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THE PMI VECTORLINK GHANA 2018 ITN DURABILITY MONITORING 36-MONTH FOLLOW-UP STUDY REPORT

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ACRONYMS

CDC	Centers for Disease Control and Prevention
IPC	Interpersonal Communication
IQR	Interquartile Range
ITN	Insecticide-treated Net
KD60	60-minute knock-down rate
MIS	Malaria Indicator Survey
NMCP	National Malaria Control Program
NMIMR	Noguchi Memorial Institute for Medical Research
pHI	Proportionate Hole Index
PMI	President's Malaria Initiative
PSI	Population Services International
REB	Research Ethics Board
USAID	United States Agency for International Development
WHO	World Health Organization
WHOPES	World Health Organization Pesticide Evaluation Scheme

EXECUTIVE SUMMARY

The importance of insecticide-treated net (ITN) field durability and estimating the *average useful life* of an ITN is one of the critical factors National Malaria Control Programs (NMCP) need to know to determine the frequency with which ITNs are replaced. The World Health Organization (WHO) recommends that countries routinely monitor ITN durability following mass distribution campaigns, and that standard guidance for monitoring has been developed.[1]

In Ghana, the United States (U.S.) President's Malaria Initiative (PMI) is supporting ITN durability monitoring of DawaPlus 2.0 ITNs distributed in Zabzugu district and Olyset ITNs distributed in Nanumba South district during June of the 2018 mass campaign. Baseline data collection was conducted December 3-9, 2018, six months after distribution, to establish the study cohort. All campaign ITNs in sampled households were identified and labeled with a unique ID number.

The 12-month follow up survey was carried out July 5-12, 2019, the 24-month survey was conducted from August 10-16, 2020, and the 36-month endline survey was conducted between March 29 - April 6, 2021. Fieldwork was conducted by University of Ghana Noguchi Memorial Institute for Medical Research (NMIMR). During each of these rounds, ITNs labeled at baseline were followed-up; the physical integrity of nets still present in the household was measured through a hole assessment and details were recorded for any nets no longer present in the household (attrition). Potential factors affecting net durability were explored through a household interview. These included environmental factors (house structure, cooking fuel, type of sleeping place), net handling (folding nets up when hanging, drying washed nets on bushes etc.) as well as attitudes towards nets and net care and repair. At each round, information was collected on bed nets obtained by the household outside of the 2018 campaign.

During the endline survey, two cohort ITNs from each cluster were selected and withdrawn to undergo bio-effectiveness and chemical content analysis. Cone bioassays were performed by NMIMR with support from PMI VectorLink; chemical content analysis was performed by Centers for Disease Control and Prevention (CDC) Atlanta on samples from the ITNs withdrawn for cone bioassays.

Household and ITN Follow-Up

A total of 230 out of 242 eligible households were interviewed for the 36-month endline survey. Of these, 179 households still had one or more cohort nets while 51 had lost all their cohort nets. Of the households not interviewed, 7 had no eligible respondent available for interview, 2 had moved out of the study area, 2 respondents refused the interview, and 1 household was screened out due to COVID-19 risks. Of the 413 nets eligible for follow-up at the 36-month round, 250 were still in the house and 32 were with family elsewhere. Nets not in households had been discarded (53 nets), given away or stolen (39 nets), lost for unknown reasons (17 nets) or had an unknown outcome (11 nets). A further 11 nets were unavailable because the household had moved outside the study area or refused to participate. By the end of the study, 242 (37%) out of the 655 labeled nets enrolled in the cohort at baseline were no longer present in the study households.

Durability Risk Factors

The proportion of households visited for the 36-month endline survey in which members slept in a room used for cooking or where food was stored was lower in Nanumba South than in Zabzugu (1% versus 37%, $p<0.001$; 30% versus 63%, $p=0.003$). Most households in Nanumba South (89%) and Zabzugu (94%) reported observing rodents in the past six months. In both study sites, across all survey rounds, a minority of cohort-nets were used over bed frames (8% to 23% in Nanumba South and 6% to 45% in Zabzugu). At 36-months most nets

[1] www.durabilitymonitoring.org

were hung above mats or the ground (60% in Nanumba South, 83% in Zabzugu) or mattresses (21% in Nanumba South, 2% in Zabzugu). The median number of times nets were washed within the past six months (3.0 in Nanumba South, 4.0 in Zabzugu) and the use of detergent or bleach to wash nets (16% in Nanumba South, 19% in Zabzugu) was similar across study sites. Respondents from approximately half of households in Nanumba South (49%) and Zabzugu (44%) reported being exposed to information about net use, care, or repair in the past six months (an increase from exposure levels in previous rounds). Almost all messaging in both study sites was received solely through interpersonal communication (IPC; >90% of households in both study sites) and not from mass media. The most commonly recalled message among respondents exposed to messaging at 36-months was about net care (93% across both districts). At the 36-month round, 42% of respondents in Nanumba South and 70% of respondents in Zabzugu were scored as having a positive attitude towards net care and repair. Zabzugu had a higher proportion of respondents with a favorable attitude toward net care and repair (70% versus 42% in Nanumba South, p=0.006). There were no statistical differences between the proportion of households experiencing holes in a net, discussing net care, or repairing nets across study sites.

ITN Ownership and Use

At endline, the proportion of cohort nets still present in households that had ever been used was 85% in Nanumba South and 72% in Zabzugu. In Nanumba South, 56% and 46% of cohort nets were reportedly used the night before the survey and every night in the week before the survey, respectively, with similar levels recorded for Zabzugu (55% and 47%, respectively). Household ownership of any non-cohort nets was higher in Nanumba South at endline (61%) compared to Zabzugu (34%) and use of non-cohort nets was similar to use of cohort nets in Nanumba South (51%) but much lower in Zabzugu (22%). In both districts, the majority of cohort nets were used by adults only (56% Zabzugu; 72% Nanumba South). In Zabzugu, non-cohort nets were also most commonly used by adults only (64%) while use patterns were mixed between adults alone and adults sharing with children in Nanumba South.

ITN Survivorship (Attrition and Physical Integrity)

In Nanumba South, total cohort ITN attrition increased from 51% at 24-months to 70% at the 36-months, with the most commonly cited reasons being discarded (also known as attrition due to wear and tear: 29%), followed by nets being given away to others (23%) and lost for unknown reasons (18%). In Zabzugu, attrition increased from 28% at 24-months to 42% at 36-months with nets commonly being discarded (24%) and given away to others (13%). Among cohort nets present at endline, 78% of nets in Zabzugu and 62% in Nanumba South had any holes and the percentage of nets that were classified as being in serviceable condition were 72% and 73%, respectively. Cohort net survival (nets present in the household and in serviceable condition, out of all cohort nets present or previously discarded) was estimated to be 51% in Zabzugu (DawaPlus 2.0) and 37% in Nanumba South (Olyset), corresponding to an estimated median survival time of 2.8 years for DawaPlus 2.0 and 2.3 years for Olyset nets, respectively.

Insecticidal Effectiveness

Thirty campaign nets were collected in each study site from cohort households, and samples underwent bio-effectiveness bioassays at NMIMR. At the 36-month round, optimal insecticidal effectiveness was higher among DawaPlus 2.0 samples from Zabzugu (80.0%) compared to Olyset samples from Nanumba South (63%). After observing declining optimal effectiveness of samples tested between the baseline and 24-month rounds, net samples tested at the 36-month round had higher levels of optimal effectiveness than either the 12- or 24-month rounds. Minimal effectiveness was similar between districts (90% in Nanumba South and 93% in Zabzugu). Chemical content testing results for Olyset samples corresponded to a 43% loss of insecticide compared to the manufacturers target dose, while DawaPlus 2.0 samples reported a 74% loss compared to the target dose.

A summary of key results from all four rounds of data collection is presented in Table 1.

TABLE 1: BASELINE, 12 MONTH, 24 MONTH AND 36 MONTH ROUND RESULTS

Site	Survey round and time since distribution (months)	Attrition wear and tear (%)	Remaining nets in serviceable condition % (N)	Remaining nets hanging over sleeping space (%)		Optimal insecticidal effectiveness in bioassay (%)
				Campaign	Other	
Nanumba South (Olyset)	Baseline: 5.8	0.3%	97.9% (N=333)	35.4%	64.9%	90.0%
	First: 12.7	2.8%	89.8% (N=245)	49.8%	40.5%	43.3%
	Second: 25.9	21.4%	69.3% (N=150)	49.6%	49.7%	40.0%
	Third: 33.5	29.3%	73.3% (N=101)	48.1%	47.9%	63.3%
Zabzugu (DawaPlus 2.0)	Baseline: 5.8	0.0%	98.6% (N=284)	52.4%	53.1%	100.0%
	First: 12.7	1.2%	96.1% (N=233)	58.0%	59.7%	46.7%
	Second: 25.9	15.5%	80.8% (N=177)	76.6%	69.3%	43.3%
	Third: 33.5	24.3%	72.1% (N=147)	52.7%	18.4%	80.0%

Conclusion

Olyset ITNs in Nanumba South had a median survival of 2.3 years and DawaPlus 2.0 ITNs in Zabzugu had a median survival of 2.8 years. Median survival in both sites was lower than the assumed 3 years. In both locations, attrition was largely driven by wear and tear and nets being given away to others. Bioassays conducted on field net samples 34 months after the 2018 campaign showed more than three-quarters (80%) of remaining DawaPlus 2.0 ITNs and almost two-thirds (63%) of remaining Olyset ITNs met the criteria for optimal effectiveness. However, the endline results were contrary to the declining trend in optimal effectiveness recorded between the baseline and 24-month survey round.

1. BACKGROUND

The proportion of households owning at least one insecticide treated net (ITN) has decreased in Ghana, from 65% (2016 MIS) to 63.5% (2019 MIS) in urban areas and increased from 82% to 84.5% in rural areas during the same period. However, at the population-level, use of ITNs remains below the target of 80% set in the Ghana National Malaria Strategic Plan 2021-2025. Population access to an ITN measures the proportion of the population that would be able to use an ITN if each ITN in a household was used by two people; in 2019 this figure was 58.5% in urban areas and 73.8% in rural areas. However, only 26.6% of the population in urban areas and 56.6% in rural areas reported using an ITN the previous night. The ITN use:access ratio, which measures population-level use in relation to population-level access to an ITN ranges from 0.33 in Greater Accra to 0.90 in Upper West. Values lower than 0.6 are classified as "poor" and those between 0.6 and 0.8 are "below target", implying improvements are required. The regions of Brong Ahafo (0.80), Upper East (0.89) and Upper West (0.90) are the only ones with a ratio value about 0.80 based on 2019 MIS data.[2]

The ITN field durability and the *average useful life* of an ITN form the critical factors National Malaria Control Programs (NMCPs) need to know to determine the frequency with which ITNs are replaced. The World Health Organization (WHO) recommends that countries routinely monitor ITN durability following mass distribution campaigns. To this end, standard guidance has been developed with funding from PMI.[3] Durability monitoring generates data on survivorship (attrition and physical integrity), insecticidal effectiveness and insecticide chemical content of ITNs over three years following a mass distribution campaign and permits comparisons to be made across brands or geographic areas. The study also explores risk factors, such as net care and repair behaviors, and their association with attrition and physical integrity.

In Ghana, PMI has supported durability monitoring of ITNs distributed during the 2018 mass campaign in two districts in the Northern region (Nanumba South and Zabzugu). These districts were selected purposively in coordination with the NMCP to establish two neighboring locations in which different ITN brands (Olyset and DawaPlus 2.0) were distributed. Olyset, distributed in Nanumba South, is a polyethylene ITN that received a full recommendation by World Health Organization Pesticide Evaluation Scheme (WHOPES) in July 2009 and was pre-qualified by WHO in July 2017.[4] DawaPlus 2.0, distributed in Zabzugu, is a polyester ITN and was pre-qualified by WHO in March 2018.

This study will provide the NMCP, PMI, and ITN partners with data on survivorship (attrition and physical integrity) and insecticidal effectiveness of ITNs under "real life" conditions to inform programmatic decisions on timing and net brands for future mass distribution campaigns and continuous distribution.

The durability monitoring study in Ghana intended to:

[2] https://www.breakthroughactionandresearch.org/resources/itn-use-and-access-report/ghana/

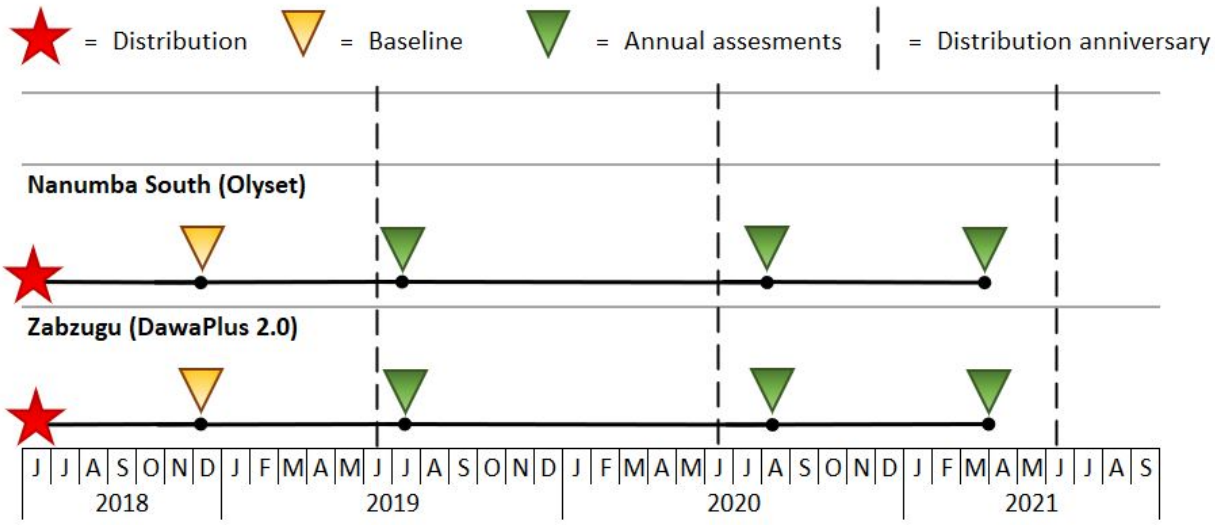
[3] www.durabilitymonitoring.org

[4] As of January 1 2017, vector control products that were previously submitted to the WHOPES for evaluation and recommendation are now evaluated by the WHO Prequalification Team Vector Control Group (PQT-VC). Briefly, under the PQT-VC process, product manufacturers receive enhanced guidance on their dossier requirements and the assessment process, assessment includes manufacturing site inspections, and there is additional focus on post-marketing quality management. During 2017, manufacturers of products with WHOPES recommendation were permitted to submit a Conversation Package to PQT-VC to have their product(s) listed by as prequalified. PQT-VC will, within 5 years of receipt of the Conversation Package, conducting a manufacturing site visit, test finished samples through post-market surveillance and review other information available. Based on the results of these activities, a decision will be made to maintain the listing, suspend the listing or delist the product.

1. Assess the physical durability (attrition and physical integrity) of DawaPlus 2.0, a 100-denier polyester ITN coated with deltamethrin (80 mg/m^2) and Olyset, a 150-denier polyethylene ITN incorporating permethrin (1000 mg/m^2) in two locations (Nanumba South and Zabzugu) over a three-year period and estimate median ITN survival and identify major determinants of field performance.
2. Describe major behavioral aspects of net care and repair and their impact on physical integrity.
3. Assess the insecticidal effectiveness (through bioassay and chemical content analysis) after three years of field use.

Baseline data collection was conducted December 3-9, 2018, under the management of the PMI VectorWorks Project. As VectorWorks closed in September 2019, management of the study transitioned to PMI VectorLink in early 2019, before all follow-up rounds were completed. Data collection for the 12-month follow-up round was conducted July 5-12, 2019, the 24-month follow up round was conducted August 10-16, 2020, and the endline 36-month round was conducted March 29 - April 6, 2021.

FIGURE 1: DURABILITY MONITORING TIMELINE

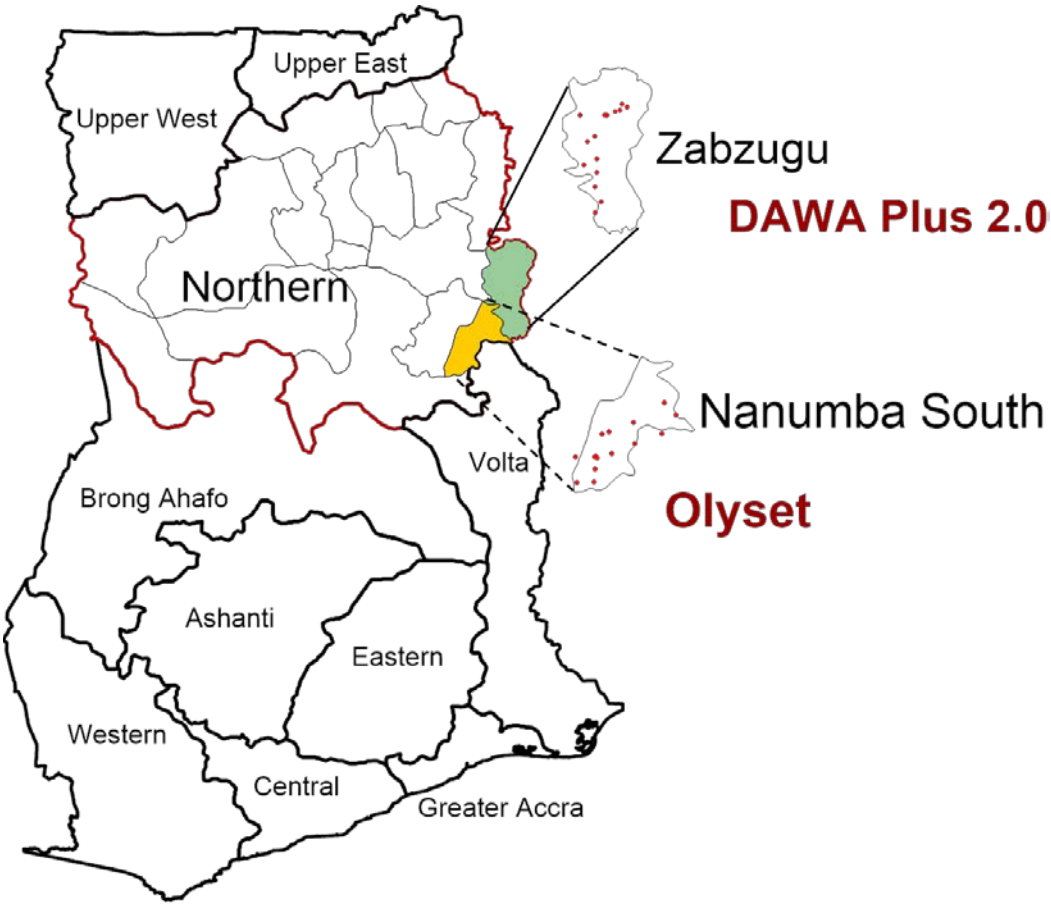


2. METHODS

2.1 STUDY SITES

Study sites were selected purposively in coordination with the NMCP and PMI based on the timing of the campaign and the type of ITN distributed in order to establish two neighboring locations in which two different ITN brands (one polyester and one polyethylene) were distributed. The two districts of Nanumba South (population 122,952 in 2018) and Zabzugu (population 95,238) were identified as the study sites (Figure 2).

FIGURE 2: STUDY SITE MAP



The Northern Region (in December 2018 split into Northern, Savannah and North East Regions) is situated in the north of Ghana at the edge of the Northern Tropical Savannah and Northern Arid climate zones. Average annual rainfall is 750 to 1,050 mm with a rainy season from May to October and a dry season from November to March/April. The economy of the region is predominantly based on agriculture. ITN coverage in the Northern Region is reported in Table 2, based on the 2019 Ghana Malaria Indicator Survey (MIS).

TABLE 2: KEY MALARIA CHARACTERISTICS IN NORTHERN REGION

Region	Proportion of households or population			
	Households with at least one ITN	Population with access to an ITN in their household	Population using ITN the night before survey	Use/Access Ratio
Northern	85.4%	66.7%	51.6%	0.77
All Ghana	74.0%	66.7%	43.2%	0.65

Source: 2019 MIS.
Population access: proportion of population that would be able to use an ITN if each ITN in a household was used by two people. Use/Access ratio: ratio of population access to population using an ITN.

2.2 ITN BRANDS MONITORED

The two brands of ITN monitored were:

(a) **DawaPlus 2.0** (distributed in Zabzugu district), 100-denier polyester ITN in blue color. The product uses coating technology with a loading dose of 80 mg/m^2 of deltamethrin. DawaPlus 2.0 received interim WHOPES recommendation in July 2009 (13th WHOPES Report) and was WHO pre-qualified in March 2018.[5]

(b) **Olyset** (distributed in Nanumba South district), 150-denier polyethylene ITN in white and blue colors uses incorporation technology with a loading dose of 1 g/m^2 of permethrin. Olyset received full WHOPES recommendation in July 2009 (13th WHOPES Report) and was WHO pre-qualified in July 2017.

2.3 STUDY DESIGN SUMMARY

The principal study design was that of a prospective study of a cohort of nets distributed through a mass campaign. The baseline round was conducted five months following the mass campaign, during which a representative sample of campaign nets from the study locations was identified through a cluster household survey with all campaign nets from consenting households forming the study cohort. These nets were labeled with a unique identifier and their presence and physical condition were assessed. At each subsequent annual survey (12-, 24- and 36-months following distribution) the presence and physical condition of each net in the study cohort were reassessed and recorded, together with household characteristics and use, care, and repair behaviors for nets. These characteristics were used to identify household- and respondent-level risk factors for net survivorship.

The sample size followed the standard guidance (http://www.durabilitymonitoring.org/) of 150 households per study site (15 clusters with 10 households each) with an expected number of 345 ITNs in each site, or 728 in total. At the end line, 279 nets are expected to be present in each study site. This sample size with the assumed design effect will allow detection of a 10-11%-points difference between locations if the assumed median survival is three years. At baseline, the ITN cohort in each site 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. Households were geolocated to facilitate subsequent visits.

In addition to the labeled ITNs from the campaign, all other mosquito nets present in the selected households were recorded to capture full and comparable data on all nets in each household. At baseline, 12- and 24-months, two campaign nets per cluster were randomly selected from households outside the cohort but within

[5] The product formerly known as DawaPlus 2.0, now called "Tsara Soft", had WHO prequalification suspended as of 12 December 2019 pending assessment of additional information (Reference: https://extranet.who.int/pqweb/vector-control-product/tsara-soft). The 36-month follow up on these nets proceeded as planned.

the same study site to undergo bioassay tests and evaluate insecticidal effectiveness. At 36-months, the 60 nets for this analysis were sampled from the main cohort. Participating households received a new, replacement ITN in exchange for the one withdrawn for the study. Bioassays for this survey round were conducted by Noguchi Memorial Institute for Medical Research (NMIMR) in accordance with standard WHO guidelines for cone and tunnel tests (where appropriate).[6] Chemical content analysis for this study was conducted by the Center for Disease Control (CDC) Atlanta.

2.4 Training and Fieldwork

Fieldwork was conducted by an implementation team of nine people per district: a dedicated study coordinator and two field teams of four people each (one team leader and three data collectors). Staff were carefully selected based on their knowledge of the local language and experience conducting household surveys. The two study coordinators and four team leaders were staff of NMIMR and participated in all survey rounds. Data collectors were community members who had been involved in the 2018 distribution campaign and all data collectors for the 36-month survey also participated in the 24-month round.

Online training of trainers for 11 staff from the NMCP, VectorLink, and NMIMR took place on March 15-17, 2021, with three days of remote instruction led by VectorLink research staff experienced in durability monitoring. In-person training for twelve data collectors took place in Tamale from March 23-26, 2021 and entailed three days of classroom-based training and one field practice day in a local community with support from VectorLink Ghana, NMCP, and NMIMR staff. Training covered the following topics: the study design and sampling procedures, ethical considerations (such as consent), COVID-19 adaptations, detailed review of the questionnaire with role play, use of tablets and the SurveyCTO software, and the physical assessment of holes and net repairs with practical exercises.

In each study village, the field team sought approval to conduct the follow-up survey from local authorities and chiefs, re-sharing information on the study objectives and processes. Communities were then sensitized and mobilized to obtain maximum cooperation. A local community guide supported field teams in locating study households.

Data for the main household survey was collected using ODK-based SurveyCTO software (version 2.70) on Android tablets. During fieldwork, each evening, team coordinators reviewed all data collected that day and gave feedback to the team on their performance, strengths, and weaknesses. Daily progress reports were shared with the study coordinator and any problems that arose were reported to the co-investigators or principal investigator via WhatsApp for resolution. The Regional Research Manager remotely downloaded and examined data each day and provided feedback to the field teams via WhatsApp.

2.5 Data Management

The questionnaire was thoroughly tested prior to deployment. Skip patterns and filters, internal consistency checks, range checks, and logical checks were programmed to support high quality data collection. Depending on the local conditions in each cluster, interviewer data was uploaded to a web-based database daily or stored on tablets until they could be transferred. At baseline, 12-, and 24-months, a one-page paper questionnaire was completed for each ITN taken for bioassay analysis. The questionnaire was stored with the ITN for transfer to the laboratory. At 36-months, no separate questionnaire was required as descriptive data for selected bioassay nets was available from the main study questionnaire. At the end of the survey, the web-based database was downloaded and converted into a Stata data file for analysis. Data values were checked for internal consistency

[6] World Health Organization: WHO Guidelines for Laboratory and Field Testing of Long-Lasting Insecticidal Nets. Geneva 2013, WHO/HTM/NTD/WHOPES/2013.3

and logic, and coding was applied for non-response or missing values. All operations were documented in Stata ".do" files.

2.6 ANALYSIS

The household sample is considered approximately self-weighting and therefore no weights were applied during analysis. Estimates of sampling errors accounted for the clustered survey design.

Attitudes towards nets and net care/repair were captured using Likert score questions, where respondents stated the extent to which they agreed or disagreed with a standard set of statements. Data from the Likert score questions were summarized into two summary scores (nets and net care/repair) by first recoding the four-level Likert scale to have a value of -2 for "strongly disagree", -1 for "disagree", +1 for "agree" and +2 for "strongly agree". These values for each response were then summed and divided by the number of statements to calculate an overall attitude score. An average score greater than 1 is interpreted as a household respondent with favorable attitudes to a given topic.

The physical integrity of campaign ITNs was assessed in accordance with WHO guidelines[7], with the number of holes of size 0.5 – 2 cm diameter (size 1), 2 – 10 cm diameter (size 2), 10 – 25 cm diameter (size 3) and >25 cm diameter (size 4) recorded for each net, following examination by the team in a well-lit location. Data from the ITN hole assessment was transformed into the proportionate Hole Index (pHI) for each ITN using the following standard equation:

$$pHI = Number\ of\ size\ 1\ holes + (No.\ of\ size\ 2\ holes \times 23) + (No.\ of\ size\ 3\ holes \times 196) + (No.\ of\ size\ 4\ holes \times 576)$$

Based on the pHI value, ITNs were categorized as "good", "serviceable" or "torn" as defined below. Note that "good" is a subset of all "serviceable" ITNs.

Good: pHI ≤ 64 (corresponding to a total hole surface area ≤ 0.01m²)

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

Torn: pHI > 642 (total hole surface area > 0.1m²)

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

At the end of the 36-month round, the median net survival was calculated, using the following formula:

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

Where tm is the median survival time, t1 and t2 are the first and second time points in years (usually the 24- and 36-month rounds), and p1 and p2 are the proportion of nets (as percentages) surviving to the first and second time points. Confidence intervals for this estimate were calculated by projecting the 95% CI from the survival estimates, as described above.

[7] World Health Organization: WHO Guidance Note for Estimating the Longevity of Long-Lasting Insecticidal Nets in Malaria Control. Geneva: 2013

Data were also set up for a survival analysis to estimate survival in a Kaplan-Meier plot. Survival analysis was done using an intention to treat approach, i.e., risk of failure was considered to start at the day of distribution irrespective of whether or when the net was hung and used. Failure was defined as a net being lost due to wear and tear or classified as "too torn" based on physical assessment. Nets that were given away or that had an unknown outcome were censored. The time of failure was directly calculated from the report of time of loss by the respondent or taken as the mid-point between the last two surveys if unknown.

The outcomes of insecticidal effectiveness were based on the bioassay results using the standard WHO cone test performed by NMIMR. A pyrethroid-sensitive Kisumu strain of *Anopheles gambiae* was used with 5 mosquitoes per cone, four sites tested on each net (standard positions 2, 3, 4 and roof) and two replicates per location (8 cone tests with 40 mosquitoes per net in total). The 60-minute knock-down (KD60) and the 24-hour mortality rate were measured. The two variables from these tests were combined into the following outcome measures:

Optimal effectiveness: KD60 ≥ 95% or mortality ≥ 80%

Minimal effectiveness: KD60 ≥ 75% or mortality ≥ 50%

Samples taken from ITNs selected for bioassays were packaged following standard procedures and shipped to CDC for chemical content testing. Outcome measures from these tests present the mean and median level of active ingredient across the net brand samples in mg/m^2 and compare these averages with manufacturer specifications for the insecticides used on the netting.

2.7 COVID-19 ADAPTATIONS

To ensure the safety of study participants, trainers, and fieldwork staff, COVID-19 mitigations measures were implemented throughout the survey round. A training of trainers was organized to eliminate the need for in-country technical assistance for training. This training was held online for study staff from NMIMR, NMCP, and VectorLink and was run in three sessions over three days. Training materials were modified from those used during in-person training, and participants focused on the study design and methods as well as how to administer the questionnaire, conduct net assessments, and follow all COVID-19 adaptations. During in-person fieldworker training, staff were instructed on all COVID-19 mitigation measures (including not to enter households), on how to examine nets with minimal contact, and on how to obtain oral consent. In the field and during training, staff were required to always wear a mask, maintain frequent hand washing, and to use a new pair of gloves when examining nets at each new study household. Personal protective equipment (PPE) including hand sanitizer, gloves, and disinfectant wipes were made available by NMIMR. A set of COVID-19 pre-screening questions were added to the questionnaire for application in the field. These questions sought to determine whether respondents were at risk from the study team (e.g., if anyone in the household had a pre-existing medical condition that would require shielding from COVID-19) and whether the study team was at risk from household members (e.g., if the household included member(s) with COVID-19 symptoms). During the 36-month round of fieldwork, one household was screened out of data collection due to a COVID-19 risk. Additional IRB approval was sought before fieldwork began, as described below.

2.8 ETHICAL CLEARANCE

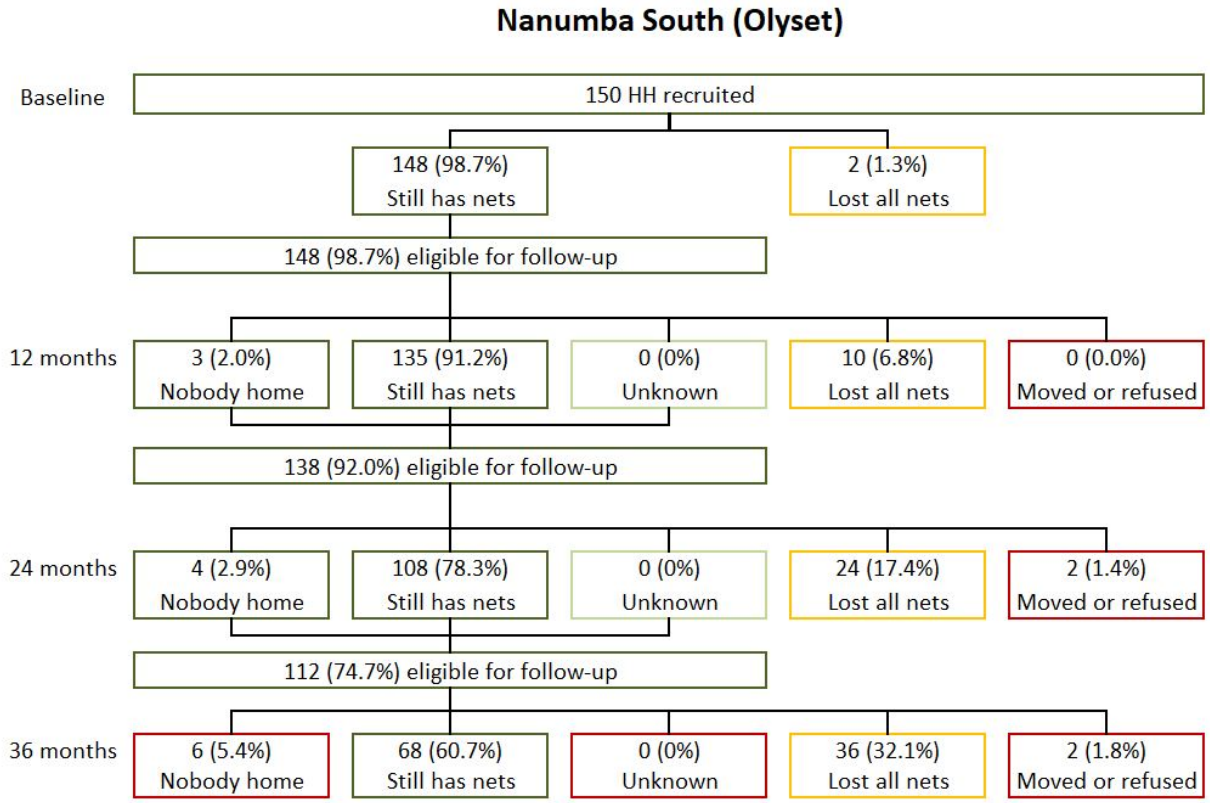
This study has been determined to be research with human subjects and received written continuing approval from the NMIMR on March 10, 2021, under reference number NMIMR-IRB CPN 006/18-19 amend 2021. The PSI Research Ethics Board (REB) granted continuing authorization on February 11, 2021, under reference number 29.2019. A third application was submitted to the PSI REB to obtain approval to resume activities under COVID-19 and authorization was granted on March 17, 2021. Staff implementing this study complied with all policies and procedures of both PSI REB and the local ethics boards. Informed oral consent was sought for all participants in this study prior to conducting the interview.

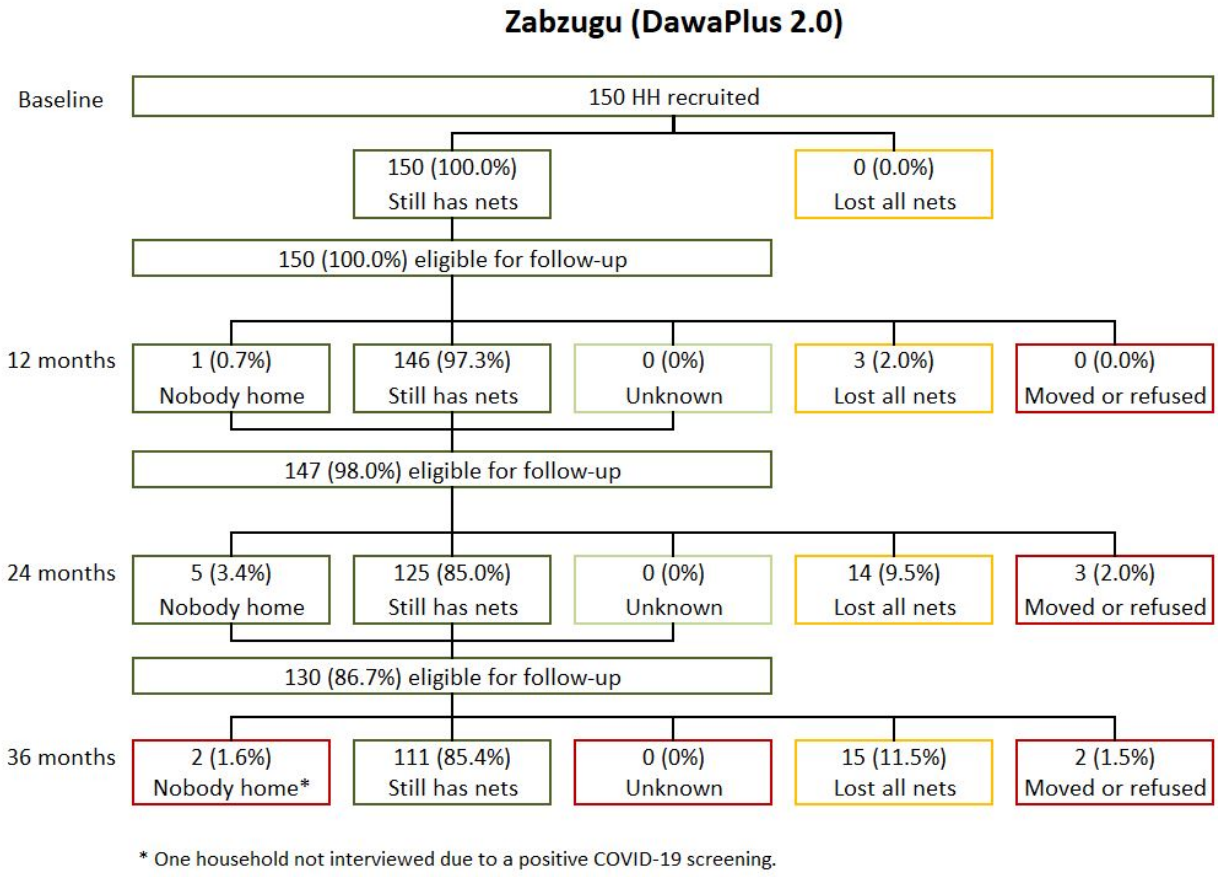
3. RESULTS

3.1 SAMPLE

At baseline, a total of 300 households were recruited for durability monitoring (150 in Nanumba South and 150 in Zabzugu), of which 242 households (112 in Nanumba South and 130 in Zabzugu) were eligible for follow-up at 36-months (Figure 3). Of the 112 eligible households in Nanumba South, 68 still had at least one cohort net present, while 36 households no longer had any cohort nets, six households had nobody home, one household had moved out of the study site, and one household refused to be interviewed. In Zabzugu, 111 of the 130 eligible households still had cohort nets, 15 no longer had any cohort nets, one household had moved out of the study site, and one household refused to be interviewed.

FIGURE 3: 36-MONTH FOLLOW-UP STATUS OF HOUSEHOLDS RECRUITED AT BASELINE





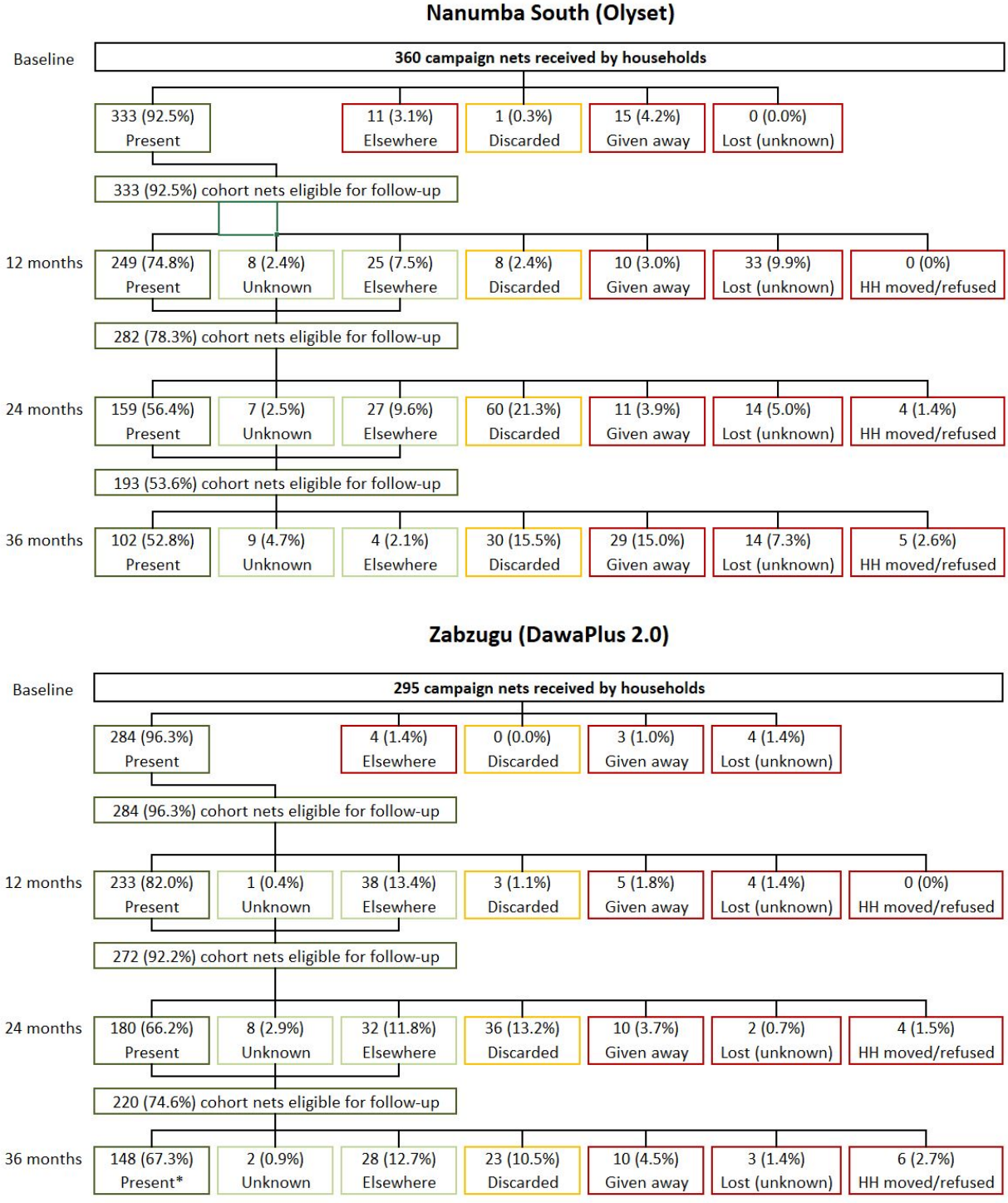
The 300 households visited at baseline reported receiving a total of 655 campaign nets (360 in Nanumba South and 295 in Zabzugu; Figure 4). Of these 655 nets, 617 (333 in Nanumba South and 284 in Zabzugu) were present in the households and were tagged for study follow-up.

In Nanumba South at the 12-month follow-up, 282 cohort nets were still in the households, had an unknown status (either due to nobody being home or lack of more precise respondent recall), or were elsewhere with family members and were eligible for follow-up in the next round. At 24-months, there were 193 nets either present, that had an unknown status, or said to be with a family member elsewhere and thus eligible for follow-up. At 36-months, the number of nets still in the households decreased to 102, nine nets had an unknown status and four were said to be with a family member elsewhere. Of the nets not in the household, 30 were discarded, 29 were stolen or given to others, and 14 were lost for unknown or other reasons. Among Olyset nets reported as present at each survey round, four, eight, and one net(s) were unavailable for assessment at 12-, 24-, and 36-months respectively due to being temporarily taken away for washing or stored in locked rooms. An additional five nets belonged to households who moved out of the study site or refused to take part in the interview.

In Zabzugu, at the 12-month round, 272 cohort nets were still in the households, had an unknown status, or were elsewhere with family members and were eligible for follow-up in the next round. At 24-months, 220 cohort nets were present, had an unknown status, or were elsewhere with family members and thus, eligible for follow-up in the next round. At 36-months, 148 cohort nets were still in the household, two had an unknown status, and 28 were with family members elsewhere. Twenty-three nets were discarded, 10 were given away to others or stolen, three were lost due to unknown or other reasons, and six could not be assessed because the household moved out of the study site or refused to be interviewed. Among DawaPlus 2.0 nets reported as

present at each survey round, three nets were unavailable for assessment at 24-months due to being temporarily taken away for washing or stored in locked rooms.

FIGURE 4: FOLLOW-UP STATUS OF COHORT ITNS RECRUITED AT BASELINE



3.2 DETERMINANTS OF DURABILITY

The study assessed household risk factors for net durability and attitudes and behaviors related to net care and repair. Factors that have previously been shown to be associated with net durability can be divided into household factors, handling factors, and net care and repair attitudes and behaviors.

Household assets can contribute indirectly to the durability of the nets as household factors. Results in Table 3 depict a highly rural environment in both sites, with some minor differences. At baseline and 36-months, household characteristics were similar in both sites. Most households had access to safe water (53% at baseline and 62% at 36-months) while less than half of households reported access to a latrine (27% at baseline and 22% at 36-months). In both sites, firewood was the most common source of energy for cooking (91% at baseline and 93% at 36-months) and animal husbandry was practiced by most households (67% at baseline and 73% at 36-months). However, at 36-months, Nanumba South had a higher proportion of households with roof sheet or tile when compared to Zabzugu (98% vs. 91%, p=0.048). The same can be said for mobile phone ownership (89% versus 75%, p=0.030). Zabzugu, had a higher proportion of households with any transportation (84% versus 66%, p=0.005) at 36-months.

TABLE 3: HOUSEHOLD CHARACTERISTICS AND ASSETS

	Baseline	36 months
Nanumba South	**N=150**	**N=104**
Roof (sheets/ tile)	96.7%	98.1%
Cooking fuel (firewood)	93.3%	98.1%
Access to safe water	46.7%	77.9%
Access to latrine	16.7%	18.3%
Radio	30.7%	36.5%
Mobile phone	66.0%	88.5%
Any transport	66.7%	66.3%
Animal husbandry	62.0%	70.2%
Owning land for farming	70.7%	86.5%
Zabzugu	**N=150**	**N=126**
Roof (sheets/ tile)	92.0%	91.3%
Cooking fuel (firewood)	88.0%	88.1%
Access to safe water	59.3%	45.2%
Access to latrine	36.7%	26.2%
Radio	30.0%	47.6%
Mobile phone	74.0%	74.6%
Any transport	72.0%	84.1%
Animal husbandry	72.7%	75.4%
Owning land for farming	86.0%	95.2%

The presence of rodents in the house and the presence of food and practice of cooking near sleeping areas are risk factors for net durability. Table 4 presents the prevalence of these risk factors at the 36-month survey. No households reported always cooking in a sleeping room, although a significantly lower proportion (p<0.001) of households in Nanumba South (1%) sometimes cooked in the same room used for sleeping compared to Zabzugu (21%). A lower proportion of households in Nanumba South also reported ever storing food in a room used for sleeping versus Zabzugu (30% versus 63%, p=0.003). In Nanumba South, 89% of households

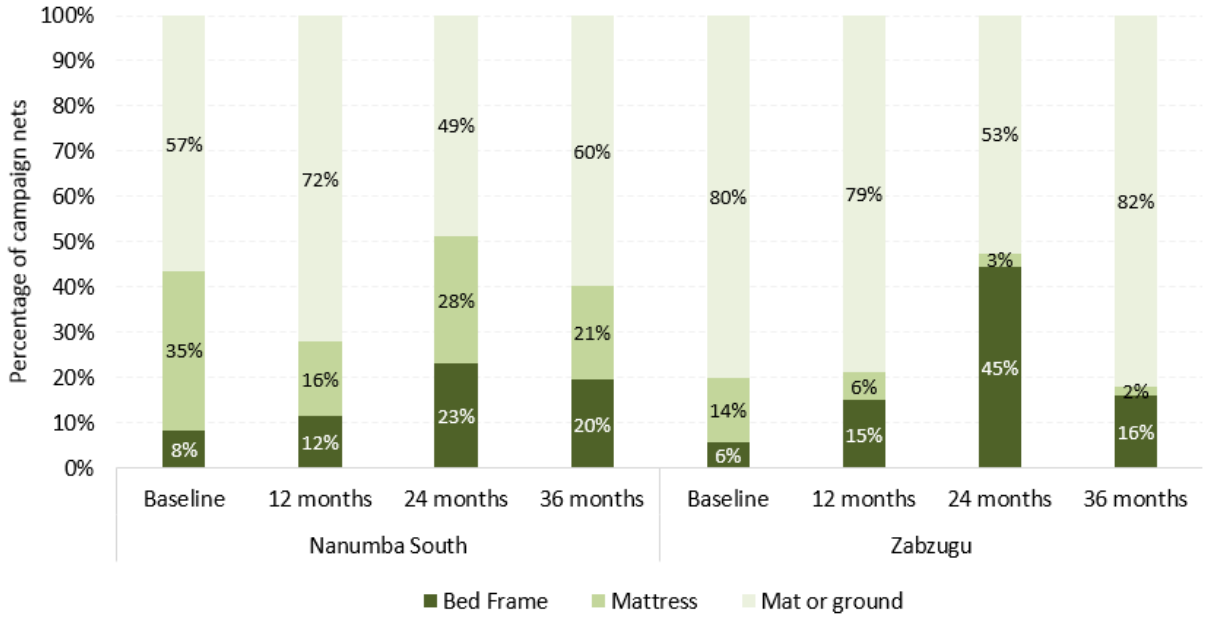
reported observing rodents in the past six months compared to 94% of households in Zabzugu. These results suggest mosquito nets in Zabzugu may be at a higher risk for damage.

TABLE 4: PREVALENCE OF HOUSEHOLD RISK FACTORS FOR DAMAGE

	Baseline	12 months	24 months	36 months
Nanumba South	**N=150**	**N=145**	**N=132**	**N=104**
Ever store food in room used for sleeping	32.7%	53.8%	46.2%	29.8%
Cook in sleeping room				
Never	90.7%	93.8%	97.0%	99.0%
Sometimes	8.7%	5.5%	1.5%	1.0%
Always	0.7%	0.7%	1.5%	0.0%
Observed rodents in last 6 months	90.7%	86.2%	82.6%	89.4%
Zabzugu	**N=150**	**N=149**	**N=139**	**N=126**
Ever store food in room used for sleeping	66.7%	62.4%	64.7%	62.7%
Cook in sleeping room				
Never	80.7%	90.6%	65.5%	78.6%
Sometimes	8.7%	8.7%	33.8%	21.4%
Always	10.7%	0.7%	0.7%	0.0%
Observed rodents in last 6 months	85.3%	89.3%	87.8%	94.4%

The type of sleeping place may also affect net durability. Generally, nets used when sleeping on mats or the ground are more prone to wear and tear than those used over mattresses and bed frames. Figure 5 shows the types of sleeping spaces over which cohort ITNs were used by site and study period. In both study sites at 36-months, the majority of nets were hanging over a mat or the ground only (60% in Nanumba South and 82% in Zabzugu) while 20% or less of nets were used over bed frames. In Nanumba South, 21% of nets were used over a mattress compared to only 2% in Zabzugu ($p<0.001$).

FIGURE 5: TYPE OF SLEEPING PLACE FOR CAMPAIGN ITNS WHEN USED



In addition to food storage and cooking practices, excessive net handling is a risk factor for durability (Table 5). Excessive washing, particularly with cleaning products like detergent or bleach, can diminish insecticide effectiveness. At 36-months, a higher proportion of cohort nets in Zabzugu (97%) compared to Nanumba South (74%) had ever been washed (p=0.009). Among washed nets, the median number of washes in the six months prior to the survey was higher in Zabzugu than in Nanumba South (four washes vs. three washes). A similar proportion of nets in Nanumba South (16%) and Zabzugu (19%) were washed using detergent or bleach. Drying washed nets on a bush or fence was more common in Nanumba South compared to Zabzugu (25% versus 4%, p=0.002). Among nets reported as hanging, 25% in Nanumba South and 19% in Zabzugu were found hanging loose.

TABLE 5: PREVALENCE OF HANDLING RISK FACTORS FOR CAMPAIGN ITNS

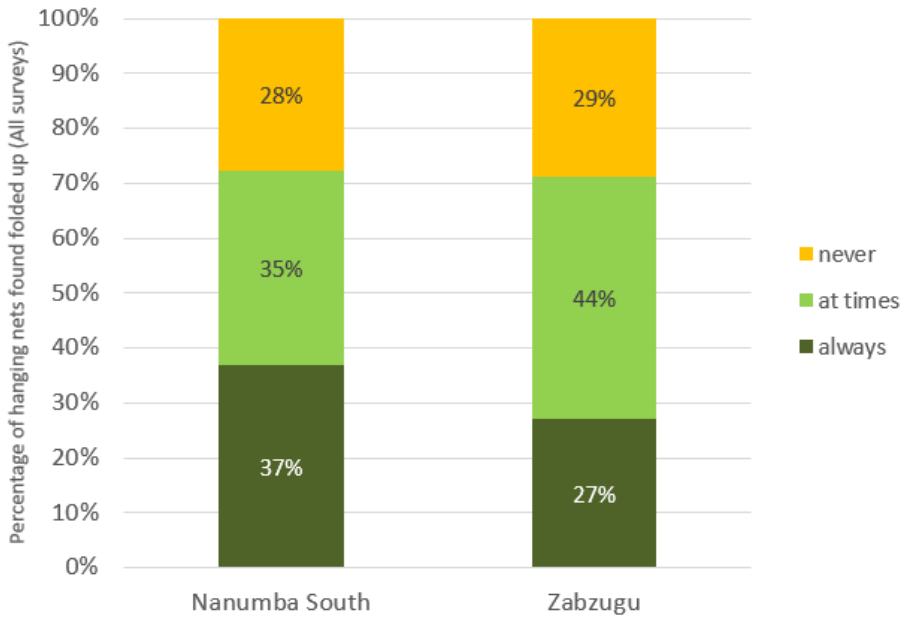
	Baseline	12 months	24 months	36 months
Nanumba South	**N=331**	**N=248**	**N=159**	**N=102**
ITNs ever washed	10.3%	60.9%	77.4%	73.5%
Among ITNs ever washed:	N=34	N=151	N=123	N=75
Median number of washes in last 6 months [IQR]	2.0 [1.0-3.5]	3.0 [2.0-4.0]	3.0 [3.0-6.0]	3.0 [3.0-6.0]
Used detergent or bleach for last wash	0.0%	18.5%	24.4%	16.0%
ITNs dried on bush or fence for last wash	17.6%	0.0%	26.0%	25.3%
Among hanging ITNs:	N=118	N=124	N=79	N=49
Hanging ITNs are <u>not</u> folded or tied up	71.2%	29.8%	27.8%	24.5%
Zabzugu	**N=284**	**N=233**	**N=180**	**N=148**
ITNs ever washed	41.5%	71.7%	84.4%	96.6%
Among ITNs ever washed:	N=118	N=167	N=152	N=143
Median number of washes in last 6 months [IQR]	2.0 [1.0-3.0]	3.0 [2.0-5.0]	3.0 [3.0-5.0]	4.0 [3.0-8.0]
Used detergent or bleach for last wash	23.7%	18.0%	27.6%	18.9%

	Baseline	12 months	24 months	36 months
ITNs dried on bush or fence for last wash	29.7%	0.0%	2.6%	4.2%
Among hanging ITNs:	N=149	N=135	N=138	N=78
Hanging ITNs are not folded or tied up	62.4%	54.8%	51.4%	19.2%

IQR: interquartile range

When considering cohort nets that were ever found hanging across all rounds of the survey, a similar proportion of cohort nets were always found folded up in Nanumba South (27%) and Zabzugu (37%) (Figure 6). Similarly, 28% of cohort nets in Nanumba South and 29% of cohort nets in Zabzugu have never been found tied up when they were hanging.

FIGURE 6: FOLDING UP OF HANGING NETS ACROSS ALL SURVEYS



Respondent exposure to information on use and care and/or repair of nets is shown in Table 6. At 36-months, similar proportions of respondents reported any exposure in the six months before the survey (49% in Nanumba South and 44% in Zabzugu). In both districts and across all four study rounds, among those that were exposed to messaging, a majority of respondents obtained the information through interpersonal communication (e.g., health workers, friends/family, and community leaders or events). The most commonly recalled message among exposed respondents at 36-months was to care for their net (93% across both districts). A higher proportion of respondents in Nanumba South recalled specific messages to repair nets (67% versus 12% in Zabzugu, $p<0.001$) and that nets prevent malaria (64% versus 4% in Zabzugu, $p<0.001$). Differences in recall of messages on using, hanging, or caring for nets between the two districts were not statistically significant.

TABLE 6: RESPONDENT EXPOSURE TO MESSAGES ABOUT NETS IN LAST 6 MONTHS

	Baseline	12 months	24 months	36 months
Nanumba South	**N=150**	**N=145**	**N=132**	**N=104**
Any exposure in last 6 months	23.3%	38.6%	32.6%	49.0%
Among those exposed:	N=35	N=56	N=43	N=51
Mean number of sources among exposed*	2.5	1.3	1.5	1.6
Type of media source among exposed				
Media only	0.0%	5.4%	2.3%	2.0%
Interpersonal communication only	88.6%	87.5%	93.0%	92.2%
Both	11.4%	7.1%	4.7%	5.9%
Messages recalled among exposed				
"Use net (every) night"	97.1%	82.1%	83.7%	84.3%
"Hang net"	80.0%	58.9%	55.8%	78.4%
"Care for net"	71.4%	69.6%	65.1%	94.1%
"Repair net"	17.1%	10.7%	41.9%	11.8%
"Nets prevent malaria"	82.9%	30.4%	48.8%	3.9%
Zabzugu	**N=150**	**N=149**	**N=139**	**N=126**
Any exposure in last 6 months	30.7%	40.3%	25.2%	43.7%
Among those exposed:	N=46	N=60	N=35	N=55
Mean number of sources among exposed*	1.6	1.6	2.0	1.8
Type of media source among exposed				
Media only	21.7%	8.3%	8.6%	1.8%
Interpersonal communication only	71.7%	81.7%	71.4%	92.7%
Both	6.5%	10.0%	20.0%	5.5%
Messages recalled among exposed				
"Use net (every) night"	89.1%	65.0%	94.3%	96.4%
"Hang net"	76.1%	30.0%	65.7%	83.6%
"Care for net"	65.2%	40.0%	68.6%	92.7%
"Repair net"	15.2%	15.0%	5.7%	67.3%
"Nets prevent malaria"	65.2%	35.0%	22.9%	63.6%

* The maximum number of sources was 9 and included: community health agent; radio; song; drama; health worker; community leader; town announcer; family/friends; mosque/church.

Data on household attitudes towards nets and net care and repair were captured in the form of Likert score questions (i.e., respondents were asked the extent to which they agreed with certain statements). Net use questions were used to understand the extent to which respondents believed they could obtain enough nets for their household, hang nets, use nets consistently and get children in the household to use nets consistently. Questions on attitudes to net care and repair were used to understand respondent beliefs about the value of nets and their capacity to keep nets in a good condition and repair net damage. These questions were converted into two summary scores by first recoding the four-level Likert scale to have a value of -2 for "strongly disagree", -1 for "disagree", +1 for "agree" and +2 for "strongly agree". The values for each response were then summed and divided by the number of statements to calculate an overall attitude score. An average score greater than 1 is interpreted as a household respondent with a favorable attitude towards a given topic.

At the 36-month endline round, the mean attitude scores for nets and net care and repair in Zabzugu were above 1.0, indicating an overall positive attitude towards nets and net care and repair. In Nanumba South, the mean attitude score towards nets was above 1.0 and the mean attitude score towards net care and repair was slightly below 1.0, indicating an unfavorable attitude towards net care and repair. Zabzugu had a higher proportion of respondents with a favorable attitude toward net care and repair (70% versus 42% in Nanumba South, p=0.006) while Nanumba South had a higher, but not statistically significant, proportion of respondents with favorable net attitude scores (67% versus 54% in Zabzugu).

TABLE 7: RESPONDENT ATTITUDES TOWARDS NETS AND NET CARE & REPAIR

	Baseline	12 months	24 months	36 months
Nanumba South	**N=150**	**N=145**	**N=132**	**N=104**
Attitude score: Nets				
Mean	1.24	0.85	0.89	1.23
(95% CI)	(1.00-1.48)	(0.56-1.14)	(0.61-1.16)	(1.03-1.43)
Percentage of respondents with score > 1.0	67.3%	45.5%	43.9%	67.3%
Attitude score: Net care and repair				
Mean	0.71	1.27	1.06	0.96
95% CI)	(0.62-0.80)	(1.09-1.44)	(0.84-1.28)	(0.84-1.08)
Percentage of respondents with score > 1.0	15.3%	64.1%	51.5%	42.3%
Zabzugu	**N=150**	**N=149**	**N=139**	**N=126**
Attitude score: Nets				
Mean	1.25	1.22	1.04	1.02
(95% CI)	(1.06-1.45)	(1.08-1.37)	(0.81-1.28)	(0.74-1.30)
Percentage of respondents with score > 1.0	64.0%	62.4%	48.2%	54.0%
Attitude score: Net care and repair				
Mean	0.90	1.32	1.10	1.36
(95% CI)	(0.77-1.03)	(1.11-1.53)	(0.94-1.26)	(1.17-1.54)
Percentage of respondents with score > 1.0	38.0%	61.7%	59.0%	69.8%

Experience with repairing holes in nets is displayed in Table 8. Across survey rounds, a progressively increasing proportion of respondents reported having ever experienced holes (from an average of 28% at baseline to 73% at 36-months, across both sites). While the proportion of respondents who reported discussing net care and repair was highest for Nanumba South at 36-months (48% versus 19% at baseline), the proportion was lowest in Zabzugu at the 36-month endline (26% versus 47% at 12-months). Among those who reported having holes in their nets, 24% of respondents in Nanumba South and 30% of respondents in Zabzugu had ever repaired a net at 36-months. There were no statistical differences between the proportion of households experiencing holes in a net, discussing net care, or repairing nets across study sites at 36-months.

TABLE 8: HOUSEHOLD NET CARE AND REPAIR EXPERIENCE

	Baseline	12 months	24 months	36 months
Nanumba South	**N=150**	**N=145**	**N=132**	**N=104**
Ever experienced holes in a net	26.7%	44.1%	56.1%	69.2%
Discussed net care and repair in last 6 months	18.7%	51.0%	43.9%	48.1%
Among households experiencing holes:	N=40	N=64	N=74	N=72
Ever repaired net	20.0%	28.1%	27.0%	23.6%
Zabzugu	**N=150**	**N=149**	**N=139**	**N=126**
Ever experienced holes in a net	28.7%	40.3%	53.2%	75.4%

	Baseline	12 months	24 months	36 months
Discussed net care and repair in last 6 months	28.7%	47.0%	30.2%	26.2%
Among households experiencing holes:	N=43	N=60	N=74	N=95
Ever repaired net	30.2%	36.7%	36.5%	29.5%

3.3 NET OWNERSHIP AND NET USE

The status and reported recent use of campaign cohort nets (Table 9) was recorded to understand net use patterns. In both study sites, at 36-months, cohort nets were most commonly found hanging and tied up with a higher proportion in Zabzugu (43%) than in Nanumba South (36%). In Nanumba South, the second most common cohort net status was stored away unpacked (26%) and in Zabzugu, the second most common cohort net status was not hanging and not stored away (21%). Reported use of cohort nets progressively increased from 41% at baseline to 85% at 36-months in Nanumba South. There was also an increase in reported cohort net use in Zabzugu from 56% at baseline to 72% at 36-months, although this is a decrease from 93% at 24 months. Cohort nets were reportedly used last night and every night last week by approximately 55% and 46% of respondents respectively in both Nanumba South and Zabzugu.

TABLE 9: STATUS AND REPORTED USE OF COHORT NETS IN THE HOUSEHOLD

	Baseline	12 months	24 months	36 months
Nanumba South	**N=333**	**N=249**	**N=159**	**N=102**
Cohort net status				
Found hanging and tied up	10.2%	34.9%	35.8%	36.3%
Found hanging, untied	25.2%	14.9%	13.8%	11.8%
Not hanging and not stored away	2.1%	17.3%	20.8%	18.6%
Stored away unpacked	2.1%	11.2%	18.9%	25.5%
Stored away in a package	60.4%	20.1%	5.7%	6.9%
Temporarily unavailable during visit	0.0%	1.6%	5.0%	0.0%
Net ever used	41.1%	73.8%	81.1%	85.3%
Net used last night	35.7%	53.2%	54.1%	55.9%
Net used every night last week	28.5%	52.0%	52.8%	46.1%
Zabzugu	**N=284**	**N=233**	**N=180**	**N=148**
Cohort net status				
Found hanging and tied up	19.7%	26.2%	37.2%	42.6%
Found hanging, untied	32.7%	31.8%	39.4%	10.1%
Not hanging and not stored away	3.5%	19.3%	13.3%	20.9%
Stored away unpacked	4.9%	6.0%	3.3%	19.6%
Stored away in a package	39.1%	16.7%	5.0%	6.1%
Temporarily unavailable during visit	0.0%	0.0%	1.7%	0.0%
Net ever used	55.6%	78.5%	93.3%	71.6%
Net used last night	54.2%	65.2%	77.2%	55.4%
Net used every night last week	52.1%	62.2%	63.9%	46.6%

Each survey round documents all mosquito nets in selected households, including nets from sources other than the 2018 mass distribution campaign (referred to as *non-cohort nets*). Household ownership of non-cohort nets and sources of these nets are presented in Table 10.

At 36-months, the proportion of households with non-cohort nets in Nanumba South was higher than in Zabzugu (61% in Nanumba South versus 34% in Zabzugu, p=0.019). In Zabzugu, this represents a continuous drop in non-cohort net ownership since the 12-month round (58%).

Most non-cohort nets came from public sources (ANC visits, a previous net campaign, schools, other public health facility visits, community workers, or an immunization campaign). At 36-months the majority of non-cohort nets were from ANC visits (58% across both study sites) with the second most common source being from a previous mass campaign (10% in Nanumba South and 32% in Zabzugu). At 36-months only 3% of nets came from private sources and 9% came from other or unknown sources (of which the majority were from family or friends).

TABLE 10: OWNERSHIP AND SOURCE OF NON-COHORT NETS

	Baseline	12 months	24 months	36 months
Nanumba South	**N=149**	**N=145**	**N=132**	**N=104**
Households with any non-cohort nets	24.2%	59.3%	64.4%	60.6%
Non-cohort net sources	**Net N=57**	**Net N=190**	**Net N=141**	**Net N=96**
ANC visit	22.8%	10.0%	23.4%	57.3%
Previous mass campaign	50.9%	31.6%	38.3%	10.4%
School	3.5%	16.3%	9.9%	7.3%
Other public source*	12.3%	35.8%	8.5%	6.3%
Private sector	0.0%	1.1%	1.4%	5.2%
Other/doesn't recall**	10.5%	5.3%	18.4%	13.5%
Zabzugu	**N=150**	**N=149**	**N=139**	**N=126**
Households with any non-cohort nets	46.7%	58.4%	43.2%	34.1%
Non-cohort net sources	**Net N=98**	**Net N=114**	**Net N=78**	**Net N=65**
ANC visit	31.6%	34.2%	50.0%	58.5%
Previous mass campaign	44.9%	29.8%	20.5%	32.3%
School	4.1%	7.0%	9.0%	4.6%
Other public source*	8.2%	23.7%	6.4%	1.5%
Private sector	2.0%	0.0%	0.0%	0.0%
Other/doesn't recall**	9.2%	5.3%	14.1%	3.1%

* Includes other (non-ANC) public health facility visits, community-based workers and immunization campaigns.
** Includes family/friends, NGO and faith-based organizations.

A total of 161 non-cohort nets (96 in Nanumba South and 65 in Zabzugu) were audited in study households at the 36-month endline round (Table 11). A higher proportion of non-cohort nets in Nanumba South compared to Zabzugu were ever used (74% versus 46%, p=0.052), used last night (51% versus 22%, p=0.013), and used every night last week (43% versus 15%, p=0.027). For all net use indicators at 36-months, the proportion of cohort nets used was higher than non-cohort nets in both provinces, especially in Zabzugu where the proportion of nets ever used, used last night, or used every night last week was approximately 30 percentage points higher. Non-cohort nets were more commonly found hanging at the time of the interview in Nanumba South compared to Zabzugu (48% versus 18% in Zabzugu, p=0.003) while nets in Zabzugu were more frequently stored away (59% versus 32% in Nanumba South, p=0.039).

TABLE 11: STATUS AND REPORTED USE OF NON-COHORT NETS IN THE HOUSEHOLD

	Baseline	12 months	24 months	36 months
Nanumba South	**N=57**	**N=190**	**N=141**	**N=96**
Non-cohort net status				
Found hanging and tied up	45.6%	32.6%	29.8%	27.1%
Found hanging, untied	19.3%	7.9%	19.9%	20.8%
Not hanging and not stored away	12.3%	16.3%	18.4%	17.7%
Stored away unpacked	1.8%	8.4%	11.3%	6.3%
Stored away in a package	12.3%	33.2%	16.3%	26.0%
Temporarily unavailable during visit	8.8%	1.6%	4.3%	2.1%
Net ever used	86.2%	61.1%	73.8%	74.0%
Net used last night	53.4%	40.5%	57.4%	51.0%
Net used every night last week	13.8%	39.5%	54.6%	42.7%
Zabzugu	**N=98**	**N=114**	**N=78**	**N=65**
Non-cohort net status				
Found hanging and tied up	33.7%	23.7%	37.2%	16.9%
Found hanging, untied	19.4%	36.0%	32.1%	1.5%
Not hanging and not stored away	30.6%	16.7%	7.7%	16.9%
Stored away unpacked	1.0%	5.3%	6.4%	43.1%
Stored away in a package	14.3%	14.0%	14.1%	15.4%
Temporarily unavailable during visit	1.0%	4.4%	2.6%	6.2%
Net ever used	70.7%	84.2%	84.6%	46.2%
Net used last night	54.5%	67.5%	70.5%	21.5%
Net used every night last week	52.5%	63.2%	57.7%	15.4%

The study captured data on the age categories of household members using cohort (Table 12) and non-cohort nets (Table 13) the night before the interview as another potential factor for durability. At 36-months, more than 50% of cohort nets were used by adults only in Nanumba South (72%) and Zabzugu (56%). This was also the case for non-cohort nets in Zabzugu (64%), whereas the majority of non-cohort nets in Nanumba South were used by children sharing with adults (51%). Cohort and non-cohort nets were rarely used by children only in either study site (6% for cohort nets and 5% for non-cohort nets).

TABLE 12: USE OF COHORT NETS BY HOUSEHOLD MEMBERS AMONG NETS USED THE PREVIOUS NIGHT

	Baseline	12 months	24 months	36 months
Nanumba South	**N=119**	**N=132**	**N=86**	**N=57**
Cohort nets				
Used by child(ren) only	21.0%	10.6%	3.5%	10.5%
Used by child(ren) sharing with adult(s)	26.1%	47.0%	46.5%	17.5%
Used by adult(s) only	52.9%	42.4%	50.0%	71.9%
Zabzugu	**N=154**	**N=152**	**N=139**	**N=82**
Cohort nets				
Used by child(ren) only	13.0%	14.5%	15.1%	2.4%
Used by child(ren) sharing with adult(s)	39.0%	46.1%	45.3%	41.5%

	Baseline	12 months	24 months	36 months
Used by adult(s) only	48.1%	39.5%	39.6%	56.1%

Children aged 0-9 years; Adults include adolescents aged 10-19 years.

TABLE 13: USE OF NON-COHORT NETS BY HOUSEHOLD MEMBERS AMONG NETS USED THE PREVIOUS NIGHT

	Baseline	12 months	24 months	36 months
Nanumba South	**N=31**	**N=77**	**N=81**	**N=49**
Non-cohort nets				
Used by child(ren) only	3.2%	6.5%	7.4%	4.1%
Used by child(ren) sharing with adult(s)	32.3%	41.6%	40.7%	51.0%
Used by adult(s) only	64.5%	51.9%	51.9%	44.9%
Zabzugu	**N=54**	**N=77**	**N=55**	**N=14**
Non-cohort nets				
Used by child(ren) only	14.8%	5.2%	21.8%	7.1%
Used by child(ren) sharing with adult(s)	27.8%	36.4%	30.9%	28.6%
Used by adult(s) only	57.4%	58.4%	47.3%	64.3%

Children aged 0-9 years; Adults include adolescents aged 10-19 years.

Access to ITNs is an important determinant of ITN use – people need access before they can use an ITN (Table 14). Access can be measured at the household and population levels. Household access is defined as the proportion of households with one ITN for every two people in the household; population access is defined as the proportion of people that could sleep under an ITN assuming each ITN in a household was used by 2 people. By both measures, access to cohort ITNs decreased from baseline to 36-months in Nanumba South and Zabzugu. Overall, at 36-months, household and population access to cohort ITNs was higher in Zabzugu (41% and 61%, respectively) than in Nanumba South (23% and 42%, respectively). That said, access to all ITNs was similar between study sites, and population use of all ITNs was slightly higher in Nanumba South (44%) compared to Zabzugu (37%).

TABLE 14: HOUSEHOLD AND POPULATION ITN ACCESS AND USE

	Baseline	36 months
Nanumba South		
Household access	**N=150**	**N=104**
All ITNs	88.0%	48.1%
Campaign cohort ITNs (Olyset)	81.3%	23.1%
Other ITNs	11.3%	17.3%
Population access	**N=511**	**N=427**
All ITNs	94.7%	63.9%
Campaign cohort ITNs (Olyset)	90.8%	41.5%
Other ITNs	19.2%	34.7%
Population use	**N=511**	**N=427**
All ITNs	N/A	44.0%
Campaign cohort ITNs (Olyset)	N/A	25.8%
Other ITNs	N/A	20.1%
Zabzugu		

	Baseline	36 months
Household access	**N=150**	**N=126**
All ITNs	85.3%	54.0%
Campaign cohort ITNs (DawaPlus 2.0)	74.0%	40.5%
Other ITNs	12.0%	9.5%
Population access	**N=525**	**N=508**
All ITNs	93.1%	71.7%
Campaign cohort ITNs (DawaPlus 2.0)	88.2%	60.8%
Other ITNs	25.9%	20.5%
Population use	**N=525**	**N=508**
All ITNs	N/A	36.8%
Campaign cohort ITNs (DawaPlus 2.0)	N/A	33.1%
Other ITNs	N/A	4.5%

3.4 DURABILITY OF CAMPAIGN ITNS

The durability of ITNs can be conceptualized as two components: *attrition*, or nets that are no longer present in the household; and the *physical integrity* of nets that are available for use in the household. Table 15 presents results for the attrition of campaign cohort nets at baseline, 12-, 24- and 36-month rounds. Of the 360 cohort nets in Nanumba South and 295 in Zabzugu enrolled at baseline, 327 and 251 nets respectively were included in the attrition calculation at the 36-month round. Excluded nets either belonged to households that were not interviewed (nobody was home or had refused), were not assessed due to inaccessibility within the house, or were said during this round to be with family elsewhere and thus their actual status could not be ascertained. Tagged nets that are reported as with family elsewhere are kept in the study cohort until the endline round in case they reappear in the household. Campaign cohort nets that were given to family elsewhere before the baseline round were not tagged and are considered as given away to others.

In Nanumba South, total campaign ITN attrition increased from 8% at baseline to 70% at 36-months (Table 15, Figure 7). In Zabzugu, total campaign attrition increased from 4% to 42% in the same time frame. At 36-months, attrition was higher in Nanumba South than in Zabzugu ($p<0.001$). During the baseline and 12-month surveys, the most common reason for attrition was given away to others for both Nanumba South (7% at baseline and 11% at 12 months) and Zabzugu (2% at baseline and 9% at 12 months). This changed during the 24- and 36-month surveys where discarded ITNs (also known as attrition due to wear and tear) accounted for the majority of total campaign attrition (19% at 24 months and 27% at 36-months in both districts combined). Prior to baseline data collection, 15 nets (11 in Nanumba South and four in Zabzugu) were reportedly used by family elsewhere and were classified as given away to others.

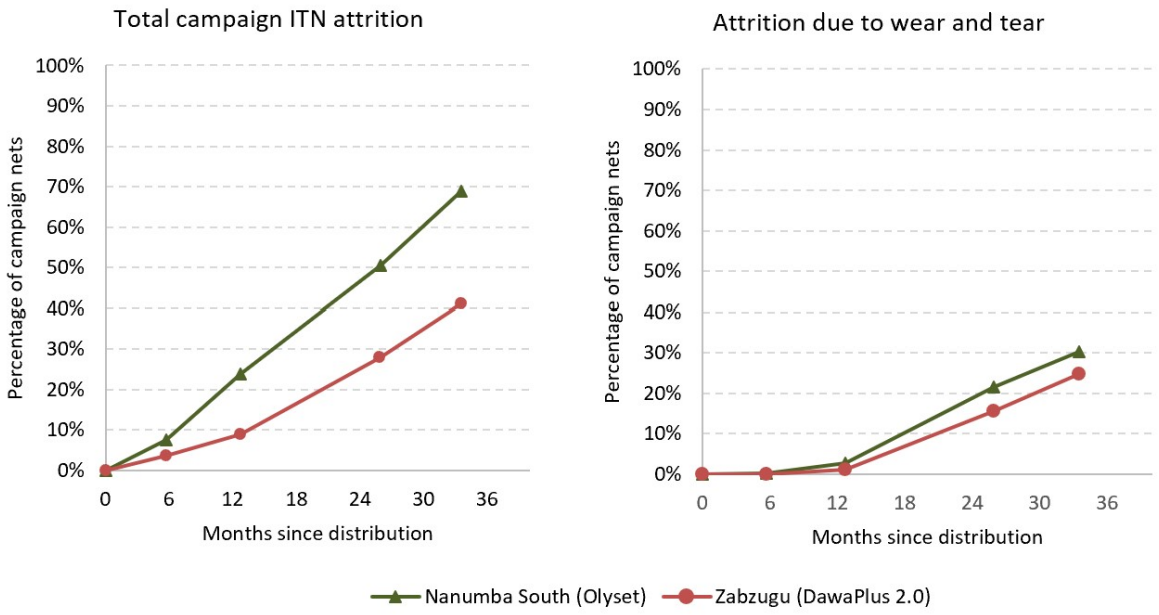
TABLE 15: CAMPAIGN COHORT ITN ATTRITION

	Baseline	12 months	24 months	36 months
Nanumba South	**N=360**	**N=327**	**N=322**	**N=327**
Total campaign ITN attrition	7.5%	23.9%	50.6%	69.8%
ITNs given away to others	7.2%	11.0%	14.6%	22.5%
ITNs discarded	0.3%	2.8%	21.4%	29.3%
ITNs lost for other/unknown reason	0.0%	10.1%	14.6%	18.0%
Zabzugu	**N=295**	**N=256**	**N=251**	**N=251**
Total campaign ITN attrition	3.7%	9.0%	28.3%	42.0%
ITNs given away to others	2.4%	4.7%	8.8%	12.5%

	Baseline	12 months	24 months	36 months
ITNs discarded	0.0%	1.2%	15.5%	24.3%
ITNs lost for other/unknown reason	1.4%	3.1%	4.0%	5.1%

Given away to others includes nets that were stolen, given to non-household members and nets that were recorded as being with family members elsewhere at baseline (e.g., at school).
Discarded (also known as attrition due to wear and tear) includes nets that were destroyed, thrown away, or used for other purposes

FIGURE 7: TRENDS IN TOTAL ATTRITION AND ATTRITION DUE TO WEAR AND TEAR (DISCARDED NETS)



Measuring the second component of ITN durability, physical integrity, is a primary study objective. Data from the ITN hole assessment was transformed into the proportionate Hole Index (pHI) for each ITN using standard weights defined by WHO:

$$pHI = Number\ of\ size\ 1\ holes + (No.\ of\ size\ 2\ holes \times 23) + (No.\ of\ size\ 3\ holes \times 196) + (No.\ of\ size\ 4\ holes \times 576)$$

Based on the pHI value, ITNs were categorized as "good", "serviceable" or "torn" as defined below. Note that "good" is a subset of all "serviceable" ITNs.

Good: pHI ≤ 64 (corresponding to a total hole surface area ≤ 0.01m²)

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

Torn: pHI > 642 (total hole surface area > 0.1m²)

Table 16 reports the physical integrity results of nets that were in the household from baseline to 36-months (nets that were in the household but were temporarily unavailable due to being washed or were locked away were not included in the assessment). In Nanumba South, the proportion of cohort nets with any holes increased from 18% at baseline to 62% at 36-months and in Zabzugu it increased from 17% to 78%. During the first three rounds, a slightly higher proportion of nets in Nanumba South were classified as too torn

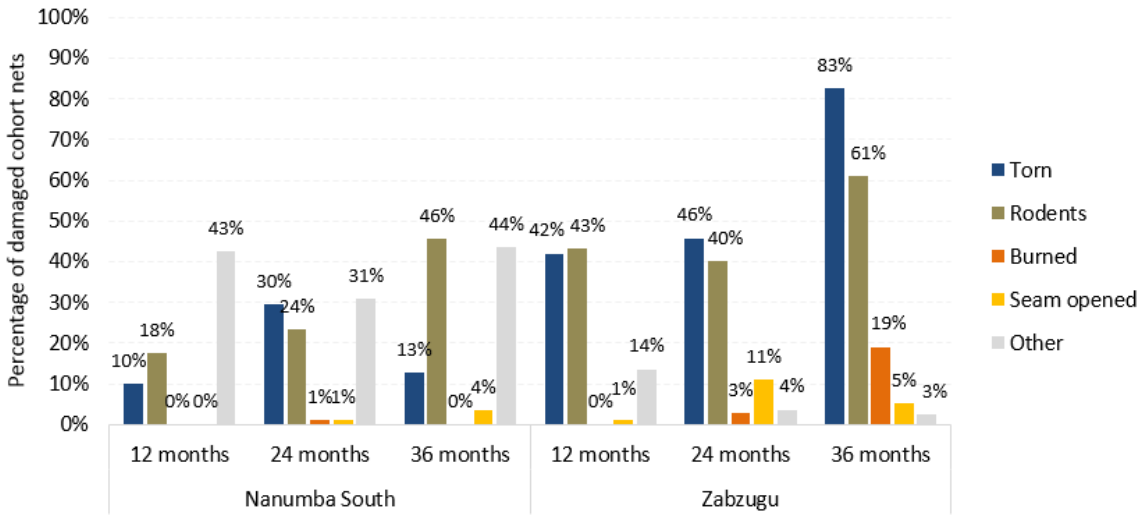
compared to Zabzugu, however, at 36-months the proportions were similar (27% in Nanumba South, 28% in Zabzugu). At endline the median pHI was comparable between districts, although pHI was substantially larger in Nanumba South during earlier surveys.

TABLE 16: PHYSICAL INTEGRITY OF OBSERVED CAMPAIGN COHORT ITNS

	Baseline	12 months	24 months	36 months
Nanumba South	**N=333**	**N=245**	**N=150**	**N=101**
Cohort ITN with any holes	18.0%	44.5%	66.0%	62.4%
ITNs classified as "Good"	93.4%	74.3%	56.0%	55.4%
ITNs classified as "Too torn"	2.1%	10.2%	30.7%	26.7%
ITNs classified as "Serviceable"	97.9%	89.8%	69.3%	73.3%
Among ITNs with any holes:	N=60	N=109	N=99	N=63
Median pHI for ITNs with any holes	47.0	102.0	306.0	273.0
Zabzugu	**N=284**	**N=233**	**N=177**	**N=147**
Cohort ITN with any holes	17.3%	47.2%	69.5%	77.6%
ITNs classified as "Good"	93.3%	82.8%	56.5%	48.3%
ITNs classified as "Too torn"	1.4%	3.9%	19.2%	27.9%
ITNs classified as "Serviceable"	98.6%	96.1%	80.8%	72.1%
Among ITNs with any holes:	N=49	N=110	N=123	N=114
Median pHI for ITNs with any holes	33.0	28.0	139.0	317.0

To understand the ways in which nets were damaged in real-life conditions, prior to the hole assessment respondents were asked what causes the holes in their nets. The responses are captured in Figure 8 (baseline figures are not presented because the low number of nets with any holes are not directly comparable to those during follow-up rounds). The most common reported damage mechanisms in Zabzugu across survey rounds were tearing on an object and damage by rodents (83% and 61% respectively at 36-months). In Nanumba South, damage from tears and rodents were less frequently reported compared to Zabzugu, however, along with "other", they accounted for nearly all reported damage mechanisms. Damage mechanisms in the "other" category include damage by children, insects, washing, and general material deterioration.

FIGURE 8: TYPES OF DAMAGE MECHANISMS REPORTED FOR DAMAGED CAMPAIGN ITNS



ITN survivorship combines the two aspects of durability (attrition and physical integrity) and is defined as the proportion of campaign ITNs originally received that are still in the possession of the household and in serviceable condition. As with attrition and physical integrity, cohort nets that were said to be used by family elsewhere (e.g., taken to school) were not included in these calculations. Additionally, nets ever given away or lost for other or unknown reasons are not included.

Table 17 reports the proportion of cohort ITNs surviving and in serviceable condition from baseline to 36-months. At baseline and 12 months, the proportion of all cohort nets that had survived were similar in Nanumba South and Zabzugu. However, at the 24-month round only 48% of nets had survived in Nanumba South compared to 66% in Zabzugu (p=0.031). At the 36-month round, the proportion of surviving cohort nets was still higher in Zabzugu (51% versus 38% in Nanumba South), however, the difference was not statistically significant. These differences reflect the previous findings that attrition was higher in Nanumba South compared to Zabzugu. The proportion of surviving cohort nets ever-used and present was similar in Nanumba South (71%) and Zabzugu (71%) at the 36-month endline survey.

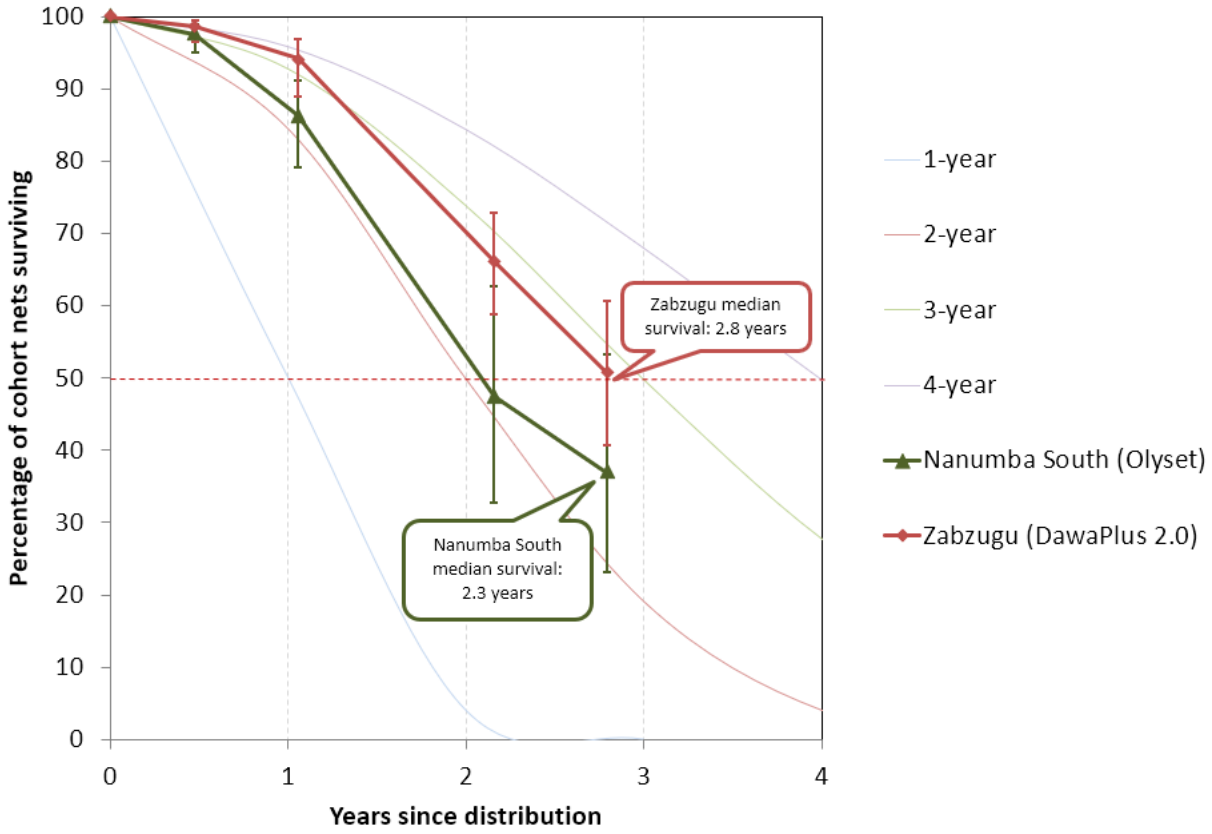
TABLE 17: CAMPAIGN COHORT ITNS SURVIVING IN SERVICEABLE CONDITION

	Baseline	12 months	24 months	36 months
Nanumba South				
All cohort nets*	N=334	N=255	N=219	N=200
Survival estimate	97.6%	85.9%	47.5%	37.5%
95% CI	95.0%-98.9%	78.4%-91.2%	32.7%-62.7%	23.7%-53.7%
Cohort nets ever-used	N=137	N=181	N=120	N=86
Survival estimate	94.9%	85.6%	62.5%	70.9%
95% CI	89.7%-97.5%	78.9%-90.5%	48.6%-74.6%	58.9%-80.6%
Zabzugu				
All cohort nets*	N=284	N=236	N=216	N=209
Survival estimate	98.6%	94.1%	66.2%	50.7%
95% CI	96.5%-99.4%	88.9%-96.9%	58.8%-72.9%	40.7%-60.7%
Cohort nets ever-used	N=158	N=183	N=166	N=106
Survival estimate	97.5%	94.0%	79.5%	70.8%
95% CI	94.0%-99.0%	88.1%-97.1%	71.9%-85.5%	58.5%-80.6%

* Among ITNs that are still in the possession of the household or discarded due to wear and tear in a previous survey round.

Figure 9 plots the proportion of nets surviving in serviceable condition against hypothetical survival curves for nets lasting one to four years using the survival data from baseline 12-, 24-, and 36-month follow up rounds. The median survival can be estimated as the relative position of the data point on a horizontal line between the two adjacent median survival curves. Using this method, the estimated median useful life for Olyset nets (in Nanumba South) is 2.1 years and for DawaPlus 2.0 (in Zabzugu) is 2.8 years.

FIGURE 9: ESTIMATED ITN SURVIVAL



Error bars show 95% confidence intervals.

Table 18 displays estimated median survival times using the most recent two data points as another method to calculate the survival estimate. Using this method, the estimated median useful life for Olyset 2.0 is 2.3 years and DawaPlus 2.0 is 2.8 years.

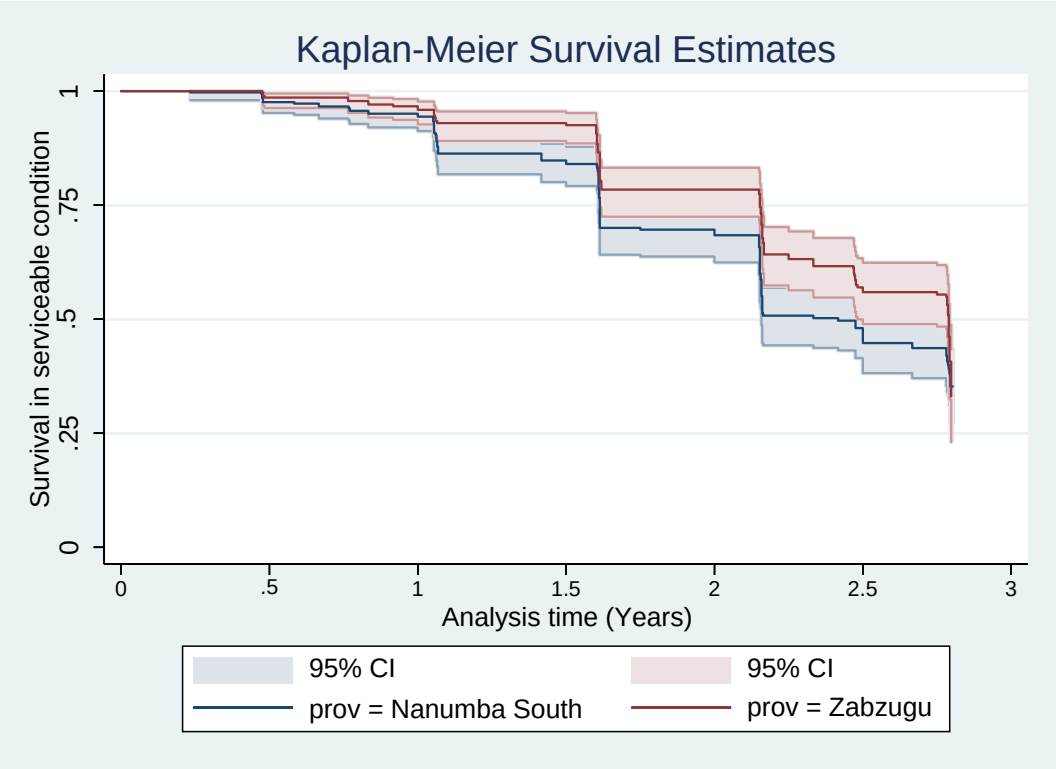
TABLE 18: ESTIMATED MEDIAN SURVIVAL OF ITNS IN YEARS USING DIFFERENT METHODS

	12 months	24 months	36 months
Nanumba South (Olyset)	**N=255**	**N=219**	**N=200**
Estimated from Figure 9	2.2	2.1	2.3
Calculated from last two data points* (95% CI)	-	-	2.3 (2.0-2.9)
Zabzugu (DawaPlus 2.0)	**N=236**	**N=216**	**N=209**
Estimated from Figure 9	3.8	2.8	2.8
Calculated from last two data points (95% CI)	-	-	2.8 (2.5-3.3)

* To calculate median life of Olyset, the 12- and 36-month data points were used to prevent underestimation of median life that would result from using two data points below 50% survival.

When data were analyzed as survival analysis in a Kaplan-Meier plot (Figure 10), Olyset ITNs in Nanumba South, overall, showed a trend of lower survival compared to DawaPlus 2.0 ITNs in Zabzugu, although the difference was not statistically significant (p=0.1485).

FIGURE 10: KAPLAN-MEIER CURVES OF PHYSICAL SURVIVAL WITH 95% CONFIDENCE INTERVALS



3.5 INSECTICIDAL EFFECTIVENESS AND CONTENT OF CAMPAIGN NETS

The outcomes of insecticidal effectiveness were based on bioassay results using the standard WHO cone test, where the 60-minute knock-down (KD60) and the 24-hour mortality rate (functional mortality) were measured. The two variables from these tests were combined into the following outcome measures:

Optimal effectiveness: KD60 ≥ 95% or mortality ≥ 80%

Minimal effectiveness: KD60 ≥ 75% or mortality ≥ 50%

Chemical content analysis was conducted by CDC on samples taken from the bioassay ITNs. Chemical content results are presented as summary statistics for active ingredients in mg/m² units.

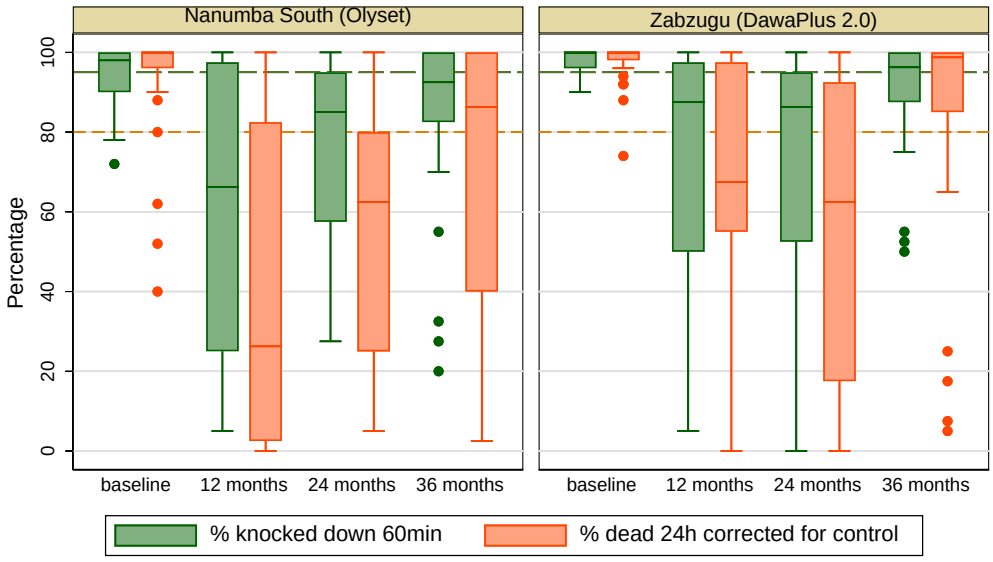
Bioassay results are shown in Table 19 and Figure 11. At 36-months, mean KD60 was similar in both study sites (84% in Nanumba South and 90% in Zabzugu) however mean mortality was slightly higher in Zabzugu (83%) compared to Nanumba South (70%). At 36-months, a higher proportion of DawaPlus 2.0 nets in Zabzugu (80%) were found to be optimally effective than Olyset nets in Nanumba South (63%), however, this difference was not statistically significant and the proportion of nets between study sites that were minimally effective was similar. In both study sites, the largest declines in effectiveness occurred between baseline and 12-months. During this period the proportion of nets considered optimally effective dropped by approximately 50% in both study sites, and the proportion of nets considered optimally and minimally effective decreased by 47% in Nanumba South and 20% in Zabzugu. Between the 24- and 36-month surveys, the proportion of nets considered optimally and minimally effective increased in both study sites. Improved effectiveness in the

bioassay net samples between 24- and 36-months may have resulted if sampled nets were recently unpacked and hung to replace previous nets that were discarded or given away.

TABLE 19: CONE BIOASSAY RESULTS

	Baseline	12 months	24 months	36 months
Nanumba South (Olyset)	**N=30**	**N=30**	**N=30**	**N=30**
Knock down 60 minutes				
Mean (95% CI)	94.9 (91.7-98.2)	59.7 (44.9-74.5)	77.3 (68.7-86.0)	84.1 (75.4-92.8)
Median [IQR]	98.0 [90.0-100.0]	66.3 [25.0-97.5]	85.0 [57.5-95.0]	92.5 [82.5-100.0]
Mortality 24 hours				
Mean (95% CI)	92.7 (86.9-98.6)	41.0 (22.8-59.2)	55.2 (41.9-68.4)	70.3 (56.7-84.0)
Median [IQR]	100.0 [96.0-100.0]	26.3 [2.5-82.5]	62.5 [25.0-80.0]	86.3 [40.0-100.0]
Optimal effectiveness				
Estimate (95% CI)	90.0% (72.7-96.8)	43.3% (25.6-63.0)	40.0% (21.8-61.4)	63.3% (41.0-81.1)
Minimal effectiveness				
Estimate (95% CI)	96.7% (77.7-99.6)	50.0% (29.0-71.0)	73.3% (50.8-88.0)	90.0% (72.7-96.8)
Zabzugu (DawaPlus 2.0)	**N=30**	**N=30**	**N=30**	**N=30**
Knock down 60 minutes				
Mean (95% CI)	97.9 (97.0-98.8)	73.5 (61.8-85.2)	70.2 (55.7-84.7)	89.8 (82.7-97.0)
Median [IQR]	100.0 [96.0-100.0]	87.5 [50.0-97.5]	86.3 [52.5-95.0]	96.3 [87.5-100.0]
Mortality 24 hours				
Mean (95% CI)	97.4 (95.4-99.4)	66.0 (51.4-80.6)	55.9 (37.6-74.2)	83.4 (71.7-95.1)
Median [IQR]	100.0 [98.0-100.0]	67.5 [55.0-97.5]	62.5 [17.5-92.5]	98.8 [85.0-100.0]
Optimal effectiveness				
Estimate (95% CI)	100.0% (--)	46.7% (29.3-64.9)	43.3% (23.8-65.2)	80.0% (58.4-91.9)
Minimal effectiveness				
Estimate (95% CI)	100.0% (--)	80.0% (58.4-91.9)	76.7% (56.1-89.4)	93.3% (75.8-98.4)

FIGURE 11: BOX PLOT OF ITN CONE BIOASSAY RESULTS



Results from WHO cone bioassays: the box plot shows the median (line), interquartile range (box), adjacent values (whiskers) and outliers (circles), lines represent WHO optimal effectiveness thresholds for knock-down (kd60, 95%) and mortality (mortality, 80%).

In addition to testing for insecticidal effectiveness, the nets collected during the 12-, 24- and 36-month follow-up periods were sent to CDC for chemical content testing. Chemical content results are presented in Table 20.

Olyset (distributed in Nanumba South) is manufactured with 1000 mg/m² of permethrin, while DawaPlus 2.0 (in Zabzugu) is manufactured with 80 mg/m² of deltamethrin. At 36-months, the mean permethrin chemical content of Olyset net samples was 572 mg/m² with a median value of 583 mg/m². The mean permethrin content of Olyset at 12-, 24- and 36-months corresponded to a 37%, 36% and 43% loss respectively compared to the original target dose. For DawaPlus 2.0 net samples at 36-months, the mean deltamethrin chemical content was 21 mg/m² with a median value of 10 mg/m². The mean deltamethrin content of DawaPlus 2.0 at 12-, 24- and 36-months corresponded to a 62%, 74% and 74% loss respectively compared to the original target dose.

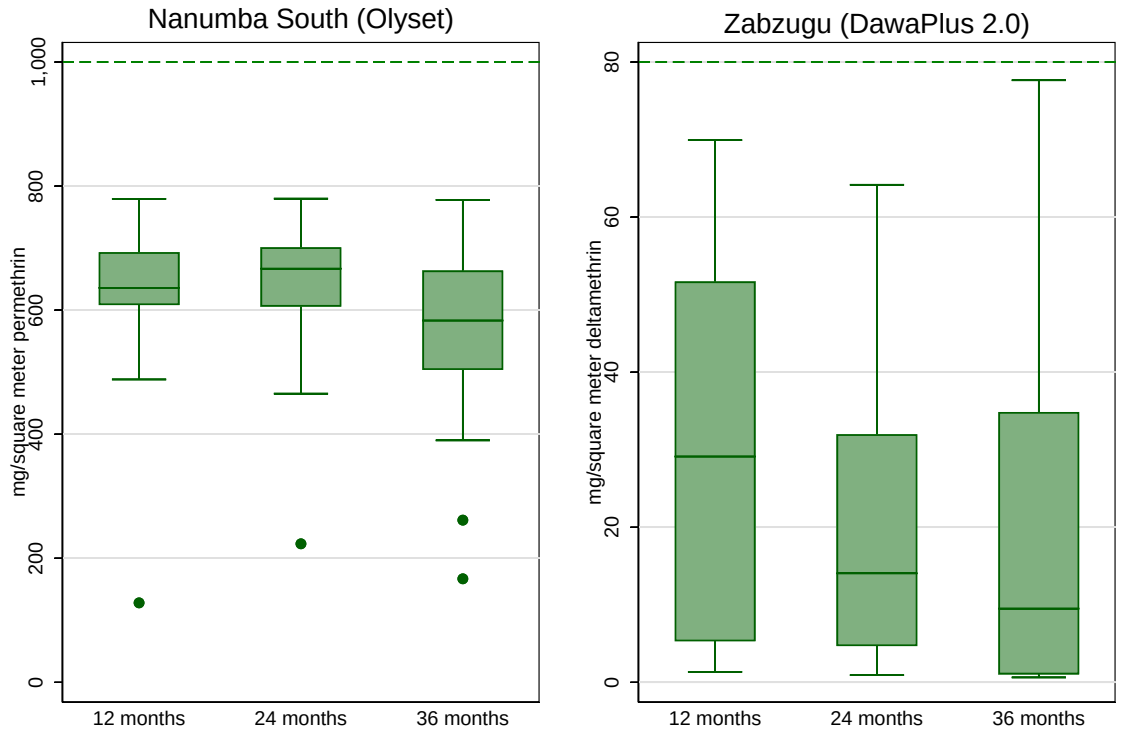
TABLE 20: CHEMICAL CONTENT RESULTS

	12 months	24 months	36 months
Nanumba South (Olyset, permethrin, 1000mg/m2)	**N=30**	**N=30**	**N=30**
Mean (95% CI)	628.64 (584.02-673.25)	640.47 (600.53-680.40)	572.42 (513.28-631.55)
Median [IQR]	635.8 [608.0-693.4]	666.7 [605.5-701.3]	583.2 [503.5-663.9]
Zabzugu (DawaPlus 2.0, deltamethrin, 80mg/m2)	**N=30**	**N=30**	**N=30**
Mean (95% CI)	30.07 (20.96-39.18)	20.49 (13.06-27.92)	21.26 (9.67-32.84)
Median [IQR]	29.1 [5.3-51.7]	14.1 [4.7-32.0]	9.5 [1.0-34.9]

Figure 12 presents box plots of the chemical content results in both districts at 12-, 24- and 36-months. Consistent with the findings on insecticidal effectiveness, the chemical content for all tested nets was

significantly below manufacturer-stated levels, but nets varied significantly as to their level of insecticide, particularly for DawaPlus 2.0 nets in Zabzugu.

FIGURE 12: BOX PLOT OF ITN CHEMICAL CONTENT RESULTS



Results from chemical content analysis: box plot shows the median (horizontal line), interquartile range (box), adjacent values (whiskers) and outliers (circles), lines represent manufactured target dose of insecticide.

Tables 21-23 present details of reported handling and use for the ITNs undergoing bioassay analysis for each survey period. At 36-months, the proportion of net users (adults only, children only, combination), sleeping places (bed, mattress, mat/ground), and washing agents (detergent/bleach, soap, combination) in Nanumba South and Zabzugu were similar for bioassay and cohort nets. However, in both Nanumba South and Zabzugu, nets sampled for bioassay were more commonly found hanging and tied up (58%) and used the previous night (77%) compared to nets not sampled for bioassay. There were minor differences in sleeping place, net users, and drying location (sun vs. shade) for bioassay nets in Nanumba South and Zabzugu, however, these differences were not statistically significant.

TABLE 21: HANDLING OF BIOASSAY TEST ITNS

	Baseline	12 months	24 months	36 months
Nanumba South	**N=30**	**N=30**	**N=30**	**N=30**
Location found				
Hanging and folded or tied	36.7%	60.0%	60.0%	56.7%
Hanging loose	46.7%	16.7%	30.0%	10.0%
Not hanging	16.7%	16.7%	10.0%	30.0%
Stored unpacked	0.0%	6.7%	0.0%	3.3%
Stored in package	0.0%	0.0%	0.0%	0.0%

	Baseline	12 months	24 months	36 months
Type of sleeping space (if used)				
Bed	23.3%	16.7%	20.0%	17.2%
Mattress	20.0%	6.7%	16.7%	31.0%
Mat/Ground	56.7%	76.7%	63.3%	51.7%
Net users				
Child(ren) only	8.0%	6.7%	20.0%	4.0%
Child(ren) and adult(s)	36.0%	56.7%	43.3%	52.0%
Adult(s) only	56.0%	36.7%	30.0%	44.0%
Zabzugu	**N=30**	**N=30**	**N=30**	**N=30**
Location found				
Hanging and folded or tied	33.3%	43.3%	16.7%	60.0%
Hanging loose	63.3%	26.7%	56.7%	16.7%
Not hanging	3.3%	23.3%	23.3%	20.0%
Stored unpacked	0.0%	6.7%	3.3%	3.3%
Stored in package	0.0%	0.0%	0.0%	0.0%
Type of sleeping space (if used)				
Bed	6.9%	10.3%	13.3%	30.8%
Mattress	6.9%	27.6%	23.3%	0.0%
Mat/Ground	86.2%	62.1%	63.3%	69.2%
Net users				
Child(ren) only	8.0%	17.2%	3.3%	0.0%
Child(ren) and adult(s)	36.0%	41.4%	43.3%	72.7%
Adult(s) only	56.0%	41.4%	50.0%	27.3%

TABLE 22: REPORTED USE OF BIOASSAY TEST ITNS

	Baseline	12 months	24 months	36 months
Nanumba South	**N=30**	**N=30**	**N=30**	**N=30**
Used last night	76.7%	83.3%	93.3%	80.0%
Used last week				
Every night	63.3%	80.0%	83.3%	60.0%
Most nights (5-6 nights)	10.0%	10.0%	13.3%	20.0%
Some nights (1-4 nights)	26.7%	3.3%	3.3%	3.3%
Not used last week	0.0%	6.7%	0.0%	13.3%
Never used	0.0%	0.0%	0.0%	3.3%
Don't know	0.0%	0.0%	0.0%	0.0%
Seasonal use				
Equally in rainy and dry seasons	50.0%	53.3%	86.7%	76.7%
Mainly rainy season	46.7%	43.3%	13.3%	16.7%
Rainy season only	0.0%	3.3%	0.0%	6.7%
Not used	0.0%	0.0%	0.0%	0.0%
Don't know	3.3%	0.0%	0.0%	0.0%

	Baseline	12 months	24 months	36 months
Zabzugu	**N=30**	**N=30**	**N=30**	**N=30**
Used last night	90.0%	76.7%	70.0%	73.3%
Used last week				
Every night	96.7%	80.0%	73.3%	60.0%
Most nights (5-6 nights)	0.0%	3.3%	16.7%	13.3%
Some nights (1-4 nights)	0.0%	3.3%	3.3%	3.3%
Not used last week	3.3%	3.3%	6.7%	10.0%
Never used	0.0%	6.7%	0.0%	13.3%
Don't know	0.0%	3.3%	0.0%	0.0%
Seasonal use				
Equally in rainy and dry seasons	76.7%	90.0%	86.7%	60.0%
Mainly rainy season	20.0%	6.7%	10.0%	16.7%
Rainy season only	0.0%	0.0%	3.3%	23.3%
Not used	0.0%	3.3%	0.0%	0.0%
Don't know	3.3%	0.0%	0.0%	0.0%

TABLE 23: REPORTED WASHING OF BIOASSAY TEST ITNS

	Baseline	12 months	24 months	36 months
Nanumba South	**N=30**	**N=30**	**N=30**	**N=30**
Ever washed	70.0%	90.0%	96.7%	90.0%
Washes in the last 6 months among all nets (if known)				
Mean	1.43	2.75	3.04	6.14
Median	1.0	2.0	2.5	3.0
Washes in the last 6 months among washed nets				
Mean	2.05	2.96	3.16	6.88
Median	2.0	2.0	3.0	3.0
Soap used for last wash				
Soap bar	76.2%	85.2%	86.2%	73.3%
Detergent or bleach	23.8%	14.8%	10.3%	16.7%
Mix	0.0%	0.0%	3.4%	0.0%
None	0.0%	0.0%	0.0%	0.0%
Don't know	0.0%	0.0%	0.0%	10.0%
Where dried after last wash				
Shade	N/A	N/A	53.3%	77.8%
Sun	N/A	N/A	36.7%	22.2%
Don't know	N/A	N/A	10.0%	0.0%
Zabzugu	**N=30**	**N=30**	**N=30**	**N=30**
Ever washed	93.3%	86.7%	86.7%	96.7%
Washes in the last 6 months among all nets (if known)				
Mean	2.92	4.86	4.58	6.75

	Baseline	12 months	24 months	36 months
Median	2.0	3.0	3.0	3.0
Washes in the last 6 months among washed nets				
Mean	3.17	5.44	5.00	7.11
Median	2.0	3.0	3.0	3.0
Soap used for last wash				
Soap bar	92.9%	80.8%	70.4%	76.7%
Detergent or bleach	7.1%	11.5%	18.5%	20.0%
Mix	0.0%	3.8%	11.1%	0.0%
None	0.0%	3.8%	0.0%	0.0%
Don't know	0.0%	0.0%	0.0%	3.3%
Where dried after last wash				
Shade	N/A	N/A	46.7%	55.2%
Sun	N/A	N/A	43.3%	44.8%
Don't know	N/A	N/A	10.0%	0.0%

4. CONCLUSIONS

4.1 SUMMARY OF FINDINGS

This 36-month round of the Ghana durability monitoring study successfully visited 242 households across two districts, each having received different ITNs during the 2018 mass campaign: Olyset in Nanumba South and DawaPlus 2.0 in Zabzugu. At baseline, a total of 655 ITNs were recorded as having been distributed to cohort households (including those lost before the baseline round). At 36-months, only 250 ITNs from the 2018 campaign were still present in the households (102 in Nanumba South and 148 in Zabzugu).

Total cohort ITN attrition at endline was 70% in Nanumba South and 42% in Zabzugu. Wear and tear (discarded) and ITNs given away were the main causes of attrition in both study sites, with 29% and 24% of cohort ITNs being subject to attrition due to wear and tear in Nanumba South and Zabzugu respectively. Except for attrition for unknown reasons at baseline, levels of attrition by all three categories (wear and tear, given away, unknown reasons) were higher in Nanumba South than Zabzugu in all survey rounds.

A Kaplan-Meier plot of ITN survival confirms a trend of lower survival in Nanumba South compared to Zabzugu. This is driven by both higher levels of attrition and poorer physical integrity outcomes in Nanumba South at each survey round. Only attrition due to wear and tear is considered alongside physical integrity in the estimate of ITN survivorship: the proportion of cohort ITNs surviving in serviceable condition. At endline, 37% of Olyset ITNs in Nanumba South and 51% of DawaPlus 2.0 ITNs in Zabzugu had survived in serviceable condition, corresponding to an estimated median useful life of 2.3 years for Olyset and 2.8 years for DawaPlus 2.0. These differences are driven by higher levels of ITNs being discarded in Nanumba South, particularly at the 24-month (21% vs 16%) and 36-month rounds (29% vs 24%) and by poorer physical integrity results for Nanumba South, particularly recorded at the 24-month survey (31% Olyset ITNs classified as "too torn" compared with 19% of DawaPlus 2.0). It is unlikely that household risk factors, or net use and care practices contributed to differences in net survivorship as these factors were similar between study sites as was the physical integrity of nets. When risk factors did differ statistically between districts, the differences were usually favorable for net survivorship in Nanumba South (e.g., lower proportion of households cooking or storing food in sleeping room, higher proportion of nets used over beds/mattresses).

The 24- and 36-month results suggest a potential preference for non-cohort nets in Nanumba South. During the study period, ownership of non-cohort nets decreased in Zabzugu but increased and remained higher in Nanumba South. At 36-months, the proportion of households with any non-cohort nets in Nanumba South was statistically higher than in Zabzugu (61% versus 34%). In Nanumba South, the use of ITNs given access was similar for cohort ITNs (0.62) and other ITNs in the household (0.52). However, household members with access to ITNs in Zabzugu were more commonly using cohort ITNs (0.54) than other available nets (0.22). A preference for attributes of non-cohort nets, a dislike of polyethylene cohort nets, or a greater perception of physical damage, may help explain the higher proportion of cohort nets reported as given away to others or lost for unknown reasons in Nanumba South.

The 36-month bioassay results showed an overall improvement in cohort-net insecticidal effectiveness, similar to or better than results from the 12-month survey. Data captured on the handling and use of nets undergoing bioassays show no substantial differences in these factors across study rounds. Olyset nets sampled at 36-months in Nanumba South were less likely to have been hanging prior to being withdrawn and nets from both sites were subject to more frequent washing than those sampled for previous rounds, but the absolute differences of these measures between rounds was small. Chemical analysis results from 36-months show that

the loss of insecticide compared to the target dose was 43% among Olyset samples and 74% among DawaPlus 2.0 samples. Contrary to the bioassay results, which saw an improvement at 36-months, the mean and median chemical analysis results declined between 12- and 36-months for both ITN brands.

4.2 KEY CHALLENGES AND LESSONS LEARNED

The study encountered three main challenges throughout all four rounds of fieldwork: 1) The restriction of the household follow-up list to include only first names posed some challenges with community guides; 2) teams needed to negotiate the cultural context when deploying COVID-19 adaptations; and 3) difficulty managing cohort nets all at once during the net assessments.

During data collection, field teams work with community guides to identify study households using the household follow-up list and GPS coordinates. Because the household list only includes first names, there was confusion among the community guides, as many individuals have the same first name. While GPS mapping software is available for the teams to use, it is sometimes difficult to take advantage of this when community guides are provided and keen to work with the printed household list. For future studies, first and last names of participants should be collected to maximize the support provided by community guides, with current considerations for data confidentiality and security maintained.

Before the start of the 24-month round the COVID-19 pandemic spread throughout Ghana and the rest of the world causing data collection to occur two months later than originally planned. To ensure no further delays to data collection, VectorLink implemented several COVID-19 mitigation measures to protect the data collection teams and the study communities. One of these adaptations required fieldworkers not to touch anything that will return to the household (except for cohort nets, which were handled while wearing gloves). This included declining to sit if offered a chair. In many communities this was seen as a lack of respect for the household. To avoid offending the study communities, data collectors were advised to accept a seat if offered, but to sanitize the seat with alcohol-based sanitizers before and after sitting. This practice should be implemented in all countries where COVID-19 mitigation measures are still in place.

A final challenge encountered during fieldwork occurred when household members brought all ITNs outside after the field team arrived. This created challenges for data collection as details about specific nets (such as who slept under a given net last night and net washing information) could be difficult to accurately recall when similar-looking ITNs are no longer in their usual hanging places. The behavior was caused in part by local community guides moving ahead of the teams to confirm the location of the next target household, which lead to household members collecting nets in time for the field team's arrival. This challenge was identified and addressed early during data collection through discussions and careful management of community guides. In future durability monitoring studies, teams should anticipate this action (from both community guides and households) and ask household members to leave ITNs in place until they are requested later in the interview.