects were recorded using a structured questionnaire at each time point.

Results: The demographic characteristics of the populations were comparable between sites—typical for rural African populations—and they did not change significantly over time. House construction at both sites was similar, with approximately 95% of roofs made from grass or thatch, 65–78% of walls made from bricks or plaster, and 72% of floors made from tile. Almost all households used firewood or charcoal for cooking, had access to a pit latrine or flush toilet, and only 16% in Unguja and 10% in Pemba used surface water from rivers and creeks for drinking. The economic situation was also very similar, with a slight advantage for Pemba, mainly because of the higher coverage of household appliances.

Most durability risk factors were very similar between the two sites, with some minor differences. The only category where a significant difference was found between sites was net handling. Initially, about half the cohort nets in both sites were hanging loose over the sleeping place (not tied or folded up), if they were found hanging. However, after two years this situation had changed significantly in Pemba, with only 9%–10% hanging loose in the last two surveys. This was not seen in Unguja, where loose hanging was reduced only at the final survey and then only to 30%. Overall, only 29% of cohort nets were always found folded up in Unguja, compared to 51% in Pemba. Similarly, 33% in Unguja and 21% in Pemba were never found tied up when they were hanging. The difference between the sites in hanging status (loose versus tied or folded) was statistically significant (p=0.01).

After three years, the all-cause attrition (i.e., losses for any reason) did not vary much between sites: 45% in Unguja and 42% in Pemba. However, the proportion of losses that were due to net damage differed between the sites. In Unguja, only 5% of losses at the 12-month follow-up were due to torn nets being discarded, while this rate was 29% in Pemba. In the next two years, losses due to damage in Pemba slowed, while it accelerated in Unguja. At the endpoint, sites were a bit closer, but Pemba still had a higher proportion of losses due to wear and tear (36% versus 27%). Of the nets discarded, 49% were destroyed, 27% were thrown away, and 25% were used for other purposes, with no difference between sites. Overall, less than 3% of nets in either site were used for other purposes, and only one net in Pemba (0.2%) was used for fishing.

The physical condition of the cohort nets still found in the households was very similar between the sites and, at the final survey, 68% in Unguja and 64% in Pemba were still in serviceable condition. Overall, survival in serviceable condition at the last survey was 55% in Unguja and 51% in Pemba. Estimated median survival was 2.9 years for the PermaNet 2.0 in Unguja (95% CI 2.6–3.3) and 2.7 years for the Olyset in Pemba (95% CI 2.5–3.0). When data was analyzed as survival analysis in a Kaplan-Meier plot, the Olyset in Pemba, overall, showed a lower survival during the study, even though the final estimates were close together and this difference was statistically significant ($p<0.0001$). This was also confirmed by a Cox proportionate hazard model with a hazard ratio of 2.77 for the difference in brands (95% CI 2.00–3.78, $p<0.0001$). The models also suggest that the narrowing of the gap between the brands was largely an effect of the changes in net handing seen in the second part of the study in Pemba and not a function of the textile qualities of the LLIN.

Although cone tests results show lower and declining knockdown and mortality rates for the Olyset in Pemba, the tunnel tests gave very good results. After 33 months, 100% of both brands still demonstrated optimal insecticidal effectiveness.

Conclusion: After three years of follow-up among similar, rural populations in the Zanzibar islands of Unguja and Pemba, the 150 denier polyethylene LLIN Olyset showed significant lower physical survival compared to the 100 denier polyester LLIN PermaNet 2.0; even though, at the end, the estimated median survival was 2.7 years for the Olyset and 2.9 years for the PermaNet. The difference between the brands came from an earlier start of failures in the Olyset, which were mitigated by improved care behaviors in Pemba in the second part of the study. Insecticidal performance was optimal for both brands throughout the follow-up.

Contents

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 President's Malaria Initiative (PMI) under the terms of USAID/ JHU Cooperative Agreement No: AID-OAA-A-14-00057. The contents do not necessarily reflect the views of USAID, PMI, or the United States Government.

4 Background

Malaria prevention with long-lasting insecticidal nets (LLIN) has seen a tremendous scale-up in sub-Saharan Africa in recent years. Many countries have achieved high ownership coverage with LLIN and 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 to sustain these successes. In this context, it is important to understand how long distributed LLIN remain in households and continue to protect net users. This information is needed to decide when to replace the LLIN 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 encompasses 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 such 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 LLIN should also routinely monitor net durability. Other donors and implementing partners, such as the President's Malaria Initiative (PMI), have accepted this recommendation; they require routine monitoring of LLIN durability in the countries they support.

To-date, few published studies use the new methodology to measure the field performance of specific LLIN brands, and compare different products in the same area, or the same product in different environments. In Western Uganda, the polyester LLIN brand Interceptor was followed up for 3.5 years, with 20% of nets lost during the study period, 87% of surviving nets still in acceptable or serviceable condition, and 71% with optimal insecticidal effectiveness1. The study concludes that this LLIN had a median functional survival of 3.5 years.

In June 2015, the vector control unit of the Zanzibar Malaria Elimination Programme (ZAMEP) undertook a cross-sectional, retrospective durability assessment of Olyset LLIN in Pemba that had been distributed three years earlier, in 2012. Of 250 nets sampled from the nets previously distributed, 74% were still in use, 20% were lost due to damage, and 6% were still in their original package. Most (90%) of the nets had holes, but the study did not calculate the proportionate hole index, so the proportion of nets in serviceable condition is not reported. Bio-assays, using the cone and tunnel tests, showed that while mortality of pyrethroid sensitive *Anopheles gambiae* s.s. was only 50% in cone assays, it was 80% in the tunnel test.

In 2016, ZAMEP, with the support of its partners, launched a repeat mass campaign to maintain universal coverage with LLIN where multiple brands of LLIN were distributed. This was in addition to ongoing distribution through antenatal and immunization services, as well as through communities. Through the recently completed durability monitoring exercise, ZAMEP wanted 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.

5 Methods

The activity was carried out by the ZAMEP, with support from the VectorWorks project and PMI.

5.1 Sites

Two districts of Zanzibar, a semi-autonomous part of the United Republic of Tanzania, with similar environments, were selected: Wete district on Pemba and North B district on Unguja. See Figure 1 with the geo-location for the study clusters. Both districts are located in the northern region of the respective islands (Kaskazini Pemba and Kaskazini Unguja) and have an estimated population of 121,000 (Wete) and 50,000 (North B).

The climate is equatorial (warm and humid), with a bi-modal rain pattern: the first rainy season lasts from March to May and the second from October to December, with an average annual rainfall of 1,500–1,700 mm.

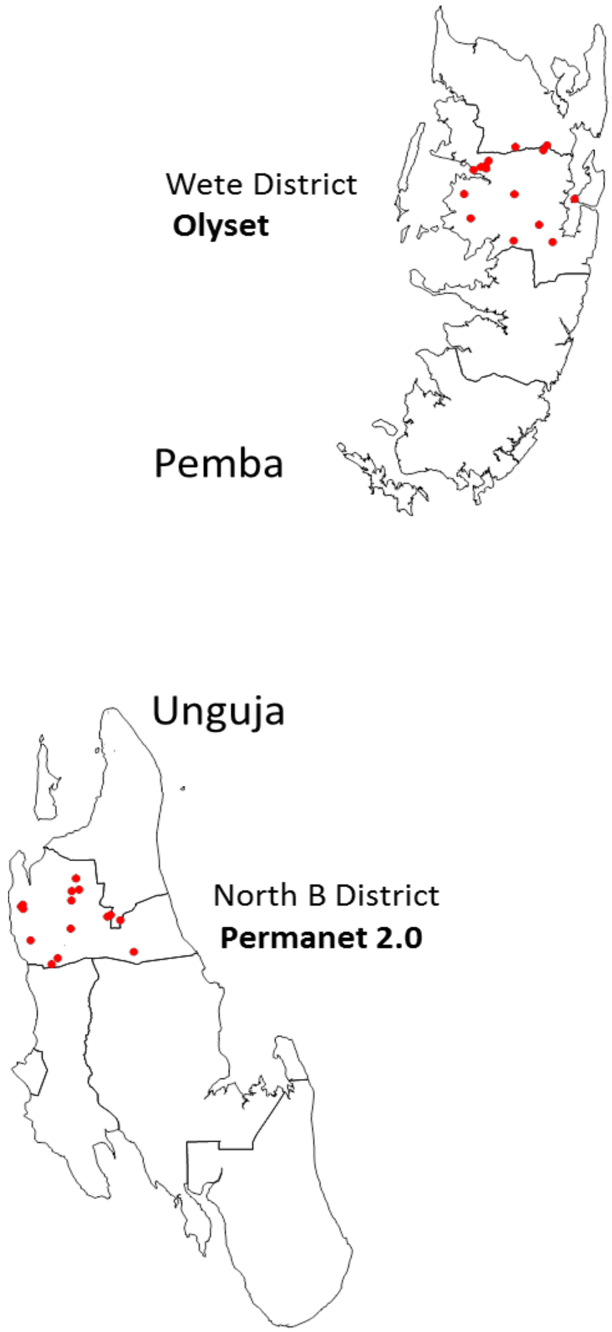


Figure 1: Site map with GPS points and LLIN brand

Based on the very long history of malaria control in Zanzibar, especially in recent years, malaria incidence and prevalence are very low. Table 1 presents some of the key malaria indicators from the 2015/16 Demographic and Health Survey (DHS).

Table 1: Malaria situation in the study areas (2015/16); HH=household

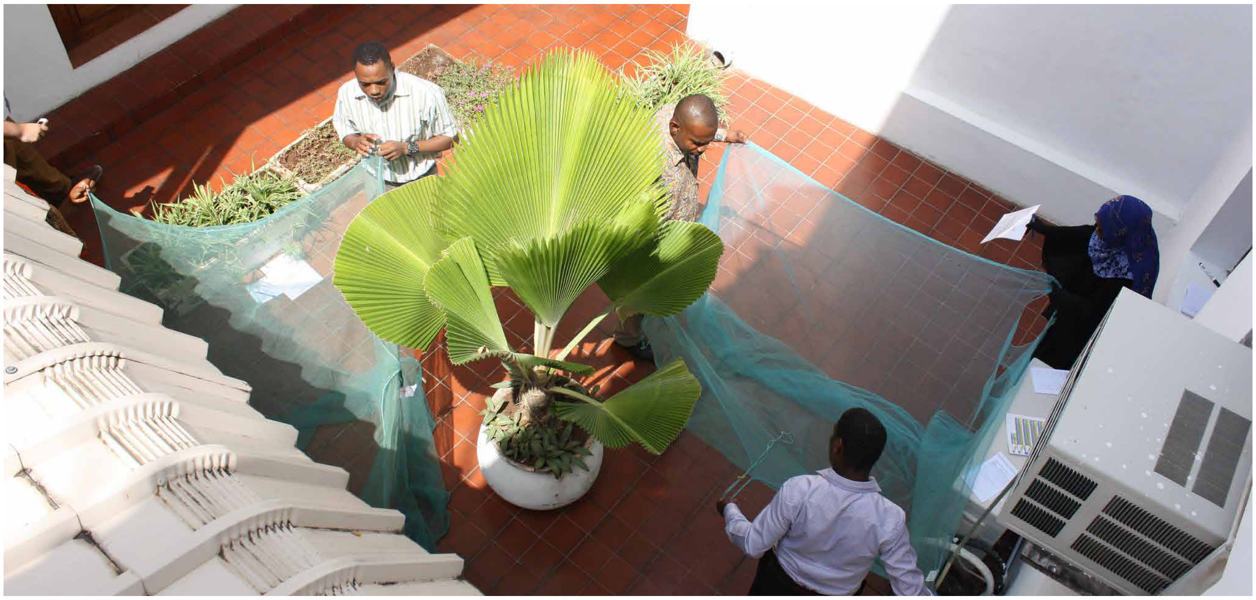
Province	Under 5s with Fever Receiving Diagnostic Test	Under 5s with Positive Malaria (microscopy)	Febrile Children Treated with Antimalarial	HH with at Least One LLIN	Population with Access to an LLIN	Population using LLIN last night
Unguja	30%	0.5%	6%	80%	68%	50%
Pemba	21%	1.1%	3%	78%	63%	55%

5.2 Brands monitored

The two brands of LLIN being monitored are—

PermaNet 2.0, a 100-denier polyester LLIN in white and blue. The LLIN uses the coating technology with a loading dose of 55 mg/m^2 of deltamethrin. PermaNet 2.0 received interim World Health Organization/Pesticide Evaluation Scheme (WHOPES) recommendation in December 2008 (12th WHOPES Report). The brand was included in the WHO pre-qualification list for vector control products in December 2017 (Ref Nr: 005–001).

Olyset, a 150-denier polyethylene LLIN in white and blue, uses incorporation technology with a loading dose of 1 g/m^2 of permethrin. Olyset received full WHOPES recommendation in July 2009 (13th WHOPES Report). WHO pre-qualification reference number is 001-004 (December 2017).



5.3 Design summary

The design generally follows PMI's guidance for LLIN durability monitoring (see www.durabilitymonitoring.org). Within six months following the mass distribution campaign, a representative cohort of campaign LLIN were sampled and labeled in each selected site and then followed up after 12, 24, and 36 months. At each time point, measures of physical durability were assessed (attrition and integrity). Except at baseline, samples were taken for an assessment of insecticidal effectiveness (bio-assay) and analyzed at the entomology laboratory of ZAMEP using a pyrethroid-sensitive strain of *Anopheles gambiae s.s.* (Kisumu). Nets that do not reach WHO criteria for optimal effectiveness (see below) were further tested in a tunnel test. At the 12- and 24-month surveys, the samples were taken from households not part of the cohort (nearest neighbor) and from the cohort at the 36-month follow-up. In the case of Zanzibar, two similar sites with two different types of LLIN brands were selected; the durability study compared two brands in areas with very similar ecological and/or behavioral characteristics.

The sample size follows the recommendation from PMI guidance with 150 households per site (15 clusters with 10 households each) and an expected number of 345 campaign nets labeled for follow-up. This sample size is targeted to detect 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 for comparing proportions in two groups with the above outlined settings was expected to result in a sample of 147 LLIN per study site, after three years. After applying the expected design effect of 2.0 and loss to follow-up of households of 5%, the required sample after three years was expected to be 279 per site. Taking into account the expected attrition rates, a sample of 345 LLIN have to be taken at baseline and, based on the expected number of LLIN distributed per household, 150 households needed to be sampled per site.

At baseline, the LLIN cohort in each district was established by selecting a representative sample of clusters (first selecting shehias and then one community in the shehias). Based on probability proportionate to size, households were selected using simple random sampling from household lists established on the day of the survey. However, as some shehias in North B district (Unguja) had previously had the mass distribution some time earlier, only the 15 shehias earmarked for the July 2016 campaign were included in the sampling frame. As soon as clusters were sampled, the local authorities and chiefs were informed of the purpose and expected time of the survey and their support was sought. To obtain maximum cooperation for the surveys, communities were then sensitized and mobilized. All LLIN received from the ZAMEP campaign by the selected households were identified and marked with a unique ID number. The physical condition of the campaign nets was measured using a hole assessment and a household interview was undertaken.

The LLIN mass distribution campaign took place in mid-July 2016 at both sites. Baseline assessments took place October 29 to November 5, 2016, in Unguja and November 8–15, 2016, in Pemba. The 12-month follow-up survey was fielded in Unguja July 24–31, 2017, and in Pemba August 2–9, 2017; the 24-month assessment was undertaken in Unguja July 2–9 and in Pemba June 24 to July 1, 2018; the final survey took place in Unguja during April 5–12 and in Pemba during March 29 to April 5, 2019. The slightly earlier dates for the 36-month survey was due to the pending close-out of the VectorWorks project.

5.4 Field work

An implementation team of nine individuals was established per site, with one overall site coordinator and two field teams each, comprising one supervisor and three interviewers. ZAMEP staff oversaw the activities in the field. Interviewers and supervisors were carefully selected to ensure they were culturally acceptable, had good knowledge of the local languages, and had experience conducting household surveys. All interviewers and supervisors for the 24-month survey participated in the 12-month survey.

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 installed. Each field team received a tablet for the household interviews and ITN 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 was 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) ITN 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, data sets were transferred to Stata version 14.0 (Stata, Texas, USA) for further aggregation, consistency checks, and preparation for analysis. Stata do-files (macros) 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 for which 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 specific household or member data were not collected.

The primary outcome measure was the **physical net survival** and was defined as—

The proportion of nets received from the ITN 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:

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

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: Measured first by the proportionate Hole Index (pHI), as recommended by WHO. Holes in the ITN of the cohort will be counted 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 was 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 m^2 or pHI<64**
Serviceable:	**total hole surface area ≤0.1 m^2 or pHI≤642**
Torn:	**total hole surface area >0.1 m^2 or pHI>642**

To 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 and defined as—

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

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

At the end of monitoring, 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, + 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 Kaplan-Meier estimates of survival function and a Cox proportionate hazard model to ease determinants of survival.

The outcomes of **insecticidal effectiveness** were based on the bio-assay results using the standard WHO cone test and an additional tunnel test if the cone test vector mortality was <80%. All tests were done at the ZAMEP facilities in Unguja (cone tests) and Pemba (tunnel test).

Five non-blood-fed, two- to five-day-old females known susceptible *Anopheles gambiae* s.s R.70, maintained at the ZAMEP insectary, were exposed for three minutes in each cone and then held for 24 hours with access to a sugar solution. Five sites were tested on each net (four sides and roof) and two replicates per location (10 cone tests with 50 mosquitoes per net in total). Knock down was measured 60 minutes after exposure and mortality was scored after 24 hours. A negative control, from an untreated net, was included in each round of cone bio-assay testing. Each piece of the LLIN was tested once, for a total of 50 mosquitoes tested per LLIN. Bio-assays were carried out at 27 ± 2° C and 80 ± 10% relative humidity. 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%.

For the tunnel test, the netting piece that resulted in mortality close to the average mortality in the cone bioassay was selected. In each netting sample, nine holes were cut that measured 1 cm in diameter, one hole was located at the center of the square, and the other eight were at the same distant and located 5 cm from the border. The LLIN piece was then held in a disposable cardboard frame.

In the shorter section of the tunnel, a rabbit was tightly held, unable to move, at 18 hours up to the end of experiment on the following day at 9.00 am. One hundred female, non-blood-fed, susceptible *Anopheles gambiae s.s,* ages between five and eight days, were introduced into the cage at the end of the longer section of the tunnel. Mosquitoes were free to fly in the tunnel, but they had to make contact with the piece of netting and locate the holes in it before passing through to reach the bait in a shorter section of the tunnel. A tunnel with an untreated netting piece with holes was used as a negative control during the test. The tunnels tests were carried out at 27 ± 2° C and 75% ± 10% relative humidity at night, in full darkness. At the end of experiment, using a sucking tube, the mosquitoes were removed from each section of the tunnel and counted separately; mortality and blood-feeding rates were recorded.

Blood-feeding inhibition was assessed by comparing the proportion of blood-fed females (alive or dead) in treated and control tunnels. Overall, mortality was measured by pooling the mortality rates of mosquitoes from the two sections of the tunnel.

The following criteria were used to evaluate the tunnel test:

Optimal effectiveness: ≥80% mortality or ≥ 90% blood-feeding inhibition.

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 Zanzibar Medical Research and Ethics Committee, Ministry of Health Zanzibar, Tanzania, (ZAMREC/0001/AUG/016).

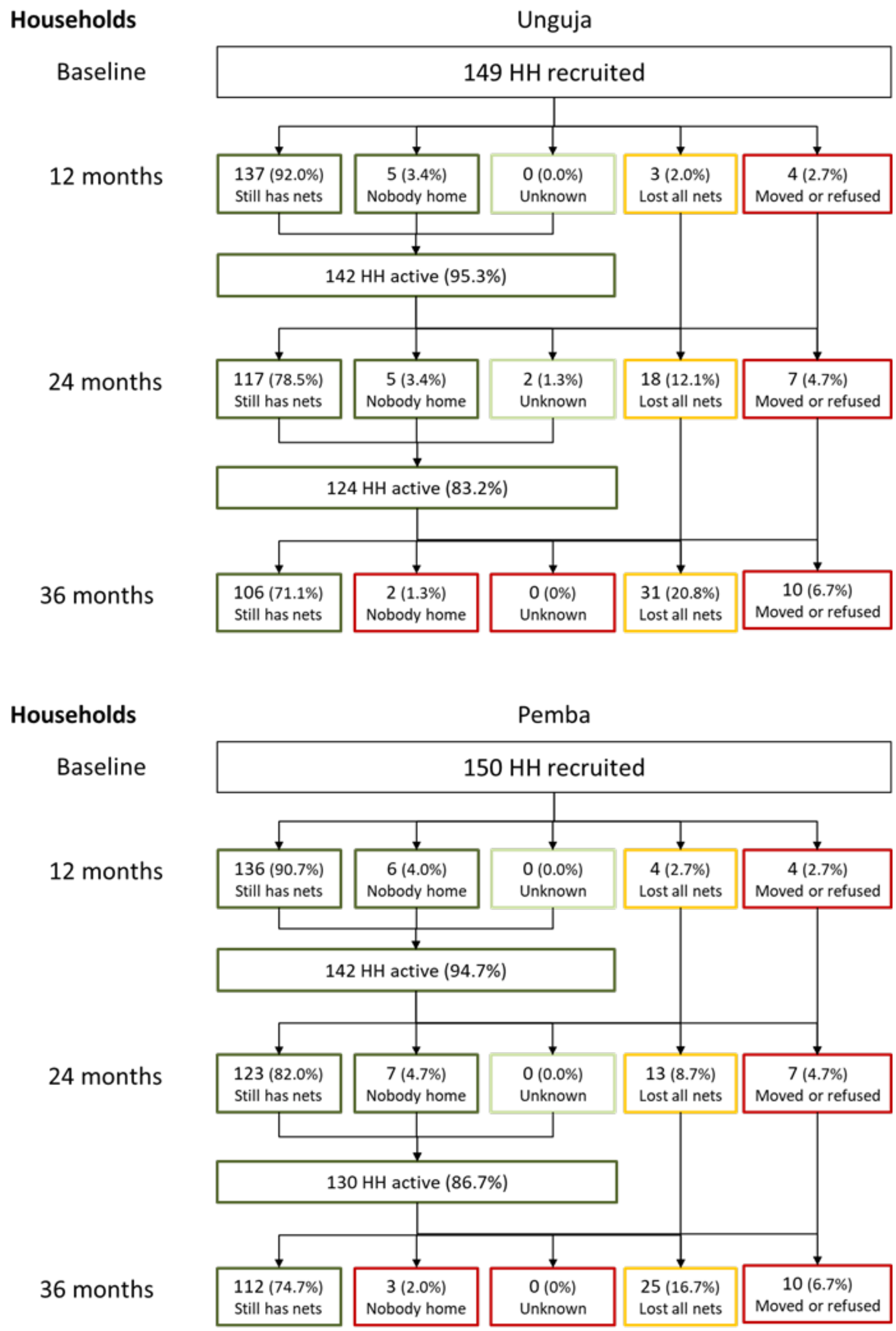
6 Results

6.1 Sample

All the targeted 300 households from 30 clusters were recruited at baseline, but one household in Unguja had already lost the LLIN it received from the campaign, so there were 299 households in the cohort for follow-up. However, the target of 345 cohort nets per site was exceeded—382 campaign nets were recruited in Unguja (111%) and 452 in Pemba (131%). See Figure 2 for a detailed summary of the recruited households and their follow-up during the study period in the two sites. Households dropped out of the study for three reasons: the most important was if they lost all their campaign nets so further follow-up was not needed. After three years, this applied to 21% of the households in Unguja and 17% of the households in Pemba. The second reason for loss to follow up was households moving away to other communities. This applied to 6% of the households in Pemba at the end of the study and 5% in Unguja. There was also some within-village migration (i.e., households moved to new homes within the village): two (1%) in Unguja and six (4%) in Pemba. These households, however, were kept in the study and the new location was recorded. The third reason for dropping out was refusal to continue participation in the study, but this was rare. Three (2%) were in Unguja and only one in Pemba.

Thanks to the excellent mobilization through the shehias leaders, the follow-up was very good; 76% of recruited households participated in all four surveys at both sites and outcomes for 98% of all still active households were determined in the final survey.

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



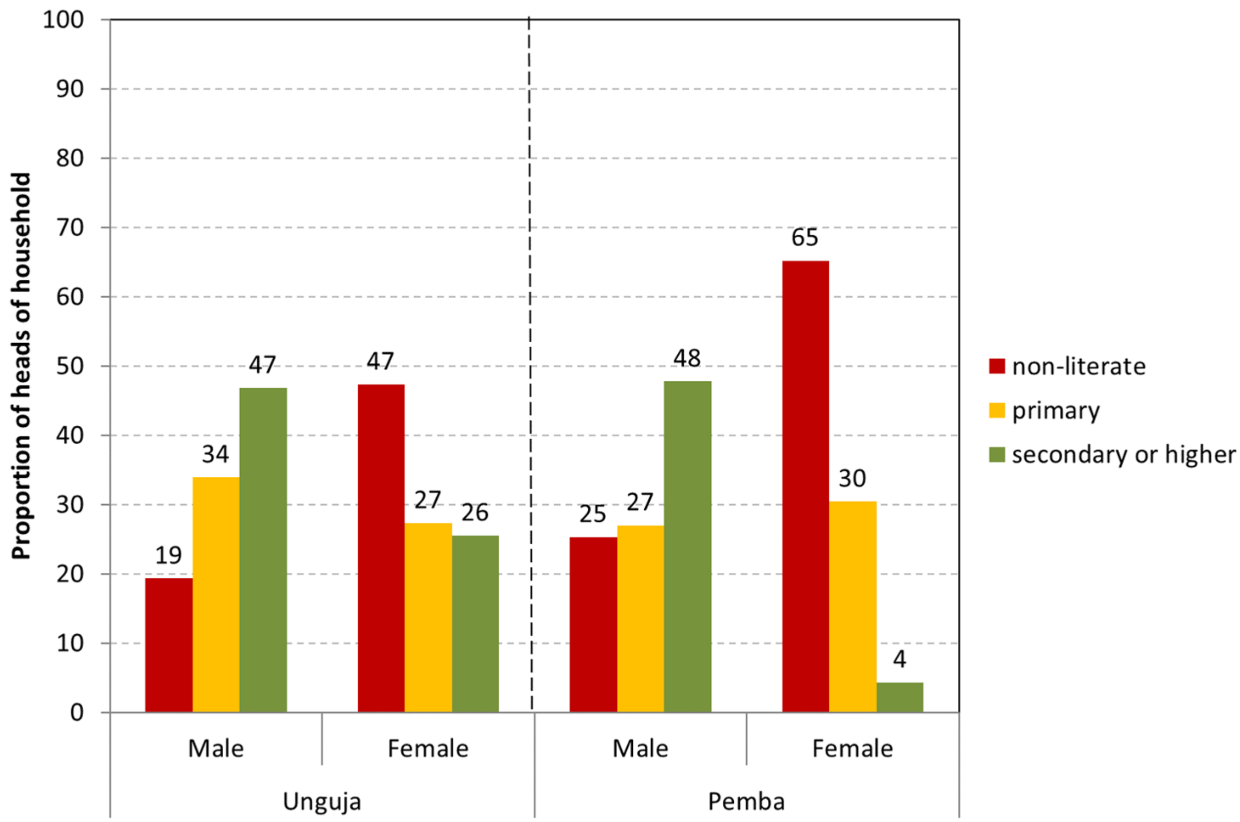
6.2 Socio-Demographic characteristics

Comparing those households that participated in the baseline and 36-month surveys (N=243), the data were explored for any demographic or socio-economic changes during the three years of the study, as well as differences between the sites.

The average number of household members remained constant, over time, at each of the sites and they averaged 5.4 persons in Unguja and 6.1 in Pemba—this difference was marginally statistically significant (p=0.0.5). The proportion of households headed by females was consistent over time and was higher in Unguja (24%) compared to Pemba (11%, p=0.02). The mean age of male heads of household at baseline was 45 years in both sites and that of female heads was 51 years. Not surprisingly, the mean age was 3–4 years higher at the 36-month survey, 48 and 55 years, respectively. The population structure, as measured by the proportion of children less than 5 years of age, also did not change over time and was 15% in Unguja and 18% in Pemba (p=0.1).

Educational status of the head of household did not change over time and was very similar between the two sites. Male heads of household had a relatively high proportion (47–48%) of at least some secondary education (Figure 2a). The educational level of female heads of household was significantly lower than that for males (p<0.0001), with 47% of female heads non-literate in Unguja and 65% in Pemba. The educational status of female heads was poorer in Pemba compared to Unguja, but because of the small numbers, this difference was not statistically significant (p=0.15).

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

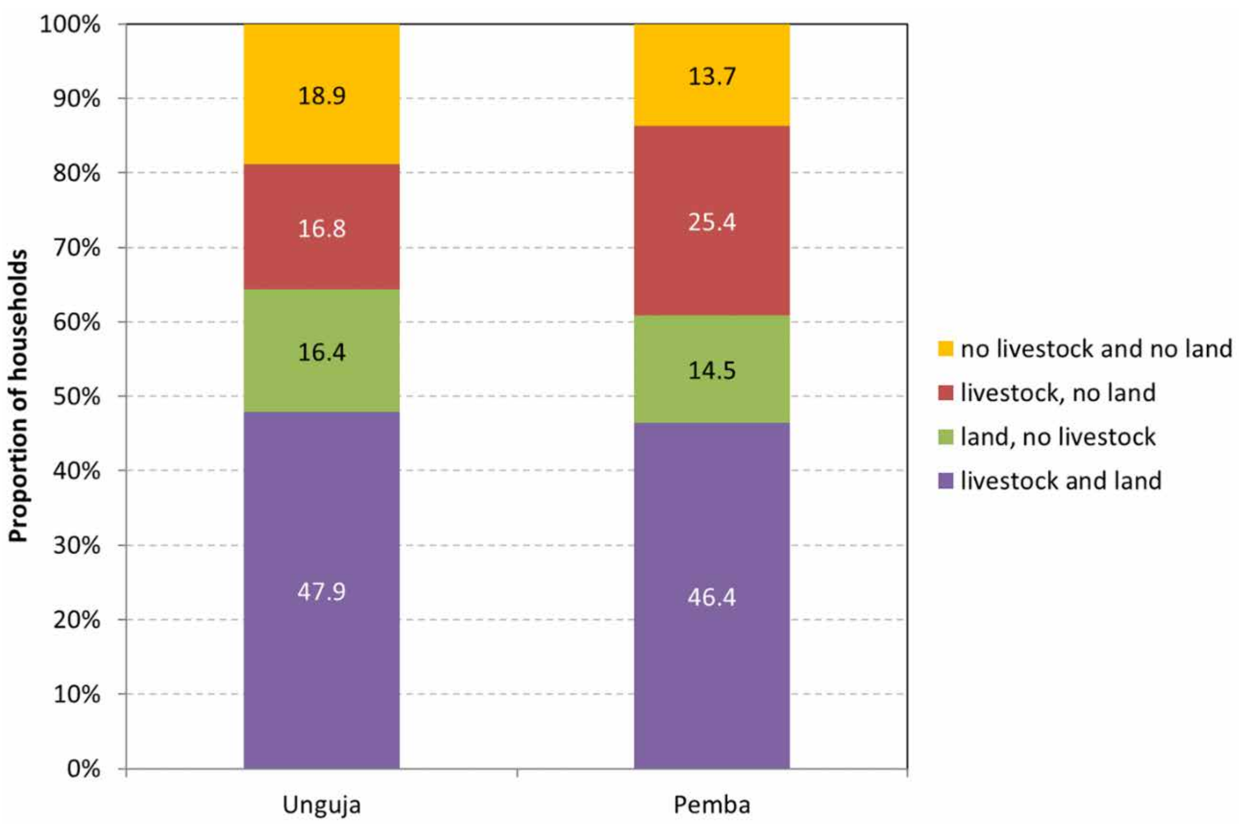


For socio-economic indicators, there was no strong evidence that the situation had changed in the three years of the durability monitoring for those households that were included in the baseline and 36-month surveys. Both sites were very similar to each other, but some indicators improved slightly (e.g., smart phone ownership). Households owned a considerable variety of assets, with the most common being mobile phones (89% in Unguja and 85% in Pemba), followed by radios (65% and 44%, respectively), and television (19% and 36%, respectively). About one in every six households in Unguja and one in every four in Pemba owned refrigerators, fans, irons, or smart phones. Transport available to households were the same in both sites, with 59% owning bicycles, 12% motorbikes, and 4% cars. Only one household in Pemba also owned a boat.

House characteristics were similar in both sites. The vast majority of roofs were grass or thatch (98%), walls were mostly plaster or brick (72%), and floors were made from tile (72%). Fuel for cooking was predominantly firewood in Unguja (93%), but in Pemba only 78%, as 21% used charcoal (p=0.02). Less than 1% of households in either site used kerosene or gas for cooking. Most households at both sites (79%) had access to tap water and only 16% in Unguja and 10% in Pemba used an open, unsafe source for drinking water (p=0.04). In Unguja, 94% of households had access to a latrine (63% pit, 31% flush), compared to 83% in Pemba (36% pit, 47% flush, p=0.02).

The economic situation is summarized in Figure 2b and shows only minor differences between sites, which were not statistically significant. Only 19% of households in Unguja and 14% in Pemba did not have either land to farm or some livestock, while about half (48% in Unguja and 46% in Pemba) had both. Livestock ownership was very similar between sites, comprising mainly chickens (61%), cows (14%), ducks or turkeys (9%), and goats (6%). There was a minor trend of female-headed households having less economic power with more female headed households in the lowest wealth tertile and less in the highest wealth tertile, but this did not reach statistical significance (p=0.6).

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



6.3 Determinants of durability

Factors that were previously associated with LLIN durability were explored. These can be divided into environmental factors, LLIN handling, type of sleeping place, and knowledge and attitudes toward LLIN and their care and repair. See Table 2 and Figure 3 for factors immediately involving the sleeping place environment. Overall, the situation remained similar throughout the three years and most of the fluctuations were due to the changing sample size—a direct comparison of only households present for all surveys did not show any significant trends in most of the indicators. The one exception was a change over time of folding up hanging nets (see Table 3).

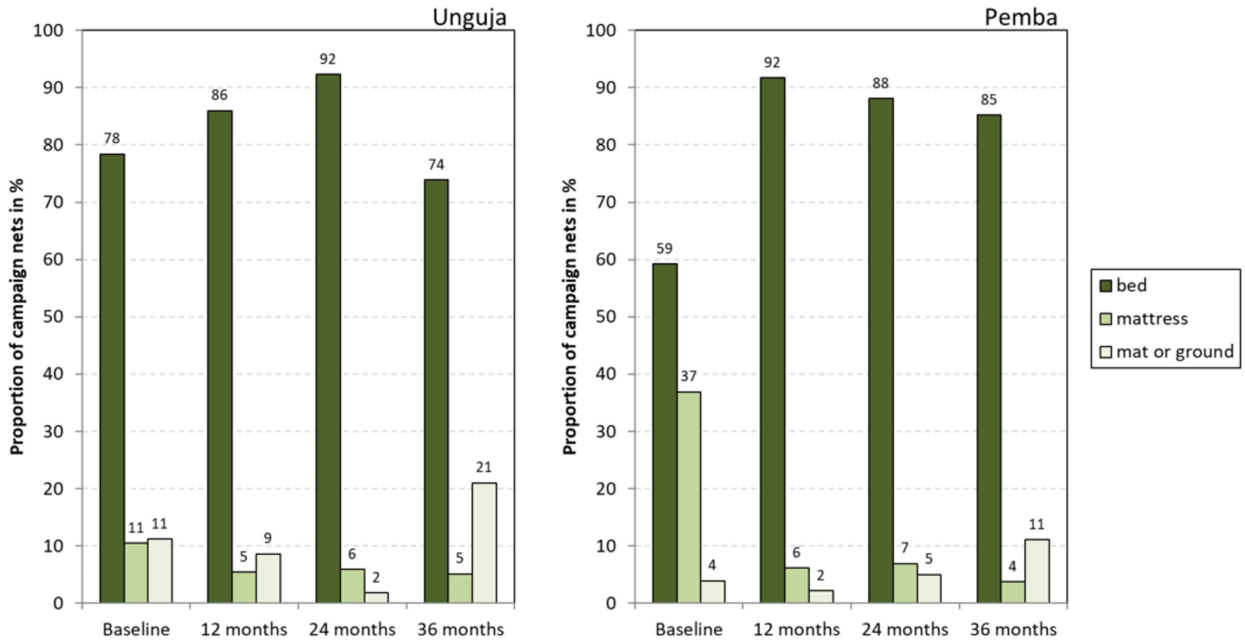
The perceived presence of rodents was generally very high and slightly higher in Unguja (90% vs. 81%, p=0.04). Storing food in the sleeping room is thought to attract rodents, which increases the potential damage to nets. This practice was reported by 76% of the households in both sites (76%). Cooking in the same room where nets are hanging is a potential source of burn damage, especially if the cooking fuel is firewood, as was typical at both sites. This practice was generally not common with 87% of households participating in all four surveys in Unguja; 95% in Pemba reporting never doing this; 10% in Unguja and 2% in Pemba did it sometimes (usually during the rains); and only 4% and 3%, respectively, reported always doing it (p=0.02 for site comparison).

Table 2: Household risk factors

Variable and Site	Baseline	12 months	24 months	36 months
Unguja	**N=149**	**N=140**	**N=132**	**N=119**
Ever store food in sleeping room	72.0%	79.3%	84.9%	71.4%
Cook in sleeping room never sometimes always	 88.0% 9.3% 2.7%	 70.7% 23.6% 5.7%	 93.2% 3.8% 3.0%	 93.3% 5.0% 1.7%
Rodents observed (last 6 m)	86.0%	85.7%	96.2%	95.8%
Pemba	**N=150**	**N=140**	**N=132**	**N=124**
Ever store food in sleeping room	66.7%	78.6%	79.6%	79.8%
Cook in sleeping room never sometimes always	 96.0% 2.7% 1.3%	 97.9% 0.7% 1.4%	 95.5% 3.0% 2.3%	 90.3% 3.2% 6.5%
Rodents observed (last 6 m)	76.7%	78.4%	84.9%	81.5%

The type of sleeping place over which the nets were used (Figure 3) was mainly bed frames in both sites with 80%, on average, with 50% being finished bed frames. Foam mattresses were the sleeping place for 18% of the cohort nets and 3% were used over reed mats or the ground (p=0.2 for site comparison).

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

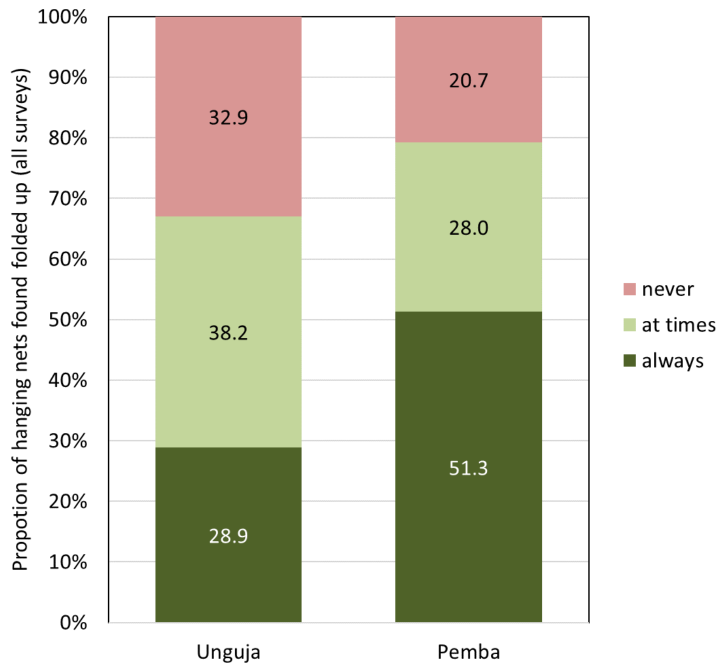


See Table 3 for the durability risk factors associated with LLIN handling. Initially, about half the cohort nets in both sites were hanging loose over the sleeping place when they were hanging, which has been shown to increase damage. However, after two years, this situation had changed significantly in Pemba, with only 9%–10% hanging loose in the last two surveys. This was not seen in Unguja, where loose hanging was reduced only at the final survey and only to 30%. Considering each of the cohort nets that were ever found hanging (Figure 3a) shows that only 29% of cohort nets were always found folded up in Unguja, compared to 51% in Pemba. Similarly, 33% in Unguja and 21% in Pemba had never been found tied up when they were hanging. The difference between the sites was statistically and programmatically significant (p=0.01). In contrast, the risk of damage to nets from drying them over bushes or fences was very low, with only 7% of washed nets in Unguja and 2% of washed nets in Pemba ever reported to be dried in this way—despite 87% of washed cohort nets reported as always dried outside.

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

Variable and site	Baseline	12 months	24 months	36 months
Unguja				
Hanging nets NOT folded or tied	54.8%	53.6%	54.0%	30.4%
Net dried on fence or bush	0.0%	3.0%	0.0%	7.0%
Net ever washed	18.1%	76.2%	89.3%	94.8%
Median washed last 6 m (IQR)	1.0 (1.0–2.0)	2.0 (1.0–3.0)	3.0 (2.0–4.0)	2.0 (2.0–3.0)
Used detergent/bleach for wash	97.1%	95.3%	99.5%	93.0%
Pemba				
Hanging nets NOT folded or tied	45.2%	43.0%	9.2%	9.9%
Net dried on fence or bush	5.4%	0.4%	0.4%	0.0%
Net ever washed	12.6%	69.0%	89.3%	88.0%
Median washed last 6 m (IQR)	2.0 (1.0–2.0)	2.0 (1.0–3.0)	2.0 (1.0-3.0)	2.0 (1.0-2.0)
Used detergent/bleach for wash	100%	95.1%	99.2%	99.0%

Figure 3a: Folding up of hanging nets across all surveys



As expected, the proportion of the cohort LLIN ever washed started out low and increased over time, reaching 95% in Unguja and 88% in Pemba at the final survey. However, the difference between the sites was not statistically or programmatically significant. The washing frequency showed little variation and was about two washes every six months at both sites or 12 washes, on average, over the three years. On the other hand, the proportion of households reporting washes with a detergent was very high, with both sites at over 95%.

See Tables 4 and 5 for exposure to LLIN related messages, message recall, and the resulting household attitude toward care and repair. At both sites, behavior change communication exposure was quite low and fluctuated a bit over time, with the highest values seen at the 12-month and 36-month surveys. On average, 12% of households in Unguja and 24% in Pemba reported any exposure (p= 0.002). Some exposure to radio messages was noted immediately after the campaign in both sites, which was still measurable in Unguja after 12 months. Otherwise, communication at both sites was predominantly through interpersonal communication, mainly through facility and community health workers and, to some extent, through community leaders (28%).

Looking at the actual recall of messages and household care and repair attitudes, calculated from a series of questions (Table 5), reflects the relatively low exposure rates and shows that messages about “repair” are consistently recalled less often than any other. Net care and repair attitude was low and fluctuated between 23% and 37% in Unguja and between 9% and 29% in Pemba. Unguja had slightly better net care and repair result, where 28% of households reported a very positive attitude (score ≥ 1.0), at least twice, in all the surveys when they were interviewed, compared to only 12% in Pemba. At least one observation with a very high score was recorded at 64% in Unguja and 54% in Pemba, meaning that 36% of households in Unguja and 46% in Pemba never recorded a very high attitude score (p=0.05 for site comparison).

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

Variable and Site	Baseline	12 months	24 months	36 months
Unguja				
Any exposure last 6m	10.7%	19.3%	6.1%	10.1%
Mean info sources (if exposed)	1.0	1.3	1.1	1.2
Type of media media only both IPC only	 48.8% 0% 56.3%	 23.1% 23.1% 53.8%	 0% 0% 100%	 8.3% 0.0% 91.7%
Pemba				
Any exposure last 6m	13.3%	30.0%	16.7%	33.1%
Mean info sources (if exposed)	1.5	1.7	1.5	1.8
Type of media media only both IPC only	 26.3% 15.8% 57.9%	 2.4% 0% 97.6%	 4.5% 9.1% 86.4%	 0.0% 4.9% 95.1%

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
Unguja				
Recalled “use net (every) night”	6.7%	13.6%	5.3%	5.0%
Recalled “nets prevent malaria”	4.0%	1.4%	2.3%	0.8%
Recalled “care for net”	4.7%	13.6%	4.6%	5.9%
Recalled “repair net”	0.0%	0.7%	0.0%	1.7%
Attitude score care and repair mean (95% CI) % with score > 1.0	 0.9 (08.–1.0) 37.2%	 0.9 (0.8–1.0) 23.0%	 0.8 (0.8–0.9) 22.7%	 0.9 (0.8–1.0) 22.7%
Pemba				
Recalled “use net (every) night”	10.0%	29.3%	16.7%	31.5%
Recalled “nets prevent malaria”	5.3%	4.3%	5.3%	11.3%
Recalled “care for net”	11.3%	17.1%	12.9%	16.9%
Recalled “repair net”	2.0%	0.7%	1.5%	4.0%
Attitude score care and repair mean (95% CI) % with score > 1.0	 0.8 (0.7–0.9) 28.9%	 0.8 (0.7–0.8) 9.4%	 0.8 (0.8–0.9) 22.0%	 0.8 (0.7–0.9) 14.5%

The final step then looked 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 LLIN increased over time, reaching 90% in Unguja and 79% in Pemba. Actual repairs increased, with increasing similar damage at both sites; at the final survey, 46% of cohort nets with any holes in Unguja and 41% in Pemba showed any sign of repair. This shows that although significantly more households in Unguja said they discussed net repair (66%)—compared to Pemba (29%, p=0.002)—the de facto repairs did not differ. It must be kept in mind, however, that repairing holes is only one aspect of net care; and preventive behaviors are at least equally, if not more, important. Households in Pemba had an advantage during the last two follow-up rounds (see Table 3).

The predominant method of repairing holes was stitching. In Pemba, with 91% of reported households that had done any repairs, compared to 12% by knotting (some households used both methods of repair). In Unguja, it was 59% and 57%, respectively. No patching was used in either site and repairs were exclusively done by family members or by 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, 68% said they had no time, 20% said repairing was not necessary or the holes were too small, 6% said it was not possible, and 5% stated they did not have materials to repair or did not know how to make the repair. Only one net in Pemba was reported to have been modified to enforce the border of the net.

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

Variable and site	Baseline	12 months	24 months	36 months
Unguja				
Ever experienced holes in net	**37.7%**	**55.0%**	**75.0%**	**89.9%**
Ever discussed care and repair	32.0%	50.0%	34.1%	65.6%
Ever repaired (if had holes)	52.7%	37.7%	50.5%	50.5%
Damaged campaign nets repaired	n.a.	18.9%	37.5%	46.3%
Pemba				
Ever experienced holes in net	28.0%	61.4%	79.6%	79.0%
Ever discussed care and repair	24.0%	20.7%	22.0%	29.0%
Ever repaired (if had holes)	40.5%	29.1%	37.1%	37.8%
Damaged campaign nets repaired	n.a.	12.4%	31.0%	41.0%

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 the level of ownership coverage.

Table 7: Hanging and use of campaign nets from cohort

Variable	Baseline	12 months	24 months	36 months
Unguja	N=391	N=305	N=225	N=195
Hanging	30.1%	76.7%	83.1%	75.9%
Taken down or stored	2.9%	15.1%	14.6%	23.6%
Still in package	66.8%	8.2%	2.2%	0.5%
Used last night	30.9%	77.1%	83.1%	77.4%
Used every night (last week)	30.1%	77.4%	82.7%	53.9%
Pemba	N=451	N=352	N=277	N=250
Hanging	20.6%	72.7%	82.7%	76.4%
Taken down or stored	2.1%	12.0%	13.0%	21.6%
Still in package	77.2%	12.8%	4.3%	2.0%
Used last night	20.8%	70.7%	76.9%	71.6%
Used every night (last week)	18.4%	68.2%	75.5%	52.0%

At baseline—3.5 months after distribution—the proportion of campaign nets found hanging was very low (Table 7), but then it increased to about 75% at 12 months, 82% after two years, and then fell back to 75% during the final survey. Initially, most campaign nets were still in their package (67% in Unguja and 77% in Pemba), but this rate then dramatically reduced to 2% or less in the final survey. Instead, the proportion of cohort nets stored or taken down during the day increased steadily, reaching 24% in Unguja and 22% in Pemba. This suggests that between two and three years after distribution, cohort nets that had already been in use were taken down again, most likely because of damage, as 55% of stored nets in the final survey had serious damage (hole index› 300) compared to only 39% of the hanging nets (p=0.003). Another factor may have been the availability of other, better nets in the household (see below).

Table 8 shows the hanging and use of the non-cohort nets found during each survey, which must be interpreted with their availability shown in Table 9 and Figure 3b.

From the beginning, and throughout the study, households owned a considerable number of other nets and new ones continued to enter the household. The proportion of households with any non-campaign nets was 73% at baseline, but then dropped to 46% at both sites after one year, suggesting that as the campaign nets began being used more (see Table 7), the older non-campaign nets were discarded or given away. Ownership of non-cohort nets then increased again, more in Pemba than in Unguja, reaching at the final survey 57% in Unguja and 67% in Pemba (p=0.09). This dynamic is also seen in Figure 3b by looking at the relative share of non-cohort nets among all nets owned by the households. It also corresponds to the proportion of households reporting having received any new nets since the campaign, which was 21% at baseline in Unguja and then steadily increased to 31% at 12 months, 34% at 24 months, and 46% at the final survey. In contrast, in Pemba, households reporting any additional nets since the campaign were 4% up to the 24-month survey, and then rapidly increased to 20% and 39%, respectively, meaning that additional nets came mainly during the second and third year. As shown in Table 8, hanging and use of non-cohort nets was high at all times, with a considerable proportion of these nets also stored and still in the package, suggesting they were not yet needed.

Table 8: Hanging and use of non-cohort nets

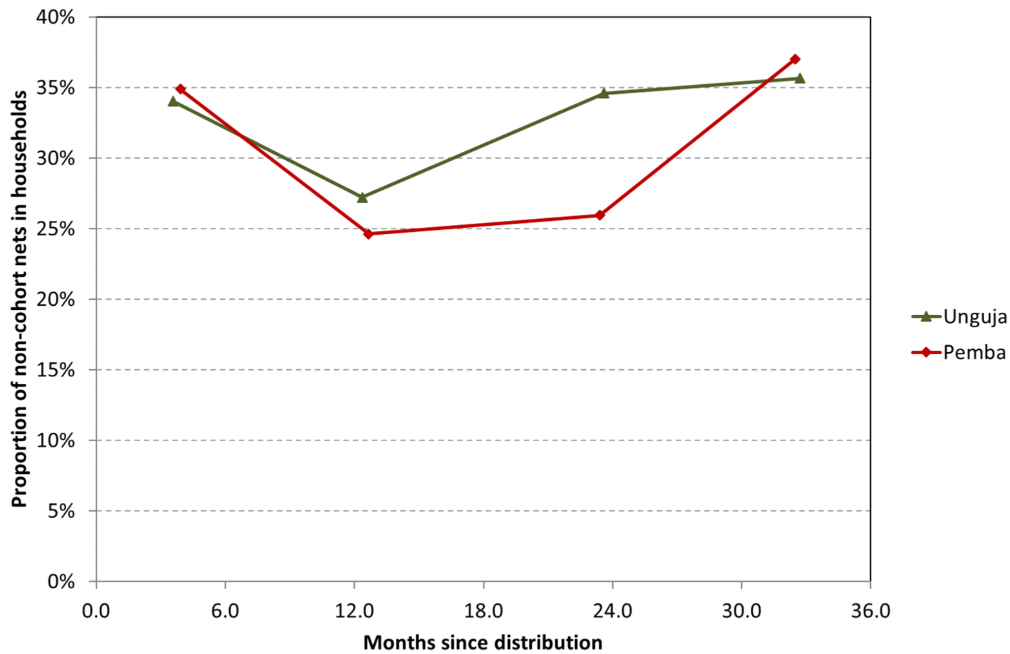
Variable	Baseline	12 months	24 months	36 months
Unguja	N=197	N=114	N=119	N=108
Hanging	84.3%	77.2%	71.4%	63.0%
Taken down or stored	6.6%	10.5%	18.5%	22.3%
Still in package	6.6%	11.4%	10.1%	14.8%
Used last night	82.7%	74.6%	78.2%	59.3%
Used every night (last week)	81.7%	75.4%	75.6%	61.1%
Pemba	N=242	N=115	N=97	N=147
Hanging	75.2%	66.1%	81.4%	74.8%
Taken down or stored	11.3%	7.8%	1.0%	9.5%
Still in package	12.6%	23.5%	17.5%	15.7%
Used last night	74.0%	65.2%	79.2%	72.8%
Used every night (last week)	61.6%	63.5%	73.2%	72.1%

Most non-cohort nets came from the public sector and, in Pemba, mainly from antenatal care (ANC) services and health facilities. Interestingly, family and friends as a source of additional nets was highest at the 12-month and 24-month surveys when input from other sources was lowest. In both sites, nets obtained through the commercial sector played a role—representing between 5% and 13% of non-cohort nets. In keeping with existing data on the Tanzania and Zanzibar commercial net markets, most of the private sector nets were untreated, 71% in Unguja and 87% in Pemba. Untreated nets were almost exclusively Safi nets and branded LLIN were Duranet, PermaNet, Dawa Plus, and Olyset in Unguja and Olyset; and PermaNet, Duranet, and Yorkool in Pemba.

Table 9: Household ownership of non-campaign nets and source of non-campaign nets

Variable	Baseline	12 months	24 months	36 months
Unguja				
Household has any other nets	73.3%	45.7%	45.5%	56.5%
Source public sector	70.1%	50.9%	70.0%	87.0%
Source ANC or HF	33.8%	27.2%	17.8%	51.8%
Source private sector	9.6%	8.9%	13.5%	6.5%
Source family or friends	2.5%	15.8%	15.3%	6.5%
Pemba				
Household has any other nets	73.3%	45.7%	50.8%	66.9%
Source public sector	82.6%	63.5%	70.1%	93.9%
Source ANC or HF	58.7%	58.8%	55.7%	89.1%
Source private sector	13.2%	10.4%	10.3%	4.7%
Source family or friends	3.6%	12.3%	18.6%	1.4%

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



Given that 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 96% of households in both sites still owned any ITNs at the final survey. The proportion of households with enough nets for all household members (one LLIN for every two people) dropped significantly from the very high values at baseline of 80% in Unguja and 85% in Pemba to 43% and 59%, respectively. Population access to an ITN within the household also showed a decline, but not as dramatic: from 93% to 74% in Unguja and from 95% to 82% in Pemba. It must be kept in mind, however, that this survey was designed to monitor LLIN durability and is not representative of post-campaign LLIN ownership coverage, which will be overestimated in this survey.

The use pattern of cohort LLIN 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 difference in use patterns was observed between the cohort and non-cohort nets.

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

Variable	Baseline	12 months	24 months	36 months
Unguja	N=118	N=235	N=187	N=151
Children only*	15.3%	18.3%	17.7%	14.6%
Children + adults**	23.7%	22.6%	25.1%	25.3%
Adults only**	61.0%	59.2%	57.2%	59.6%
Pemba	N=94	N=249	N=213	N=179
Children only*	16.0%	21.3%	24.9%	22.9%
Children + adults**	33.0%	30.5%	18.8%	25.1%
Adults only**	51.0%	48.2%	56.3%	52.0%

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

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

Variable	Baseline	12 months	24 months	36 months
Unguja	N=162	N=85	N=93	N=64
Children only*	22.8%	22.4%	10.8%	26.6%
Children + adults**	18.5%	23.5%	18.3%	15.6%
Adults only**	58.6%	54.1%	71.0%	57.8%
Pemba	N=179	N=75	N=76	N=107
Children only*	24.6%	17.3%	17.1%	15.0%
Children + adults**	27.9%	29.3%	22.4%	35.5%
Adults only**	47.5%	53.3%	60.5%	49.5%

*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 LLIN for the durability cohort after the final survey. Of the 382 LLIN labeled in Unguja, a definite outcome for the durability measurement could be established for 328 (86%). Namely, 195 (51%) were present, 43 (11%) were discarded, 83 (22%) given away, and seven (1%) lost for unknown reasons. Among those with an unknown outcome for 28 (7%) LLIN 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, 22 (6%) were taken when the family moved, and four (1%) nets were used by families elsewhere and their status was also unknown.

In Pemba, 404 of the 452 (89%) labeled campaign nets had a definite outcome. Here 250 (55%) were still present after 32 months, 83 were given away (22%), followed by 43 (7%) discarded, and seven (1%) definitely lost for an known reason. Among cohort nets with an unknown outcome those where the location could not be recalled were most frequent (7%), followed by moving away (6%), and using the net elsewhere (1%).

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

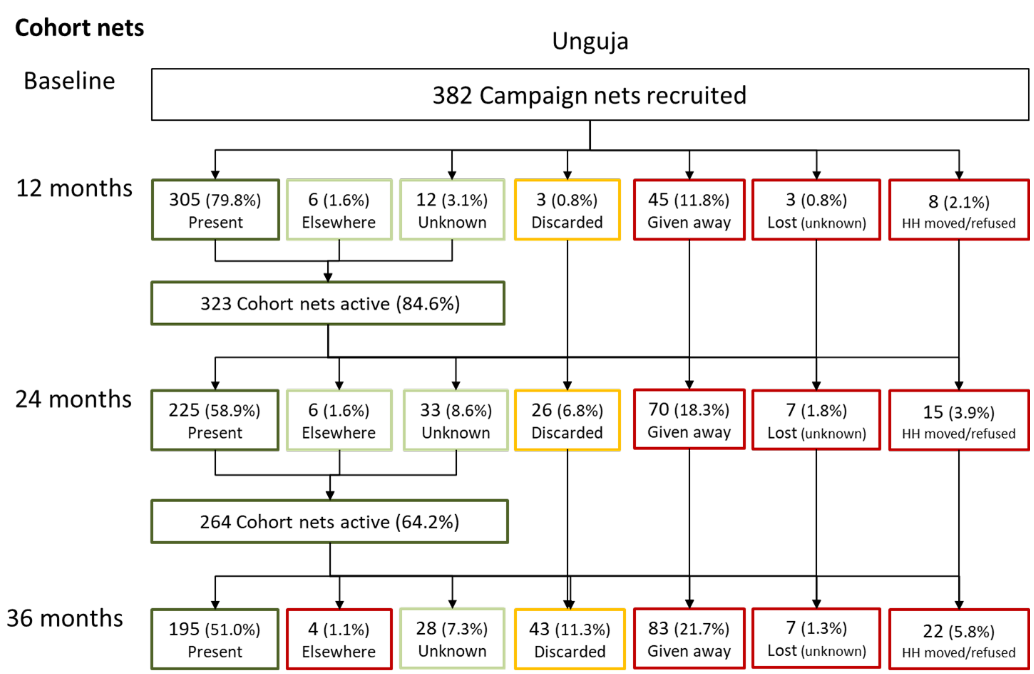
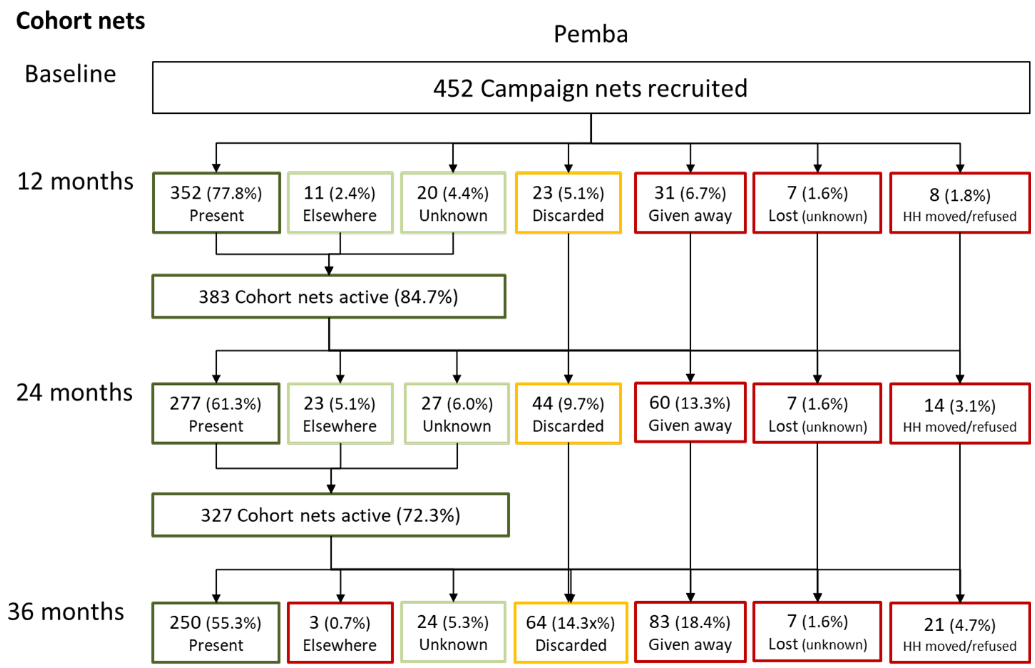


Figure 5: Status of cohort LLIN recruited at baseline in Pemba province

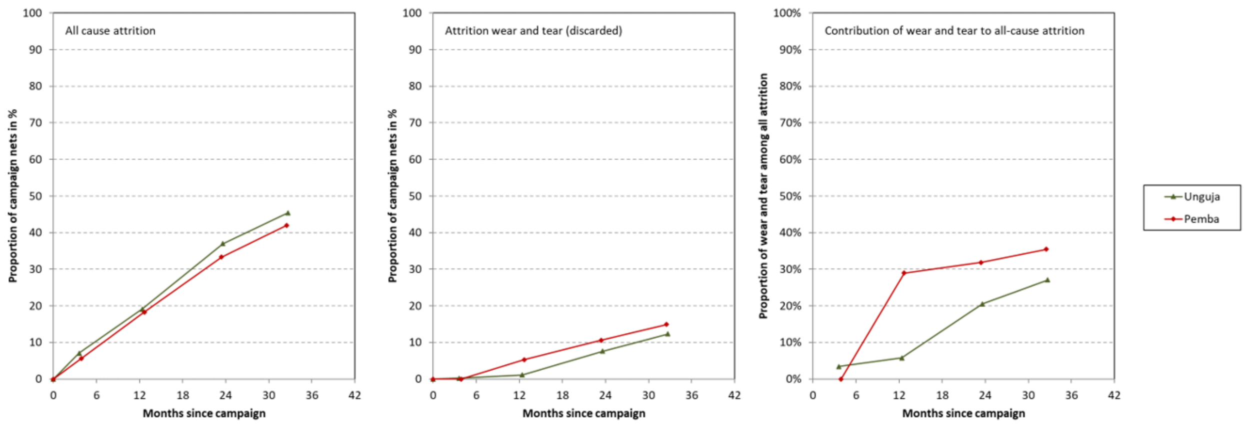


See Table 12 and Figure 7 for the resulting all-cause attrition rates and losses due to wear and tear since the campaign, including LLIN that were reportedly lost between the 2016 campaign and the baseline survey. These include only those nets with a definitive outcome. All-cause attrition was very similar in both sites, but always slightly higher in Unguja, reaching 45% in Unguja and 42% in Pemba during the final survey. By contrast, attrition due to wear and tear was consistently higher in Pemba. When attrition due to wear and tear is expressed as a proportion of all-cause attrition (Figure 7, right panel), the difference between the sites is obvious, with a significantly higher portion of losses due to discarding nets because of damage in Pemba at 12 months (29% versus 5%). In the next two years, losses due to damage in Pemba slowed, while it accelerated in Unguja, so that at the endpoint, sites were a bit closer but Pemba still had a higher proportion of losses due to wear and tear (36% versus 27%).

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

Variable	Campaign – baseline	Campaign – 12 months	Campaign – 24 months	Campaign – 36 months
Unguja	N=411	N=377	N=357	N=357
Given away	5.6%	18.0%	26.1%	29.7%
Discarded (wear & tear)	0.2%	1.1%	7.6%	12.3%
Unknown	1.2%	0.0%	3.4%	3.4%
Total	**7.1%**	**19.1%**	**37.0%**	**45.4%**
Pemba	N=479	N=431	N=415	N=431
Given away	5.2%	13.0%	20.5%	25.1%
Discarded (wear & tear)	0%	5.3%	10.6%	14.9%
Unknown	0.4%	0.0%	2.2%	2.1%
Total	**5.6%**	**18.3%**	**33.3%**	**42.0%**

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



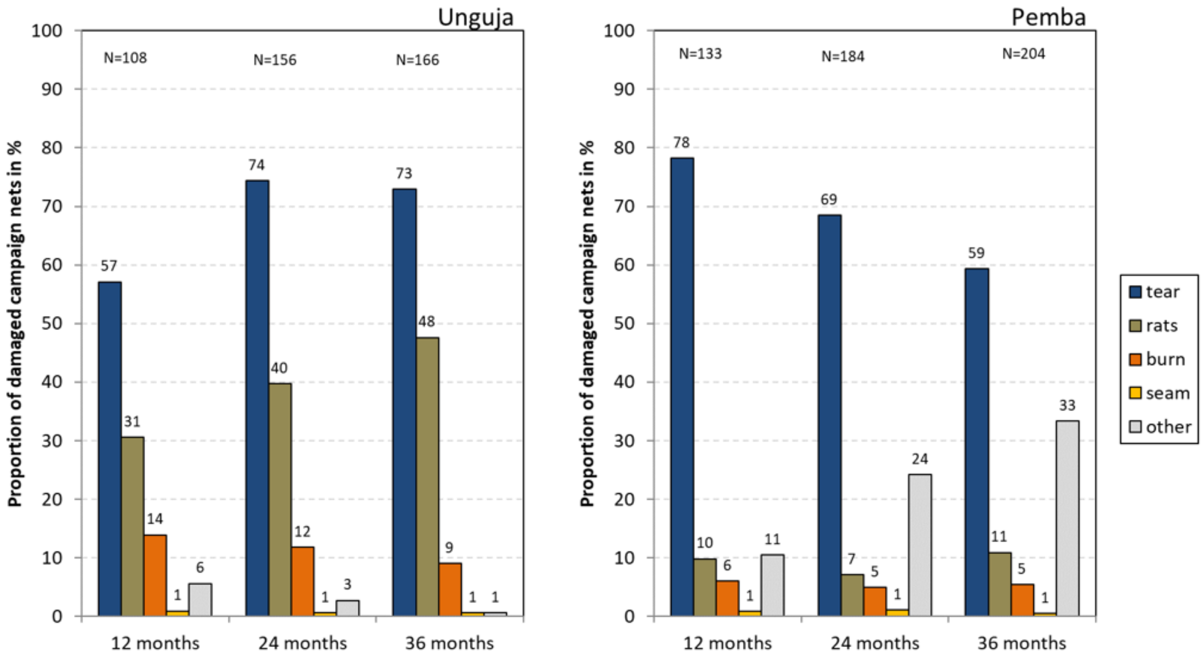
Reasons for loss among the discarded nets were identical between the sites (p=0.8) with 49% destroyed, 27% thrown away, and 25% used for other purposes. When calculated over all campaign nets with known outcome, the rate of alternative use was only 3% or 27 nets in total. In Unguja, nets were used as window or door curtains (22%) or cut up for various household uses (78%). While in Pemba, alternative uses were more diverse—with 72% used to protect crops, 17% cut up for various purposes, one net (5%) used in a latrine, and one (5%) for fishing. The latter must be considered misuse, but it was only 0.2% of all campaign nets with known outcome.

As expected, the proportion of LLINs still present in the surveyed households with any sign of damage initially increased rapidly, but then the increase slowed as older nets were discarded (Table 13). At the final survey, 90% of nets in Unguja and 89% in Pemba had any holes; and the level of damage was very similar in both sites, based on median hole index of nets with any holes and the proportion of nets in good and serviceable condition (p=0.8).

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

Variable	Baseline	12 months	24 months	36 months
Unguja	N=382	N=305	N=225	N=195
Any holes	9.9%	48.5%	78.2%	89.7%
Median pHI (if any hole)	25	48	191	269
Good (pHI<64)	96.3%	78.4%	50.2%	33.3%
Too torn (pHI>642)	0.8%	4.9%	15.1%	32.3%
Serviceable (pHI≤642)	**99.2%**	**95.1%**	**84.9%**	**67.7%**
Pemba	N=452	N=352	N=277	N=250
Any holes	7.3%	54.8%	75.8%	88.8%
Median pHI (if any hole)	55	50	181	324
Good (pHI<64)	96.5%	74.7%	49.1%	34.8%
Too torn (pHI>642)	0.9%	8.2%	22.4%	36.0%
Serviceable (pHI≤642)	**99.1%**	**91.8%**	**77.6%**	**64.0%**

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 Unguja, high levels of rodent damage was reported, which were absent or minimal in Pemba. This is probably a difference in perception rather than actual damage mechanisms.

Overall, the physical survival of LLINs in serviceable condition after 32 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 LLIN was 55% in Unguja and 51% in Pemba (p=0.4). This means that the gap between the two sites and products was closing—from a 8% difference at 12 months to 9% at 24 months, to just 4% at the final survey. When only the cohort LLINs that had been used at all (taken out of package) were considered, the survival estimate was reduced only minimally by 1%–4% in Unguja and Pemba, respectively.

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

Variable	Baseline	12 months	24 months	36 months
Unguja	N=382	N=309	N=252	N=239
Survival estimate	99.2%	93.9%	75.8%	55.2%
95% CI	96.7–99.8	89.6–96.4	67.1–82.8	46.2–63.9
Only nets ever used	N=125	N=281	N=247	N=222
Survival estimate	97.6%	93.6%	75.3%	54.5%
95% CI	90.9–99.4	89.4–96.2	66.8–82.3	45.5–63.6
Pemba	N=452	N=375	N=321	N=314
Survival estimate	%	86.1%	67.0%	51.0%
95% CI	97.9–99.8	78.7–91.2	60.6–72.6	44.5–57.4
Only nets ever used	N=102	N=299	N=309	N=276
Survival estimate	%	82.9%	65.7%	47.5%
95% CI	96.8–99.9	74.6–88.9	59.7–71.2	39.6–55.4

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). It is clear that the survival estimate for Unguja follows the hypothetical curve, while that for Pemba appears to “cross over” toward the second part of the study, from closer to the 2-year line to closer to the 3-year line.

In addition to estimating median survival at each time point from the graph,2 it was also calculated from the final two data points (see methods). See Table 14a for the results.

The calculated median survival was 2.9 years in Unguja (PermaNet 2.0 LLIN) and 2.7 years in Pemba (Olyset LLIN). Estimates obtained from the graph were very similar to the calculated ones at the time of the final survey. But, they also show that earlier estimates from the graph at 12 and 24 months were higher for the PermaNet and lower for the Olyset. Considering the confidence intervals around the median survival, it can be said that performance at both sites of the tested LLIN was below the three-year mark, but confidence intervals still include three years. When data were analyzed as survival analysis in a Kaplan-Meier plot (Figure 9a), the Olyset in Pemba, overall, showed a lower survival in the study and this difference was statistically significant in a log-rank test (p<0.0001).

The Cox proportionate hazard models showed that some determinants significantly contributed to explaining the outcome. A significantly increased hazard ratio (HR), indicating a decreased likelihood of survival, was seen in cohort nets that were never observed folded up when hanging (HR 1.89, 95% CI 1.33–2.60, p<0.0001); while a better survival was seen in nets from households that recorded at least two very positive care and repair attitude scores (HR 0.68, 0.48–0.97, p=0.04) and for nets in households in the highest wealth tertile (HR 0.74, 0.54–1.00, p=0.05). The brand (i.e., difference between sites controlling for all other factors) was still the strongest determinant of survival, with HR 2.77 (2.00–3.78, p<0.0001). Interestingly, the HR increased in the final multivariable model compared to the HR 2.49 (1.90–3.20) in the bivariable Cox model, suggesting that the narrowing of the gap between the brands was largely an effect of the described changes in net handing seen in the second part of the study in Pemba and it was not a function of the textile qualities of the LLIN.

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

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

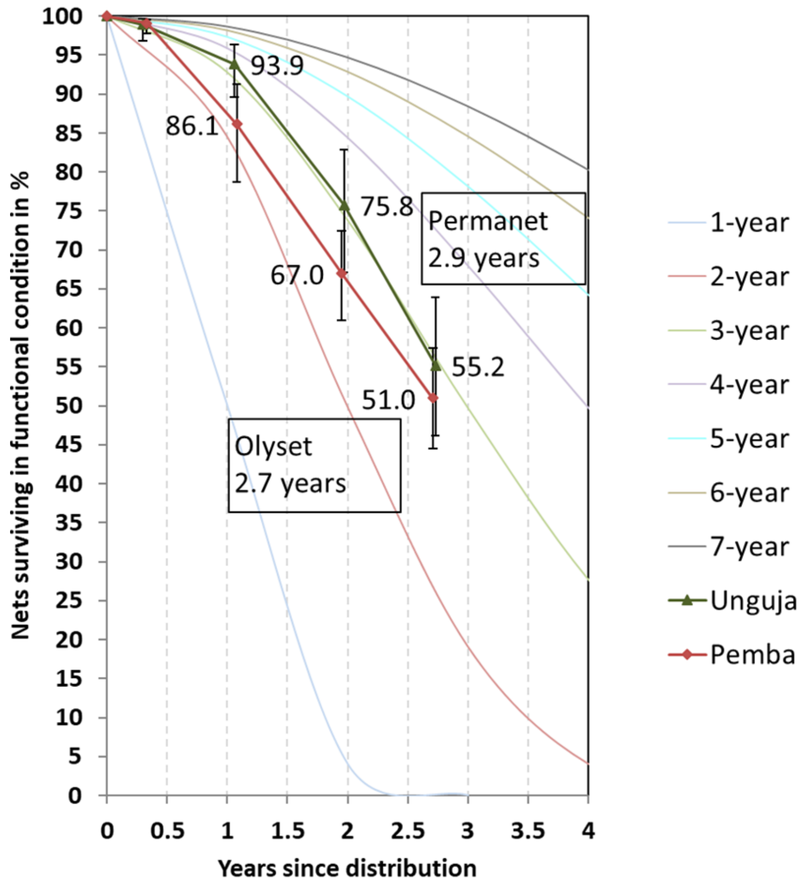
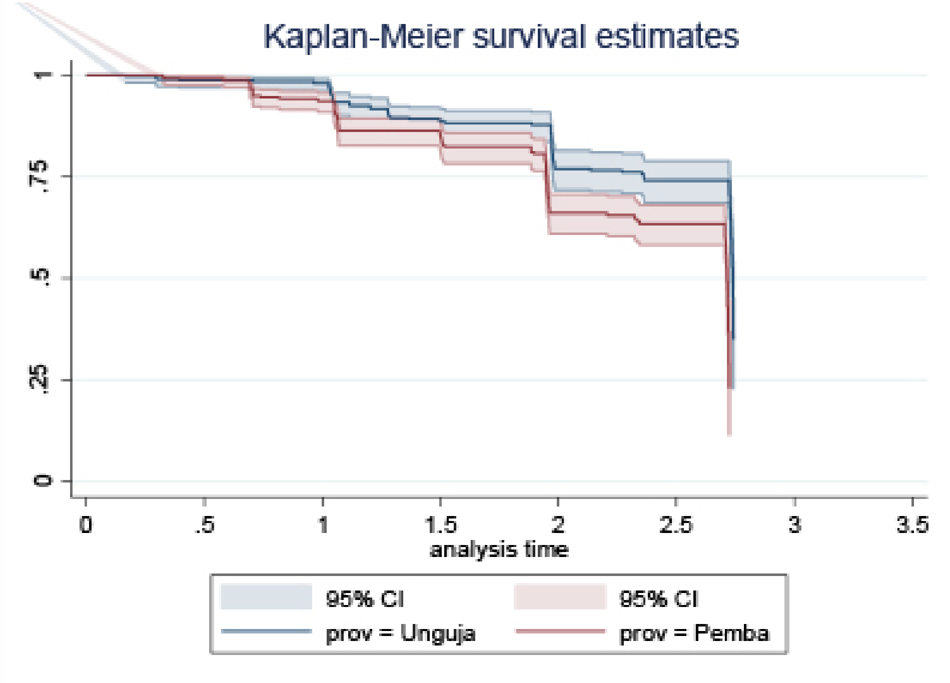


Table 14a: Estimated median survival of LLIN in years using different methods

Variable	12 months	24 months	36 months
Unguja			
Estimated from Figure 9[1]	3.3	3.1	**2.9**
Calculated from last two data points (95% CI)			**2.9 (2.6–3.3)**
Pemba			
Estimated from Figure 9	2.3	2.6	**2.7**
Calculated from last two data points (95% CI)			**2.7 (2.5–3.0)**

Figure 9a: Kaplan-Meier curves of physical survival with 95% confidence intervals



6.6 Insecticidal effectiveness of campaign LLINs

The target of sampling 30 campaign nets at each site for bio-assay testing was achieved at all time points and at both sites. See Table 15 and Figure 10 for the results of the WHO cone and tunnel tests. For the PermaNet, a polyester LLIN treated with deltamethrin using the coating technology, 60-minute knockdown remained very high at all time points, while 24-hour mortality declined, over time, from a median of 93% to 72% at the final assessment. Even without the tunnel test, the optimal insecticidal performance was above or equal to 90% at all time points. For the permethrin-treated Olyset, with the polyethylene incorporation technology, mortality rates of sensitive vectors were significantly lower and declining, reaching only 44% at the final survey. This known phenomenon when testing Olyset with cone tests is caused by the high expellant capacity of permethrin, which causes the mosquito to avoid contacting the netting under the cone. However, when the tunnel test was applied to samples failing the cone test, all samples showed optimal performance after 33 months of follow-up.

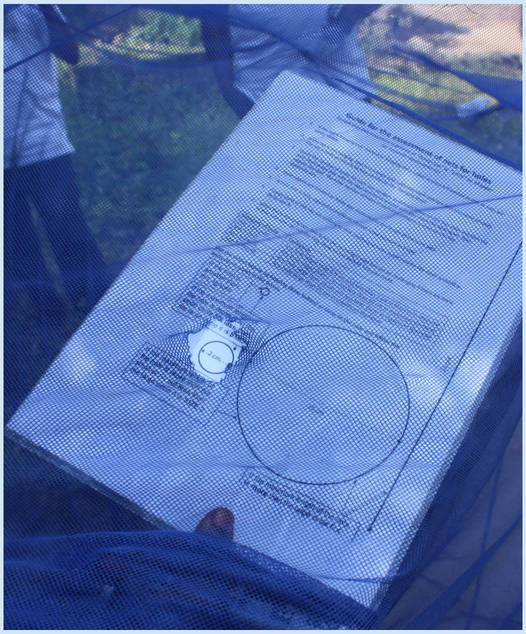
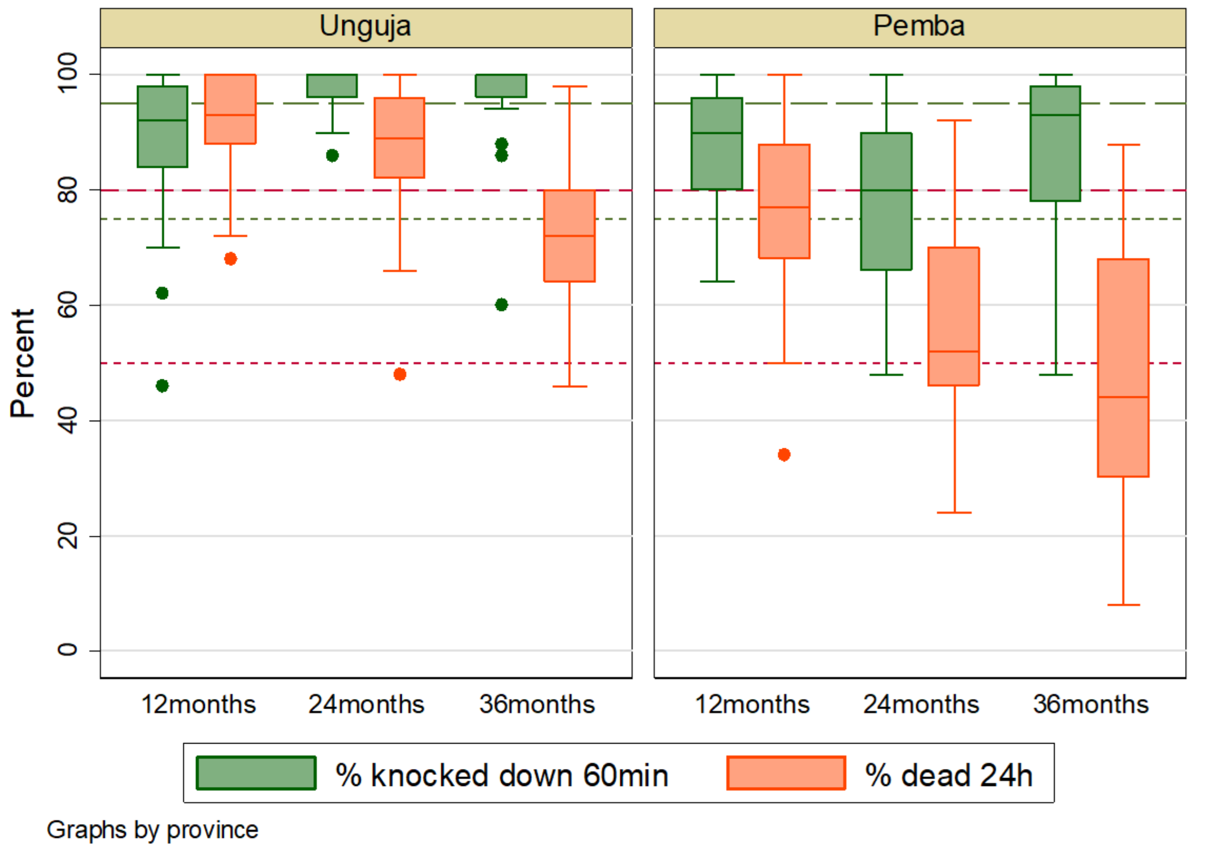


Table 15: Results from bio-assays and tunnel test

Variable	12 months	24 months	36 months
Unguja	N=30	N=30	N=30
Knockdown 60 minutes Mean (95% CI) Median (IQR)	 89.0% (83.9–94.3) 92.0% (84.0–98.0)	 97.8% (96.6–99.0) 100% (96.0–100)	 96.9% (94.1–99.7) 100% (96.0–100)
Mortality 24 hours Mean (95% CI) Median (IQR)	 92.1% (88.3–95.9) 93.0% (88.0–100)	 86.4% (80.5–92.3) 89.0% (82.0–96.0)	 71.5% (66.0–76.9) 72.0% (64.0–80.0)
Optimal effectiveness Estimate (95% CI)	 90.0% (63.5–97.9)	 96.7% (77.7–99.6)	 90.0% (63.4–97.9)
Minimal effectiveness Estimate (95% CI)	 100%	 100%	 100%
Optimal effectiveness (incl. tunnel) Estimate (95% CI)	 -.-	 100%	 100%
Minimal effectiveness (incl. tunnel) Estimate (95% CI)	 -.-	 100%	 100%
Pemba	N=30	N=30	N=30
Knockdown 60 minutes Mean (95% CI) Median (IQR)	 86.7% (82.9–90.4) 90.0% (80.0–96.0)	 77.9% (72.1–83.7) 80.0% (66.0–90.0)	 87.4% (83.2–1.6) 93.0% (78.0–8.0)
Mortality 24 hours Mean (95% CI) Median (IQR)	 76.6% (69.4–83.8) 77.0% (68.0–88.0)	 55.9% (49.2–62.5) 52.0% (46.0–70.0)	 47.9% (39.1–6.6) 44.0% (30.0–8.0)
Optimal effectiveness Estimate (95% CI)	 53.0% (32.8–72.8)	 20.0% (9.8–36.6)	 50.0% (30.5–9.5)
Minimal effectiveness Estimate (95% CI)	 96.7% (77.7–99.6)	 76.7% (52.3–90.8)	 90.0% (71.3–7.0)
Optimal effectiveness (incl. tunnel) Estimate (95% CI)	 96.7% (77.7–99.6)	 80.0% (58.4–91.9)	 100%
Minimal effectiveness (incl. tunnel) Estimate (95% CI)	 100%	 96.7% (77.7–99.6)	 100%

Figure 9: Results from WHO cone bio-assays: the box plot shows the median (horizontal line), Inter-Quartile-Range (box), adjacent values[3] (whiskers), and outliers (circles); lines represent cut-offs for optimal and minimal insecticidal effectiveness



[3] Adjacent values: +/- 1.5* IQR

Tables 16–18 show the details of handling and use of these bio-assay nets. Most had been hung and used the previous night and most were used over a bed frame. Generally, the use and washing pattern was not different from what it had been for the cohort campaign nets and it did not differ significantly between sites.

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

Variable	12 months	24 months	36 months
Unguja	N=30	N=30	N=30
Location found			
hanging loose	100%	47%	27%
hanging folded/tied	0%	40%	53%
not hanging	0%	13%	20%
Type of sleeping place			
bed	97%	87%	80%
mattress	3%	3%	3%
mat/ground	0%	10%	17%
Net users			
young child only	4%	0%	0%
young child + adult	4%	44%	20%
older child, adult only	92%	56%	80%
Pemba	N=30	N=30	N=30
Location found			
hanging loose	70%	67%	10%
hanging folded/tied	30%	33%	60%
not hanging	0%	0%	30%
Type of sleeping place			
bed	50%	93%	80%
mattress	43%	7%	3%
mat/ground	7%	0%	17%
Net users			
young child only	11%	21%	11%
young child + adult	14%	7%	21%
older child, adult only	75%	72%	68%

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

Variable	12 months	24 months	36 months
Unguja	N=30	N=30	N=30
Used last night	97%	83%	83%
Use last week			
every night	97%	77%	83%
most nights (5–6)	3%	7%	0%
some nights (1–4)	0%	10%	3%
not used	0%	7%	13%
don't know	0%	0%	0%
Seasonal use			
equally rain and dry	97%	77%	77%
mainly rain	3%	23%	13%
rain only	0%	0%	10%
Pemba	N=30	N=30	N=30
Used last night	97%	93%	63%
Use last week			
every night	87%	80%	63%
most nights (5–6)	3%	13%	0%
some nights (1–4)	10%	0%	0%
not used	0%	7%	37%
don't know	0%	0%	0%
Seasonal use			
equally rain and dry	70%	90%	97%
mainly rain	20%	7%	3%
rain only	10%	3%	0%

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

Variable	12 months	24 months	36 months
Unguja	N=30	N=30	N=30
Ever washed	87%	83%	97%
Washes last 6 months (all)			
Mean	2.0	2.1	2.2
Median	2.0	2.0	2.0
Washes last 6 months (if washed)			
Mean	2.3	2.6	2.2
Median	2.0	2.0	2.0
Soap used			
country soap bar	8%	16%	7%
detergent or bleach	92%	84%	93%
mix	0%	0%	0%
Pemba	N=30	N=30	N=30
Ever washed	90%	97%	83%
Washes last 6 months (all)			
Mean	2.2	2.2	1.9
Median	2.0	2.0	2.0
Washes last 6 months (if washed)			
Mean	2.5	2.2	1.9
Median	2.0	2.0	2.0
Soap used			
country soap bar	4%	3%	0%
detergent or bleach	96%	97%	100%
mix	0%	0%	0%

Summary and Conclusion

This report presents the findings of a three-year durability monitoring study comparing two LLIN brands (PermaNet 2.0 and Olyset), which were distributed through a mass campaign in two districts in Zanzibar with similar ecological and demographic environments: Unguja Island (North B district) and Pemba Island (Wete district). At baseline, 3.5 months after the 2016 mass campaign, a cohort of households representative for the selected districts 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 site. These targets were achieved or exceeded with 149 (99%) households and 382 (111%) cohort nets recruited in Unguja and 150 (100%) and 452 (131%), respectively, in Pemba.

During the three follow-up surveys, the durability outcome for 328 of the cohort nets in Unguja (86%) could be determined, while 6% were lost when the households moved away, 7% were lost because household members were not available during the survey or could not recall the whereabouts of the net, and 1% were used by family members elsewhere. In Pemba, the proportion of cohort nets with a definite outcome was higher, with 89% (404 out of 452), reasons for unknown outcome where the LLIN location could not be recalled (5%,) followed by moving away (5%), and using the net elsewhere (1%).

Demographic and socio-economic characteristics

The study design for comparing durability performance of two LLIN brands assumes that other factors that could influence durability are kept 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 not likely to significantly impact durability. Average household size was between five and six persons, with a rate of 24% of female-headed households in Unguja and 11% in Pemba. Population structure was similar, with 15%–18% of the population under 5 years old.

The educational status of the male heads of households was quite high and it was the same at both sites, with 47% having had at least some secondary school education; only 19% in Unguja and 25% in Pemba were non-literate. This was quite different from female heads of households: 47% in Unguja and 65% in Pemba were non-literate; and 26% and 4%, respectively, had some secondary education.

House construction at both sites was similar, with more than 95% of roofs made from grass or thatch, 65–78% of walls made from bricks or plaster, and 72% of floors made from tile. Almost all households used firewood or charcoal for cooking, had access to a pit latrine or flush toilet, and only 16% in Unguja and 10% in Pemba used surface water from rivers and creeks for drinking.

The economic situation was very similar, with a slightly better socio-economic situation found in Pemba. Household assets were mobile phones, radios, and television, but about 15% in Unguja and 25% in Pemba also owned other items: a refrigerator, fan, or iron. Means of transport were bicycles (59%), motorbikes (13%), and cars (3%). Income generation was mainly from farming, with 80–86% of households having either land for agriculture, livestock, or both (48% in Unguja and 47% in Pemba). Around 60% of households owned chickens, 14% cows, and less than 10% ducks or goats.

Durability risk factors

A number of behavioral factors that are known to, or thought to be, associated with damage of nets were monitored. These 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 most categories, none or only minor differences were seen: about 75% of 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 the rate was slightly higher in Pemba (14% versus 5%, p=0.02). In both sites, bed frames comprised about 80% of the sleeping places, with about half finished bed frames. Exposure to net-related messages and recall was similar in both sites and was, generally, low. Immediately after the campaign, some radio messages were broadcast; but, thereafter, almost all exposure was through health workers and, to a lesser extent, community leaders. For care and repair attitude, Unguja had a slight advantage; 28% of households reported a very positive attitude (score ≥ 1.0) at least twice, compared to only 12% in Pemba; and 36% of households in Unguja and 46% in Pemba never recorded a high attitude score (p=0.05 for site comparison). The use pattern of nets was very similar in both sites, with 15% to 20% used by children only and about 50% used by adults only. The rate for drying washed nets on bushes was similarly low in both sites and most households used detergent to wash their nets.

Net handling was the only category where a significant difference was found between the sites. Initially, about half the cohort nets in both sites were hanging loose over the sleeping place when they were hanging. However, after two years this situation had changed significantly in Pemba, with only 9%–10% hanging loose in the last two surveys. This was not seen in Unguja, where loose hanging was reduced only at the final survey to 30%. Overall, in Unguja, only 29% of cohort nets were always found folded up, compared to 51% in Pemba. Similarly, 33% in Unguja and 21% in Pemba were never found tied up when they were hanging. The difference between the sites was statistically significant (p=0.01).

Net hanging and use

Hanging and use of the durability cohort nets cannot be interpreted without taking into account the household net ownership from other sources. Initially, most campaign nets were still in their package (67% in Unguja and 77% in Pemba) because 73% of households in both sites still had other nets and they used these first. At the 12-month follow-up, the number of non-cohort nets were significantly reduced by discarding and giving away; >70% of the campaign nets in both sites were now hanging. Hanging rate increased to >80% at the 24-month survey, but —declined again to about 75%, with an increasing number stored away, probably because of damage. Additional nets came in throughout the study, mainly from the public sector. While the influx of these nets was steady over time in Unguja, new non-cohort nets were concentrated during the last two years in Pemba.

Physical durability outcomes

After three years, the all-cause attrition (i.e., losses for any reason) did not vary much between sites: 45% in Unguja and 42% in Pemba. However, the proportion of losses that were due to net damage differed between the sites. While, in Unguja, only 5% of losses at 12 months were from discarding torn nets; this rate was 29% in Pemba. In the next two years, losses due to damage in Pemba slowed, while it accelerated in

Unguja. At the endpoint, sites were somewhat closer, but Pemba still had a higher proportion of losses due to wear and tear (36% versus 27%). Of the nets discarded, 49% were destroyed, 27% were thrown away, and 25% were used for other purposes, with no difference between the sites. Overall, less than 3% of nets in either site was used for other purposes, and only one net in Pemba (0.2%) was used for fishing.

The physical condition of the cohort nets still found in the households was very similar between sites; at the final survey, 68% in Unguja and 64% in Pemba were still in serviceable condition. Overall, survival in serviceable condition at the last survey was 55% in Unguja and 51% in Pemba. Estimated median survival was 2.9 years for the PermaNet 2.0 in Unguja (95% CI 2.6–3.3) and 2.7 years for the Olyset in Pemba (95% CI 2.5–3.0). When data were analyzed as survival analysis in a Kaplan-Meier plot, the Olyset in Pemba, overall, showed a lower survival during the study, even though the final estimates were close together and this difference was statistically significant ($p<0.0001$). This was also confirmed by a Cox proportionate hazard model with a hazard ratio of 2.77 for the difference in brands (95% CI 2.00–3.78, $p<0.0001$). The models also suggest that the narrowing of the gap between the brands was largely an effect of the changes in net handing seen in the second part of the study in Pemba, and not a function of the textile qualities of the LLIN.

Insecticidal durability outcomes

Using the cone and tunnel tests, samples were taken at each time point after the baseline to assess insecticidal effectiveness. Although cone test results showed lower and diminishing knockdown and mortality rates for the Olyset in Pemba, the tunnel tests gave very good results; after 33 months, 100% of both brands still had optimal insecticidal effectiveness.

Limitations

Some of the durability risk factors—for example, net care and repair attitude—as well as some of the outcomes, such as reason for net losses, were based on the answers from 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 district, the district selection was purposive and some caution is required when generalizing the findings to Zanzibar as a whole.

Conclusion

After three years of following similar, rural populations in the Zanzibar islands of Unguja and Pemba, the 150-denier polyethylene LLIN Olyset showed a significant lower physical survival compared to the 100-denier polyester LLIN PermaNet 2.0, even though, at the end, estimated median survival was 2.7 years for the Olyset and 2.9 years for the PermaNet. The difference between the brands came from an earlier start of failures in the Olyset, which were mitigated by improved care behaviors in Pemba in the second part of the study. Insecticidal performance was optimal for both brands throughout the follow-up.