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

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ACRONYMS

CERMES	Centre de Recherche Médicale et Sanitaire
DHS	Demographic and Health Survey
DM	Durability Monitoring
IQR	Interquartile Range
IPC	Interpersonal Communication
ITN	Insecticide-Treated Net
KD60	60-minute Knock-Down rate
NMCP	National Malaria Control Program
pHI	Proportionate Hole Index
PMI	President's Malaria Initiative
PSI	Population Services International
REB	Research Ethics Board
WHO	World Health Organization
WHOPES	World Health Organization Pesticide Evaluation Scheme

EXECUTIVE SUMMARY

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

In Niger, the U.S. President's Malaria Initiative (PMI) is supporting ITN durability monitoring of Olyset nets (permethrin) distributed during the June 2018 mass campaign in two districts: Gazaoua (in the Maradi region) and Madaoua (Tahoua region). Baseline data collection was conducted October 8-23, 2018, to establish the study cohort. All campaign ITNs in sampled households were identified and labeled with a unique ID number.

The 12-month study round was carried out July 2-16 2019, the 24-month survey was conducted August 17-31, 2020 (postponed due to COVID-19), and the 36-month study round was conducted June 16 - July 1, 2021. Fieldwork was conducted by VectorLink Niger. During each of these rounds, ITNs labeled at baseline were followed-up; the physical integrity of nets still present in the household was measured through a hole assessment and details were recorded for any nets no longer present in the household (attrition). Potential factors affecting net durability were explored through a household interview. These included environmental factors (house structure, cooking fuel, type of sleeping place), net handling (folding nets up when hanging, drying washed nets on bushes etc.) as well as attitudes towards nets and net care and repair. At each round, information was collected on bed nets obtained by the household outside of the 2018 campaign. Furthermore, there was a net campaign that was initiated in May 2021 by the NMCP with support from the Global Fund that distributed nets to six high risk malaria regions including Gazaoua (Maradi region) and Madaoua (Tahoua region). To minimize its impact on this study, data collection was held in June, three weeks after the mass campaign.

During the 36-month survey, two cohort ITNs from each cluster were selected and withdrawn to undergo bio-effectiveness and chemical content analysis. Cone bioassays were performed by the *Centre de Recherche Médicale et Sanitaire* (CERMES) with support from PMI VectorLink. The nets samples have been sent to CDC for chemical content analysis and results will be added to this report when available.

Household and ITN Follow-Up

A total of 196 out of 215 eligible households were interviewed for the 36-month study round. Of these, 118 households still had one or more cohort nets while 78 had lost all their cohort nets. Of the households not interviewed, four had no eligible respondent available for interview, three had moved out of the study area, and 12 were not interviewed due to security concerns. Of the 503 nets eligible for follow-up at the 36-month study round, 189 were still in the house and 11 were with family elsewhere. Nets not in households had been discarded (208 nets), given away or stolen (61 nets), or were lost for unknown reasons (two nets). Twenty-eight cohort nets had an unknown outcome at the 36-month round, of which 24 in Madaoua belonged to households that couldn't be visited due to security concerns. A further four nets were unavailable because the household had

1 www.durabilitymonitoring.org

moved outside the study area or refused to participate. In total, 638 out of 827 (77%) nets received at baseline were no longer present in households.

Durability Risk Factors

A higher proportion of households in Madaoua reported ever storing food in a room used for sleeping (88% versus 72% in Gazaoua; p=0.026), however, a slightly higher proportion of households in Gazaoua sometimes cooked in the same room used for sleeping (49% versus 33% in Madaoua, p=0.088). Most households in Gazaoua (88%) and Madaoua (86%) reported observing rodents in the past six months. Among washed nets, the median number of washes in the six months prior to the survey was higher in Madaoua than in Gazaoua (12 washes versus five washes) and a slightly higher proportion of cohort nets in Madaoua were last washed with detergent or bleach (89% versus 83% in Gazaoua; p=0.029). Although a higher proportion of nets were hung over a mat or the ground in Madaoua during the 12- and 24-month surveys, the types of sleeping place cohort nets were hung at 36-months were almost identical between sites (52% over bed frame, 10% over mattress, 38% over mat/ground). Nets hung over a mat/ground in previous rounds in Madaoua may have been somewhat protected considering that a higher proportion of cohort nets (among nets ever found hanging across all survey rounds) were always found folded up in Madaoua (56% versus 34% in Gazaoua; p=0.006)

At 36-months, respondents from approximately three-quarters of households in Gazaoua (78%) and Madaoua (69%) reported being exposed to information about net use, care, or repair in the past six months. A higher proportion of respondents received information from both media and interpersonal communication (IPC) in Gazaoua (66% versus 42% in Madaoua; p=0.005), while IPC only was more common in Madaoua (56% versus 13% in Gazaoua; p<0.001). Nearly all respondents exposed to net messaging at 36-months recalled "use net (every) night" (~100% across both districts). A higher proportion of respondents in Gazaoua compared to Madaoua recalled messaging about net repair (40% versus 7% in Madaoua; p<0.001). There was a similar proportion of respondents with favorable attitudes towards nets (89% in Gazaoua, 84% in Madaoua) and net care and repair (69% in Gazaoua, 53% in Madaoua) between study sites. There were no statistical differences between the proportion of households experiencing holes in a net, discussing net care and repair, or repairing nets across study sites at 36-months.

ITN Ownership and Use

At 36-months, a higher proportion of cohort nets in Gazaoua compared to cohort nets in Madaoua were used last night (44% versus 16%; p=0.014) and every night last week (37% versus 13%; p=0.024). In both study sites, cohort net use during the 36-month survey decreased substantially from the 24-month survey when approximately three-quarters of nets were reportedly used last night and every night last night. On the other hand, household ownership of non-cohort nets increased at 36-months at which time nearly all households owned one or more non-cohort nets (97% in Gazaoua, 99% in Madaoua). The vast majority of these nets were obtained from the 2021 distribution campaign, which occurred two months prior to data collection (93% in Gazaoua, 85% in Madaoua). Although a higher proportion of households were in possession of non-cohort nets at 36-months, non-cohort net use dropped from 80% to 24% in Gazaoua and from 86% to 23% in Madaoua from the 24-month to 36-month surveys. A high proportion of cohort and non-cohort nets were found stored away at 36-months (43% and 77% of cohort nets, and 77% and 84% of non-cohort nets in Gazaoua and Madaoua respectively). Although, population access to ITNs was high at 36-months (78% in Gazaoua, 95% in Madaoua), population use was low (39% in Gazaoua, 33% in Madaoua). The proportion of nets used by users of different age groups was not statistically different between sites for cohort or non-cohort nets at 36-months.

ITN Survivorship (Attrition and Physical Integrity)

In Gazaoua, total campaign ITN attrition increased from 44% at 24-months to 75% at 36-months. In Madaoua, total campaign attrition increased from 41% to 77% during the same time frame. At 36-months, in both study sites, the most common reason for attrition was discarded (also known as attrition due to wear and tear) (40% in Gazaoua, 45% in Madaoua) and the second most common reason was given away to others (29% in Gazaoua, 31% in Madaoua). Among cohort nets present at 36-months, 88% of nets in Gazaoua and 92% in Madaoua had any holes and the percentage of nets that were classified as being in serviceable condition was lower in

Gazaoua (61% versus 78% in Madaoua; p=0.025). Cohort net survival (nets present in the household and in serviceable condition, out of all cohort nets present or previously discarded) was estimated to be 24% in Gazaoua and 26% in Madaoua, corresponding to an estimated median survival time of 2.4 years for Olyset nets in both Gazaoua and Madaoua.

Insecticidal Effectiveness

At baseline, 12- and 24-months, two campaign nets per cluster 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, campaign nets were selected from among remaining cohort nets to undergo bioassays. At the 24-month round, optimal insecticidal effectiveness was higher among Olyset samples from Madaoua compared to Olyset samples from Gazaoua (23% versus 3%, p=0.029). However, following a generally declining trend in optimal effectiveness from baseline to 24-months, insecticidal effectiveness increased at the 36-month round in Gazaoua (43%) and remained static in Madaoua (23%). Improved effectiveness in the bioassay net samples may have resulted if nets sampled at the 36-month round were more likely to have been taken from storage, or to have been only recently unpacked and hung to replace previous nets that were discarded or given away. The bioassays were consistent with the results of the chemical assays of the Olyset nets as these results show lower levels of chemical content than indicated by the manufacturer in Madaoua and Gazaoua for the same brand of net (Olyset).

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

Table 1: Baseline, 12 Month, 24 Month and 36 Month Round Results

Site	Survey round and time since distribution (months)	Attrition wear and tear (%)	Remaining nets in serviceable condition % (N)	Remaining nets hanging over sleeping space (%)		Optimal insecticidal effectiveness in bioassay (%)
				Campaign	Other	
Gazaoua (Olyset)	Baseline: 4.0	0.0%	97.6% (N=381)	29.2%	26.9%	35.5%
	First: 12.7	2.3%	93.6% (N=314)	40.2%	27.1%	56.7%
	Second: 26.2	15.4%	74.0% (N=218)	65.8%	61.5%	3.3%
	Third: 36.2	39.7%	61.2% (N=96)	41.7%	23.2%	43.3%
Madaoua (Olyset)	Baseline: 4.0	0.7%	98.7% (N=373)	55.7%	60.3%	79.3%
	First: 12.7	2.6%	95.5% (N=173)	N/A*	N/A*	70.0%
	Second: 26.2	16.0%	78.1% (N=224)	77.9%	89.9%	23.3%
	Third: 36.2	40.9%	78.2% (N=93)	20.1%	12.8%	23.3%

* Due to a misinterpretation of the survey question response options in Madaoua, location results for the nets in these households were not available at 12-months.

Conclusion

Campaign net physical integrity was poorer in Gazaoua (61% nets serviceable) compared to Madaoua (78% nets serviceable). In both study sites, total campaign ITN attrition was similar (~75%) and was driven by both wear and tear and nets being given away to others. The estimated median survival time of Olyset ITNs in Gazaoua and also in Madaoua was 2.4 years.

1. BACKGROUND

The proportion of households owning at least one insecticide treated net (ITN) has increased in Niger, from 37% (2006 DHS) to 70% (2012 DHS) in urban zones and from 44% to 60% in rural areas during the same period.[2] However, at the population-level both population access and population use of ITNs remain low. 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 2012 this figure was 45% in urban zones and 36% in rural zones. Population use is the proportion of the population that reportedly used an ITN the previous night and was 25% and 11% in urban and rural zones respectively in 2012. As ITN use first requires access to an ITN, these two indicators can be combined in an ITN use:access ratio, which measures population-level use in relation to population-level access to an ITN. This ratio is universally low in Niger, ranging from 0.23 in Tahoua to 0.66 in Niamey, and except for Niamey this ratio is well below the 0.60 threshold for a "poor" rating. Thus, even when ITNs are available to household populations, their use is suboptimal and further exploration of reasons for the non-use of available nets is needed.[3]

The importance of ITN field durability and estimating the *average useful life* of an ITN is 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. To this end, standard guidance has been developed with funding from PMI.[4] 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 Niger, PMI is supporting ITN durability monitoring of ITNs distributed during the June 2018 mass campaign in two districts: Gazaoua (Maradi region) and Madaoua (Tahoua region). The populations in these districts all received Olyset brand ITNs during the campaign. Since the aim of this study is to compare the same mosquito net in two different geographical regions, Olyset was chosen as the target of this study as its durability has been studied less often than PermaNet 2.0; at the time of study planning, PermaNet 2.0 was the target of six ongoing durability monitoring studies in other malaria endemic countries, compared to two studies of Olyset.

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

The durability monitoring study in Niger intended to:

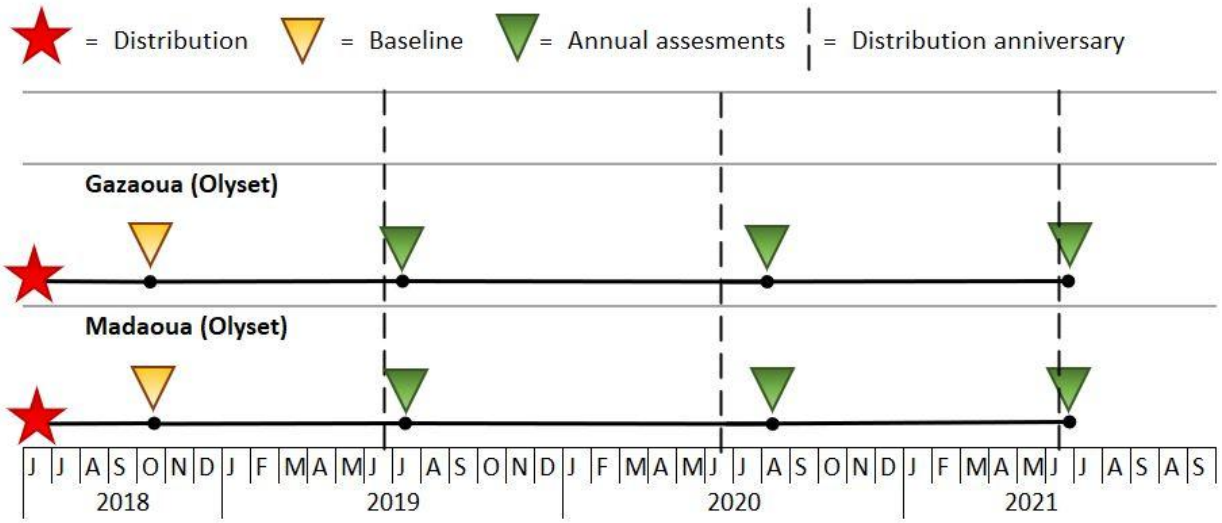
1. Assess the physical durability of Olyset, a 150-denier polyethylene ITN incorporating permethrin (1000 mg/m^2) in two locations (Gazaoua and Madaoua) over a three-year period and estimate median ITN survival and identify major determinants of field performance.

2 More recent data are unfortunately not available: data quality issues with the 2017 DHS led the results to be withdrawn from circulation.
3 Koenker H, Ricotta E, Olapeju B, Choiriyyah I. October 2018. Insecticide-Treated Nets (ITN) Access and Use Report. Baltimore, MD. PMI | VectorWorks Project, Johns Hopkins Center for Communication Programs.
4 www.durabilitymonitoring.org

2. Describe major behavioral aspects of net care and repair and their impact on physical integrity.
3. Assess insecticidal effectiveness (through bioassay and chemical content analysis) of Olyset over 36 months.

Baseline data collection was conducted October 8 - 23, 2018. Data collection for the 12-month study round was conducted July 2 - 15, 2019, the 24-month study round was conducted August 17 - 31, 2020, and the 36-month study round was conducted June 16 - July 1, 2021 (Figure 1).

Figure 1: Durability Monitoring Timeline



2. METHODS

2.1 STUDY SITES

The study was conducted across two districts with different socio-ecological profiles. Sites were selected in collaboration with the NMCP and PMI and are the district of Gazaoua in the Maradi region and the district of Madaoua in the Tahoua region (Figure 2).

Figure 2: Study Site Map

Both districts experience a hot dry climate with hyperendemic malaria transmission. Agriculture is the main economic activity of the populations in both districts. In addition, recent years have seen a large out-migration of people from Tahoua region to urban areas of Niger and to other West Africans countries. The 2012 DHS reports higher total fertility and child mortality in Maradi district, while fever prevalence among children under five was higher in Tahoua. Secondary analysis of the 2012 DHS shows a similar level of ITN ownership by household and ITN access and use at the population-level for regions within the districts studied (Table 2). The ITN use:access ratio in the two regions is very low.[5]

5 Koenker H, Ricotta E, Olapeju B, Choiriyyah I. October 2018. Insecticide-Treated Nets (ITN) Access and Use Report. Baltimore, MD. PMI | VectorWorks Project, Johns Hopkins Center for Communication Programs.

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
Gazaoua (Maradi Region)	73.9%	39%	11.3%	0.29
Madaoua (Tahoua Region)	67.0%	36%	8.1%	0.23

Source: ITN Access and Use Report 2018.
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 ITN brand that is monitored for this study is Olyset, manufactured by Sumitomo Chemical. The ITNs were distributed as part of the mass campaign in June 2018. In total, 113,464 ITNs were distributed in Gazaoua and 355,883 ITNs in Madaoua, and all areas in these two districts were covered by the campaign.

Olyset ITNs are white, rectangular with size 190 x 180 x 150 cm, and made from 150-denier polyethylene with a permethrin coating. Olyset received full WHOPES recommendation in July 2009 (13th WHOPES Report).

2.3 STUDY DESIGN SUMMARY

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

The sample size follows the recommendation from PMI guidance of 120 households per district (12 clusters with 10 households each) and an expected number of 345 ITNs in each district, or 728 in total. This sample size is targeted at detecting a deviation of 18%-points from the expected 50% survival after three years comparing the two districts (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 ITN cohort in each site was established by selecting a representative sample of clusters (communities) based on probability proportionate to size. Households were selected using simple random sampling from household lists. Households were geolocated to facilitate subsequent visits.

In addition to the labeled ITNs from the campaign, all other mosquito nets present in the selected households were recorded to capture full and comparable data on all nets in each household. At baseline, 12- and 24-months, two campaign nets per cluster were randomly selected from households outside the cohort but within the same study site to undergo bioassay tests and evaluate insecticidal effectiveness. At 36-months, 57 nets were sampled from the main cohort. Three additional nets could not be sampled due to security reasons in Madaoua. Participating households received a new, replacement ITN in exchange for the one withdrawn for the study.

Bioassays for the 36-month round were conducted by CERMES with support from PMI VectorLink in accordance with standard WHO guidelines for cone and tunnel tests (where appropriate).[6]

2.4 Training and Fieldwork

Fieldwork was conducted by an implementation team of nine people per district. Each district team comprised one coordinator and two field teams of one supervisor and three interviewers. 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 had participated in the 24-month round.

Online training of trainers for eight staff from the NMCP and VectorLink took place June 7 – 9, 2021 with three days of remote instruction led by VectorLink research staff experienced in durability monitoring. In-person training for eight data collectors took place in Niamey from June 11 - 14, 2021 and entailed three days of classroom-based training and one field practice day in a local community with support from the NMCP and VectorLink Niger staff. Training covered the following topics: the study design and sampling procedures, ethical considerations (such as consent), COVID-19 adaptations, detailed review of the questionnaire with role play, use of tablets and the SurveyCTO software, and the physical assessment of holes and net repairs with practical exercises.

In each study village, the field team sought approval to conduct the 36-month study 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

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

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

2.6 ANALYSIS

Data were weighted to account for different sampling probabilities for clusters in each district prior to estimating aggregate results. 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 recording 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 one is interpreted as a household respondent with favorable attitudes to a given topic.

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

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

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

Good:	pHI ≤ 64 (corresponding to a total hole surface area ≤ 0.01m^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 was plotted against the hypothetical survival curves with defined median survival and the median survival was taken as the relative position of the data point on a horizontal line between the two adjacent median survival curves.

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

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

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

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

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

irrespective of whether or when the net was hung and used. Failure was defined as a net being lost due to wear and tear or classified as "too torn" based on physical assessment. Nets that were given away or that had an unknown outcome were censored. The time of failure was directly calculated from the report of time of loss by the respondent or taken as the mid-point between the last two surveys if unknown.

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

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

Samples taken from ITNs selected for bioassays were packaged following standard procedures and shipped to CDC for chemical content testing. Outcome measures from these tests present the mean and median level of active ingredient across the net brand samples in g/kg and compare these averages with manufacturer specifications for the insecticides used on the netting. Chemical content testing on samples from the 36-month endline round are ongoing and will be added to this report when they become available.

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 the NMCP and VectorLink and was run in three sessions over three days. Training materials were modified from those used during in-person training, and participants focused on the study design and methods as well as how to administer the questionnaire, conduct net assessments, and follow all COVID-19 adaptations. During in-person fieldworker training, staff were instructed on all COVID-19 mitigation measures (including not to enter households), on how to examine nets with minimal contact, and on how to obtain oral consent. In the field and during training, staff were required to always wear a mask, maintain frequent hand washing, and to use a new pair of gloves when examining nets at each new study household. Personal protective equipment (PPE) including hand sanitizer, gloves, and disinfectant wipes were provided by VectorLink Niger. A set of COVID-19 pre-screening questions were added to the questionnaire for application in the field. These questions sought to determine whether respondents were at risk from the study team (e.g., if anyone in the household had a pre-existing medical condition that would require shielding from COVID-19) and whether the study team was at risk from household members (e.g., if the household included member(s) with COVID-19 symptoms). During the 36-month round of fieldwork, no households were screened out of data collection due to a COVID-19 risk. Additional IRB approval was sought before fieldwork began, as described below.

2.8 ETHICAL CLEARANCE

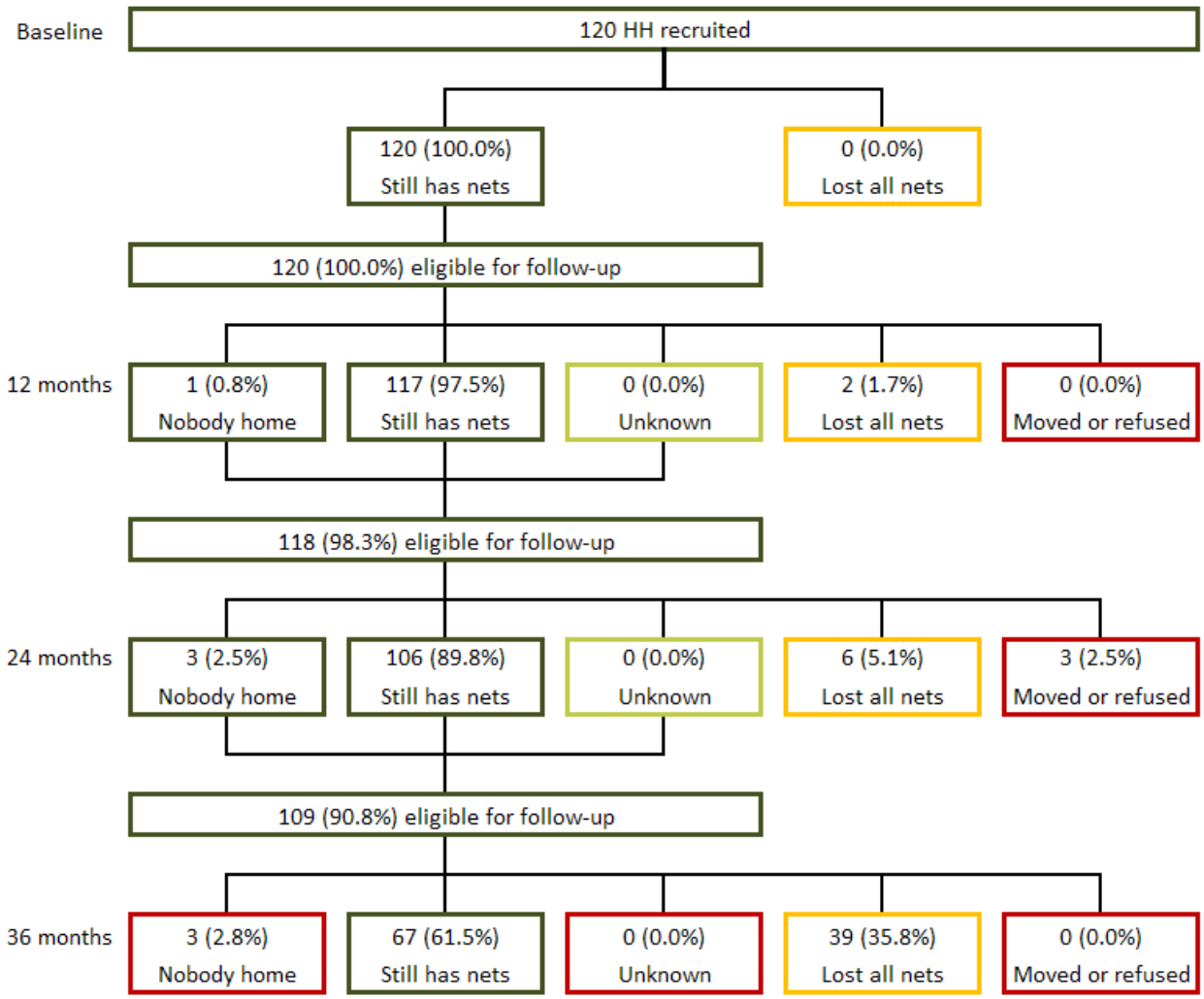
This study has been determined to be research with human subjects and received written approval from the Nigerien *Comité National d'Ethique pour la Recherche en Santé* on October 8, 2018 under reference number 025/2018/CNERS. The PSI Research Ethics Board (REB) granted authorization on August 29, 2018 under reference number 33.2018. Following an application for continuing review, the PSI Research Ethics Board (REB) granted authorization on June 2, 2020 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 June 11, 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.

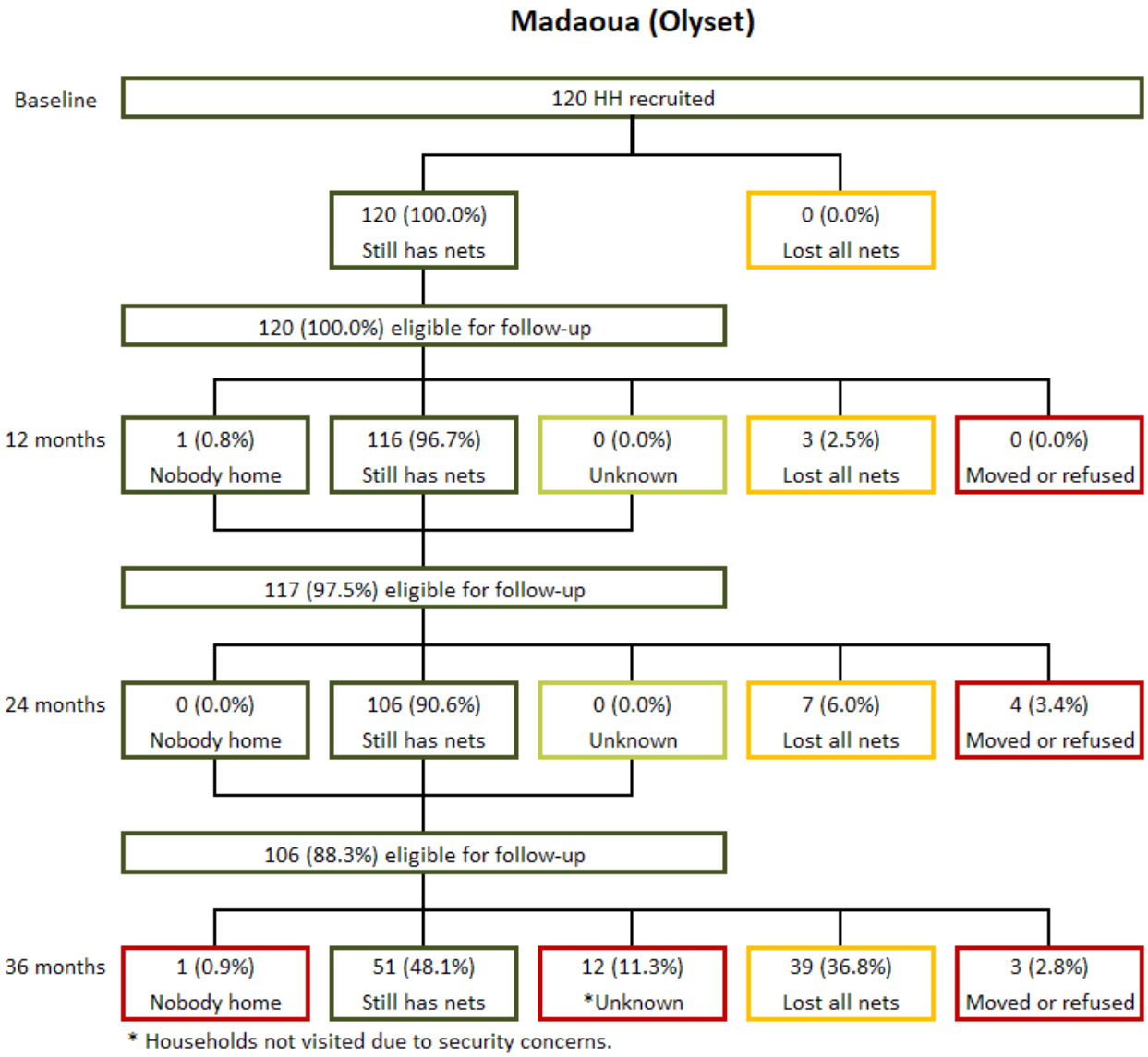
3. RESULTS

3.1 SAMPLE

At baseline, a total of 240 households were recruited for durability monitoring (120 in Gazaoua and 120 in Madaoua), of which 215 households (109 in Gazaoua and 106 in Madaoua) were eligible for follow-up at 36-months (Figure 3). Of the 109 eligible households in Gazaoua, 67 still had at least one cohort net present, while 39 households no longer had any cohort nets, and three households had nobody home. In Madaoua, 51 of the 106 eligible households still had cohort nets, 39 no longer had any cohort nets, one household had nobody home, three households moved out of the study site. There were 12 households in Madaoua that could not be visited at the 36-months timepoint because of security concerns (unknown household status).

Figure 3: 36-Month Follow-Up Status of Households Recruited at Baseline
Gazaoua (Olyset)



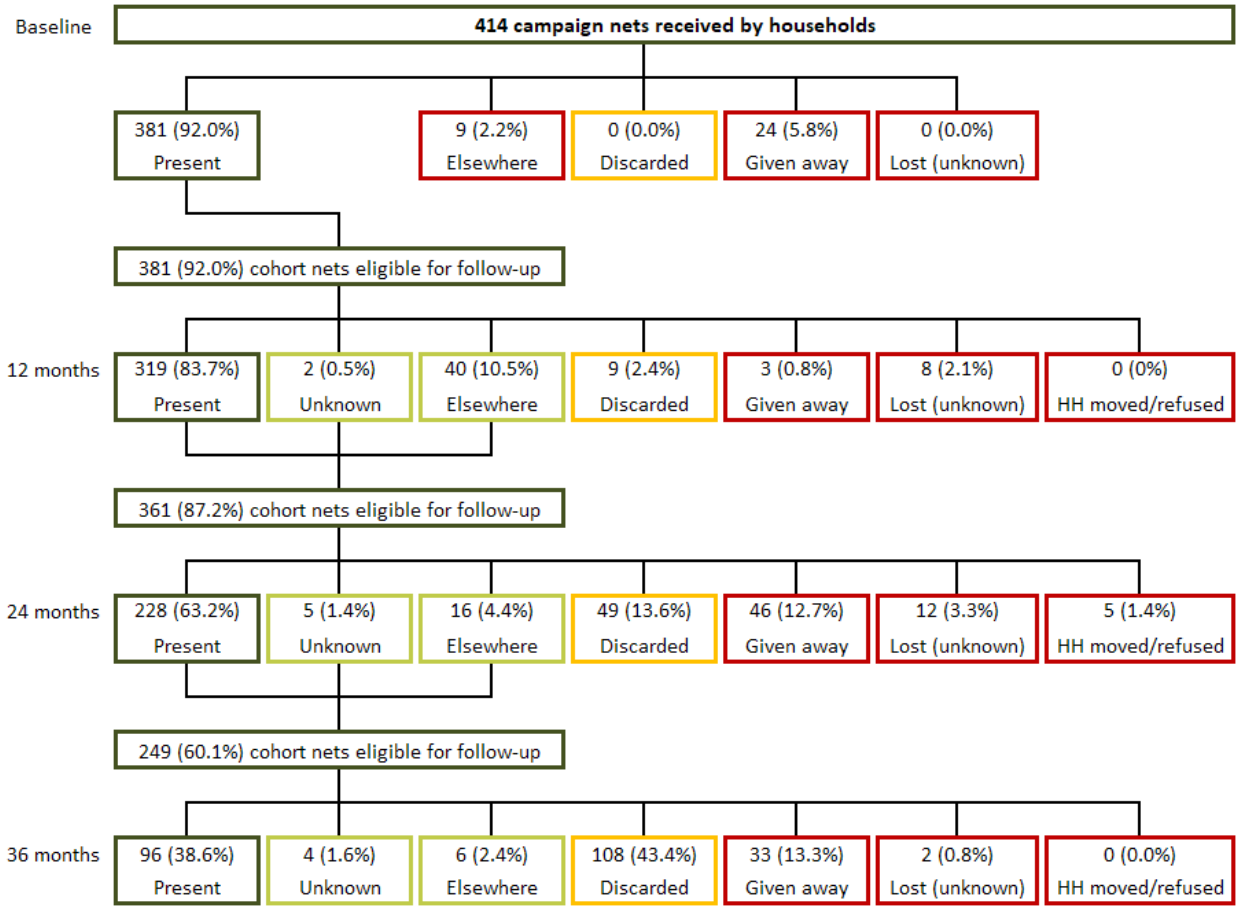


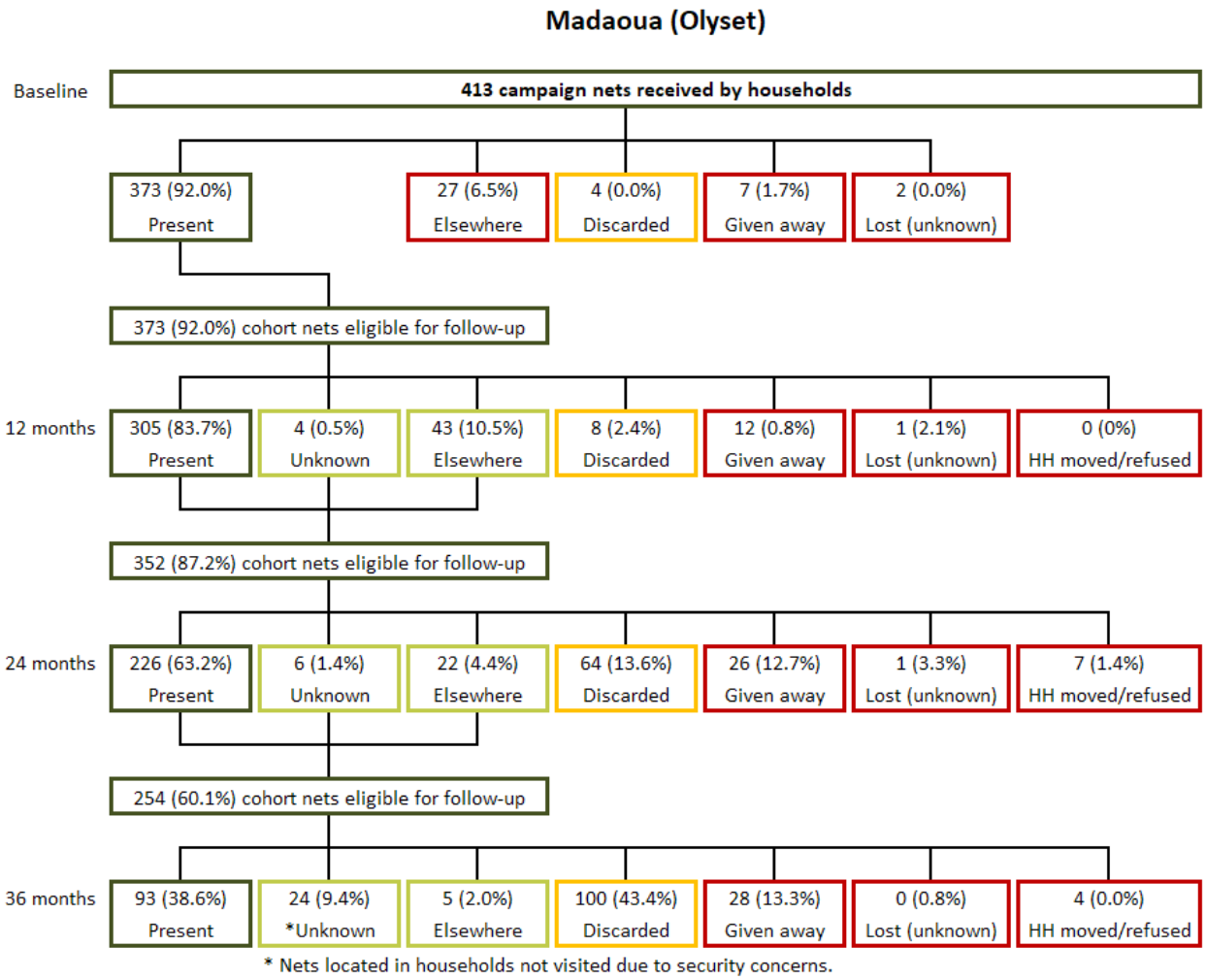
The 240 households visited at baseline reported receiving a total of 827 campaign nets (414 in Gazaoua and 413 in Madaoua; Figure 4). Of these nets, 754 (381 in Gazaoua and 373 in Madaoua) were present in the households and were tagged for study follow-up.

In Gazaoua at 12-months, 361 cohort nets were still in the households, had an unknown status (either due to nobody being home or lack of more precise respondent recall), or were elsewhere with family members and were eligible for follow-up in the next round. At 24-months, there were 249 nets either present, that had an unknown status, or said to be with a family member elsewhere and thus eligible for follow-up. At 36-months, the number of nets still in the households decreased to 96, four nets had an unknown status and six were said to be with a family member elsewhere. Of the nets not in the household, 108 were discarded, 33 were stolen or given to others, and two were lost for unknown reasons. Among Olyset nets reported as present, five and 12 nets were unavailable for assessment at 12- and 24-months respectively due to being temporarily taken away for washing or stored in locked rooms.

In Madaoua, at 12-months, 352 cohort nets were still in the households, had an unknown status, or were elsewhere with family members and were eligible for follow-up in the next round. At 24-months, 254 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, 24 had an unknown status (located in households not visited due to security concerns), and five were with family members elsewhere. One hundred nets were discarded, 28 were given away to others or stolen, and four could not be assessed because the household moved out of the study site or refused to be interviewed. Among Olyset nets reported as present, 132 nets were unavailable for assessment at 12-months and two nets at 24-months due to being temporarily taken away for washing or stored in locked rooms. During data cleaning and analysis of the 12-month study round, it became clear that the field team in Madaoua had systematically misinterpreted the response option "Temporarily taken away" when recording ITN status. Examination of other ITN data points and field team comments strongly suggest many nets recorded as "Temporarily taken away" were in fact present in the household when the field team visited. This data capture error means it is not possible to accurately describe ITN status in Madaoua at 12-months.

Figure 4: Follow-Up Status of Cohort ITNs Recruited at Baseline
Gazaoua (Olyset)





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 (Table 3). At baseline and 36-months, household characteristics were similar in both sites, with a few minor differences. In both sites, less than 10% of all households lived in a house with roof sheets or tiles at baseline (1%) and at 36-months (8%). Firewood was the most common source of energy used for cooking (81% at baseline and 100% at 36-months) and nearly all households had access to safe water (97.7% at baseline and 96.1% at 36-months). At baseline, access to latrines was low in both sites (9%), however, at 36-months a higher proportion of households had access to latrines in Gazaoua (76% versus 26% in Madaoua; p=0.001). Radio ownership was similar between sites (51% at baseline, 44% at 36-months across both sites) but mobile phone ownership was higher in Madaoua at baseline (75% versus 47% in Gazaoua; p<0.001) and at 36-months (79% versus 61% in Gazaoua; p=0.019). The proportion of households reporting animal husbandry (87% at baseline, 86% at 36-months) or owning farming land (90% at baseline, 95% at 36-months) was high, reflecting the rural environment of the study sites.

Table 3: Household Characteristics and Assets

	Baseline	36 months
Gazaoua	**N=119**	**N=106**
Roof (sheets/ tile)	6.9%	9.2%
Cooking fuel (firewood)	75.6%	100.0%
Access to safe water	97.7%	96.1%
Access to latrine	11.4%	75.8%
Radio	46.0%	41.2%
Mobile phone	47.2%	60.8%
Any transport	34.1%	40.5%
Animal husbandry	84.7%	85.0%
Owning land for farming	89.8%	96.1%
Madaoua	**N=120**	**N=90**
Roof (sheets/ tile)	3.1%	4.8%
Cooking fuel (firewood)	98.4%	100.0%
Access to safe water	93.2%	100.0%
Access to latrine	1.0%	26.0%
Radio	64.6%	51.4%
Mobile phone	74.5%	78.8%
Any transport	64.6%	56.8%
Animal husbandry	92.7%	89.7%
Owning land for farming	92.2%	91.8%

The presence of rodents in the house and the presence of food and practice of cooking near sleeping areas are risk factors for net durability. Table 4 presents the prevalence of these risk factors at 36-months. A higher proportion of households in Madaoua reported ever storing food in a room used for sleeping (88% versus 72% in Gazaoua; p=0.026), however, a slightly higher proportion of households in Gazaoua sometimes cooked in the same room used for sleeping (49% versus 33% in Madaoua, (p=0.088). In both study sites, across all survey rounds, nearly 90% of household observed rodents in the last six months. These results suggest that household risk factors for net damage were similar in Gazaoua and Madaoua.

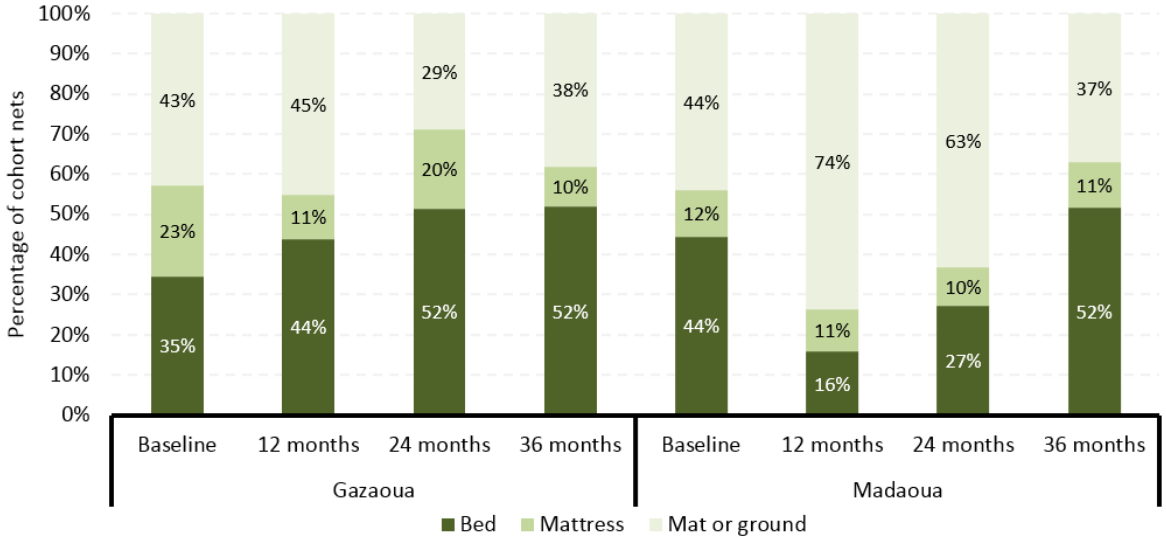
Table 4: Prevalence of Household Risk Factors for Damage

	Baseline	12 months	24 months	36 months
Gazaoua	**N=120**	**N=119**	**N=112**	**N=106**
Ever store food in room used for sleeping	89.8%	32.6%	91.4%	71.9%
Cook in sleeping room				
Never	51.7%	86.6%	86.4%	51.0%
Sometimes	48.3%	12.8%	13.0%	49.0%
Always	0.0%	0.0%	0.6%	0.0%
Don't know	0.0%	0.6%	0.0%	0.0%
Observed rodents in last six months	97.7%	89.5%	95.7%	88.2%

	Baseline	12 months	24 months	36 months
Madaoua	**N=120**	**N=119**	**N=113**	**N=90**
Ever store food in room used for sleeping	95.8%	85.9%	93.3%	88.4%
Cook in sleeping room				
Never	79.2%	63.4%	70.2%	67.1%
Sometimes	18.2%	36.6%	29.2%	32.9%
Always	2.6%	0.0%	0.0%	0.0%
Don't know	0.0%	0.0%	0.6%	0.0%
Observed rodents in last six months	83.3%	90.1%	86.5%	86.3%

The type of sleeping place may also affect net durability. Generally, nets used when sleeping on mats or the ground are more prone to wear and tear than those used over mattresses and bed frames. Figure 5 shows the types of sleeping spaces over which cohort ITNs were used by site and study period. Although a higher proportion of nets were hung over a mat or the ground in Madaoua during the 12- and 24-month surveys, the type of sleeping place cohort nets used at 36-months was almost identical between sites (52% over bed frame, 10-11% over mattress, 37-38% over mat/ground).

Figure 5: Type of Sleeping Place for Cohort 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, the majority of cohort nets in both sites had ever been washed (89% in Gazaoua, 94% in Madaoua). Among washed nets, the median number of washes in the six months prior to the survey was higher in Madaoua than in Gazaoua (12 washes versus five washes) and a higher proportion of cohort nets in Madaoua were last washed with detergent or bleach (89% versus 83% in Gazaoua; p=0.029). The proportion of nets last dried on a bush or fence was 23% in Gazaoua and 38% in Madaoua (p=0.272). Among nets reported as hanging, the proportion of nets not folded or tied up during the baseline, 12-, and 24-month surveys varied, somewhat unpredictably, between study sites and survey rounds. That said, at 36-months, close to 90% of nets were not folded or tied up (90% in Gazaoua, 88% in Madaoua). More frequent washing and use of detergent/bleach may place nets in Madaoua at higher risk of damage compared to nets in Gazaoua.

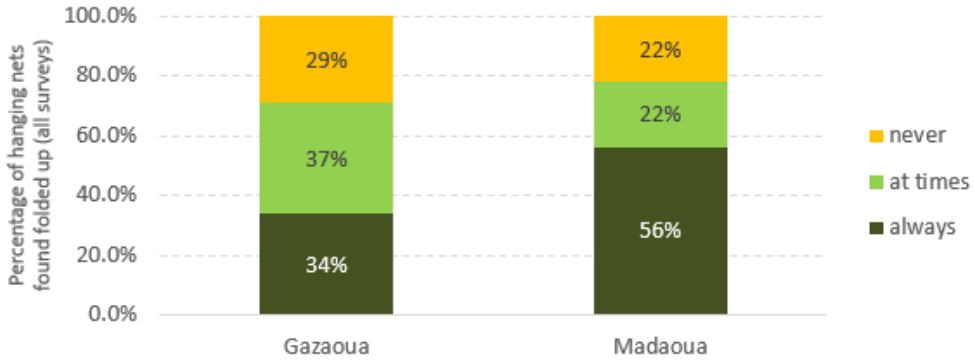
Table 5: Prevalence of Handling Risk Factors for Cohort ITNs

	Baseline	12 months	24 months	36 months
Gazaoua	**N=381**	**N=319**	**N=228**	**N=96**
ITNs ever washed	39.0%	62.9%	92.0%	89.2%
Among ITNs ever washed:	N=114	N=193	N=212	N=86
Median number of washes in last 6 months IQR]	2.0 [1.0-2.0]	3.0 [2.0-4.0]	12.0 [6.0-18.0]	5.0 [3.0-8.0]
Used detergent or bleach for last wash	53.6%	0.4%	83.4%	73.4%
ITNs dried on bush or fence for last wash	39.0%	41.5%	32.5%	23.4%
Among hanging ITNs:	N=128	N=140	N=156	N=47
Hanging ITNs are not folded or tied up	82.4%	47.8%	11.1%	89.7%
Madaoua	**N=373**	**N=305**	**N=226**	**N=93**
ITNs ever washed	38.7%	59.1%	73.1%	94.1%
Among ITNs ever washed:	N=147	N=186	N=169	N=86
Median number of washes in last 6 months IQR]	2.0 [1.0-2.0]	2.0 [1.0-3.0]	2.0 [1.0-4.0]	12.0 [4.0-18.0]
Used detergent or bleach for last wash	83.6%	67.6%	83.6%	89.3%
ITNs dried on bush or fence for last wash	44.2%	42.1%	58.7%	37.5%
Among hanging ITNs:	N=201	N=91	N=173	N=18
Hanging ITNs are not folded or tied up	41.1%	10.6%	25.0%	87.5%

IQR: interquartile range

When considering cohort nets that were ever found hanging across all rounds of the survey, a higher proportion of cohort nets were always found folded up in Madaoua (56% versus 34% in Gazaoua; p=0.006) (Figure 6).

Figure 6: Folding Up of Hanging Nets Across All Surveys



Respondent exposure to information on use and care and/or repair of nets is shown in Table 6. At 36-months, similar proportions of respondents reported any exposure in the six months before the survey (78% in Gazaoua and 69% in Madaoua). In both districts, during the baseline, 12- and 24-month surveys, the majority of respondents obtained net information from interpersonal communication (e.g., health workers, friends/family, and community leaders or events; IPC), however, at 36-months information was obtained from a more balanced mix of both IPC and media. At 36-months, a higher proportion of respondents received information from both media and IPC in Gazaoua (66% versus 42% in Madaoua; p=0.005), while IPC only was more common in Madaoua (56% versus 13% in Gazaoua; p<0.001). Nearly all respondents exposed to net messaging recalled "use net (every) night" (~100% across both districts). The second most commonly recalled message in Gazaoua was "care for net" (79%) and in Madaoua was "hang net" (68%). A higher proportion of respondents in Gazaoua recalled "repair net" (40% versus 7% in Madaoua; p<0.001). Differences in recall of messages on

using, hanging, and caring for nets, and about malaria prevention were not statistically significant between districts.

Table 6: Respondent Exposure to Messages About Nets in Last 6 Months

	Baseline	12 months	24 months	36 months
Gazaoua	**N=117**	**N=119**	**N=112**	**N=106**
Any exposure in last six months	52.4%	18.0%	38.3%	77.8%
Among those exposed:	N=58	N=23	N=38	N=84
Mean number of sources among exposed*	1.6	1.3	1.5	2.1
Type of media source among exposed				
Media only	19.1%	38.7%	24.2%	21.0%
Interpersonal communication only	19.1%	41.9%	51.6%	13.4%
Both	61.8%	19.4%	24.2%	65.5%
Messages recalled among exposed				
"Use net (every) night"	96.6%	100.0%	100.0%	100.0%
"Hang net"	83.1%	58.1%	37.1%	51.3%
"Care for net"	64.0%	29.0%	19.4%	78.2%
"Repair net"	1.1%	9.7%	6.5%	40.3%
"Nets prevent malaria"	62.9%	48.4%	87.1%	46.2%
Madaoua	**N=120**	**N=119**	**N=111**	**N=90**
Any exposure in last six months	46.4%	50.3%	77.3%	69.2%
Among those exposed:	N=47	N=58	N=77	N=65
Mean number of sources among exposed*	1.4	1.8	1.3	2.0
Type of media source among exposed				
Media only	19.1%	4.2%	5.9%	2.0%
Interpersonal communication only	60.7%	74.0%	90.4%	56.4%
Both	20.2%	21.9%	3.7%	41.6%
Messages recalled among exposed				
"Use net (every) night"	96.6%	97.9%	100.0%	99.0%
"Hang net"	39.3%	66.7%	97.8%	68.3%
"Care for net"	37.1%	57.3%	91.2%	58.4%
"Repair net"	4.5%	0.0%	14.7%	6.9%
"Nets prevent malaria"	57.3%	63.5%	94.1%	44.6%

* During the 36-month survey, the maximum number of sources was five and included: community health agent; radio message/show; radio song; health worker; town announcer.

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 recording 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 one is interpreted as a household respondent with a favorable attitude towards a given topic.

The mean attitude scores for nets and net care and repair fluctuated between survey rounds but there was an overall positive trend in both Gazaoua and Madaoua where all attitude scores were higher at 36-months than they were at baseline. At 36-months, the mean attitude scores in Gazaoua and Madaoua were above 1.0, indicating an overall positive attitude towards nets and net care and repair. In both study sites, there were a similar proportion of respondents with favorable attitudes towards nets (89% in Gazaoua, 84% in Madaoua) and net care and repair (69% in Gazaoua, 53% in Madaoua).

Table 7: Respondent Attitudes Towards Nets and Net Care & Repair

	Baseline	12 months	24 months	36 months
Gazaoua	**N=119**	**N=119**	**N=112**	**N=106**
Attitude score: Nets				
Mean	1.67	1.73	1.72	1.69
(95% CI)	(1.58-1.76)	(1.62-1.84)	(1.65-1.80)	(1.60-1.77)
Percentage of respondents with score > 1.0	88.0%	83.7%	90.1%	88.9%
Attitude score: Net care and repair				
Mean (95% CI)	0.97 (0.88-1.05)	1.41 (1.33-1.50)	1.29 (1.13-1.45)	1.25 (1.10-1.39)
Percentage of respondents with score > 1.0	30.4%	87.8%	72.2%	69.3%
Madaoua	**N=119**	**N=119**	**N=113**	**N=90**
Attitude score: Nets				
Mean	1.15	1.01	0.79	1.57
(95% CI)	(0.85-1.45)	(0.72-1.31)	(0.50-1.08)	(1.49-1.66)
Percentage of respondents with score > 1.0	58.7%	57.6%	38.2%	84.2%
Attitude score: Net care and repair				
Mean	0.77	1.04	1.01	1.11
(95% CI)	(0.69-0.85)	(0.92-1.16)	(0.86-1.16)	(0.89-1.32)
Percentage of respondents with score > 1.0	20.3%	45.0%	50.0%	53.4%

Experience with repairing holes in nets is displayed in Table 8. From baseline to 24-months, a progressively increasing proportion of respondents reported having ever experienced holes (from an average of 49% at baseline to 94% at 24-months, across both sites). However, at 36-months the proportion of respondents having ever experienced holes dropped to 68% in Gazaoua and 62% in Madaoua. The proportion of respondents who reported discussing net care and repair was 50% in Gazaoua and 68% in Madaoua. Among those who reported having holes in their nets, 66% of respondents in Gazaoua and 68% of respondents in Madaoua had ever repaired a net at 36-months. There were no statistical differences between the proportion of households experiencing holes in a net, discussing net care and repair, or repairing nets across study sites at 36-months.

Table 8: Household Net Care and Repair Experience

	Baseline	12 months	24 months	36 months
Gazaoua	**N=119**	**N=119**	**N=112**	**N=106**
Ever experienced holes in a net	48.0%	61.0%	95.1%	68.0%
Discussed net care and repair in last six months	42.6%	60.5%	41.4%	49.7%
Among households experiencing holes:	N=57	N=71	N=107	N=67
Ever repaired net	45.2%	35.2%	88.3%	66.3%

	Baseline	12 months	24 months	36 months
Madaoua	**N=120**	**N=119**	**N=113**	**N=90**
Ever experienced holes in a net	53.6%	64.9%	88.8%	62.3%
Discussed net care and repair in last six months	62.0%	38.7%	78.7%	67.8%
Among households experiencing holes:	N=63	N=80	N=105	N=59
Ever repaired net	61.2%	48.4%	68.4%	68.1%

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. At 36-months, in both sites, cohort nets were most commonly found stored away unpacked with a higher proportion in Madaoua than in Gazaoua (76% and 39%; $p<0.001$). The proportion of nets found hanging untied was higher in Gazaoua and was the second most common net status in both study sites (37% in Gazaoua, 18% in Madaoua; $p=0.013$). From the 24-month survey to the 36-month survey, the proportion of nets stored away unpacked increased by 28 and 70 percentage points in Gazaoua and Madaoua respectively. At 36-months, 58% of cohort nets were no longer found hanging in Gazaoua and 80% in Madaoua; an increase of 24 and 36 percentage points from 24-months in Gazaoua and Madaoua respectively.

Reported use of cohort nets also decreased from 24-months to 36-months. At 24-months 73% of cohort nets in Gazaoua were used every night last week compared to 37% at 36-months. In Madaoua, the proportion of cohort nets used every night last week decreased from 76% to 13% during the same time period. This also reflects the decrease in proportion of nets found hanging (tied or un-tied) at both sites. At 36-months, a higher proportion of nets in Gazaoua were used last night (44% versus 16% in Madaoua; $p=0.014$) and every night last week (37% versus 13% in Madaoua; $p=0.024$). Nets obtained in more recent net campaigns may have displaced previously used cohort nets potentially explaining the observed decrease in cohort net usage at 36-months.

Table 9: Status and Reported Use of Cohort Nets in the Household

	Baseline	12 months	24 months	36 months
Gazaoua	**N=381**	**N=319**	**N=228**	**N=96**
Cohort net status				
Found hanging and tied up	5.2%	21.0%	58.5%	4.3%
Found hanging, untied	24.4%	19.2%	7.3%	37.4%
Not hanging and not stored away	33.8%	37.7%	18.9%	15.1%
Stored away unpacked	34.7%	19.2%	11.0%	38.8%
Stored away in a package	1.9%	0.4%	0.3%	4.3%
Temporarily unavailable during visit	0.0%	2.5%	4.0%	0.0%
Net ever used	62.7%	79.6%	93.3%	92.8%
Net used last night	61.6%	69.4%	73.4%	43.9%
Net used every night last week	60.7%	67.9%	73.0%	37.4%
Madaoua	**N=370**	**N=305**	**N=226**	**N=93**
Cohort net status				
Found hanging and tied up	32.8%	N/A*	58.4%	2.5%
Found hanging, untied	22.9%	N/A*	19.5%	17.6%
Not hanging and not stored away	10.5%	N/A*	15.6%	2.5%
Stored away unpacked	33.5%	N/A*	5.5%	75.6%

	Baseline	12 months	24 months	36 months
Stored away in a package	0.4%	N/A*	0.3%	1.7%
Temporarily unavailable during visit	0.0%	N/A*	0.6%	0.0%
Net ever used	65.9%	81.5%	96.4%	97.5%
Net used last night	61.5%	35.9%	76.9%	16.0%
Net used every night last week	59.5%	30.2%	75.6%	13.4%

* Due to a misinterpretation of the survey question responses in Madaoua, location results for the nets in these households were not available at 12-months.

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

At 36-months, nearly all households had any non-cohort nets (97% in Gazaoua, 99% in Madaoua) and the vast majority of these nets were obtained from a net campaign other than the 2018 campaign (93% in Gazaoua, 85% in Madaoua). Compared to the 24-month survey, this represents an increase in ownership of non-cohort nets, indicating an injection of new nets from a more recent net campaign. The second most common source of nets was from ANC visits (5% in Gazaoua, 10% in Madaoua). Nets were rarely ever obtained from the private sector (<1% across both sites). A higher proportion of nets in Gazaoua compared to Madaoua were obtained from other net campaigns (93% versus 85% in Madaoua; p=0.028). Differences in other net sources were not significantly different between study sites.

Table 10: Ownership and Source of Non-Cohort Nets

	Baseline	12 months	24 months	36 months
Gazaoua	**N=120**	**N=119**	**N=112**	**N=106**
Households with any non-cohort nets	84.7%	80.2%	87.0%	96.7%
Non-cohort net sources	**Net N=271**	**Net N=274**	**Net N=222**	**Net N=393**
ANC visit	15.3%	10.8%	0.0%	4.9%
Other net campaign	75.0%	77.8%	33.6%	92.8%
School	0.0%	0.0%	0.0%	0.0%
Other public source*	1.8%	4.1%	32.1%	0.4%
Private sector	3.1%	3.3%	8.9%	0.4%
Other/doesn't recall**	4.8%	4.1%	25.4%	1.5%
Madaoua	**N=120**	**N=119**	**N=113**	**N=90**
Households with any non-cohort nets	93.8%	96.3%	69.1%	99.3%
Non-cohort net sources	**Net N=308**	**Net N=321**	**Net N=172**	**Net N=496**
ANC visit	23.0%	27.0%	29.4%	10.1%
Other net campaign	54.4%	51.5%	35.1%	84.8%
School	0.0%	0.6%	0.0%	0.0%
Other public source*	5.3%	6.0%	7.0%	0.1%
Private sector	7.7%	5.0%	15.4%	1.1%
Other/doesn't recall**	9.5%	10.0%	13.2%	3.9%

* 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 889 non-cohort nets (393 in Gazaoua and 496 in Madaoua) were audited in study households at the 36-month survey round (Table 11).[8] Similar to cohort nets, most non-cohort nets were found stored away unpacked in both Gazaoua and Madaoua. The overall proportion of non-cohort nets stored away were similar in Madaoua and Gazaoua (84% in Madaoua, 76% in Gazaoua), with a higher proportion of nets stored unpacked in Madaoua (83% versus 61% in Gazaoua; p=0.004), and a higher proportion stored in a package in Gazaoua (15% versus 1% in Madaoua; p<0.001). The second most common non-cohort net status was hanging untied (21% in Gazaoua, 13% in Madaoua). Compared to the 24-month survey when the majority of non-cohort nets were found hanging and tied up (59% in Gazaoua, 56% in Madaoua), hardly any non-cohort nets were found hanging tied at 36-months (3% in Gazaoua, 0% in Madaoua).

Although a higher proportion of non-cohort nets were ever used in Gazaoua at 36-months (57% versus 39% in Madaoua; p=0.016), the proportion of nets used last night or every night last week were similar across sites (28% and 24% respectively in Gazaoua; 24% and 23% respectively in Madaoua). At 36-months, the proportion of nets used last night or every night last week was higher for cohort nets compared to non-cohort nets in Gazaoua (44% versus 28% used last night; 37% versus 24% used every night), however, the reverse was true in Madaoua (16% versus 24% used last night; 13% versus 23% used every night). Non-cohort net usage was lowest at 36-months. From 24-months to 36-months, net use every night last week dropped from 80% to 24% in Gazaoua and from 86% to 23% in Madaoua. Decreased cohort and non-cohort net usage, as well as the high proportion of nets stored away suggests that study households were in possession of a surplus of nets at 36-months.

Table 11: Status and Reported Use of Non-Cohort Nets in the Household

	Baseline	12 months	24 months	36 months
Gazaoua	**N=270**	**N=274**	**N=222**	**N=393**
Non-cohort net status				
Found hanging and tied up	5.9%	15.2%	59.0%	2.7%
Found hanging, untied	21.0%	11.9%	12.5%	20.5%
Not hanging and not stored away	60.0%	52.0%	18.7%	0.4%
Stored away unpacked	9.5%	14.9%	7.0%	61.3%
Stored away in a package	3.6%	5.7%	2.1%	15.2%
Temporarily unavailable during visit	0.0%	0.0%	0.6%	0.0%
Net ever used	90.3%	81.8%	92.7%	56.5%
Net used last night	82.1%	50.9%	82.9%	27.7%
Net used every night last week	81.4%	46.6%	80.1%	24.3%
Madaoua	**N=256**	**N=321**	**N=172**	**N=496**
Non-cohort net status				
Found hanging and tied up	48.6%	N/A	55.7%	0.0%
Found hanging, untied	11.7%	N/A	34.2%	12.8%
Not hanging and not stored away	32.6%	N/A	8.8%	1.5%
Stored away unpacked	4.3%	N/A	0.0%	82.8%
Stored away in a package	2.9%	N/A	1.3%	0.8%
Temporarily unavailable during visit	0.0%	N/A	0.0%	2.1%

8 The most common brands audited were PermaNet 2.0 (n=768), Olyset (n=50), and Olyset Plus (n=16).

	Baseline	12 months	24 months	36 months
Net ever used	94.0%	88.2%	98.2%	38.8%
Net used last night	68.6%	42.1%	87.7%	24.1%
Net used every night last week	62.8%	35.9%	86.0%	22.6%

* Due to a misinterpretation of the survey question responses in Madaoua, location results for the nets in these households were not available at 12-months.

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, approximately 40% of cohort and non-cohort nets were used by adults only in Gazaoua and Madaoua. The proportion of non-cohort nets used by children only was approximately twice that of cohort nets in both sites (13% versus 7% in Gazaoua, 19% versus 11% in Madaoua). The proportion of nets used by users of different age groups was not statistically different between sites for cohort or non-cohort nets.

Table 12: Use of Cohort Nets by Household Members Among Nets Used the Previous Night

	Baseline	12 months	24 months	36 months
Gazaoua	**N=243**	**N=224**	**N=174**	**N=50**
Cohort nets				
Used by child(ren) only	9.4%	8.7%	12.7%	6.6%
Used by child(ren) sharing with adult(s)	42.4%	53.1%	59.7%	54.1%
Used by adult(s) only	48.2%	38.3%	27.6%	39.3%
Madaoua	**N=220**	**N=109**	**N=172**	**N=15**
Cohort nets				
Used by child(ren) only	14.4%	11.3%	20.3%	10.5%
Used by child(ren) sharing with adult(s)	15.4%	50.7%	41.8%	47.4%
Used by adult(s) only	70.2%	38.0%	38.0%	42.1%

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

Table 13: Use of Non-Cohort Nets by Household Members Among Nets Used the Previous Night

	Baseline	12 months	24 months	36 months
Gazaoua	**N=224**	**N=146**	**N=188**	**N=113**
Non-cohort nets				
Used by child(ren) only	12.7%	12.8%	8.9%	13.0%
Used by child(ren) sharing with adult(s)	46.6%	44.1%	62.4%	44.5%
Used by adult(s) only	40.7%	43.1%	28.8%	42.5%
Madaoua	**N=208**	**N=155**	**N=157**	**N=122**
Non-cohort nets				
Used by child(ren) only	22.0%	12.8%	16.5%	18.9%
Used by child(ren) sharing with adult(s)	23.4%	54.2%	48.0%	40.6%
Used by adult(s) only	54.6%	33.0%	35.5%	40.6%

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

Access to ITNs is an important determinant of ITN use – people need access before they can use an ITN (Table 14). Access can be measured at the household and population levels. Household access is defined as the proportion of households with one ITN for every two people in the household; population access is defined

as the proportion of people that could sleep under an ITN assuming each ITN in a household was used by two people.

From baseline to 36-months, household and population access to all ITNs decreased in Gazaoua (27 and 16 percentage point decrease respectively) and slightly increased in Madaoua (3 and 5 percentage point increase respectively). However, in both study sites, household and population access to cohort ITNs decreased (44% to 3% and 73% to 23% respectively in Gazaoua; 37% to 4% and 72% to 21% respectively in Madaoua), and access to other ITNs increased (21% to 43% and 49% to 68% respectively in Gazaoua; 31% to 74% and 50% to 92% respectively in Madaoua). At 36-months, household and population access to all ITNs was lower in Gazaoua compared to Madaoua, driven by lower access to other ITNs in Gazaoua (43% versus 74% household access in Madaoua, p=0.004; 68% versus 92% population access in Madaoua, p<0.001). Although access to other ITNs was lower in Gazaoua at 36-months, population use of other ITNs was similar between study sites (27% in Gazaoua, 29% in Madaoua). Population use of campaign cohort ITNs was low in both sites but higher in Gazaoua (12% versus 5% in Madaoua; p=0.037).

Table 14: Household and Population ITN Access

	Baseline	36 months
Gazaoua		
Household access	**N=120**	**N=106**
All ITNs	85.2%	57.5%
Cohort ITNs (Olyset)	43.8%	3.3%
Other ITNs	20.5%	43.1%
Population access	**N=976**	**N=860**
All ITNs	92.7%	77.7%
Cohort ITNs (Olyset)	72.5%	23.4%
Other ITNs	49.2%	67.7%
Population use	**N=976**	**N=860**
All ITNs	N/A	38.7%
Cohort ITNs (Olyset)	N/A	12.2%
Other ITNs	N/A	27.0%
Madaoua		
Household access	**N=120**	**N=90**
All ITNs	77.1%	80.8%
Cohort ITNs (Olyset)	36.5%	4.1%
Other ITNs	31.3%	74.0%
Population access	**N=935**	**N=821**
All ITNs	90.1%	95.4%
Cohort ITNs (Olyset)	71.9%	21.2%
Other ITNs	49.5%	92.3%
Population use	**N=935**	**N=821**
All ITNs	N/A	33.0%
Cohort ITNs (Olyset)	N/A	4.5%
Other ITNs	N/A	28.5%

3.4 DURABILITY OF CAMPAIGN ITNS

The durability of ITNs can be conceptualized as two components: *attrition*, or nets that are no longer present in the household; and the *physical integrity* of nets that are available for use in the household. Table 15 presents results for the attrition of cohort nets at baseline, 12-, 24- and 36-month rounds. Of the 414 cohort nets in Gazaoua and 413 nets in Madaoua enrolled at baseline, 399 and 373 nets respectively were included in the attrition calculation at 36-months. Excluded nets either belonged to households that were not interviewed (nobody was home or had refused), were not assessed due to inaccessibility within the house, or were said during this round to be with family elsewhere and thus their actual status could not be ascertained. Tagged nets that are reported as with family elsewhere are kept in the study cohort until the 36-month study 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.

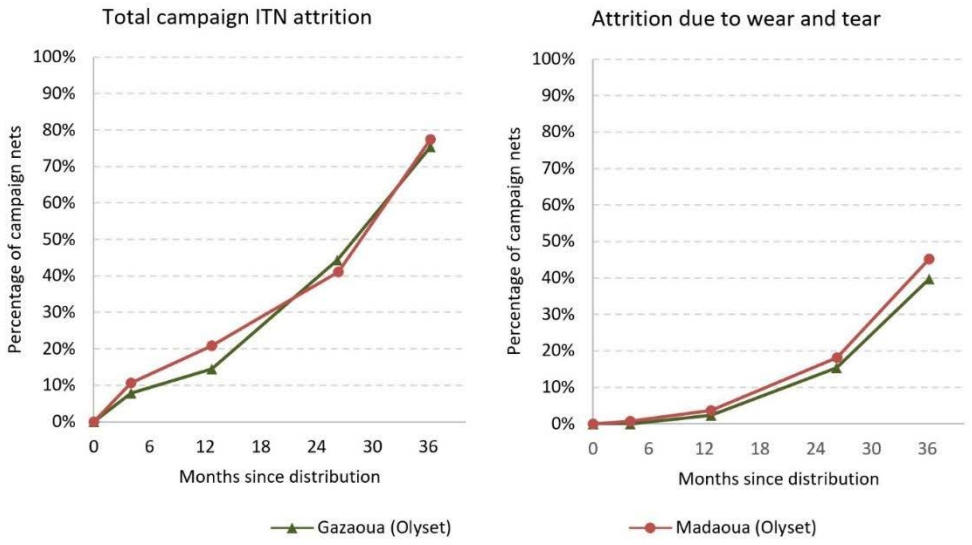
In Gazaoua, total campaign cohort ITN attrition increased from 8% at baseline to 75% at 36-months (Table 15, Figure 7). In Madaoua, total campaign cohort attrition increased from 11% to 77% during the same time frame. At 36-months, in both study sites, the most common reason for attrition was discarded (also known as attrition due to wear and tear) (40% in Gazaoua, 45% in Madaoua) and the second most common reason was given away to others (29% in Gazaoua, 31% in Madaoua). A higher proportion of nets in Madaoua were lost for other/unknown reasons (6% versus 1% in Madaoua; $p<0.001$). Total campaign cohort ITN attrition, ITNs given away to others, and ITNs discarded were similar between sites. Prior to baseline data collection, 36 nets (nine in Gazaoua and 27 in Madaoua) were reportedly used by family elsewhere and were classified as given away to others.

Table 15: Campaign Cohort ITN Attrition

	Baseline	12 months	24 months	36 months
Gazaoua	**N=414**	**N=372**	**N=388**	**N=399**
Total campaign ITN attrition	7.9%	14.5%	44.3%	75.3%
ITNs given away to others	7.9%	9.5%	22.8%	29.4%
ITNs discarded	0.0%	2.3%	15.4%	39.7%
ITNs lost for other/unknown reason	0.0%	2.7%	6.1%	6.2%
Madaoua	**N=413**	**N=366**	**N=378**	**N=373**
Total campaign ITN attrition	10.7%	20.8%	41.1%	77.4%
ITNs given away to others	9.6%	16.7%	22.2%	31.4%
ITNs discarded	0.7%	3.6%	18.2%	45.2%
ITNs lost for other/unknown reason	0.3%	0.6%	0.8%	0.8%

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

Figure 7: Trends in Total Attrition And Attrition Due to Wear and Tear (Discarded Nets)



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

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

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

Good:	pHI ≤ 64 (corresponding to a total hole surface area ≤ 0.01m²)
Serviceable:	pHI ≤ 642 (total hole surface area ≤ 0.1 m²)
Torn:	pHI > 642 (total hole surface area > 0.1m²)

Table 16 reports the physical integrity results of nets that were in the household from baseline to 36-months (nets that were in the household but were temporarily unavailable due to being washed or were locked away were not included in the assessment). In Gazaoua, the proportion of cohort nets with any holes increased from 41% at baseline to 88% at 36-months and in Madaoua increased from 44% to 92%. The majority of this increase was between baseline and 12-months (25 percentage points), and 12-months and 24-months (21%) in Gazaoua, and between 12-months and 24-months in Madaoua (41 percentage points). At 36-months, the proportion of cohort nets with any holes was similar between sites (88% in Gazaoua, 92% in Madaoua), however, the proportion of nets classified as "serviceable" was lower in Gazaoua (61% versus 78% in Madaoua; p=0.025).

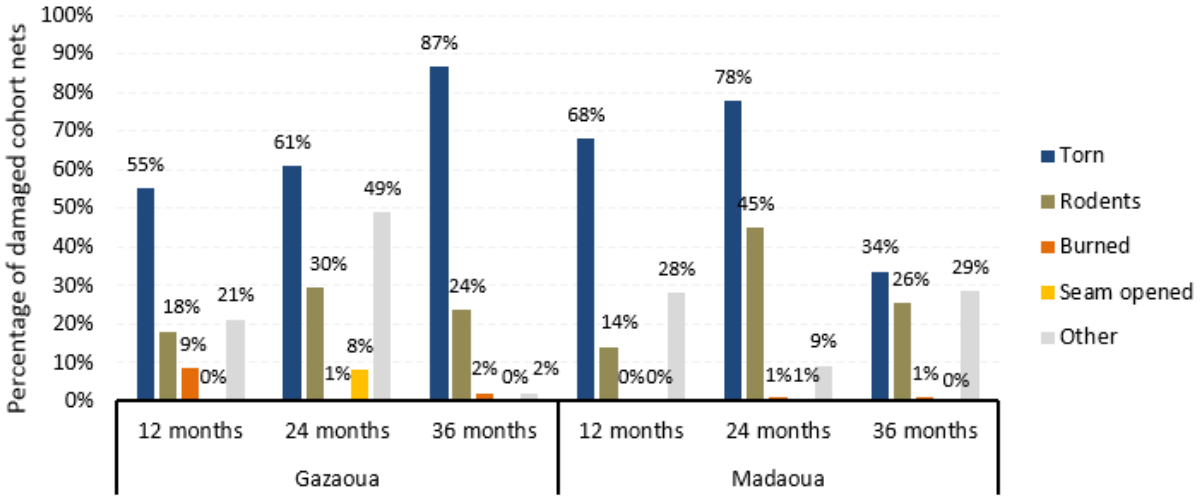
Table 16: Physical Integrity of Observed Campaign Cohort ITNs

	Baseline	12 months	24 months	36 months
Gazaoua	**N=381**	**N=314**	**N=218**	**N=96**
Cohort ITN with any holes	40.7%	65.2%	86.5%	87.8%
ITNs classified as "Good"	89.7%	79.9%	50.5%	30.2%
ITNs classified as "Too torn"	2.4%	6.4%	26.0%	38.8%
ITNs classified as "Serviceable"	97.6%	93.6%	74.0%	61.2%
Among ITNs with any holes:	N=162	N=209	N=193	N=84
Median pHI for ITNs with any holes	23.5	17.0	125.0	518.5

	Baseline	12 months	24 months	36 months
Madaoua	**N=373**	**N=173**	**N=224**	**N=93**
Cohort ITN with any holes	44.3%	48.5%	85.6%	92.4%
ITNs classified as "Good"	85.7%	86.6%	52.6%	34.5%
ITNs classified as "Too torn"	1.3%	4.5%	21.9%	21.8%
ITNs classified as "Serviceable"	98.7%	95.5%	78.1%	78.2%
Among ITNs with any holes:	N=152	N=73	N=194	N=84
Median pHI for ITNs with any holes	26.0	31.0	88.5	163.5

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 subsequent study rounds). The most commonly reported damage mechanism in Madaoua and Gazaoua across survey rounds was tearing on an object, however, the proportion of nets for which tearing was reported fluctuated widely between the 12-, 24- and 36-month surveys (55%, 61%, 87% respectively in Gazaoua; 68%, 78% and 34% in Madaoua). Damage by rodents and from other reasons were consistently the second and third most commonly reported damage mechanisms. At 36-months damage from tears was more commonly reported in Gazaoua (87% versus 34% in Madaoua, $p<0.001$) and damage from other reasons was more common in Madaoua (29% versus 2% in Gazaoua; $p=0.001$). At 36-months, damage mechanisms in the "other" category included damage caused by bedding material (millet stems) and general net material deterioration.

Figure 8: Types of Damage Mechanisms Reported for Damaged Campaign Cohort ITNs



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

Table 17 reports the proportion of cohort ITNs surviving and in serviceable condition from baseline to 36-months. At baseline, 12-months, and 24-months the proportion of surviving all cohort nets, and cohort nets ever-used and present, were similar in Gazaoua and Madaoua. At the 36-month round the proportion of surviving all cohort nets were similar between sites (24% in Gazaoua, 26% in Madaoua), however, the proportion of surviving cohort nets ever-used, and present was lower in Gazaoua (58%) compared to Madaoua

(78%) (p=0.017). This difference reflects the previous finding of poorer cohort net physical integrity in Gazaoua.

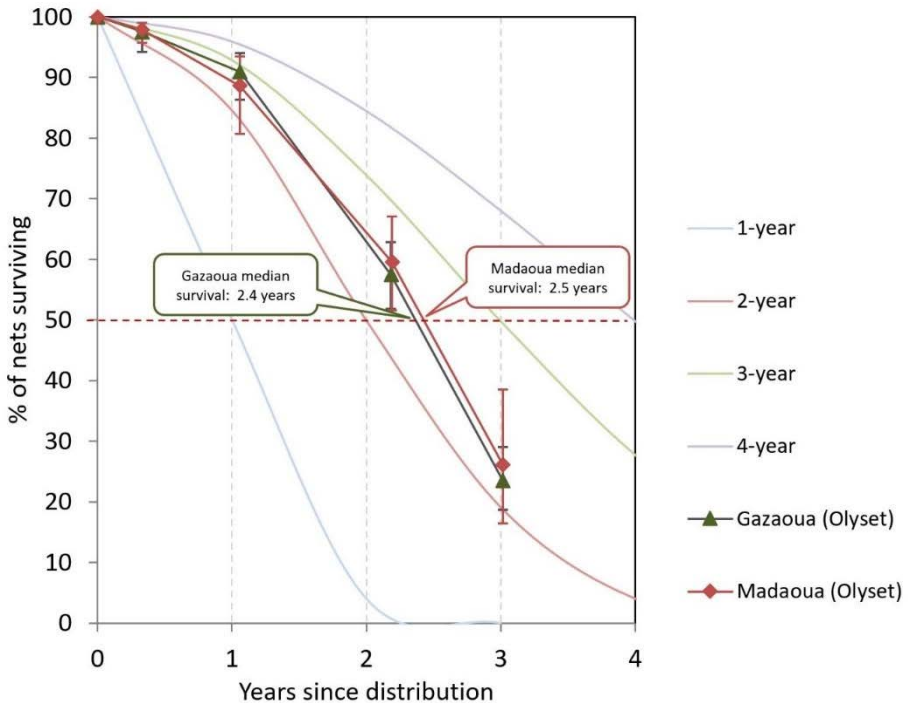
Table 17: Campaign Cohort ITNs Surviving in Serviceable Condition

	Baseline	12 months	24 months	36 months
Gazaoua				
All cohort nets*	N=381	N=323	N=276	N=262
Survival estimate	97.6%	90.9%	57.5%	23.5%
95% CI	94.2%-99.0%	86.3%-94.0%	51.9%-62.9%	18.7%-29.1%
Cohort nets ever-used and present	N=245	N=251	N=207	N=90
Survival estimate	96.1%	91.7%	72.4%	58.1%
95% CI	91.0%-98.4%	87.8%-94.5%	63.8%-79.6%	44.5%-70.6%
Madaoua				
All cohort nets*	N=377	N=187	N=300	N=269
Survival estimate	97.9%	88.6%	59.6%	26.1%
95% CI	95.7%-99.0%	80.7%-93.5%	51.6%-67.1%	16.5%-38.5%
Cohort nets ever-used and present	N=236	N=128	N=213	N=90
Survival estimate	98.0%	93.0%	77.6%	77.6%
95% CI	94.9%-99.2%	86.4%-96.6%	68.7%-84.6%	67.4%-85.3%

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

Figure 9 plots the proportion of nets surviving in serviceable condition against hypothetical survival curves for nets lasting one to four years using the survival data from baseline 12-, 24-, and 36-month study rounds. The median survival can be estimated as the relative position of the data point on a horizontal line between the two adjacent median survival curves. Using this method, the estimated median useful life for Olyset nets in Gazaoua is 2.4 years and for Olyset nets in Madaoua is 2.5 years.

Figure 9: Estimated ITN Survival



Error bars show 95% confidence intervals.

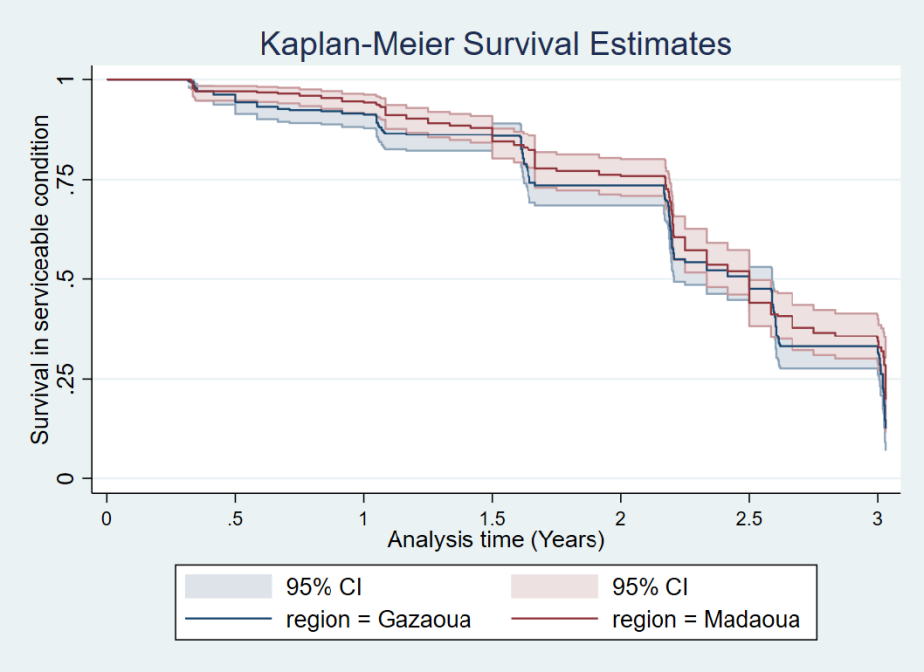
Table 18 displays estimated median survival times using the most recent two data points as another method to calculate the survival estimate. Using this method, the estimated median useful life for Olyset nets is 2.4 years in both Gazaoua and Madaoua.

Table 18: Estimated Median Survival of ITNs in Years Using Different Methods

	12 months	24 months	36 months
Gazaoua (Olyset)	**N=323**	**N=276**	**N=262**
Estimated from figure 9	2.8	2.4	2.1
Calculated from last two data points (95% CI)	-	-	2.4 (2.2-2.5)
Madaoua (Olyset)	**N=187**	**N=300**	**N=269**
Estimated from figure 9	2.6	2.5	2.2
Calculated from last two data points (95% CI)	-	-	2.4 (2.2-2.7)

When data were analyzed as survival analysis in a Kaplan-Meier plot (Figure 10), Olyset ITNs in Gazaoua, showed a slight trend of lower survival compared to Olyset ITNs in Madaoua, although this difference was not statistically significant (p=0.115).

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:

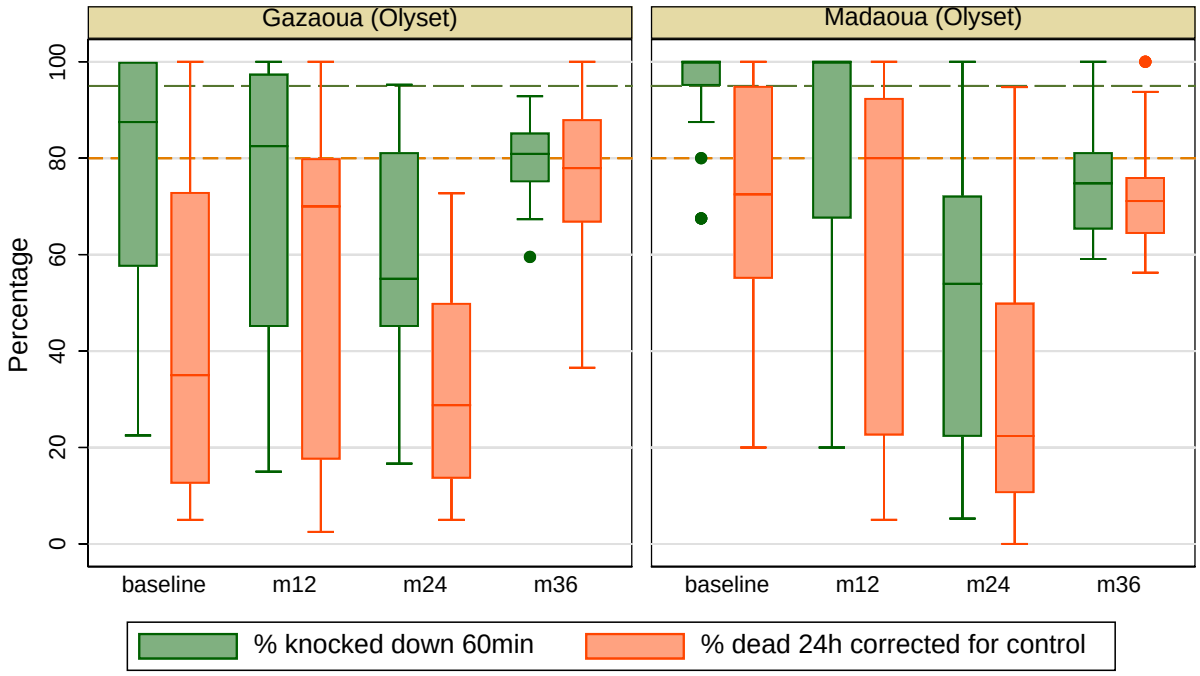
Optimal effectiveness: KD60 ≥ 95% or mortality ≥ 80%
Minimal effectiveness: KD60 ≥ 75% or mortality ≥ 50%

Bioassay results are shown in Table 19 and Figure 11. Insecticidal effectiveness, as measured by KD60 and mortality on samples from campaign nets, generally declined between the baseline and 24-month round before increasing at the 36-month round. Between baseline and the 24-month round the proportion of nets classified as optimally effective declined from 36% to 3% in Gazaoua and from 79% to 23% in Madaoua. Samples from Madaoua were more likely than those from Gazaoua to be optimally effective at each of the first three rounds. At 36-months, mean KD60 was 80% in Gazaoua and 75% in Madaoua, and mean mortality was 76% in Gazaoua and 72% in Madaoua. Though similar, the slightly lower mean results in Madaoua correspond to a lower proportion of net samples being optimally effective in Madaoua (23%) compared to Gazaoua (43%). However, all samples from both sites met the criteria for minimal effectiveness at 36-months (100%). A higher proportion of net samples were optimally effective in Gazaoua at 36-months compared with 24-months, while optimal effectiveness remained static in Madaoua over the last two study rounds despite increases in both mean KD60 and mortality. As noted above, insecticidal effectiveness appears to have improved between the 24- and 36-month study rounds. Improved effectiveness in the bioassay net samples may have resulted if nets sampled at the 36-month round were more likely to have been taken from storage, or to have been only recently unpacked and hung to replace previous nets that were discarded or given away.

Table 19: Cone Bioassay Results

	Baseline	12 months	24 months	36 months
Gazaoua	**N=31**	**N=29**	**N=30**	**N=30**
Knock down 60 minutes				
Mean	76.4%	72.2%	58.7%	80.0%
(95% CI)	(68.0%-84.8%)	(60.8%-83.7%)	(51.9%-65.6%)	(77.0%-82.9%)
Median [IQR]	87.5 [57.5-100.0]	82.5 [45.0-97.5]	55.0 [45.0-81.2]	80.9 [75.0-85.3]
Mortality 24 hours				
Mean	41.7%	53.4%	32.7%	75.9%
(95% CI)	(30.3%-53.4%)	(40.8%-65.9%)	(25.7%-39.6%)	(69.6%-82.2%)
Median [IQR]	35.0 [12.5-73.0]	70.0 [17.5-80.0]	28.8 [13.5-50.0]	77.9 [66.7-88.1]
Optimal effectiveness				
Estimate	35.5%	56.7%	3.3%	43.3%
(95% CI)	(17.6%-53.3%)	(36.7%-74.7%)	(0.4%-22.1%)	(25.7%-62.0%)
Minimal effectiveness				
Estimate	58.1%	56.7%	40.0%	100.0%
(95% CI)	(39.7%-76.5%	(36.7%-74.7%)	(26.5%-55.2%)	-
Madaoua	**N=29**	**N=30**	**N=30**	**N=30**
Knock down 60 minutes				
Mean	95.3%	81.1%	52.3%	75.3%
(95% CI)	(91.9%-98.8%)	(69.0%-93.2%)	(38.8%-65.8%)	(70.4%-80.1%)
Median [IQR]	100.0 [95.0-100.0]	100.0 [67.5-100.0]	53.9 [22.2-72.2]	74.8 [65.2-81.3]
Mortality 24 hours				
Mean	69.4%	64.4%	35.5%	72.1%
(95% CI)	(59.9%-78.9%)	(49.1%-79.7%)	(24.2%-46.8%)	(66.5%-77.7%)
Median [IQR]	72.5 [55.0-95.0]	80.0 [22.5-92.5]	22.4 [10.5-50.0]	71.1 [64.3-76.1]
Optimal effectiveness				
Estimate	79.3%	70.0%	23.3%	23.3%
(95% CI)	(63.6%-95.0%)	(48.5%-85.3%)	(12.5%-39.4%)	(10.8%-43.4%)
Minimal effectiveness				
Estimate	93.1%	70.0%	26.7%	100.0%
(95% CI)	(83.3%-100%)	(48.5%-85.3%)	(15.4%-42.1%)	-

Figure 11: Box Plot of ITN Cone Bioassay Results



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

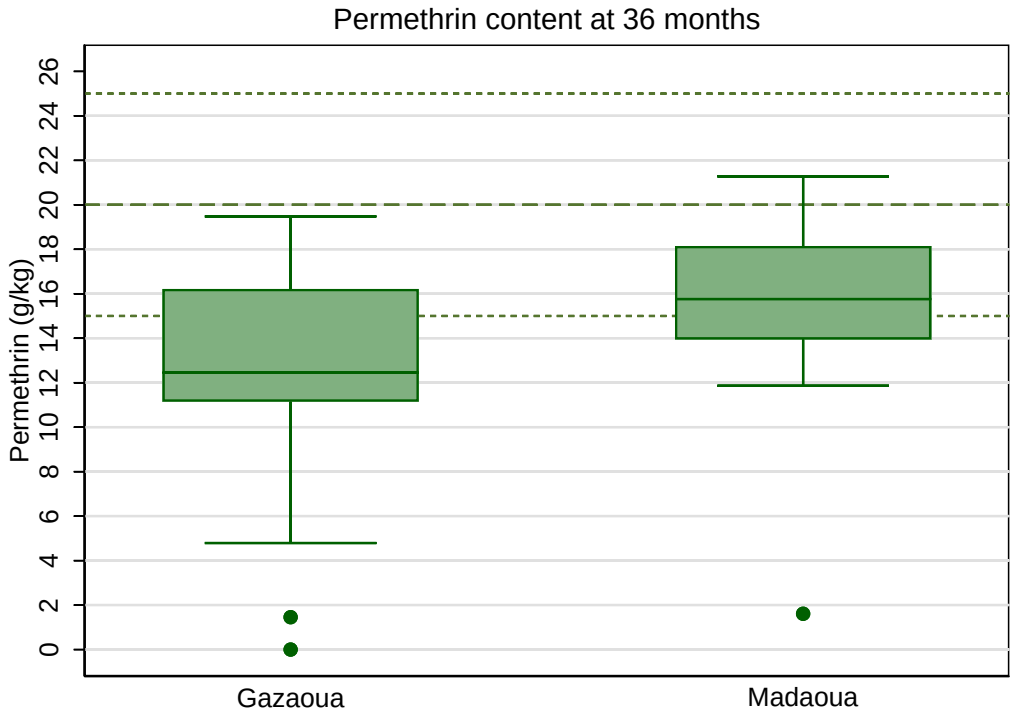
In addition to testing for insecticidal effectiveness, the nets collected during the 36-month follow-up survey were sent to CDC for chemical content testing. Chemical content results are presented in Table 20. Olyset (distributed in Gazaoua and Madaoua) is manufactured with 20g/kg of permethrin. At 36-months, the mean permethrin chemical content of Gazaoua net samples was 12.5g/kg, compared with mean of 15.7g/kg in permethrin content in Madaoua respectively compared to the original target dose.

Table 20: Chemical Content Results

	36 months
Gazaoua (Olyset, permethrin, 20 g/kg)	**N=30**
Mean (95% CI)	12.522 (11.032-14.013)
Median [IQR]	12.5 [11.149-16.216]
Madaoua (Olyset, permethrin, 20 g/kg)	**N=30**
Mean (95% CI)	15.765 (14.544-16.985)
Median [IQR]	15.762 [13.946-18.147]

Figure 12 presents box plots of the chemical content results in both districts at 36-months. The box plot shows the median (horizontal line), interquartile range (box), adjacent values (whiskers) and outliers (circles), dashed lines represent the manufacturer's insecticide target dose. Consistent with the findings on insecticidal effectiveness, the chemical content for Olyset net was below manufacturer-stated level in Madaoua, as compared to Gazaoua level of insecticide, for same brand of net (Olyset).

Figure 12: Box Plot of ITN chemical content results



Tables 21-23 present details of reported handling and use for the ITNs undergoing bioassay analysis for each survey period. At 36-months, sleeping place (bed, mattress, mat/ground), net users (children only, adults only, children/adults sharing), and net use and washing frequency, in Gazaoua and Madaoua were similar for bioassay nets and cohort nets not sampled for bioassay analysis. In Gazaoua, a higher proportion of bioassay nets compared to cohort nets were found hanging and tied up (13% versus 4% of non-sampled cohort nets) and hanging untied (60% versus 37% of non-sampled cohort nets). Bioassay nets also differed from cohort nets in Madaoua where bioassay nets were less commonly washed with detergent or bleach (77% versus 89% of non-sampled bioassay nets).

Bioassay nets differed between study sites with respect to the location they were found (60% hanging loose in Gazaoua versus 20% in Madaoua; p=0.002), use frequency (50% used every night in Gazaoua versus 13% in Madaoua; p=0.004), seasonal use (20% rainy season only in Gazaoua versus 53% in Madaoua; p<0.001), and washed nets being dried in the sun (21% in Gazaoua versus 90% in Madaoua; p<0.001).

The reported handling and use of bioassay nets withdrawn at 36-months also differed from nets withdrawn during previous rounds. Nets withdrawn at 36-months were more likely to have been stored away prior to being withdrawn (Gazaoua 20%; Madaoua 77%) and less likely to have been used the night before the survey (Gazaoua: 57%; Madaoua: 17%). These characteristics may explain the increased insecticidal effectiveness recorded for samples in the 36-month round.

Table 21: Handling of Bioassay Test ITNs

	Baseline	12 months	24 months	36 months
Gazaoua				
Location found	N=31	N=29	N=27	N=30
Hanging and folded or tied	6.5%	41.4%	14.8%	13.3%
Hanging loose	48.4%	24.1%	70.4%	60.0%
Not hanging	35.5%	17.2%	7.4%	6.7%
Stored unpacked	9.7%	17.2%	7.4%	20.0%
Stored in package	0.0%	0.0%	0.0%	0.0%
Type of sleeping space (if used)	N=29	N=30	N=28	N=29
Bed	34.5%	46.7%	46.4%	65.5%
Mattress	34.5%	0.0%	7.1%	6.9%
Mat/Ground	31.0%	53.3%	46.4%	27.6%
Net users	N=29	N=29	N=27	N=17
Child(ren) only	10.3%	31.0%	25.9%	5.9%
Child(ren) and adult(s)	55.2%	41.4%	40.7%	41.2%
Adult(s) only	34.5%	17.2%	22.2%	52.9%
Other	0.0%	10.3%	11.1%	0.0%
Madaoua				
Location found	N=27	N=29	N=29	N=30
Hanging and folded or tied	37.0%	48.3%	6.9%	0.0%
Hanging loose	33.3%	13.8%	62.1%	20.0%
Not hanging	11.1%	31.0%	24.1%	3.3%
Stored unpacked	18.5%	6.9%	6.9%	76.7%
Stored in package	0.0%	0.0%	0.0%	0.0%
Type of sleeping space (if used)	N=29	N=30	N=29	N=30
Bed	34.5%	16.7%	13.8%	50.0%
Mattress	20.7%	23.3%	20.7%	10.0%
Mat/Ground	44.8%	60.0%	65.5%	40.0%
Net users	N=29	N=30	N=29	N=5
Child(ren) only	10.3%	23.3%	37.9%	0.0%
Child(ren) and adult(s)	44.8%	56.7%	37.9%	60.0%
Adult(s) only	41.4%	20.0%	13.8%	40.0%
Other	3.4%	0.0%	10.3%	0.0%

Table 22: Reported Use of Bioassay Test ITNs

	Baseline	12 months	24 months	36 months
Gazaoua	N=30	N=30	N=28	N=30
Used last night	90.0%	73.3%	89.3%	56.7%
Used last week	N=30	N=30	N=28	N=30
Every night	86.7%	63.3%	85.7%	50.0%
Most nights (5-6 nights)	3.3%	10.0%	3.6%	6.7%
Some nights (1-4 nights)	6.7%	6.7%	0.0%	13.3%

	Baseline	12 months	24 months	36 months
Not used last week	0.0%	16.7%	0.0%	26.7%
Never used	3.3%	0.0%	0.0%	3.3%
Don't know	0.0%	3.3%	10.7%	0.0%
Seasonal use	N=30	N=29	N=27	N=30
Equally in rainy and dry seasons	36.7%	31.0%	59.3%	16.7%
Mainly rainy season	60.0%	44.8%	29.6%	63.3%
Rainy season only	0.0%	24.1%	11.1%	20.0%
Not used	3.3%	0.0%	0.0%	0.0%
Don't know	0.0%	0.0%	0.0%	0.0%
Madaoua	N=29	N=30	N=29	N=30
Used last night	93.1%	50.0%	75.9%	16.7%
Used last week	N=29	N=30	N=29	N=30
Every night	89.7%	43.3%	75.9%	13.3%
Most nights (5-6 nights)	3.4%	3.3%	10.3%	0.0%
Some nights (1-4 nights)	3.4%	20.0%	0.0%	6.7%
Not used last week	3.4%	33.3%	13.8%	80.0%
Never used	0.0%	0.0%	0.0%	0.0%
Don't know	0.0%	0.0%	0.0%	0.0%
Seasonal use	N=29	N=30	N=29	N=30
Equally in rainy and dry seasons	41.4%	20.0%	24.1%	33.3%
Mainly rainy season	37.9%	53.3%	55.2%	13.3%
Rainy season only	20.7%	26.7%	17.2%	53.3%
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
Gazaoua	N=31	N=30	N=28	N=30
Ever washed	51.6%	86.7%	96.4%	96.7%
Washes in the last six months among all nets (if known)	N = 29	N = 30	N = 26	N = 30
Mean	1.3	2.8	5.9	5.8
Median	0.0	2.0	4.0	5.0
Washes in the last six months among washed nets	N = 14	N = 26	N = 26	N = 29
Mean	2.8	3.3	5.9	6.0
Median	1.5	2.0	4.0	5.0
Soap used for last wash	N=15	N=28	N=28	N=30
Soap bar	33.3%	57.1%	60.7%	23.3%
Detergent or bleach	60.0%	39.3%	35.7%	73.3%
Mix	0.0%	0.0%	0.0%	0.0%
None	6.7%	3.6%	3.6%	0.0%
Don't know	0.0%	0.0%	0.0%	3.3%

	Baseline	12 months	24 months	36 months
Where dried after last wash	N/A	N/A	N=27	N=29
Shade	N/A	N/A	25.9%	79.3%
Sun	N/A	N/A	70.4%	20.7%
Don't know	N/A	N/A	3.7%	0.0%
Madaoua	N=28	N=30	N=29	N=30
Ever washed	57.1%	93.3%	82.8%	96.7%
Washes in the last six months among all nets (if known)	N = 28	N = 30	N = 28	N = 30
Mean	1.5	5.0	3.5	12.5
Median	1.0	2.0	2.0	18.0
Washes in the last six months among washed nets	N = 15	N = 28	N = 23	N = 26
Mean	2.6	5.4	4.3	13.4
Median	2.0	2.0	3.0	18.0
Soap used for last wash	N=23	N=29	N=24	N=30
Soap bar	21.7%	27.6%	25.0%	16.7%
Detergent or bleach	52.2%	72.4%	75.0%	76.7%
Mix	0.0%	0.0%	0.0%	0.0%
None	26.1%	0.0%	0.0%	3.3%
Don't know	0.0%	0.0%	0.0%	3.3%
Where dried after last wash	N/A	N/A	N=24	N=29
Shade	N/A	N/A	4.2%	10.3%
Sun	N/A	N/A	95.8%	89.7%
Don't know	N/A	N/A	0.0%	0.0%

4. CONCLUSIONS

4.1. SUMMARY OF FINDINGS

This 36-month round of the Niger durability monitoring study successfully visited 215 households across two districts, each having received Olyset brand ITNs during the 2018 mass campaign. At baseline, a total of 827 ITNs were recorded as having been distributed to cohort households (including those lost before the baseline round). At 36-months, 189 ITNs from the 2018 campaign were still present (96 in Gazaoua and 93 in Madaoua).

Total cohort ITN attrition at 36-months was 75% in Gazaoua and 77% in Madaoua. Wear and tear (ITNs discarded) and ITNs given away were the main causes of attrition in both study sites: attrition due to wear and tear was 40% in Gazaoua and 45% in Madaoua. Overall attrition, attrition due to wear and tear, and attrition from nets given away were similar between study sites at 36-months (attrition for other/unknown reasons was higher in Gazaoua although its contribution to overall attrition in both sites was low).

At 36-months, 24% and 26% of cohort ITNs in Gazaoua and Madaoua respectively had survived in serviceable condition, corresponding to an estimated median life of 2.4 years for cohort nets in both study sites. It's not surprising that the median life of cohort nets in both sites were similar considering measured durability risk factors were relatively balanced between sites, therefore, damage to nets caused by household and handling factors were similar in Gazaoua and Madaoua. Cohort nets in Gazaoua at 36-months had poorer physical integrity as measured by median pHI (518.5 versus 163.5 in Madaoua) and the proportion of nets classified as serviceable (61% versus 78% of nets in Madaoua). The slightly lower attrition level in Gazaoua and slightly poorer physical integrity among remaining nets in Madaoua offset one another and lead to similar estimates of median useful life.

There were 393 non-cohort nets audited in Gazaoua and 496 in Madaoua during the 36-month round. This is over twice the number of non-cohort nets audited during the 24-month round (222 in Gazaoua, 172 in Madaoua). The majority of these nets (93% in Gazaoua, 85% in Madaoua) were reportedly obtained from a net distribution campaign other than the 2018 campaign, many households reporting receiving one or more nets from a campaign in 2021. These nets were most likely received from the net campaign that was initiated in May 2021 by the NMCP with support from the Global Fund that distributed nets to six high risk malaria regions including Gazaoua (Maradi region) and Madaoua (Tahoua region). Maradi region received approximately 1,525,000 LLINs (102% coverage) and Tahoua received 1,042,064 (98% coverage).[9] This infusion of new nets is evident in the 36-month round where a high proportion of nets were stored away (43% of cohort nets in Gazaoua and 77% in Madaoua; 77% of non-cohort nets in Gazaoua and 84% in Madaoua) and net use every night last week decreased markedly from the 24-month survey (73% to 37% in Gazaoua and 76% to 13% in Madaoua for cohort nets; 80% to 24% in Gazaoua and 86% to 23% in Madaoua for non-cohort nets). However, it is also worth noting that the delayed 24-month round took place in August 2020 during the rainy season, while the 36-month round took place in June and July, before the main rains. This can also explain the low rate of net use every night last week observed at 36-month round data collection. The influx of 2021 campaign nets may have increased the likelihood that households discarded older cohort nets, and in both sites attrition due

9 Organisation d´une campagne de masse et gratuite de distribution des moustiquaires imprégnées d´insecticides à longue durée d´action dans le contexte de la COVID-19 au Niger (2021). Aboubakar F, Jackou H, Anya BP, Hamani B, Katoto P, Wiysonge CS. *Pan Afr Med J*. Feb 3;38:119. doi: 10.11604/pamj.2021.38.119.26664. eCollection 2021.

to wear and tear increased more sharply between 24- and 36-months than between any previous two rounds. It's possible that without the 2021 net campaign, cohort net attrition would have been lower, the proportion of nets surviving in serviceable condition higher, and the estimated median life of Olyset nets in Gazaoua and Madaoua longer.

At 36-months household and population ITN access was high. Access to all ITNs was higher at baseline in Gazaoua district (85% versus 58% household access; 93% versus 78% population access) but was higher at 36-months in Madaoua (81% versus 77% household access; 95% versus 90% population access), where almost twice as many new non-cohort nets were received (324 new non-cohort nets versus 171 in Gazaoua). As expected, access to non-cohort nets was much higher than cohort nets (approximately 40 and 70 percentage points higher in Gazaoua and Madaoua respectively). Less expected was the low levels of population use considering such high access, though this may be explained by the different timings of the rounds. At 36-months, population use of all ITNs was 39% in Gazaoua (12.2% cohort net use, 27% non-cohort net use) and 33% in Madaoua (5% cohort net use, 29% non-cohort net use).

Although the 2021 campaign achieved near universal coverage, population ITN use was still relatively low, highlighting the importance of behavior change communication interventions and other strategies to increase net usage. That said, exposure to net messaging was high, and respondent attitudes towards nets were favorable at 36-months. Approximately three-quarters of respondents in Gazaoua and Madaoua reported exposure to net messaging in the previous six months and nearly all respondents exposed to messaging recalled "use net (every) night". Furthermore, respondents in both Gazaoua and Madaoua had high net attitude scores (mean score of 1.69 in Gazaoua and 1.57 in Madaoua). Novel strategies may be needed to increase net usage in the Niger context where universal net coverage has been achieved, the importance of net usage is widely understood, and attitudes towards nets are positive.

Compared with previous rounds, the 36-month bioassay results showed no further decline in cohort-net optimal effectiveness and increases in mean 60-minute knock-down and one-hour mortality compared to results from 24-months. Cohort nets withdrawn for testing at 36-months were more likely to have been stored away and/or unused in recent days, compared with nets withdrawn at 24-months. Between baseline and the 24-month round the proportion of nets classified as optimally effective declined from 36% to 3% in Gazaoua and from 79% to 23% in Madaoua. At 36-months, optimal effectiveness increased to 43% in Gazaoua and remained static at 23% in Madaoua. Mean KD60 was 80% in Gazaoua and 75% in Madaoua, and mean mortality was 76% in Gazaoua and 72% in Madaoua at 36-months. In almost all cases, a mortality results above 80% was the reason a net sample was classified as optimally effective. The bioassays were consistent with the results of the chemical assays of the Olyset nets as these results show lower levels of chemical content than indicated by the manufacturer in Madaoua and Gazaoua for the same brand of net (Olyset)..

4.2. Key Challenges and Lessons Learned

Over the entire course of the study, three main challenges during fieldwork were encountered: under-estimating the time required for data collection, misinterpreting response options, and security issues.

In the more remote areas of rural districts, fieldworkers found they under-estimated the amount of time required for data collection. Fieldwork days were long and at times involved up to five hours of driving from safe lodging to selected villages. In future studies, data collection teams should work with the local authorities and leaders to accurately assess the amount of time required to travel to study sites. Budgeting additional fieldwork days as a "buffer" can also provide staff with adequate rest days and can help to ensure high-quality data collection.

During data cleaning and analysis of data from the 12-month round, it became clear that the field team in Madaoua had systematically misinterpreted the response option "Temporarily taken away" when recording how an ITN was found in the household. Examination of other ITN data points and field team comments strongly suggest many nets recorded as "Temporarily taken away" were present in the household when the field team

visited. This data capture error means it is not possible to accurately describe how ITNs in Madaoua were located in the household during the survey team's visit. To avoid this confusion for future studies, data collection staff should spend extra time on this question during training to ensure the fieldworkers accurately interpret this response option.

Finally, during the 36-month round, security issues were raised in the Bangui health region. It was determined the southern part of the health region bordering Nigeria had been declared a red zone of insecurity by the administrative authorities after discussions among Madaoua health district leaders, District Core Team members, and the Bangui Health Facility Manager. As a result, data collection could not be carried out in one cluster for the 36-month round. This resulted in missing data for 11 households, 22 cohort nets and three bioassay nets. The lack of data was not significant and should not materially limit the conclusions of the study. In future durability monitoring studies, it will be important to work closely with health and administrative authorities to ensure the safety of data collection staff while in the field.