NET DURABILITY STUDY FINAL REPORT

MONITORING DURABILITY OF YORKOOL AND ROYAL SENTRY NETS DISTRIBUTED NATIONWIDE IN 2016 IN MALAWI

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ABBREVIATIONS AND ACRONYMS

DHO	District Health Office
ITN	Insecticide Treated Net
HSA	Health Surveillance Assistant
Kd	Knock down
kPA	Kilo-Pascal
LLIN	Long-lasting Insecticide Treated Nets
MAC	Malaria Alert Centre
MAC CDAC	Malaria Alert Centre Communicable Diseases Action Centre
MIS	Malaria Indicator Survey
NMCP	National Malaria Control Program
pHI	Proportionate Hole Index
PMI	President's Malaria Initiative
WHO	World Health Organization
WHOPES	World Health Organization Pesticides Evaluation Scheme

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ABSTRACT

Malaria control relies largely on the use of long-lasting insecticidal nets (LLINs) that are periodically distributed nationwide free to all at-risk populations and routinely to pregnant women at antenatal care clinics across Malawi. To sustain the gains made in controlling the disease, there is a need to monitor nets that are distributed during mass campaigns for their durability. Evidence generated from durability monitoring will inform the control program on the frequency of net distributions. Similarly, durability monitoring provides feedback to the various net manufacturers on performance of the products. This report presents findings of the durability monitoring of two net brands, Royal Sentry and Yorkool, that were distributed in 2016 across the country.

Two districts, Kasungu and Mangochi, were selected for durability monitoring activities. Nets were enrolled into the study at baseline, and three follow-up surveys were carried out at 12, 24, and 36 months. The findings of these surveys are briefly reported below.

Overall, 810 of 901 (89.9%) campaign nets were lost at 36 months after distribution and use in the field. In Mangochi, 93.0 percent (n=292) of Royal Sentry nets were lost, and in Kasungu, 79.6 percent (n=273) of Yorkool nets were lost. High net attrition was observed across the two study districts at the end of 36 months. Only 69 of 489 Yorkool nets (14.1%) were found in Kasungu representing an attrition rate of 85.9 percent. Also, 22 of 412 Royal Sentry nets (5.3%) were found in Mangochi, representing a 94.7 percent attrition rate. Attrition was attributed to three main reasons: 1) net given away; 2) net thrown away; and 3) unknown reasons. The proportion of nets given away decreased with time. However, the proportions of nets thrown away and nets lost due to unknown reasons increased with time.

The proportion of available nets with holes in Kasungu District increased from 63.8 percent at 12 months to 85.7 percent at the end of the study. Similarly, in Mangochi District, the proportion of available nets with holes increased from 64.4 percent at 12 months to 77.3 percent at the end of the study. There was a corresponding increase in the proportionate hole index of Yorkool nets (34.8 to 108.9) in Kasungu and Royal Sentry (481) nets in Mangochi (9.1 to 383.6) from first follow-up to third follow up.

The survival rate of the campaign nets decreased over the three-year study period. In Kasungu, at 12 months follow-up, the survival rate was 82.4 percent. At 24 months, the rate decreased to 62.9 percent, and finally at 36 months there was a vast decrease to 23.7 percent. Likewise, in Mangochi, at 12 months the survival rate was 80.7 percent, at 24 months it decreased to 47.1 percent, and finally at 36 months there was a vast decrease to 85 percent.

Although high cohort net attrition was observed at 36 months after nets were distributed, many households (>70%) had one or more nets to sleep under; many of which were obtained from the more recent 2018 nationwide net distribution campaign in both districts.

The insecticidal effectiveness did decrease, but not significantly. At the end of the study, both brands of nets showed over 50 percent insecticidal effectiveness.

1. BACKGROUND

Two LLINs, Yorkool® LN (Yorkool International Co., Ltd) and Royal Sentry® (Disease Control Technologies, US) distributed nationwide during the 2016 campaign were monitored for attrition, physical integrity, and biological efficacy in Kasungu and Mangochi districts over a three-year period (2016 – 2019). This report presents results for the third follow-up survey carried out 36 months after nets were distributed as well as the results from the three prior surveys (baseline, 12 months, and 24 months).

Malaria vector control relies primarily on the use of LLINs in Malawi. To achieve universal coverage and protection of the at-risk populations, two models have been adopted by the Ministry of Health to distribute nets throughout the country (NMCP 2010). First, LLINs are given free of charge at antenatal clinics, at the first antenatal visit, followed by a second net provided at the birth of the child. Second, nets are periodically (normally every three years) distributed nationwide to all households with a target of universal coverage which is defined as one net per two people. Outside these channels, the general population has access to LLINs through churches, non-governmental organizations, and commercially from various retail shops.

Although the National Malaria Control Program (NMCP) adopted the use of insecticide-treated nets (ITNs) as a strategic intervention for malaria control as far back as 1995, the first nationwide distribution of free nets occurred in 2012. Through this campaign, one net was given to every two people. However, during the 2016 nationwide net distribution, nets were distributed to cover every sleeping space. With an increase in net ownership, there has been a concomitant increase in net use which is an important factor for malaria control (MIS 2017).

LLINs are expected to last up to three years following the campaigns, while net coverage is supplemented through routine distribution systems to account for new births and for nets lost over time. However, net durability varies by type of net as well as by geographic location. In some settings, nets have been found to last three years or more, while in other settings, nets have been observed to have a median lifespan substantially less than three years. Therefore, the World Health Organization (WHO) and the President's Malaria Initiative (PMI) recommend that NMCPs monitor the durability of LLINs that are periodically provided to all populations across the country (WHO 2013). The objective of monitoring is to: (a) guide NMCPs on optimal distribution systems to ensure high coverage; (b) identify LLIN brands that may be consistently under-performing; and (c) provide feedback to manufacturers which may be useful in the quality improvement of LLINs.

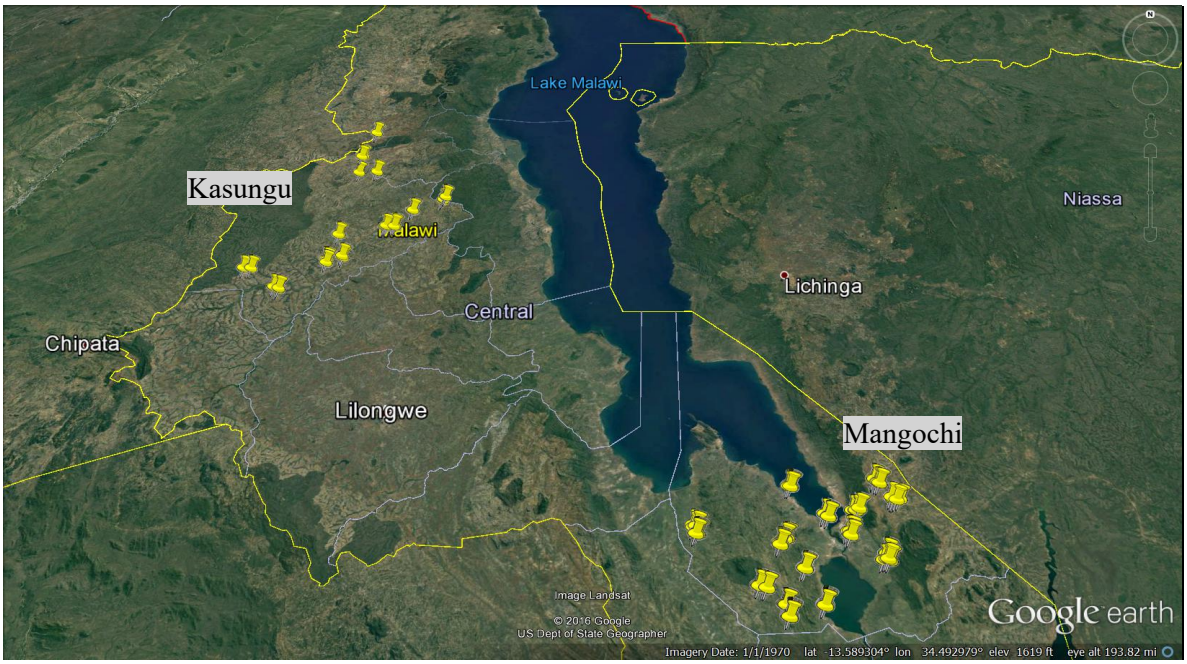
The present net durability monitoring activity represents the first national monitoring of campaign nets in Malawi. The study was designed to monitor two nets brands (Yorkool and Royal Sentry) that were distributed nationwide in 2016. Three LLIN brands were distributed during the 2016 net campaign, DuraNet© (Shobikaa Impex Pvt Ltd), Yorkool, and Royal Sentry. However, only Yorkool and Royal Sentry were selected for monitoring. This was the first time these two net types were deployed in the country on a large scale for malaria control.

2. METHODS

2.1 SITES

Two districts, Mangochi and Kasungu, located in the south and central regions of Malawi respectively, were selected for monitoring the durability of the two net brands. Mangochi District is located on the shore of Lake Malawi and is characterized by hot and humid conditions with year-round transmission of malaria. Fishing and tourism are the predominant economic activities in the district in addition to subsistence and commercial farming. Kasungu District is largely an agricultural area with more temperate conditions and marked seasonality. Tobacco and maize are some of the major crops produced in the district. The locations of the districts and villages selected for monitoring are shown in Figure 1. The two districts were selected to represent the lakeshore and inland areas representative of many areas in the country. The yellow pins represent the villages visited for the net durability monitoring.

FIGURE 1: MAP OF MALAWI SHOWING THE TWO LLIN STUDY DISTRICTS, KASUNGU DISTRICT IN CENTRAL MALAWI AND MANGOCHI DISTRICT IN MALAWI'S SOUTHERN REGION. THE YELLOW PINS DENOTE THE SENTINEL VILLAGES.



2.2 BRANDS MONITORED

Two net brands were selected for monitoring, Yorkool® LN (Yorkool International Co., Ltd) and Royal Sentry® (Disease Control Technologies, US). Both brands are pre-qualified by the WHO after conversion from recommendations by the WHO Pesticide Evaluation Scheme. Both LLIN products received their initial recommendations through extension of specifications whereby the

net is determined to be equivalent to an existing LLIN product. The characteristics of each net are as follows:

- Yorkool (190 x 180 x 150 cm) – the net is made of 7575 denier multi-filament polyester material. The net has a mesh size of 25 holes per cm^2, bursting strength of 405 kPa and has sides with a reinforced bottom border. It is treated with deltamethrin. The Yorkool net is considered equivalent to a PermaNet 2.0 LN.
- Royal Sentry (190 x 180 x 150 cm) – the net is made of polyethylene material of 150±7.5 denier monofilament yarn incorporating technical grade alpha-cypermethrin. This net has a mesh size of 132 holes per in^2 or 20 holes per cm^2 and has bursting strength and seam strength of >450 kPa. The Royal Sentry is considered equivalent to the DuraNet LN.

2.2.1 PRE-SHIPMENT TESTING

Nets for the nationwide mass distribution were procured centrally by the Global Fund to Fight AIDS, Tuberculosis and Malaria. It was assumed that pre-shipment testing was carried out at central procurement level, but this information was not available at the time of this report.

2.3 DESIGN SUMMARY

Four surveys (baseline, 12-, 24-, and 36-months follow-up) have been completed. Below is a brief description of the major activities in the surveys:

- **Baseline net assays** – 30 sample nets of each brand were obtained from warehouses at Mangochi District Hospital (Royal Sentry) and Lilongwe District Health Office (DHO) (Yorkool) for the assays at baseline.
- **Tracing/selecting study nets** - The Malawi NMCP distributed three net brands (Royal Sentry, Yorkool, and DuraNet) across the country using no particular distribution plan. The first task in this study; therefore, was to trace where the two brands of nets of interest had been distributed. The inclusion of these two net brands in this activity was determined by two main factors. First, the nets were being used on a large scale for malaria control in the country. Second, a separate study carried out by MAC to evaluate durability of several net brands had already generated data on DuraNet. Tracing of nets was achieved by working directly with the respective DHOs of Kasungu and Mangochi to identify areas that had received only one type of LLIN. Thirty health facilities were randomly selected in each district. At each health facility, five health surveillance assistants (HSAs) were randomly selected. Each HSA was tasked to list the net brands received by 10 households in two villages under their supervision. Field information was collated and consolidated into an Excel file and processed. Villages that contained households with a mixture of net brands were dropped. Finally, two villages at 15 randomly selected health facilities in each district were selected.
- **Net tagging** – Field teams were dispatched and equipped with an abridged baseline questionnaire and tablets to enroll households into the durability monitoring study. Individual households were randomly selected from the net distribution list. The list was obtained from the central monitoring and evaluation office in each of the two DHOs. Under the guidance of HSAs, the field team first met the village head to seek permission to work in their village. Once permission was granted, enumerators working in pairs went to each

of the selected households and explained the study objectives prior to seeking an informed written consent. A study questionnaire was then administered. Only campaign nets that were used the night prior to the visit were tagged with a unique identification (ID) number and the same number on the tag was marked on the net label with a permanent marker.[1] This error was corrected at the first follow up visit when all identifiable, remaining campaign nets excluded at baseline were tagged and added to the cohort. At each health facility, nets were tagged at 10 households at one village for monitoring attrition and physical integrity while 15 households in the second village were tagged for net bioassays. Furthermore, nets were tagged after five months following distribution.

- **Twelve months follow up survey:** The first follow-up survey was carried out at approximately 12 months from the time nets were distributed. A full questionnaire that followed PMI guidelines was administered to all cohort households to capture information on net use and attrition, and all campaign nets remaining in the household were assessed for holes. Available campaign nets that were not in use at baseline, and therefore not tagged at baseline, were tagged and included in the questionnaire. Further, the survey team used the net distribution charts obtained from the DHO to capture the number of nets each household received from the campaign, ensuring that nets not tagged at baseline and missing at the 12-month follow-up survey were retrospectively added to the cohort. In addition, in each of the villages allocated for monitoring of insecticidal activity of the nets, two nets (total of 30 of each brand) were sampled with replacement for net bioassays.
- **Twenty-four months follow up survey:** At 24 months an updated questionnaire was used to collect data from all cohort households. In each of the villages allocated for monitoring of insecticidal activity of the nets, two nets per village (total of 30 of each brand) were sampled with replacement for net bioassays.
- **Thirty-six months follow-up survey**: The above process was repeated at 36 months after net distribution. Information was captured on net use and attrition and all campaign nets remaining in the household were assessed for holes. In each of the villages allocated for monitoring of insecticidal activity of the nets, two nets (total of 30 of each brand) were randomly selected for sampling for net bioassays.

However, nets for bio-efficacy became scarce at the 24- and 36-month follow-up surveys. To achieve adequate numbers of nets for bioassays, nets were retrieved from the attrition cohort village. However, at 36 months, only 2,525 Yorkool and 2,323 Royal Sentry nets were retrieved and subsequently assayed.

2.4 FIELD WORK

The field team comprised 20 enumerators, two investigators, and one data officer (Appendix 1). All enumerators had a minimum qualification of Malawi Schools Certificate of Education, the equivalent of O-Levels. Training of enumerators for the end line survey was conducted at MAC CDAC in Blantyre for three days from April 15-18, 2019, including pre-testing of the survey tools.

[1] According the standard process, all campaign nets in the household should have been tagged at baseline, even those not in use. Investigators corrected this error at first follow up.

Components of the training included theory, survey ethics, questionnaire orientation, assessment of the physical condition of nets (i.e., counting of holes) and pre-testing (Appendix 2).

Three people supervised the process (i.e., two investigators and one data officer). Their roles included deployment of field teams, resolving questionnaire queries, and troubleshooting of issues with tablets.

Communities were informed by HSAs of the respective villages of the field visit one day before the visit took place. The HSAs were contacted through their mobile phones using the list of the names in the database.

Some of the field challenges included problems related to finding nets for bioassays due to the high rates of attrition. In addition, some village visits had to be rescheduled due to funerals within the community.

2.5 DATA MANAGEMENT

The survey questionnaire was designed using the open data kit, uploaded on tablets, and administered in the field. All households participating in the survey were assigned a unique ID and were uploaded onto the tablets including the expected number of campaign nets at each household. In the cohort villages, household information (demographic characteristics and socioeconomic status), net ownership, use and net attrition, and hole assessment data were collected. In the villages for determination of bio efficacy of nets, two randomly selected households were visited, and a short questionnaire was administered. Randomly selected nets were retrieved for bioassays and replaced with new nets. At the end of each survey day, data were directly downloaded into a REDCap database. This allowed the data manager to generate data reports to check any missing information while in the field.

2.6 ANALYSIS

Data from the tablets were downloaded directly into the REDCap database specifically created for the study. All data were saved on a data server housed at the MAC CDAC. All data cleaning and analyses were carried out in Stata. During data cleaning, duplicate household IDs were removed. For attrition, proportions were reported. Where possible, the interquartile ranges were provided. Using net distribution registers and household verification, a total of 489 nets were expected from Kasungu. Of these, 264 and 119 nets were tagged at baseline and 12 months follow-up respectively. In Mangochi, a total of 412 nets were distributed. Of these, 239 and 111 nets were tagged at baseline and 12 months follow-up respectively (Figure. 7). To estimate attrition, all tagged nets (baseline plus 12 months follow-up) and those deemed missing at 12 months formed the denominators in each study area. All tagged and untagged nets (except those from the 2016 campaign) not found at the household were considered lost. Further, all tagged nets found at the household were physically assessed and hole sizes scored to estimate the proportionate hole index (pHI).

2.7 ETHICAL CLEARANCE

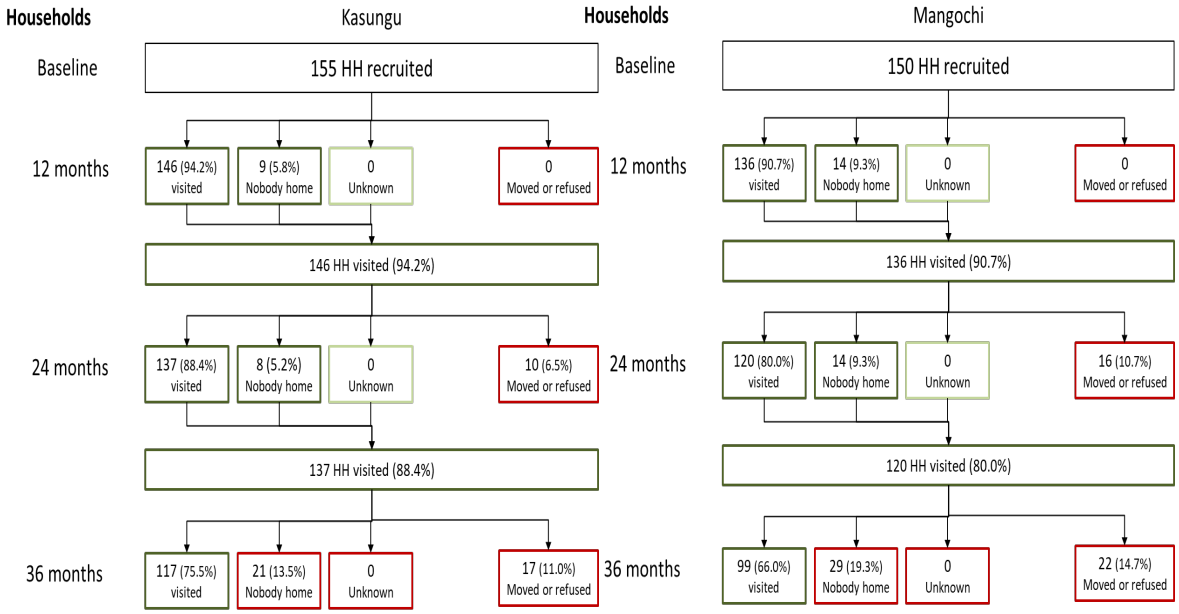
Ethical clearance was obtained from the College of Medicine Research Ethics Committee. The study protocol number is P.09/15/1802.

3. RESULTS

3.1 SAMPLE

Figure 2 shows the summary of the follow-up activities across the two study districts at the household level. Households enrolled in this study were followed throughout the 36 months survey period (in the event that nets previously recorded as lost due to being given away or lost for unknown reasons were later returned to the households' possession). A total of 216 of 305 (70.8%) households were interviewed across the two study districts at 36 months. Of these, 117 of 155 nets (75.5%) were from Kasungu and 99 of 150 nets (66.0%) were from Mangochi. The main reasons for the loss to follow-up for most households was migration or refusal to continue participating in the study.

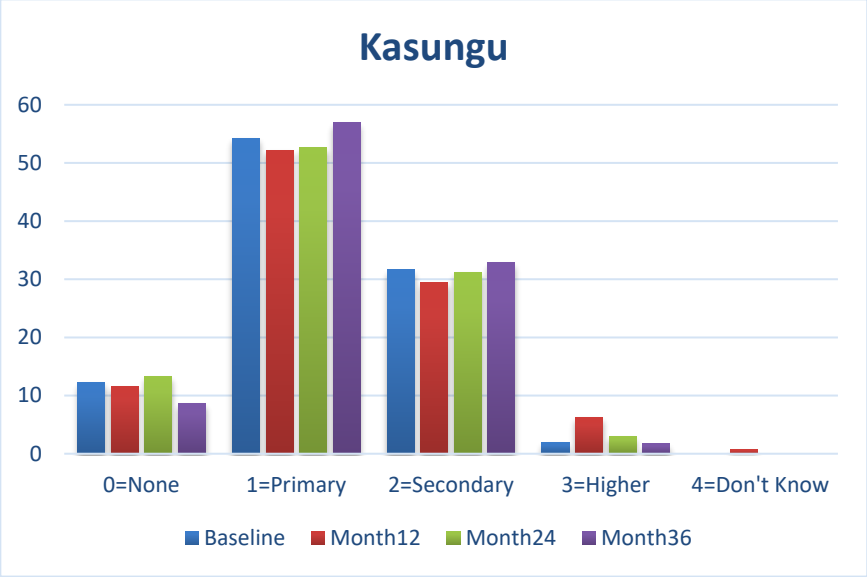
FIGURE 2: CUMULATIVE FOLLOW-UP STATUS AFTER 36 MONTHS OF HOUSEHOLDS RECRUITED AT BASELINESTUDY SITE

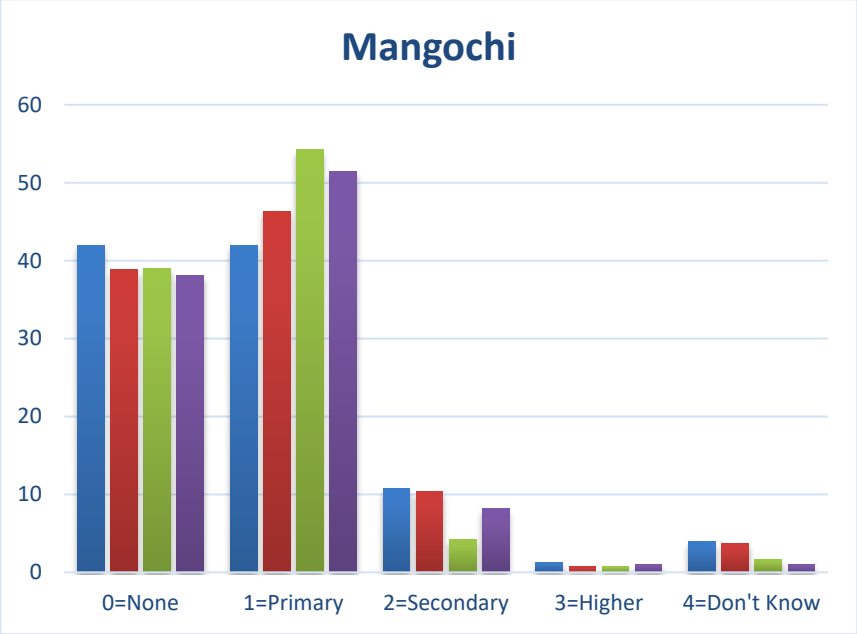


3.2 SOCIO-DEMOGRAPHIC CHARACTERISTICS

Figure 3 illustrates the education level of the heads of households from the two districts over the period of the study. In Kasungu, a higher number of the heads of households had attained a secondary education compared to those in Mangochi. However, during the period of the study, most of the heads of households had only attained a primary education in both study districts.

FIGURE 3: EDUCATIONAL STATUS OF HEADS OF HOUSEHOLDS DURING THE FOUR SURVEYS BY STUDY SITE





3.3 DETERMINANTS OF DURABILITY

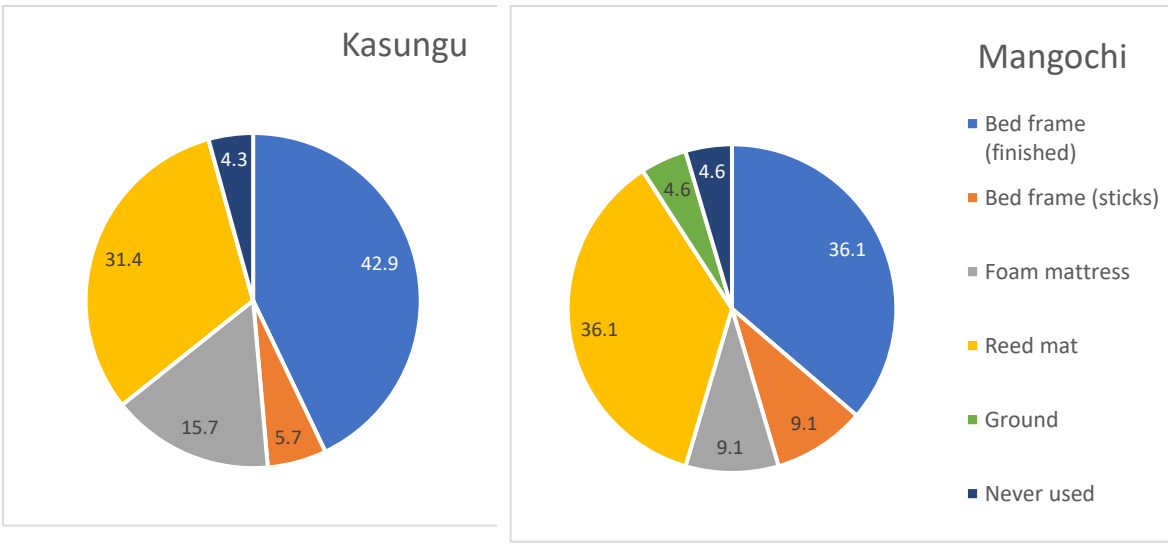
Physical stress on the net resulting from the type of sleeping material a net is constantly in contact with affects the physical integrity of a net. Household users were therefore asked about the type of sleeping place associated with each campaign net that was present and reportedly used at 36 months. The results are shown in Figure 33 for Kasungu and Mangochi respectively. The primary sleeping place type for most campaign nets at 36 months follow-up in Kasungu were bed frames (42.9%) followed by reed mats (31.4%). In Mangochi, an equal number of campaign nets (36.1%) were used over bed frames and reed mats (36.1%). However, when the results were averaged across the surveys, mats were the predominant sleeping space both in Kasungu (46.9%) and Mangochi (48.2%), followed by bed frames reported at 29.2 percent and 24.6 percent respectively.

Further, survey respondents were asked about risk factors associated with net durability such as storing food, cooking in rooms used for sleeping and the presence of rodents inside the house. The results are shown in Table 1. In Kasungu, the proportion of households storing food inside the house varied between 25.6 percent (n=115) to 41.9 percent (n=155) at 36 months and baseline respectively. A large proportion (>97.0%) of households reported never cooking in rooms used for sleeping. Further, a large proportion of households (>70.0%) consistently reported presence of rodents inside their homes. In Mangochi, similar observations were made. Households storing food inside living rooms varied between 26.7 percent (n=120) at 24 months and 41.2 percent (n=136) at 12 months follow-up. A large proportion of households reported never cooking in rooms used for sleeping (>92.0%) and reported seeing rodents (>70.0%) inside their homes.

Table 1: Household risk factors related to storing food, cooking and presence of rodents inside study households

Variable and site	Baseline	12 months	24 months	36 months
Kasungu	**N=155,155**	**N=145,145**	**N=137,137**	**N=115,115**
Ever store food in sleeping room	41.9%	28.88%	33.6%	25.6%
Cook in sleeping room				
never	98.7%	100.0%	97.1%	98.3 %
sometimes	1.3%	0%	2.2%	0 %
always	0.0%	0%	0.7%	1.7 %
Rodents observed (last 6 m)	NA	78.1%	85.4%	70.1 %
Mangochi	**N=150,150**	**N=136,136**	**N=120,120**	**N=100,100**
Ever store food in sleeping room	38.7%	41.2%	26.7%	40.0 %
Cook in sleeping room				
never	92.6%	92.6%	96.7%	94. %
sometimes	6.7%	4.4%	3.3%	5.0 %
always	0.7%	2.9%	0%	1.0 %
Rodents observed (last 6 m)	NA	77.2%	80.8%	71.0 %

FIGURE 4: MAIN TYPES OF SLEEPING PLACES FOR CAMPAIGN NETS IF USED AND RECORDED AT 36 MONTHS



Households were asked about hanging, wash frequency, use of detergent or bleach and drying practices of campaign nets, and the results are shown in Table 2. In Kasungu, less than 30 percent of campaign nets were reported hanging over a bed space and folded away at baseline. However, at 12 months, more than a half (57.8%; n=327) of the nets were reported hanging. The proportion of campaign nets reportedly never washed increased from 63.3 percent at 12 months to more than 80.0 percent at 24 months and 36 months follow-ups as expected. Washed nets were seldom dried on a bush or fence (<8.0% across all rounds with data). Among washed nets, the median number of washes in the last six months was two. Use of a detergent or bleach was fairly common in the district as reported at 44.4 percent, 37.8 percent and 31.6 percent at 12-, 24-, and 36-months follow-up respectively. In Mangochi, one third of the households reported hanging their nets. Similarly, most households in Mangochi (90.9%) reported hanging nets over sleeping spaces and folding/tying up. The proportion of campaign nets reportedly ever washed increased from 69.2 percent at first follow-up to 90.9 percent at 36 months, and nets were washed at least twice in six months from the date of the interview. Many households (70.0%) reported using a detergent/bleach for washing (median = 2.0) in the last 6 months. Few nets were reportedly dried on a bush or fence after washing except at 24 months when results indicate that 16 nets were dried in this way. Use of bleach or detergent for washing nets was a common practice in the study communities. At first follow-up, 42.0 percent (n=193) of washed nets were reportedly washed using detergent, and the proportion increased to 58.4 percent (n=101) and 70 percent (n=20) at second and third follow-up.

Table 2: Handling of campaign LLINs (IQR=Inter-Quartile-Range)

Variable and site	Baseline	12 months	24 months	36 months
Kasungu	**% (N)**	**% (N)**	**% (N)**	**% (N)**
Hanging nets AND folded or tied	29.4% (265)	57.8% (327)	26.2% (187)	24.3% (69)
Net dried on fence or bush	NA	7.7% (207)	2.6% (156)	6.9% (57)
Net ever washed	NA	63.3% (207)	83.4% (156)	82.6% (57)
Median washed last 6 m (IQR)	NA	2.0	2.0	2.0
Used detergent/bleach for wash	NA	44.4% (207)	37.8% (156)	31.6% (57)
Mangochi	**% (N)**	**% (N)**	**% (N)**	**% (N)**
Hanging nets ANDAND folded or tied	34.7% (239)	37.6% (279)	29.7% (118)	31.8% (22)
Net dried on fence or bush	NA	9.8% (193)	16.8% (101)	0.0% (20)
Net ever washed	NA	69.2% (193)	85.6% (101)	90.9% (20)
Median washed last 6 m (IQR)	NA	2.0	2.0	2.5
Used detergent/bleach for wash	NA	42.0% (193)	58.4% (101)	70.0% (20)

Behaviour change communication is important to encourage net use among malaria at risk communities. Households were asked whether they received information on net use, the importance of nets, care for nets, and repair of torn nets from any source in the past six months prior to the survey and the results are shown in Table 3. The proportion of households who had received the information on all the indicators varied between surveys. The proportion was high (39.2%) at 12 months, low at 24 months (<1.9%) and slightly increased at 36 months (<15.3%) in Kasungu. Similar results were obtained in Mangochi: recall of information was high at 12 months (37.2%), low at 24 months (<1.3%), and slightly increased at 36 months (<10.9%). These findings possibly reflect a lack of systematic and targeted behaviour change communication surrounding LLIN use in the country to control malaria.

Table 3: Recall of messages and attitude towards net care and repair (based on all surveyed households)

Variable and site	Baseline	12 months	24 months	36 months
Kasungu		N=207	N=156	N=57
Recalled "use net (every) night"	NA	39.2%	1.3%	15.3%
Recalled "nets prevent malaria"	NA	39.2%	1.9%	13.9%
Recalled "care for net"	NA	39.2%	1.9%	13.2%
Recalled "repair net"	NA	39.2%	0.7%	8.3%
Attitude score care and repair mean (95% CI) % with score > 1.0	NA		1.8 (1.7-1.9) 85.4%	1.6 (1.5-1.7) 85.4%
Mangochi		N=193,193	N=101,101	N=2,020
Recalled "use net (every) night"	NA	37.2%	0.7%	8.0%
Recalled "nets prevent malaria"	NA	37.2%	1.3%	10.9%
Recalled "care for net"	NA	37.2%	1.3%	8.8%
Recalled "repair net"	NA	37.2%	1.3%	5.8%
Attitude score care and repair mean (95% CI) % with score > 1.0	NA		1.8 (1.7 - 1.9) 78.8%	1.5(1.3-1.6) 78.8%

Repairing a torn net prolongs its lifespan and protects individuals sleeping under it from infectious mosquito bites. Table 4 shows results of study participants' practices when handling campaign nets with holes. Both in Kasungu and Mangochi, most people reported "ever experienced holes in nets." However, over time the percentage of households that experienced holes in the nets decreased from 70.5 percent to 53.0 percent in Kasungu, and 66.2 percent to 48.5 percent in Mangochi. The proportions of households that discussed net care and repair decreased from 38.4 percent to 29.1 percent in Kasungu, and 40.4 percent to 20.3 percent in Mangochi. Further, the proportion of households that had repaired a campaign net was very low in the two study areas. It varied between 9.1 percent (12 months) and 14.7 percent (36 months) in Kasungu and between 3.5 percent (12 months) and 22.7 percent (36 months) in Mangochi.

Over the period the study, Mangochi District showed an increase in the number of households that had ever repaired their damaged nets at 36 months.

Table 4: Household experience with care and repair of any nets and actual repairs made in damaged campaign nets

Variable and site	Baseline	12 months	24 months	36 months
Kasungu		**N = 146**	**N = 137**	**N = 117**
Ever experienced holes in net	NA	70.5%	73.0%	53.0%
Ever discussed care and repair	NA	38.4%	41.2%	29.1%
Ever repaired (if had holes)	NA	26.2%	35.0%	33.9%
Damaged campaign nets repaired	NA	9.1%	7.0%	14.7%
Mangochi		**N = 136**	**N = 120**	**N = 100**
Ever experienced holes in net	NA	66.2%	77.5%	48.5%
Ever discussed care and repair	NA	40.4%	0.0%	20.3%
Ever repaired (if had holes)	NA	23.3%	44.1%	41.7%
Damaged campaign nets repaired	NA	3.5%	12.7%	22.7%

3.4 Net Use and Ownership

Study participants were asked whether they used campaign nets to sleep under the night before the survey, used these nets every night the week before the survey, and whether the net was hanging over the sleeping space. Responses are shown in Table 5. In Kasungu, results indicate that net use the night before and every night the week before the survey was consistently high across the survey. Use of nets to sleep under the night before the survey was 89.8 percent, 81.7 percent, 81.8 percent, and 62.3 percent at baseline, 12, 24 and 36 months respectively. While use of nets every night the week before the survey was reported at 82.6 percent, 81.8 percent, and 63.8 percent at 12, 24, and 36 months respectively. The proportion of nets reported hanging varied between 27.8 percent at 12 months and 45.3 percent at baseline. A smaller proportion of nets were reported taken down and stored (<17.4%) or still in the package (<4.9%). Similar findings were reported in Mangochi. Results indicated that the use of nets to sleep under the night before the survey was 82.4 percent, 76.3 percent, and 83 percent at baseline, 12, 24 and 36 months respectively. While use of nets the week prior to the survey was reported at 74.6 percent, 83.1 percent, and 81.8 percent at 12, 24, and 36 months respectively. Nets reported hanging varied between 40.0 percent and 50.0 percent. Furthermore, nets that were taken down or stored (<14.4%) and those that were still in original packaging (<4.6%) were few. The standard practice in Malawi during distribution is that a net is removed from its packaging before handing over to the

beneficiary hence the finding of some campaign nets in packages is a little surprising. These nets were presumably being stored in other packaging such as any available plastic bag.

Table 5: Hanging and use of campaign nets from cohort

Variable	Baseline	12 months	24 months	36 months
Kasungu	**N = 265**	**N = 327**	**N = 187**	**N = 69**
Hanging	45.3%	27.8%	56.1%	43.5%
Taken/Stored away unpacked	8.3%	9.8%	9.1%	17.4%
Still in package	4.9%	2.1%	0.5%	1.4%
Used last night	89.8%	81.7%	81.8%	62.3%
Used every night (last week)	NA	82.6%	81.8%	63.8%
Mangochi	**N = 239**	**N = 279**	**N = 118**	**N = 22**
Hanging	40.2%	40.5%	46.6%	50%
Taken down or stored	13.8%	14.0%	14.4%	9.1%
Still in package	4.6%	3.2%	0%	4.5%
Used last night	82.4%	76.3%	83.9%	77.3%
Used every night (last week)	NA	74.6%	83.1%	81.8%

Study participants were asked whether they used other (non-cohort) nets every night the week before the survey. Use was moderate. At the 24- and 36-month follow-up, use of nets the night before the survey was 69.8 percent and 64.8 percent respectively while for the same periods before the survey, use of nets was reported at 68.6 percent and 64.1 percent respectively. Between 39.5 percent and 47.9 percent of the respondents had their nets hanging. A smaller proportion of households, 12.8 percent at 24 months and 17.5 percent at 36 months reported taking down the nets. Very few households at 24 months (6.9%) and 36 months (13.7%) had the other nets still in their original packaging. In Mangochi, higher rates of net use were recorded. At 24 and 36 months, 81.3 percent and 76.0 percent of respondents stated that they had used nets the night before the survey. For the same periods, 80.0 percent and 75.5 percent of respondents reported using nets to sleep under every night the week before the survey. Almost half (50.7%) and slightly less than half (42.0%) of the other nets were reported hanging over sleeping places. At 24 and 36 months, 17.3 percent and 13.0 percent of households reported taking down nets during the day. Very few households at 24 and 36 months reported having the other nets still in their original packaging. Nets that are still in the package means they were not being used to sleep under at the time of the survey.

Table 6: Hanging and use of other nets (non-cohort nets) owned by study participants

Variable	Baseline	12 months	24 months	36 months
Kasungu			**N = 86**	**N = 234**
Hanging	NA	NA	39.5%	47.9%
Taken down or stored	NA	NA	12.8%	17.5%
Still in package	NA	NA	6.9%	13.7%
Used last night	NA	NA	69.8%	64.8%
Used every night (last week)	NA	NA	68.6%	64.1%
Mangochi			**N = 75**	**N = 200**
Hanging	NA	NA	50.7%	42.0%
Taken down or stored	NA	NA	17.3%	13.0%
Still in package	NA	NA	1.3%	7.0%
Used last night	NA	NA	81.3%	76.0%
Used every night (last week)	NA	NA	80.0%	75.5%

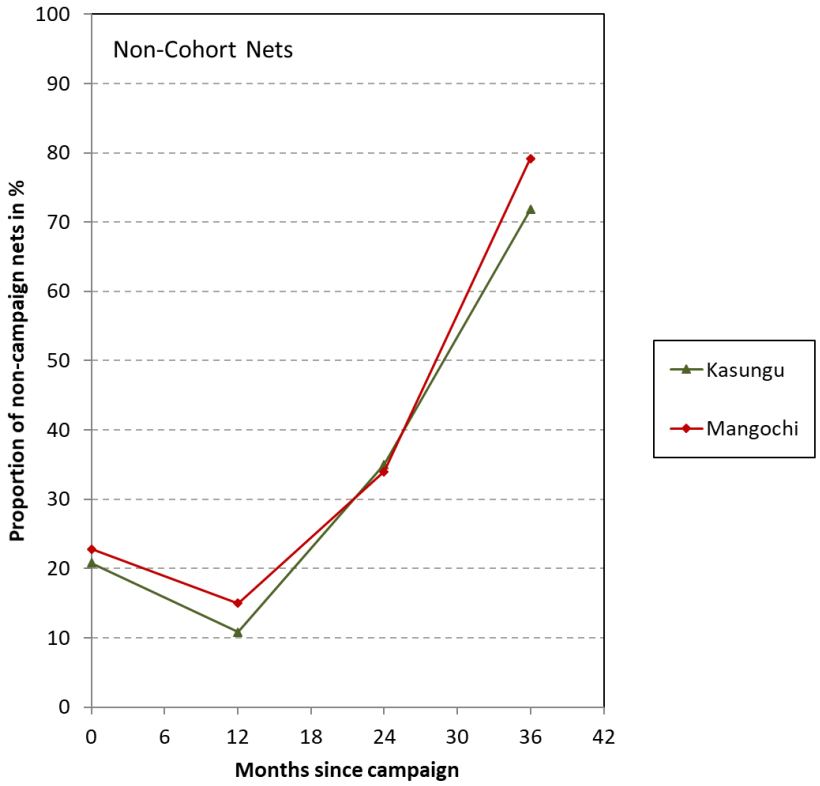
Households were asked whether they owned nets other than the ones they obtained during the nationwide campaign in 2016, and the results are shown in Table 7. Overall, the percentage ownership of other, non-campaign nets had decreased significantly and was recorded at 24 months for all four household visits in the two study areas. Further, in both sites' areas, ownership of other nets was high at baseline, low in between (12 and 24 months), and increased again at 36 months follow-up. In Kasungu, the percentage of households who owned other nets was 82.6 percent, 14.6 percent, 35.0 percent, and 92.5 percent at baseline, 12, 24 and 36 months respectively. It is possible that most nets reported at baseline had outlived their lifespan by the second visit. No data was available at baseline on the source of the other nets owned by study households. The public sector and other campaigns were the main sources of the other nets owned by study households. In Mangochi, ownership of other nets was 74.0 percent, 14.7 percent, 34.0 percent, and 95.8 percent at baseline, first, second and third follow-up visits respectively. Similarly, there was a huge decrease in ownership of other nets between baseline and first and second follow-up visits. Ownership of other nets peaked again at 36 months. The increase in ownership of "other" nets at 36 months is attributable to the 2018 nationwide net distribution. There could be several factors to explain the fluctuations of ownership of other nets at the 12- and 24-month follow-up visits including nets obtained at antenatal care clinics. Similarly, the public sector and other campaign were the main sources of other nets in the study area. Figure 4 shows ownership of other nets was low at first and second follow-up visits and increased substantially at the third household visit in both study areas.

Table 7: Ownership of other (non-cohort) nets and where households obtained them

Variable	Baseline	12 months	24 months	36 months
Kasungu	**N = 155**	**N = 145**	**N = 117**	**N = 107**
Household has any other nets	82.6%	14.6%	35.0%	92.5%
Source public sector	NA	9.3%	44.6%	98.3%
Source other campaign*	NA	5.6%	23.8%	92.3%
Source private sector	NA	19.4%	6.9%	0.0%
Source family or friends	NA	4.9%	4.9%	0.8%
Mangochi	**N = 150**	**N = 136**	**N = 102**	**N = 95**
Household has any other nets	74.0%	14.7%	34.0%	95.8%
Source public sector	NA	10.8%	33.3%	96.0%
Source other campaign*	NA	5.9%	28.6%	94.5%
Source private sector	NA	5.9%	8.3%	1.0%
Source family or friends	NA	0 %	14.3%	0.0%

*Previous or subsequent to cohort campaign

FIGURE 5: PROPORTION OF OTHER (NON-COHORT) NETS AMONG ALL OWNED NETS IN SURVEYED HOUSEHOLDS



Households were asked who uses the campaign nets, and the results are shown in Table 8. In both districts, survey results indicate that campaign nets were mostly used by adults at the 36-month follow-up [i.e., Kasungu (67.4%) and Mangochi (64.7%)]. Only 9.3 percent of nets in Kasungu and 5.9 percent of nets in Mangochi were used only by children. Similar observations were recorded at first and second follow-up visits.

Table 8: Net users of tagged campaign nets (cohort nets)

Variable	Baseline	12 months	24 months	36 months
Kasungu	**NA**			
Children only*	NA	6.4%	10.0%	9.3%
Children + adults**	NA	22.5%	27.0%	23.3%
Adults only**	NA	71.1%	63.0%	67.4%
Overall	NA	100.0%	100.0%	100.0%
Mangochi	**NA**			
Children only*	NA	6.8%	33.1%	5.9%
Children + adults**	NA	26.3%	26.5%	29.4%
Adults only**	NA	66.5%	56.4%	64.7%
Overall	NA	100.0%	100.0%	100.0%

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

Households were also asked which family members use the other (non-cohort) nets, and the results are shown in Table 9. In both Kasungu (79.5%) and Mangochi (86.2%) non-cohort nets were mostly used by adults only at the 36-month follow-up. Survey results indicated that 32.5

percent of non-cohort nets in Kasungu and 40.1 percent of non-cohort nets in Mangochi were used only by children.

Table 9: Net users of other (non-cohort) nets

Variable	Baseline	12 months	24 months	36 months
Kasungu	**NA**	**N=124**	**N=60**	**N=151**
Children only*	NA	10.0%	40.1%	77.9%
Children + adults**	NA	20.0%	17.0%	12.6%
Adults only**	NA	70.0%	42.9%	79.5%
Overall	NA	100.0%	100.0%	100.0%
Mangochi	**NA**	**N=118**	**N=61**	**N=152**
Children only*	NA	16.7%	36.0%	44.8%
Children + adults**	NA	31.4%	15.0%	99.0%
Adults only**	NA	51.9%	49.0%	86.2%
Overall	NA	100.0%	100.0%	100.0%

* Age 0-9 years; ** Includes adolescents aged 10-19 years

3.5 DURABILITY OF CAMPAIGN LLINS

The status of the campaign nets from the durability cohort throughout the study is shown in Figures. 5 and 6. Of the 489 nets tagged in Kasungu, 69 (14.11%) were still present during the 36-month follow-up survey. The main reasons for net loss at the 12-month follow-up was "given away during (10.4%) and 24-months (8.4%) compared to other reasons. However, at the 36-month follow-up, more than half of the nets present at the previous follow-up were discarded (20.9%). In Mangochi, of the 412 tagged nets, only 22 (5.3%) nets were still present at the 36 months follow-up survey. The main reasons for net loss at the 12-month follow-up was that nets were given away (9.7%), at 24 months and 36 months, the major reason for net loss was that the nets were thrown away (10.9% and 24.5% respectively).

FIGURE 6: STATUS OF COHORT NETS RECRUITED AT BASELINE KASUNGU

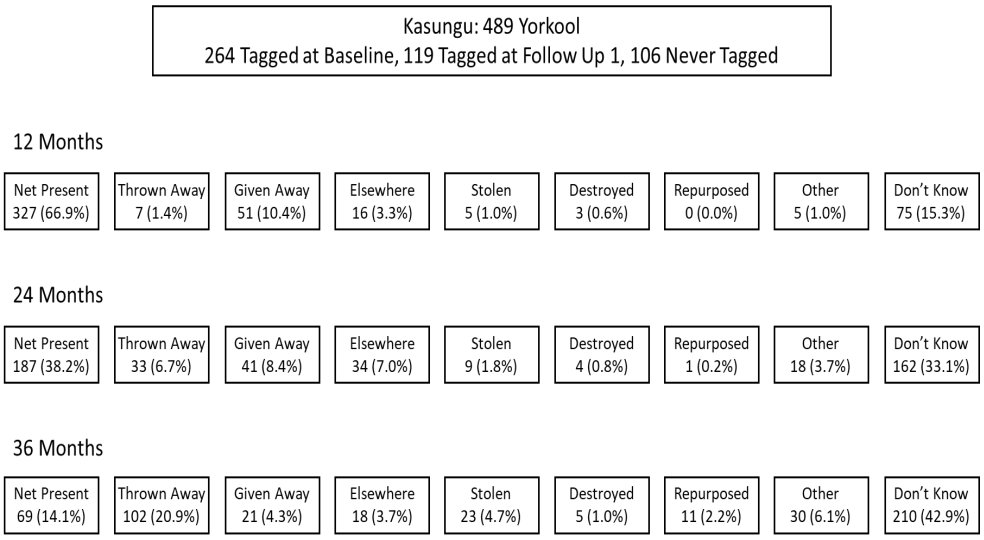
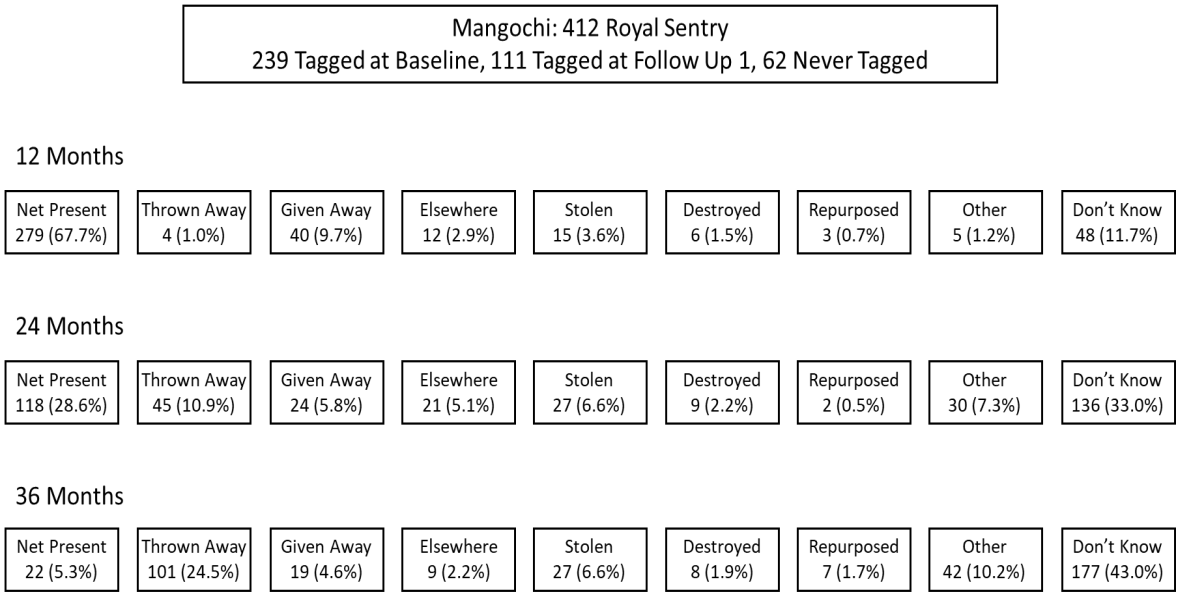


FIGURE 6: STATUS OF COHORT NETS RECRUITED AT BASELINE IN MANGOCHI

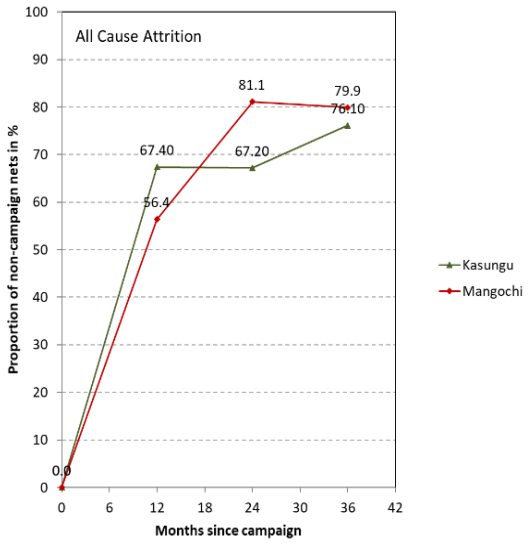


Household owners were asked about the causes of net loss after nets were distributed, and the results are shown in Table 10 and Figure 7. At 12 months, the major reason in both sites was that the nets were given away (i.e., 57.3% in Kasungu and 42.5% in Mangochi). While at 36 months, the major reason that about a quarter of the nets were thrown away was because they were considered no longer useful due to wear and tear [i.e., Kasungu (25.2%) and Mangochi (25.5%)] In Kasungu, 15.3 percent (n=75) of households at 12 months said they did not know the reason for net loss, and at 36 months many more households (42.9%, n=210) could not recall the reason for net loss. The same was observed in Mangochi where 11.7 percent (n=14) of the households at 12 months said they did not know the reasons for net loss and 43.0 percent (n=177) of the households at 36 months said they did not know the reason for net loss. It is possible respondents could not recall or they were embarrassed to mention the actual reasons for net loss. Overall, there was an increase in nets being discarded over the period of the survey in both sites, while the number of nets being given away decreased over the period of the study in both sites.

Table 10: 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
Kasungu	**N=XXX**	**N=94**	**N=314**	**N=373**
Given away	NA	57.3%	12.1%	6.3%
Discarded (wear & tear)	NA	7.9%	15.6%	25.2%
Unknown	NA	2.2%	39.5%	44.6%
Total	NA	67.4%	67.2%	76.1%
Mangochi	**N=XXX**	**N=94**	**N=282**	**N=373**
Given away	NA	42.5%	9.5%	3.5%
Discarded (wear & tear)	NA	4.3%	10.6%	25.5%
Unknown	NA	9.6%	61.0%	50.9%
Total	NA	56.4%	81.1%	79.9%

FIGURE 7: TRENDS IN ALL CAUSE ATTRITION AND WEAR AND TEAR (DISCARDED LLINS) AS A FUNCTION OF TIME SINCE DISTRIBUTION



Tagged nets that were present in the study households were physically assessed for holes and the hole pHI was calculated. The results are shown in Table 11. At 36 months, 69 Yorkool nets were assessed in Kasungu. Of the few nets that had remained, most of them (85.7%) had at least one hole. Results also indicated that 43.5 percent of the nets were deemed good, and 31.9 percent were "too torn". The median hole pHI for Yorkool nets was 108.9. The proportion of "too torn" Yorkool nets increased over the period of the study. In Mangochi, 22 Royal Sentry nets were assessed at 36 months, and most of them (40.9%) were "too torn" and only 27.3 percent were deemed good. The median Hole pHI for Royal Sentry nets was 383.6. The proportion of "too torn" Royal Sentry nets increased over the period of the study as well.

Table 11: Physical condition (integrity) of surviving cohort nets (pHI)

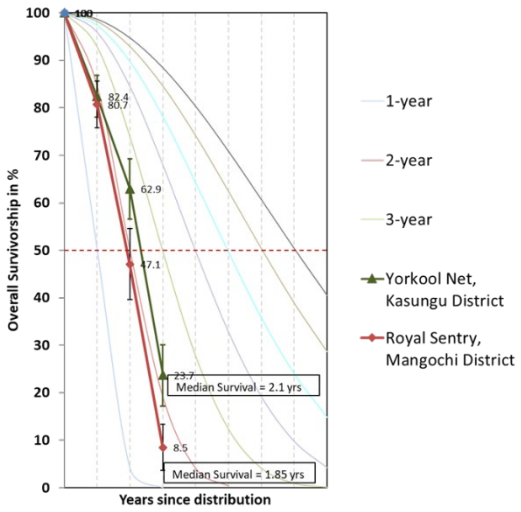
Variable	Baseline	12 months	24 months	36 months
Kasungu		**N=327**	**N=187**	**N=69**
Any holes	NA	63.8%	75.3%	85.7%
Median pHI (if any hole)	NA	34.8	74.1	108.9
Good (pHI<64)	NA	59.3%	47.1%	43.5%
Too torn (pHI>642)	NA	12.2%	24.6%	31.9%
Serviceable (pHI≤≤642)	NA	28.4%	28.3%	68.1%
Mangochi		**N=279**	**N=118**	**N=22**
Any holes	NA	63.4%	81.5%	77.3%
Median pHI (if any hole)	NA	9.1	95.9	383.6
Good (pHI<64)	NA	68.5%	43.3%	27.3%
Too torn (pHI>642)	NA	14.0%	31.4%	40.9%
Serviceable (pHI≤642)	NA	22.2%	25.4%	59.1%

As shown in Table 12 and Figure 8, the proportion of nets surviving in serviceable condition decreased over the period of the study. For instance, in Kasungu, at 12 months the proportion was 82.4 percent, at 24 months the proportion decreased to 62.9 percent, and finally at 36 months, there was a vast decrease to 23.7 percent. Likewise, in Mangochi, at 12 months the proportion was 80.7 percent, at 24 months it went down to 47.1 percent, and finally at 36 months there was a vast decrease to 8.5 percent.

Table 12: Nets surviving in serviceable condition (including nets discarded before baseline)

Variable	Baseline	12 months	24 months	36 months
Kasungu	**NA**	**N = 327**	**N=222**	**N=70**
Survival estimate	NA	82.4%	62.9%	23.7%
95% CI	NA	78.0 – 86.8	56.6 – 69.3	17.2 – 30.1
Only nets ever used	NA			
Survival estimate	NA	93.7%	74.3%	21.5%
95% CI	NA	90.2 – 95.9	68.9 – 78.2	16.6 – 26.7
Mangochi	**NA**	**N=226**	**N=171**	**N=22**
Survival estimate	NA	80.7%	47.1%	8.5%
95% CI	NA	75.8 – 85.6	39.6 – 54.6	3.7 – 13.4
Only nets ever used	NA			
Survival estimate	NA	96.2%	70.1%	8.3%
95% CI	NA	88.6 – 95.3	63.9 – 75.4	5.1 – 12.5

FIGURE 8: ESTIMATED LLIN SURVIVAL IN SERVICEABLE CONDITION WITH 95 PERCENT CONFIDENCE INTERVALS (ERROR BARS) PLOTTED AGAINST HYPOTHETICAL SURVIVAL CURVES WITH DEFINED MEDIAN SURVIVAL.



After plotting the calculated survival estimate against the hypothetical survival curves, the graphs for both Kasungu and Mangochi followed the two-year curve closely with median survival times of 2.1 years and 1.85 years respectively.

3.6 INSECTICIDAL EFFECTIVENESS OF CAMPAIGN NETS

A sub-sample of nets were retrieved from a selected number of households, and then prepared and tested for their biological efficacy according to standard WHO test procedures. Results for nets assayed at 36 months together with previous survey assays are shown in Table 13. Overall, nets available for bio-efficacy tests decreased over the time of the survey due to unavailability of nets both in Kasungu and Mangochi. Yorkool nets showed reduced efficacy (67.2% mortality; n=25) at 36 months compared to 80.2 percent mortality (n=29) recorded at 24 months. Mean knockdown rates of 93.3 percent, 93.3 percent, and 84.8 percent were recorded at 12, 24, and 36 months respectively. Although Royal Sentry nets showed mortality (84.0%; n=23) above the WHO threshold at 36 months, this was lower compared to the mortality rate (92.3%; n=27) recorded at 24 months. High mean knockdown rates of 99.4 percent, 96.2 percent, and 96.4 percent were recorded at 12, 24 and 36 months respectively.

Table 13: Knockdown (%) at 60 minutes and mortality (%) at 24 hours of *Anopheles gambiae* Kisumu tested against Yorkool and Royal Sentry nets

Variable	12 months	24 months	36 months
Kasungu	**N=30**	**N=29**	**N=25**
Knock down 60 minutes Mean (95% CI) Median [IQR]	 93.3% (91.3 – 95.2) 100%	 93.3% (90.6 – 96.1) 100%	 84.8% (79.7 – 89.9) 100%
Mortality 24 hours Mean (95% CI) Median [IQR]	 82.6% (79.6 – 85.6) 89.4% [83.3 – 90.5]	 80.2% (76.5 – 83.9) 90% [83.3 – 91.7]	 67.2% (60.6 -73.6) 90% [83.3 – 91.7]
Optimal Effectiveness Estimate (95% CI)	31.2% (20.0 – 42.3)	31.0% (22.9 – 39.1)	20.1% (0.9 – 39.3)
Minimal Effectiveness Estimate (95% CI)	84.7% (82.2 – 87.3)	86.3% (83.8 – 88.8)	92.3% (86.3 – 98.3)
Mangochi	**N=30**	**N=27**	**N=23**
Knock down 60 minutes Mean (95% CI) Median [IQR]	 99.4% (98.9 – 99.9) 100%	 96.2% (93.0 – 99.4) 100%	 96.4% (93.4 – 99.4) 100%
Mortality 24 hours Mean (95% CI) Median [IQR]	 97.9 (96.5 – 99.3) 100%	 92.3% (88.8 – 95.8) 100%	 84.0% (78.2 – 89.8) 100%
Optimal Effectiveness Estimate (95% CI)	34.5% (4.5 – 64.5)	9.2% (0 – 25.8)	29.1% (0 – 81.9)
Minimal Effectiveness Estimate (95% CI)	98.7% (98.0 – 99.4)	96.0% (94.3 – 97.8)	100% (.-.)

4. SUMMARY AND CONCLUSION

The results of this survey indicate that most of the households were still present in the two districts. Only a small percentage of the households were missing from the previous number of households that were available at 24 months follow-up. The major reason for loss to follow-up was relocation or migration.

However, although the number of households has not changed dramatically from the 24-month visit, the number of nets found changed significantly. Table 10 illustrates evidence that many of the nets that were enrolled at 12 months were no longer available in the households to sleep under. According to Figures 5 and 6, three main reasons were given to explain net loss in both study areas: 1) "net thrown away"; 2) "net given away"; and 3) "don't know". The response "net thrown away" showed an increasing trend (i.e., low at 12 months and high at 36 months follow-up). The response "net given away" showed a decreasing trend (i.e., high at 12 months and low at 36 months). The response "don't know" showed an increasing trend (i.e., less frequent at 12 months and more frequent at 36 months). These findings were expected. However, the increased failure by respondents to give reasons for net loss (don't know) especially from 24 to 36 months, reflects challenges with recall. Further, more nets at 36 months follow-up were reported thrown away, likely because they were torn and no longer useful. In some instances, nets were reported burned to kill bed bugs.

Physical integrity of nets was expected to be compromised with net age. This was shown by the high proportion of nets with any holes both in Kasungu (85.7%) and Mangochi (77.3%) at 36 months. Similarly, the diameter of holes increased over time although it was relatively higher in Mangochi (383.6) compared to Kasungu (108.9) which possibly reflects inherent differences between net brands. This study has shown that survival of campaign nets was lower than the three years interval adopted by the NMCP for mass net campaigns. In Kasungu, nets lasted two years on average, and 1.9 years in Mangochi on average.

It was encouraging to note high use of nets to sleep under the previous night among study participants. Tables 5 and 6 show that >60% of the available nets, both campaign and other nets, were used every night to sleep under. The use of campaign nets the night before and every night the week before the survey was higher (>70%) in Mangochi than in Kasungu (>60%). Mangochi is considered a malaria endemic district and malaria transmission is high throughout the year, hence people are more likely to use a net to sleep under than in Kasungu. Lower rates (55%) of household net use have been reported previously in Malawi (MIS 2017). This study seems to suggest that most people who have nets are likely to use them.

It is known that torn nets pose a risk of malaria infection. Yet this study revealed that many households do not repair their nets despite most of them observing holes on the net. Only a few households in Mangochi (22.7%) and Kasungu (14.7%) repaired nets. There is need for deliberate action by the program to invest in behavior change communication messaging to create awareness surrounding the importance of sleeping under an intact net.

Table 13 shows that the nets' effectiveness did decrease over time, but not substantially. At the end of the study both brands of nets showed over 50 percent insecticidal effectiveness. Results of net bioassays showed that that both Royal Sentry and Yorkool nets remained effective up to 36 months (Table 13). In Kasungu, knockdown rates in excess of 80 percent were registered at 36 months, while mean mortality dropped to 67.2 percent. In Mangochi on the other hand, both knockdown rates (>96%) and mortality (>84%) remained high. These findings provide evidence that the insecticide on the two LLINs tested was available on the net to kill mosquitoes for up to three years.

The study had some limitations. For instance, at baseline not all campaign nets were tagged for follow-up. Only nets that were being used to sleep under were tagged. Further, a modified survey tool was deployed at baseline which led to failure to capture some baseline information. Some participants removed the net tags which may have contributed to loss to follow-up and therefore affected overall attrition.

Despite the limitations cited above, the findings of this survey show high attrition of nets at 36 months. Furthermore, both net brands show a two-year lifespan in terms of physical integrity. In order to sustain coverage between mass campaigns, the NMCP may want to consider bolstering continuous distribution channels to inject additional ITNs into households.

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