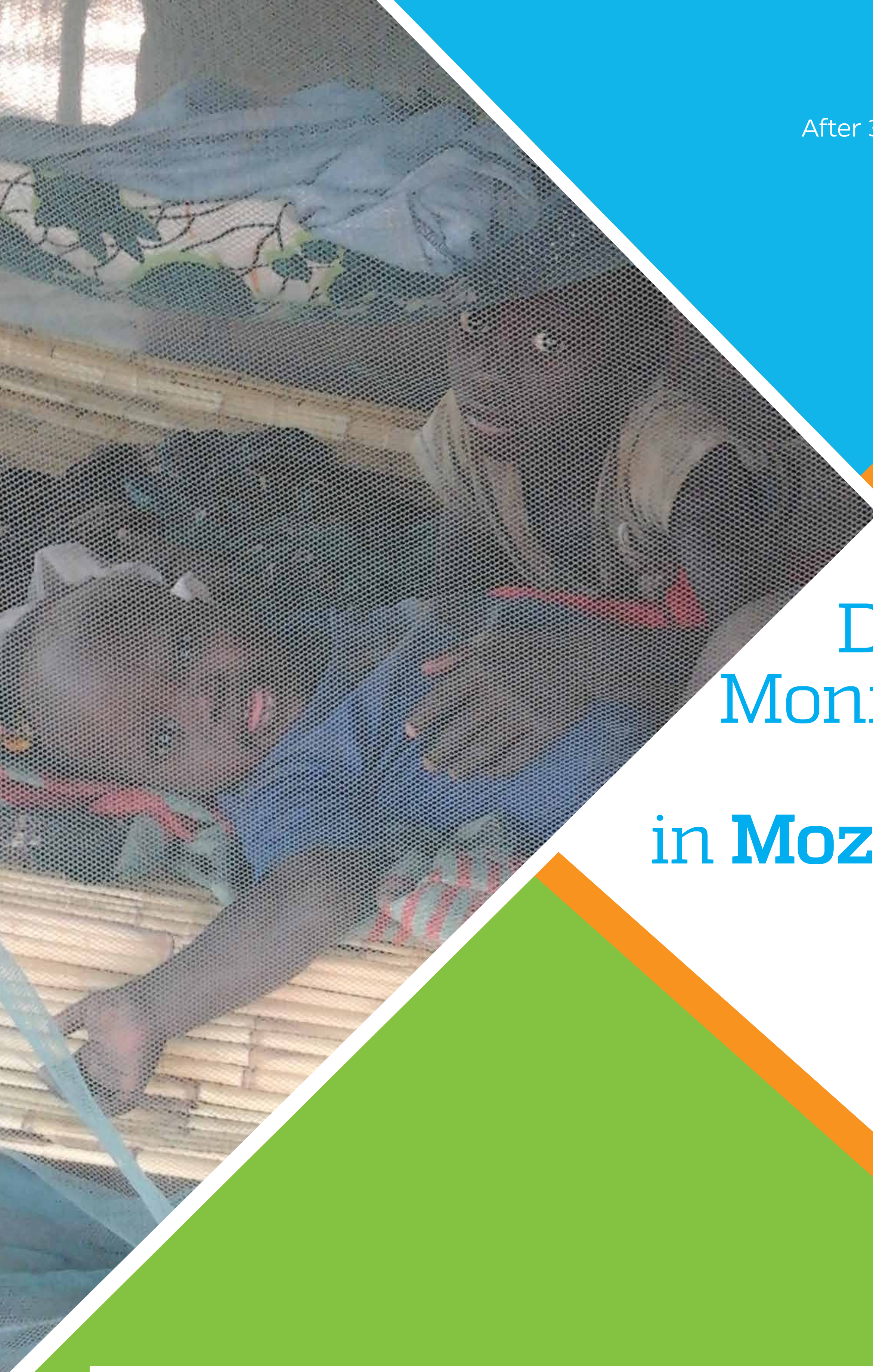
FINAL REPORT
After 36 months follow-up
DECEMBER 2018



Durability Monitoring of LLINs in **Mozambique**

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CDC Centers for Disease Control and Prevention

U.S. President's Malaria Initiative

VectorWorks
Scaling Up Vector Control for Malaria Prevention

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Abstract

Background: Malaria prevention with long-lasting insecticidal-treated mosquito nets (LLINs) has seen a tremendous scale-up in sub-Sahara Africa in recent years; however, studies suggest that the physical durability of the same or similar LLINs may vary significantly. These differences are largely driven by environmental and behavioral factors, and country programs should implement regular monitoring of LLIN durability. Following guidance from the U.S. President's Malaria Initiative (PMI), durability monitoring of two brands of LLINs with identical specifications distributed in the 2015 mass distribution campaign in Mozambique over three years was set up in three districts of ecologically different provinces: Nampula, Tete, and Inhambane. The activity was carried out by the National Malaria Control Program and the National Health Institute, with support from the VectorWorks project and PMI.

Methods: This prospective cohort study recruited representative samples of households from each district at baseline, one to six months after the mass campaign. All campaign nets in these households were labeled, and followed up over 33 to 36 months. A total of 998 households (98% of target) and 1,988 campaign nets (85%) were included in the study. Definite outcomes could be determined for 80% of the cohort nets in Inhambane, 45% in Tete (due to high mobility), and 68% in Nampula. Outcomes measures for physical durability were attrition (all-cause attrition and attrition due to wear and tear) and physical integrity, based the proportionate Hole Index (pHI) and subsequent categorization of cohort nets as serviceable (pHI<643). 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). The outcome for insecticidal durability was determined by bio-assay (World Health Organization [WHO] cone test) from sub-samples of campaign nets and was defined as the proportion of nets that showed optimal insecticidal effectiveness (24-hour mortality of ≥80% or 60-minute knockdown of ≥95%). In addition, demographic, social-economic, and behavioral aspects were recorded through a structured questionnaire at each time point.

Results: The demographic characteristics of the populations were comparable across sites and did not change significantly over time. All three areas were relatively poor, but the Inhambane site was clearly economically better off compared to Tete and Nampula, as measured by access to agricultural land and ownership of livestock and household assets. Risk factors for damage were grouped into four categories, namely net use environment in the household, net handling, type of sleeping place, and knowledge and attitudes toward net care and repair. These risk factors were relatively high in all three sites, but highest in Nampula, followed by Tete and then Inhambane. Exposure to behavior change communication was relatively low: around 30%–60% at most time points. Resulting net care and repair attitude of respondents was poor at all three sites, with only 20% to 25% showing a very positive attitude.

At baseline, between 13% and 29% of the cohort nets were found hanging, but this changed at the 12-month follow-up when 50%–76% of the nets were in use, increasing further to 66%–87% in the 24- and 36-month surveys. All households had other nets available for use and all sites received additional nets from a mass campaign during follow-up; these nets were used as often as the cohort nets. In Tete, net use was lowest and 18% of households stated that they used the nets only during the rainy seasons.

After three years, the all-cause attrition (i.e., losses for any reason) varied between 74% in Nampula, 56% in Inhambane, and 50% in Tete. The proportion of losses due to wear and tear among all-cause attrition increased gradually; at 36 months these losses comprised 41% in Tete, 33% in Nampula, and 28% in

Inhambane. Net integrity also was most favorable in Inhambane, where only 22% of cohort nets found in households at the final survey were too damaged to be serviceable. In contrast, this rate was 36% in Tete and 37% in Nampula. Together, this resulted in a proportion of nets surviving in serviceable condition at 57% after 33 months in Inhambane, 43% after 36 months in Tete, and 33% after 33 months in Nampula. Expressing the outcome as a median survival time (i.e., the time until 50% of the distributed nets are no longer serviceable), the results were 3.0 years (95%CI 2.8\–-3.3) for the Royal Sentry in Inhambane, 2.8 years (2.4–3.5) for MAGNet in Tete, and 2.4 years (2.1–2.6) for Royal Sentry in Nampula. Although MAGNet and Royal Sentry are produced by different manufacturers, they have the same specifications and, therefore, can be considered as "same LLIN brand." Differences in median survival can be interpreted as differences between sites rather than LLIN brand.

Insecticidal effectiveness was optimal for all sampled nets (100%), in all three sites, up through the 24-month follow-up, but declined somewhat at 36 months. In Inhambane, only 3% of samples showed optimal effectiveness, 11% in Tete, and 29% in Nampula. However, most nets (96% overall) still had minimal effectiveness and only 4% had insufficient insecticidal effect.

Conclusion: After three years of follow-up among rural district populations in the provinces of Inhambane, Tete, and Nampula, the 150-denier polyethylene LLIN Royal Sentry/MAGNet showed significant differences in median physical survival, ranging from 3.0 years in Inhambane to 2.8 in Tete and 2.4 in Nampula. The survival estimate for Nampula was significantly below the assumed three-year LLIN survival, while, at the other two sites, it was consistent with that assumption. The differences in survival could be attributed, at least in part, to house and net environment, and net care and repair behaviors. Insecticidal performance was optimal up to 24 months after distribution, but then dropped significantly. However, 96% of samples at 36 months still showed minimal effectiveness and provided at least some insecticidal protection.

Contents

3 Acknowledgments

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4 Background

Malaria prevention with long-lasting insecticidal-treated mosquito nets (LLINs) has seen a tremendous scale-up in sub-Saharan Africa in recent years. Many countries have achieved high ownership coverage with LLINs and are approaching the universal coverage target recommended by the World Health Organization (WHO)[1]. A critical question now is how these successes can be sustained; previous studies suggest that the physical durability of the same or similar LLINs may vary significantly—from less than two to four or more years—and these differences are largely driven by environmental and behavioral factors and not by the product type.

In 2006, Mozambique introduced a national policy for free distribution of LLINs to children under 5-years-old and pregnant women; in 2009, Mozambique adopted the policy of universal coverage (targeting one LLIN for every sleeping place and using an allocation algorithm that takes into account prevailing sleeping patterns [2]). The U.S. President's Malaria Initiative (PMI) has also supported the free distribution of LLINs through antenatal clinics (ANCs), including 1,252,731 LLINs distributed to pregnant women in 2015. In Mozambique, previous LLIN campaigns have been conducted at the district level, with an estimated 7.6 million LLINs distributed by both the Ministry of Health and partners through mass distribution campaigns between 2000 and 2012 [3]; and an additional 14,394,364 LLINs were distributed in Mozambique between 2013–2015 [4]. Universal coverage campaigns were conducted in 45 districts in 2011, 21 districts in 2012, 23 districts in 2013, and 64 districts in 2014/2015, distributing 5.2 million LLINs [5]. A nationwide mass campaign began in late 2016, which aimed to cover all districts of the country by the end of 2017.

The 2007 Malaria Indicator Survey reported 15.8%[6] of households owned at least one LLIN, increasing to 51.4% in the 2011 Demographic and Household Survey (DHS)[7], and 66.0% in the 2015 AIDS and Malaria Indicator Survey (IMASIDA)[8]. The proportion of the population with access to an LLIN within the household increased from 8.5% to 37.0% to 53.8%, respectively. Additionally, the proportion of children under 5 and pregnant women who had used an LLIN the night before increased from 7% and 7% in 2007, to 36% and 34% in 2011, and 47.9% and 52.1% in 2015, respectively[6,7,8].

Between 2008 and 2011, a study on the durability of two types of LLINs was undertaken in Nampula [9] comparing a 100-denier polyester LLIN—PermaNet 2.0—to a 150-denier polyethylene LLIN—Olyset—over three years. No difference was found in attrition between the LLIN types, but the results showed that early losses were mostly due to LLINs being given away to others to use in the first year. Losses due to wear and tear were low initially (5% of all losses) and then increased to 37% and 51% after two and three years, respectively. The study also found better performance of LLINs in households away from the coast (inland) compared to the coastal area. Preliminary analysis of residual insecticide efficacy shows that both Olyset and PermaNet LLINs retain their efficacy for one year of use, under normal household use, in rural Mozambique. The efficacy gradually declined and, after two years, only PermaNet insecticide residual efficacy was within the WHO recommendation of >80% using the standard cone bio-assay to show optimal effectiveness (manuscript in preparation).

5 Methods

The activity was carried out by the National Malaria Control Program and the National Health Institute, with support from the VectorWorks project and PMI.

5.1 Sites

Three districts in three ecologically different provinces were purposively selected as the study sites, based on the timing of campaigns, malaria epidemiology, and environmental factors. Angoche district (Nampula province) is a coastal district located in the Northern region with high malaria transmission; it has a population of 322,151 (recorded at the last national census). Changara district (Tete province) is located inland in the Central region with moderate to high malaria transmission and has a population of 194,463. Jangamo district (Inhambane province), located in the Southern region with moderate malaria transmission, is coastal and has a population of 108,493. Table 1 presents data from the 2011 Demographic and Health Survey[6], to give a brief profile of the malaria situation in the study districts.

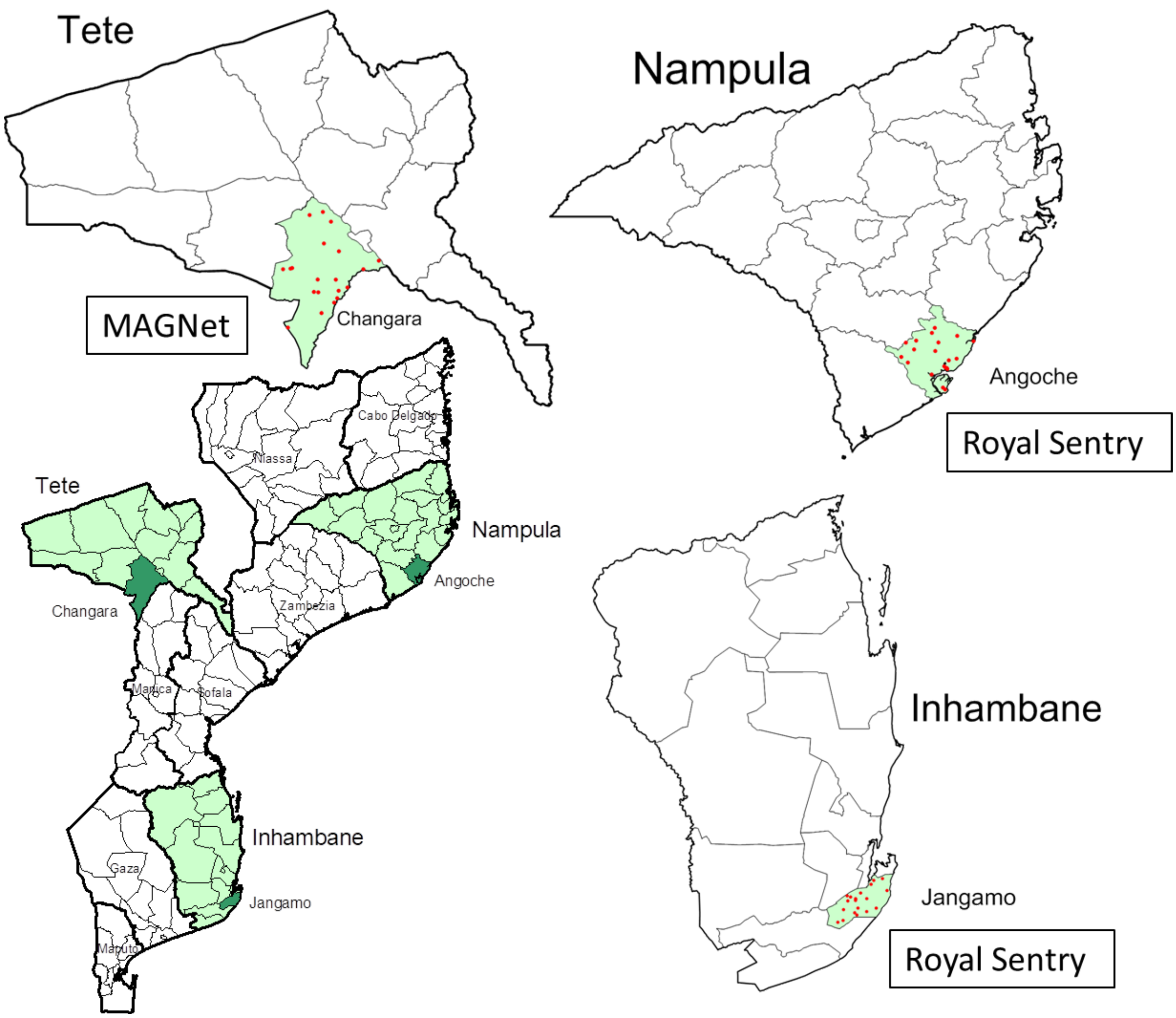
Table 1: Socio-demographic and malaria situation in the study provinces in 2011

Province	% of HH* with Electricity	% of HH with Access to Safe Water	% of Population in Lowest SES Quintile	% of Children 6–59m Blood Slide Positive for Malaria	% of Febrile Children under 5 Treated with an Anti malarial	% of HH with at Least One LLIN	% of HH Population Who Slept under an LLIN the Night Before
Nampula	14.5	38.5	27.8	43.3	42.9	59.7	43.1
Tete	11.8	43.5	23.3	36.9	16.8	46.1	23.8
Inhambane	18.9	60.3	5.0	36.8	34.2	51.5	19.1

* HH = household, SES= socioeconomic status

The mass campaign for which this durability monitoring is carried out was undertaken in Tete in May 2015 and in Inhambane and Nampula in October 2015. Since then, additional mass distribution campaigns have been carried out in these sites in 2016 and 2017.

Figure 1: Site map with GPS points and LLIN brand



5.2 Brands monitored

Two brands of LLIN were distributed in the 2014/15 mass distribution campaign and they were selected to be monitored for their durability: MAGNet® in Tete province and Royal Sentry® in Nampula and Inhambane. Both brands are 145-denier polyethylene-based LLINs with 260 mg/m^2 alphacypermethrin incorporated. They follow the specifications of the Duranet® previously evaluated by World Health Organization/Pesticide Evaluation Scheme (WHOPES) and given interim recommendation in 2007[10] and full recommendation in 2013 [11]. Both—MAGNet® and Royal Sentry®—then received recommendation for public health use from WHOPES in 2011[12], based on the process of "extension of specification" where products only need to show that they meet the specifications of a previously recommended product.

5.2.1 Pre-shipment testing

Pre-shipment quality control data is not available for the LLIN used in this Mozambique campaign.

5.3 Design summary

This is a prospective study of a cohort of LLINs from the 2014/5 mass distribution campaign that was followed up over three years. The design follows the guidance of PMI for LLIN durability monitoring (see www.durabilitymonitoring.org), although the sample size is slightly higher because planning was completed before this guidance was finalized. Applying a design effect of 2.0 and 5% loss to follow-up of households, the required sample of LLINs, after three years, was 631 per site in order to detect a 12%-point difference between sites or estimate median survival of LLIN with a precision of ± 0.5 years (at alpha error 0.05 and beta error of 0.2). Considering the expected attrition rates, a sample of 782 LLINs was estimated to be needed at baseline and, based on the expected number of LLIN distributed per household (2.5), 340 households were needed to be sampled per site. These were sampled from 20 clusters (communities) with 17 households selected per cluster.

At baseline, the LLIN cohort in each district was established by selecting a representative sample of clusters (communities), based on probability proportionate to size. Households were selected using simple random sampling from household lists established on the day of the survey. As soon as clusters were sampled, the local authorities and chiefs were informed of the purpose and the expected time of the survey, and their support was requested. To obtain maximum cooperation for the surveys, communities were then sensitized and mobilized. All LLINs received from the mass campaign by the selected households were identified and marked with a unique ID number, plus a barcode was stapled to the net. The physical condition of the campaign LLIN was measured using a hole assessment and a household interview was undertaken. At the three follow-up surveys—12, 24, and 36 months after distribution—the selected households that were still active (still present with campaign nets in their possession) were revisited and the status of the labeled campaign cohort LLINs were assessed, including the physical integrity measurement of the LLINs. In addition, at each follow-up survey, 30 campaign LLINs were collected in each province for bio-assay tests. At 12 and 24 months, these were taken from the neighbors of randomly selected households from the cohort, and at 36 months, bio-assay nets were randomly sampled from the original campaign net cohort. In all cases, replacement LLINs were given.

The baseline assessment took place in October/November 2015 in all three sites. The 12-month survey was done in Tete on June 23–29, 2016; and, in Nampula and Inhambane, on August 8–14, 2016. The 24-month follow-up took place on May 20–30, 2017, in Tete; on August 5–13, 2017, in Inhambane; and August 11–16, 2017, in Nampula. The 36-month final follow-up was in May 7–15, 2018, in Tete; July 27–August 2, 2018, in Nampula; and August 2–8, 2018, in Inhambane.

An additional LLIN mass campaign was carried out in Nampula during September/October 2016. In addition, all sites were included in the national 2017 LLIN mass campaign that took place between the 24- and 36-month surveys in all three sites.

5.4 Field work

An implementation team of 13 individuals was established per site, with one overall site coordinator and three field teams each, comprising one supervisor and three interviewers. The head of project of the National Malaria Control Program for each province 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 in conducting household surveys. While interviewers and supervisors were replaced during the study, most field teams participated in all four surveys. For the final survey in Nampula, a new coordinator was assigned. He had been trained previously by participating in training and field work in Tete.

Prior to each follow-up survey 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)
- participating in a detailed study of interview with role play
- introducing and practicing with the data entry device, including the mapping software to track households
- physically assessing the holes and repairs in LLINs with practical exercises
- collecting sample campaign LLINs for bio-assays and issuing replacement LLINs.

5.5 Data management

For data collection, tablet PCs (Samsung Galaxy Tab 4) were used and were installed with the data collection software, Open Data Kit (ODK) [13], a free and open-source mobile data collection tool[10]. Each field team was provided with a tablet for the household interviews and LLIN hole counting; data from each interviewer was collected and directly uploaded to a Dropbox folder (if internet was available) or collected on a local storage device (laptop) by the site coordinator until it could be transferred. Data were then checked and verified before it was deleted from the tablets, and any inconsistencies followed up the following day. From the data, four types of data files were created and updated after each assessment round:

- household files
- household member files (only baseline and m36 surveys)
- campaign (cohort) LLIN files
- files for other nets owned by the households.

5.6 Analysis

Data were converted from the ODK system to comma-delimited data files (*.csv format) using the ODK briefcase tool for daily inspection of incoming data. After completion of the survey, 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 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 recorded; these are analyzed by recoding the four-level Likert scale score to have a value of -2 for "strongly disagree," -1 for "disagree," +1 for "agree," and +2 for "strongly agree." These attitude scores for each respondent were then summed and divided by the number of statements to calculate an overall attitude score for which zero (0) represents a neutral result and positive values a positive result. For each site, the proportion of households with a score above 1 (very positive attitude) were calculated. Two attitude scores were used, one for general attitude toward net use and one, specifically, for care and repair.

A wealth index was calculated for the baseline and 36-month data sets using the basic household assets and using a principal component analysis, with the first component used as the index. Households were then grouped into tertiles. At the 12- and 24-month surveys, no specific household or member data were collected.

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

The proportion of nets received from the LLIN distribution not given away for use by others that are still present and in serviceable physical condition (definition provided below). It is calculated for each time point as follows:

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

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

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

Net integrity: Measured first by the proportionate Hole Index (pHI), as recommended by WHO. Holes in the LLIN of the cohort were counted as 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:

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

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

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

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

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

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

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

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

...where tm is the median survival time, t1 and t2 the first and second time points in years, and p1 and p2 the proportion surviving to first and second time point, respectively, in percentage. Confidence intervals for this estimate was calculated by projecting the 95% CI from the survival estimates in the same way as described above.

The secondary outcomes of insecticidal effectiveness were based on the bio-assay results using the standard WHO cone test. A pyrethroid-sensitive strain of *Anopheles arabiensis* was used with 10 mosquitoes per cone, five sites tested on each net (four sides and roof), and four replicates per location (20 cone tests with 200 mosquitoes per net in total). Recorded were 60-minute knockdown (KD60) and 24-hour mortality. The two variables from these tests, KD60 rate, and 24-hour mortality rate were combined into the following outcome measures:

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

5.7 Ethical Clearance

Ethical clearance was obtained from the Institutional Review Board of the Johns Hopkins University, Baltimore, USA (IRB No.: 6361) and the Bioethics Committee of the National Health Institute, Maputo, Mozambique (Ref No: 047/CIBS-INS/2015)

6 Results

6.1 Sample

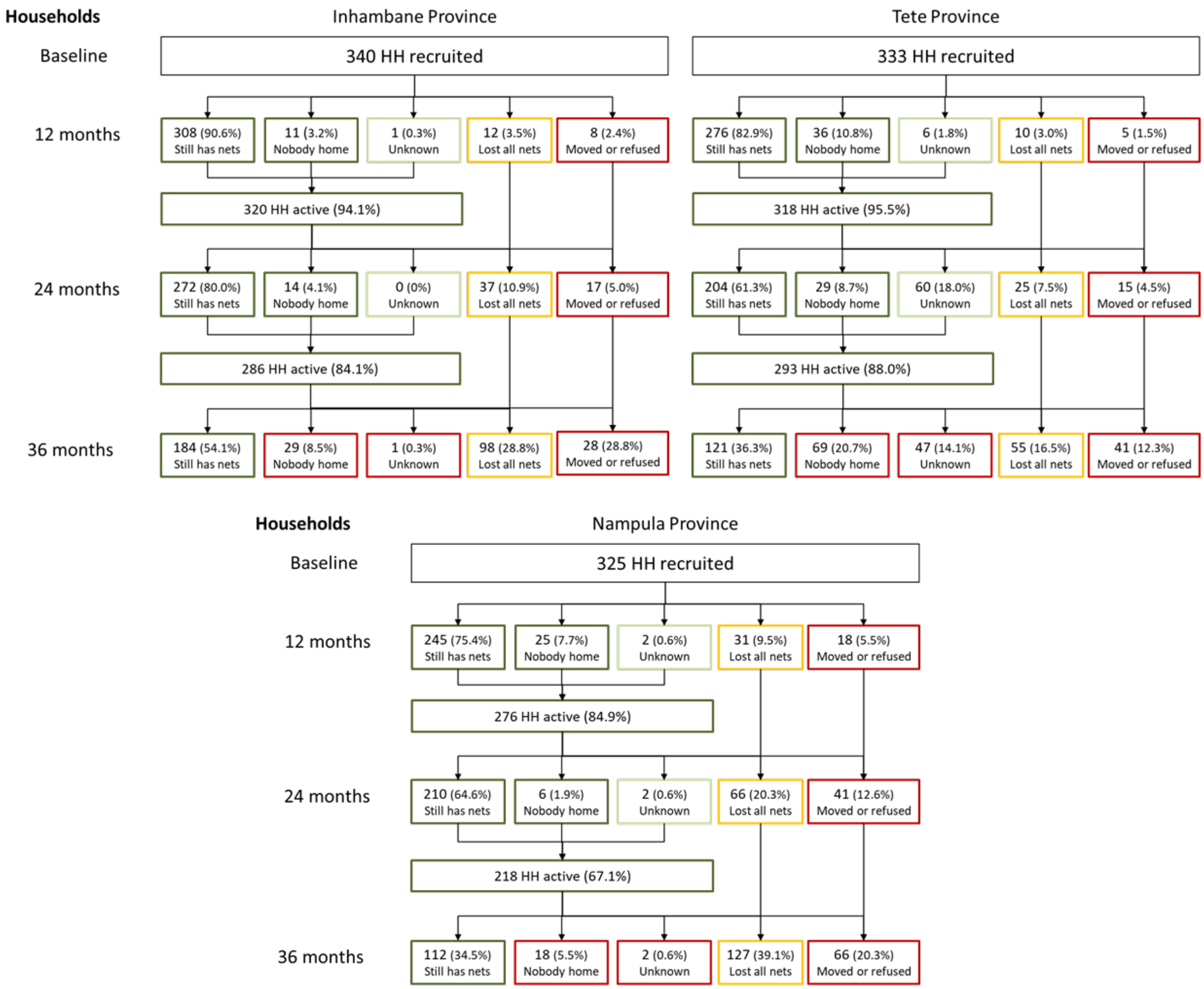
At baseline, a total of 998 households were recruited and 1,988 campaign nets were labeled for follow-up. See Figure 2 for a detailed summary of the recruited households and their follow-up in all three sites. Households had three reasons for dropping out of the study: the most important being the loss of all their campaign nets so no further follow-up was needed. After three years, this applied to 39% of the 325 recruited households in Nampula, 29% of the 340 recruited households in Inhambane, and 17% of the 333 recruited households in Tete. The second reason for loss to follow-up was households moving away to other communities. This was most common in Nampula, applying to 18% of the households at the end of the study, while migration was lower in Inhambane (8%) and Tete (10%). There was also some within-village migration (i.e., households shifted to new homes within the village). This was rare in Inhambane and Tete, with less than 1%; but more in keeping with the pattern of higher mobility seen in Nampula (6%). 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 these were rare. None were encountered in Inhambane and only 2% and 3% in Tete and Nampula, respectively.

In Tete, a considerable number of households were categorized as "unknown," particularly at the 24-month survey. This was mostly because teams did not record the "nobody found in the home" status. In the last survey, some of the "unknown" outcomes were because the field teams could not reach two clusters when the roads flooded. Absence of the household on the survey day was not an issue in Inhambane and Nampula, but it was a problem in Tete. Many households were at their far-away farms, or had temporarily taken up work in mining or gone to Zimbabwe for jobs; at the last survey, 21% of the originally recruited households could not be interviewed.

Overall, the follow-up was very good in Inhambane, with 78% of the recruited households available at all four surveys. In Nampula, the rate was 63%, mainly because the percentage of households that lost all their nets was higher than in Inhambane. Due to the frequent absence of households in Tete, only 39% of recruited households were included in all four surveys. However, 57% of the households in Tete were seen at the baseline and 36-month surveys. These rates were 84% in Inhambane and 68% in Nampula.

Finally, the data from two clusters in Tete for the 36-month survey (last day of field work) were suspicious. Not only were all the nets in households without holes—even though these same nets were recorded as damaged in the previous survey—but, also, time stamps for the start of interviews were only 5–10 minutes apart, although the standard follow-up visit was 20–30 minutes. This suggested that these data were fabricated and, therefore, these two clusters from Tete were excluded from the final analysis.

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



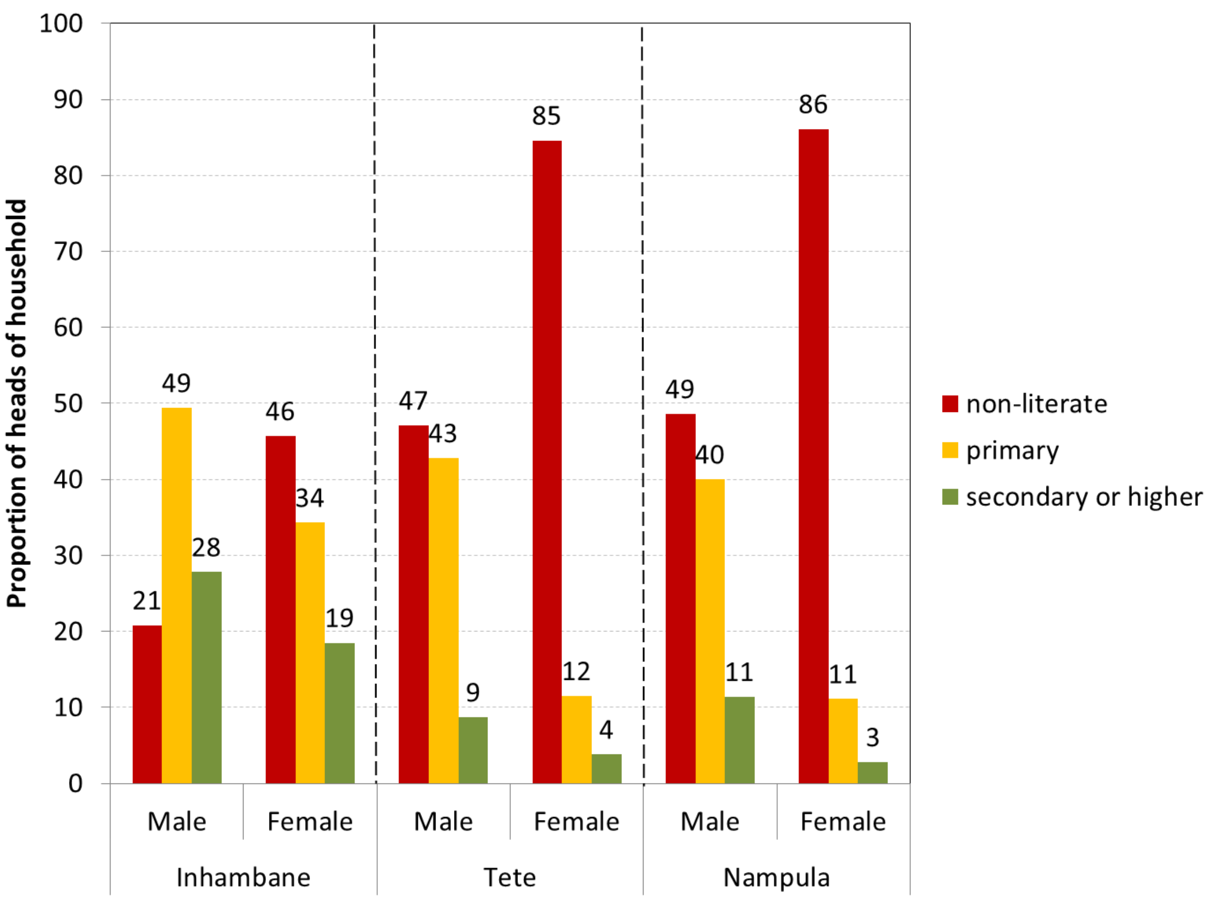
6.2 Socio-demographic characteristics

Comparing the households that participated in the baseline and 36-month surveys (N=1,100), the data were explored for any demographic or socio-economic changes during the three years of the study.

The average number of household members remained constant in Nampula with 4.1, and decreased somewhat in Inhambane (from 5.3 to 4.7), and Tete (4.5 to 3.5), but neither of these changes was statistically significant. The proportion of households headed by females also remained the same, with minor fluctuations: 25% in Inhambane, 15% in Tete, and 12% in Nampula. As expected, the mean age of the heads of household increased during the three years of the study, but only within the expected limits. The mean age was 51 years at the 36-month survey in Inhambane and Nampula and 49 years in Tete. In all three sites, the mean age of female heads of household was between four and seven years older than that of male heads of household: 52 years for females and 45 years for males. Population structure, as measured by the proportion of children less than 5-years-old, also did not change over time and was 12% in Inhambane and 14% in Tete and Nampula.

Educational status of the head of household did not change over time, but it was significantly lower for females than males ($p<0.0001$). It was better in Inhambane compared to the other two sites ($p=0.001$) for both male and female heads of household (see Figure 2a). The educational level of female heads of household in Nampula and Tete was alarmingly low, with only 16% and 14%, respectively, ever attending school, even after considering these women were in school in the 1980s (during the Civil War).

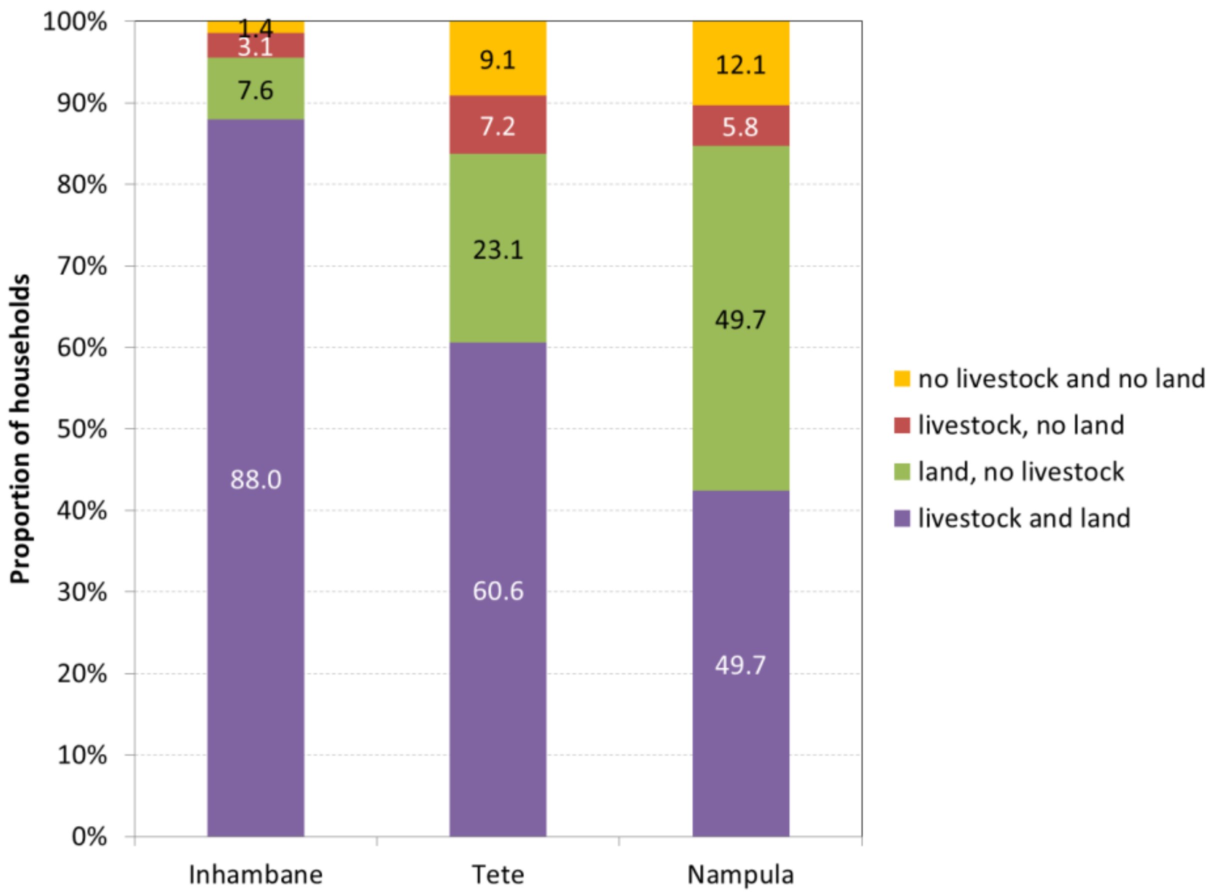
Figure 2a: Educational status of heads of household by gender and site



For socio-economic indicators, very little changed in the three years of the durability monitoring for the households that were included in the baseline, as well as the 36-month survey. The only significant change was a reduction in mobile phone ownership (any kind) in Inhambane from 85% at baseline to 62% at 36 months ($p<0.0001$). However, at the same time, the ownership of smart phones in Inhambane increased from 9% to 27%, mostly concentrated in the highest wealth tertile.

On the other hand, the three sites across all indicators were clearly different, showing that Jangamo district in Inhambane was economically significantly better off than the other two sites; and Changara in Tete and Angoche in Nampula were quite similar, with some advantages for Tete. This situation is best shown by the ownership of livestock and access to land for horticulture or agriculture (Figure 2b). The type of livestock also differed with goats and cows more common in Tete and chicken and ducks in Inhambane. Nampula was similar to Inhambane, but fewer households owned any livestock and the number of animals per household was also lower. Not captured in this indicator is the fact that six communities in Nampula were on the coast or on islands and fishing was also an economic activity.

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



Other indicators confirm the differences between sites. Access to safe water was 99% in Inhambane and 87% and 88% in Tete and Nampula, respectively. Any type of latrine was available for 98% of households in Inhambane, compared to 64% in the other two sites. Ownership of any phone was similar at 36 months in Inhambane (62%) and Nampula (64%), but lower in Tete (27%) where some parts of Changara district do not have coverage. However, ownership of smart phones was 27% in Inhambane, only 6% in Tete, and 0.5% in Nampula. A similar difference was seen for other "luxury" household assets, such as television (44% versus 8% and 14% respectively), refrigerator (19% versus 5% and 4%, respectively), and fan (13% versus 4% and 3%, respectively).

Quality of housing was more similar—mainly thatch or grass roofs, but the wealth difference can be seen in the floor materials. In Inhambane, 83% of houses had floors made from tiles or cement, while only 15% in Tete and 17% in Nampula.

6.3 Determinants of durability

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

The perceived presence of rodents was generally very high and highest in Nampula, where at least 90% of household respondents were aware of rodents at all time points; followed by Inhambane, with a consistent reporting of rodent presence by 75% of respondents. Only Tete had some variation, with lower values at baseline—especially at 12 months—and increased reported rodent presence in the last two surveys, even when looking at only households that participated in all surveys. This could reflect the fluctuations in rodent populations in this area.

Storing food in the sleeping room is thought to attract rodents and, thereby, increase the potential damage of nets by rodents. This practice was not very common in Inhambane or Tete with rates around 20%–30%, but was reported by 70% of households in Nampula ($p<0.0001$ for comparison between Nampula and the other two sites).

Cooking in the same room where nets are hanging is a potential source of burn damage, especially if the cooking fuel is firewood or charcoal, as was the case for 99% of all enrolled households. This practice was again very uncommon or non-existent in Inhambane and Tete, but was reported by more than 50% of households in Nampula ($p<0.0001$).

The type of sleeping place over which the nets were used was mainly bed frames in Inhambane and Nampula (Figure 3) and 75% were finished bed frames in both sites. In contrast, the few beds encountered in Tete were from unfinished materials and the dominant type of sleeping place was reed mats.

Table 2: Household risk factors

Variable and Site	Baseline	12 months	24 months	36 months
Inhambane	N=340	N=320	N=279	N=245
Ever store food in sleeping room	31.5%	30.0%	19.2%	21.6%
Cook in sleeping room				
never	89.4%	85.3%	93.2%	96.3%
sometimes	10.6%	13.1%	6.6%	3.7%
always	0.0%	1.3%	0.0%	0.0%
Rodents observed (last 6 months)	77.1%	83.1%	62.6%	76.7%
Tete	N=333	N=286	N=219	N= 132
Ever store food in sleeping room	24.0%	19.2%	34.4%	25.0%
Cook in sleeping room				
never	90.7%	67.3%	53.2%	74.2%
sometimes	2.7%	21.0%	39.0%	24.2%
always	4.5%	2.8%	7.9%	1.6%
Rodents observed (last 6 months)	45.7%	28.7%	62.1%	71.2%
Nampula	N=325	N=280	N=245	N= 173
Ever store food in sleeping room	69.2%	71.8%	58.8%	66.5%
Cook in sleeping room				
never	46.8%	30.0%	40.4%	30.1%
sometimes	51.4%	49.3%	46.1%	66.5%
always	1.8%	20.0%	13.5%	3.5%
Rodents observed (last 6 months)	91.1%	89.6%	89.0%	98.3%

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

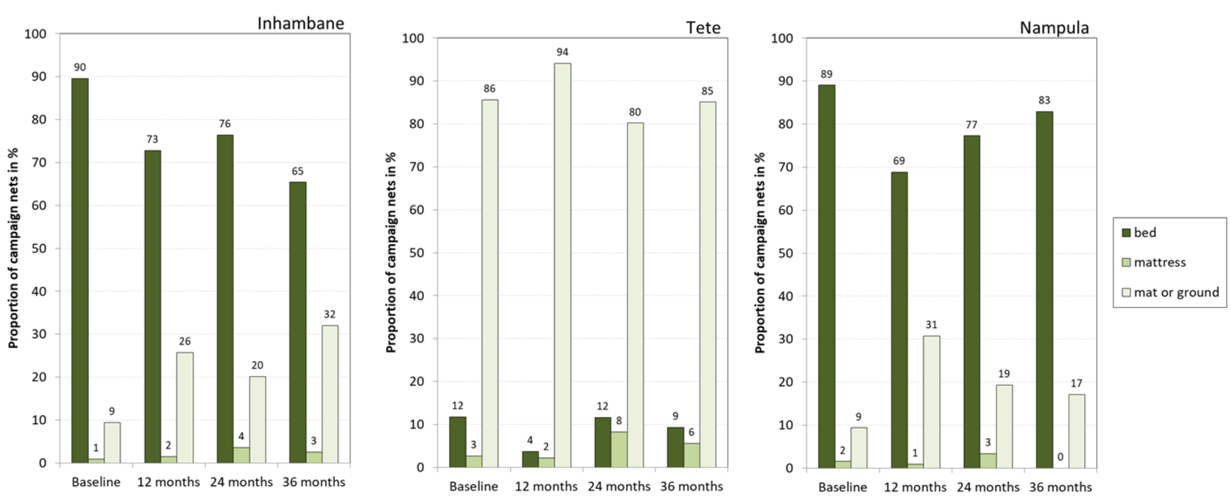


Table 3: Handling of campaign LLINs (Inter-Quartile-Range [IQR])

Variable and Site	Baseline	12 months	24 months	36 months
Inhambane				
Hanging LLINs NOT folded or tied	92.8%	93.8%	91.7%	93.4%
LLIN dried on fence or bush	45.2%	33.5%	21.3%	28.6%
LLIN ever washed	1.9%	39.1%	70.9%	79.0%
Median washes last 6 months (IQR)	1.0 (1–1)	1.0 (1–2)	2.0 (1–2)	2.0 (1–2)
Used detergent/bleach for wash	7.1%	11.7%	20.1%	13.3%
Tete				
Hanging LLINs NOT folded or tied	77.4%	45.9%	39.7%	33.8%
LLIN dried on fence or bush	25.9%	75.5%	45.8%	34.1%
LLIN ever washed	10.0%	43.3%	77.1%	76.8%
Median washes last 6 months (IQR)	3.0 (1–4)	2.0 (1–3)	4.0 (2–6)	2.0 (1–3)
Used detergent/bleach for wash	83.3%	81.1%	28.3%	23.5%
Nampula				
Hanging LLINs NOT folded or tied	89.2%	78.2%	95.8%	34.8%
LLIN dried on fence or bush	37.3%	23.6%	31.4%	40.4%
LLIN ever washed	7.9%	40.8%	70.2%	88.4%
Median washes last 6 m (IQR)	1.0 (1–2)	3.0 (1–5)	3.0 (2–4)	2.0 (1–2)
Used detergent/bleach for wash	28.9%	16.1%	8.0%	34.2%

See Table 3 for durability risk factors associated with LLIN handling. The proportion of cohort LLINs that were hanging loose over the sleeping place, and were not folded up or tied during the day, remained very high in Inhambane, with over 90%; but, it was lower and declining in Tete, reaching only 34% at 36-month follow-up ($p<0.0001$ for site comparison). In Nampula, most campaign nets were hanging loose in place for the first three surveys. Only at the last survey did the rate decrease to just 35%, but this would not have influenced LLIN durability significantly. About one-third of households dried LLINs on bushes or fences, with no significant difference between sites.

As expected, the proportion of cohort LLINs ever washed started out low and increased over time, reaching 40% at 12 months and around 70% at 24 months. At the final survey, nets ever washed appeared to reach a saturation point in Inhambane; Tete had only a modest increase to 79%. Only in Nampula was a further 18% increase observed, from 70% to 88%. The washing frequency showed some variations, but settled at a rate of about two washes every six months at all three sites. The proportion of households reporting washes with a detergent remained low in Inhambane at 13% and Tete at 23%, and moderately high in Nampula at 34%.

Table 4: Exposure to LLIN messaging in the last six months

Variable and Site	Baseline	12 months	24 months	36 months
Inhambane				
Any exposure last 6 months	62.1%	80.9%	51.5%	52.2%
Mean info sources (if exposed)	2.9	3.4	2.0	1.8
Type of media				
media only	0.0%	0.7%	4.1%	0.8%
both	18.5%	31.3%	20.3%	8.7%
IPC only	81.6%	68.0%	75.7%	90.6%
Tete				
Any exposure last 6 months	12.9%	42.7%	41.1%	43.1%
Mean info sources (if exposed)	3.7	2.3	2.3	2.1
Type of media				
media only	4.7%	0.0%	6.8%	1.8%
both	44.2%	12.3%	26.1%	28.1%
IPC only	51.2%	87.7%	67.1%	70.2%
Nampula				
Any exposure last 6 months	36.0%	37.9%	58.4%	37.0%
Mean info sources (if exposed)	2.6	2.4	2.5	2.1
Type of media				
media only	3.4%	3.9%	0.7%	0.0%
both	16.4%	17.3%	32.2%	21.9%
IPC only	80.2%	78.9%	67.1%	78.1%

Exposure to LLIN related messages, message recall, and the resulting household attitude toward care and repair are shown in Tables 4 and 5. After a peak in Inhambane at 12 months behavior change communication exposure declined there again to 52%, similar to Tete that remained at 41% and Nampula—with exposure rates around 37% with one spike of 58% during the 24-month survey. The previous observation that communications was mainly through interpersonal communication still holds true, although, in Tete and Nampula, exposure to media (mainly radio) increased slightly, while it declined in Inhambane.

Looking at the actual recall of messages and household care and repair attitudes calculated from a series of questions (Table 6) reflects the low exposure rates and shows that messages about “repair” are consistently recalled less than any other. Net care and repair attitude was generally low at all three sites, with only 10% to 20% of household respondents showing strongly positive attitudes. There was some variation in Nampula, with higher values at 12- and 24-month follow-up, but there Is no explanation for this variation in the data. It is most likely that this is a chance variance, or was influenced by the way the questions were asked, rather than a true variation in attitude.

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

Variable and Site	Baseline	12 months	24 months	36 months
Inhambane				
Recalled "use LLIN (every) night"	59.4%	79.7%	46.5%	51.0%
Recalled "LLINs prevent malaria"	37.7%	57.8%	5.7%	34.7%
Recalled "care for LLIN"	57.1%	76.1%	28.6%	48.6%
Recalled "repair LLIN"	25.6%	15.3%	1.7%	15.9%
Attitude score care and repair mean (95% CI) % with score >1.0	 0.7 (0.6–0.9) 22.4%	 0.6 (0.4–0.7) 9.4%	 0.7 (0.5–0.8) 18.3%	 0.7 (0.5–0.8) 25.3%
Tete				
Recalled "use LLIN (every) night"	12.9%	42.7%	38.8%	41.7%
Recalled "nets prevent malaria"	11.4%	36.4%	37.9%	30.0%
Recalled "care for net"	12.6%	37.3%	35.6%	36.4%
Recalled "repair net"	7.2%	26.9%	24.2%	19.7%
Attitude score care and repair mean (95% CI) % with score >1.0	 0.7 (0.6–0.8) 16.0%	 0.7 (0.5–0.8) 17.9%	 0.7 (0.6–0.8) 13.7%	 0.4 (0.3–0.5) 3.0%
Nampula				
Recalled "use net (every) night"	32.3%	31.1%	48.6%	36.4%
Recalled "nets prevent malaria"	21.9%	15.8%	31.8%	26.0%
Recalled "care for net"	21.2%	22.3%	18.4%	25.4%
Recalled "repair net"	7.1%	3.7%	2.9%	5.2%
Attitude score care and repair mean (95% CI) % with score >1.0	 0.7 (0.6–0.8) 6.5%	 0.8 (0.7–1.0) 37.6%	 1.1 (0.9–1.2) 60.9%	 0.6 (0.5–0.7) 10.4%

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 LLINs increased, reaching 65% in Inhambane, 62% in Tete, and 83% in Nampula. Actual repairs remained low even with increasing damage in Inhambane and Nampula, with about 10% of damaged campaign nets showing any repairs. In contrast, the repair rate increased continuously in Tete, reaching 27% in the final survey (p=0.003). This could impact the final estimate of LLIN survival.

Stitching was the dominant method of repairing holes: 83% in Inhambane, 80% in Nampula, and 69% in Tete; followed by tying the hole up in a knot with 14%, 56%, and 30%, respectively. Using patches was less common with 17%, 6%, and 10%, respectively (respondents could mention multiple methods so the rates do not add up to 100%). Households with hole experience who said they had never repaired holes were asked why they did not repair the net. Among those that replied, 53% in Nampula said they had no time for repairs, followed by "don't know how" (17%), "don't have materials for repair" (13%), and "not necessary" (10%). In contrast, the most common response in Inhambane was "not necessary" (28%) and in Tete "lack materials" (27%), with the other responses spread out more evenly.

In Inhambane, the baseline assessment had a better performance with respect to risk factors for durability, followed by Tete and Nampula (to the extent that risk factors are understood to-date). This order still holds after the 36-month survey, although the differences between provinces appear to be somewhat reduced, especially between Tete and Nampula, with Nampula showing some improvements.

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

Variable and Site	Baseline	12 months	24 months	36 months
Inhambane				
Ever experienced holes in net	35.6%	34.1%	63.3%	64.5%
Ever discussed care and repair	51.5%	73.4%	58.1%	31.4%
Ever repaired (if had holes)	60.3%	64.2%	49.5%	18.4%
Damaged campaign LLINs repaired	0.0%	0.8%	12.1%	4.7%
Tete				
Ever experienced holes in net	8.7%	25.5%	70.3%	61.4%
Ever discussed care and repair	14.1%	39.2%	37.4%	27.3%
Ever repaired (if had holes)	13.8%	9.6%	16.9%	19.8%
Damaged campaign LLINs repaired	4.3%	7.4%	21.4%	27.3%
Nampula				
Ever experienced holes in net	1.2%	43.1%	54.3%	82.7%
Ever discussed care and repair	29.2%	31.2%	35.7%	30.6%
Ever repaired (if had holes)	n.a.	16.1%	15.8%	14.0%
Damaged campaign LLINs repaired	n.a.	10.1%	10.6%	9.7%

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.

From the observation at baseline that most cohort LLINs were found still in the package and not hung, there had been some concern about the feasibility of durability monitoring if the LLINs were not used. After 12 months, the situation had significantly improved and it continued to improve up to the 24-month follow-up and then remained at around 70%–80% at 36-month follow-up at all three sites (Table 7). Only between 2% and 4% of the cohort nets present in the households were still in the package. About one-fifth (11%–31%) of the cohort LLINs were not hanging, but some were still used the previous night (especially in Tete with 88% of "taken down" nets being used and Nampula with 30%), indicating that they might be removed during the day to gain space in the house. This also explains why, in Tete, the proportion of cohort LLINs used last night was higher than the rate hanging. Reported regular use (every day last week) was still significantly below use last night. Of the household respondents, 81% in Inhambane, 73% in Nampula, and 65% in Tete said they used the nets equally in the rainy and dry season. However, a significant proportion of 18% in Tete also said they used them only during the rains, while only 4% in Inhambane, and none in Nampula, stated this.

Table 7: Hanging and use of campaign LLINs from cohort

Variable	Baseline	12 months	24 months	36 months
Inhambane	N=726	N=589	N=423	N=405
Hanging	13.4%	50.3%	68.6%	71.2%
Taken down or stored	1.1%	19.5%	20.1%	28.9%
Still in package	85.5%	29.4%	10.9%	3.9%
Used last night	12.6%	51.1%	66.0%	66.5%
Used every night (last week)	13.2%	41.0%	44.5%	40.7%
Tete	N=601	N=464	N=306	N=232
Hanging	20.6%	57.8%	68.3%	66.1%
Taken down or stored	11.3%	29.4%	24.5%	31.3%
Still in package	68.1%	9.7%	0.0%	2.7%
Used last night	18.8%	55.0%	70.9%	72.3%
Used every night (last week)	10.8%	19.3%	39.3%	21.1%
Nampula	N=661	N=414	N=268	N=240
Hanging	29.4%	76.3%	80.6%	86.8%
Taken down or stored	3.9%	12.3%	18.0%	10.9%
Still in package	66.7%	9.7%	0.8%	1.6%
Used last night	28.7%	78.5%	95.2%	86.1%
Used every night (last week)	37.8%	53.3%	53.3%	38.8%

See Table 8 for the hanging and use of the non-cohort nets found during each survey. At the baseline survey in November 2015 (i.e., at the end of the dry season), non-cohort net hanging and use was similar to cohort net use in Tete suggesting generally lower use. This corresponds to the responses obtained on the “seasonal use” question mentioned above. In the follow-up surveys, which were done at the end of the rains in Tete, nets found hanging varied between 60% and 80%; they were always slightly higher than those of the cohort nets. In contrast, hanging and use of non-cohort nets in Inhambane and Nampula was significantly higher at baseline—just one month after the distribution of the cohort nets there—suggesting reasonable net use even in the dry season, but preference initially for the nets already owned rather than the new ones. During follow-up, hanging and use rates were similar to the cohort nets except at the 36-month survey in Inhambane when non-cohort nets were used less and 25% were still in the package.

Table 8: Hanging and use of non-cohort nets (n.a.=not applicable)

Variable	Baseline	12 months	24 months	36 months
Inhambane	N=264	N=127	N=198	N=584
Hanging	68.5%	62.2%	77.8%	57.9%
Taken down or stored	22.3%	26.4%	9.2%	16.3%
Still in package	9.2%	9.6%	11.2%	25.2%
Used last night	71.6%	64.3%	73.0%	55.4%
Used every night (last week)	56.4%	45.7%	70.7%	48.9%
Tete	N=91	N=34	N=24	N=151
Hanging	13.2%	70.6%	79.2%	61.6%
Taken down or stored	4.6%	20.6%	0.0%	11.2%
Still in package	82.2%	8.8%	8.7%	19.2%
Used last night	6.7%	64.7%	66.7%	64.2%
Used every night (last week)	6.6%	20.6%	41.7%	51.7%
Nampula	N=89	N=2	N=221	N=176
Hanging	93.6%	n.a.	70.1%	85.8%
Taken down or stored	0.7%	n.a.	1.8%	8.4%
Still in package	5.7%	n.a.	25.5%	5.1%
Used last night	92.1%	n.a.	70.8%	87.4%
Used every night (last week)	61.8%	n.a.	69.7%	87.5%

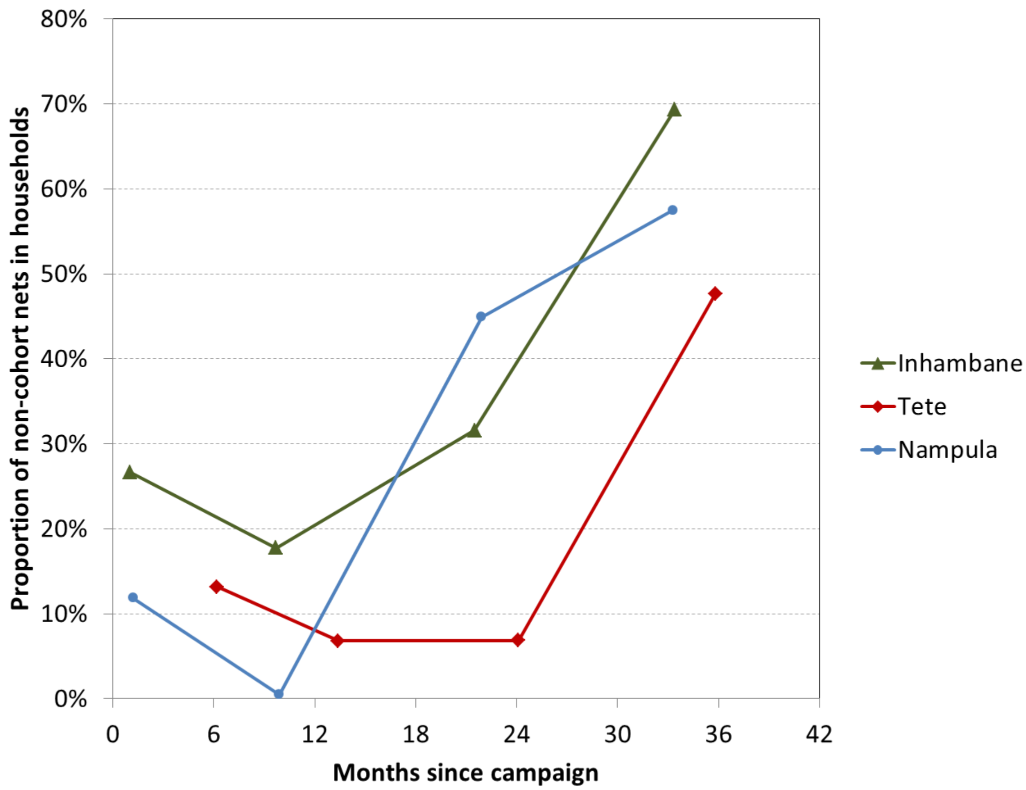
Table 9: Ownership of any non-cohort nets by households and source for these nets ANC=antenatal care; HF=health facility; NGO=nongovernmental organization

Variable	Baseline	12 months	24 months	36 months
Inhambane	N=264	N=127	N=198	N=584
Household has any other nets	40.0%	26.3%	41.4%	80.7%
Source public sector	86.3%	80.2%	54.8%	94.7%
Source other campaign*	16.3%	9.5%	15.7%	83.9%
Source ANC, HF	70.0%	70.0%	39.1%	10.5%
Source private sector	4.9%	6.3%	3.5%	0.5%
Source family/friends, NGO, other	8.7%	13.5%	41.9%	4.8%
Tete	N=91	N=34	N=24	N=151
Household has any other nets	21.3%	9.4%	10.1%	33.5%
Source public sector	97.8%	76.5%	87.5%	100%
Source other campaign*	3.3%	2.9%	4.2%	92.1%
Source ANC, HF	94.5%	73.6%	83.3%	7.3%
Source private sector	0.0%	11.8%	8.3%	0.0%
Source family/friends, NGO, other	2.2%	11.8%	4.2%	0.0%
Nampula	N=89	N=2	N=221	N=176
Household has any other nets	11.4%	0.7%	42.5%	45.4%
Source public sector	91.0%	n.a.	99.5%	100%
Source other campaign*	40.5%	n.a.	95.0%	87.4%
Source ANC, HF	50.5%	n.a.	4.5%	12.6%
Source private sector	7.9%	n.a.	0.5%	0.0%
Source family/friends, NGO, other	1.1%	n.a.	0.5%	0.0%

*Previous or subsequent to cohort campaign

To assess the use of the cohort nets, the overall net ownership situation needs to be considered (see Table 9 and Figure 3a). Initially, a significant number of non-cohort nets were only found in Inhambane because, during the 2015 campaign some Olyset nets were distributed among the recruited households, but they were not included in the durability monitoring cohort. At all sites, the proportion of households with any non-cohort net, and the proportion of these among all nets owned by the households, declined sharply, suggesting that older nets had been discarded. In Nampula, new campaign nets came in both in 2016 and 2017 (in both cases, Duranet), resulting in an increase to near or above 50% of non-cohort nets, but only reaching about 40%–45% of the study households. It is unclear whether this was caused by the poor reach of the campaign in this area or a significant under-reporting of these nets by the households. In Tete, the situation was similar. A campaign that preceded the 36-month survey raised the proportion of non-cohort nets among the net crop to around 50% (a mix of Olyset and Magnet), but only 33% of study households had nets from other sources; which, in this case, was 87% from the most recent campaign. In Inhambane, there was a sharp increase of non-cohort nets in the 36-month survey (all Magnet), with 81% of households reached and non-cohort nets reaching a share of 70% of the net crop—clearly from the campaign. However, a moderate increase was also seen at the 24-month survey and these nets (mostly Dawa Plus) were described, in part, as being from “health facilities” and, in part, as “from NGOs” which could represent the same source. In this case, only 40% of households were reportedly reached.

Figure 3a: 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 all sites received additional free nets from campaigns or routine distributions, it is not surprising that between 92% (Tete) and 99% (Inhambane) of households still owned any LLINs at the final survey. The proportion of households with enough nets for all household members (one LLIN for every two people) at the final survey was unusually high in Inhambane, with 81% compared to 61% at baseline (i.e., immediately following the 2015 campaign), suggesting some oversupply. Indeed, the proportion of households with one net for every person increased from 29% at baseline to 44% at 36 months; 92% of the population had access to an LLIN (up from 78% at baseline). In contrast, net ownership and access in Tete and Nampula was lower and more typical of a post-campaign situation. Households with enough LLINs for all was 63% in Tete (up from 43% at baseline) and 78% of the population in sampled households had access (compared to 71% at baseline). In Nampula, the proportion of households with enough nets was 57% (down from 71% at baseline and population access was 72% (down from 85%). It must be kept in mind, however, that this survey was designed to monitor LLIN durability and is not necessarily representative of post-campaign LLIN ownership coverage.

The use pattern of cohort LLINs, as well as non-cohort nets, did not change dramatically over time (see Tables 10 and 11). Use patterns were similar at all sites, with a tendency for a slightly higher proportion of nets in Tete shared by adults and children. In all sites, the largest proportion of nets were used by adults only. No significant differences in use patterns were observed between the cohort and non-cohort nets.

Table 10: LLIN users of campaign cohort LLINs

Variable	Baseline	12 months	24 months	36 months
Inhambane				
Children only*	13.2%	15.6%	11.5%	13.5%
Children + adults**	35.2%	14.3%	15.1%	15.3%
Adults only**	51.7%	70.1%	73.5%	71.2%
Tete				
Children only*	14.2%	16.5%	12.9%	12.4%
Children + adults**	52.2%	47.1%	54.8%	29.6%
Adults only**	33.6%	36.5%	32.3%	58.0%
Nampula				
Children only*	16.3%	12.6%	6.7%	10.8%
Children + adults**	29.5%	13.9%	20.8%	10.8%
Adults only**	54.2%	73.5%	72.6%	76.6%

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

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

Variable	Baseline	12 months	24 months	36 months
Inhambane	N=201	N=81	N=143	N=323
Children only*	13.4%	25.9%	23.8%	13.9%
Children + adults**	22.4%	13.6%	10.5%	25.7%
Adults only**	64.2%	60.5%	65.7%	60.4%
Tete	N=6	N=22	N=16	N=97
Children only*	n.a.	18.2%	31.3%	13.4%
Children + adults**	n.a.	63.6%	37.5%	30.9%
Adults only**	n.a.	18.2%	31.3%	55.7%
Nampula	N=82	N=2	N=155	N=153
Children only*	17.1%	n.a.	27.7%	24.2%
Children + adults**	23.2%	n.a.	21.3%	32.0%
Adults only**	59.8%	n.a.	51.0%	43.8%

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

6.5 Durability of campaign LLINs

See Figures 4, 5, and 6 for the status of the campaign LLINs for the durability cohort after 36 months. Of the 726 LLINs labeled in Inhambane, 257 (35%) were present at the final survey; for 95 (13%) LLINs, the status was unknown because the household could not be interviewed during the survey. An additional 52 nets (7%) were lost to follow-up because they had been in households that moved away. Losses for any reason were 322 (44%), but these were predominantly due to giving away LLINs and not due to wear and tear. For 13 nets (2%), the respondent could not recall the reason for loss.

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

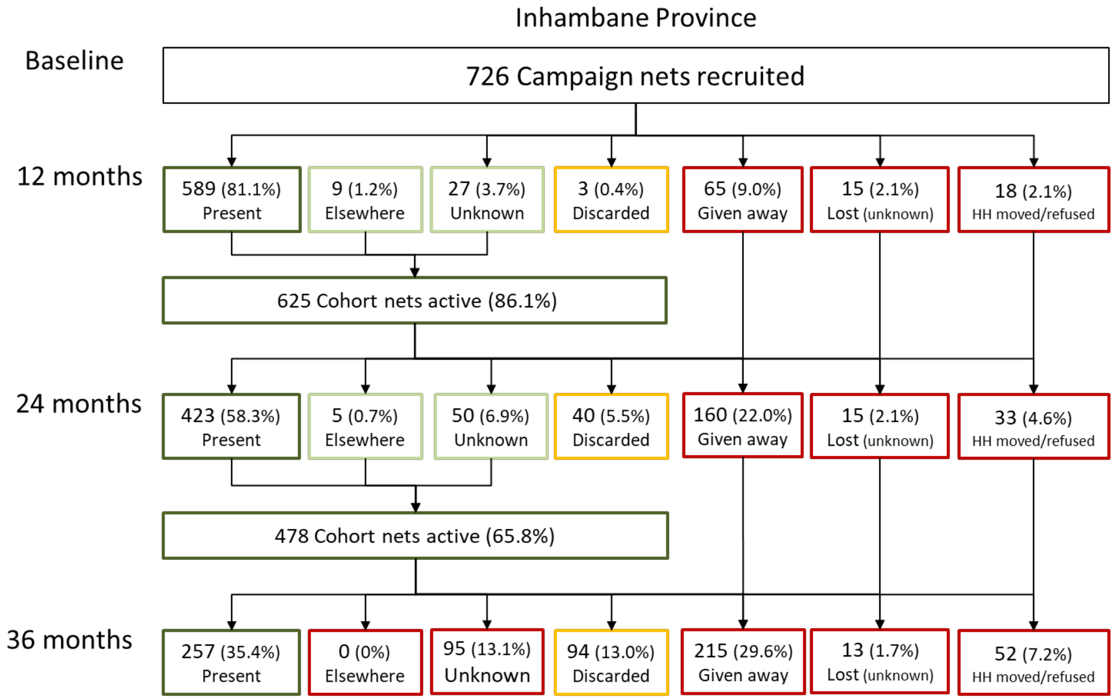


Figure 5: Status of cohort LLIN recruited at baseline in Tete province

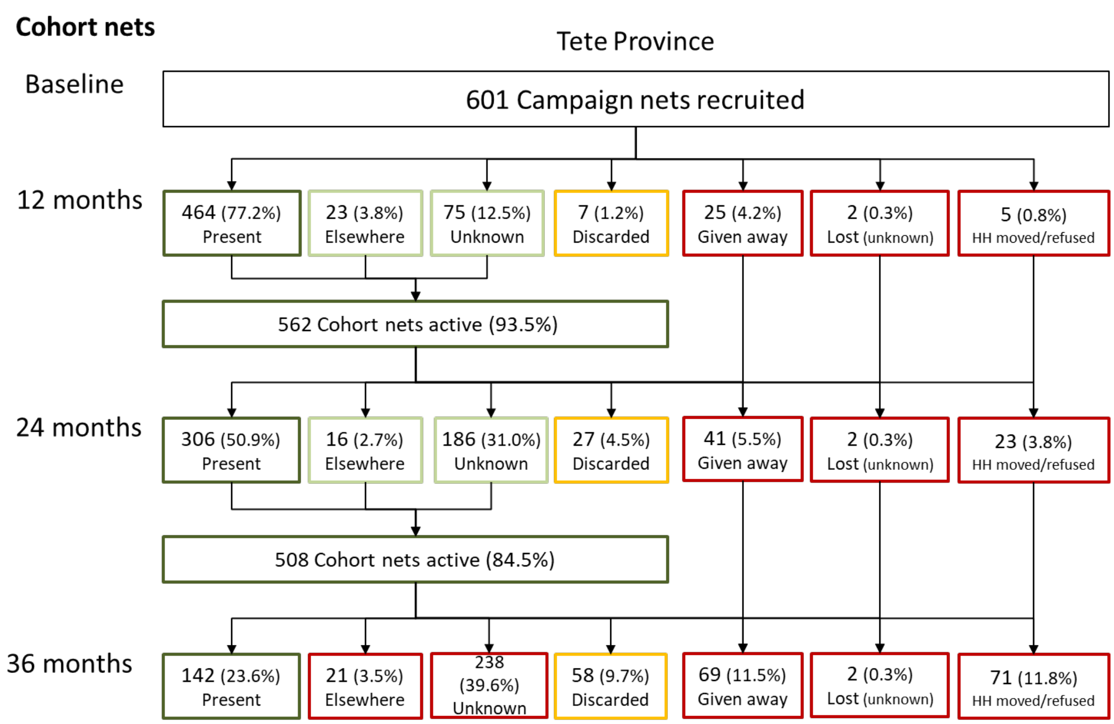
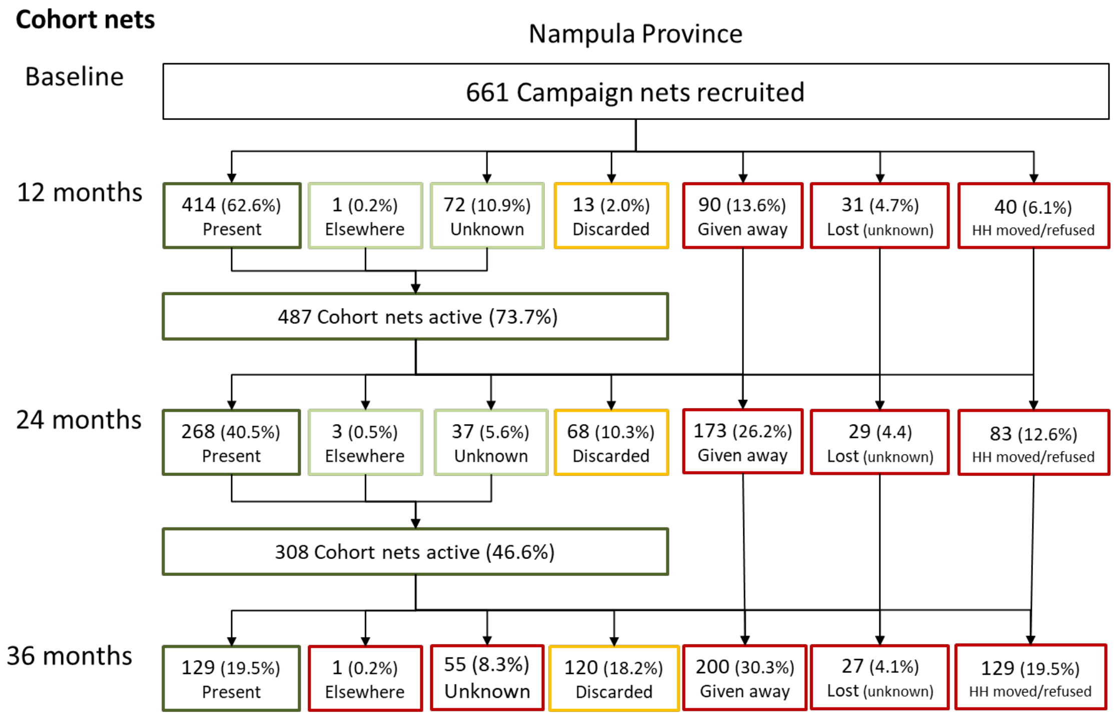


Figure 6: Status of cohort LLINs recruited at baseline in Nampula province



In Tete, only 142 (24%) of the originally labeled nets of the cohort were present at the 36-month follow-up and the households used 21 (4%) in other locations. Due to the high mobility at this site, the fate of 238 cohort nets (40%) remained unknown and 71 (12%) moved away with the households. In Tete, 128 LLINs were definitely lost (21%), similar to the percentage given away or discarded. Only for two nets, the reason for loss could not be recalled.

In Nampula, 129 nets (20%) from the original cohort were still in the household at the final survey, one was used elsewhere, and 55 (8%) had an unknown status because the households were not present on the day of the survey. Confirmed losses were the highest across all sites, with 375 or 57%; however, a large portion of these—200 (30%)—were given away and for 27 (4%), the reason for loss could not be determined.

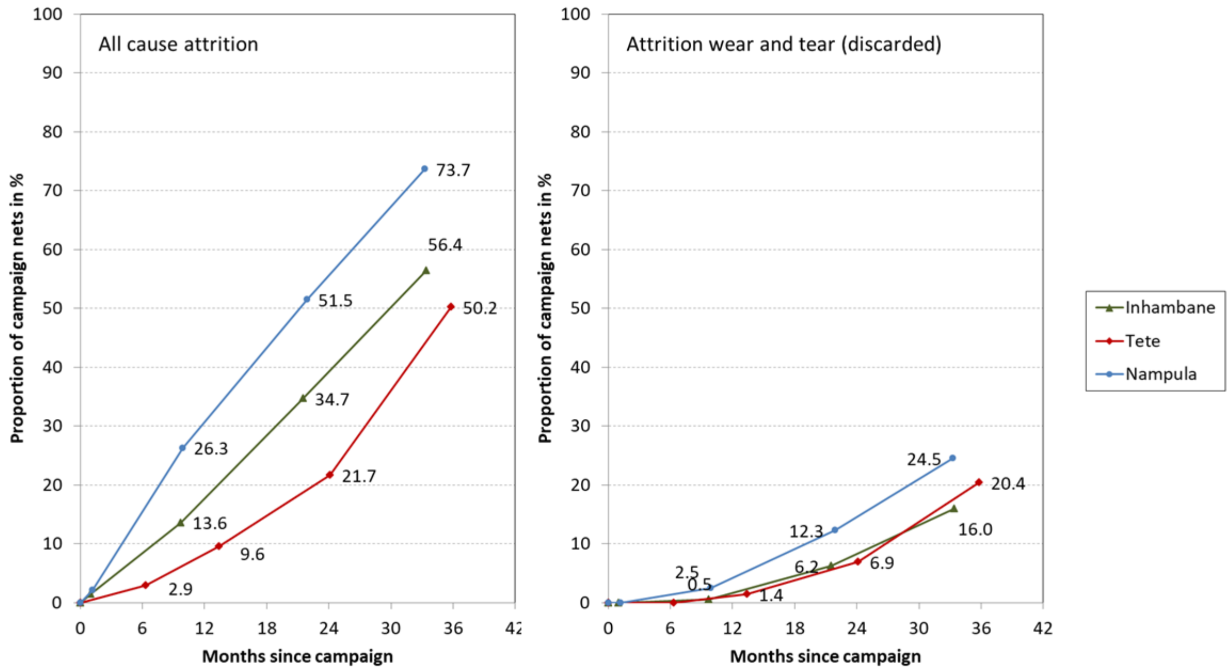
See Table 12 for the resulting all-cause attrition rates and losses due to wear and tear since the campaign, including LLINs that were reported to have been lost between the 2015 campaign and the baseline survey. These include only those nets for which a definitive outcome could be determined. The highest all-cause attrition was seen in Nampula, with 74%, followed by Inhambane at 56%, and Tete with 50%. However, taking into account the different times of observation between Tete and the other two sites (see Figure 7) reveals that attrition increased more or less linearly at all three sites and was highest in Nampula, followed by Tete; it was lowest in Inhambane. Attrition due to wear and tear increased in a more curvilinear fashion, with very slow increase initially, followed by near exponential gains. Attrition due to wear and tear was very similar in Inhambane and Tete, but clearly higher in Nampula.

Table 12: Attrition (including LLINs lost between campaign and baseline but excluding LLINs for which a definite outcome is not known)

Variable	Campaign – baseline	Campaign – 12 months	Campaign – 24 months	Campaign – 36 months
Inhambane	N=737	N=682	N=648	N=589
Given away	1.4%	11.0%	26.2%	38.2%
Discarded (wear & tear)	0.0%	0.4%	6.2%	16.0%
Unknown	0.1%	2.2%	2.3%	2.2%
Total	**1.5%**	**13.6%**	**34.7%**	**56.4%**
Tete	N=619	N=513	N=391	N=285
Given away	2.4%	7.8%	14.3%	29.5%
Discarded (wear & tear)	0.0%	1.4%	6.9%	20.4%
Unknown	0.5%	0.4%	0.5%	0.4%
Total	**2.9%**	**9.6%**	**21.7%**	**50.2%**
Nampula	N=675	N=562	N=552	N=490
Given away	2.1%	18.5%	33.9%	43.7%
Discarded (wear & tear)	0.0%	2.3%	12.3%	24.5%
Unknown	0.0%	5.5%	5.3%	5.5%
Total	**2.1%**	**26.3%**	**51.5%**	**73.7%**

The proportion of losses due to wear and tear among all-cause attrition increased gradually. At 36 months, these losses were 41% in Tete, 33% in Nampula, and 28% in Inhambane. Reasons for loss among the discarded nets was similar across the three sites (p=0.3), with 54% thrown away, 36% destroyed, and 10% used for other purposes. Overall, there were only 28 cohort nets used for other purposes or 2% of all cohort nets with a known outcome. Nets protecting plants was the most commonly reported use in Inhambane and Tete. In Nampula, six of the 14 cohort nets used otherwise, or 1.2% of all nets with known outcome, were reported as used for fishing and one for drying fish. Other uses were cutting the net up for various uses (two) and as a window cover (one).

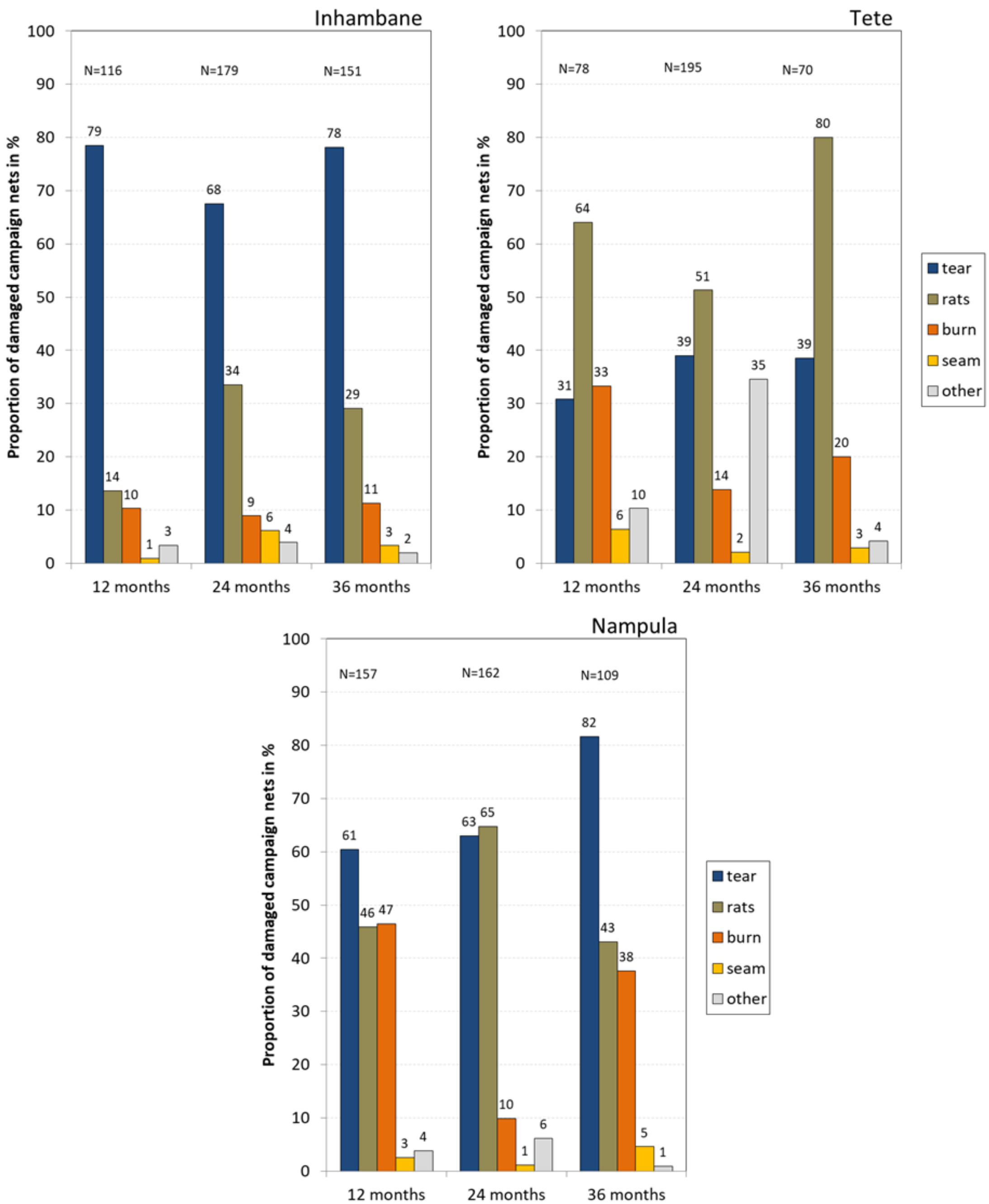
Figure 7: Trends in all-cause attrition and wear and tear (discarded LLINs) as a function of time since distribution



As expected, the proportion of LLINs still in the surveyed households with any sign of damage continued to increase significantly during the monitoring period (Table 13). In Inhambane and Nampula, the increases continued up to the final survey; while, in Tete, an equilibrium seems to have been reached where nets getting holes and nets being discarded occurred at similar rates so that the proportion with any hole no longer increased. The proportion of surviving LLINs that were no longer fit for use due to the level of damage (too torn) significantly increased at the final survey compared to the modest increases seen previously. In Inhambane, it reached 22%, while in Tete it was 36%, and in Nampula 37%. This suggests that nets in Inhambane were discarded at lower levels of damage compared to Tete, as both had similar attrition rates due to wear and tear, but significantly fewer damaged nets were found in Inhambane. This is also reflected by the median pHI among those nets with any damage, which was 269 in Inhambane, but 1,745 in Tete. In Nampula, the proportion of too-torn nets was highest and, accordingly, the proportion of surviving nets found in serviceable condition after three years was lowest, with 63%, followed closely by Tete with 64% and Inhambane with 78%.

See Figure 8 for the type of damage mechanisms reported by the households for each campaign LLIN with any holes. The general damage pattern throughout each time period monitored was similar within each site, but differed between the sites. In Inhambane, mechanical damage was most common followed by moderately frequent reports of rodent damage and low levels of burn holes and open seams. By contrast, rodent damage was consistently most often reported in Tete, including high levels of mechanical damage. Burn holes were more frequently reported than in Inhambane, but open seams were similarly uncommon. Finally, in Nampula, mechanical damage was the leading reported cause of damage, but was closely followed by rodent damage and also high rates of burn holes. Even though seam openings were rare in Nampula, this damage mechanism appears more wide spread, which is in keeping with the higher rate of torn nets, combined with high attrition from wear and tear.

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



Overall, physical survival of LLINs in serviceable condition after 36 months (i.e., the combination of attrition due to wear and tear) and the integrity of the still existing LLIN, was 57% in Inhambane, 43% in Tete, and 33% in Nampula (Table 14). Inhambane performed best and the result was statistically significantly different compared to Nampula (p=0.0004), but not compared to Tete (p=0.15). This was due to the higher design effect in Tete of 6.9 (compared to 1.7 in Inhambane and 2.8 in Nampula), which resulted in a wide confidence interval. In other words, there was a high variation between communities in durability in Tete. When only the cohort LLINs that had been used at all (taken out of package) were considered, the survival estimates were reduced only minimally by 2% and 1% in Inhambane and Tete, respectively, and it remained unchanged in Nampula.

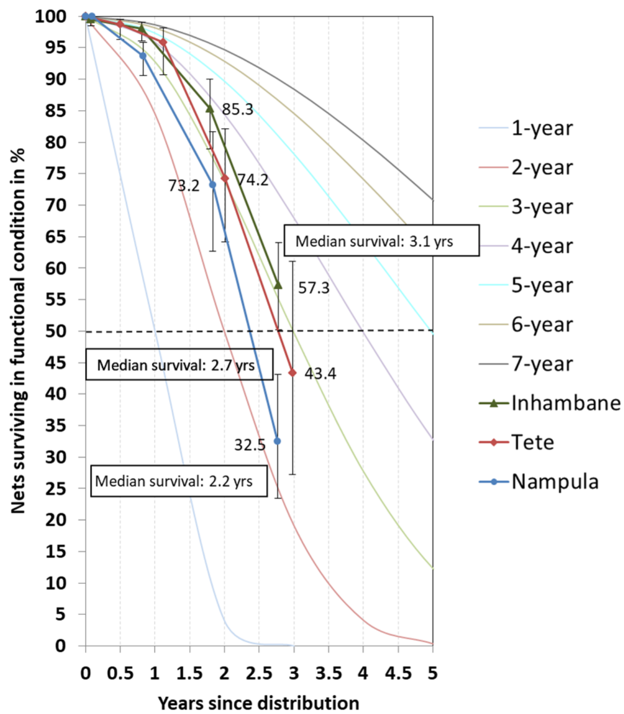
Table 13: Physical condition (integrity) of surviving cohort LLINs (proportionate Hole Index [pHI])

Variable	Baseline	12 months	24 months	36 months
Inhambane	N=726	N=589	N=423	N=257
Any holes	2.3%	20.0%	46.8%	58.4%
Median pHI (if any hole)	23	23	60	269
Good (pHI<64)	99.6%	94.2%	77.8%	58.4%
Too torn (pHI>642)	0.3%	1.5%	6.6%	21.8%
Serviceable (pHI≤642)	**99.7%**	**98.5%**	**93.4%**	**78.2%**
Tete	N=601	N=464	N=306	N=112
Any holes	7.7%	17.5%	62.8%	58.9%
Median pHI (if any hole)	137	54	162	1,745
Good (pHI<64)	95.7%	92.0%	58.5%	47.3%
Too torn (pHI>642)	1.3%	2.8%	19.3%	35.7%
Serviceable (pHI≤642)	**98.7%**	**97.2%**	**80.7%**	**64.3%**
Nampula	N=661	N=414	N=268	N=129
Any holes	0.6%	38.2%	56.3%	88.4%
Median pHI (if any hole)	n.a.	47	98	584
Good (pHI<64)	99.9%	82.6%	68.3%	23.4%
Too torn (pHI>642)	0.0%	3.4%	8.2%	37.2%
Serviceable (pHI≤642)	**100%**	**96.6%**	**91.8%**	**62.8%**

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

Variable	Baseline	12 months	24 months	36 months
Inhambane	N=726	N=592	N=463	N=351
Survival estimate	99.7%	98.0%	85.3%	57.3%
95% CI	98.1–99.9	96.0–99.0	78.9–90.0	50.2–64.1
Only LLINs ever used	N=107	N=361	N=332	N=258
Survival estimate	100%	96.7%	82.8%	54.7%
95% CI	-.-	93.7–98.3	74.4–88.2	45.0–64.0
Tete	N=601	N=471	N=333	N=166
Survival estimate	98.7%	95.8%	74.2%	43.4%
95% CI	96.3–99.5	90.7–98.1	64.2–82.1	27.2–61.1
Only LLINs ever used	N=199	N=409	N=312	N=154
Survival estimate	97.5%	95.4%	73.7%	41.6%
95% CI	92.1–99.2	91.0–97.9	64.2–81.4	25.5–59.7
Nampula	N=661	N=427	N=336	N=249
Survival estimate	100%	93.7%	73.2%	32.5%
95% CI	-.-	90.6–95.8	62.7–81.7	23.5–43.1
Only LLINs ever used	N=268	N=358	N=313	N=229
Survival estimate	100%	92.5%	73.2%	30.6%
95% CI	-.-	88.8–95.0	62.2–81.9	22.1–40.6

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



Comparing the survival in serviceable condition is hampered by the fact that time of follow-up differed slightly between Tete (35.8 months at the last survey) compared to Inhambane (33.4) and Nampula (33.3). To standardize the analysis, the results were plotted against the hypothetical survival curves with defined median survival (Figure 9). It can be seen that the survival estimates roughly follow the hypothetical curves and the relationship between the three sites was the same throughout the time of follow-up.

In addition to estimating median survival at each time point from the graph,1 it was also calculated from the final two data points (see methods) and results are shown in Table 15. Calculated median survival was 3.0 years in Inhambane (Royal Sentry LLIN), 2.8 years in Tete (Magnet LLIN), and 2.4 years in Nampula (Royal Sentry LLIN). Estimates obtained from the graph were very similar to the calculated ones at 36 months, but also show that early on in the monitoring the results tend to overestimate the final outcome. Considering the confidence intervals around the median survival, in Inhambane LLINs performed according to the three-year expectation; also, in Tete, the result was still compatible with the "three-year durability" although given the huge variation between communities in that site; it was not true for all villages. In contrast, in Nampula median survival was clearly below the three-year mark.

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

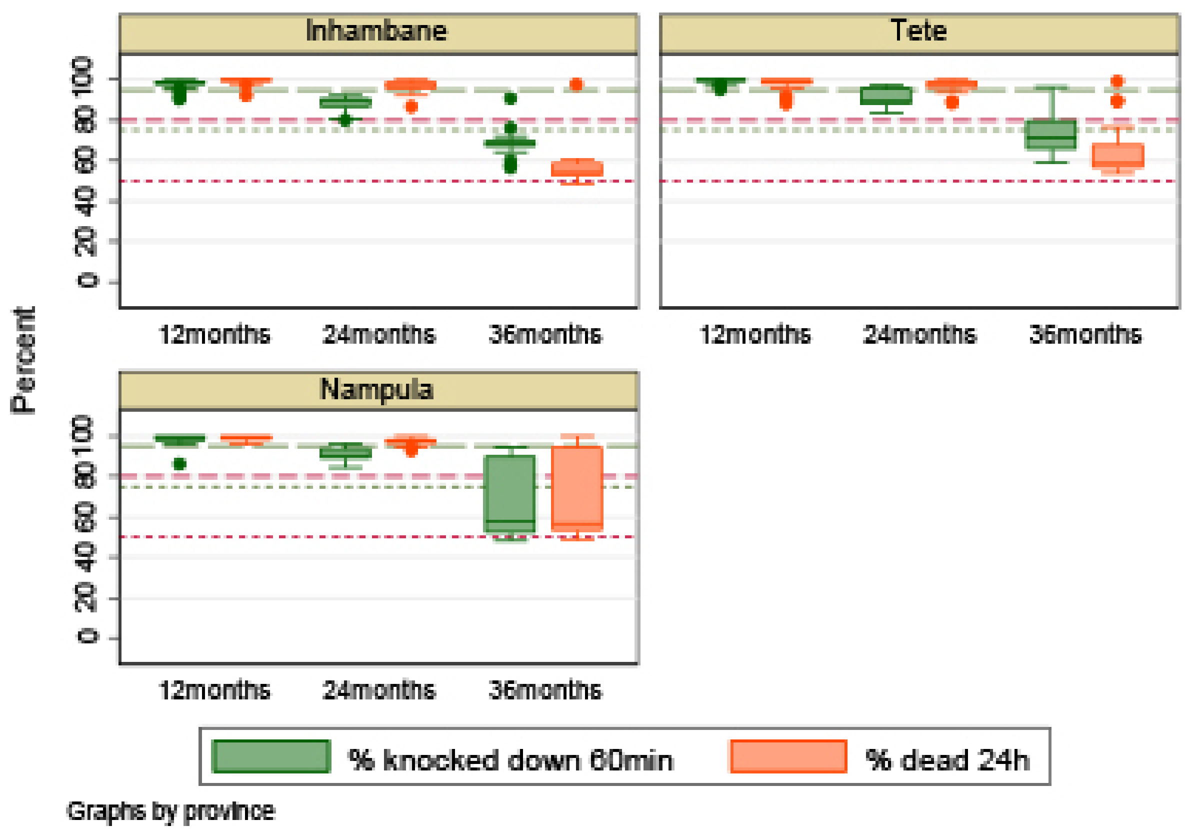
Table 15: Estimated median survival of LLIN in years using different methods

Variable	12 months	24 months	36 months
Inhambane			
Estimated from Figure 9[1]	4.9	3.7	**3.1**
Calculated from last two data points (95% CI)	-.-	-.-	**3.0 (2.8–3.3)**
Tete			
Estimated from Figure 9	4.5	3.1	**2.7**
Calculated from last two data points (95% CI)	-.-	-.-	**2.8 (2.4–3.5)**
Nampula			
Estimated from Figure 9	2.8	2.7	**2.2**
Calculated from last two data points (95% CI)	-.-	-.-	**2.4 (2.1–2.6)**

6.6 Insecticidal effectiveness of campaign LLINs

The target of sampling 30 campaign nets at each site with bio-assay testing was achieved at 12 and 24 months; but, at 36 months, 30 nets were sampled from Inhambane, while only 27 each could be obtained from Tete and Nampula. See Figure 10 and Table 16 for the results of the bio-assay testing. There was a decline, over time, of 60-minute knockdown percentage at all three sites, with a median of 58% after 36 months in Inhambane and Nampula, and 72% in Tete. Decline of vector mortality at the final survey was even more pronounced, with a median of 55% in Inhambane, 59% in Tete, and 57% in Nampula. This implies that optimal insecticidal effectiveness, which was 100% at 12 and 24 months at all sites dropped to just 3% in Inhambane, 11% in Tete, and 29% in Nampula. However, most samples still achieved the minimal effectiveness threshold with 93% in Inhambane, 100% in Tete, and 96% in Nampula—meaning that, overall, only 4% of the 36-month samples must be considered as providing insufficient insecticidal protection.

Figure 10: Results from WHO cone bio-assays: the box plot shows the median (horizontal line), Inter-Quartile-Range (box), adjacent values2 (whiskers), and outliers (circles); lines represent cut-offs for optimal and minimal insecticidal effectiveness



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

Table 16: Results from bio-assays

Variable	12 months	24 months	36 months
Inhambane	N=30	N=30	N=30
Knockdown 60 minutes			
Mean (95% CI)	97.7% (96.7–98.7)	88.2% (86.8–89.7)	68.3% (66.2–70.5)
Median (IQR)	98.5% (97.5–99.0)	89.3% (86.5–90.5)	68.4% (67.9–69.7)
Mortality 24 hours			
Mean (95% CI)	99.4% (98.8–99.9)	97.0% (98.7–99.9)	56.7% (53.4–60.0)
Median (IQR)	100% (99.0–100)	98.0% (95.5–98.5)	55.0% (52.5–58.5)
Optimal effectiveness			
Estimate (95% CI)	100% (-.-)	100% (-.-)	3.3% (0.4–21.0)
Minimal effectiveness			
Estimate (95% CI)	100% (-.-)	100% (-.-)	93.3% (76.0–98.4)
Tete	N=30	N=25	N=27
Knockdown 60 minutes			
Mean (95% CI)	99.1% (98.7–99.6)	91.2% (89.8–92.5)	72.8% (68.5–77.1)
Median (IQR)	100% (99.0–100)	89.5% (87.5–95.5)	71.5% (65.7–79.5)
Mortality 24 hours			
Mean (95% CI)	98.0% (96.9–99.1)	97.1% (95.9–98.3)	63.8% (59.7–68.0)
Median (IQR)	99.0% (98.0–100)	98.0% (96.0–99.0)	58.7% (56.4–67.8)
Optimal effectiveness			
Estimate (95% CI)	100% (-.-)	100% (-.-)	11.1% (3.8–28.4)
Minimal effectiveness			
Estimate (95% CI)	100% (-.-)	100% (-.-)	100% (-.-)
Nampula	N=30	N=30	N=27
Knockdown 60 minutes			
Mean (95% CI)	98.2% (97.1–99.3)	90.8% (89.8–91.9)	66.5% (59.8–73.2)
Median (IQR)	98.0% (98.0–100)	90.5% (89.0–93.5)	57.9% (52.1–89.5)
Mortality 24 hours			
Mean (95% CI)	98.8% (98.4–99.1)	97.0% (96.3–97.7)	68.3% (60.9–75.8)
Median (IQR)	99.0% (98.0–100)	97.0% (96.5–98.0)	56.7% (53.3–94.5)
Optimal effectiveness			
Estimate (95% CI)	100% (-. -)	100% (-.-)	29.3% (15.4–49.4)
Minimal effectiveness			
Estimate (95% CI)	100% (-. -)	100% (-.-)	96.3% (77.3–99.5)

See Tables 17–19 for the details of the net handling and use of the nets sampled for bio-assay. The results show that, overall, the net handling and use of the sampled nets, which were external from the cohort at 12 and 24 months, was comparable to that of the cohort nets; therefore, the bio-assay samples can be considered representative for the overall campaign nets at these sites.

Table 17: Variables related to handling of bio-assay test LLINs

Variable	12 months	24 months	36 months
Inhambane	N=28	N=30	N=30
Location found			
hanging loose	82%	83%	70%
hanging folded/tied	4%	3%	10%
not hanging/stored	14%	14%	20%
Type of sleeping place			
bed	64%	63%	67%
mattress	4%	20%	3%
mat/ground	32%	17%	30%
Net users			
young child only	7%	0%	4%
young child + adult	7%	0%	0%
older child, adult only	43%	33%	78%
other	43%	67%	18%
Tete	N=30	N=25	N=27
Location found			
hanging loose	57%	44%	50%
hanging folded/tied	10%	32%	39%
not hanging/stored	33%	24%	11%
Type of sleeping place			
bed	0%	8%	15%
mattress	7%	0%	8%
mat/ground	93%	92%	77%
Net users			
young child only	4%	16%	4%
young child + adult	26%	24%	13%
older child, adult only	48%	12%	67%
other	22%	48%	16%
Nampula	N=30	N=30	N=27
Location found			
hanging loose	80%	60%	44%
hanging folded/tied	13%	30%	52%
not hanging/stored	7%	20%	4%
Type of sleeping place			
bed	30%	37%	74%
mattress	50%	47%	0%
mat/ground	20%	16%	26%
Net users			
young child only	40%	0%	8%
young child + adult	20%	3%	8%
older child, adult only	17%	70%	80%
other	23%	27%	4%

Table 18: Variables related to use of bio-assay test LLINs

Variable	12 months	24 months	36 months
Inhambane	N=28	N=30	N=30
Used last night	79%	60%	76.7%
Use last week			
every night	86%	60%	73%
most nights (5–6)	0%	10%	3%
some nights (1–4)	4%	13%	0%
not used	7%	13%	24%
don't know	3%	4%	0%
Seasonal use			
equally rain and dry	82%	73%	83%
mainly rain	18%	17%	13%
rain only	0%	10%	4%
don't know	0%	0%	0%
Tete	N=30	N=25	N=27
Used last night	63%	76%	92.3%
Use last week			
every night	47%	72%	39%
most nights (5–6)	13%	8%	19%
some nights (1–4)	13%	8%	27%
not used	10%	8%	0%
don't know	17%	4%	15%
Seasonal use			
equally rain and dry	60%	84%	67%
mainly rain	20%	12%	4%
rain only	7%	0%	22%
don't know	13%	4%	7%
Nampula	N=30	N=30	N=27
Used last night	87%	100%	92.6%
Use last week			
every night	77%	93%	74%
most nights (5–6)	7%	3%	19%
some nights (1–4)	7%	3%	4%
not used	3%	0%	3%
don't know	6%	0%	0%
Seasonal use			
equally rain and dry	63%	97%	74%
mainly rain	17%	0%	26%
rain only	0%	3%	0%
don't know	20%	0%	0%

Table 19: Variables related to washing of bio-assay test LLINs

Variable	12 months	24 months	36 months
Inhambane	N=28	N=30	N=30
Ever washed	61%	83%	77%
Washes last 6 months (all)			
Mean	1.0	1.4	1.4
Median	1.0	1.0	1.0
Washes last 6 months (if washed)			
Mean	1.7	1.7	1.4
Median	2.0	1.0	1.0
Soap used			
country soap bar	59%	43%	87%
detergent or bleach	41%	33%	13%
mix	0%	0%	0%
none	0%	23%	0%
Tete	N=30	N=25	N=27
Ever washed	83%	88%	81%
Washes last 6 months (all)			
Mean	2.4	2.4	1.8
Median	3.0	2.0	2.0
Washes last 6 months (if washed)			
Mean	2.7	2.7	2.7
Median	3.0	2.0	2.0
Soap used			
country soap bar	56%	36%	71%
detergent or bleach	40%	44%	29%
mix	0%	4%	0%
none	4%	16%	0%
Nampula	N=30	N=30	N=27
Ever washed	60%	73%	93%
Washes last 6 months (all)			
Mean	0.6	1.6	2.4
Median	0.0	1.0	1.0
Washes last 6 months (if washed)			
Mean	1.0	2.1	2.4
Median	1.0	1.0	1.0
Soap used			
country soap bar	27%	47%	68%
detergent or bleach	13%	27%	28%
mix	0%	0%	0%
none	60%	27%w	4%

7 Summary and Conclusion

This report presents the findings of a three-year durability monitoring study of LLINs (MAGNet and Royal Sentry) distributed through a mass campaigns in three locations in Mozambique with different ecological, demographic, and behavioral environments: Inhambane province (Jangamo District) located in the south, Tete province (Changara district) in the west, and Nampula province (Angoche district) in the north. At baseline, between one and six months after the 2015 mass campaign, a cohort of households representative for the selected district was recruited. 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 340 households (20 communities and 17 households each) and 782 cohort nets from the campaign at each of the three sites. While the household target was more or less reached with 998 (98%), the number of cohort nets was somewhat below target with 1,988 (85%), as the household size was smaller than expected.

During the three follow-up surveys, the outcome for 579 out of 726 cohort nets in Inhambane (80%) could be determined, while 7% were lost to follow-up as households had moved away, and 13% were lost because household members were not available at the time of the survey. In Tete, mobility of people was considerably higher and 309 (51%) of the 601 cohort nets were lost to follow-up, mainly because households were temporarily not available (39%) or had moved away (12%). For an additional 4% of LLINs, the outcome was unknown. A definite outcome was determined for 269 cohort nets (45%). In Nampula, households moving away were the predominant cause of cohort net loss (20%); another 8% households were not present at the day of the final survey. For 4% of LLINs, the fate was unknown and a definite outcome was determined for 449 nets (68%).

Demographic and socio-economic characteristic

All three sites were rural and agricultural. Mean household size was around four in Nampula and Tete, and around 4.5 in Inhambane. Only a small proportion of households were headed by women (25% in Inhambane, 15% in Tete, and 12% in Nampula). Female heads tended to be older (52 years) than men (45 years) and had significantly lower levels of education, particularly in Tete and Nampula where 85% were non-literate. Population structure was very similar at all three sites with 12%–14% of children under 5-years-old. None of the demographic characteristics changed during the course of the study. All three areas were

poor, but the Inhambane site was clearly economically better off compared to Tete and Nampula, as measured by access to agricultural land and ownership of livestock and household assets.

Durability risk factors

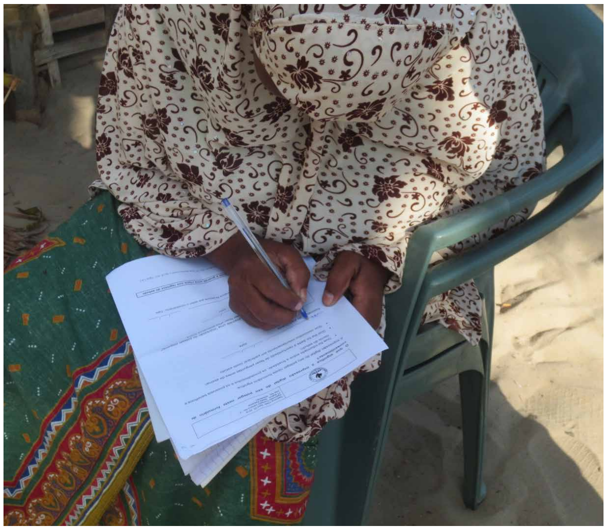
A number of behavioral factors that are known or thought to be associated with damage of nets were monitored. These can be divided into four groups: factors of the net use environment in the household, net handling, type of sleeping place, and knowledge and attitude toward net care and repair. Overall risk factors for damage were relatively high in all three sites, but highest in Nampula, followed by Tete and then Inhambane. This was particularly true for factors of the house environment with an almost ubiquitous presence of rodents combined with around 66% of households storing food in their sleeping rooms and around 70% sometimes cooking in that same room, most commonly with firewood. In Nampula and Inhambane, over 90% of hanging nets were not folded up or tied during the day to keep them away from risks of damage. In Tete, this rate was only around 40%. Drying nets on bushes or fences was not very common, but most frequent in Nampula (with 40%). Regarding the type of sleeping places nets were used over, Tete had the highest risk because more than 80% of nets were used over reed mats; while, in Inhambane and Nampula, bed frames were most common. Exposure to messages on net care and repair was quite low at all sites, considering that an additional campaign was implemented during the study with only 36%–58% in Nampula recalling any messages, 13%–43% in Tete, and 51%–81% in Inhambane. Most messages were delivered through interpersonal communication (health or community workers and local leaders). Resulting net care and repair attitude of respondents was poor at all three sites, with only 20% to 25% showing a very positive attitude. Only in Nampula did this rate reach 60% at the 24-month survey, but fell back to 10% during the final survey.

Net ownership and use

The 2015 mass campaign was successful in the three sites, with an average of 79% of the population having access to an LLIN during the baseline survey, conducted between one (Inhambane and Nampula) and six months (Tete) after distribution. However, at this time, only between 13% (Inhambane) and 29% (Nampula) of the campaign nets recruited for the durability cohort were hanging and most nets were

found in the package. This changed at the 12-month survey when 50%–76% were found hanging. It further increased to 66%–87% in the last two years of monitoring. Generally, nets hanging were also used the previous night, but regular use (every night the previous week) was reported for only 30%–50% of the cohort nets. Tete reported the lowest net use, with 18% of respondents also reported using the nets only during the rains, compared to year-round reported net use in other sites.

Use of the durability cohort nets cannot be interpreted without considering the household net ownership from other sources; especially, since at all three sites at least one additional mass campaign took place during the period of follow-up. At baseline, the other, older nets were used more often than the new nets, but soon a shift occurred, and the older nets were discarded rapidly. New nets came almost exclusively from public sources. Nets obtained from routine health services, such as antenatal care, were low in Nampula and Tete, and high in Inhambane. The most important additional source was the 2017 mass campaign. Particularly in Inhambane, where the net crop of non-cohort nets had already been high and routine nets were more available, the second campaign resulted in very high population access (92%) at the final survey—with some indication of oversupply–demonstrated by 44% of households owning one net for every person in the household. This oversupply contributed to a lower net utilization rate of cohort LLINs. Population access in Tete and Nampula at the final survey was around 75%, but it must be kept in mind that these were the remaining households from the durability monitoring cohort and households that lost all their cohort nets were excluded from follow-up; therefore, this was not representative for net ownership, overall, in the district.



Physical durability outcomes

After three years, the all-cause attrition (i.e., losses for any reason) variefactd between 74% in Nampula, 56% in Inhambane, and 50% in Tete. At 12 months, 81% of losses in Inhambane and Tete and 70% in Nampula were because nets were given away to others or were stolen. However, the proportion of losses due to wear and tear among all-cause attrition increased gradually; at 36 months, these losses included 41% in Tete, 33% in Nampula, and 28% in Inhambane. The second element of physical durability (i.e., net integrity) also was most favorable in Inhambane, with only 22% of cohort nets still found in households at the final survey being too damaged to be considered serviceable. In contrast, this rate was 36% in Tete and 37% in Nampula. Together, this resulted in the proportion of nets surviving in serviceable condition of 57% after 33 months in Inhambane, 43% after 36 months in Tete, and 33% after 33 months in Nampula. Expressing the outcome as a median survival time (i.e., the time until 50% of the distributed nets are no longer serviceable), the results were 3.0 years (95% CI 2.8–3.3) for the Royal Sentry in Inhambane, 2.8 years (95% CI 2.4–3.5) for MAGNet in Tete, and 2.4 years (95% CI 2.1–2.6) for Royal Sentry in Nampula. Although MAGNet and Royal Sentry are produced by different manufacturers, they have the same specifications and, therefore, can be considered as "same LLIN brand" and differences in median survival can be interpreted as difference between sites rather than the LLIN brand.

Insecticidal durability outcomes

Insecticidal effectiveness was optimal for all sampled nets (100%) in all three sites, up through the 24-month follow-up, but declined somewhat at 36 months. In Inhambane, only 3% of samples showed optimal effectiveness: 11% in Tete, and 29% in Nampula. However, most nets (96% overall) still had minimal effectiveness and only 4% had insufficient insecticidal effect.

Limitations

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

Conclusion

After three years of follow-up among rural district populations in the provinces of Inhambane, Tete, and Nampula, the 150-denier polyethylene LLIN Royal Sentry/MAGNet showed significant differences in median physical survival—ranging from 3.0 years in Inhambane to 2.8 in Tete, and 2.4 in Nampula. These differences could be attributed, at least in part, to house and net environment, and net care and repair behaviors. This means that in two of the three sites, the assumption of a three-year rhythm of campaign distributions holds; while, in the Nampula site, either a more frequent distribution or more intense or targeted BCC activities could be considered. Insecticidal performance was optimal as tested by bio-assay for 100% of samples up to the 24-month follow-up, but declined somewhat at 36 months. In Inhambane only, 3% of samples showed optimal effectiveness, 11% in Tete, and 29% in Nampula. However, most nets (96% overall) still had minimal effectiveness and provide at least some level of protection.

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