THE PMI VECTORLINK KENYA 2017 ITN DURABILITY MONITORING 36-MONTH FOLLOW-UP STUDY REPORT

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ACRONYMS

CDC	Centers for Disease Control and Prevention
CHW	Community Health Worker
DHS	Demographic and Health Survey
DNMP	Department of National Malaria Program
HH	Household
IPC	Interpersonal Communication
IQR	Interquartile Range
ITN	Insecticide-treated Net
KD60	60-minute knock-down rate
KEMRI	Kenya Medical Research Institute
MIS	Malaria Indicator Survey
NMCP	National Malaria Control Program
PAMCA	Pan African Mosquito Control Association
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 the *average useful life* of an ITN, is increasingly recognized as one of 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, and PMI has supported the development of standard guidance for monitoring ITN durability based on WHO guidelines.[1]

In Kenya, the U.S. President's Malaria Initiative (PMI) is supporting ITN durability monitoring of DawaPlus 2.0 ITNs distributed in Busia County and DuraNet ITNs distributed in Kwale County during November and December of the 2017 mass campaign. Baseline data collection was conducted from April 29 – May 15, 2018, five 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 from November 16 – December 3, 2018, the 24-month survey was carried out from November 8 – 26, 2019 and the 36-month end line survey was carried out from November 6 – 23, 2020. During each of these rounds, all 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 on bushes etc.) as well as knowledge and attitudes regarding nets and net care and repair. The survey also collected information on household bed nets obtained outside of the 2018 campaign. Two cohort ITNs from each cluster were further sampled for bio-effectiveness and chemical content analysis. Cone bioassays are being performed by VectorLink Kenya at the Kenya Medical Research Institute (KEMRI) Centre for Global Health Research in Kisumu; chemical content analysis is being performed by the Centers for Disease Control and Prevention (CDC) Atlanta on samples from the ITNs undergoing cone bioassays.

Household and ITN Follow-Up

A total of 190 out of 202 eligible households were interviewed for the 36-month follow-up survey. Of these, 153 still had one or more cohort nets while no cohort nets remained in 37 households. Of the households not interviewed, 5 had no eligible respondent available for interview and 7 had moved out of the study area. In total, 229 cohort nets were still in the house and 32 were with family elsewhere. Of the nets not in households, 780were discarded and 25 given away or stolen. Since the baseline round, 551 out of 874 (63.0%) nets had been lost.

Durability Risk Factors

Durability risk factors like storing food and cooking near sleeping places, rodents, sleeping on mats or the ground, and tying/folding up hanging nets were similar across both counties. In general, most households reported never sleeping in a room used for cooking (79.2% in Busia and 59.0% in Kwale), although an average of 73.5% reported having ever stored food in the room used for sleeping. More than 60% of respondents reported observing rodents in the last six months. In terms of sleeping place, more than 90% of nets were used over beds. In Kwale, the median number of net washes in the six months prior to the survey was 5.0, and household members were more likely to use detergent or bleach to wash the nets in Kwale (51.9%) compared to Busia (13.3%). In terms of exposure to net and malaria messaging, in both study sites, the exposure to any information decreased between the 24-month and 36-month rounds. Among those exposed, "interpersonal communication" was the principal source of information. "Use nets every night" was the most recalled message

[1] www.durabilitymonitoring.org

(90.9%) followed by "care for net" (72.0%). Respondents in Busia showed a favorable attitude to nets (mean score 1.22) and to net care and repair practices (mean score 1.16). In Kwale, net attitudes were favorable (mean score 1.24) and net care and repair attitudes were slightly less than favorable (mean score 0.99). Among households that experienced holes in their nets, only 55.7% in Busia and 46.3% in Kwale had ever repaired them.

ITN Ownership and Use

The proportion of present cohort nets that had ever been used increased from 49.9% at baseline to 93.9% at 36-months in Busia and from 41.1% at baseline to 87.1% at 36-months in Kwale; 85.3% and 80.6% (respectively) were used the night prior to the survey. Household ownership of one or more non-cohort nets was similar in both sites (61.7% in Busia and 59.0% in Kwale). According to the respondents, 90.5% of non-cohort nets in Busia and 92.6% of non-cohort nets in Kwale had been used at some point. Both cohort and non-cohort nets were most commonly used by adults only (defined for this study as individuals over the age of 10 years).

ITN Survivorship (Attrition and Physical Integrity)

In Busia, total cohort ITN attrition was 67.6% at the 36-month follow-up period, with the most common reason being given away to others (28.0%), followed by being discarded (also known as attrition due to wear and tear; 26.7%) and for unknown reasons (12.9%). In Kwale, total attrition was 77.6% at 36 months with slightly more nets being discarded (37.2%) as opposed to given away to others (31.6%). Of the cohort nets in the household, 84.4% in Busia and 74.7% in Kwale had any holes, and the percentage of nets in serviceable condition was 68.0% and 66.7%, respectively. Cohort net survival (nets present in the household and in serviceable condition, out of all cohort nets either in the household or previously discarded) was estimated to be 37.0% in Busia (DawaPlus 2.0) and 24.8% in Kwale (DuraNet), with estimated median survival time of 2.4 years and 2.0 years, respectively.

Insecticidal Effectiveness

Thirty campaign nets were collected in each study site from cohort households. Cone bioassays were conducted by VectorLink and chemical content analysis was performed by CDC. At endline, DuraNet nets in Kwale appeared to have higher optimal effectiveness (13%) than the DawaPlus 2.0 nets in Busia (0%). Minimal effectiveness was also higher for DuraNet nets in Kwale (37%) than DawaPlus 2.0 nets in Busia (3%). Chemical content results show a mean deltamethrin content of 7.8 mg/m^2 in Busia, corresponding to a 90% loss compared to the original dose. In Kwale, results show a mean alpha-cypermethrin content of 90.5 mg/m^2, corresponding to a 65% loss compared to the original target dose.

A summary of key results from all four rounds of data collection is presented below.

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

Site	Survey 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	
Busia County (DawaPlus 2.0)	Baseline: 5.3	0.5	97.8 (N=359)	44.5	71.8	96.7
	12m: 12.3	2.4	88.3 (N=274)	65.4	55.8	23.3
	24m: 24.0	17.7	81.8 (N=165)	65.6	68.9	82.8
	36m: 35.6	26.2	68.0 (N=128)	84.5	81.0	0.0
Kwale County (DuraNet)	Baseline: 4.7	0.9	98.1 (N=370)	37.3	89.6	100.0
	12m: 10.9	7.1	86.4 (N=257)	49.5	82.5	96.7
	24m: 22.7	27.9	74.8 (N=131)	57.5	77.1	100.0
	36m: 34.9	37.0	66.7 (N=87)	80.7	90.4	13.3

Conclusion

At the 36-month follow-up period, survivorship of DuraNet ITNs in Kwale (median survival: 2.0 years) was lower than DawaPlus 2.0 nets in Busia (median survival: 2.4 years), both because of attrition due to wear and tear and lower physical integrity. In addition, ITNs were given away at a higher rate in Kwale. Estimated median survival for ITNs in both sites was lower than the assumed 3 years.

1. BACKGROUND

The proportion of households owning at least one insecticide treated net (ITN) has increased slightly in Kenya in recent years, from 58% (2008-09 DHS) to 65% (2015 MIS) in urban zones and from 55% to 63% in rural areas during the same period. 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 2015 this figure was 54% in urban zones and 52% in rural zones. This falls short of the country's aim to achieve universal coverage of ITNs. However, data suggest that most Kenyans who have access to ITNs will use them. 49% of the population in urban areas and 47% 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 0.81 in Central region to 1.02 in North-Eastern (a ratio above 0.80 is considered "good").[2]

The importance of ITN field durability and the *average useful life* of an ITN is increasingly recognized as one of the critical factors 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 Kenya, PMI is supporting durability monitoring of ITNs distributed during the 2017 mass campaign in Busia and Kwale Counties. These sites were selected purposively in coordination with the Division of National Malaria Program (DNMP, formerly known as the National Malaria Control Program [NMCP]) to assess durability in different climates and socio-cultural environments. DawaPlus 2.0, distributed in Busia County, is a polyester ITN and was pre-qualified by WHO in March 2018. DuraNet, distributed within Kwale County, is a polyethylene ITN that received a full recommendation by World Health Organization Pesticide Evaluation Scheme (WHOPES) in July 2013 and was pre-qualified by World Health Organization (WHO) in December 2017.[4]

This study provides the DNMP, 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 for Kenya was designed to:

[2] Koenker H, Ricotta E, Olapeju B, Choiriyyah I. April 2019. Insecticide-Treated Nets (ITN) Access and Use Report. Baltimore, MD. PMI | VectorWorks Project, Johns Hopkins Center for Communication Programs.

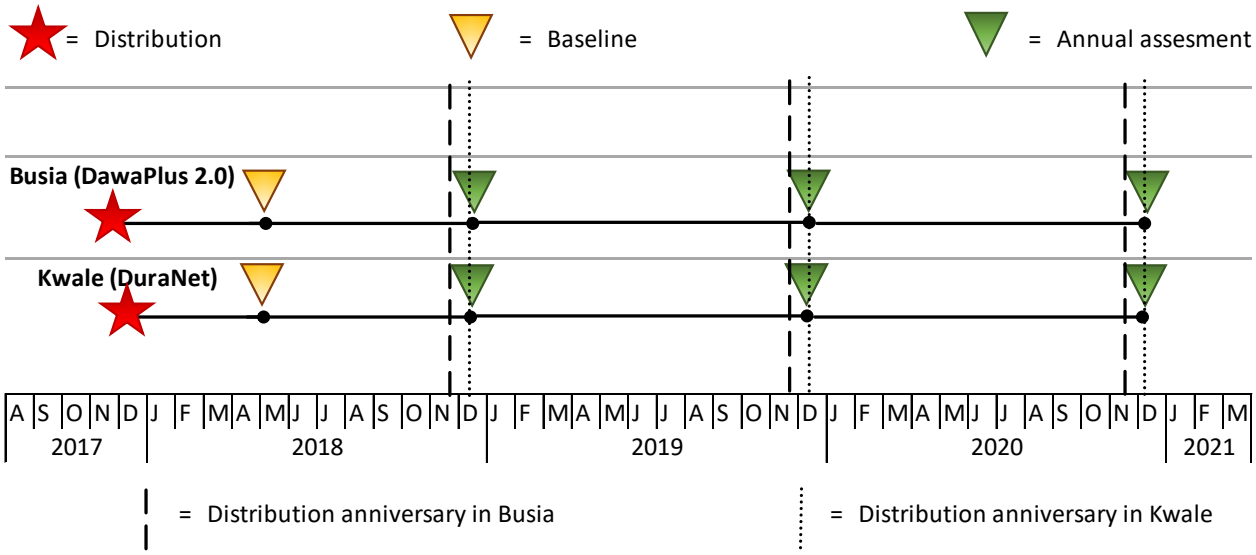
[3] www.durabilitymonitoring.org

[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 DuraNet, a 145-denier polyethylene ITN incorporating alphacypermethrin (260 mg/m^2) in two locations (Busia and Kwale Counties) 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 from April 29 – May 15, 2018, under the management of the PMI VectorWorks Project. Data collection for the 12-month follow-up round was conducted from November 16 – December 3, 2018, also under the PMI VectorWorks Project. As VectorWorks closed in September 2019, management of the study transitioned to PMI VectorLink in early 2019. Data collection for the 24-month follow-up round was conducted from November 8 – 26, 2019. Data collection for the end line 36-month round was conducted from November 6 – 23, 2020.

FIGURE 1: DURABILITY MONITORING TIMELINE

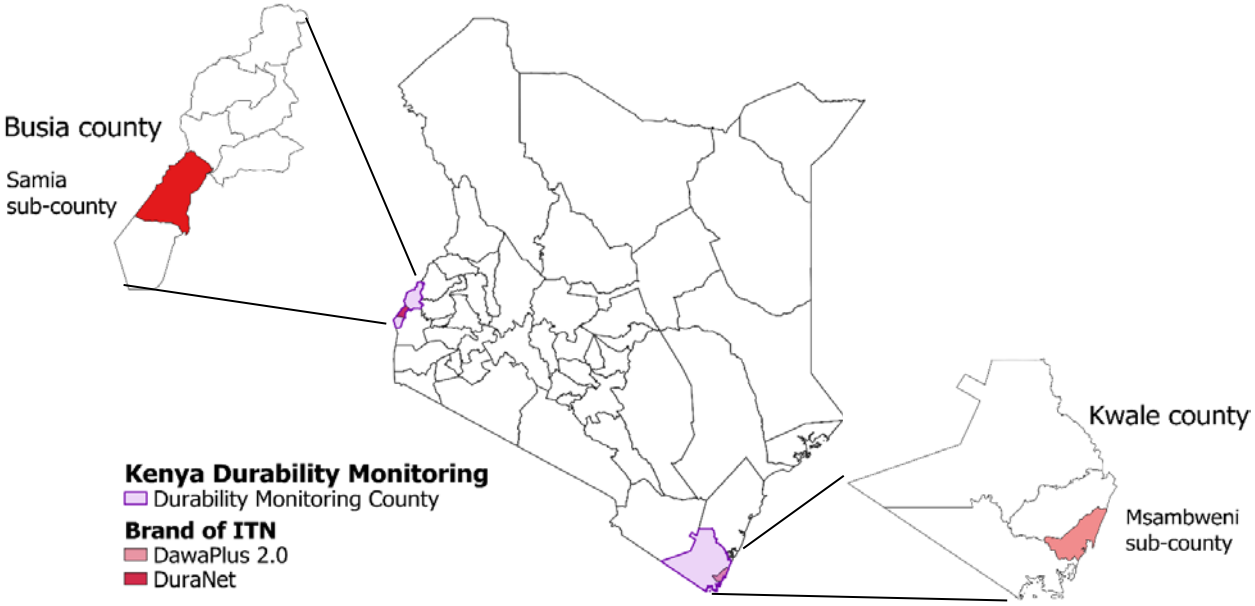


2. METHODS

2.1 STUDY SITES

Study sites were selected purposively in coordination with the DNMP and PMI to assess durability in different climates and socio-cultural environments. Samia sub-county in Busia County, and Msambweni sub-county in Kwale County were identified as study sites (Figure 2).

FIGURE 2: STUDY SITE MAP



Although these regions represent different climates and socio-cultural contexts, both sites are predominantly rural, agricultural areas and have a shoreline with some fishing activity. ITN coverage in the regions in which the study sites are located is reported in Table 2, based on secondary analysis of the 2015 Kenya Malaria Indicator Survey (MIS), reported in the ITN Access and Use Report 2019.

TABLE 2: KEY MALARIA CHARACTERISTICS IN STUDY SITES

Study site (Region containing each county)	Proportion of households (HH) or population			
	HH with at least one ITN	Population with access to an ITN in their household	Population using ITN the night before survey	Use/Access Ratio
Busia (Western)	79%	57%	55%	0.98
Kwale (Coast)	72%	58%	57%	1.00

Source: ITN Access and Use Report 2019.
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 use to population access.

2.2 ITN BRANDS MONITORED

The study protocol originally intended to assess one brand of ITN (DuraNet) in two sites exhibiting different environmental and cultural characteristics. During baseline field work, it was discovered that DawaPlus 2.0 ITNs had been distributed in Samia sub-county, Busia, and that the behaviors and characteristics of the study populations at the two sites were not significantly different. This assumption was confirmed by the demographic structure and housing design of the two sub-counties from the baseline results. Thus, the study evolved to one in which two different brands of ITNs were assessed among similar population groups. The two brands of ITNs monitored are:

(a) **DawaPlus 2.0** (distributed in Samia sub-county, Busia), 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) **DuraNet** (distributed in Msambweni sub-county, Kwale), 145-denier polyethylene ITN in blue color uses incorporation technology with a loading dose of 260 mg/m^2 of alphacypermethrin. DuraNet received full WHOPES recommendation in July 2013 (16th WHOPES Report) and was WHO pre-qualified in December 2017.

2.3 STUDY DESIGN SUMMARY

The principal study design is that of a prospective study of 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 were 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 was assessed. At each subsequent annual assessment (12-, 24- and 36-months following distribution) the presence and physical condition of each net in the study cohort was reassessed and recorded, together with household characteristics and use, care and repair behavior for the net. These characteristics are used to identify household- and respondent-level risk factors for net survivorship.

The sample size follows the standard www.durabilitymonitoring.org guidance of 150 households per study site (15 clusters with 10 households each) and an expected number of 345 ITNs in each site, or 728 in total. The expected number of ITNs present at end line is 279 in each site. This sample size will permit the estimate of the number of ITNs surviving to 36 months for each brand independently with a margin of error of at most 8.3 percentage-points.

At baseline, the ITN cohort in each county was established by selecting a representative sample of clusters (communities) based on probability proportionate to size and households were selected using simple random sampling from household lists. All ITNs received from the campaign by the selected households were identified and labeled with a unique ID number and 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. In the baseline, 12- and 24-month data collection rounds, samples of campaign nets were randomly selected from households outside the cohort but within the same study site to undergo bioassay tests and evaluate insecticidal effectiveness. At 36 months, 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 will be conducted by VectorLink Kenya at KEMRI facilities in Kisumu in accordance with standard WHO guidelines

[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://www.who.int/pq-vector-control/prequalified-lists/dawaplus_2.0/en/). The 36-month follow up on these nets will proceed as planned.

for cone and tunnel tests (where appropriate).[6] Chemical content analysis for this study will be conducted by CDC Atlanta.

2.4 Training and Fieldwork

Fieldwork was conducted by staff from the Pan Africa Mosquito Control Association (PAMCA). Fieldwork was overseen by a dedicated study coordinator and conducted by two teams of four people each. Staff were carefully selected based on their knowledge of the local language and experience conducting household surveys. All fieldwork staff for the 36-month survey also participated in the 24-month round.

Online training of trainers took place on October 28 – 30, 2020 with three days of remote instruction led by VectorLink research staff experienced in durability monitoring. In-person interview training took place in Kisumu from November 2 – 5, 2020 and entailed three days of classroom-based training and one field practice day in a local community with support from VectorLink Kenya, DNMP and PAMCA staff. Training covered the following topics: the study design and sampling procedures, ethical considerations (such as consent), COVID-19 adaptations, detailed review of questionnaire with role plays, use of smartphones 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 Regional Research Manager 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 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 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 so 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

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

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, 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.[7] 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 x 23) + (No. of size 3 holes x 196) + (No. of size 4 holes x 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 < 0.01m^2)
Serviceable:	pHI ≤ 642 (total hole surface area ≤ 0.1 m^2)
Torn:	pHI > 642 (total hole surface area > 0.1m^2)

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

At the end of the 36-month round, the median net survival was calculated, using the last two time points; the lowest is below 85%, using the following formula:

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

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

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 to wear and tear or "too torn" based on physical assessment. Nets that were given away or with 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 VectorLink Kenya. 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%

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

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/m² 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 PAMCA, 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 were trained on the study design and methods as well as how to administer the questionnaire, conduct net assessments, and all COVID-19 adaptations. During in-person fieldworker training, staff were instructed not to enter households, trained on how to examine nets with minimal contact, and trained on how to obtain oral consent. In the field and during training, staff were required to always wear a mask, maintain high levels of hand washing, and to use a new pair of gloves when examining nets at each new study household. 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 were at risk from household members (e.g. if the household included member(s) with COVID-19 symptoms). During fieldwork, no households were screened out of data collection during this round due to their COVID-19 risk. Additional IRB approval was sought before fieldwork began, as described below.

2.8 ETHICAL CLEARANCE

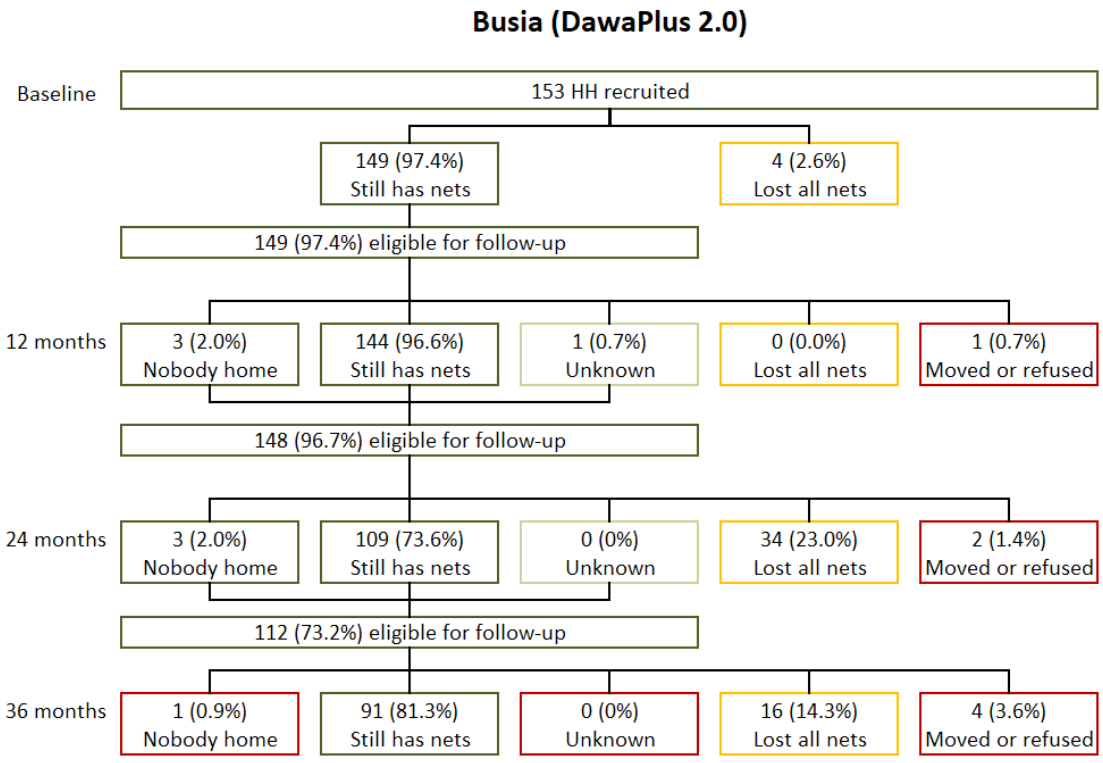
This study has been determined to be research with human subjects and received written approval from the KEMRI Scientific and Ethics Review Unit on May 24, 2020 under reference number KEMRI/RES/7/3/1. The PSI Research Ethics Board (REB) granted authorization on October 25, 2019 under reference number 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 November 4, 2020. Staff implementing this study complied with all policies and procedures of both PSI REB and the local ethics board. Informed oral consent was sought for all participants in this study prior to conducting the interview.

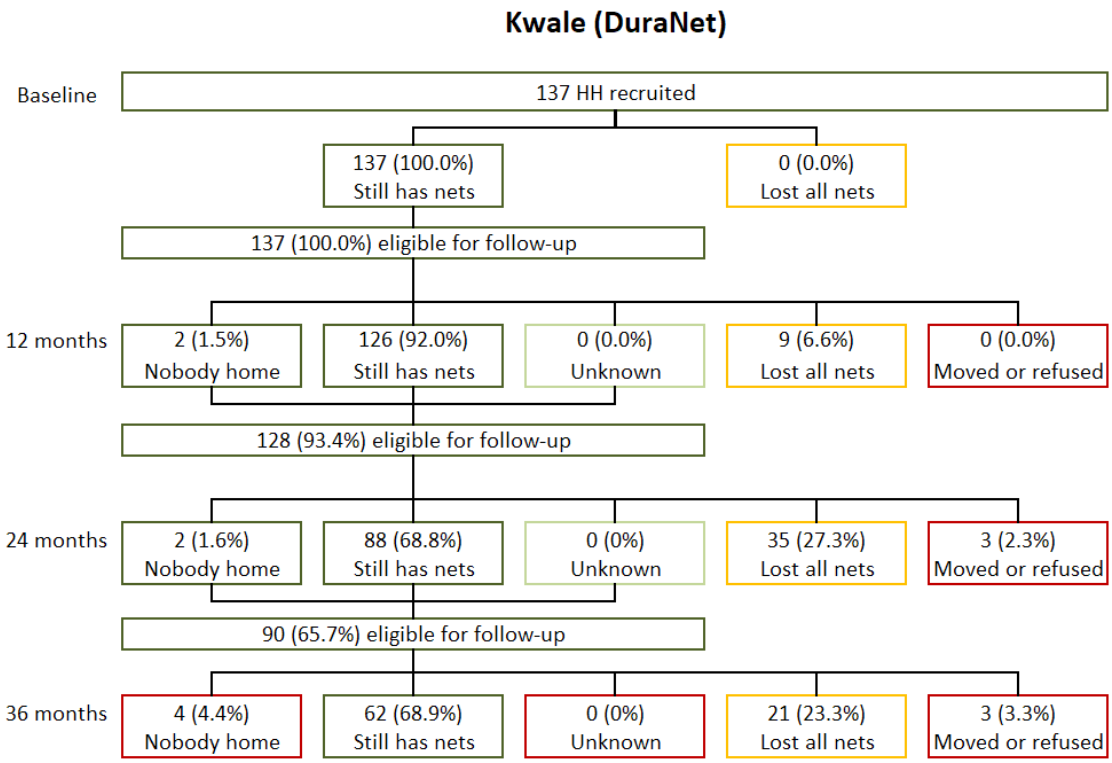
3. RESULTS

3.1 SAMPLE

A total of 290 households were recruited for durability monitoring (153 in Busia and 137 in Kwale), of which 202 households (112 in Busia and 90 in Kwale) were eligible for follow-up at 36 months (Figure 3). Of the 112 eligible households in Busia, 91 households still had at least one cohort net, while 16 households had lost all nets, 1 household had nobody home, and 4 households had moved out of the study site. In Kwale, 62 of the 90 eligible households still had cohort nets, 21 had lost all their nets, 4 had no one home, and 3 had moved out of the study site, at the time of the survey.

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

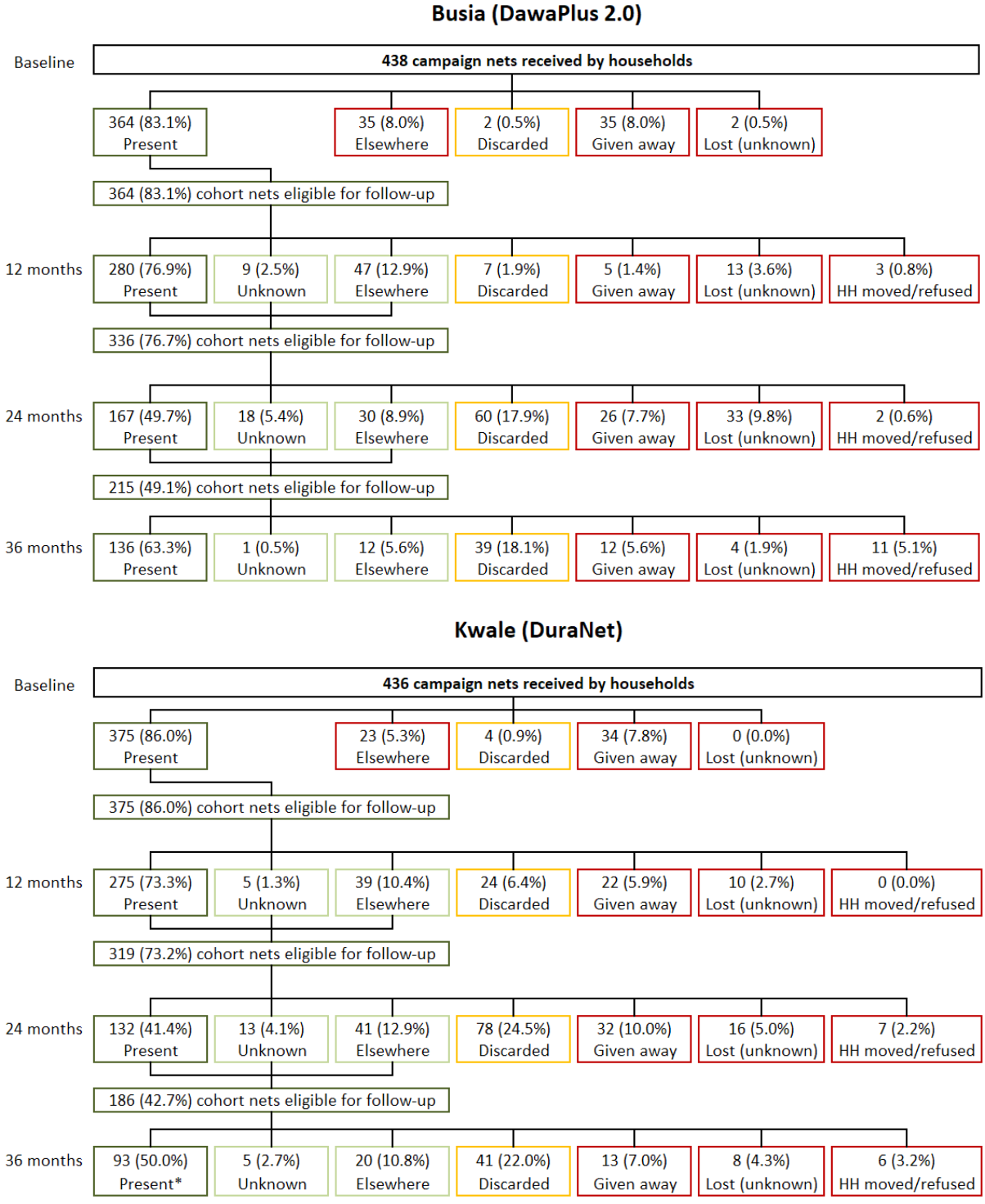




The 290 households visited at baseline reported receiving a total of 874 campaign nets (438 in Busia and 436 in Kwale; Figure 4). Of these 874 nets, 739 (364 in Busia and 375 in Kwale) were present in the household and were tagged for study follow-up. In Busia at the 12-month follow-up, 336 cohort nets were still in the household, had an unknown status (either due to no one being home or a survey capture error), or were elsewhere with family members and were eligible for follow-up in the next round. At 24 months, the number of nets present, had an unknown status, or were said to be with a family member elsewhere was 215. At 36 months, the number of nets still in the house decreased to 136, 1 net had an unknown status, and 12 were said to be with a family member elsewhere. Of the nets not in the household, 39 were discarded, 12 were stolen or given to others, and 4 were lost for unknown or other reasons. Among DawaPlus 2.0 nets reported as present at each survey round, 5, 6, and 4 nets were unavailable for assessment at baseline, 12-month and 24-months respectively due to being temporarily taken away for washing or stored in locked rooms. An additional 11 nets belonged to households who moved out of the study site.

In Kwale, at the 12-month follow-up 319 cohort nets were still in the household, had an unknown status, or were elsewhere with family members and were eligible for follow-up in the next round. At 24 months, 186 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, 93 cohort nets were still in the household, 5 had an unknown status, and 20 were with family members elsewhere. Forty-one nets were discarded, 13 were given away to others or stolen, 8 were lost due to unknown or other reasons, and 6 could not be assessed because the household moved out of the study site. Among DuraNet nets reported as present at each survey round, 5, 18, 1, and 1 net(s) were unavailable for assessment at baseline, 12-month, 24-months, and 36-months respectively due to being temporarily taken away for washing or stored in locked rooms. Temporarily unavailable nets were those washed, locked in a room, at tailor during the visit.

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. When considering the ownership of a radio, a mobile phone, and any form of transport, minor differences were seen between study sites at baseline and 36-months (Table 3). However, when compared to Kwale, Busia had a higher proportion of households with roof sheet or tile (90.6% vs. 63.9%, $p<0.001$), access to a latrine (100% versus 92.8%, $p=0.049$) and owned agricultural land (96.2% versus 69.9%, $p<0.001$).

TABLE 3: HOUSEHOLD CHARACTERISTICS AND ASSETS

	Baseline	36 months
Busia	**N=151**	**N=106**
Roof (sheets/ tile)	84.8%	90.6%
Cooking fuel (firewood)	91.4%	89.6%
Access to safe water	75.5%	63.2%
Access to latrine	99.3%	100.0%
Radio	69.5%	66.0%
Mobile phone	81.5%	81.1%
Any transport	55.6%	51.4%
Animal husbandry	92.1%	92.5%
Owning land for farming	96.0%	96.2%
Kwale	**N=137**	**N=83**
Roof (sheets/ tile)	54.0%	63.9%
Cooking fuel (firewood)	81.8%	83.1%
Access to safe water	94.9%	75.9%
Access to latrine	93.4%	92.8%
Radio	66.4%	66.3%
Mobile phone	86.1%	90.4%
Any transport	44.5%	39.8%
Animal husbandry	73.7%	72.3%
Owning land for farming	72.3%	69.9%

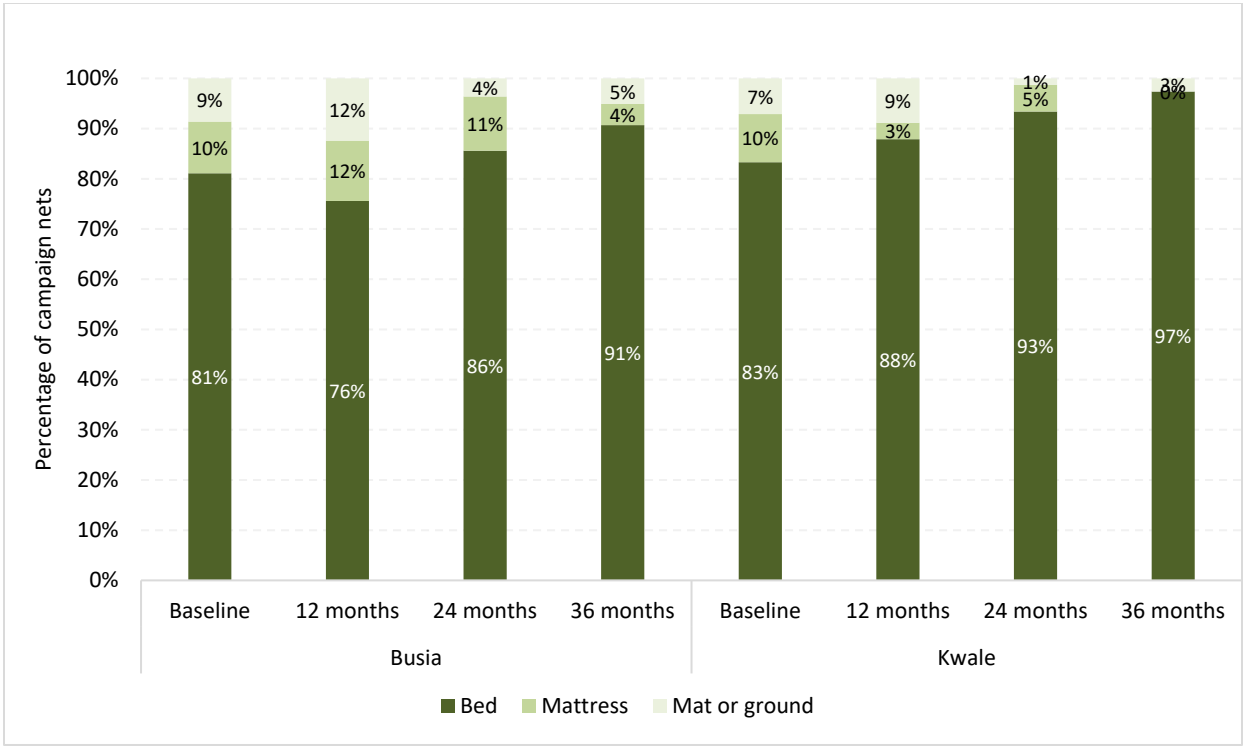
The presence of rodents in the household and the presence of food and practice of cooking near sleeping areas are risk factors for net durability. Table 4 presents the prevalence of these risk factors at 36-months. Most households reported never cooking in a sleeping room, although a significantly lower proportion ($p=0.025$) of household in Busia (6.6%) always cooked in the same room used for sleeping comparing to Kwale (12.0%). In Busia, 78.3% of households reported ever storing food in a room used for sleeping versus 68.7% in Kwale. In Busia, 59.4% of households reported observing rodents in the six months before the survey compared to 65.1% of households in Kwale.

TABLE 4: PREVALENCE OF HOUSEHOLD RISK FACTORS FOR DAMAGE

	Baseline	12 months	24 months	36 months
Busia	**N=151**	**N=144**	**N=143**	**N=106**
Ever store food in room used for sleeping	76.2%	81.3%	76.9%	78.3%
Cook in sleeping room				
Never	76.8%	75.7%	76.9%	79.2%
Sometimes	13.2%	16.7%	11.2%	14.2%
Always	9.9%	7.6%	11.9%	6.6%
Observed rodents in last 6 months	51.0%	62.5%	69.2%	59.4%
Kwale	**N=137**	**N=135**	**N=123**	**N=83**
Ever store food in room used for sleeping	67.2%	70.4%	63.4%	68.7%
Cook in sleeping room				
Never	67.9%	65.9%	71.5%	59.0%
Sometimes	15.3%	14.8%	4.9%	28.9%
Always	16.8%	19.3%	23.6%	12.0%
Observed rodents in last 6 months	65.7%	66.7%	77.2%	65.1%

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 which types of sleeping space were used with cohort ITNs by site and study period. In both counties, more than 90% of nets were used over beds during the 36-month follow up period.

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, 93.8% of cohort nets in Busia and 87.5% of nets in Kwale had ever been washed. Among washed nets, the median number of washes in the six months prior to the survey was higher in Kwale than in Busia (5 washes vs. 3 washes). In addition, a higher proportion of nets in Kwale were washed using detergent or bleach (51.9% compared with 13.3% in Busia, $p<0.001$). Drying washed nets on a bush or fence was relatively uncommon in both sites (less than 6% across both sites). Among nets reported as hanging, a lower proportion were not folded or tied up in Busia compared to in Kwale (96.9% versus 94.3%, $p=0.003$) and a lower number of ITNs were found hanging in Kwale compared to Busia (70 ITNs versus 120 ITNs).

TABLE 5: PREVALENCE OF HANDLING RISK FACTORS FOR CAMPAIGN ITNS

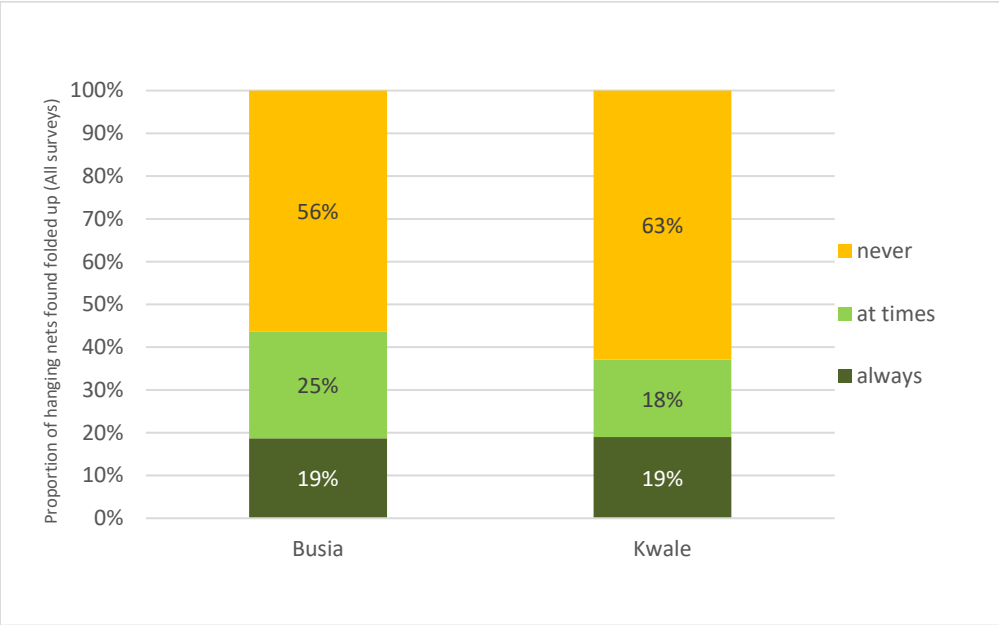
	Baseline	12 months	24 months	36 months
Busia	**N=363**	**N=280**	**N=169**	**N=136**
ITNs ever washed	24.5%	70.7%	79.3%	93.8%
Among ITNs ever washed:	N=88	N=197	N=134	N=120
Median number of washes in last 6 months [IQR]	1.5 [1.0-2.0]	2.0 [2.0-3.0]	2.0 [2.0-4.0]	3.0 [2.0-6.0]
Used detergent or bleach for last wash	21.6%	21.8%	20.1%	13.3%
ITNs dried on bush or fence for last wash	11.4%	6.1%	10.4%	5.8%
Among hanging ITNs:	N=88	N=197	N=134	N=120
Hanging ITNs are <u>not</u> folded or tied up	70.4%	67.8%	72.1%	69.6%
Kwale	**N=374**	**N=275**	**N=132**	**N=93**
ITNs ever washed	17.9%	42.9%	70.5%	87.5%
Among ITNs ever washed:	N=67	N=118	N=93	N=77
Median number of washes in last 6 months [IQR]	2.0 [1.0-2.0]	2.0 [1.0-3.0]	3.0 [2.0-4.0]	5.0 [2.5-6.0]
Used detergent or bleach for last wash	38.8%	57.6%	43.0%	51.9%
ITNs dried on bush or fence for last wash	1.5%	5.9%	4.3%	1.3%
Among hanging ITNs:	N=140	N=136	N=76	N=70
Hanging ITNs are <u>not</u> folded or tied up	65.7%	66.9%	85.5%	93.3%

IQR: interquartile range

In sum, the results from Tables 2-5 are evidence of a highly rural environment in both sites with no statistically or programmatically significant differences at baseline in the risk factors known to affect net durability.

Among cohort nets that were ever found hanging across all rounds of the survey, 19% of cohort nets were always found folded up in both Busia and Kwale (Figure 6). Similarly, 56% of cohort nets in Busia and 63% of cohort nets in Kwale had 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. In Busia, the exposure to any information in the past six months decreased from between 24- and 36-months (35.0% at 24 months and 20.8% at 36 months). The same observations were made in Kwale where exposure to any information in the past six months decreased from 37.4% at 24-months to 3.6% at 36-months. In both counties, among those that were exposed to messaging, most respondents obtained the information through interpersonal communication (e.g. health workers, friends/family, and community leaders or events). At each round in the study, messages on net care were recalled by a higher proportion of respondents in Busia than in Kwale. At 36-months, 45.5% of respondents in Busia recalled messages of "hang net" and 36.4% recalled messages of "repair net". In Kwale, no respondents reported hearing messages on hanging nets or repairing nets.

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

	Baseline	12 months	24 months	36 months
Busia	**N=151**	**N=144**	**N=143**	**N=106**
Any exposure in last 6 months	51.7%	52.1%	35.0%	20.8%
Among those exposed:	N=78	N=75	N=50	N=22
Mean number of sources among exposed*	1.6	1.1	1.3	1.1
Type of media source among exposed				
Media only	1.3%	1.3%	4.0%	4.5%
Interpersonal communication only	92.3%	90.7%	92.0%	90.9%
Both	5.1%	6.7%	4.0%	4.5%
Messages recalled among exposed				
"Use net (every) night"	88.5%	92.0%	88.0%	81.8%
"Hang net"	69.2%	66.7%	58.0%	45.5%
"Care for net"	71.8%	85.3%	92.0%	77.3%

"Repair net"	20.5%	21.3%	6.0%	36.4%
"Nets prevent malaria"	39.7%	14.7%	28.0%	27.3%
Kwale	**N=136**	**N=135**	**N=123**	**N=83**
Any exposure in last 6 months	35.3%	40.7%	37.4%	3.6%
Among those exposed:	N=48	N=55	N=46	N=3
Mean number of sources among exposed*	1.2	1.1	1.5	1.0
Type of media source among exposed				
Media only	2.1%	1.8%	0.0%	0.0%
Interpersonal communication only	83.3%	94.5%	93.5%	100.0%
Both	6.3%	1.8%	4.3%	0.0%
Messages recalled among exposed				
"Use net (every) night"	87.5%	80.0%	82.6%	100.0%
"Hang net"	72.9%	40.0%	50.0%	0.0%
"Care for net"	77.1%	83.6%	76.1%	66.7%
"Repair net"	6.3%	12.7%	6.5%	0.0%
"Nets prevent malaria"	29.2%	20.0%	23.9%	33.3%

* The maximum number of sources was 3 and included: community health agent; radio message/show; radio song.

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.

Across all four rounds of the survey, the mean net attitude score was above 1.0 in both study sites, indicating an overall positive attitude towards nets. When considering net care and repair attitudes, the mean attitude score was under 1.0 at baseline, 12-months, and 36 months, with a score of 1.10 at 24 months. At 36 months, 65.1% of respondents in Busia had an attitude score above 1.0 for both net care and repair. In Kwale, 63.9% of respondents had a net attitude score above 1.0 and 68.7% of respondents had a net care and repair attitude score above 1.0.

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

	Baseline	12 months	24 months	36 months
Busia	**N=151**	**N=144**	**N=143**	**N=106**
Attitude score: Nets				
Mean	1.57	1.49	1.30	1.22
(95% CI)	(1.45-1.68)	(1.35-1.64)	(1.14-1.45)	(1.09-1.36)
Percentage of respondents with score > 1.0	78.8%	77.1%	68.5%	65.1%
Attitude score: Net care and repair				
Mean	0.87	0.91	1.14	1.16
(95% CI)	(0.79-0.94)	(0.80-1.02)	(0.93-1.35)	(1.01-1.30)
Percentage of respondents with score > 1.0	44.4%	41.7%	63.6%	65.1%

Kwale	N=137	N=135	N=123	N=83
Attitude score: Nets				
Mean	1.60	1.53	1.40	1.24
(95% CI)	(1.47-1.74)	(1.42-1.65)	(1.26-1.55)	(0.99-1.49)
Percentage of respondents with score > 1.0	82.5%	83.0%	73.2%	63.9%
Attitude score: Net care and repair				
Mean	0.73	0.78	1.10	0.99
(95% CI)	(0.59-0.88)	(0.67-0.88)	(0.91-1.29)	(0.82-1.15)
Percentage of respondents with score > 1.0	37.2%	25.9%	59.3%	68.7%

Experience with repairing holes in nets are displayed in Table 8. Although progressively increasing proportions of respondents reported experiencing holes in nets (from an average of 43.2% at baseline to 86.1% at 36 months, across both sites), a lower proportion of respondents reported discussing net care and repair in the last six months as compared to earlier rounds (Kwale: from 57.6% at baseline to 19.8% at 36 months; Busia: from 36.5% at baseline to 6.0% at 36 months). Among respondents who reported having holes in their nets, 55.7% of respondents in Busia and 46.3% of respondents in Kwale had ever repaired a net.

TABLE 8: HOUSEHOLD NET CARE AND REPAIR EXPERIENCE

	Baseline	12 months	24 months	36 months
Busia	**N=151**	**N=144**	**N=143**	**N=106**
Ever experienced holes in a net	47.7%	63.2%	83.9%	91.5%
Discussed net care and repair in last 6 months	57.6%	45.8%	28.7%	19.8%
Among households experiencing holes:	N=72	N=91	N=120	N=97
Ever repaired net	36.1%	33.0%	50.0%	55.7%
Kwale	**N=137**	**N=135**	**N=123**	**N=83**
Ever experienced holes in a net	38.7%	51.1%	75.6%	80.7%
Discussed net care and repair in last 6 months	36.5%	41.5%	27.6%	6.0%
Among households experiencing holes:	N=53	N=69	N=93	N=67
Ever repaired net	32.1%	29.0%	54.8%	46.3%

3.3 NET OWNERSHIP AND NET USE

Each survey round all mosquito nets in selected households, including nets from sources other than the 2017 mass distribution campaign (referred to as *non-cohort nets*) were documented. 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 untied (58.8% in Busia and 75.3% in Kwale). In Busia, the second most common cohort net status was hanging and tied up (25.7%) and in Kwale, the second most common cohort net status was stored away in a package (7.5%). Reported use of cohort nets increased from 49.9% at baseline to 93.9% at 36-months in Busia and from 41.1% at baseline to 87.1% at 36-months in Kwale. In Busia, 85.3% of cohort nets were used the previous night and 87.9% were used every night in the last week. In Kwale, 80.6% of cohort nets were used the previous night and 78.5% were used every night in the last week.

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

	Baseline	12 months	24 months	36 months
Busia	**N=364**	**N=280**	**N=169**	**N=136**
Cohort net status				
Found hanging and tied up	13.2%	21.1%	18.3%	25.7%
Found hanging, untied	31.3%	44.3%	47.3%	58.8%
Not hanging and not stored away	5.2%	11.4%	11.2%	6.6%
Stored away unpacked	6.0%	7.1%	8.9%	2.2%
Stored away in a package	42.9%	13.9%	11.8%	3.7%
Temporarily unavailable during visit	1.4%	2.1%	2.4%	2.9%
Net ever used	49.9%	80.9%	85.8%	93.9%
Net used last night	46.4%	72.9%	71.6%	85.3%
Net used every night last week	45.5%	73.0%	69.2%	87.9%
Kwale	**N=375**	**N=275**	**N=132**	**N=93**
Cohort net status				
Found hanging and tied up	12.8%	16.4%	8.3%	5.4%
Found hanging, untied	24.5%	33.1%	49.2%	75.3%
Not hanging and not stored away	4.3%	8.0%	9.1%	4.3%
Stored away unpacked	8.0%	6.5%	11.4%	6.5%
Stored away in a package	49.1%	29.5%	21.2%	7.5%
Temporarily unavailable during visit	1.3%	6.5%	0.8%	1.1%
Net ever used	41.1%	62.1%	78.8%	87.1%
Net used last night	38.4%	51.3%	56.1%	80.6%
Net used every night last week	38.4%	50.4%	53.8%	78.5%

Household ownership of non-cohort nets and sources of these nets are presented in Table 10. At 36 months, the proportion of households in Busia and Kwale that had at least one net from a source other than the 2017 campaign decreased to 61.7% and 59.0%, respectively, at 36-months. In Busia and Kwale, the most common source of non-cohort nets was a previous mass campaign. At 36 months, the private sector and previous mass campaigns accounted for 16.8% and 37.9%, respectively, of non-cohort nets in Busia and for 29.8% and 24.5% of non-cohort nets, respectively, in Kwale.

TABLE 10: OWNERSHIP AND SOURCE OF NON-COHORT NETS

	Baseline	12 months	24 months	36 months
Busia	**N=151**	**N=144**	**N=143**	**N=107**
Households with any non-cohort nets	57.0%	62.5%	70.6%	61.7%
Non-cohort net sources	**Net N=139**	**Net N=147**	**Net N=180**	**Net N=95**
ANC visit	18.7%	20.4%	23.9%	21.1%
Previous mass campaign	44.6%	57.8%	58.3%	37.9%
School	0.0%	0.0%	0.6%	1.1%
Other public source*	21.6%	12.2%	3.9%	17.9%
Private sector	8.6%	2.7%	5.6%	16.8%
Other/doesn't recall**	6.5%	6.8%	7.8%	5.3%
Kwale	**N=137**	**N=135**	**N=123**	**N=83**

Households with any non-cohort nets	57.7%	52.6%	71.5%	59.0%
Non-cohort net sources	**Net N=155**	**Net N=102**	**Net N=166**	**Net N=94**
ANC visit	20.6%	21.6%	32.5%	20.2%
Previous mass campaign	65.8%	70.6%	29.5%	24.5%
School	0.0%	1.0%	1.2%	0.0%
Other public source*	0.6%	5.9%	16.9%	10.6%
Private sector	9.0%	1.0%	11.4%	29.8%
Other/doesn't recall**	3.9%	0.0%	8.4%	14.9%

* 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 187 non-cohort nets (95 in Busia and 94 in Kwale) were audited in study households (Table 11). According to respondents in Busia, 90.5% of non-cohort nets have been used at least once and in Kwale, 92.6% of non-cohort nets have been used at least once. Most non-cohort nets were found hanging at the time of the interview, either untied (50.5% in Busia and 76.6% in Kwale) or hanging and tied up (30.5% in Busia and 13.8% in Kwale).

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

	Baseline	12 months	24 months	36 months
Busia	**N=138**	**N=147**	**N=180**	**N=95**
Non-cohort net status				
Found hanging and tied up	29.0%	16.3%	18.3%	30.5%
Found hanging, untied	42.8%	39.5%	50.6%	50.5%
Not hanging and not stored away	8.0%	16.3%	11.7%	7.4%
Stored away unpacked	7.2%	6.8%	9.4%	7.4%
Stored away in a package	8.0%	19.0%	8.3%	4.2%
Temporarily unavailable during visit	5.1%	2.0%	1.7%	0.0%
Net ever used	88.3%	72.8%	88.3%	90.5%
Net used last night	79.1%	61.2%	76.7%	83.2%
Net used every night last week	78.1%	58.5%	73.9%	82.1%
Kwale	**N=154**	**N=103**	**N=166**	**N=94**
Non-cohort net status				
Found hanging and tied up	24.0%	17.5%	18.7%	13.8%
Found hanging, untied	65.6%	65.0%	58.4%	76.6%
Not hanging and not stored away	4.5%	3.9%	1.8%	1.1%
Stored away unpacked	1.9%	2.9%	4.2%	4.3%
Stored away in a package	2.6%	8.7%	12.7%	3.2%
Temporarily unavailable during visit	1.3%	1.9%	4.2%	1.1%
Net ever used	93.5%	67.2%	85.5%	92.6%
Net used last night	84.5%	77.7%	74.7%	85.1%
Net used every night last week	81.9%	57.7%	72.9%	85.1%

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, most

nets were used by adults only in both Busia (71.6%) and in Kwale (69.3%). A lower proportion were used by children sharing with adults (19.0% in Busia and 22.7% in Kwale), and the lowest proportion were used by children only (9.5% in Busia and 8.0% in Kwale). The same trends were observed for non-cohort nets (Table 13).

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

	Baseline	12 months	24 months	36 months
Busia	**N=169**	**N=204**	**N=121**	**N=116**
Cohort nets				
Used by child(ren) only	13.0%	10.3%	9.1%	9.5%
Used by child(ren) sharing with adult(s)	20.1%	20.1%	19.0%	19.0%
Used by adult(s) only	66.9%	69.6%	71.9%	71.6%
Kwale	**N=144**	**N=141**	**N=74**	**N=75**
Cohort nets				
Used by child(ren) only	12.5%	12.8%	1.4%	8.0%
Used by child(ren) sharing with adult(s)	33.3%	26.2%	36.5%	22.7%
Used by adult(s) only	54.2%	61.0%	62.2%	69.3%

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
Busia	**N=110**	**N=90**	**N=138**	**N=79**
Non-cohort nets				
Used by child(ren) only	18.2%	24.4%	13.0%	13.9%
Used by child(ren) sharing with adult(s)	17.3%	23.3%	27.5%	20.3%
Used by adult(s) only	64.5%	52.2%	59.4%	65.8%
Kwale	**N=131**	**N=80**	**N=124**	**N=80**
Non-cohort nets				
Used by child(ren) only	13.0%	13.8%	8.9%	5.0%
Used by child(ren) sharing with adult(s)	19.1%	31.3%	29.8%	31.3%
Used by adult(s) only	67.9%	55.0%	61.3%	63.7%

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 level. 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 household members that could sleep under an ITN assuming each ITN is used by 2 people. By both measures, access to cohort ITNs decreased from baseline to 36-months in Busia and Kwale. Overall, at 36-months, household and population access to cohort ITNs was higher in Busia (59.8% and 77.2%, respectively) than in Kwale (43.4% and 64.5%, respectively). Population use of all ITNs was 63.9% in Busia and 49.1% in Kwale.

TABLE 14: HOUSEHOLD AND POPULATION ITN ACCESS

	Baseline	36 months
Busia		
Household access	**N=153**	**N=107**
All ITNs	83.7%	59.8%
Campaign cohort ITNs (DawaPlus 2.0)	67.3%	39.3%
Other ITNs	15.0%	11.2%
Population access	**N=680**	**N=460**
All ITNs	92.8%	77.2%
Campaign cohort ITNs (DawaPlus 2.0)	84.4%	55.4%
Other ITNs	28.8%	32.0%
Population use	**N=680**	**N=460**
All ITNs	N/A	63.9%
Campaign cohort ITNs (DawaPlus 2.0)	N/A	42.2%
Other ITNs	N/A	23.0%
Kwale		
Household access	**N=137**	**N=83**
All ITNs	75.9%	43.4%
Campaign cohort ITNs (DuraNet)	63.5%	31.3%
Other ITNs	12.4%	4.8%
Population access	**N=728**	**N=409**
All ITNs	88.0%	64.5%
Campaign cohort ITNs (DuraNet)	80.8%	46.9%
Other ITNs	25.7%	19.1%
Population use	**N=728**	**N=409**
All ITNs	N/A	49.1%
Campaign cohort ITNs (DuraNet)	N/A	32.3%
Other ITNs	N/A	17.1%

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 438 cohort nets in Busia and 436 in Kwale, 408 and 397 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 a survey error, 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 end line round in case they reappear in the household. Campaign cohort nets that were given to family elsewhere before the baseline round and were not tagged are considered as given away to others.

In Busia, total campaign ITN attrition increased from 17.1% at baseline to 67.6% at 36 months (Figure 7). In Kwale, total campaign attrition increased from 14.2% to 77.6% in the same time frame. At 36 months, attrition was higher in Kwale than in Busia (p=0.003). Across each round, the most common reason for attrition in Busia was given away to others, rising from 16.2% at baseline to 28.0% at 36 months. In Kwale, at baseline,

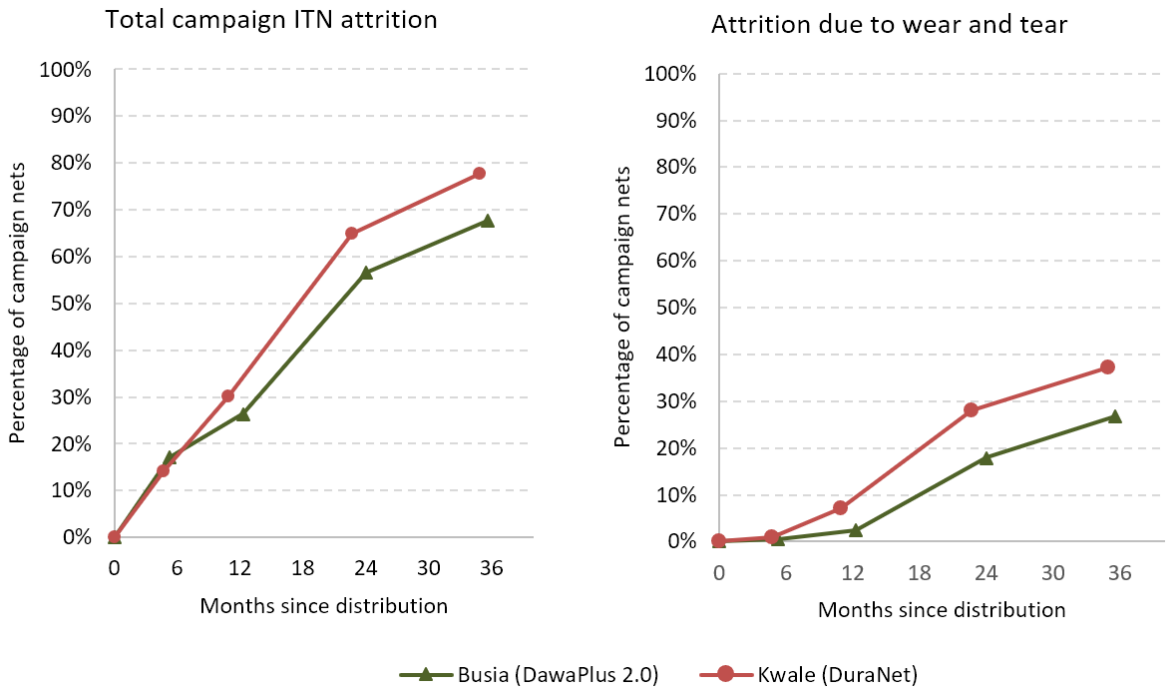
12-, and 24-months, the most common reason for attrition was given away to others. At 36-months the most common reason was ITNs discarded due to wear and tear. At 36-months, 37.2% of nets were discarded in Kwale compared to only 26.7% in Busia.

TABLE 15: CAMPAIGN COHORT ITN ATTRITION

	Baseline	12 months	24 months	36 months
Busia	**N=433**	**N=375**	**N=385**	**N=404**
Total campaign ITN attrition	17.1%	26.4%	56.6%	67.6%
ITNs given away to others	16.2%	20.0%	26.2%	28.0%
ITNs discarded	0.5%	2.4%	17.9%	26.7%
ITNs lost for other/unknown reason	0.5%	4.0%	12.5%	12.9%
Kwale	**N=431**	**N=388**	**N=375**	**N=393**
Total campaign ITN attrition	14.2%	30.2%	64.8%	77.6%
ITNs given away to others	13.2%	20.4%	29.6%	31.6%
ITNs discarded	0.9%	7.2%	28.0%	37.2%
ITNs lost for other/unknown reason	0.0%	2.6%	7.2%	8.9%

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 1holes + (No. of size 2 holes x 23) + (No. of size 3 holes x 196) + (No. of size 4 holes x 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 < 0.01m^2)
Serviceable:	pHI ≤ 642 (total hole surface area ≤ 0.1 m^2)
Torn:	pHI > 642 (total hole surface area > 0.1m^2)

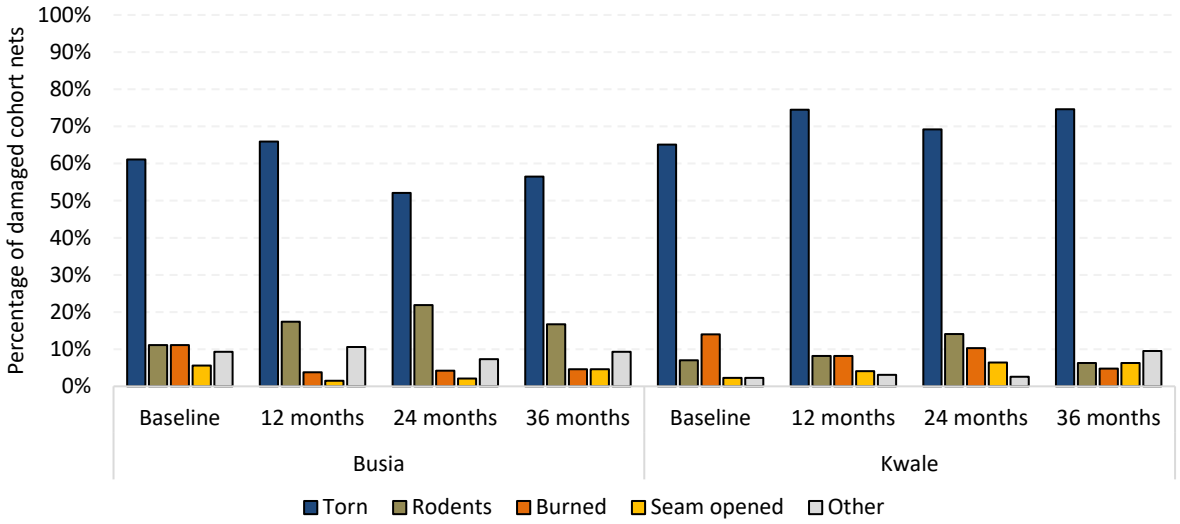
Table 16 reports the physical integrity results of nets that were in the household from baseline to 36-months (nets that were in the household but were temporarily unavailable due to being washed or were locked away were not included in the assessment). In Busia, the proportion of cohort nets with any holes increased from 14.5% at baseline to 84.4% at 36 months and in Kwale it increased from 11.1% to 74.7%. At 12-, 24-, and 36-months, a slightly higher proportion of nets in Kwale were observed to be too torn compared to Busia at each survey round.

TABLE 16: PHYSICAL INTEGRITY OF OBSERVED CAMPAIGN COHORT ITNS

	Baseline	12 months	24 months	36 months
Busia	**N=359**	**N=274**	**N=165**	**N=128**
Cohort ITN with any holes	14.5%	47.1%	58.8%	84.4%
ITNs classified as "Good"	91.6%	74.8%	61.2%	40.6%
ITNs classified as "Too torn"	2.2%	11.7%	18.2%	32.0%
ITNs classified as "Serviceable"	97.8%	88.3%	81.8%	68.0%
Among ITNs with any holes:	**N=52**	**N=129**	**N=97**	**N=108**
Median pHI for ITNs with any holes	87.0	81.0	244.0	248.0
Kwale	**N=370**	**N=257**	**N=131**	**N=87**
Cohort ITN with any holes	11.1%	35.8%	57.3%	74.7%
ITNs classified as "Good"	94.3%	74.7%	59.5%	47.1%
ITNs classified as "Too torn"	1.9%	13.6%	25.2%	33.3%
ITNs classified as "Serviceable"	98.1%	86.4%	74.8%	66.7%
Among ITNs with any holes:	**N=41**	**N=92**	**N=75**	**N=65**
Median pHI for ITNs with any holes	73.0	273.0	434.0	578.0

To understand the ways in which nets were damaged in real-life conditions, prior to the hole assessment respondents were asked whether they could remember the cause of the holes in their nets. The responses are captured in Figure 8. Across each survey round and for both sites, the most common damage mechanism was tearing on an object or by pulling (57% in Busia at 36 months and 75% in Kwale at 36 months). At 36 months, 17% of respondents in Busia reported rodents as causing damage while only 5% in Kwale reported rodents to cause damage.

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 survival of cohort ITNs from baseline to 36 months. At baseline and 12 months, the proportion of all cohort nets that had survived were similar in Busia and Kwale. However, after 24 months only 41.5% of nets had survived in Kwale, compared with 57.3% in Busia (p=0.031). This proportion decreased again at 36 months as only 37.0% of the nets survived in Busia compared with 24.8% in Kwale (p=0.074). These differences reflect the previous findings that attrition was higher and the proportion of nets that were serviceable was lower in Kwale compared to Busia. Among cohort nets that were ever used and present, survival was also higher in Busia versus Kwale at 36 months (68.6% in Busia and 65.3% in Kwale).

TABLE 17: CAMPAIGN COHORT ITNS SURVIVING IN SERVICEABLE CONDITION

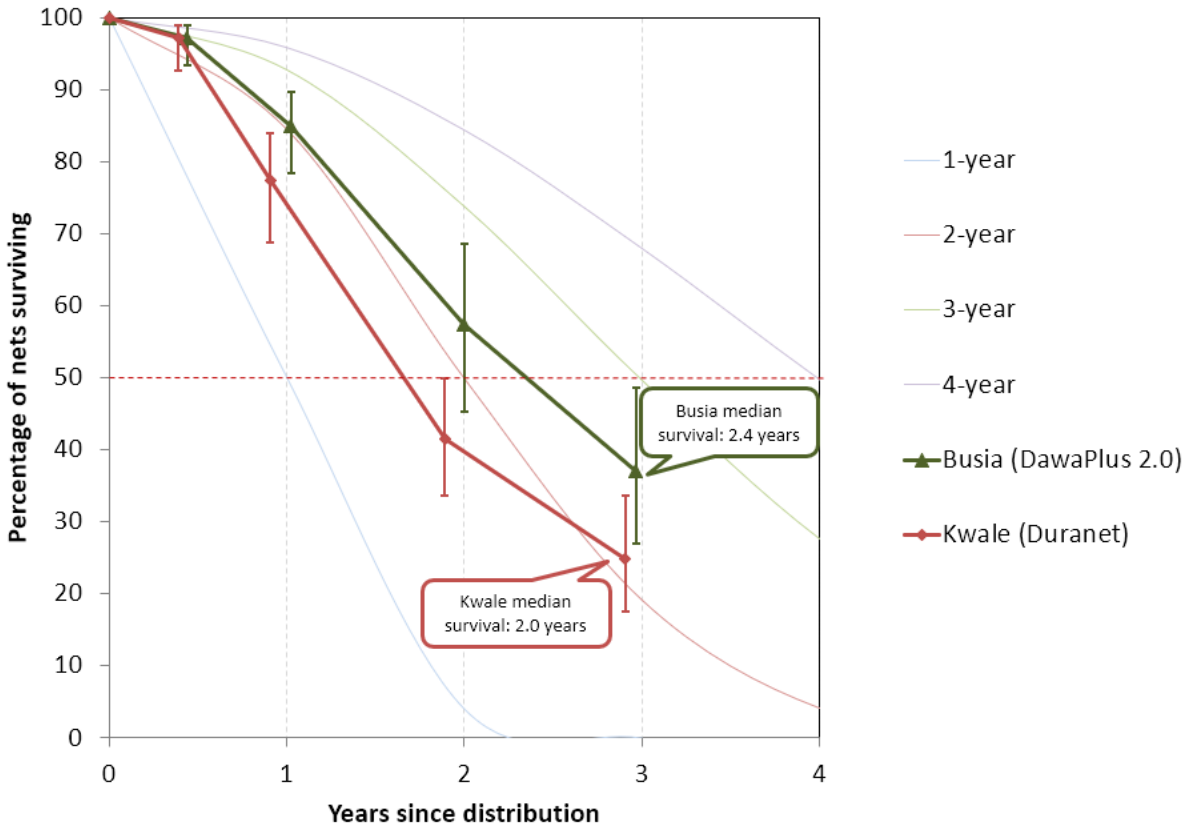
	Baseline	12 months	24 months	36 months
Busia				
All cohort nets*	N=361	N=285	N=232	N=235
Survival estimate	97.2%	84.9%	57.3%	37.0%
95% CI	93.4%-98.9%	78.4%-89.7%	45.2%-68.6%	26.9%-48.5%
Cohort nets ever-used and present	N=180	N=222	N=139	N=121
Survival estimate	95.6%	86.5%	78.4%	68.6%
95% CI	89.4%-98.2%	79.4%-91.4%	63.3%-88.5%	53.4%-80.6%
Kwale				
All cohort nets*	N=374	N=299	N=236	N=234
Survival estimate	97.1%	77.3%	41.5%	24.8%
95% CI	92.6%-98.9%	68.8%-84.0%	33.6%-49.9%	17.6%-33.7%
Cohort nets ever-used and present	N=154	N=168	N=103	N=75

Survival estimate	95.5%	81.5%	68.9%	65.3%
95% CI	90.8%-97.8%	75.8%-86.2%	60.3%-76.4%	54.5%-74.8%

* Among presents nets observed and discarded nets at each round.

Figure 9 plots the survival against hypothetical survival curves for nets lasting one to four years. Based on the survival data from month 12-, 24- and 36-month follow up. The estimated median useful life for DawaPlus 2.0 nets (in Busia) is 2.4 years; the estimated median useful life for DuraNet (in Kwale) is 2.0 years.

FIGURE 9: ESTIMATED ITN SURVIVAL



Error bars show 95% confidence intervals.

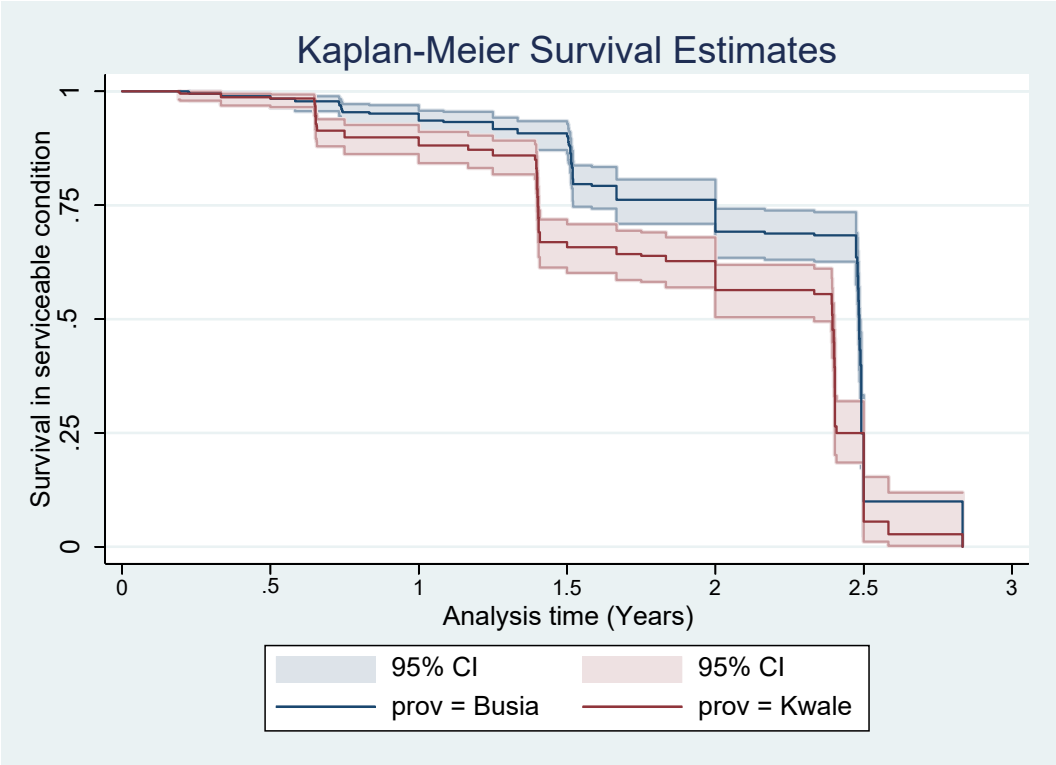
Table 18 presents results from using the most recent two data points as another method to calculate the survival estimate. Based on the data from 24 and 36-month follow up, the estimated median useful life for DawaPlus 2.0 is 2.4 years and 2.0 years for DuraNet.

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

	12 months	24 months	36 months
Busia (DawaPlus 2.0)	**N=283**	**N=234**	**N=235**
Estimated from Figure 9	2.1	2.2	2.5
Calculated from last two data points (95% CI)	-	-	2.4 (1.8-2.9)
Kwale (DuraNet)	**N=285**	**N=237**	**N=235**
Estimated from Figure 9	1.7	1.7	2.1
Calculated from last two data points (95% CI)	-	-	2.0 (1.6-2.3)

When data were analyzed as survival analysis in a Kaplan-Meier plot (Figure 10), DuraNet ITNs in Kwale, overall, showed a lower survival compared to the DawaPlus 2.0 ITNs in Busia (p<0.0001).

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%

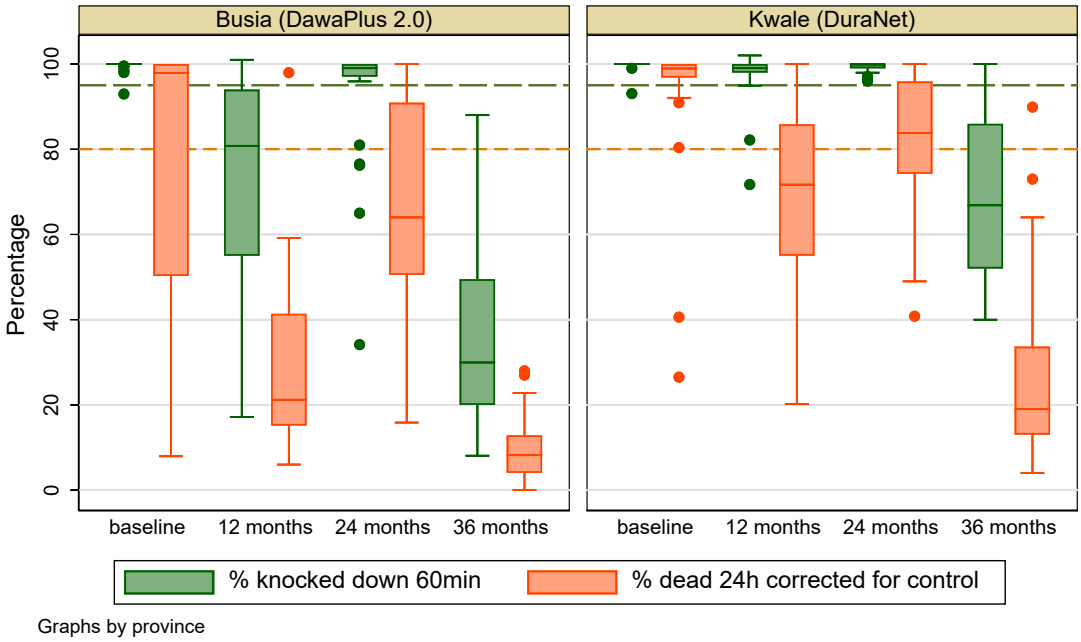
Bioassay results from baseline, 12- 24 and 36-months are shown in Table 19 and Figure 11. Nets dedicated for bioassay activities at the endline, were randomly sampled among the cohort nets while they were collected from households neighboring the cohort households in the previous rounds.

At 36-months, 13% of DuraNet nets in Kwale were found to be optimally effective compared to none of the DawaPlus 2.0 nets in Busia. DuraNet nets in Kwale were also more minimally effective (37%) than DawaPlus 2.0 nets in Busia (3%). The higher optimal and minimal effectiveness levels found in Kwale were driven both by higher mortality and higher knock-down. There is a strong decrease between the 24-month and 36-month rounds but the inexplicable greater knock-down and mortality at 24 months compared to the 12-month results may contribute to this huge difference.

TABLE 19: CONE BIOASSAY RESULTS

	Baseline	12 months	24 months	36 months
Busia (DawaPlus 2.0)	**N=30**	**N=30**	**N=29**	**N=30**
Knock down 60 minutes				
Mean (95% CI)	99.6 (99.1-100.1)	73.3 (65.9-80.6)	93.5 (88.5-98.6)	35.3 (27.8-42.7)
Median [IQR]	100.0 [100.0-100.0]	80.8 [55.0-94.0]	99.0 [97.0-100.0]	30.0 [20.0-49.5]
Mortality 24 hours				
Mean (95% CI)	77.0 (66.8-87.1)	28.6 (22.8-34.3)	66.6 (59.9-73.3)	9.6 (6.7-12.6)
Median [IQR]	97.9 [50.2-100.0]	21.2 [15.2-41.4]	64.0 [50.5-90.9]	8.2 [4.0-12.9]
Optimal effectiveness				
Estimate (95% CI)	96.7% (77.6-99.6)	23.3% (12.4-39.5)	82.8% (65.6-92.4)	0.0%
Minimal effectiveness				
Estimate (95% CI)	100.0% -	53.3% (37.8-68.3)	93.1% (75.2-98.4)	3.3% (0.4-22.4)
Kwale (DuraNet)	**N=30**	**N=30**	**N=29**	**N=30**
Knock down 60 minutes				
Mean (95% CI)	99.7 (99.3-100.2)	97.7 (95.5-99.9)	99.5 (99.1-99.9)	68.5 (61.7-75.3)
Median [IQR]	100.0 [100.0-100.0]	99.0 [98.0-100.0]	100.0 [99.0-100.0]	66.8 [52.0-86.0]
Mortality 24 hours				
Mean (95% CI)	93.2 (84.2-102.1)	70.6 (63.9-77.2)	81.6 (76.2-86.9)	26.7 (20.0-33.5)
Median [IQR]	99.0 [96.8-100.0]	71.7 [55.0-85.9]	83.8 [74.2-95.9]	19.0 [13.0-33.7]
Optimal effectiveness				
Estimate (95% CI)	96.7% (77.4-99.6)	90.0% (72.3-96.9)	100.0% -	13.3% (5.2-30.1)
Minimal effectiveness				
Estimate (95% CI)	100.0% -	96.7% (77.4-99.6)	100.0% -	36.7% (22.5-53.5)

FIGURE 11: BOX PLOT OF ITN CONE BIOASSAY RESULTS



Results from WHO cone bioassays: the box plot shows the median (black dot), interquartile range (box), adjacent values[8] (whiskers) and outliers (circles), lines represent WHO optimal effectiveness thresholds for knock-down (kd60, 95%) and mortality (mortality, 80%).

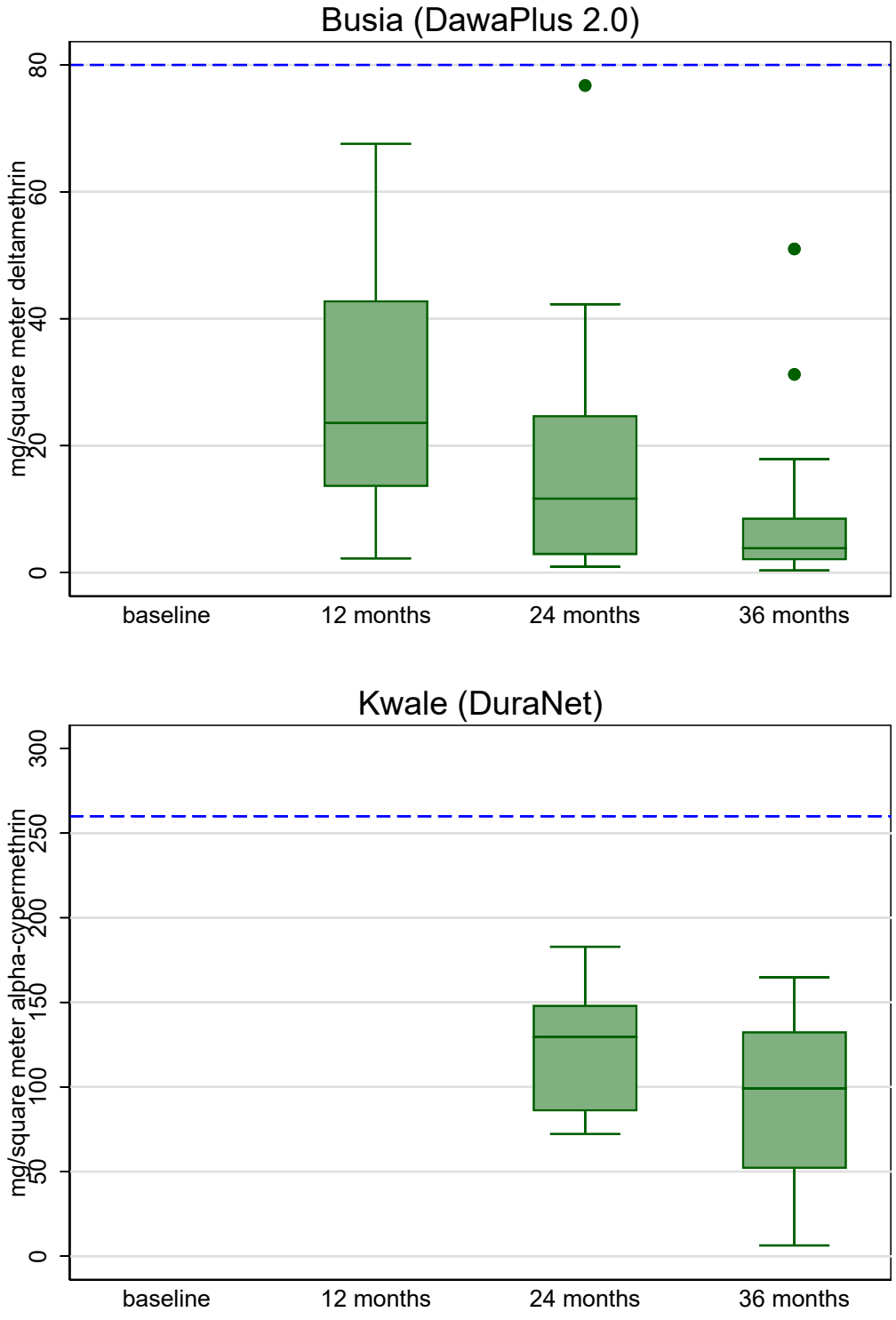
In addition to testing for insecticidal effectiveness, the nets collected were sent to CDC/Atlanta for chemical content testing. DawaPlus 2.0 is manufactured with 80 mg/m² deltamethrin. DuraNet is manufactured with 260 mg/m² alpha-cypermethrin. Chemical content results presented in Table 16 show a mean deltamethrin content of 7.8 mg/m² in Busia, corresponding to a 90% loss compared to the original dose. In Kwale, results show a mean alpha-cypermethrin content of 90.5 mg/m², corresponding to a 65% loss compared to the original target dose.

TABLE 20: CHEMICAL CONTENT RESULTS

	12 months	24 months	36 months
Busia (DawaPlus 2.0, 80 mg/m2 deltamethrin)	**N=30.0**	**N=29.0**	**N=58.0**
Mean (95% CI)	28.4 (21.3-35.5)	16.0 (10.3-21.7)	7.8 (4.2-11.4)
Median [IQR]	23.6 [13.5-42.9]	11.6 [2.8-24.8]	3.8 [1.9-8.6]
Kwale (DuraNet, 260 mg/m2 alpha-cypermethrin)	**N/A**	**N=29.0**	**N=58.0**
Mean (95% CI)	N/A	121.9 (108.1-135.8)	90.5 (69.6-111.3)
Median [IQR]		129.5 [85.6-148.4]	99.1 [51.7-132.8]

[8] Adjacent values are ± 1.5 * Interquartile range.

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 of the ITNs undergoing bioassay analysis at 36 months. Net characteristics were similar for sampled ITNs from both sites in terms the percentage of nets used every night in the last week, the percentage of net users' category, the percentage of nets that have ever been washed and the average frequency of washing. More nets from Kwale were found hanging and folded or tied up in Busia (23.3%) than in Kwale (3.3%). Also, more nets in Kwale (36.7%) had been washed using water and detergent or bleach than in Busia (20.0%), where the use of bar soap was more common (80.0%).

TABLE 21: HANDLING OF BIOASSAY TEST ITNS

	Baseline	12 months	24 months	36 months
Busia	**N=30**	**N=30**	**N=29**	**N=30**
Location found				
Hanging and folded or tied	20.0%	10.0%	13.8%	23.3%
Hanging loose	66.7%	66.7%	65.5%	63.3%
Not hanging	13.3%	23.3%	17.2%	10.0%
Stored unpacked	0.0%	0.0%	3.4%	3.3%
Stored in package	0.0%	0.0%	0.0%	0.0%
Type of sleeping space (if used)				
Bed	86.7%	76.7%	75.9%	89.7%
Mattress	10.0%	13.3%	13.8%	6.9%
Mat/Ground	3.3%	10.0%	10.3%	3.4%
Net users				
Child(ren) only	13.8%	19.2%	10.3%	7.4%
Child(ren) and adult(s)	41.4%	19.2%	24.1%	48.1%
Adult(s) only	44.8%	61.5%	65.5%	44.4%
Kwale	**N=30**	**N=29**	**N=29**	**N=30**
Location found				
Hanging and folded or tied	36.7%	17.2%	6.9%	3.3%
Hanging loose	63.3%	65.5%	82.8%	86.7%
Not hanging	0.0%	17.2%	6.9%	6.7%
Stored unpacked	0.0%	0.0%	3.4%	3.3%
Stored in package	0.0%	0.0%	0.0%	0.0%
Type of sleeping space (if used)				
Bed	96.7%	89.7%	93.1%	100.0%
Mattress	0.0%	3.4%	6.9%	0.0%
Mat/Ground	3.3%	6.9%	0.0%	0.0%
Net users				
Child(ren) only	10.3%	18.2%	31.0%	7.4%
Child(ren) and adult(s)	31.0%	50.0%	24.1%	48.1%
Adult(s) only	58.6%	31.8%	44.8%	44.4%

TABLE 22: REPORTED USE OF BIOASSAY TEST ITNS

	Baseline	12 months	24 months	36 months
Busia	**N=30**	**N=30**	**N=29**	**N=30**
Used last night	96.7%	86.7%	93.1%	90.0%
Used last week				
Every night	96.7%	83.3%	86.2%	90.0%
Most nights (5-6 nights)	0.0%	6.7%	3.4%	3.3%
Some nights (1-4 nights)	0.0%	3.3%	6.9%	0.0%
Not used last week	3.3%	6.7%	3.4%	6.7%
Never used	0.0%	0.0%	0.0%	0.0%
Don't know	0.0%	0.0%	0.0%	0.0%
Seasonal use				
Equally in rainy and dry seasons	96.7%	100.0%	96.6%	100.0%
Mainly rainy season	3.3%	0.0%	0.0%	0.0%
Rainy season only	0.0%	0.0%	0.0%	0.0%
Not used	0.0%	0.0%	0.0%	0.0%
Don't know	0.0%	0.0%	3.4%	0.0%
Kwale	**N=30**	**N=30**	**N=29**	**N=30**
Used last night	100.0%	73.3%	82.8%	90.0%
Used last week				
Every night	100.0%	76.7%	82.8%	83.3%
Most nights (5-6 nights)	0.0%	3.3%	0.0%	0.0%
Some nights (1-4 nights)	0.0%	3.3%	3.4%	10.0%
Not used last week	0.0%	13.3%	13.8%	3.3%
Never used	0.0%	3.3%	0.0%	3.3%
Don't know	0.0%	0.0%	0.0%	0.0%
Seasonal use				
Equally in rainy and dry seasons	100.0%	93.1%	93.1%	93.3%
Mainly rainy season	0.0%	6.9%	3.4%	6.7%
Rainy season only	0.0%	0.0%	0.0%	0.0%
Not used	0.0%	0.0%	0.0%	0.0%
Don't know	0.0%	0.0%	3.4%	0.0%

TABLE 23: REPORTED WASHING OF BIOASSAY TEST ITNS

	Baseline	12 months	24 months	36 months
Busia	**N=30**	**N=30**	**N=29**	**N=30**
Ever washed	40.0%	80.0%	93.1%	100.0%
Washes in the last 6 months among all nets (if known)				
Mean	0.70	2.70	4.18	5.07
Median	0.0	2.0	3.0	4.0
Washes in the last 6 months among washed nets				
Mean	1.75	3.38	4.50	5.07

Median	1.0	2.5	3.0	4.0
Soap used for last wash				
Soap bar	75.0%	62.5%	81.5%	80.0%
Detergent or bleach	16.7%	37.5%	14.8%	20.0%
Mix	0.0%	0.0%	0.0%	0.0%
None	8.3%	0.0%	3.7%	0.0%
Where dried after last wash				
Shade	N/A	N/A	61.5%	90.0%
Sun	N/A	N/A	34.6%	10.0%
Don't know	N/A	N/A	0.0%	0.0%
Kwale	**N=30**	**N=30**	**N=29**	**N=30**
Ever washed	46.7%	50.0%	96.6%	100.0%
Washes in the last 6 months among all nets (if known)				
Mean	1.10	7.67	3.81	4.96
Median	0.0	0.5	3.0	6.0
Washes in the last 6 months among washed nets				
Mean	2.36	15.33	3.96	4.96
Median	2.0	2.0	3.0	6.0
Soap used for last wash				
Soap bar	21.4%	20.0%	31.0%	53.3%
Detergent or bleach	78.6%	80.0%	69.0%	36.7%
Mix	0.0%	0.0%	0.0%	10.0%
None	0.0%	0.0%	0.0%	0.0%
Where dried after last wash				
Shade	N/A	N/A	57.7%	83.3%
Sun	N/A	N/A	42.3%	16.7%
Don't know	N/A	N/A	0.0%	0.0%

4. CONCLUSIONS

4.1 SUMMARY OF FINDINGS

This 36-month round of the Kenya durability monitoring study successfully visited 202 households across two districts, each having received different ITNs during the 2017 mass campaign: DawaPlus 2.0 in Busia and DuraNet in Kwale. At baseline, a total of 874 ITNs were recorded as having been distributed to cohort households (including those lost before the baseline round). At 36-months, only 229 ITNs from the 2017 campaign were still present in the households (136 in Busia and 93 in Kwale). Total campaign ITN attrition was 67.6% in Busia and 77.6% in Kwale. Attrition due to wear and tear (discarded) and ITNs given away were the main causes of attrition in both study sites.

At 36 months, survivorship of campaign nets was analyzed using a Kaplan-Meier plot. Results showed significantly lower survival in Kwale compared to Busia (24.8% versus 37.0%; $p<0.0001$). Attrition due to wear and tear (discarded ITNs) was also worse in Kwale than in Busia (37.2% versus 26.7%). Physical integrity follows the same pattern between the two study sites with a median pHI in Kwale that is more than twice that of Busia (578 median pHI vs. 248 median pHI) although the proportion of nets classified as "too torn" according to their pHI value was similar between the two sites (33.3% in Kwale and 32.0% in Busia). Potential reasons for lower survivorship include a higher use of bleach or detergent in Kwale (51.9% compared to 13.3% in Busia), and not tying up a hanging net (69.6% in Busia vs. 93.3% in Kwale), though respondents who reported always tying nets up across the three years of the study were very rare (almost zero) in both study sites.

Additionally, households in Kwale more frequently cooked in the room used for sleeping, although the effect of this practice on integrity may have been relatively small since only a slightly higher proportion of respondents in Kwale reported damage caused by burns. Other potential risk factors for diminished physical integrity were statistically similar across both study sites such as having observed rodents in the last six months (59.4% in Busia and 65.1% in Kwale) and hanging a mosquito net above a bed as opposed to a mat or on the floor (91% in Busia and 97% in Kwale). Attitudes towards nets and net care and repair were also generally positive in both sites. However, households in Busia appeared more willing to discuss repairing nets than those in Kwale.

There was also a disparity in the general behavior change communication between the study sites. Households in Busia appeared significantly more exposed to any messages on mosquito nets in the previous six months than in Kwale where interpersonal communication was the only source of exposure. Additionally, none of the households in Kwale recalled hearing messages about repairing or hanging nets.

The attrition, physical integrity, and survival results from Kenya can be compared to studies in other east African countries. ITNs in Zanzibar seem to perform better than Kenya: attrition due to wear and tear ranged from 12% - 15%, median pHI values ranged from 269 to 324, and survival rates ranged from 51% - 55%.

DawaPlus 2.0 nets have also been monitored in Myanmar[9] (one site) and Nigeria[10] (three sites). Endline results for DawaPlus 2.0 nets from these settings have levels of attrition due to wear and tear ranging from 9% to 20%, median pHI values ranging from 67 to 213, and survival rates ranging from 55% - 80%. These outcomes correspond to median useful life ranging from 3.2 to 5.3 years in Nigeria (data from Myanmar not available),

[9] https://www.pmi.gov/docs/default-source/default-document-library/pmi-reports/durability-monitoring-of-llin-in-burma-final-report-after-36-months-follow-up-(2019).pdf?sfvrsn=4

[10] Obi, E., Okoh, F., Blaufuss, S. *et al.* Monitoring the physical and insecticidal durability of the long-lasting insecticidal net DawaPlus® 2.0 in three States in Nigeria. *Malar J* **19,** 124 (2020). https://doi.org/10.1186/s12936-020-03194-9

longer than the 2.4 years median life recorded for DawaPlus 2.0 in Kenya. In one site in DRC, 48% of DawaPlus 2.0 nets were discarded due to wear and tear after 36 months, the remaining nets with holes had a median pHI value of 1184, and the survival rate was 17%. These outcomes correspond to a median useful life of 1.6 years, shorter than Kenya by 0.8 years.

DuraNet ITNs were also monitored in the DRC study, where 26% of nets were discarded due to wear and tear at endline and the brand recorded a survival rate of 37%, corresponding to a median useful life of 2.2 years. These results indicate DuraNet ITNs performed slightly better in DRC than in Kenya (2.0 years median useful life).

150 denier, polyethylene MAGNet and Royal Sentry ITNs, with similar characteristics to DuraNet, have been monitored in 3 sites Mozambique[11]. Attrition due to wear and tear after 36 months ranged from 16% - 25%, the median pHI values ranged from 269 to 1745, and survival rates ranged from 33% - 58%. The corresponding median useful life for nets from the 3 sites were 3.1, 2.2, and 1.7 years: longer than Kenya for 2 sites and shorter for 1 site.

Bioassay results at 36-months in Kenya can be compared to those in DRC for the same brand nets (DuraNet and DawaPlus 2.0 nets) at 35 months. For DawaPlus 2.0 nets, optimal effectiveness was 0.0 in both countries however, minimal effectiveness for DawaPlus 2.0 nets was 3.3% (compared to 47%), 24-hour mortality was 9.6% (compared to 29%), and the knock-down rate was 35.3% (compared to 70%). For DuraNet ITNs, optimal effectiveness was 13.3% (compared to 100%), minimal effectiveness was 36.7% (compared to 100%), 24-hour mortality was 26.7% (compared to 85%), and the knock-down rate was 68.5% (compared to 98%).

Chemical content results show a mean deltamethrin content of 7.8 mg/m^2 in Busia, corresponding to a 90% loss compared to the original dose. In Kwale, results show a mean deltamethrin content of 90.5 mg/m^2, corresponding to a 65% loss compared to the original target dose.

4.2 KEY CHALLENGES AND LESSONS LEARNED

The main challenge faced by the field teams during this survey round was the non-availability of the expected remaining nets in the cohort households among which the bioassay nets should be withdrawn in each cluster. In several instances, the household selected for bioassays had lost all their cohort nets and thus, had nothing to provide for bioassays. To overcome this issue, the team randomly selected other cohort households to collect the remaining bioassay nets. In a case where the entire cluster only had 2 cohort nets present (and from the same household), those two nets were selected and replaced. All these processes followed the protocol on bioassay net removal.

Another challenge the teams faced was the higher number of households with nobody home at the time of the interview. Data collectors were required to return to the household more than three times before leaving the cluster to ensure these households were not excluded from the final sample.

[11] Abílio, A.P., Obi, E., Koenker, H. *et al.* Monitoring the durability of the long-lasting insecticidal nets MAGNet and Royal Sentry in three ecological zones of Mozambique. *Malar J* **19,** 209 (2020). https://doi.org/10.1186/s12936-020-03282-w