THE PMI VECTORLINK LIBERIA 2018 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
HH	Household
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
pHI	Proportionate Hole Index
PMI	President's Malaria Initiative
PSI	Population Services International
REB	Research Ethics Board
UL-PIRE	University of Liberia - Pacific Institute for Research & Evaluation
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 mosquito net is one of the critical factors National Malaria Control Programs (NMCP) need to know to determine the frequency with which nets are replaced. The World Health Organization (WHO) recommends that countries routinely monitor net durability following mass distribution campaigns, and standard guidance for monitoring has been developed.[1]

In Liberia, the President's Malaria Initiative (PMI) is supporting net durability monitoring of DuraNet (alpha-cypermethrin) nets distributed in Grand Gedeh and Lofa counties during April of the 2018 mass campaign. Baseline data collection was conducted August 1-16, 2018, to establish the study cohort. All campaign nets in sampled households were identified and labeled with a unique ID number.

The 12-month follow up survey was conducted April 15 - May 1, 2019. The 24-month survey was originally scheduled to occur in March 2020, however, due to COVID-19 restrictions, the survey was delayed and ultimately carried out August 8-26, 2020, 29 months post-distribution. The end line, 36-month survey was conducted March 29 - April 6, 2021. During each of these rounds, all nets 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 attitudes towards nets and net care and repair.

The survey also collected information on mosquito nets obtained outside of the 2018 mass campaign. Separate to the study cohort, nets identified as coming from the 2018 mass campaign were sampled from neighboring households for bio-effectiveness and chemical content analysis. Bioassays are being performed by VectorLink Liberia and chemical content analysis by the Centers for Disease Control and Prevention (CDC) Atlanta.

Household and ITN Follow-Up at 36 months

A total of 237 out of 265 (89%) eligible households were interviewed for the 36-monthsurvey round. Of these, the vast majority 90% (214/237) still had one or more cohort nets and 23/237 (10%) households had lost all their cohort nets. Of the 28 households not interviewed, 16 had no eligible respondent available for interview, 11 had moved out of the study area, and one was excluded based on the COVID-19 screening. Three years after the 2018 mass campaign, 39% (342 nets out of 872 tagged at baseline) of cohort nets were still in the house. Over the three-year study period, 60% of cohort nets (519 out of 872 nets) were no longer present in households. Of the 519 cohort nets not present in households, 42% (218/519) were given away or stolen, 33% (170/519) were with family elsewhere, 12% (64/519) were discarded, and 13% (67/519) were lost for another/unknown reason. 17% (87/519) of cohort nets were not followed up with because the household moved or refused to participate.

Durability Risk Factors

At 36-months, the proportion of households that have ever stored food in a room used for sleeping was lower in Grand Gedeh compared to in Lofa (75% versus 89%, p=0.044). Almost all households reported never cooking in a room used for sleeping (98% in both study sites) and most households reported observing rodents

[1] www.durabilitymonitoring.org

in the past six months (95% versus 88% in Lofa). In both counties, less than 5% of cohort nets were used over a mat or ground and approximately half were used over a bed frame (48% in Grand Gedeh, 56% in Lofa). The median number of times nets were washed within the past six months (2.0 in Grand Gedeh and Lofa) and the use of detergent or bleach to wash nets (55% in Grand Gedeh, 53% in Lofa) were similar across study sites. Approximately one-quarter of households in Grand Gedeh (27%) and Lofa (25%) reported being exposed to information about net use, care or repair in the past six months (a decrease from exposure levels in previous survey rounds). Messaging in both study sights was received through a relatively even mix of media and interpersonal communication. In both sites, the most commonly recalled messages among exposed respondents was "use net every night" (97%), "hang net" (95%), and "care for net" (90%). At 36-months, the mean net attitude scores and net care and repair scores were above 1.0 in both study sites, indicating an overall positive attitude towards nets and net care and repair. There were no statistical differences between the proportion of households experiencing holes in a net, discussing net care, or repairing nets across study sites. Overall, at 36-months, levels of net durability risk factors were similar in Grand Gedeh and Lofa.

Across the three-year life of the study (from 2018 – 2021), risk factors varied between study sites. In both Grand Gedeh and Lofa, the proportion of individuals who store food in a room used for sleeping, reported seeing rodents in the last 6 months, reported any exposure to messaging in the last 6 months, leave hanging nets unfolded or tied up, and have ever discussed care and repair decreased between the baseline and 36-month survey rounds. Conversely, in both study sites the proportion of households who cook in a room used for sleeping and use detergent or bleach when washing a net increased. This indicates a general improvement in the care of mosquito nets. This is also reflected in an increase in median net care and repair attitude score between baseline and 36-months. However, the median net attitude score decreased between the same time.

ITN Ownership and Use

The proportion of cohort nets that had ever been used was 86% in Grand Gedeh and 93% in Lofa at 36 months. A higher proportion of cohort nets in Lofa compared to Grand Gedeh were reportedly used last night (66% versus 53%, p=0.046) and every night last week (65% versus 50%, p=0.005). Over half of households in Grand Gedeh (60%) and Lofa (59%) had at least one non-cohort net. Similar to cohort net use patterns, a higher proportion of non-cohort nets were ever used in Lofa versus Grand Gedeh (94% versus 78%, p=0.016) and used every night last week (66% versus 46%, p=0.013). For all net use indicators, the proportion of cohort nets and non-cohort nets used was similar in Grand Gedeh and Lofa. In both study sites, approximately 60% of cohort and non-cohort nets were used by adults only.

Across the three-year life of the study (from 2018 – 2021), cohort net use increased in both study sites. Similarly, the proportion of nets found hanging also increased from baseline to the 36-month survey round. In Grand Gedeh, non-cohort net ownership increased slightly between the baseline and 36-month survey rounds. Despite this slight increase, the proportion of nets found hanging in Grand Gedeh decreased within the same time period. In Lofa, households experienced a decrease in non-cohort net ownership between the baseline and 12-month survey rounds and then an increase between 12- and 29-months and 29- and 36-months. Consistent with non-cohort net ownership, the proportion of non-cohort nets found hanging was relatively similar between the baseline and 36-month study rounds.

ITN Survivorship (Attrition and Physical Integrity)

A total of 519/872 (60%) of cohort nets were not found in households at 36 months. In Grand Gedeh, total cohort net attrition was 59% at the 36-month survey round, with the most common reason being given away to others (38%), followed by discarded (also known as attrition due to wear and tear; 11%) and lost for unknown reasons (10%). In Lofa, attrition was 44% at 36-months, of which most nets were given away to others (29%), and fewer were discarded (7%) or lost for unknown reasons (9%). Of nets present in the household, 68% in Grand Gedeh and 78% in Lofa had any holes and the percentage of available nets that were classified as serviceable was 91% and 89%, 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 70% in Grand Gedeh and 77% in Lofa, with an estimated median survival time of 4.0 and 4.6 years, respectively.

Insecticidal Effectiveness

At each data collection round, thirty campaign nets were collected in each study site for bioassay and chemical content testing. Baseline results stratified by study site are not available because net identifiers were not correctly recorded. At 36-months, a higher proportion of nets in Lofa were optimally effective compared to in Grand Gedeh (83% versus 60%, p=0.038). DuraNet, the campaign net in Grand Gedeh and Lofa, is manufactured with 5.8 g/kg alpha-cypermethrin. At 29-months, chemical content results showed a 4.2 g/kg mean of alpha-cypermethrin in both Grand Gedeh and Lofa, corresponding to a 28% loss compared to the original target dose (5.8 g/kg). Results for nets sampled at 36-months show a slight increase in alpha-cypermethrin dose, with a mean 4.8 g/kg in Grand Gedeh and 4.6 g/kg in Lofa, corresponding to a loss of 17% and 22% 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, 29 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	
Grand Gedeh (DuraNet)	First: 4.4	0.0	99.7 (N=380)	34.4	87.4	N/A
	Second: 12.5	1.2	98.9 (N=278)	53.3	73.3	86.7
	Third: 28.7	8.6	96.4 (N=162)	77.3	89.0	53.3
	Fourth: 35.9	10.9	90.5 (N=124)	63.7	67.3	60.0
Lofa (DuraNet)	First: 4.0	0.0	99.7 (N=379)	29.7	83.6	N/A
	Second: 12.8	2.9	98.5 (N=263)	48.0	75.5	86.7
	Third: 28.2	4.0	93.2 (N=221)	67.9	85.4	90.0
	Fourth: 36.1	6.9	88.5 (N=138)	63.6	83.7	83.3

Conclusion

Total campaign net attrition was lower in Lofa than in Grand Gedeh (44% versus 59%) and nets in Grand Gedeh exhibited overall poorer net physical integrity. At the 36-month survey round, survivorship of DuraNet nets in Grand Gedeh (70%, estimated median survival: 4.0 years) and Lofa (77%, estimated median survival: 4.6 years) were similar.Net durability risk factors were remarkably similar across study sites and in both Grand Gedeh and Lofa, most risk factors decreased between the baseline and 36-month survey rounds. Despite this, an increase in the proportion of respondents who cook food in a room used for sleeping and who use detergent or bleach to wash their nets increased from the start of the study to the final 36-month survey round.

1. BACKGROUND

The proportion of households owning at least one insecticide treated net (ITN) has increased in Liberia, from 59% (2016 MIS) to 49% (2019 DHS) in urban zones and from 65% to 63% in rural areas during the same period[2]. However, at the population-level, net use remains far below the 2020 target of 80% set in the Liberia National Malaria Strategic Plan 2016-2020[3]. Population access to a net measures the proportion of the population that would be able to use a net if each net in a household was used by two people; in 2019 this figure was 39% in urban zones and 45% in rural zones. However, only 37% of the population in urban zones and 43% of the population in rural zones reportedly used a net the previous night. The net use:access ratio, which measures population-level use in relation to population-level access to a net ranges from 0.91 in South Eastern B region to 1.0 in North Western region.[4] Values lower than 0.6 are classified as "poor" and those between 0.6 and 0.8 are "below target" and imply that improvements are required. All of the use:access ratios for each region in Liberia are at or above the threshold of 0.80.

The importance of net field durability and estimating the *average useful life* of a net is one of the critical factors NMCPs need to know to determine the frequency with which nets should be replaced. The World Health Organization (WHO) recommends that countries routinely monitor net durability following mass distribution campaigns. To this end, standard guidance has been developed with funding from PMI.[5] Durability monitoring generates data on survivorship (attrition and physical integrity), insecticidal effectiveness, and insecticide chemical content of nets 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 Liberia, PMI is supporting durability monitoring of nets distributed during the 2018 mass campaign in two counties in Liberia (Grand Gedeh in South Eastern A region and Lofa in North Central region). These counties were selected purposively in coordination with the NMCP to establish two different locations in which DuraNet ITNs were distributed. DuraNet is polyethylene net treated with alpha-cypermethrin and was pre-qualified by WHO in December 2017.

This study will provide the NMCP, PMI, and net partners with data on survivorship (attrition and physical integrity) and insecticidal effectiveness of nets 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 Liberia intends to:

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[2] U.S. President's Malaria Initiative Liberia Malaria Operational Plan FY 2020. Retrieved from (www.pmi.gov)

[4]Koenker, H., Olapeju, B., Toso, M., & Ricotta, E. Insecticide-Treated Nets (ITN) Access and Use Report. Breakthrough ACTION and PMI VectorWorks projects, Johns Hopkins Center for Communication Programs. Published August 2019. Updated April 2020. Retrieved from http://itnuse.org/.

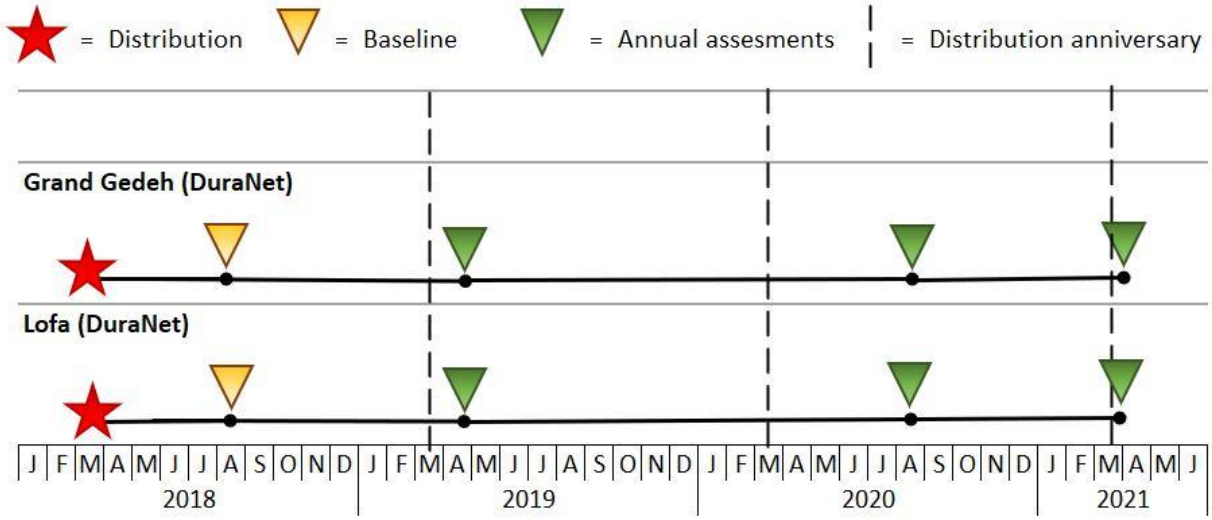
[4]Koenker, H., Olapeju, B., Toso, M., & Ricotta, E. Insecticide-Treated Nets (ITN) Access and Use Report. Breakthrough ACTION and PMI VectorWorks projects, Johns Hopkins Center for Communication Programs. Published August 2019. Updated April 2020. Retrieved from http://itnuse.org/.

[5] www.durabilitymonitoring.org

1. Assess the physical durability (attrition and physical integrity) of DuraNet, a 150-denier polyethylene net coated with alpha-cypermethrin (5.8 g/kg w/w ±25%) in two locations (Grand Gedeh and Lofa) over a three-year period and estimate median net 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 August 1-16, 2018 and the first survey round was conducted April 15 - May 1, 2019 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 the 29- and 36-month survey rounds were completed. Data collection for the 29-month survey round was conducted August 8-26, 2020 (originally set to be a 24-month survey round but was delayed due to the COVID-19 pandemic restrictions), and the end line 36-month survey round was conducted March 29 - April 6, 2021.

FIGURE 1: DURABILITY MONITORING TIMELINE

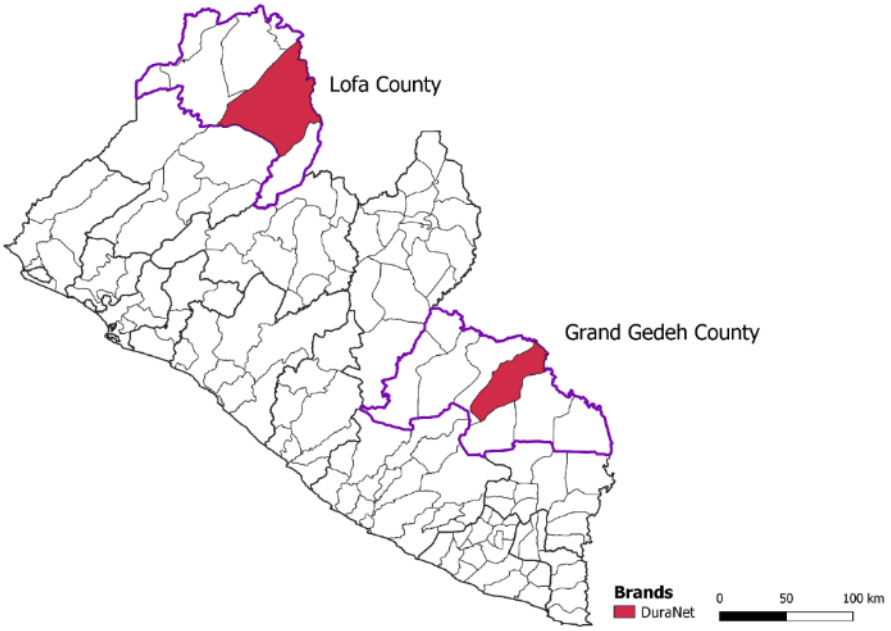


2. METHODS

2.1 STUDY SITES

In coordination with the NMCP and PMI, study sites were selected to represent two different ecological locations set to receive the same brand of nets. The South Eastern A and North Central regions were selected and within them, the two counties of Grand Gedeh (population 125,258 in 2008) and Lofa (population 276,863 in 2008), respectively, were identified as study sites (Figure 2).

FIGURE 2: STUDY SITE MAP



Lofa is situated in the north of Liberia within the Northern Tropical Monsoon climate zone. Average annual rainfall is 2,921 mm. The economy of the region is predominantly based on agriculture. Grand Gedeh is situated among Tropical Monsoon, Tropical Rainforest, and Tropical Savannah climate zones and the average rainfall is 2,019 mm[6]. Rainy season in both study sites occurs from May – October each year. The malaria situation and ITN coverage in both counties is shown in Table 1, based on the 2016 Liberia Malaria Indicator Survey (MIS).

[6] https://en.climate-data.org/africa/liberia/grand-gedeh-county/zwedru-53086/

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
Grand Gedeh	66%	53%	54%	0.98
Lofa	69%	49%	51%	0.96

Source: Liberia Institute of Statistics and Geo-Information Services (LISGIS), Ministry of Health [Liberia], and ICF. 2021. Liberia Demographic and Health Survey 2019-20. Monrovia, Liberia and Rockville, Maryland, USA: Liberia Institute of Statistics and Geo-Information Services (LISGIS), Ministry of Health, and ICF.
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 net brand monitored was DuraNet, 150-denier polyethylene net in blue color. The product incorporates 5.8 g/kg alpha-cypermethrin into the fibers of the net. DuraNet received full WHO Pesticide Evaluation Scheme (WHOPES) recommendation in 2013 (16th WHOPES Report) and was WHO pre-qualified in December 2017.

2.3 STUDY DESIGN SUMMARY

The principal study design was that of a prospective study of cohort of nets distributed through a mass campaign. The baseline round was conducted four months following the mass campaign, during which a representative sample of campaign nets from the study sites 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-, 29- 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 behaviors for the net. These characteristics are used to identify household- and respondent-level risk factors for net survivorship.

The sample size was estimated using the standard template from the durability monitoring toolkit, which indicated 15 clusters of 12 households would generate an expected number of 362 nets in each study site, or 724 nets in total. This sample size is targeted at detecting a deviation of 9-10%-points from the expected 50% survival after three years comparing the two sites (i.e. detecting a difference of at least 41% [poorest result] to 59% [best result]). These figures correspond to a median survival difference across sites of about 0.5 years; the minimum difference which has historically been considered important to detect for the purposes of campaign planning.

At baseline, the net cohort in each site 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. Households were geolocated to facilitate subsequent visits.

In addition to the labeled nets 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 29-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 net in exchange for the one withdrawn for the study. Bioassays for this survey round are being

conducted by VectorLink Liberia in accordance with standard WHO guidelines for cone and tunnel tests (where appropriate).[7] Chemical content analysis for this study was conducted by CDC Atlanta.

2.4 Training and Fieldwork

Fieldwork was conducted by an implementation team of 11 people. Fieldwork was overseen by a dedicated study coordinator and conducted by two teams of five people each. The team was supported by one representative from the NMCP. 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 29-month survey round.

Online training of trainers took place on March 9, 11, and 12, 2021 with three days of remote instruction led by VectorLink research staff experienced in durability monitoring. In-person interview training took place in Monrovia from March 15 – 19, 2021 and entailed three days of classroom-based training and one field practice day in a local community with support from VectorLink Liberia, NMCP, and University of Liberia - Pacific Institute for Research & Evaluation (UL-PIRE) 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 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 survey round 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. Questions to be used for analysis of nets selected for bioassay were included in the cohort 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 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.

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

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 nets 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.[8] Data from the net hole assessment was transformed into the proportionate Hole Index (pHI) for each net 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, nets were classified as "good", "serviceable" or "torn" as defined below. Note that "good" is a subset of all "serviceable" nets.

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 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 survey round, the median net survival was calculated, using the last two time points; the lowest is below 85%, 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, and p1 and p2 are 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.

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

The outcomes of insecticidal effectiveness were based on the bioassay results using the standard WHO cone test performed by VectorLink Liberia. A susceptible *Anopheles coluzzii* strain 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 nets selected for bioassays were packaged following standard procedures and shipped to CDC Atlanta for chemical content testing. Outcome measures from these tests present the mean and median level of active ingredient across the net brand samples in g/kg 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 29- and 36-month survey rounds. 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 UL-PIRE, NMCP, and VectorLink and was run in 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 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 VectorLink Liberia. 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, one household was screened out of data collection during this survey round due to their COVID-19 risk. Additional IRB approval was sought before fieldwork began, as described below.

2.8 ETHICAL CLEARANCE

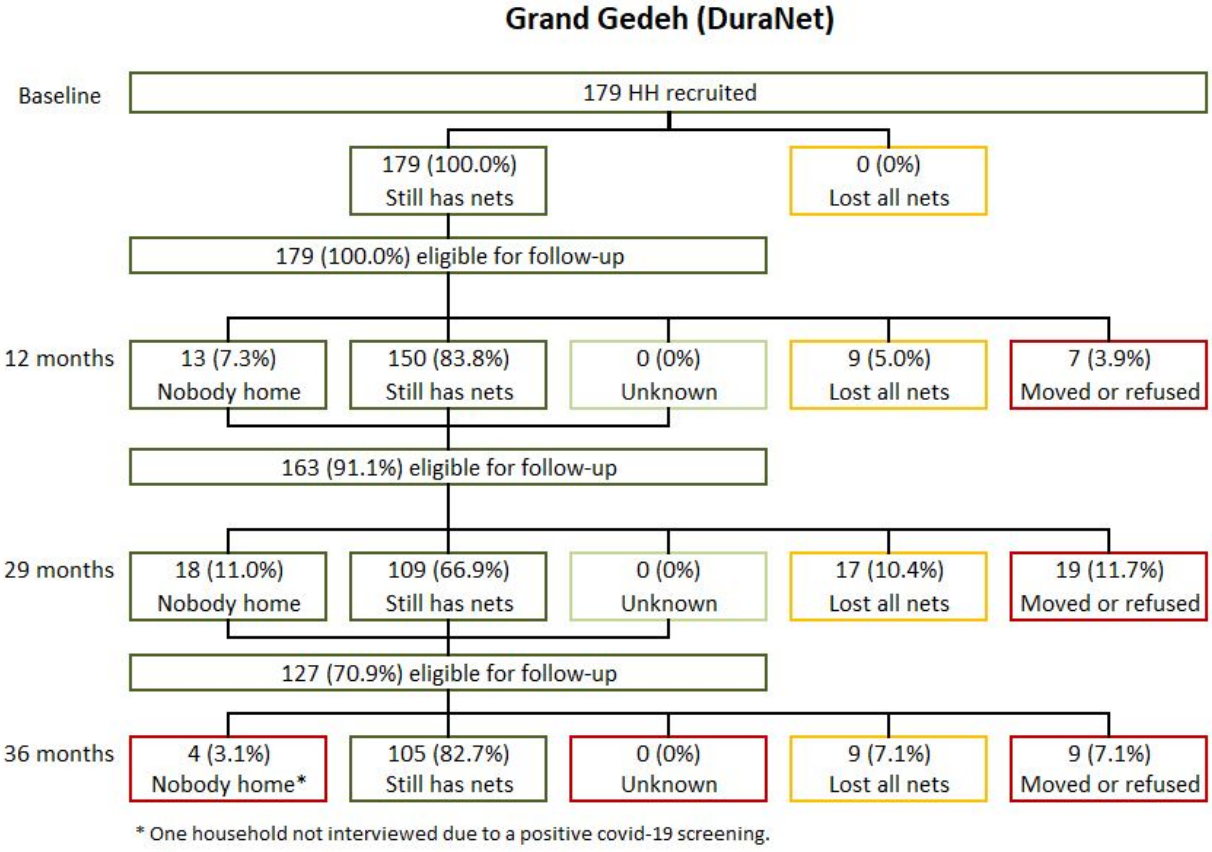
This study has been determined to be research with human subjects and received written continuing approval from UL-PIRE on June 8, 2020 under reference number FWA00004853. The PSI Research Ethics Board (REB) granted authorization on March 17, 2020. A third application was submitted to the PSI REB to obtain approval to resume activities under COVID-19 and authorization was granted on March 12, 2021. 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.

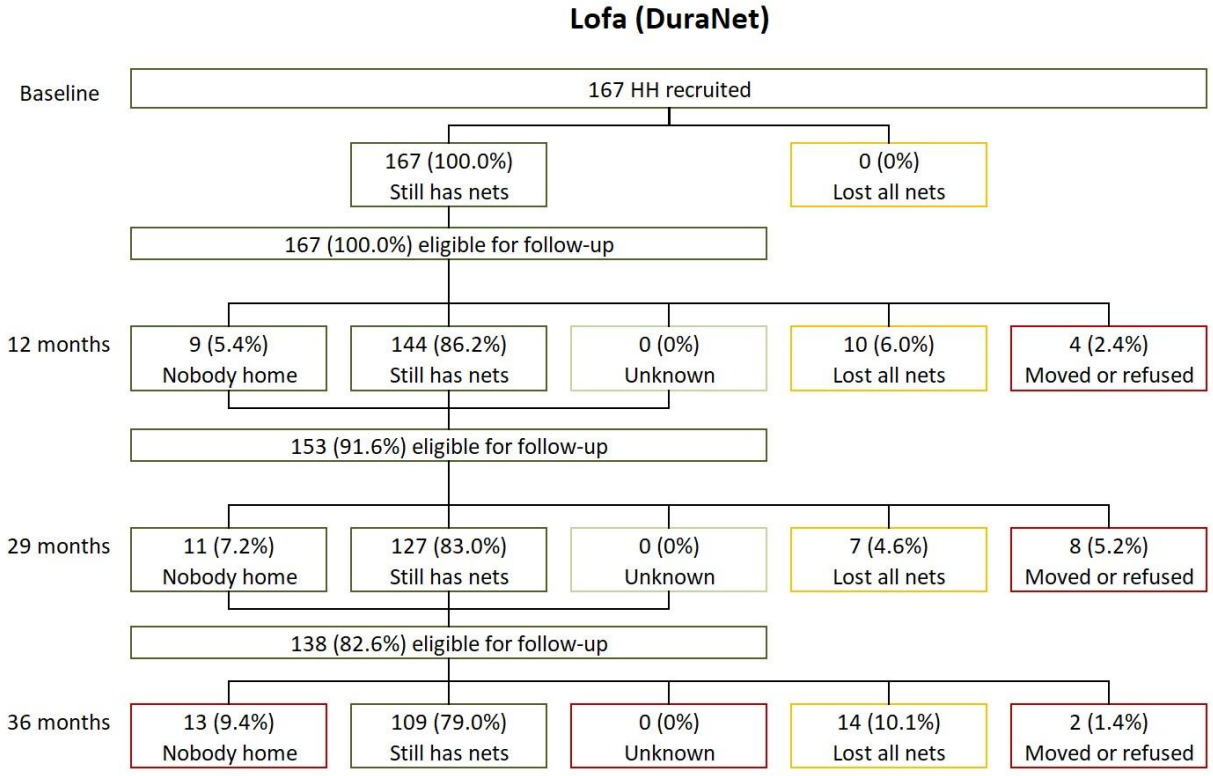
3. RESULTS

3.1 SAMPLE

At baseline, a total of 346 households were recruited for durability monitoring (179 in Grand Gedeh and 167 in Lofa), of which 265 households (127 in Grand Gedeh and 138 in Lofa) were eligible for follow-up at 36-months (Figure 3). Of the 127 eligible households in Grand Gedeh, 105 still had at least one cohort net, while 9 households no longer had any cohort nets, 4 households had nobody home, and 9 households moved out of the study site. In Lofa, 109 of the 138 eligible households still had cohort nets, 14 no longer had any cohort nets, 13 households had nobody home, and 2 households moved out of the study site.

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



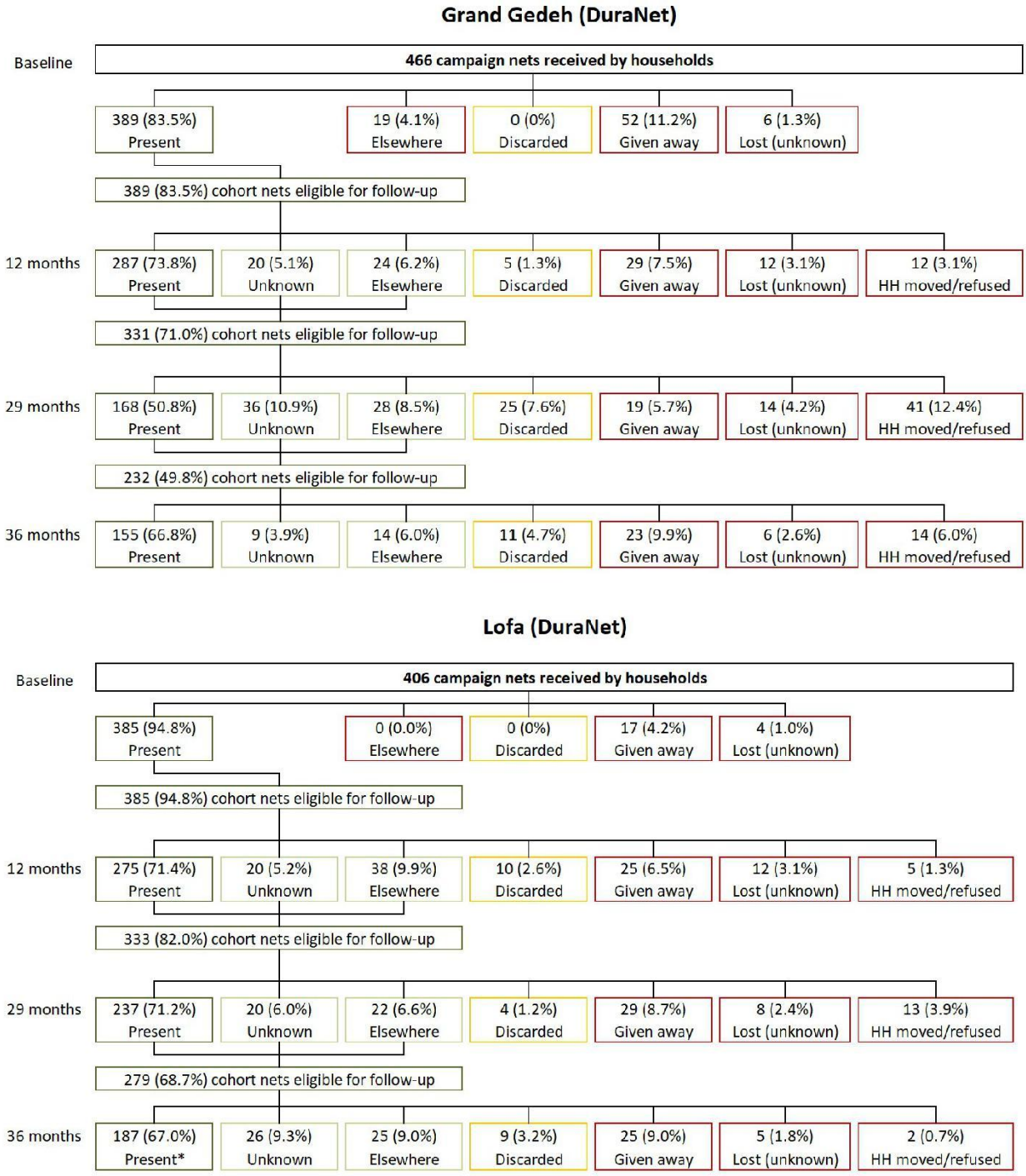


The 346 households visited at baseline reported receiving a total of 872 campaign nets (466 in Grand Gedeh and 406 in Lofa; Figure 4). Of these 872 nets, 774 (389 in Grand Gedeh and 385 in Lofa) were present in the households and were tagged for study follow-up.

In Grand Gedeh at the 12-month survey round, 331 (85%) cohort nets were still in the household, 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 survey round. At 29-months, there were 232 nets either present, that had an unknown status, or said to be with a family member elsewhere. At 36-months, 155 were nets still in the households, 9 nets had an unknown status and 14 were said to be with a family member elsewhere. Of the nets not in the household, 11 were discarded, 23 were stolen or given to others, and 6 were lost for unknown or other reasons. Among cohort nets reported as present at each survey round, 6, 10, and 18 net were unavailable for assessment at 12-months, 29-months and 36-months respectively, due to being temporarily taken away for washing or stored in locked rooms. An additional 14 nets belonged to households who moved out of the study site or refused to take part in the interview.

In Lofa, at the 12-month survey round 333 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 29-months, 279 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, 187 cohort nets were still in the household, 26 had an unknown status, and 25 were with family members elsewhere. Nine nets were discarded, 25 were given away to others or stolen, 5 were lost due to unknown or other reasons, and 2 could not be assessed because the household moved out of the study site or refused to be interviewed. Among cohort nets reported as present at each survey round, 8, 25, and 31 nets were unavailable for assessment at 12-months, 29-months, and 36-months, respectively due to being temporarily taken away for washing or stored in locked rooms.

FIGURE 4: FOLLOW-UP STATUS OF COHORT NETS 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 rural environments in Grand Gedeh and Lofa counties, with several differences between both sites. At baseline and 36 months, household characteristics were similar in both sites. Almost all households had access to safe water (94% at baseline and 98% at 36 months) and in both sites mobile phone ownership was high (69% at baseline and 87% at 36 months). However, animal husbandry and owning land for farming was more common in Lofa (68% and 74% respectively at 36 months) compared to Grand Gedeh (40% and 44% respectively at 36-months). Additionally, use of firewood as cooking fuel was more common in Lofa (94%) compared to Grand Gedeh (42%; $p<0.001$). Grand Gedeh, had a higher proportion of households owning any means of transportation (59% versus 31%, $p<0.001$) and with access to a latrine (92% versus 42%, $p<0.001$) at 36-months.

TABLE 3: HOUSEHOLD CHARACTERISTICS AND ASSETS

	Baseline	36 months
Grand Gedeh	**N=179**	**N=114**
Roof (sheets/ tile)	89.9%	93.0%
Cooking fuel (firewood)	36.3%	42.1%
Access to safe water	95.0%	96.5%
Access to latrine	84.9%	92.1%
Radio	52.5%	61.4%
Mobile phone	75.4%	82.5%
Any transport	30.2%	58.8%
Animal husbandry	54.2%	39.5%
Owning land for farming	38.5%	43.9%
Lofa	**N=167**	**N=123**
Roof (sheets/ tile)	94.0%	98.4%
Cooking fuel (firewood)	86.8%	94.3%
Access to safe water	93.4%	98.4%
Access to latrine	31.1%	42.3%
Radio	50.3%	52.8%
Mobile phone	62.9%	89.4%
Any transport	15.0%	30.9%
Animal husbandry	73.7%	68.3%
Owning land for farming	79.0%	74.0%

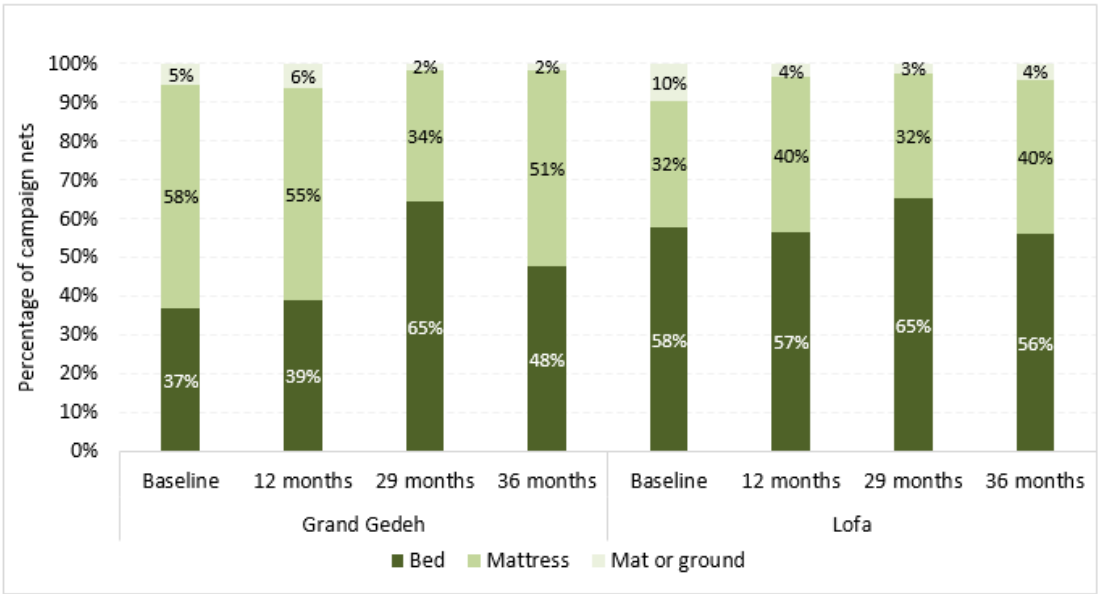
The presence of rodents in the household and the storage of food and practice of cooking near sleeping areas are risk factors for net durability. Table 4 presents the prevalence of these risk factors at 36-months. The proportion of households ever storing food in a room used for sleeping was lowest at 36-months for both study sites and was lower in Grand Gedeh compared to Lofa (75% versus 89%, $p=0.044$). Almost all households reported never cooking in a room used for sleeping (>98% in both study sites). In Grand Gedeh, a higher proportion of households reported observing rodents in the past six months compared to in Lofa (95% versus 88% in Lofa, $p=0.050$).

TABLE 4: PREVALENCE OF HOUSEHOLD RISK FACTORS FOR DAMAGE

	Baseline	12 months	29 months	36 months
Grand Gedeh	**N=178**	**N=159**	**N=126**	**N=114**
Ever store food in room used for sleeping	92.1%	92.5%	81.7%	74.6%
Cook in sleeping room				
Never	100.0%	95.0%	92.1%	97.4%
Sometimes	0.0%	3.8%	6.3%	1.8%
Always	0.0%	1.3%	1.6%	0.9%
Observed rodents in last 6 months	97.8%	97.5%	93.7%	94.7%
Lofa	**N=167**	**N=154**	**N=134**	**N=123**
Ever store food in room used for sleeping	91.0%	98.1%	91.8%	88.6%
Cook in sleeping room				
Never	95.2%	96.1%	93.3%	99.2%
Sometimes	4.2%	3.2%	6.7%	0.8%
Always	0.6%	0.6%	0.0%	0.0%
Observed rodents in last 6 months	95.8%	98.1%	87.3%	87.8%

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 spaces were used with cohort nets by site and study round. Figure 5 shows which types of sleeping spaces were used with cohort nets by site and survey round. There were no significant differences in type of sleeping place where nets were used between study sites. In both sites, less than 5% of nets were used over a mat or the ground and approximately half were used over a bed frame (48% in Grand Gedeh, 56% in Lofa) at the 36-month end line survey round.

FIGURE 5: TYPE OF SLEEPING PLACE FOR CAMPAIGN NETS 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 Lofa (81%) compared to Grand Gedeh (74%) had ever been washed (p=0.037).

Other net washing practices were nearly identical across study sites. Among washed nets, the median number of washes in the six months prior to the survey was two in Grand Gedeh and Lofa. A similar proportion of nets in Grand Gedeh (55%) and Lofa (53%) were washed using detergent or bleach and drying washed nets on a bush or fence was rare (0% in Grand Gedeh, 1% in in Lofa). Among nets reported as hanging, 63% in both study sites were found hanging loose.

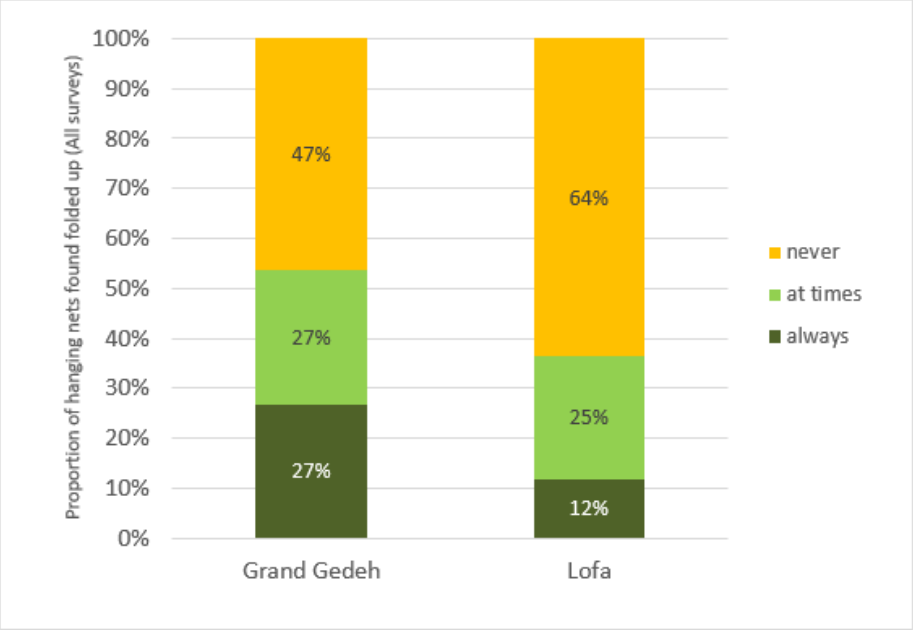
TABLE 5: PREVALENCE OF HANDLING RISK FACTORS FOR CAMPAIGN NETS

	Baseline	12 months	29 months	36 months
Grand Gedeh	**N=388**	**N=287**	**N=168**	**N=151**
Nets ever washed	8.2%	38.0%	63.7%	73.5%
Among nets ever washed:	N=32	N=109	N=107	N=111
Median number of washes in last 6 months [IQR]	1.0 [1.0-2.0]	2.0 [1.0-3.0]	2.0 [1.0-4.0]	2.0 [1.0-3.0]
Used detergent or bleach for last wash	46.9%	65.1%	58.9%	55.0%
Nets dried on bush or fence for last wash	0.0%	4.6%	0.0%	0.0%
Among hanging nets:	N=134	N=153	N=113	N=98
Hanging nets are not folded or tied up	69.4%	57.5%	57.5%	63.3%
Lofa	**N=379**	**N=275**	**N=237**	**N=187**
Nets ever washed	17.2%	44.4%	71.3%	80.7%
Among nets ever washed:	N=65	N=120	N=169	N=151
Median number of washes in last 6 months [IQR]	1.0 [1.0-2.0]	2.0 [1.0-3.0]	2.0 [1.0-3.0]	2.0 [1.0-3.0]
Used detergent or bleach for last wash	32.3%	85.8%	46.7%	53.0%
Nets dried on bush or fence for last wash	3.2%	2.5%	0.0%	0.7%
Among hanging nets:	N=114	N=132	N=161	N=119
Hanging nets are not folded or tied up	90.4%	81.8%	73.3%	63.0%

IQR: interquartile range

Folding or tying up a hanging net can protect it from damage. Considering cohort nets that were found hanging in one or more survey rounds, a higher proportion of cohort nets were always found folded up in Grand Gedeh (27%) compared to Lofa (12%) although the difference was not statistically significant (p=0.059; Figure 6). Conversely, 47% of nets in Grand Gedeh and 64% of nets in Lofa were never 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. Exposure to any information in the six months preceding the surveys decreased from 77% at baseline in 2018 to 27% at 36-months in 2021 in Grand Gedeh and 43% at baseline in 2018 to 25% at 36-months in 2021 in Lofa. Among those that were exposed to messaging, close to half of respondents obtained information through both interpersonal communication (e.g. health workers, friends/family, and community leaders or events) and media (45% in Grand Gedeh, 42% in Lofa) at the 36-month survey round in 2021. In both counties, the most commonly recalled messages among exposed respondents at 36-months was "use net every night" (97%), "hang net" (95%), and "care for net" (90%). There were no statistically significant differences in net messaging across study sites.

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

	Baseline	12 months	29 months	36 months
Grand Gedeh	**N=179**	**N=158**	**N=126**	**N=114**
Any exposure in last 6 months	77.1%	53.2%	23.8%	27.2%
Among those exposed:	N=138	N=84	N=30	N=31
Mean number of sources among exposed*	3.4	3.8	1.8	2.3
Type of media source among exposed				
Media only	0.0%	3.6%	16.7%	29.0%
Interpersonal communication only	65.2%	52.4%	56.7%	25.8%
Both	34.8%	44.0%	26.7%	45.2%
Messages recalled among exposed				
"Use net (every) night"	92.8%	94.0%	100.0%	93.5%
"Hang net"	95.7%	91.7%	96.7%	93.5%
"Care for net"	89.1%	86.9%	96.7%	87.1%
"Repair net"	28.3%	28.6%	26.7%	51.6%

	Baseline	12 months	29 months	36 months
"Nets prevent malaria"	81.2%	82.1%	73.3%	87.1%
Lofa	**N=167**	**N=154**	**N=134**	**N=123**
Any exposure in last 6 months	43.1%	51.9%	26.9%	25.2%
Among those exposed:	N=72	N=80	N=36	N=31
Mean number of sources among exposed*	4.1	4.3	3.1	2.4
Type of media source among exposed				
Media only	1.4%	1.3%	11.1%	22.6%
Interpersonal communication only	47.2%	63.7%	36.1%	35.5%
Both	51.4%	35.0%	52.8%	41.9%
Messages recalled among exposed				
"Use net (every) night"	95.8%	96.3%	100.0%	100.0%
"Hang net"	91.7%	97.5%	94.4%	96.8%
"Care for net"	93.1%	93.8%	88.9%	93.5%
"Repair net"	37.5%	51.2%	41.7%	32.3%
"Nets prevent malaria"	86.1%	86.3%	83.3%	90.3%

* The maximum number of sources was 11 and included: community health agent; radio; song; drama; health worker; community leader; shop attendant; town announcer; family/friends; mosque/church; news.

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 end line round, the mean attitude scores for nets and net care and repair in Grand Gedeh and Lofa were above 1.0, indicating an overall positive attitude towards nets and net care and repair. The mean attitude score towards nets (1.63 in Grand Gedeh, 1.64 in Lofa) and the mean attitude score towards net care and repair (1.04 in Grand Gedeh, 1.13 in Lofa) were similar across study sites at 36-month round. Lofa had a higher, but not statistically significant, proportion of respondents with a favorable attitude toward net care and repair (60% versus 46% in Grand Gedeh).

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

	Baseline	12 months	29 months	36 months
Grand Gedeh	**N=179**	**N=159**	**N=126**	**N=114**
Attitude score: Nets				
Mean (95% CI)	1.81 (1.71-1.92)	1.71 (1.63-1.80)	1.71 (1.63-1.79)	1.63 (1.56-1.70)
% respondents with score > 1.0	91.6%	95.6%	94.4%	90.4%
Attitude score: Nets care and repair				
Mean (95% CI)	0.89 (0.79-0.98)	0.78 (0.67-0.89)	0.92 (0.72-1.11)	1.04 (0.91-1.17)

	Baseline	12 months	29 months	36 months
% respondents with score > 1.0	40.2%	32.1%	46.8%	45.6%
Lofa	**N=165**	**N=154**	**N=134**	**N=123**
Attitude score: Nets				
Mean (95% CI)	1.78 (1.70-1.86)	1.67 (1.61-1.74)	1.56 (1.46-1.67)	1.64 (1.57-1.71)
% respondents with score > 1.0	92.7%	96.8%	92.5%	89.4%
Attitude score: Net care and repair				
Mean (95% CI)	0.93 (0.84-1.02)	0.74 (0.65-0.83)	0.88 (0.77-0.98)	1.13 (1.01-1.24)
% respondents with score > 1.0	39.8%	33.1%	34.3%	60.2%

Experience with repairing holes in nets are displayed in Table 8. Across survey rounds, a progressively increasing proportion of respondents reported having ever experienced holes (from an average of 12% at baseline to 63% at 36-months, across both sites). Overall, there were no significant differences in net care and repair experiences between sites. However, a higher proportion of respondents had discussed net care and repair in the six months preceding the survey round in Grand Gedeh (52%) compared with Lofa (37%), even though a higher proportion of households in Lofa (68%) had ever experienced holes compared with Grand Gedeh (55%). Among respondents who reported having holes in their nets, 27% of respondents in Grand Gedeh and 29% of respondents in Lofa had ever repaired a net.

TABLE 8: HOUSEHOLD NET CARE AND REPAIR EXPERIENCE

	Baseline	12 months	29 months	36 months
Grand Gedeh	**N=179**	**N=159**	**N=126**	**N=114**
Ever experienced holes in a net	10.6%	25.8%	44.4%	55.3%
Discussed net care and repair in last 6 months	67.6%	51.6%	47.6%	51.8%
Among households experiencing holes:	N=19	N=41	N=56	N=63
Ever repaired net	26.3%	19.5%	17.9%	27.0%
Lofa	**N=167**	**N=154**	**N=134**	**N=123**
Ever experienced holes in a net	13.2%	20.1%	64.2%	68.3%
Discussed net care and repair in last 6 months	45.5%	44.2%	46.3%	36.6%
Among households experiencing holes:	N=22	N=31	N=86	N=84
Ever repaired net	22.7%	16.1%	22.1%	28.6%

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 untied (40% in Grand Gedeh and Lofa), and second most commonly found hanging and tied (23% in Grand Gedeh and 24% in Lofa). Reported use of cohort nets progressively increased from 39% at baseline to 86% at 36-months in Grand Gedeh, and from 32% to 93% in Lofa. A higher proportion of cohort nets in Lofa, compared to Grand Gedeh, were reportedly used last night (66% versus 53%, p=0.046) and every night last week (65% versus 50%, p=0.005).

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

	Baseline	12 months	29 months	36 months
Grand Gedeh	**N=389**	**N=287**	**N=168**	**N=154**
Cohort net status				
Found hanging and tied up	10.5%	22.6%	28.6%	23.4%
Found hanging, untied	23.9%	30.7%	38.7%	40.3%
Not hanging and not stored away	7.7%	3.8%	4.8%	5.8%
Stored away unpacked	30.8%	26.1%	15.5%	16.2%
Stored away in a package	24.9%	14.6%	6.5%	2.6%
Temporarily unavailable during visit	2.1%	2.1%	6.0%	11.7%
Net ever used	38.7%	64.5%	84.5%	86.1%
Net used last night	35.5%	52.3%	61.9%	52.9%
Net used every night last week	34.5%	53.7%	60.7%	49.7%
Lofa	**N=384**	**N=275**	**N=237**	**N=187**
Cohort net status				
Found hanging and tied up	2.9%	8.7%	18.1%	23.5%
Found hanging, untied	26.8%	39.3%	49.8%	40.1%
Not hanging and not stored away	1.3%	3.3%	3.8%	8.6%
Stored away unpacked	39.1%	29.1%	12.7%	8.6%
Stored away in a package	28.6%	16.7%	5.1%	2.7%
Temporarily unavailable during visit	1.3%	2.9%	10.5%	16.6%
Net ever used	32.0%	62.5%	85.7%	92.5%
Net used last night	31.2%	48.0%	65.4%	66.3%
Net used every night last week	30.7%	50.9%	60.3%	64.7%

Each survey round documented 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.

The proportion of households with non-cohort nets stayed relatively stable from baseline (47% in Grand Gedeh and 43% in Lofa) to 36-months (60% in Grand Gedeh and 61% in Lofa). At 36-months, the proportion of households with non-cohort nets in Grand Gedeh and Lofa was similar (60% in Grand Gedeh, 59% in Lofa). The majority of non-cohort nets at 36-months came from public sources (ANC visits, a previous net campaign, other public sources) (69% in Grand Gedeh, 67% in Lofa) and a much smaller proportion came from private sources (19% in Grand Gedeh, 8% in Lofa). A higher proportion of non-cohort nets came from other sources (family/friends, NGOs) in Lofa (26%) versus Grand Gedeh (12%; p=0.034).

TABLE 10: OWNERSHIP AND SOURCE OF NON-COHORT NETS

	Baseline	12 months	29 months	36 months
Grand Gedeh	**N=179**	**N=159**	**N=126**	**N=114**
Households with any non-cohort nets	55.9%	52.8%	46.8%	59.6%
Non-cohort net sources	**Net N=149**	**Net N=122**	**Net N=82**	**Net N=119**
ANC visit	4.0%	9.8%	20.7%	31.1%

	Baseline	12 months	29 months	36 months
Previous mass campaign	64.4%	54.9%	25.6%	23.5%
School	0.0%	0.0%	0.0%	0.0%
Other public source*	15.4%	18.0%	12.2%	14.3%
Private sector	8.7%	4.9%	17.1%	19.3%
Other/doesn't recall**	7.4%	12.3%	24.4%	11.8%
Lofa	**N=167**	**N=154**	**N=134**	**N=123**
Households with any non-cohort nets	60.5%	42.9%	45.5%	59.3%
Non-cohort net sources	**Net N=151**	**Net N=116**	**Net N=82**	**Net N=117**
ANC visit	0.0%	8.6%	28.0%	23.9%
Previous mass campaign	79.5%	63.8%	34.1%	34.2%
School	0.0%	0.0%	0.0%	0.0%
Other public source*	9.9%	6.9%	17.1%	8.5%
Private sector	3.3%	6.0%	8.5%	7.7%
Other/doesn't recall**	7.3%	14.7%	12.2%	25.6%

* 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 236 non-cohort nets (119 in Grand Gedeh and 117 in Lofa) were audited in study households at the 36-month end line round (Table 11). A higher proportion of non-cohort nets in Lofa compared to Grand Gedeh were ever used (94% versus 78%, p=0.016) and used every night last week (66% versus 46%, p=0.013). For all net use indicators, the proportion of cohort nets and non-cohort nets used was similar in Grand Gedeh and Lofa. At 36-months, non-cohort nets were most commonly found hanging and tied (37%) in Grand Gedeh and hanging and untied in Lofa (54%). The second most common net status was hanging and untied in Grand Gedeh (30%) and hanging and tied in Lofa (30%).

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

	Baseline	12 months	29 months	36 months
Grand Gedeh	**N=150**	**N=120**	**N=82**	**N=119**
Non-cohort net status				
Found hanging and tied up	30.7%	32.5%	31.7%	37.0%
Found hanging, untied	56.7%	40.8%	57.3%	30.3%
Not hanging and not stored away	6.0%	4.2%	1.2%	3.4%
Stored away unpacked	4.0%	16.7%	6.1%	9.2%
Stored away in a package	1.3%	3.3%	1.2%	15.1%
Temporarily unavailable during visit	1.3%	2.5%	2.4%	5.0%
Net ever used	92.7%	86.1%	97.6%	78.2%
Net used last night	84.2%	66.4%	84.1%	58.8%
Net used every night last week	85.4%	66.4%	80.5%	46.2%
Lofa	**N=152**	**N=114**	**N=82**	**N=117**
Non-cohort net status				
Found hanging and tied up	13.2%	16.7%	13.4%	29.9%
Found hanging, untied	70.4%	58.8%	72.0%	53.8%
Not hanging and not stored away	7.2%	1.8%	1.2%	1.7%

	Baseline	12 months	29 months	36 months
Stored away unpacked	5.9%	9.6%	2.4%	6.0%
Stored away in a package	0.7%	9.6%	8.5%	5.1%
Temporarily unavailable during visit	2.6%	3.5%	2.4%	3.4%
Net ever used	91.5%	89.7%	90.2%	94.0%
Net used last night	79.4%	76.5%	81.7%	70.9%
Net used every night last week	83.7%	73.3%	79.3%	65.8%

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, the highest proportion of cohort nets were used by adults only in Grand Gedeh (61%) and Lofa (58%). Non-cohort nets were also most commonly used by adults only (61% in Grand Gedeh, 52% in Lofa). Cohort and non-cohort nets were rarely used by children only in either study site (1% for cohort nets and 2-3% for non-cohort nets).

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

	Baseline	12 months	29 months	36 months
Grand Gedeh	**N=138**	**N=150**	**N=104**	**N=82**
Cohort nets				
Used by child(ren) only	8.7%	6.0%	3.8%	1.2%
Used by child(ren) sharing with adult(s)	41.3%	40.7%	27.9%	37.8%
Used by adult(s) only	50.0%	53.3%	68.3%	61.0%
Lofa	**N=120**	**N=132**	**N=155**	**N=124**
Cohort nets				
Used by child(ren) only	6.7%	3.0%	5.8%	1.6%
Used by child(ren) sharing with adult(s)	35.8%	36.4%	45.2%	40.3%
Used by adult(s) only	57.5%	60.6%	49.0%	58.1%

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	29 months	36 months
Grand Gedeh	**N=128**	**N=81**	**N=69**	**N=70**
Non-cohort nets				
Used by child(ren) only	3.1%	4.9%	5.8%	2.9%
Used by child(ren) sharing with adult(s)	42.2%	40.7%	34.8%	35.7%
Used by adult(s) only	54.7%	54.3%	59.4%	61.4%
Lofa	**N=123**	**N=88**	**N=67**	**N=83**
Non-cohort nets				
Used by child(ren) only	10.6%	5.7%	7.5%	2.4%
Used by child(ren) sharing with adult(s)	39.8%	43.2%	38.8%	45.8%
Used by adult(s) only	49.6%	51.1%	53.7%	51.8%

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

Access can be measured at the household and population level (Table 14). Household access is defined as the proportion of households with one net for every two people in the household; population access is defined as the proportion of people that could sleep under an net assuming each net in a household was used by 2 people. By both measures, access to cohort nets decreased from baseline to 36-months in Grand Gedeh and Lofa. Overall, at 36-months, household and population access to cohort Nets was similar in Grand Gedeh (32% and 49%) and Lofa (32% and 56%) (population access: p=0.169). Although measures of cohort net access were similar between sites, population cohort net use was higher in Lofa compared to in Grand Gedeh (41% versus 30% in Grand Gedeh, p=0.018).

TABLE 14: HOUSEHOLD AND POPULATION NET ACCESS

	Baseline	36 months
Grand Gedeh		
Household access	**N=179**	**N=111**
All nets	77.1%	54.1%
Campaign cohort nets (DuraNet)	62.6%	32.4%
Other nets	17.3%	21.6%
Population access	**N=751**	**N=605**
All nets	87.9%	72.4%
Campaign cohort nets (DuraNet)	78.6%	49.1%
Other nets	34.2%	35.7%
Population use	**N=751**	**N=605**
All nets	N/A	52.7%
Campaign cohort nets (DuraNet)	N/A	29.8%
Other nets	N/A	23.0%
Lofa		
Household access	**N=167**	**N=122**
All nets	78.4%	57.4%
Campaign cohort nets (DuraNet)	64.7%	32.0%
Other nets	20.4%	16.4%
Population access	**N=674**	**N=654**
All nets	89.9%	77.1%
Campaign cohort nets (DuraNet)	81.9%	56.0%
Other nets	37.7%	32.7%
Population use	**N=674**	**N=654**
All nets	N/A	67.4%
Campaign cohort nets (DuraNet)	N/A	41.4%
Other nets	N/A	26.1%

3.4 DURABILITY OF CAMPAIGN NETS

The durability of nets 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-, 29- and 36-month rounds. Of the 466 cohort nets at baseline in Grand Gedeh and 406 in Lofa, 376 (81%) and 335 (83%) 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 lack of more precise respondent

recall, 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 were not tagged and are considered as given away to others.

In Grand Gedeh, the total campaign net attrition increased from 17% at baseline to 59% at 36-months (Table 15, Figure 7). In Lofa, total campaign attrition increased from 5% to 44% in the same time frame. At 36-months, attrition was higher in Grand Gedeh than in Lofa (59% versus 44%, $p<0.001$). During all survey rounds, the most common reason for attrition was given away to others in both study sites. The proportion of cohort nets given away to others during the end line survey was higher in Grand Gedeh (38%) compared to Lofa (29%), although the difference was not statistically significant ($p=0.06$). Prior to baseline data collection, 19 nets (all in Grand Gedeh) were reportedly used by families elsewhere and were classified as given away to others.

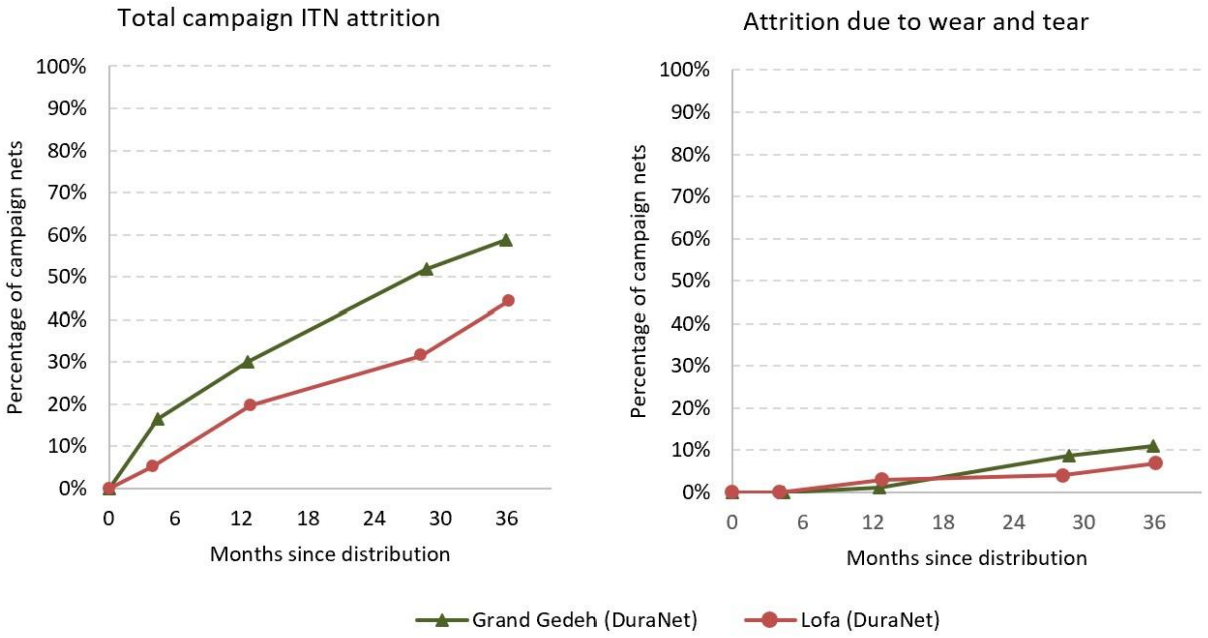
TABLE 15: CAMPAIGN COHORT NET ATTRITION

	Baseline	12 months	29 months	36 months
Grand Gedeh	**N=466**	**N=410**	**N=349**	**N=376**
Total campaign net attrition	16.5%	30.0%	51.9%	58.8%
Nets given away to others	15.2%	24.4%	34.1%	37.8%
Nets discarded	0.0%	1.2%	8.6%	10.9%
Nets lost for other/unknown reason	1.3%	4.4%	9.2%	10.1%
Lofa	**N=406**	**N=343**	**N=346**	**N=335**
Total campaign Net attrition	5.2%	19.8%	31.5%	44.2%
Net given away to others	4.2%	12.2%	20.5%	28.7%
Net discarded	0.0%	2.9%	4.0%	6.9%
Net lost for other/unknown reason	1.0%	4.7%	6.9%	8.7%

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 net durability, physical integrity, is a primary study objective. Data from the net hole assessment was transformed into the proportionate Hole Index (pHI) for each net 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, nets were classified as "good", "serviceable" or "torn" as defined below. Note that "good" is a subset of all "serviceable" nets.

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 Grand Gedeh, the proportion of cohort nets with any holes increased from 4% at baseline to 68% at 36-months and in Lofa it increased from 8% to 78%. At 36-months, the proportion of nets classified as good, too torn, and serviceable were similar in Grand Gedeh and Lofa. Among cohort nets with any holes, the median pHI in Grand Gedeh (55) and Lofa (78) met or nearly met the pHI classification of "good" (pHI < 64).

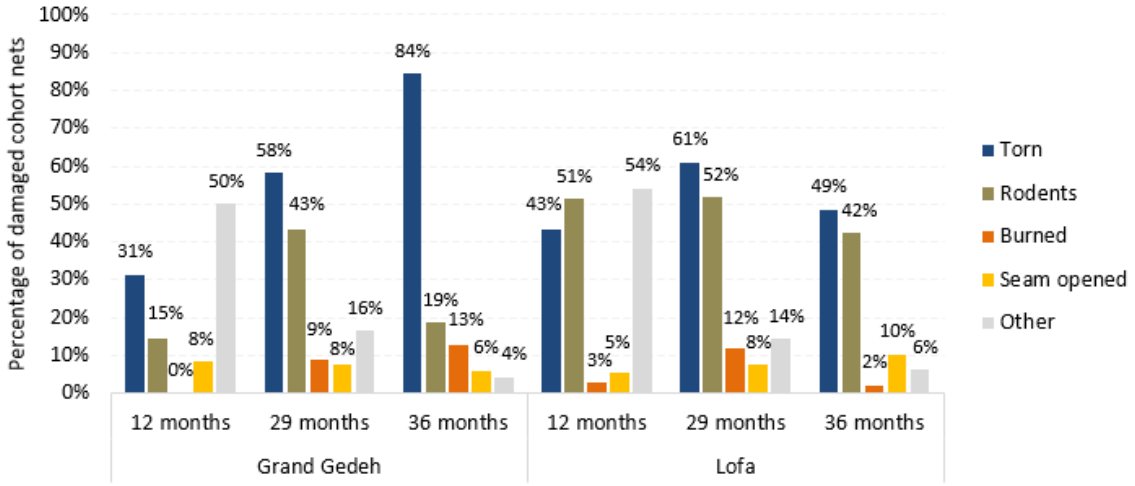
TABLE 16: PHYSICAL INTEGRITY OF OBSERVED CAMPAIGN COHORT NETS

	Baseline	12 months	29 months	36 months
Grand Gedeh	**N=381**	**N=281**	**N=168**	**N=137**
Cohort net with any holes	3.9%	16.0%	44.0%	67.9%

	Baseline	12 months	29 months	36 months
Nets classified as "Good"	99.0%	94.3%	81.5%	67.2%
Nets classified as "Too torn"	0.3%	1.1%	3.6%	9.5%
Nets classified as "Serviceable"	99.7%	98.9%	96.4%	90.5%
Among nets with any holes:	N=15	N=45	N=74	N=93
Median pHI for nets with any holes	7.0	10.0	47.0	55.0
Lofa	**N=380**	**N=267**	**N=237**	**N=156**
Cohort net with any holes	8.2%	13.1%	55.7%	77.6%
Nets classified as "Good"	97.1%	95.5%	74.7%	57.7%
Nets classified as "Too torn"	0.3%	1.5%	6.8%	11.5%
Nets classified as "Serviceable"	99.7%	98.5%	93.2%	88.5%
Among nets with any holes:	N=31	N=35	N=132	N=121
Median pHI for nets with any holes	47.0	28.0	55.5	78.0

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 damage mechanisms in Lofa across survey rounds were tearing on an object and damage by rodents (49% and 42% respectively at 36 months). At 36-months, a higher proportion of nets in Lofa were damaged by rodents compared to in Grand Gedeh (42% versus 19% in Grand Gedeh, p=0.006) while damage from tears was more common in Grand Gedeh (84% versus 49% in Lofa, p=0.001). Damage mechanisms in the "other" category include damage by children, insects, and general material deterioration.

FIGURE 8: TYPES OF DAMAGE MECHANISMS REPORTED FOR DAMAGED CAMPAIGN NETS AT 12-, 29-, AND 36-MONTHS OF FOLLOW-UP



Net survivorship combines the two aspects of durability (attrition and physical integrity) and is defined as the proportion of campaign nets 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 were not included.

Table 17 reports the survival of cohort nets from baseline to 36-months. At every survey round, the proportion of cohort nets that had survived were similar in Grand Gedeh and Lofa. After 36-months of field use, the proportion of surviving cohort nets was 70% in Grand Gedeh and 77% in Lofa. Similar survivorship in Grand Gedeh and Lofa is supported by previous findings showing lower net attrition in Lofa but overall poorer net physical integrity in Grand Gedeh (trends as such, although differences in physical integrity not statistically significant). The proportion of surviving cohort nets ever-used and present were similar in Grand Gedeh (92%) and Lofa (87%) at the 36-month end line survey.

TABLE 17: CAMPAIGN COHORT NETS SURVIVING IN SERVICEABLE CONDITION

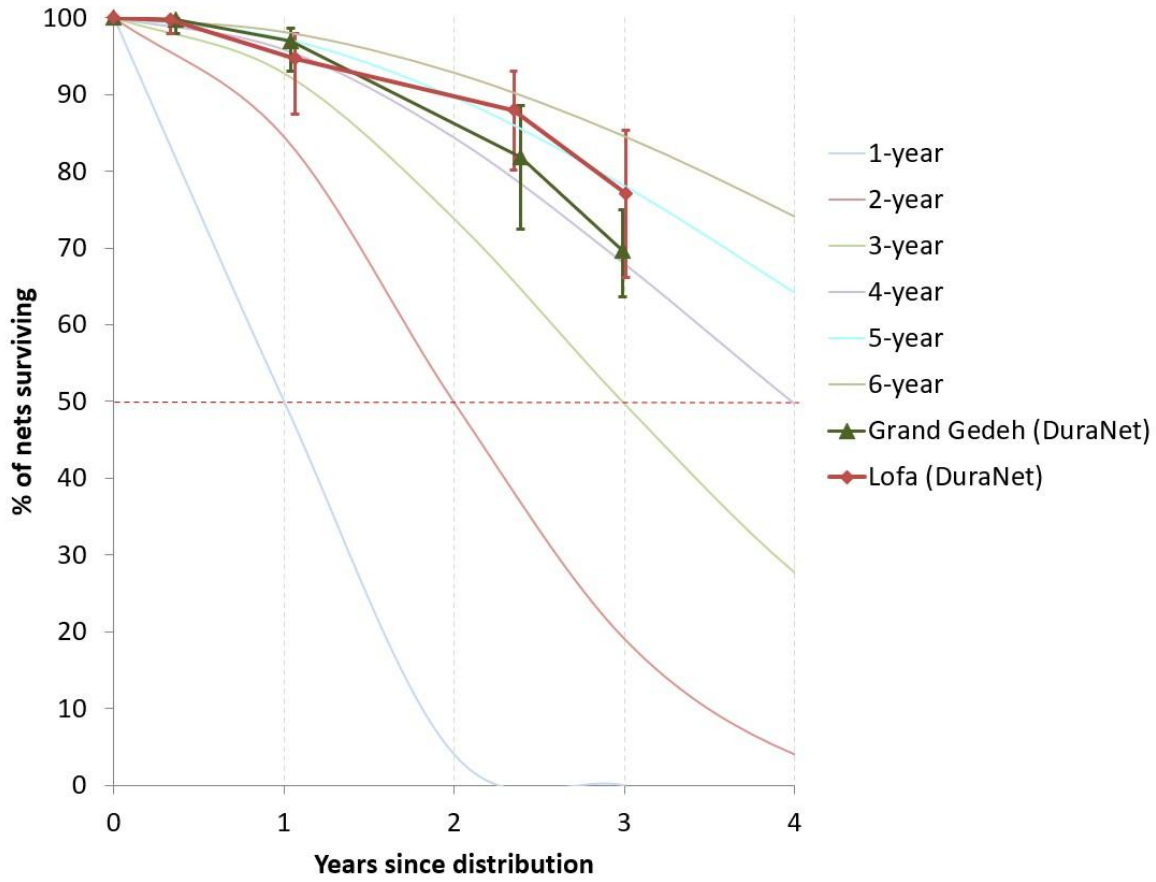
	Baseline	12 months	29 months	36 months
Grand Gedeh				
All cohort nets*	N=389	N=292	N=198	N=178
Survival estimate	99.7%	96.9%	81.8%	69.7%
95% CI	98.0%-100.0%	93.0%-98.7%	72.4%-88.5%	63.7%-75.0%
Cohort nets ever-used and present	N=150	N=185	N=142	N=117
Survival estimate	99.3%	99.5%	95.8%	91.5%
95% CI	94.7%-99.9%	95.8%-99.9%	90.1%-98.3%	84.3%-95.5%
Lofa				
All cohort nets*	N=385	N=285	N=251	N=179
Survival estimate	99.7%	94.7%	88.0%	77.1%
95% CI	98.0%-100.0%	87.5%-97.9%	80.2%-93.0%	66.1%-85.3%
Cohort nets ever-used and present	N=123	N=172	N=203	N=143

	Baseline	12 months	29 months	36 months
Survival estimate	100.0%	97.1%	92.6%	87.4%
95% CI	---	92.0%-99.0%	88.6%-95.3%	81.7%-91.5%

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

Figure 9 plots the survival against hypothetical survival curves for nets lasting one to six years based on the survival data from month 12-, 29-, and 36-month follow up. 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. The estimated median useful life for DuraNet in Grand Gedeh is 4.1 years and in Lofa is 4.9 years.

FIGURE 9: ESTIMATED NET SURVIVAL



Error bars show 95% confidence intervals.

Table 18 displays results using the most recent two data points as another method to calculate the survival estimate. Using this method, the estimated median useful life for DuraNet in Grand Gedeh is 4.0 years and in Lofa is 4.6 years.

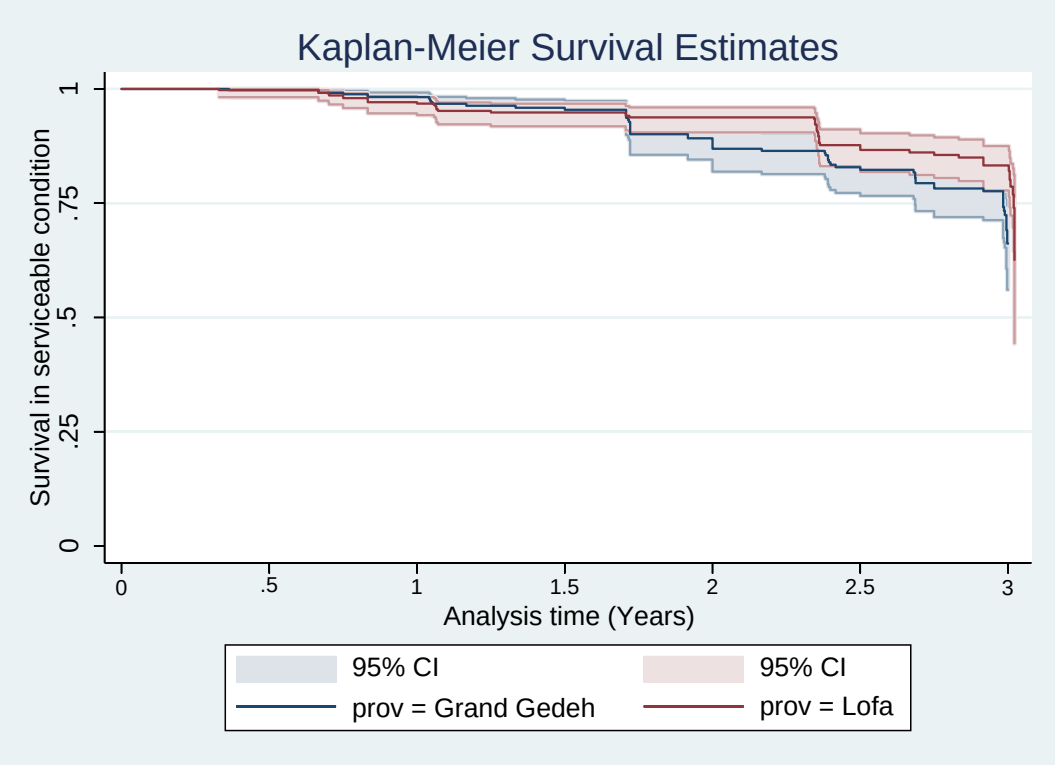
TABLE 18: ESTIMATED MEDIAN SURVIVAL OF NETS IN YEARS USING DIFFERENT METHODS

	12 months	29 months	36 months
Grand Gedeh	**N=286**	**N=199**	**N=178**

	12 months	29 months	36 months
Estimated from figure 9	5.0	4.2	4.1
Calculated from last two data points (95% CI)	-	-	4.0 (3.9-4.2)
Lofa	**N=277**	**N=251**	**N=179**
Estimated from figure 9	3.9	5.3	4.9
Calculated from last two data points (95% CI)	-	-	4.6 (3.8-6.0)

When data were analyzed as survival analysis in a Kaplan-Meier plot (Figure 10), DuraNet nets in Grand Gedeh and Lofa showed similar survival curves (log-rank test for equality, $p<0.001$).

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



3.5 INSECTICIDAL EFFECTIVENESS AND CHEMICAL 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 Atlanta on samples taken from the bioassay nets. Chemical content results are presented as summary statistics for active ingredients in g/kg units.

Baseline, 12-, 29-, and 36-month bioassay results are shown in Table 19 and Figure 11. Unfortunately, an error occurred at baseline when the net samples were prepared for shipment to the entomological laboratory and the net ID numbers were not correctly recorded. This made it impossible to allocate samples to specific study sites. Additionally, baseline data corresponded to unusually low results. Samples were reanalyzed at CDC Atlanta and the baseline results presented in Table 19 and Figure 9 are those reported by the CDC Atlanta. The 12-, 29-, and 36-month survey round samples were correctly labeled, all were tested by CDC Atlanta, and the results are shown by site.

At 36-months, a higher proportion of nets in Lofa were found to be optimally effective compared to in Grand Gedeh (83% versus 60%, p=0.038). Measures of 60-minute knock down, 24-hour mortality and minimal effectiveness were higher in Lofa compared to Grand Gedeh, although the differences were minimal and not statistically significant. In Grand Gedeh, most indicators increased from 29- to 36-months. Mortality increased from 54% to 65%, optimal effectiveness increased from 53% to 60%, and minimal effectiveness increased from 87% to 93%. However, from 12 months to 36 months, all indicators in both study sites experienced an overall decrease.

TABLE 19: CONE BIOASSAY RESULTS (BASELINE)

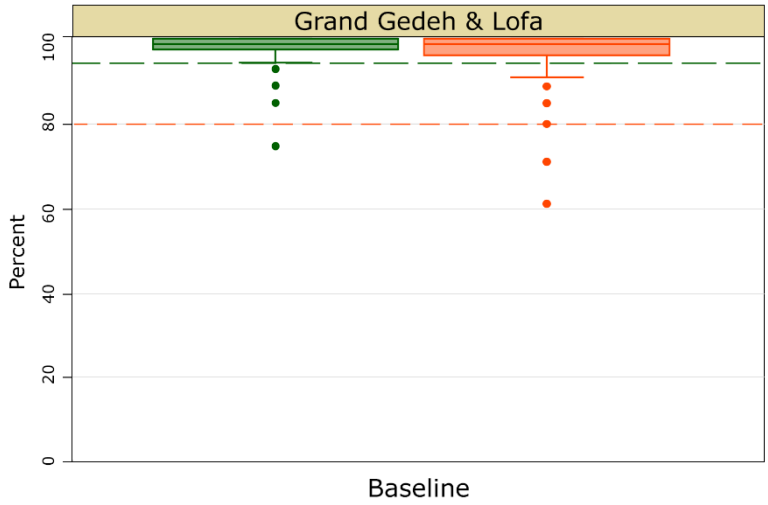
	Baseline
Grand Gedeh and Lofa	**N=59**
Knock down 60 minutes	
Mean (95% CI)	94.4% (96.3%-98.7%)
Median [IQR]	98.7% [97.5%-100.0%]
Mortality 24 hours	
Mean (95% CI)	96.2% (94.4%-98.7%)
Median [IQR]	98.7% [96.0%-100.0%]
Optimal effectiveness	
Estimate (95% CI)	82.8% (74.6%-90.9%)
Minimal effectiveness	
Estimate (95% CI)	98.3% (95.5%-100.0%)

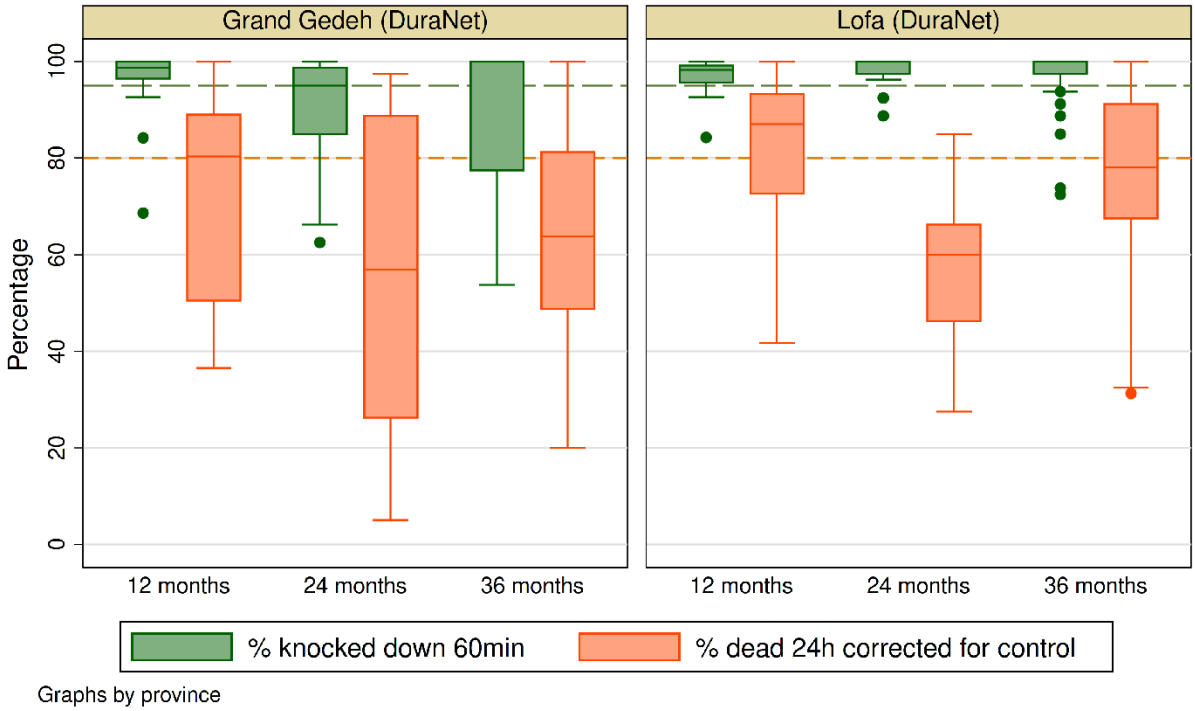
TABLE 20: CONE BIOASSAY RESULTS (12-, 29-, AND 36-MONTHS)

	12 months	29 months	36 months
Grand Gedeh	**N=30**	**N=30**	**N=30**
Knock down 60 minutes			
Mean (95% CI)	96.6 (94.5-98.7)	89.9 (86.4-93.4)	88.8 (83.3-94.4)
Median [IQR]	98.7 [96.5-100.0]	95.0 [85.0-98.8]	100.0 [77.5-100.0]
Mortality 24 hours			
Mean (95% CI)	72.3 (66.4-78.3)	53.6 (44.6-62.6)	64.9 (55.8-73.9)
Median [IQR]	80.4 [50.5-89.0]	56.9 [26.3-88.8]	63.8 [48.8-81.2]
Optimal effectiveness			
Estimate (95% CI)	86.7% (69.4%-94.9%)	53.3% (37.8%-68.2%)	60.0% (42.9%-75.0%)
Minimal effectiveness			
Estimate (95% CI)	96.7% (77.7%-99.6%)	86.7% (69.5%-94.9%)	93.3% (75.8%-98.4%)
Lofa	**N=30**	**N=30**	**N=30**
Knock down 60 minutes			

	12 months	29 months	36 months
Mean (95% CI)	97.4 (96.3-98.5)	98.4 (97.4-99.3)	96.6 (94.1-99.1)
Median [IQR]	98.3 [95.6-99.2]	100.0 [97.5-100.0]	100.0 [97.5-100.0]
Mortality 24 hours			
Mean (95% CI)	80.0 (73.1-86.9)	57.3 (52.5-62.0)	75.4 (68.0-82.7)
Median [IQR]	87.0 [72.6-93.3]	60.0 [46.3-66.3]	78.1 [67.5-91.2]
Optimal effectiveness			
Estimate (95% CI)	86.7% (69.5%-94.9%)	90.0% (72.6%-96.8%)	83.3% (66.4%-92.7%)
Minimal effectiveness			
Estimate (95% CI)	100.0% (98.3%)	100.0% (93.3%)	96.7% (77.7%-99.6%)

FIGURE 11: BOX PLOT OF NET CONE BIOASSAY RESULTS





Results from WHO cone bioassays: the box plot shows the median (horizontal lines), interquartile range (box), adjacent values[9] (whiskers) and outliers (circles), dashed 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 baseline, 29-month and 36-month survey rounds were sent to CDC Atlanta for chemical content testing.

DuraNet is manufactured with 5.8 g/kg alpha-cypermethrin. Chemical content results presented in Table 20 show a 5.5 g/kg mean of alpha-cypermethrin across both study sites at baseline, corresponding to a 5% loss compared to the original dose. At 29-months, results show a 4.2 g/kg mean of alpha-cypermethrin in both Grand Gedeh and Lofa, corresponding to a 28% loss compared to the original target dose. Results for nets sampled at 36-months show a slight increase in alpha-cypermethrin dose, with a mean 4.8 g/kg in Grand Gedeh and 4.6 g/kg in Lofa, corresponding to a loss of 17% and 22% compared to the original target dose.

TABLE 21: CHEMICAL CONTENT RESULTS

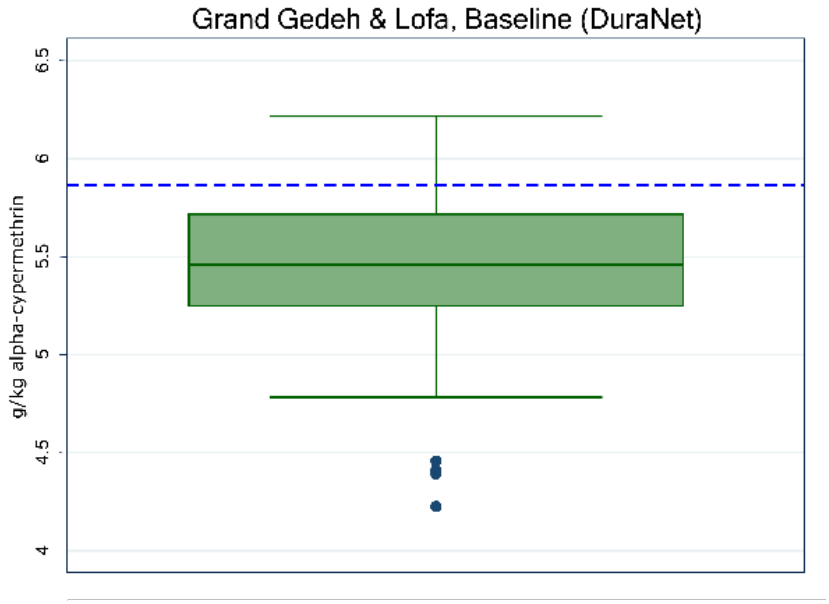
	Baseline
Grand Gedeh and Lofa (DuraNet, alpha-cypermethrin 5.8 g/kg)	**N = 59**
Mean (95% CI)	5.5 (5.3-5.6)
Median [IQR]	5.5 [5.2-5.7]
	29 months
Grand Gedeh (DuraNet, alpha-cypermethrin 5.8 g/kg)	**N = 29**

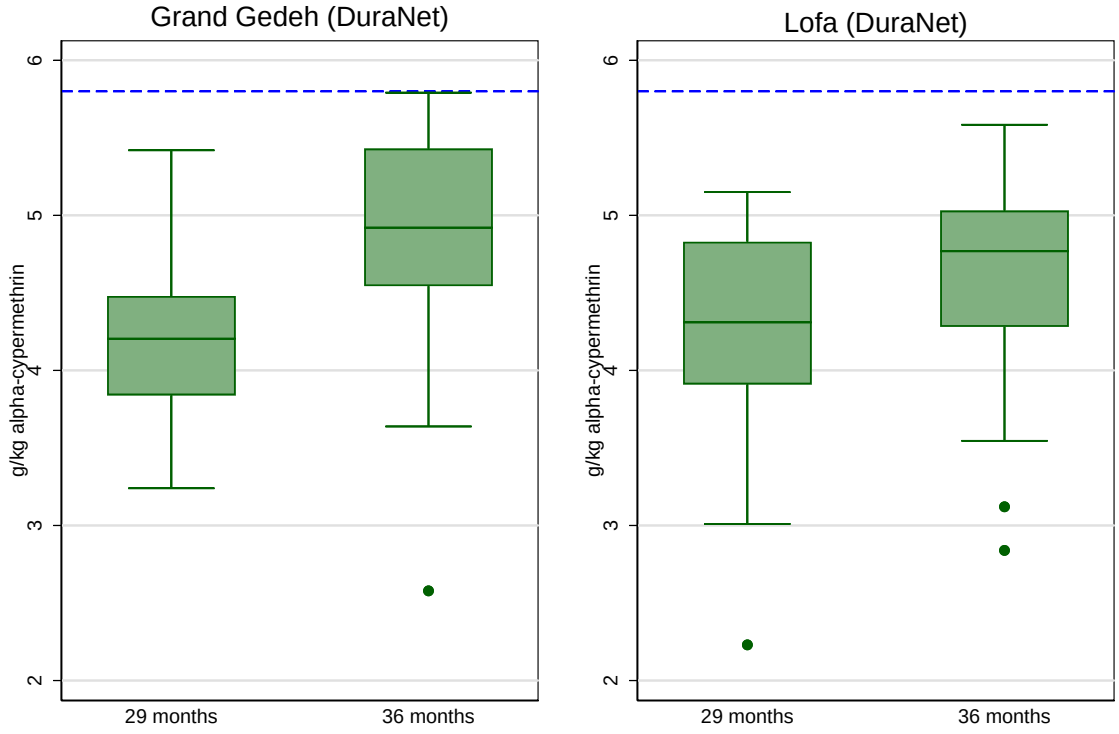
[9] Adjacent values are ± 1.5 * Interquartile range.

	Baseline
Mean (95% CI)	4.2 (3.9-4.4)
Median [IQR]	4.2 [3.8-4.5]
Lofa (DuraNet, alpha-cypermethrin 5.8 g/kg)	**N=30**
Mean (95% CI)	4.2 (3.9-4.5)
Median [IQR]	4.3 [3.9-4.8]
	36 months
Grand Gedeh (DuraNet, alpha-cypermethrin 5.8 g/kg)	**N = 29**
Mean (95% CI)	4.8 (4.6-5.1)
Median [IQR]	4.9 [4.5-5.4]
Lofa (DuraNet, alpha-cypermethrin 5.8 g/kg)	**N=30**
Mean (95% CI)	4.6 (4.4-4.8)
Median [IQR]	4.8 [4.3-5.0]

Figure 12 presents box plots of the chemical content results at baseline (Grand Gedeh and Lofa combined), and 29-months and 36-months (Grand Gedeh and Lofa separate).

FIGURE 12: BOX PLOT OF NET CHEMICAL CONTENT RESULTS





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

Tables 21-23 present details of reported handling and use for the nets undergoing bioassay analysis for each survey period. Overall, at 36-months, net location (hanging, tied, stored), net users (adults only, children only, combination), sleeping places (bed frame, mattress, mat/ground), and washing practices (median number of washes) in Grand Gedeh and Lofa were similar for bioassay and cohort nets. However, in both Grand Gedeh and Lofa, compared to cohort nets, a higher proportion of nets sampled for bioassay were used the previous night (73% versus 60% of cohort nets) and a lower proportion were washed with detergent or bleach (42% versus 54% of cohort nets). There were minor differences in net location, sleeping place, net users, use of nets, and washing practices for bioassay nets in Grand Gedeh and Lofa, however, these differences were not statistically significant.

TABLE 22: HANDLING OF BIOASSAY TEST NETS

	Baseline	12 months	29 months	36 months
Grand Gedeh	**N=30**	**N=30**	**N=28**	**N=29**
Location found				
Hanging and folded or tied	57.0%	36.7%	25.0%	24.1%
Hanging loose	13.0%	40.0%	75.0%	48.3%
Not hanging	20.0%	23.3%	0.0%	10.3%
Stored unpacked	10.0%	0.0%	0.0%	10.3%
Stored in package	0.0%	0.0%	0.0%	3.4%
Type of sleeping space (if used)				

	Baseline	12 months	29 months	36 months
Bed	38.0%	42.9%	35.7%	46.4%
Mattress	62.0%	53.6%	64.3%	50.0%
Mat/Ground	0.0%	3.6%	0.0%	3.6%
Net users				
Child(ren) only	0.0%	10.0%	14.3%	0.0%
Child(ren) and adult(s)	0.0%	55.0%	35.7%	47.4%
Adult(s) only	100.0%	35.0%	50.0%	52.6%
Lofa	**N=30**	**N=29**	**N=29**	**N=30**
Location found				
Hanging and folded or tied	40.0%	10.3%	20.7%	20.0%
Hanging loose	3.0%	82.8%	75.9%	63.3%
Not hanging	57.0%	6.9%	0.0%	6.7%
Stored unpacked	0.0%	0.0%	3.4%	3.3%
Stored in package	0.0%	0.0%	0.0%	3.3%
Type of sleeping space (if used)				
Bed	77.0%	56.7%	48.3%	50.0%
Mattress	23.0%	43.3%	51.7%	46.7%
Mat/Ground	0.0%	0.0%	0.0%	3.3%
Net users				
Child(ren) only	12.0%	0.0%	10.3%	0.0%
Child(ren) and adult(s)	38.0%	40.0%	20.7%	48.0%
Adult(s) only	50.0%	60.0%	69.0%	52.0%

TABLE 23: REPORTED USE OF BIOASSAY TEST NETS

Blank cell	Baseline	12 months	29 months	36 months
Grand Gedeh	**N=30**	**N=30**	**N=29**	**N=30**
Used last night	66.7%	76.7%	93.1%	63.3%
Used last week				
Every night	63.0%	83.3%	89.7%	65.5%
Most nights (5-6 nights)	3.0%	0.0%	6.9%	10.3%
Some nights (1-4 nights)	7.0%	3.3%	3.4%	3.4%
Not used last week	27.0%	3.3%	0.0%	13.8%
Never used	NA	10.0%	0.0%	3.4%
Don't know	NA	0.0%	0.0%	3.4%
Seasonal use				
Equally in rainy and dry seasons	67.0%	90.0%	93.1%	86.7%
Mainly rainy season	0.0%	0.0%	6.9%	10.0%
Rainy season only	3.0%	0.0%	0.0%	0.0%
Not used	N/A	0.0%	0.0%	3.3%
Don't know	30.0%	10.0%	0.0%	0.0%
Lofa	**N=30**	**N=30**	**N=28**	**N=30**
Used last night	43.3%	86.7%	89.3%	83.3%
Used last week				
Every night	43.0%	86.7%	93.1%	80.0%
Most nights (5-6 nights)	3.0%	3.3%	3.4%	0.0%
Some nights (1-4 nights)	0.0%	0.0%	3.4%	3.3%
Not used last week	54.0%	6.7%	0.0%	16.7%
Never used	0.0%	3.3%	0.0%	0.0%
Don't know	0.0%	0.0%	0.0%	0.0%
Seasonal use				
Equally in rainy and dry seasons	43.0%	90.0%	93.1%	96.7%
Mainly rainy season	3.0%	6.7%	6.9%	3.3%
Rainy season only	0.0%	0.0%	0.0%	0.0%
Not used	N/A	0.0%	0.0%	0.0%
Don't know	54.0%	3.3%	0.0%	0.0%

TABLE 24: REPORTED WASHING OF BIOASSAY TEST NETS

	Baseline	12 months	29 months	36 months
Grand Gedeh	**N=30**	**N=30**	**N=28**	**N=29**
Ever washed	80.0%	50.0%	75.0%	86.2%
Washes in the last 6 months among all nets (if known)				
Mean	0.3	1.38	2.04	2.52
Median	0.0	0.0	2.0	2.0
Washes in the last 6 months among washed nets				
Mean	1.7	2.86	2.72	3.00

	Baseline	12 months	29 months	36 months
Median	1.0	1.5	2.0	2.0
Soap used for last wash				
Soap bar	67.0%	33.3%	45.5%	36.7%
Detergent or bleach	17.0%	53.3%	50.0%	40.0%
Mix	0.0%	13.3%	4.5%	0.0%
None	16.0%	0.0%	0.0%	6.7%
Don't know	0.0%	0.0%	0.0%	16.7%
Where dried after last wash				
Shade	N/A	N/A	77.3%	96.0%
Sun	N/A	N/A	22.7%	4.0%
Don't know	N/A	N/A	0.0%	0.0%
Lofa	**N=30**	**N=30**	**N=29**	**N=30**
Ever washed	70.0%	73.3%	75.9%	93.3%
Washes in the last 6 months among all nets (if known)				
Mean	0.4	1.50	1.29	3.31
Median	0.0	1.0	2.0	2.0
Washes in the last 6 months among washed nets				
Mean	1.4	2.05	1.80	3.56
Median	1.0	2.0	2.0	2.0
Soap used for last wash				
Soap bar	50.0%	18.2%	54.5%	50.0%
Detergent or bleach	12.0%	68.2%	45.5%	43.3%
Mix	0.0%	13.6%	0.0%	0.0%
None	38.0%	0.0%	0.0%	0.0%
Don't know	0.0%	0.0%	0.0%	6.7%
Where dried after last wash				
Shade	N/A	N/A	66.7%	85.7%
Sun	N/A	N/A	28.6%	14.3%
Don't know	N/A	N/A	4.8%	0.0%

4. CONCLUSIONS

4.1 SUMMARY OF FINDINGS

At the 36-month survey round the Liberia durability monitoring team successfully visited 265 households across two counties. At baseline, a total of 872 DuraNet nets were enrolled in the study as cohort nets (including those lost before the baseline round). At 36-months, only 342 cohort nets were still present in the households (155 in Grand Gedeh county and 187 in Lofa county).

Cohort net survivorship at 36-months was higher in Lofa than Grand Gedeh (77% versus 70%, $p<0.001$). Survivorship is a measure that combines attrition and physical integrity, and the higher survival for Lofa was driven by a higher proportion of cohort nets being discarded due to wear and tear in Grand Gedeh (11%) compared to Lofa (7%) over the study period. The physical integrity of cohort nets in Lofa was equal to or worse than that of nets in Grand Gedeh in each survey round, and at endline 12% of cohort nets in Lofa were classified as "too torn" compared with 10% in Grand Gedeh. It should be remarked that among cohort nets that remained active in the study until the 36-month study round, physical integrity was generally high, with 91% (Grand Gedeh) and 89% (Lofa) of cohort nets remaining in a "serviceable" condition. After 29 months in the field, less than half of active cohort nets had any holes in Grand Gedeh (44%), while 56% had any holes in Lofa.

Unlike other VectorLink countries where study sites received different net brands, households in Grand Gedeh and Lofa both received DuraNet nets (manufactured with 5.8 g/kg alpha-cypermethrin). This offers the opportunity to investigate how factors other than the intrinsic physical properties of nets contribute to net survivorship. Overall, household risk factors for net durability and household member attitudes related to net care and repair were remarkably similar between the two study sites. Of the households that reported washing a net in the 6 months prior to the survey round, 55% in Grand Gedeh and 53% in Lofa used detergent or bleach. This is an increase from the baseline proportions of 47% and 32%, respectively ($p=0.262$). At 36-months, the proportion of respondents who received net messaging was also similar between sites with 27% in Grand Gedeh and 25% in Lofa. However, this is a decrease from the baseline proportions of 77% in Grand Gedeh and 43% in Lofa ($p=0.000$). Attitudes towards nets and net care and repair were also similar between study sites across study rounds. At baseline respondents in Grand Gedeh had a mean net attitude score of 1.81 compared to respondents in Lofa with a mean score of 1.78. At 36-months this decreased slightly with a mean net attitude score of 1.63 in Grand Gedeh and 1.64 in Lofa. The mean net care and repair attitude score in Grand Gedeh at baseline was 0.89 and in Lofa was 0.93. Both scores increased throughout the study with a mean score of 1.04 in Grand Gedeh and 1.13 in Lofa at the 36-month survey round. This indicates a general improvement in the care of mosquito nets in both study sites.

The proportion of cohort nets found hanging tied and untied were nearly equivalent in Grand Gedeh and Lofa (hanging tied 23% versus 24%; hanging untied 40% in both). There were no significant differences in cohort net users (e.g. adults versus children). In Lofa, a higher proportion of cohort nets were reportedly used last night (66%) versus 53% in Grand Gedeh ($p=0.046$) and every night last week, (65% in Lofa versus 50% in Grand Gedeh, $p=0.005$). More frequent net use may partially explain the observed trend of poorer net integrity in Lofa. In Grand Gedeh, the use of nets given access was similar for cohort nets (0.61) and other nets in the household (0.64). Household members with access to nets in Lofa were also similarly using cohort nets (0.74) compared to other available nets (0.80).

In laboratory bioassays at 36-months, 83% of net samples from Lofa met the criteria for optimal effectiveness compared with only 60% of samples from Grand Gedeh (p=0.038). Net samples from Lofa were as likely or more likely to be optimally effective than those from Grand Gedeh at the 12- and 29-month survey rounds, in addition to the 36-month survey round. At 36-months, higher optimal effectiveness among samples from Lofa was driven by both higher 24-hour mortality (75% vs 65%) and higher knock down (97% vs 89%), with the mean knock down in Lofa surpassing the WHO threshold of 95%. These results may reflect households taking care of nets that survived to the 36-month survey round, particularly considering the physical integrity results described above. This hypothesis is partly supported by the chemical testing results at 36-months, which show higher mean and median alpha-cypermethrin concentrations in net samples from both Grand Gedeh and Lofa countries than at 29-months.

4.2 Key Challenges and Lessons Learned

Over the entire course of the study, three main challenges during fieldwork were encountered: road conditions in the field, farming season, and issues with bioassay labels.

Because of COVID-19, the 24-month data collection round could not be conducted as scheduled. The survey round occurred instead 29-months after distribution, in August 2020, during the rainy season and with deteriorated road conditions. During travel to each study site and between clusters, data collection teams encountered severe road conditions, and in many instances, roads were impassable. To reach each cluster, teams had to take long detours to avoid washed out roads.

In addition to the rainy season, the 29-month round of data collection was conducted in the middle of farming season in Liberia. This proved difficult for several reasons. First, many households relocated to their farms and data collectors often found locked study households, where no occupants were available for interview. Second, if individuals were home to be interviewed, teams found that many cohort nets had been transferred for use on the farms. This led to an increased number of nets being recorded as temporarily unavailable for assessment. To avoid these issues in future durability monitoring studies, data collection should consider the timing of rainy and farming seasons in-country, in addition to campaign timing. Good timing can allow for easier travel to and from study sites and will ensure a maximum number of cohort households and nets are available at the time of the interview.

The team also experienced issues when labeling bioassay net samples. At baseline and 24-month survey rounds, nets were incorrectly labeled. At baseline this meant samples were not able to be disaggregated by study site. At 24-months, this resulted in delays to completing chemical tests. To address this issue, a bioassay handover sheet was developed for use by the data collection team and the VectorLink team. This sheet was checked by the VectorLink HQ staff at each step of the bioassay process to ensure all nets were accurately labeled before being handed off to the next partner. In future durability monitoring studies, this handover form should be used to ensure all net samples are labeled correctly.