U.S. PRESIDENT'S MALARIA INITIATIVE

THE PMI VECTORLINK MADAGASCAR 2018 DURABILITY MONITORNG 36-MONTH FOLLOW-UP STUDY REPORT

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ACRONYMS

ANC	Antenatal Care
CDC	Centers for Disease Control and Prevention
DHS	Demographic and Health Survey
IQR	Interquartile Range
IPC	Interpersonal Communication
IPM	Institut Pasteur de Madagascar
IRB	Institutional Review Board
ITN	Insecticide-Treated Net
KD60	60-minute Knock-Down rate
MIS	Malaria Indicator Survey
NMCP	National Malaria Control Program
ODK	Open Data Kit
pHI	Proportionate Hole Index
PMI	President's Malaria Initiative
PQT-VC	WHO Prequalification Team Vector Control Group
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 Madagascar, the United States (U.S.) President's Malaria Initiative (PMI) is supporting ITN durability monitoring of DawaPlus 2.0 ITNs distributed in Farafangana, Bekily and Maintirano, and PermaNet 2.0 ITNs distributed in Fort Dauphin in August during the 2018 mass campaign. Baseline data collection to establish the DawaPlus 2.0 cohorts was conducted September 7 - October 13, 2018, one month after distribution. Driven by a global concern over the insecticidal effectiveness of key brands commonly procured by PMI, a fourth study site was added following baseline data collection to monitor PermaNet 2.0 brand ITNs. The first round of data collection for PermaNet 2.0 ITNs took place 12-months after distribution. In all settings, all campaign ITNs in sampled households were identified and labeled with a unique ID number.

The 12-month survey was carried out August 25 - September 28, 2019, the 24-month survey was conducted October 1-25, 2020, and the 36-month endline survey was conducted July 12 - August 1, 2021. Fieldwork was conducted by Population Services International (PSI) Madagascar. During each of these rounds, ITNs labeled at baseline were followed-up; the physical integrity of nets still present in the household was measured through a hole assessment and details were recorded for any nets no longer present in the household (attrition). Potential factors affecting net durability were explored through a household interview. These included environmental factors (house structure, cooking fuel, type of sleeping place), net handling (folding nets up when hanging, drying washed nets on bushes etc.) as well as attitudes towards nets and net care and repair. At each round, information was collected on bed nets obtained by the household outside of the 2018 campaign.

During the 36-month survey, cohort ITNs from each cluster were selected and withdrawn to undergo bio-effectiveness and chemical content analysis. Cone bioassays are being performed by Institut Pasteur de Madagascar (IPM), and chemical content analysis is being performed by the Centers for Disease Control and Prevention (CDC) Atlanta on samples from the ITNs selected for cone bioassays.

Household and ITN Follow-Up

A total of 413 out of 517 eligible households were interviewed for the 36-month study round. Of these, 266 households still had one or more cohort nets and 147 households had lost all their cohort nets. Of the 104 households not interviewed, 51 had no eligible respondent available for interview, 52 had moved out of the study area, and one household was screened out due to COVID-19 risks. Of the 814 nets eligible for follow-up at the 36-month study round, 308 were still in the house and 65 were with family elsewhere. Nets not in households had been discarded (219 nets), given away or stolen (51 nets), lost for unknown reasons (10 nets) or had an unknown outcome (161 nets, including 87 nets belonging to households that had moved out of the study areas). By the end of the study, 1,342 (81%) out of the 1,650 labeled nets enrolled in the cohorts were no longer present in the study households.

Durability Risk Factors

In general, households in Farafangana and Bekily had a more rudimentary construction and reported lower access to safe water, latrines, and most household assets except for ownership of livestock and agricultural land, reflecting the rural environment of households in Farafangana and Bekily. Among households visited at 36-

[1] www.durabilitymonitoring.org

months, storing food in the same room used for sleeping was highest in Bekily (100% in Bekily, 84% in Farafangana, 88% in Maintirano, and 82% in Fort Dauphin; p=0.026 from the chi-squared test for homogeneity of outcomes across the four study sites); however, a higher proportion of households in Farafangana always cooked where they slept (50% in Farafangana, 9% in Bekily, 8% in Maintirano, and 21% in Fort Dauphin; p<0.001). Households in all sites commonly reported observing rodents in the past six months (80% in Farafangana, 100% in Bekily, 72% in Maintirano, and 79% in Fort Dauphin; p<0.001). A higher proportion of nets were hung over a mat or ground in Farafangana (74%) and Bekily (65%) compared with other sites (36% in Maintirano and 24% in Fort Dauphin; p<0.001). Although washing frequency of cohort nets was similar across study sites, the use of detergent or bleach for washing differed by site (67% in Bekily, 19% in Farafangana, 41% in Maintirano, 32% in Fort Dauphin; p<0.001) and the proportion of nets last dried on a bush or fence was highest in Farafangana (69% in Farafangana, 44% in Bekily, 12% in Maintirano, and 41% in Fort Dauphin; p=0.003). Among hanging cohort nets, a higher proportion of nets in Bekily were not folded or tied up (68% in Bekily, 25% in Farafangana, 30% in Maintirano, and 19% in Fort Dauphin; p=0.005).

At 36-months, similar proportions of respondents reported exposure to information on net use and care and/or repair of nets in the six months before the survey (22% in Farafangana, 25% in Bekily, 23% in Maintirano, and 20% in Fort Dauphin). Media sources were most common in Maintirano (53% in Maintirano, 19% in Farafangana, 0% in Bekily, and 22% in Fort Dauphin; p<0.008), while interpersonal communication (IPC) was more common in Farafangana (68%), Bekily (100%) and Fort Dauphin (61%) than Maintirano (33%; p<0.001). The proportion of respondents with favorable attitudes towards nets differed across study sites and was highest in Maintirano and Fort Dauphin (85% in Maintirano, 86% in Fort Dauphin, 74% in Farafangana, 59% in Bekily; p=0.004). A lower proportion of respondents had favorable attitudes towards net care and repair in Farafangana; however, results were not statistically different across the four sites (49% in Farafangana, 70% in Bekily, 69% in Maintirano, and 61% in Fort Dauphin; p=0.067). The proportion of respondents who reported discussing net care and repair was lowest in Farafangana and Fort Dauphin and there was indication that differences existed across the sites (18% in Farafangana, 15% in Fort Dauphin, 41% in Bekily, 60% in Maintirano; p=0.006). There were no statistical differences between the proportion of households experiencing holes in a net or repairing nets across study sites at 36-months.

ITN Ownership and Use

At endline, all measures of cohort net use were lowest in Maintirano (84% of cohort nets ever used in Maintirano versus 97% across other sites combined, p=0.003; 59% used last night in Maintirano versus 86% across other sites combined, p<0.001; 59% used every night last week in Maintirano versus 85% across other sites combined, p<0.001). Non-cohort net ownership differed between districts with 89% of households in Farafangana owning non-cohort nets, 73% in Bekily, 88% in Maintirano, and 56% in Fort Dauphin (p<0.001). The most common source of non-cohort nets was community continuous distribution[2] in Farafangana (33%) and Bekily (75%), and markets in Maintirano (49%) and Fort Dauphin (33%). The proportion of non-cohort nets ever used for sleeping under was slightly higher in Maintirano and Fort Dauphin (97% in Maintirano, 99% in Fort Dauphin, 92% in Farafangana and 89% in Bekily; p=0.024), however, the proportion of non-cohort nets used last night and used every night last week did not differ significantly across sites (86% and 85% across all sites combined). Cohort nets were most commonly found hanging and tied up in Farafangana (65%), Maintirano (43%), and Fort Dauphin (57%) compared to Bekily (29%; p=0.011) and found hanging untied in Bekily (61% in Bekily, 21% in Farafangana, 18% in Maintirano, and 12% in Fort Dauphin; p=0.004). The proportion of non-cohort nets found hanging tied and untied for each district was similar to that of cohort nets.

Household and population access to cohort ITNs at endline differed between sites and was highest in Maintirano (28% and 47% in Maintirano, 12% and 31% in Farafangana, 9% and 25% in Bekily, and 8% and 26% in Fort Dauphin; p<0.001 for household access, p=0.002 for population access). Although measures of

[2] In a community continuous distribution system, community health workers (called community health volunteers in Madagascar) routinely visit homes to identify ongoing ITN needs and issue a coupon when required which can be redeemed for a new ITN at a community distirbution point. Community continuous distirbution is implemented in 12 districts in Madagascar, including Bekily and Farafangana.

cohort ITN access differed between sites, population cohort ITN use was similar (26% across all sites). Population use was higher than population access in Farafangana, Bekily and Fort Dauphin, suggesting that on average, more than two household members slept under each available net. There were no significant differences between sites in the age groups using cohort and non-cohort nets at endline.

ITN Survivorship (Attrition and Physical Integrity)

Total cohort ITN attrition in Farafangana increased from 4% at baseline to 70% at 36-months, from 2% to 82% in Bekily, and from 5% to 75% in Maintirano. In Fort Dauphin, all-cause attrition increased from 15% at 12-months to 77% at 36-months. Differences in total attrition between study sites at endline were significant (p=0.028) as were differences in attrition from nets given away to others (p<0.001) and from nets being discarded (also known as attrition due to wear and tear, p<0.001). Attrition due to wear and tear was highest in Bekily (58.5%) and lowest in Maintirano (14.1%). In Farafangana, Bekily and Fort Dauphin, the most common reason for attrition was nets being discarded (39%, 59%, and 45%), while nets in Maintirano were most commonly given away to others (40%). At 36-months, the proportion of cohort nets with any holes was similar between study sites (91% across all sites), however, the physical integrity classification of nets differed statistically with 55% of nets in Farafangana, 88% in Bekily, 47% in Maintirano, and 74% in Fort Dauphin classified as "serviceable" (p<0.001). 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 Farafangana, 21% in Bekily, 28% in Maintirano, and 24% in Fort Dauphin, corresponding to an estimated median survival time of 2.1, 2.0 and 2.5 years for DawaPlus 2.0 nets in Farafangana, Bekily and Maintirano respectively, and 2.1 years for PermaNet 2.0 nets in Fort Dauphin.

Insecticidal Effectiveness

At baseline, 12- and 24-months, thirty campaign nets were collected in each study site, from households outside the cohort but within the same study site to undergo bioassay tests and evaluate insecticidal effectiveness. At 36-months, the 30 nets withdrawn for bioassay tests were collected from the remaining cohort nets. At 24-months, less than 7% of nets were found to be optimally effective (none in Farafangana, 7% in Bekily, and 3% in both Maintirano and Fort-Dauphin). There is some evidence that PermaNet 2.0 in Fort-Dauphin (30% found to be minimally effective) performed better than DawaPlus 2.0 in the three other sites (less than 23% found to be minimally effective). Contrary to expectations, mortality actually increased in the 36-month round resulting in an increase of the optimal and minimal efficiency between the 24- and 36-month round in all three locations. For PermaNet 2.0, for example, the values increased from 3.3% to 43.3% for optimal effectiveness and from 30% to 86.7% for minimum effectiveness. Mean chemical content values on 10 DawaPlus 2.0 samples per site from the 24-month survey corresponded to a loss of 83% (Maintirano), 87% (Farafangana) and 93% (Bekily) compared to the manufacturer target dose of deltamethrin. Sample results from Fort Dauphin correspond to a 68% loss compared to the target dose. Among DawaPlus 2.0 samples withdrawn and tested at the 36-month survey, chemical concentration increased compared to 24-month survey results. Results corresponded to a loss of 43% (Maintirano), 58% (Farafangana), and 69% (Bekily) compared to the manufacturer target dose for deltamethrin. Among PermaNet 2.0 samples from Fort Dauphin, chemical concentration corresponded to an 86% loss compared to the manufacturer target dose.

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

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

Site	Survey round and time since distribution (months)	Attrition wear and tear (%)	Remaining nets in serviceable condition % (N)	Remaining nets hanging over sleeping space (%)		Optimal insecticidal effectiveness in bioassay (%)
				Campaign	Other	
Farafangana (DawaPlus 2.0)	Baseline (1.3)	0.2%	99.4% (N=488)	35.4%	72.1%	96.7%
	12m (12.5)	1.7%	83.6% (N=347)	67.1%	80.6%	3.3%
	24m (25.9)	17.5%	64.6% (N=223)	74.2%	75.1%	0.0%
	36m (35.2)	39.2%	55.1% (N=127)	86.7%	85.6%	23.3%

Bekily (DawaPlus 2.0)	Baseline (1.4)	0.0%	100.0% (N=408)	41.4%	68.4%	86.7%
	12m (12.5)	4.3%	83.0% (N=264)	61.5%	48.5%	16.7%
	24m (25.9)	39.4%	89.2% (N=130)	74.8%	55.7%	6.7%
	36m (35.1)	58.5%	87.5% (N=56)	89.3%	83.7	50.0%
Maintirano (DawaPlus 2.0)	Baseline (1.1)	0.3%	100.0% (N=335)	35.8%	61.6%	95.5%
	12m (12.6)	0.5%	89.1% (N=165)	67.9%	100.0%	16.7%
	24m (25.9)	5.2%	74.7% (N=79)	75.3%	67.5%	3.3%
	36m (35.2)	14.1%	46.5% (N=43)	61.3%	82.1%	16.7%
Fort Dauphin (PermaNet 2.0)	Baseline (N/A)	N/A	N/A	N/A	N/A	N/A
	12m (12.7)	4.1%	86.2% (N=312)	64.4%	65.0%	10.0%
	24m (25.9)	26.9%	67.1% (N=167)	68.6%	64.0%	3.3%
	36m (35.2)	45.4%	74.0% (N=73)	69.8%	83.2%	43.3%

Conclusion

Total campaign ITN attrition was highest in Bekily (82%), followed by lower attrition levels in Fort Dauphin (77%), Maintirano (75%), and Farafangana (70%). Attrition was primarily driven by nets being discarded in Farafangana, Bekily and Fort Dauphin (39%, 59%, and 45%), and by nets being given away to others in Maintirano (40%). Cohort attrition due to wear and tear was highest in Bekily (58.5%) and lowest in Maintirano (14.1%), and, among remaining nets, the proportion in serviceable condition was highest in Bekily (87.5%) and lowest in Maintirano (46.5%). Results for Farafangana (55.1%) and PermaNet 2.0 ITNs in Fort Dauphin (74.0%) fell between these extremes. In settings with higher attrition due to wear and tear, remaining nets were in better physical condition than in settings with lower attrition due to wear and tear. This pattern led to estimates of median survival that all fell in the range 2.0 to 2.5 years: 2.1, 2.0 and 2.5 years for DawaPlus 2.0 nets in Farafangana, Bekily and Maintirano, respectively, and 2.1 years for PermaNet 2.0 nets in Fort Dauphin.

1. BACKGROUND

The proportion of households owning at least one insecticide treated net (ITN) has increased in Madagascar in the last decade, from 60% (2008 Demographic and Health Survey, or DHS) to 85% (2016 Malaria Indicator Survey, or MIS) in urban zones and from 56% to 79% during the same period in rural areas.[3] The ratio of ITN use to access in Madagascar, which measures population-level use in relation to population-level access to an ITN, is the highest among United States (U.S.) President's Malaria Initiative (PMI) countries, calculated at 1.1 in 2016. The lowest regional ratio value in 2016 was 0.90 in the Analamanga region. The use/access ratio is high in regions with both low and high levels of net ownership, indicating a strong net culture even in low-risk areas.[4]

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.[5] 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 Madagascar, PMI has supported durability monitoring of ITNs distributed during the 2018 mass campaign in four districts: Farafangana, Atsimo Atsinanana region (Southeast Coast); Maintirano, Melaky region (West Coast); Bekily, Androy region (South); and Fort Dauphin, Anosy region (extreme Southeast Coast). Farafangana, Maintirano and Bekily are the original study sites, selected to monitor the DawaPlus 2.0 ITN brand with cohorts established during the baseline study round. The population of Fort Dauphin received the Permanet 2.0 ITN brand during the 2018 campaign and this study site was added at PMI's request following completion of the baseline DawaPlus 2.0 round. DawaPlus 2.0 is a polyester ITN coated with deltamethrin. It is manufactured by Tana Netting Co. Ltd. (Thailand) and was pre-qualified by WHO in March 2018[6]. PermaNet 2.0 is a polyester ITN also coated with deltamethrin and manufactured by Vestergaard. It received full World Health Organization Pesticide Evaluation Scheme (WHOPES) recommendation in 2009 and WHO pre-qualification in 2017.

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

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

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

[5] www.durabilitymonitoring.org

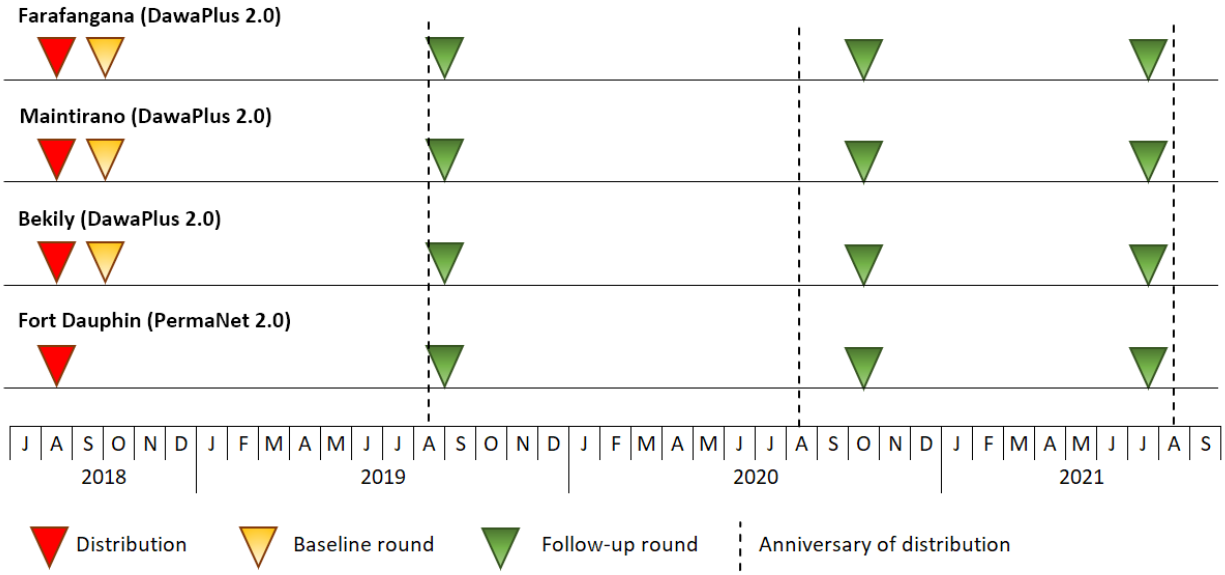
[6] As of January 1, 2017, vector control products that were previously submitted to the WHOPES for evaluation and recommendation are now evaluated by the WHO Prequalification Team Vector Control Group (PQT-VC). Briefly, under the PQT-VC process, product manufacturers receive enhanced guidance on their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

The durability monitoring study in Madagascar intended to:

1. Assess the physical durability of DawaPlus 2.0 (Farafangana, Maintirano, Bekily districts) and PermaNet 2.0 (Fort Dauphin district) over a three-year period and estimate median ITN survival and identify major determinants of field performance.
2. Describe major behavioral aspects of net care and repair and their impact on physical integrity.
3. Assess insecticidal effectiveness (through bioassay and chemical content analysis) after three years of field use.

Baseline data collection was conducted September 7 - October 13 for DawaPlus 2.0 in Farafangana, Maintirano and Bekily districts. Data collection for the 12-month study round, which included the PermaNet 2.0 cohort in Fort Dauphin, was conducted August 25 - September 28, 2019. In all four districts, data collection for the 24-month survey round was conducted October 1 - 25, 2020, and for the 36-month survey round July 12 - August 1, 2021.

FIGURE 1: DURABILITY MONITORING TIMELINE



2. METHODS

2.1 STUDY SITES

The study was conducted in Farafangana, Maintirano, Bekily, and Fort Dauphin districts. These areas and populations were selected for their differing malaria transmission, climate, population behavior, and socio-ecological profiles (Table 2).

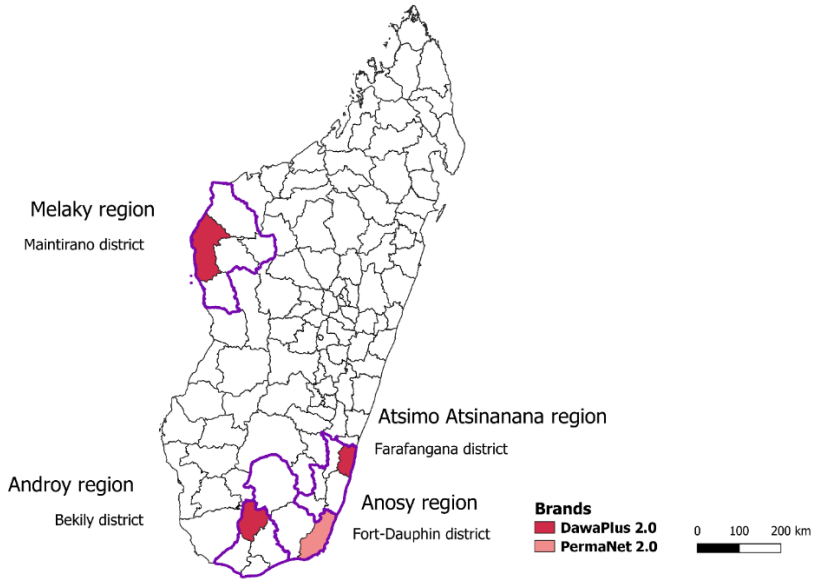
TABLE 2: DEMOGRAPHIC, ENVIRONMENTAL AND HEALTH INDICATORS IN THE STUDY AREAS

	Maintirano	Bekily	Farafangana	Fort Dauphin
Region	Melaky	Androy	Atsimo Atsinanana	Anosy
Population	102,332	158,149	328,145	199,976
Annual rainfall precipitation (mm)	1,200	680	2,500	2,500
Malaria transmission	Long transmission	Seasonal and short transmission	Perennial transmission	Perennial transmission
Climate (Koppen-Geiger classification)	Tropical, savannah (Aw)	Arid, steppe, hot (BSh)	Tropical, rainforest (Af)	Tropical, rainforest (Af)
Population main activity	Fishing, agriculture	Livestock, agriculture	Agriculture	Tourism, Agriculture

Source of climate classification: Beck et al. Present and future Koppen-Geiger climate classification maps at 1-km resolutions. Scientific Data 5:180214 (2018).

Maintirano district is in Melaky region on the Western Coast, Farafangana is located in Atsimo Atsinanana region on the Southeast coast, and Bekily is in Androy region, inland in the South of the country. Fort Dauphin is located in the Anosy region on the Southeastern coast (Figure 2).

FIGURE 2: STUDY SITE MAP



Secondary analysis of the 2016 Madagascar Malaria Indicator Survey (MIS) shows the estimated proportion of households with at least one ITN is high for each of the regions in which the study districts fall: 96% in Maintirano, 92% in Farafangana, 89% in Bekily, and 93% in Fort Dauphin (Table 3). The proportion of the population with access to an ITN within their own household was high in Maintirano (80%) and lower in Farafangana (67%) and Bekily (53%). The proportion of the population using ITN the night before survey was high: 90% in Maintirano, 86% in Farafangana and 73% in Bekily.

TABLE 3: KEY MALARIA CHARACTERISTICS IN STUDY AREAS (2016)

Study site (region containing each district)	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	Children aged 6-59m blood slide positive for malaria (transmission zone)
Farafangana (Atsimo Atsinanana)	92%	67%	86%	9.0% (Equatorial)
Bekily (Androy)	89%	53%	73%	5.2% (Subdesert)
Maintirano (Melaky)	96%	80%	90%	8.8% (Tropical)
Fort Dauphin (Anosy)	93%	70%	84%	9.0% (Equatorial)

Source: 2016 MIS.
Population access: proportion of population that would be able to use an ITN if each ITN in a household was used by two people.

2.2 ITN BRANDS MONITORED

The two brands of ITNs monitored are:

1. **DawaPlus 2.0**[7], a 100-denier polyester ITN in white color. The product uses coating technology with a loading dose of 80 mg/m² of deltamethrin. DawaPlus 2.0 received interim WHO recommendation in July 2009 (13th WHOPES Report) and was WHO pre-qualified in March 2018.
2. **PermaNet 2.0**, a 100-denier polyester ITN in white and blue colors. This ITN uses incorporation technology with a loading dose of 55 mg/m² of deltamethrin. PermaNet 2.0 received full WHO recommendation in December 2008 (12th WHOPES Report) and was WHO pre-qualified in August 2017.

2.3 STUDY DESIGN SUMMARY

The principal study design was that of a prospective study of a cohort of nets distributed through a mass campaign. The baseline round for DawaPlus 2.0 was conducted one month following the mass campaign, during which a representative sample of campaign nets from the study locations were identified through a cluster household survey with all campaign nets from consenting households forming the study cohort. The PermaNet 2.0 cohort in Fort Dauphin was established during the 12-month survey round. DawaPlus 2.0 and PermaNet 2.0 nets were recruited to the cohort if the nets matched the size, shape and color of the campaign nets, had the correct net label and were reported as coming from the campaign by the respondent. Eligible cohort nets were labeled with a unique identifier and their presence and physical condition was 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

[7] The product formerly known as DawaPlus 2.0, now called "Tsara Soft", had WHO prequalification suspended as of 12 December 2019 pending assessment of additional information (Reference: https://www.who.int/pq-vector-control/prequalified-lists/dawaplus_2.0/en/).

and use, care, and repair behaviors for nets. These characteristics were used to identify household- and respondent-level risk factors for net survivorship.

Following the standard guidance (www.durabilitymonitoring.org), sample size requirements for the DawaPlus 2.0 cohort were estimated at 423 ITNs in each district, coming from 210 households per district. For ease of study planning, the same sample size was implemented for PermaNet 2.0 ITNs in Fort Dauphin, with 210 households targeted at 12 months. 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, 30 campaign ITNs per cluster were randomly sampled from households outside the cohort but within the same study site to undergo biological tests and evaluate insecticidal effectiveness. At 36-months, 119 nets were sampled from the main cohort. Participating households received a new, replacement ITN in exchange for the one withdrawn for the study. Bioassays for this study were conducted by Institut Pasteur de Madagascar (IPM) in accordance with standard WHO guidelines for cone and tunnel tests (where appropriate).[8] Chemical content analysis for this study were conducted by the Centers for Disease Control and Prevention (CDC) Atlanta.

2.4 TRAINING AND FIELDWORK

Fieldwork was conducted by PSI Madagascar using an implementation team of four people per district. Each district team was comprised 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 survey.

Online training of trainers for eight staff from VectorLink Madagascar (including focal points from PSI Madagascar) and the NMCP, and took place on June 28-29, 2021 with two days of remote instruction led by VectorLink research staff experienced in durability monitoring. In-person training for data collectors took place in Antananarivo from July 5-9, 2021 and entailed four days of classroom-based training and one field practice day in a local community with support from VectorLink Madagascar, PSI Madagascar and NMCP 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 survey round from local authorities and chiefs, re-sharing information on the study objectives and processes. Communities were then sensitized and mobilized to obtain maximum cooperation. A local community guide supported field teams in locating study households.

Data for the main household survey was collected using the Open Data Kit (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 Principal Investigator remotely downloaded and examined data each day and provided feedback to the field teams via WhatsApp.

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

2.5 DATA MANAGEMENT

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

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. Results by site were typically compared using chi-squared tests for homogeneity that accounted for the study design and primary study indicators are presented with 95% confidence intervals. Unless specifically stated, p-values do not represent pairwise tests between two categories or study sites.

Attitudes towards nets and net care/repair were captured using Likert score questions, where respondents stated the extent to which they agreed or disagreed with a standard set of statements. Data from the Likert score questions were summarized into two summary scores (nets and net care/repair) by first recoding the four-level Likert scale to have a value of -2 for "strongly disagree", -1 for "disagree", +1 for "agree" and +2 for "strongly agree". These values for each response were then summed and divided by the number of statements to calculate an overall attitude score. An average score greater than 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 guidelines9, 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 x 23) + (No. of size 3 holes x 196) + (No. of size 4 holes x 576)

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

Good:	pHI $\leq$ 64 (corresponding to a total hole surface area $\leq$ 0.01m^2)
Serviceable:	pHI $\leq$ 642 (total hole surface area $\leq$ 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.

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

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

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

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 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 IPM. A pyrethroid-sensitive Kisumu strain of *Anopheles gambiae* was used with five 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.

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 virtual 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 VectorLink Madagascar and the NMCP 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 maintain physical distance, 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. A set of COVID-19 pre-screening questions were added to the questionnaire for application in the field. These questions sought to determine whether respondents were at risk from the study team (e.g., if anyone in the household had a pre-existing medical condition that would require shielding from COVID-19) and whether the study team was at risk from household members (e.g., if the household included member(s) with COVID-19 symptoms). During the 36-month round of fieldwork, one household was screened out of data collection due to a COVID-19 risk. Additional Institutional Review Board (IRB) approval was sought before fieldwork began, as described below.

2.8 ETHICAL CLEARANCE

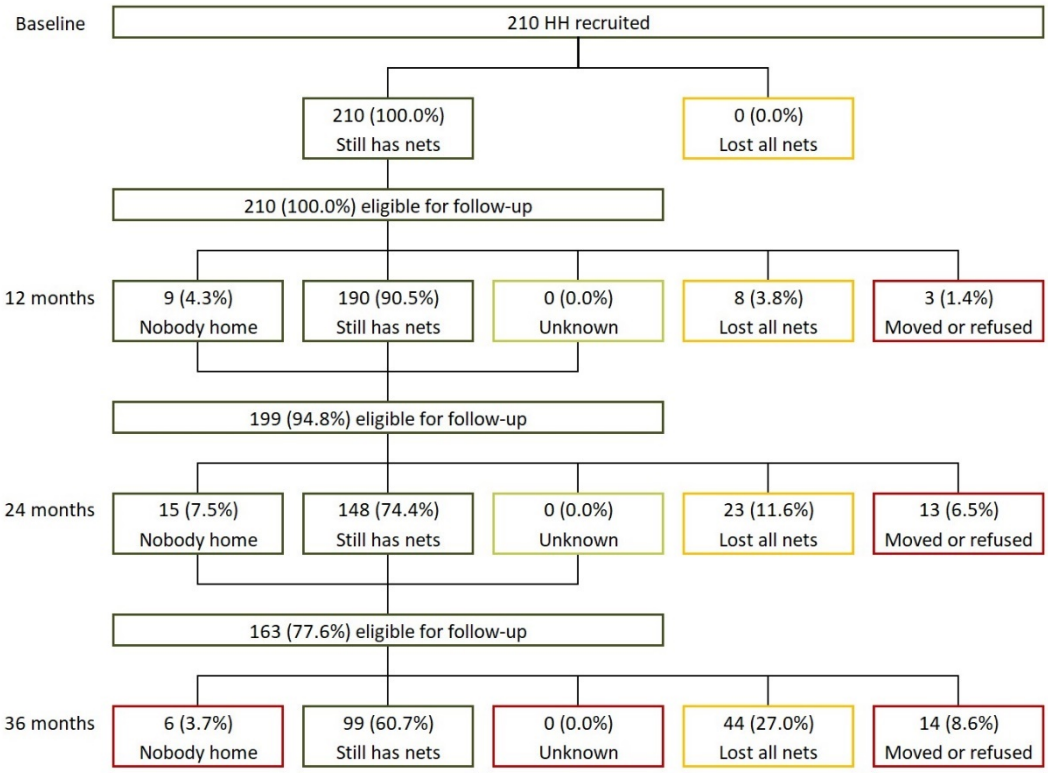
Prior to commencing baseline activities, study protocols were submitted to the national Comité d'Ethique de la Recherche Biomédicale à Madagascar and PSI for review. The national board determined that this activity was not research with human subjects and was exempt from in-country ethical review. PSI determined the study to be research with human subjects and the study team received written approval from the PSI Research Ethics Board (REB) on September 7, 2018, under reference number 00006961 (2018). The PSI REB granted a modification approval on June 7, 2019, to cover the additional site in Fort-Dauphin for PermaNet 2.0. For fieldwork rounds conducted since the start of the COVID-19 pandemic, additional applications were submitted to the PSI REB to obtain approval to resume fieldwork activities under COVID-19. Authorization was granted on September 16, 2020, to cover the 24-month round and on June 24, 2021, to cover the 36-month round. Staff implementing this study complied with all policies and procedures of both PSI REB and the local ethics board. Informed consent was sought for all participants in this study prior conducting the interview.

3. RESULTS

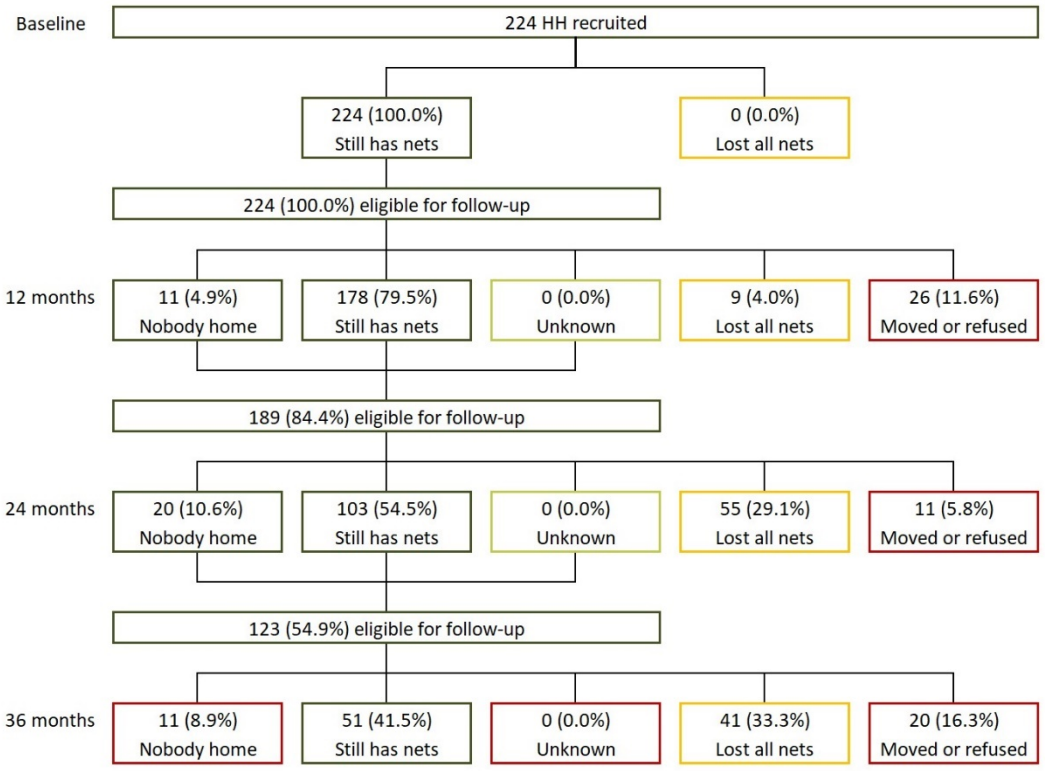
3.1 SAMPLE

At baseline, a total of 797 households were recruited for durability monitoring (210 in Farafangana, 224 in Bekily, 154 in Maintirano), of which 378 households (163 in Farafangana, 123 in Bekily, 92 in Maintirano) were eligible for follow-up at 36-months (Figure 3). At 12 months, an additional 209 households in Fort Dauphin were recruited to study the durability of PermaNet 2.0 ITNs. At 36-months, 139 of these households were eligible for follow-up. Of the 163 eligible households in Farafangana, 99 still had at least one cohort net present, 44 lost all their nets, six households had nobody home, and 14 households moved out of the study site. In Bekily, 51 of the 123 eligible households still had cohort nets, 41 lost all their nets, 11 households had nobody home, and 20 households moved out of the study site. In Maintirano, 51 of the 92 eligible households still had cohort nets, 14 lost all their nets, 14 households had nobody home, and 13 households moved away. Of the 139 eligible households in Fort Dauphin, 65 still had cohort nets, 48 lost all their nets, 20 households had nobody home, five households moved out of the study site, and one household was not interviewed because of a positive COVID-19 screening.

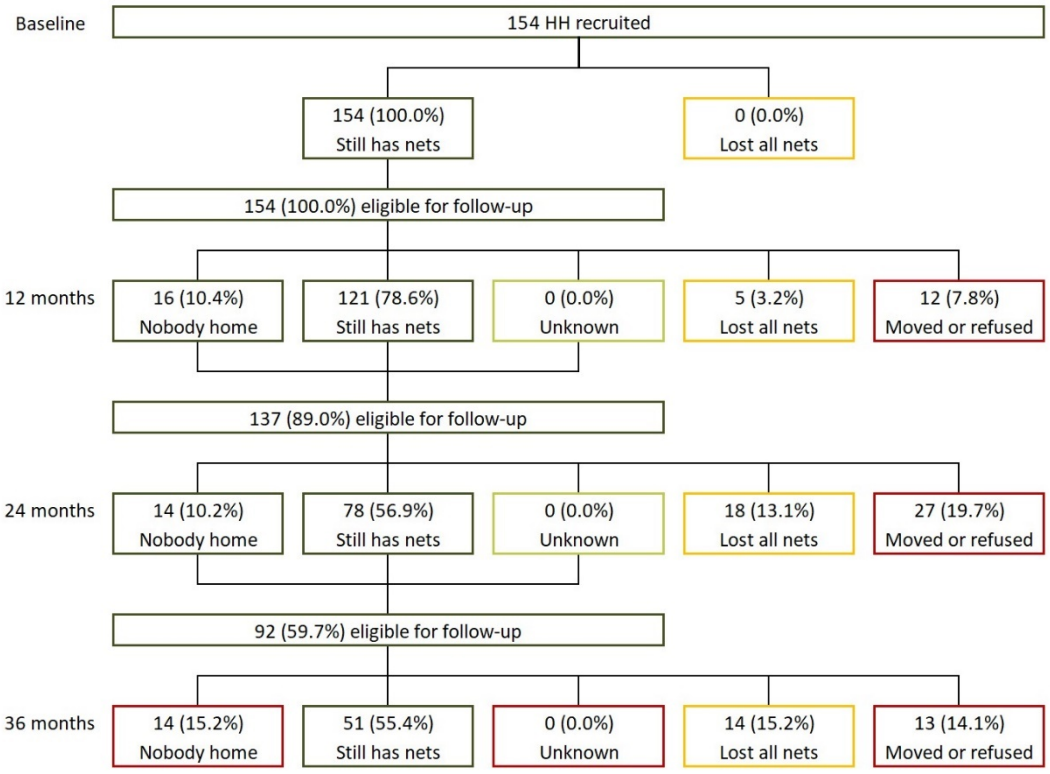
FIGURE 3: 36-MONTH FOLLOW-UP STATUS OF HOUSEHOLDS RECRUITED AT BASELINE
Farafangana (DawaPlus 2.0)

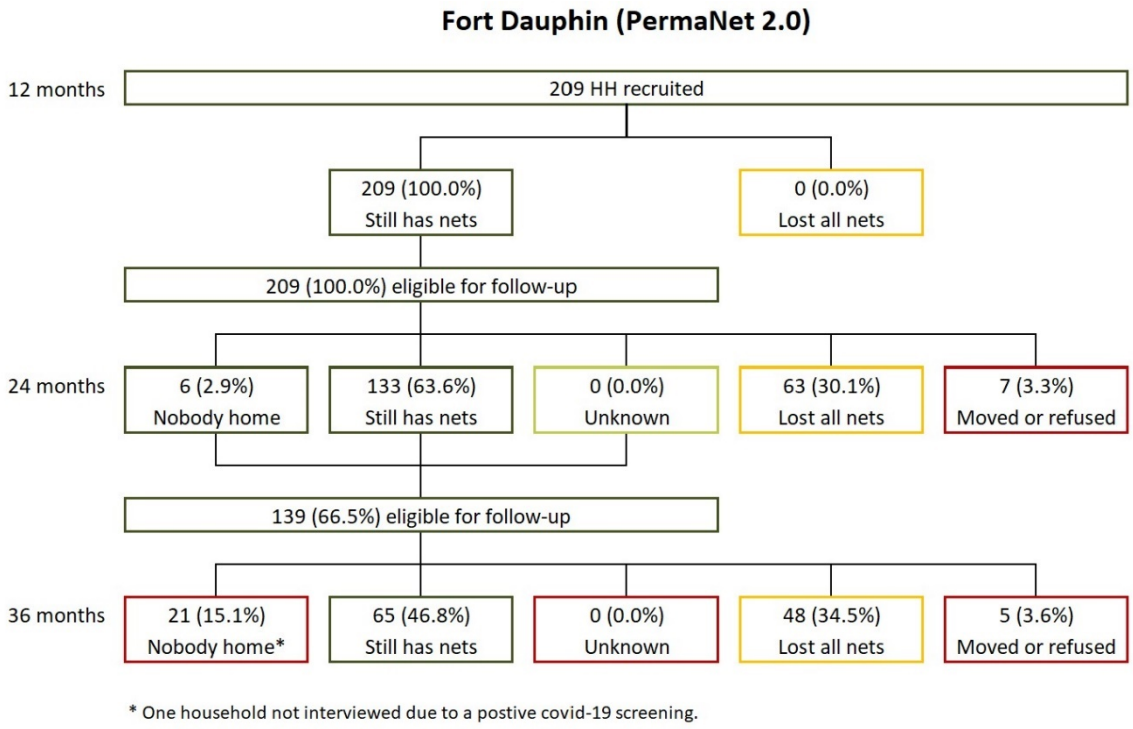


Bekily (DawaPlus 2.0)



Maintirano (DawaPlus 2.0)





The 588 households visited at baseline reported receiving a total of 1,281 campaign nets (510 in Farafangana, 418 in Bekily, and 353 in Maintirano) and the 209 households in Fort Dauphin visited at 12-months reported receiving 369 nets (Figure 4). Of these 1,650 total nets, 1,543 (488 in Farafangana, 408 in Bekily, 335 in Maintirano, and 312 in Fort Dauphin) were present in the household and were tagged for study follow-up.

In Farafangana at 12-months, 429 (84%) 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 301 (59%) 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 127 (25%), 10 nets had an unknown status and 26 were said to be with a family member elsewhere. Of the 138 nets not in the household, 94 were discarded, 19 were given away or had been stolen, one had an unknown status, and 24 could not be assessed because the household moved out of the study site or refused to be interviewed. Among cohort nets reported as present at each survey round, three nets were unavailable for assessment at 12-months and six nets at 24-months due to being temporarily taken away for washing or being stored in locked rooms.

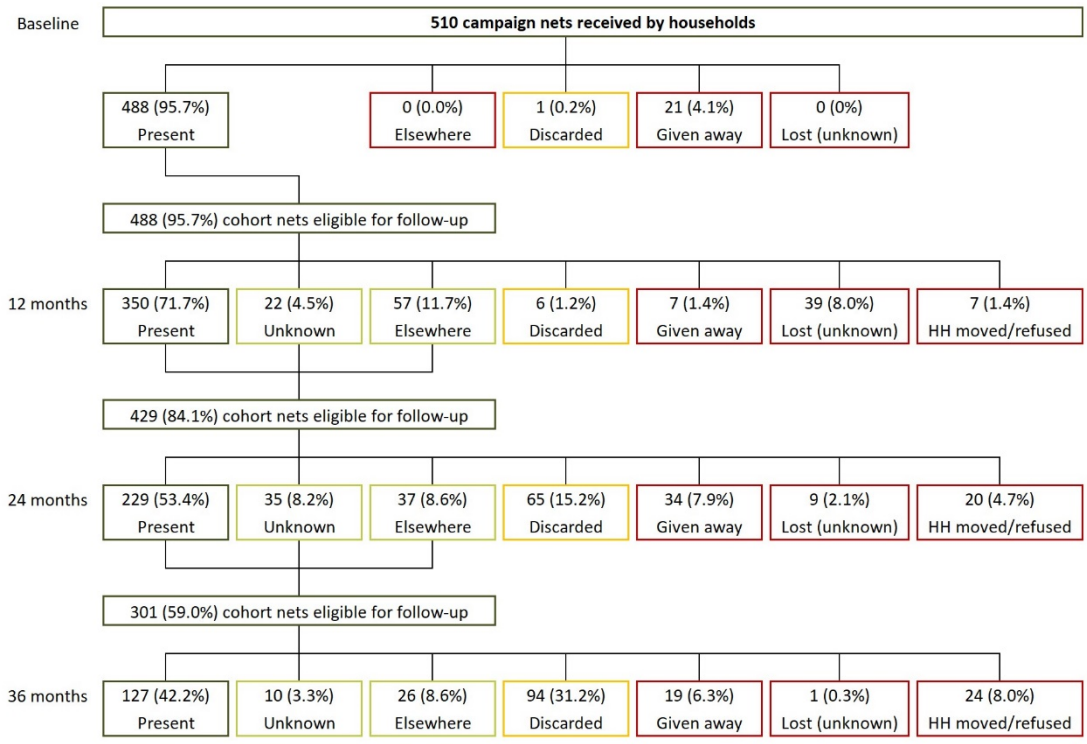
In Bekily, at 12-months, 317 (76%) cohort nets were still in the households, had an unknown status, or were elsewhere with family members and were eligible for follow-up in the next round. At 24-months, 172 (41%) cohort nets were present, had an unknown status, or were elsewhere with family members and thus, eligible for follow-up in the next round. At 36-months, 56 (13%) cohort nets were still in the household, 17 had an unknown status, and nine were with family members elsewhere. Of the 90 nets not in the household, 54 nets were discarded, eight were given away to others or stolen, two had an unknown status, and 26 could not be assessed because the household moved out of the study site or refused to be interviewed. Among cohort nets reported as present, one net was unavailable for assessment at 12-months due to being temporarily taken away for washing or stored in locked rooms.

In Maintirano, at 12-months, 273 (77%) 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, 164 (47%) cohort nets were present, had an unknown status, or were elsewhere with family members and thus,

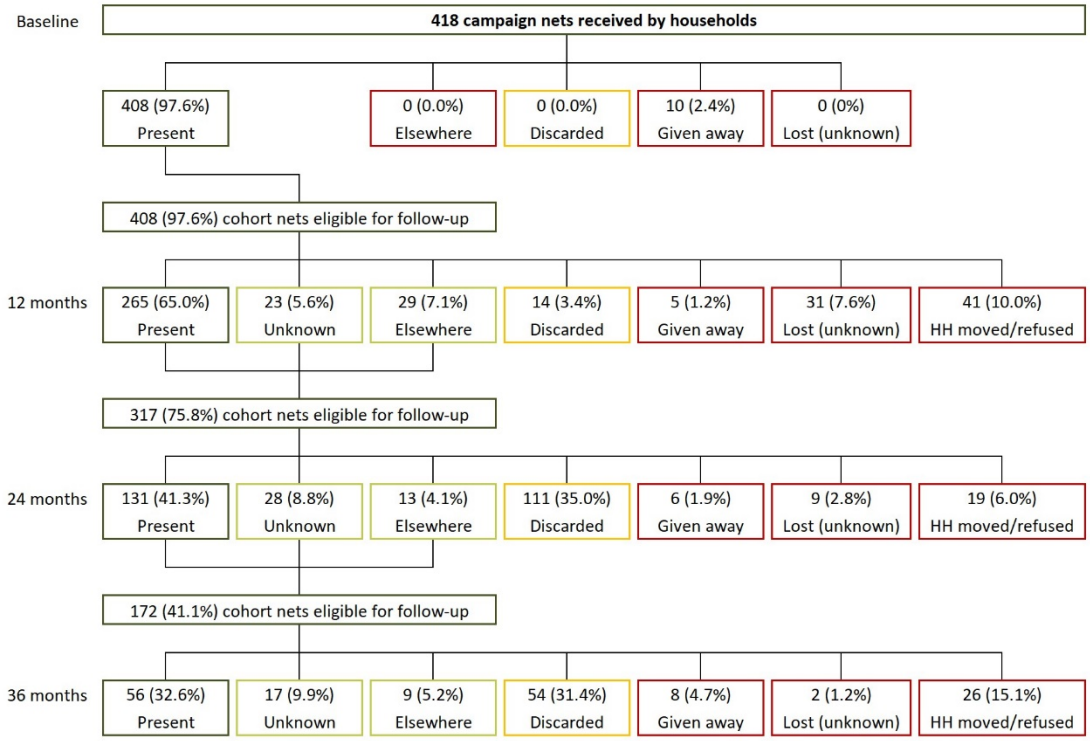
eligible for follow-up in the next round. At 36-months, 49 (14%) cohort nets were still in the household, 20 had an unknown status, and 30 were with family members elsewhere. Of the 65 nets not in the household, 18 nets were discarded, 11 were given away to others or stolen, seven had an unknown status, and 29 could not be assessed because the household moved out of the study site or refused to be interviewed. Among cohort nets reported as present at each survey round, three, two, and six nets were unavailable for assessment at 12-months, 24-months and 36-months respectively, due to being temporarily taken away for washing or stored in locked rooms.

In Fort Dauphin, at 24-months, 177 (48%) 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 36-months, 76 (21%) cohort nets were still in the household, and 27 had an unknown status. Of the 74 nets not in the household, 53 nets were discarded, 13 were given away to others or stolen, and 8 could not be assessed because the household moved out of the study site or refused to be interviewed. Among cohort nets reported as present at each survey round, two nets were unavailable for assessment at 24-months and three nets at 36-months due to being temporarily taken away for washing or being stored in locked rooms.

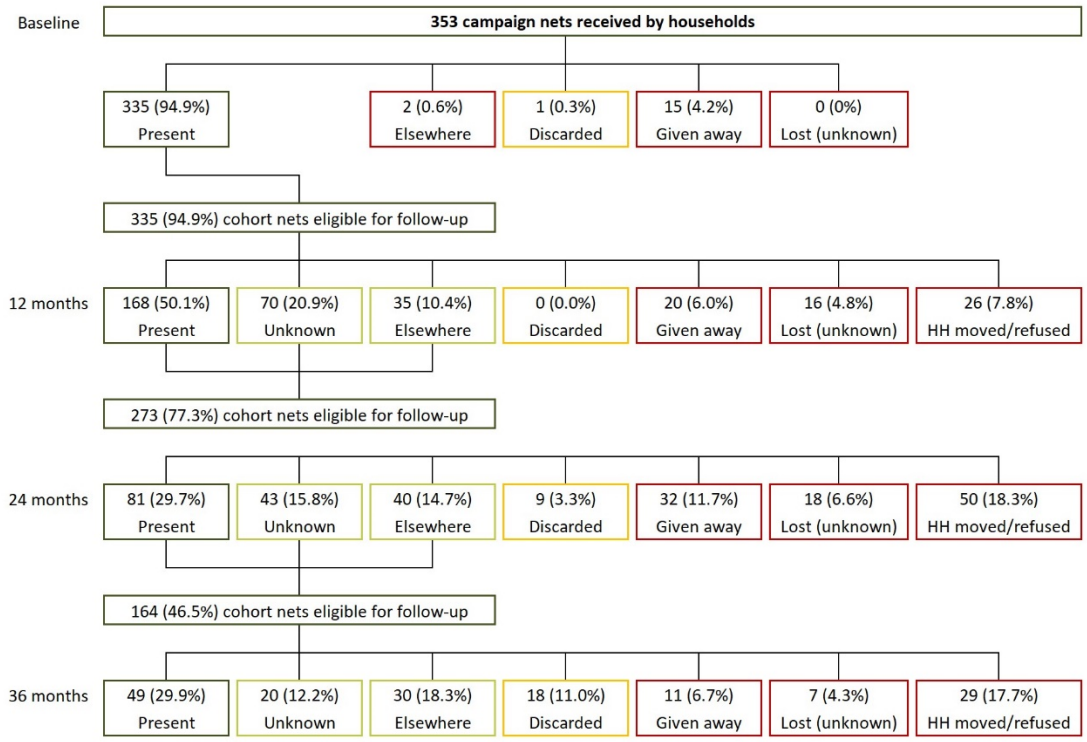
FIGURE 4: FOLLOW-UP STATUS OF COHORT ITNS RECRUITED AT BASELINE
Farafangana (DawaPlus 2.0)

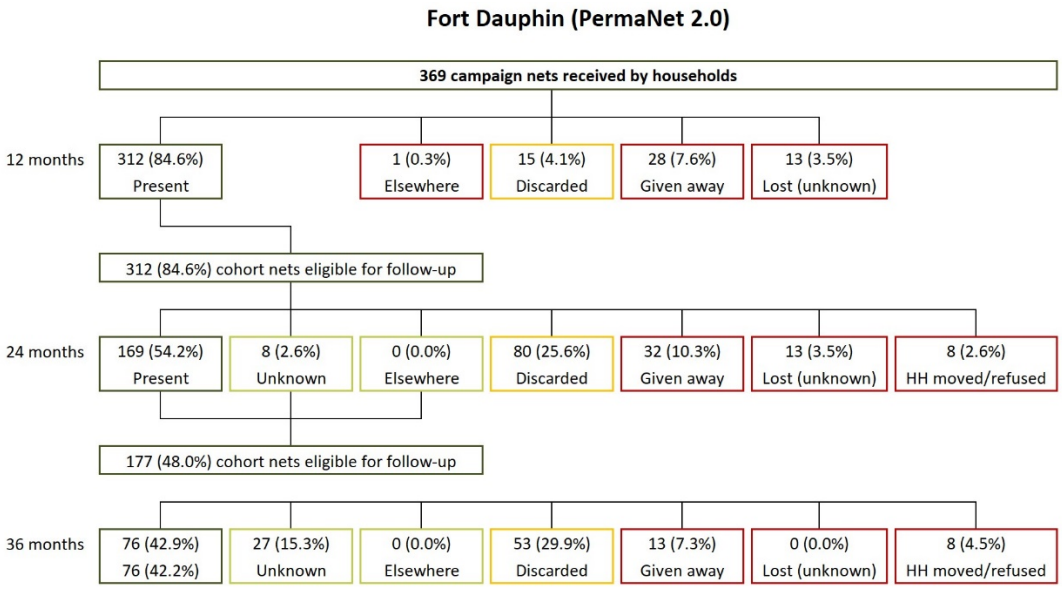


Bekily (DawaPlus 2.0)



Maintirano (DawaPlus 2.0)





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 characteristics and assets can contribute indirectly to the durability of the nets as household factors (Table 4). At baseline (12-months in Fort Dauphin) and 36-months, household characteristics differed between households remaining in the study across the four sites in several ways. In general, households in Maintirano and Fort Dauphin reported higher access to most household assets, except for ownership of livestock and agricultural land, reflecting the more rural environment of households in Farafangana and Bekily. At baseline and at 36-months, less than 20% of households in Farafangana and 5% of households in Bekily had roofs made of metal sheets or tiles, whereas greater than 35% of households in Maintirano and 55% in Fort Dauphin had metal/tiled roofs ($p<0.001$ at baseline and 36-months). Firewood was the most common source of fuel used for cooking in all districts, though use in Fort Dauphin was lower than other districts among households at baseline and 36-months (36-months: 93% in Farafangana, 100% in Bekily, 71% in Maintirano, 66% in Fort Dauphin; $p<0.001$). A lower proportion of households in Farafangana reported access to safe water at baseline (34% in Farafangana, 84% in Bekily, 85% in Maintirano; $p<0.001$) and at 36-months (18% in Farafangana, 82% in Bekily, 83% in Maintirano, 63% in Fort Dauphin; $p<0.001$). At baseline, access to latrines was low (21% in Farafangana, 20% in Bekily, 36% in Maintirano), however, at 36-months a higher proportion of households in Maintirano and Fort Dauphin reported latrine access (60% in Maintirano and 67% in Fort Dauphin, 35% in Farafangana and 29% in Bekily; $p=0.028$).

At baseline and 36-months, radio ownership was lowest in Bekily (14% and 29% in Bekily, 41% and 40% in Farafangana, 37% and 52% in Maintirano, and 43% in Fort Dauphin at 12- and 36-months; $p<0.001$ at baseline, $p=0.102$ at 36-months) and mobile phone ownership was lowest in Farafangana (22% and 25% in Farafangana, 33% and 47% in Bekily, 58% and 72% in Maintirano, and 30% and 43% in Fort Dauphin at 12- and 36-months; $p<0.001$ at baseline and 36-months). Farafangana also had the lowest proportion of households with any transportation at baseline and 36-months (13% and 8% in Farafangana, 34% and 37% in Bekily, 40% and 40% in Maintirano, and 18% and 21% in Fort Dauphin at 12- and 36-months; $p=0.004$ at baseline and $p<0.001$ at 36-months). At baseline and 36-months animal husbandry was more common in Farafangana and Bekily (84% and 80% in Farafangana, 78% and 86% in Bekily, 69% and 74% in Maintirano, and 53% and 48% in Fort Dauphin at 12- and 36-months; $p=0.118$ at baseline, $p<0.001$ at 36-months) as was owning farmland (83% and

90% in Farafangana, 95% and 94% in Bekily, 70% and 62% in Maintirano, and 47% and 59% in Fort Dauphin at 12- and 36-months; p=0.001 at baseline and 36-months).

TABLE 4: HOUSEHOLD CHARACTERISTICS AND ASSETS

	Baseline	36 months
Farafangana	**N=210**	**N=143**
Roof (sheets/ tile)	10.5%	15.4%
Cooking fuel (firewood)	100.0%	93.0%
Access to safe water	34.3%	17.5%
Access to latrine	21.4%	35.0%
Radio	41.4%	39.9%
Mobile phone	21.9%	25.2%
Any transport	13.3%	7.7%
Animal husbandry	83.8%	79.7%
Owning land for farming	83.3%	89.5%
Bekily	**N=224**	**N=92**
Roof (sheets/ tile)	3.6%	4.3%
Cooking fuel (firewood)	100.0%	100.0%
Access to safe water	83.9%	81.5%
Access to latrine	20.1%	29.3%
Radio	14.3%	29.3%
Mobile phone	33.0%	46.7%
Any transport	33.5%	37.0%
Animal husbandry	78.1%	85.9%
Owning land for farming	95.1%	93.5%
Maintirano	**N=154**	**N=65**
Roof (sheets/ tile)	35.1%	36.9%
Cooking fuel (firewood)	99.4%	70.8%
Access to safe water	85.1%	83.1%
Access to latrine	36.4%	60.0%
Radio	37.0%	52.3%
Mobile phone	58.4%	72.3%
Any transport	40.3%	40.0%
Animal husbandry	68.8%	73.8%
Owning land for farming	70.1%	61.5%
	12 months	**36 months**
Fort Dauphin*	**N=209**	**N=113**
Roof (sheets/ tile)	56.9%	73.5%
Cooking fuel (firewood)	72.2%	65.5%
Access to safe water	68.4%	62.8%
Access to latrine	63.2%	67.3%
Radio	43.1%	42.5%
Mobile phone	29.7%	42.5%
Any transport	18.2%	21.2%

Animal husbandry	53.1%	47.8%
Owning land for farming	46.9%	59.3%

* The first round of data collection in Fort Dauphin was the 12-month survey.

The presence of rodents in the house, the presence of food and the practice of cooking near sleeping areas are potential risk factors for net durability. Table 5 presents the prevalence of these risk factors at all survey rounds. At endline, storing food in the same room used for sleeping was common in all districts and was highest in Bekily where all respondents reported storing food where they sleep (84% in Farafangana, 100% in Bekily, 88% in Maintirano, and 82% in Fort Dauphin; p=0.026). All households in Bekily also reported observing rodents in the past six months (80% in Farafangana, 100% in Bekily, 72% in Maintirano, and 79% in Fort Dauphin; p<0.001). Households in Farafangana were more likely to always cook in the same room used for sleeping (50% in Farafangana, 9% in Bekily, 8% in Maintirano, and 21% in Fort Dauphin, p<0.001). Taken together, and across all survey rounds, these results suggest that household risk factors for net damage were more common in Farafangana and Bekily compared to Maintirano and Fort Dauphin.

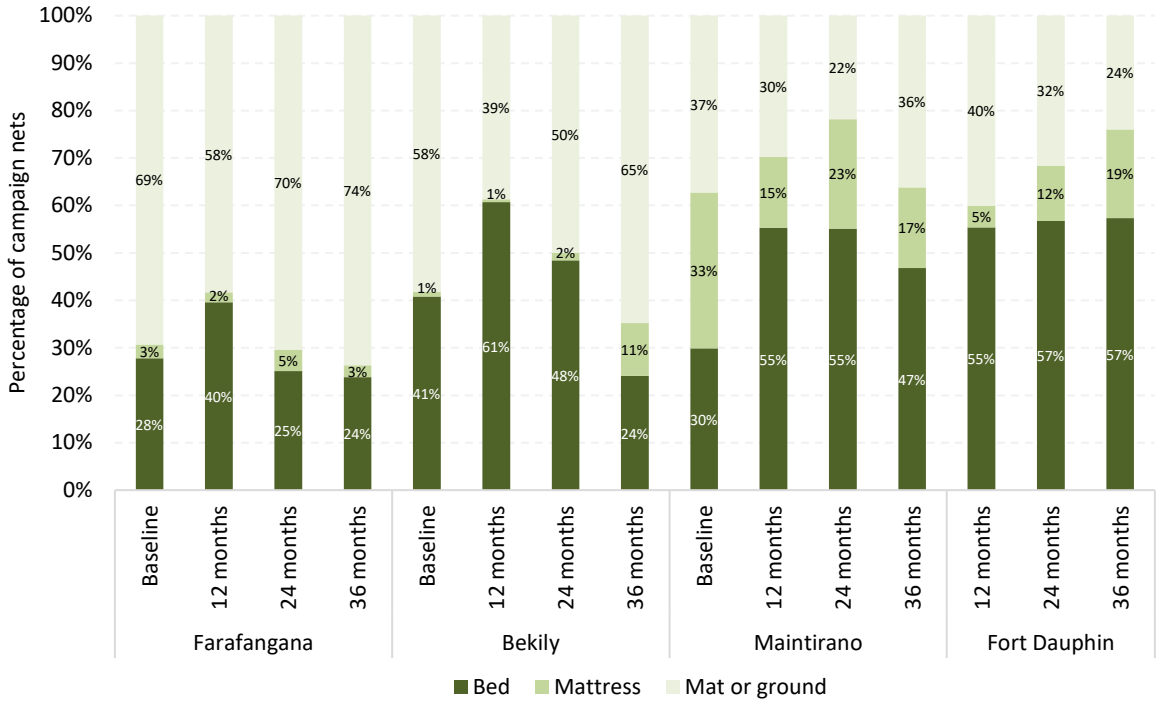
TABLE 5: PREVALENCE OF HOUSEHOLD RISK FACTORS FOR DAMAGE

	Baseline	12 months	24 months	36 months
Farafangana	**N=210**	**N=198**	**N=171**	**N=143**
Ever store food in room used for sleeping	80.0%	80.3%	85.4%	83.9%
Cook in sleeping room				
Never	44.3%	58.6%	48.5%	39.2%
Sometimes	3.8%	3.5%	6.4%	10.5%
Always	51.9%	37.9%	45.0%	50.3%
Don't know	0.0%	0.0%	0.0%	0.0%
Observed rodents in last 6 months	82.9%	89.4%	74.9%	80.4%
Bekily	**N=224**	**N=187**	**N=158**	**N=92**
Ever store food in room used for sleeping	75.9%	73.3%	70.9%	100.0%
Cook in sleeping room				
Never	67.4%	71.1%	84.2%	78.3%
Sometimes	6.3%	8.0%	4.4%	8.7%
Always	26.3%	20.3%	11.4%	13.0%
Don't know	0.0%	0.5%	0.0%	0.0%
Observed rodents in last 6 months	96.4%	90.4%	92.4%	100.0%
Maintirano	**N=154**	**N=126**	**N=96**	**N=65**
Ever store food in room used for sleeping	70.8%	76.2%	57.3%	87.7%
Cook in sleeping room				
Never	82.5%	65.9%	89.6%	87.7%
Sometimes	8.4%	12.7%	3.1%	7.7%
Always	9.1%	21.4%	7.3%	4.6%
Don't know	0.0%	0.0%	0.0%	0.0%
Observed rodents in last 6 months	86.4%	84.1%	81.3%	72.3%
Fort Dauphin	**N/A**	**N=209**	**N=196**	**N=113**
Ever store food in room used for sleeping	N/A	89.0%	74.5%	82.3%
Cook in sleeping room				
Never	N/A	53.6%	66.8%	65.5%

Sometimes	N/A	18.2%	10.7%	13.3%
Always	N/A	28.2%	22.4%	21.2%
Don't know	N/A	0.0%	0.0%	0.0%
Observed rodents in last 6 months	N/A	90.0%	90.8%	78.8%

The type of sleeping place may also affect net durability. Generally, nets used when sleeping on mats or the ground are more prone to wear and tear than those used over mattresses and bed frames. Figure 5 shows the types of sleeping spaces over which cohort ITNs were used by site and study round. The majority of cohort nets were hung over a mat or ground in Farafangana and Bekily across all survey rounds, while use over beds and mattresses was most common in Maintirano and Fort Dauphin. At 36-months, a higher proportion of nets were hung over a mat or ground in Farafangana and Bekily (74% in Farafangana, 65% in Bekily, 36% in Maintirano and 24% in Fort Dauphin; $p<0.001$).

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 6). Excessive washing, particularly with cleaning products like detergent or bleach, can diminish insecticide effectiveness. At 36-months, almost all remaining cohort nets in all sites had ever been washed (94% in Farafangana, 98% in Bekily, 100% in Maintirano, and 99% in Fort Dauphin). Among washed nets, the median number of washes in the six months prior to the survey was three in Farafangana and Bekily, and four in Maintirano and Fort Dauphin. A higher proportion of cohort nets in Bekily were last washed with detergent or bleach (67% in Bekily, 19% in Farafangana, 41% in Maintirano, 32% in Fort Dauphin; $p<0.001$). The proportion of nets dried on a bush or fence after their last wash differed between sites and was highest in Farafangana (69% in Farafangana, 44% in Bekily, 12% in Maintirano, and 41% in Fort Dauphin; $p=0.003$). Among nets reported as hanging, the proportion of nets not folded or tied up during the baseline, 12-, and 24-month surveys varied, with no clear pattern, between study sites and survey rounds. At 36-months, a higher proportion of nets in Bekily were not folded or tied up (68% in Bekily, 25% in Farafangana, 30% in Maintirano, and 19% in Fort Dauphin; $p=0.005$). These results suggest that the prevalence of handling risk factors for net damage varied across sites over time, with no clear pattern to suggest remaining nets in one site were more or less at risk over the study period.

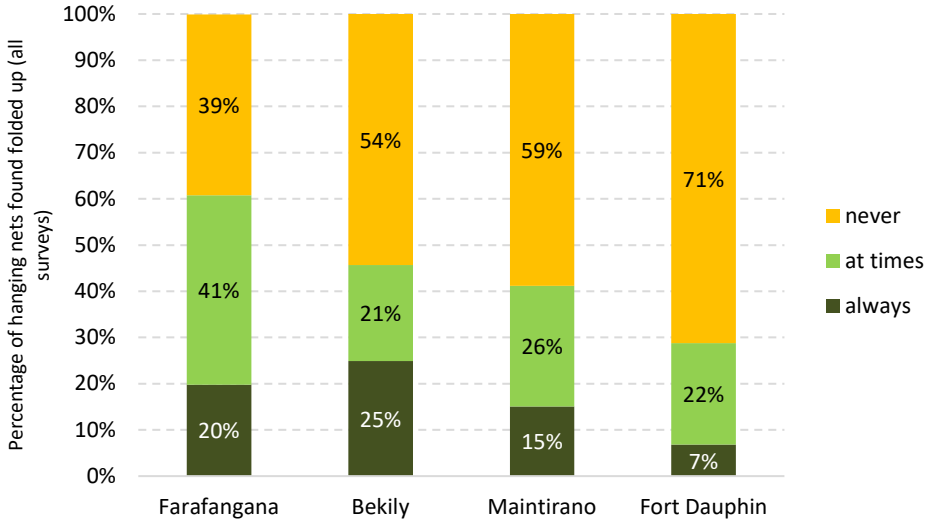
TABLE 6: PREVALENCE OF HANDLING RISK FACTORS FOR COHORT ITNS

	Baseline	12 months	24 months	36 months
Farafangana	**N=488**	**N=350**	**N=229**	**N=127**
ITNs ever washed	12.3%	77.4%	93.9%	93.7%
Among ITNs ever washed:	N=60	N=234	N=215	N=119
Median number of washes in last 6 months [IQR]	1.0 [1.0-1.0]	2.0 [1.0-3.0]	3.0 [2.0-4.0]	3.0 [2.0-3.0]
Used detergent or bleach for last wash	25.0%	10.7%	28.8%	18.5%
ITNs dried on bush or fence for last wash	65.0%	36.9%	66.5%	68.9%
Among hanging ITNs:	N=173	N=235	N=170	N=110
Hanging ITNs are not folded or tied up	61.3%	94.9%	12.9%	24.5%
Bekily	**N=408**	**N=265**	**N=131**	**N=56**
ITNs ever washed	13.7%	79.2%	90.8%	98.2%
Among ITNs ever washed:	N=56	N=205	N=119	N=55
Median number of washes in last 6 months [IQR]	1.0 [1.0-1.0]	3.0 [2.0-5.0]	2.0 [2.0-3.0]	3.0 [2.0-4.0]
Used detergent or bleach for last wash	78.6%	65.9%	67.2%	67.3%
ITNs dried on bush or fence for last wash	25.0%	86.7%	68.1%	43.6%
Among hanging ITNs:	N=169	N=163	N=98	N=50
Hanging ITNs are not folded or tied up	60.4%	65.6%	75.5%	68.0%
Maintirano	**N=335**	**N=168**	**N=81**	**N=49**
ITNs ever washed	14.3%	76.2%	93.8%	100.0%
Among ITNs ever washed:	N=48	N=64	N=76	N=49
Median number of washes in last 6 months [IQR]	1.0 [1.0-1.0]	3.0 [2.0-4.0]	6.0 [3.0-12.0]	4.0 [3.0-8.0]
Used detergent or bleach for last wash	22.9%	29.7%	39.5%	40.8%
ITNs dried on bush or fence for last wash	16.7%	32.8%	7.9%	12.2%
Among hanging ITNs:	N=120	N=114	N=61	N=30
Hanging ITNs are not folded or tied up	71.7%	100.0%	29.5%	30.0%
Fort Dauphin	**N/A**	**N=312**	**N=169**	**N=76**
ITNs ever washed	N/A	81.1%	94.7%	98.7%
Among ITNs ever washed:	N/A	N=253	N=160	N=75
Median number of washes in last 6 months [IQR]	N/A	3.0 [2.0-5.0]	3.0 [2.0-6.0]	4.0 [3.0-7.0]
Used detergent or bleach for last wash	N/A	46.6%	51.2%	32.0%
ITNs dried on bush or fence for last wash	N/A	36.0%	48.8%	41.3%
Among hanging ITNs:	N/A	N=201	N=116	N=53
Hanging ITNs are not folded or tied up	N/A	96.5%	73.3%	18.9%

IQR: interquartile range

We can consider the hanging practices of cohort nets for all rounds in which a net was present in the study (Figure 6). The proportion of nets that were found always folded, sometimes folded and never folded differed between sites ($p<0.001$ for always, compared to sometimes and never). Fort Dauphin had the highest proportion of hanging nets never folded (71% in Fort Dauphin, 39% in Farafangana, 54% in Bekily, and 59% in Maintirano). Conversely, Farafangana had the highest proportion of nets either always or sometimes folded (61% in Farafangana, 46% in Bekily, 41% in Maintirano, and 29% in Fort Dauphin).

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 7. At 36-months, similar proportions of respondents reported any exposure in the six months before the survey (22% in Farafangana, 25% in Bekily, 23% in Maintirano, and 20% in Fort Dauphin). During the baseline, 12- and 24-month surveys, respondents most commonly obtained net information from interpersonal communication (e.g., health workers, friends/family, and community leaders or events; IPC), however, there were a few notable exceptions where a substantial proportion of respondents obtained information from media sources (media only reported by 25% of respondents at baseline and 40% at 12-months in Farafangana, and 64% of respondents at 24-months in Maintirano). At 36-months, a higher proportion of respondents received information from media only in Maintirano (53% in Maintirano, 19% in Farafangana, 0% in Bekily, and 22% in Fort Dauphin; $p<0.008$), while IPC only was more common in Farafangana (68%), Bekily (100%) and Fort Dauphin (61%) compared to Maintirano (33%; $p<0.001$). The most commonly recalled message in all study sites was "Use net (every) night" (81% in Farafangana, 100% in Bekily and Maintirano, and 78% in Fort Dauphin) and the second most commonly recalled message was "Care for net" in Farafangana (65%), "Hang net" in Bekily (74%), and "nets prevent malaria" in both Maintirano (53%) and Fort Dauphin (61%).

TABLE 7: RESPONDENT EXPOSURE TO MESSAGES ABOUT NETS IN LAST 6 MONTHS

	Baseline	12 months	24 months	36 months
Farafangana	**N=210**	**N=198**	**N=171**	**N=143**
Any exposure in last 6 months	59.0%	23.7%	25.7%	21.7%
Among those exposed:	N=124	N=47	N=44	N=31
Mean number of sources among exposed*	1.2	1.1	1.5	1.2
Type of media source among exposed				
Media only	25.0%	40.4%	15.9%	19.4%
Interpersonal communication only	63.7%	55.3%	72.7%	67.7%
Both	11.3%	4.3%	11.4%	12.9%
Messages recalled among exposed				
"Use net (every) night"	85.5%	70.2%	88.6%	80.6%
"Hang net"	25.0%	19.1%	31.8%	29.0%
"Care for net"	50.8%	59.6%	56.8%	64.5%
"Repair net"	8.9%	19.1%	11.4%	19.4%
"Nets prevent malaria"	38.7%	14.9%	27.3%	16.1%

Bekily	**N=224**	**N=187**	**N=158**	**N=92**
Any exposure in last 6 months	37.5%	19.3%	32.9%	25.0%
Among those exposed:	N=84	N=36	N=52	N=23
Mean number of sources among exposed*	1.5	1.0	1.1	1.2
Type of media source among exposed				
Media only	0.0%	0.0%	0.0%	0.0%
Interpersonal communication only	98.8%	100.0%	98.1%	100.0%
Both	1.2%	0.0%	1.9%	0.0%
Messages recalled among exposed				
"Use net (every) night"	95.2%	94.4%	98.1%	100.0%
"Hang net"	27.4%	41.7%	61.5%	73.9%
"Care for net"	17.9%	75.0%	51.9%	34.8%
"Repair net"	1.2%	5.6%	7.7%	8.7%
"Nets prevent malaria"	34.5%	8.3%	38.5%	4.3%
Maintirano	**N=154**	**N=126**	**N=96**	**N=65**
Any exposure in last 6 months	61.0%	27.8%	14.6%	23.1%
Among those exposed:	N=94	N=35	N=14	N=15
Mean number of sources among exposed*	1.2	1.0	1.5	1.7
Type of media source among exposed				
Media only	14.9%	5.7%	64.3%	53.3%
Interpersonal communication only	75.5%	91.4%	14.3%	33.3%
Both	9.6%	2.9%	21.4%	13.3%
Messages recalled among exposed				
"Use net (every) night"	76.6%	77.1%	85.7%	100.0%
"Hang net"	38.3%	14.3%	7.1%	33.3%
"Care for net"	40.4%	51.4%	50.0%	33.3%
"Repair net"	2.1%	2.9%	7.1%	13.3%
"Nets prevent malaria"	18.1%	22.9%	35.7%	53.3%
Fort Dauphin	**N/A**	**N=209**	**N=196**	**N=113**
Any exposure in last 6 months	N/A	31.6%	15.8%	20.4%
Among those exposed:	N/A	N=66	N=31	N=23
Mean number of sources among exposed*	N/A	1.3	1.0	1.5
Type of media source among exposed				
Media only	N/A	9.1%	16.1%	21.7%
Interpersonal communication only	N/A	83.3%	80.6%	60.9%
Both	N/A	7.6%	3.2%	17.4%
Messages recalled among exposed				
"Use net (every) night"	N/A	75.8%	77.4%	78.3%
"Hang net"	N/A	47.0%	6.5%	47.8%
"Care for net"	N/A	54.5%	29.0%	52.2%
"Repair net"	N/A	10.6%	3.2%	21.7%
"Nets prevent malaria"	N/A	40.9%	3.2%	60.9%

* During the 36-month survey, the maximum number of sources reported by a household was three.

Data on household attitudes towards nets and net care and repair were captured in the form of Likert score questions (i.e., respondents were asked the extent to which they agreed with certain statements). Net use questions were used to understand the extent to which respondents believed they could obtain enough nets for their household, hang nets, use nets consistently and get children in the household to use nets consistently. Questions on attitudes to net care and repair were used to understand respondent beliefs about the value of nets and their capacity to keep nets in a good condition and repair net damage. These questions were converted into two summary scores by first recoding the four-level Likert scale to have a value of -2 for "strongly disagree", -1 for "disagree", +1 for "agree" and +2 for "strongly agree". The values for each response were then summed and divided by the number of statements to calculate an overall attitude score. An average score greater than 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, however, attitude scores were higher among respondents at 36-months than they were at baseline in Maintirano and Fort Dauphin, while the opposite was the case in Farafangana and Bekily (Table 8). That said, at 36-months, the mean attitude scores in all study sites were above one, indicating an overall positive attitude towards nets and net care and repair. The proportion of respondents with favorable attitudes towards nets differed across study sites and was highest in Maintirano and Fort Dauphin (85% in Maintirano, 86% in Fort Dauphin, 74% in Farafangana, 59% in Bekily; p=0.004). A lower proportion of respondents had favorable attitudes towards net care and repair in Farafangana, however, this difference was not statistically significant (49% in Farafangana, 70% in Bekily, 69% in Maintirano, and 61% in Fort Dauphin, p=0.067).

TABLE 8: RESPONDENT ATTITUDES TOWARDS NETS AND NET CARE & REPAIR

	Baseline	12 months	24 months	36 months
Farafangana	**N=210**	**N=198**	**N=171**	**N=143**
Attitude score: Nets				
Mean	1.60	1.21	1.31	1.41
(95% CI)	(1.51-1.69)	(1.13-1.29)	(1.19-1.43)	(1.25-1.57)
Percentage of respondents with score > 1.0	91.9%	65.7%	69.6%	74.1%
Attitude score: Net care and repair				
Mean	1.19	1.08	1.39	1.08
(95% CI)	(1.10-1.28)	(0.91-1.25)	(1.29-1.49)	(0.90-1.26)
Percentage of respondents with score > 1.0	58.6%	52.0%	73.7%	49.0%
Bekily	**N=224**	**N=187**	**N=158**	**N=92**
Attitude score: Nets				
Mean	1.36	1.13	1.31	1.14
(95% CI)	(1.26-1.45)	(0.98-1.28)	(1.20-1.42)	(0.99-1.30)
Percentage of respondents with score > 1.0	76.8%	62.6%	67.7%	58.7%
Attitude score: Net care and repair				
Mean	1.34	0.91	1.28	1.27
(95% CI)	(1.29-1.40)	(0.77-1.06)	(1.21-1.35)	(1.14-1.40)
Percentage of respondents with score > 1.0	71.9%	43.9%	71.5%	69.6%
Maintirano	**N=154**	**N=126**	**N=96**	**N=65**
Attitude score: Nets				
Mean	1.48	1.38	1.62	1.54
(95% CI)	(1.44-1.53)	(1.23-1.54)	(1.50-1.75)	(1.42-1.65)
Percentage of respondents with score > 1.0	79.2%	72.2%	89.6%	84.6%
Attitude score: Net care and repair				
Mean	1.20	1.26	1.29	1.33
(95% CI)	(1.08-1.31)	(1.06-1.45)	(1.13-1.46)	(1.22-1.45)
Percentage of respondents with score > 1.0	63.6%	68.3%	68.8%	69.2%

Fort Dauphin	N/A	N=209	N=196	N=113
Attitude score: Nets				
Mean (95% CI)	N/A	1.34 (1.22-1.45)	1.28 (1.16-1.40)	1.53 (1.45-1.62)
Percentage of respondents with score > 1.0	N/A	74.6%	67.3%	85.8%
Attitude score: Net care and repair				
Mean (95% CI)	N/A	1.02 (0.94-1.11)	1.00 (0.92-1.08)	1.16 (1.04-1.29)
Percentage of respondents with score > 1.0	N/A	51.2%	50.5%	61.1%

Experience with repairing holes in nets is presented in Table 9. From baseline to 36-months, a progressively increasing proportion of respondents reported having ever experienced holes (from an average of 48% at baseline to 93% at 36-months, across all sites). At 36-months, the proportion of respondents who reported discussing net care and repair was lowest in Farafangana and Fort Dauphin (18% in Farafangana, 15% in Fort Dauphin, 41% in Bekily, 60% in Maintirano; p=0.006). Among those who reported having holes in their nets, the proportion of respondents who ever repaired a net was similar across districts (65% in Farafangana, 51% in Bekily, 63% in Maintirano, and 56% in Fort Dauphin).

TABLE 9: HOUSEHOLD NET CARE AND REPAIR EXPERIENCE

	Baseline	12 months	24 months	36 months*
Farafangana	**N=210**	**N=198**	**N=171**	**N=141**
Ever experienced holes in a net	75.2%	88.4%	91.8%	98.6%
Discussed net care and repair in last 6 months	41.9%	29.8%	43.9%	18.2%
Among households experiencing holes:	N=158	N=175	N=157	N=139
Ever repaired net	60.1%	44.6%	68.8%	64.7%
Bekily	**N=224**	**N=187**	**N=158**	**N=77**
Ever experienced holes in a net	18.3%	79.1%	78.5%	87.0%
Discussed net care and repair in last 6 months	28.6%	16.6%	22.8%	41.3%
Among households experiencing holes:	N=41	N=148	N=124	N=67
Ever repaired net	58.5%	27.0%	52.4%	50.7%
Maintirano	**N=154**	**N=126**	**N=96**	**N=61**
Ever experienced holes in a net	53.2%	60.3%	74.0%	88.5%
Discussed net care and repair in last 6 months	24.7%	15.9%	34.4%	60.0%
Among households experiencing holes:	N=82	N=76	N=71	N=54
Ever repaired net	62.2%	46.1%	69.0%	63.0%
Fort Dauphin	**N/A**	**N=209**	**N=196**	**N=98**
Ever experienced holes in a net	N/A	65.6%	85.7%	90.8%
Discussed net care and repair in last 6 months	N/A	9.1%	9.7%	15.0%
Among households experiencing holes:	N/A	N=137	N=168	N=89
Ever repaired net	N/A	32.8%	45.2%	56.2%

* At 36-months, questions related to net care and repair experience were only asked to respondents who reported owning one or more nets. This excluded the following number of respondents from these questions (Farafangana, n=2; Bekily, n=15; Maintirano, n=4; Fort Dauphin, n=15).

3.3 NET OWNERSHIP AND NET USE

The status and reported recent use of campaign cohort nets (Table 10) was recorded to understand net use patterns. At 36-months, cohort nets were most commonly found hanging and tied up in Farafangana (65%), Maintirano (43%), and Fort Dauphin (57%) compared to Bekily (29%; p=0.011), while nets were more commonly found hanging untied in Bekily (61% in Bekily, 21% in Farafangana, 18% in Maintirano, and 12% in Fort Dauphin; p=0.004). At baseline, a substantial proportion of cohort nets were found stored away (55% in Farafangana, 53% in Bekily, and 61% in Maintirano) but few nets remained stored at 36-months (11% in Farafangana, 11% in Bekily, and 25% in Maintirano).

Use of cohort nets progressively increased during the study period. From baseline to 36-months, use of cohort nets every night last week increased from 38% to 84% in Farafangana, 46% to 88% in Bekily, and 35% to 59% in Maintirano. A more modest increase from 79% at 12-months to 83% at 36-months was observed in Fort Dauphin. At 36-months, a lower proportion of cohort nets in Maintirano were ever used compared to other sites (84% in Maintirano, 96% in Farafangana, 96% in Bekily, and 99% in Fort Dauphin; p=0.006). Cohort nets in Maintirano were also less likely to be reported as used last night (59% in Maintirano, 84% in Farafangana, 95% in Bekily, and 84% in Fort Dauphin; p<0.001), or used every night last week (59% in Maintirano, 84% in Farafangana, 88% in Bekily, and 83% in Fort Dauphin; p<0.001).

TABLE 10: STATUS AND REPORTED USE OF COHORT NETS IN THE HOUSEHOLD

	Baseline	12 months	24 months	36 months
Farafangana	**N=488**	**N=350**	**N=229**	**N=127**
Cohort net status				
Found hanging and tied up	13.7%	3.4%	64.6%	65.4%
Found hanging, untied	21.7%	63.7%	9.6%	21.3%
Not hanging and not stored away	5.9%	3.4%	3.5%	2.4%
Stored away unpacked	48.8%	21.7%	17.0%	6.3%
Stored away in a package	9.8%	6.9%	2.6%	4.7%
Temporarily unavailable during visit	0.0%	0.9%	2.6%	0.0%
Net ever used	41.6%*	81.7%	96.9%	96.1%
Net used last night	38.5%	65.7%	73.4%	84.3%
Net used every night last week	38.1%	64.6%	71.2%	84.3%
Bekily	**N=408**	**N=265**	**N=131**	**N=56**
Cohort net status				
Found hanging and tied up	16.4%	21.1%	18.3%	28.6%
Found hanging, untied	25.0%	40.4%	56.5%	60.7%
Not hanging and not stored away	5.4%	18.5%	16.0%	0.0%
Stored away unpacked	30.4%	18.9%	6.1%	8.9%
Stored away in a package	22.8%	0.8%	3.1%	1.8%
Temporarily unavailable during visit	0.0%	0.4%	0.0%	0.0%
Net ever used	48.5%*	83.0%	92.4%	96.4%
Net used last night	46.6%	79.2%	87.8%	94.6%
Net used every night last week	45.8%	77.7%	87.0%	87.5%
Maintirano	**N=335**	**N=168**	**N=81**	**N=49**
Cohort net status				
Found hanging and tied up	10.1%	0.0%	53.1%	42.9%
Found hanging, untied	25.7%	67.9%	22.2%	18.4%

Not hanging and not stored away	3.6%	1.2%	4.9%	2.0%
Stored away unpacked	32.8%	18.5%	12.3%	24.5%
Stored away in a package	27.8%	10.7%	4.9%	0.0%
Temporarily unavailable during visit	0.0%	1.8%	2.5%	12.2%
Net ever used	40.3%*	82.7%	96.3%	83.7%
Net used last night	35.5%	72.0%	76.5%	59.2%
Net used every night last week	35.2%	71.4%	76.5%	59.2%
Fort Dauphin	**N/A**	**N=312**	**N=169**	**N=76**
Cohort net status				
Found hanging and tied up	N/A	2.2%	18.3%	56.6%
Found hanging, untied	N/A	62.2%	50.3%	13.2%
Not hanging and not stored away	N/A	14.7%	14.8%	11.8%
Stored away unpacked	N/A	17.0%	14.2%	9.2%
Stored away in a package	N/A	3.8%	1.2%	5.3%
Temporarily unavailable during visit	N/A	0.0%	1.2%	3.9%
Net ever used	N/A	90.1%	94.7%	98.7%
Net used last night	N/A	80.1%	78.7%	84.2%
Net used every night last week	N/A	78.8%	76.9%	82.9%

* Due to a difference in the questionnaire skip pattern at baseline, results are not directly comparable with subsequent rounds and the baseline figures are lower-bound estimates for this indicator.

At each survey round, teams recorded 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 11.

In all districts, the proportion of households owning any non-cohort nets was higher at 36-months compared to previous rounds. At 36-months non-cohort net ownership differed between districts with 89% of households in Farafangana owning non-cohort nets, 73% in Bekily, 88% in Maintirano, and 56% in Fort Dauphin ($p<0.001$). The most common source of non-cohort nets was community continuous distribution[10] in Farafangana (33%) and Bekily (75%), and private sources in Maintirano (49%) and Fort Dauphin (33%). Among private sources, 99% of 138 non-cohort nets were bought from markets. The second most common source of non-cohort nets was previous mass campaign in Farafangana (25%), Maintirano (32%) and Fort Dauphin (32%), and private sector in Bekily (10%).

TABLE 11: OWNERSHIP AND SOURCE OF NON-COHORT NETS

	Baseline	12 months	24 months	36 months
Farafangana	**N=210**	**N=198**	**N=171**	**N=143**
Households with any non-cohort nets	86.2%	67.2%	81.3%	88.8%
Non-cohort net sources	**Net N=366**	**Net N=212**	**Net N=265**	**Net N=256**
Antenatal Care (ANC) visit	0.0%	2.4%	4.2%	6.6%
Previous mass campaign	89.3%	79.7%	34.7%	24.6%
Community continuous distribution	0.0%	0.0%	0.0%	32.8%
School	0.0%	0.5%	0.0%	0.0%

[10] In a community continuous distribution system, community health workers (called community health volunteers in Madagascar) routinely visit homes to identify ongoing ITN needs and issue a coupon when required which can be redeemed for a new ITN at a community distirbution point. Community continuous distirbution is implemented in 12 districts in Madagascar, including Bekily and Farafangana.

Other public source*	1.6%	3.8%	29.8%	5.9%
Private sector	8.5%	10.4%	16.6%	18.4%
Other/doesn't recall**	0.5%	3.3%	14.7%	11.7%
Bekily	**N=224**	**N=187**	**N=158**	**N=92**
Households with any non-cohort nets	52.7%	32.1%	66.5%	72.8%
Non-cohort net sources	**Net N=152**	**Net N=68**	**Net N=149**	**Net N=92**
ANC visit	0.0%	2.9%	8.7%	3.3%
Previous mass campaign	78.9%	75.0%	20.1%	5.4%
School	0.7%	0.0%	0.0%	0.0%
Community continuous distribution	0.0%	0.0%	1.3%	75.0%
Other public source*	3.3%	4.4%	45.0%	3.3%
Private sector	9.9%	10.3%	18.8%	9.8%
Other/doesn't recall**	7.2%	7.4%	6.0%	3.3%
Maintirano	**N=154**	**N=126**	**N=96**	**N=65**
Households with any non-cohort nets	85.7%	6.3%	85.4%	87.7%
Non-cohort net sources	**Net N=276**	**Net N=10**	**Net N=129**	**Net N=106**
ANC visit	0.0%	10.0%	6.2%	6.6%
Previous mass campaign	73.9%	0.0%	59.7%	32.1%
School	0.0%	0.0%	0.0%	0.0%
Community continuous distribution	0.0%	0.0%	0.0%	0.0%
Other public source*	5.1%	0.0%	6.2%	10.4%
Private sector	19.2%	70.0%	19.4%	49.1%
Other/doesn't recall**	1.8%	20.0%	8.5%	1.9%
Fort Dauphin	**N/A**	**N=209**	**N=196**	**N=113**
Households with any non-cohort nets	N/A	33.5%	46.9%	55.8%
Non-cohort net sources	**N/A**	**Net N=100**	**Net N=147**	**Net N=107**
ANC visit	N/A	2.0%	9.5%	10.3%
Previous mass campaign	N/A	47.0%	36.1%	31.8%
School	N/A	0.0%	0.0%	0.0%
Community continuous distribution	0.0%	0.0%	0.0%	0.0%
Other public source*	N/A	11.0%	15.6%	12.1%
Private sector	N/A	34.0%	25.2%	32.7%
Other/doesn't recall**	N/A	6.0%	13.6%	13.1%

* Includes other (non-ANC) public health facility visits, community-based workers and immunization campaigns.

** Includes family/friends, NGO and faith-based organizations.

A total of 561 non-cohort nets (256 in Farafangana, 92 in Bekily, 106 in Maintirano, and 107 in Fort Dauphin) were audited in study households at the 36-month survey round (Table 12). The pattern of net location and status for non-cohort nets was similar to cohort nets at 36-months. Most non-cohort nets were found hanging and tied up in Farafangana (59%), Maintirano (67%), and Fort Dauphin (76%) compared to Bekily (30%; p=0.003), while nets were more commonly found hanging untied in Bekily (53% in Bekily, 26% in Farafangana, 15% in Maintirano, and 8% in Fort Dauphin; p<0.001).

The proportion of non-cohort nets ever used, used last night, and used every night last week was highest at 36-months in all study sites (except in Maintirano, where the highest values were recorded at 12-months). Non-

cohort net use differed across study sites with 92% of non-cohort nets ever used in Farafangana, 89% in Bekily, 97% in Maintirano, and 99% in Fort Dauphin (p=0.024). The proportion of non-cohort nets used last night and used every night last week did not differ significantly across sites (86% and 85% across all sites).

TABLE 12: STATUS AND REPORTED USE OF NON-COHORT NETS IN THE HOUSEHOLD

	Baseline	12 months	24 months	36 months
Farafangana	**N=366**	**N=212**	**N=265**	**N=256**
Non-cohort net status				
Found hanging and tied up	39.6%	1.4%	61.9%	59.4%
Found hanging, untied	32.5%	79.2%	13.2%	26.2%
Not hanging and not stored away	11.7%	4.2%	1.1%	3.9%
Stored away unpacked	11.7%	11.3%	19.2%	5.1%
Stored away in a package	2.2%	2.8%	4.2%	5.5%
Temporarily unavailable during visit	2.2%	0.9%	0.4%	0.0%
Net ever used	88.0%	90.1%	87.5%	91.8%
Net used last night	76.8%	77.8%	74.3%	85.9%
Net used every night last week	73.8%	74.5%	73.2%	85.2%
Bekily	**N=152**	**N=68**	**N=149**	**N=92**
Non-cohort net status				
Found hanging and tied up	24.3%	8.8%	20.8%	30.4%
Found hanging, untied	44.1%	39.7%	34.9%	53.3%
Not hanging and not stored away	5.9%	36.8%	22.1%	0.0%
Stored away unpacked	11.2%	14.7%	11.4%	4.3%
Stored away in a package	3.3%	0.0%	10.1%	12.0%
Temporarily unavailable during visit	11.2%	0.0%	0.7%	0.0%
Net ever used	82.9%	85.3%	75.2%	89.1%
Net used last night	70.4%	75.0%	65.8%	85.9%
Net used every night last week	69.7%	72.1%	64.4%	85.9%
Maintirano	**N=276**	**N=10**	**N=129**	**N=106**
Non-cohort net status				
Found hanging and tied up	10.5%	10.0%	38.8%	67.0%
Found hanging, untied	51.1%	90.0%	28.7%	15.1%
Not hanging and not stored away	5.8%	0.0%	9.3%	4.7%
Stored away unpacked	20.3%	0.0%	20.2%	7.5%
Stored away in a package	6.5%	0.0%	3.1%	3.8%
Temporarily unavailable during visit	5.8%	0.0%	0.0%	1.9%
Net ever used	82.2%	100.0%	96.9%	97.2%
Net used last night	64.1%	100.0%	76.7%	84.0%
Net used every night last week	61.2%	100.0%	76.0%	82.1%
Fort Dauphin	**N/A**	**N=100**	**N=147**	**N=107**
Non-cohort net status				
Found hanging and tied up	N/A	0.0%	24.5%	75.7%
Found hanging, untied	N/A	65.0%	39.5%	7.5%
Not hanging and not stored away	N/A	7.0%	14.3%	5.6%
Stored away unpacked	N/A	25.0%	15.0%	4.7%

Stored away in a package	N/A	3.0%	3.4%	6.5%
Temporarily unavailable during visit	N/A	0.0%	3.4%	0.0%
Net ever used	N/A	81.0%	89.8%	99.1%
Net used last night	N/A	65.0%	72.1%	89.7%
Net used every night last week	N/A	63.0%	72.1%	87.9%

The study captured data on the age categories of household members using cohort (Table 13) and non-cohort nets (Table 14) the night before the interview as another potential factor for durability. At 36-months, the age pattern of cohort and non-cohort net users did not differ between study sites. Slightly less than half of cohort and non-cohort nets were used by adults only across study sites (45% of cohort nets, 47% of non-cohort nets). Use of nets by children alone was only above 10% for cohort nets in Maintirano (10%) and Bekily (17%).

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

	Baseline	12 months	24 months	36 months
Farafangana	**N=188**	**N=230**	**N=168**	**N=107**
Cohort nets				
Used by child(ren) only	6.9%	8.7%	10.7%	5.6%
Used by child(ren) sharing with adult(s)	56.4%	60.0%	62.5%	51.4%
Used by adult(s) only	36.7%	31.3%	26.8%	43.0%
Bekily	**N=190**	**N=210**	**N=115**	**N=53**
Cohort nets				
Used by child(ren) only	8.4%	6.2%	8.7%	17.0%
Used by child(ren) sharing with adult(s)	51.1%	66.2%	66.1%	35.8%
Used by adult(s) only	40.5%	27.6%	25.2%	47.2%
Maintirano	**N=119**	**N=121**	**N=62**	**N=29**
Cohort nets				
Used by child(ren) only	8.4%	9.9%	11.3%	10.3%
Used by child(ren) sharing with adult(s)	43.7%	50.4%	37.1%	37.9%
Used by adult(s) only	47.9%	39.7%	51.6%	51.7%
Fort Dauphin	**N/A**	**N=250**	**N=133**	**N=64**
Cohort nets				
Used by child(ren) only	N/A	5.6%	3.8%	4.7%
Used by child(ren) sharing with adult(s)	N/A	48.4%	59.4%	50.0%
Used by adult(s) only	N/A	46.0%	36.8%	45.3%

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

TABLE 14: USE OF NON-COHORT NETS BY HOUSEHOLD MEMBERS AMONG NETS USED THE PREVIOUS NIGHT

	Baseline	12 months	24 months	36 months
Farafangana	**N=281**	**N=165**	**N=197**	**N=220**
Non-cohort nets				
Used by child(ren) only	6.4%	10.3%	7.1%	5.0%
Used by child(ren) sharing with adult(s)	50.5%	50.3%	47.2%	52.7%
Used by adult(s) only	43.1%	39.4%	45.7%	42.3%
Bekily	**N=107**	**N=51**	**N=98**	**N=79**
Non-cohort nets				

Used by child(ren) only	5.6%	11.8%	14.3%	8.9%
Used by child(ren) sharing with adult(s)	53.3%	47.1%	54.1%	50.6%
Used by adult(s) only	41.1%	41.2%	31.6%	40.5%
Maintirano	**N=177**	**N=10**	**N=99**	**N=89**
Non-cohort nets				
Used by child(ren) only	12.4%	10.0%	8.1%	6.7%
Used by child(ren) sharing with adult(s)	29.4%	30.0%	42.4%	37.1%
Used by adult(s) only	58.2%	60.0%	49.5%	56.2%
Fort Dauphin	**N/A**	**N=65**	**N=106**	**N=96**
Non-cohort nets				
Used by child(ren) only	N/A	6.2%	7.5%	4.2%
Used by child(ren) sharing with adult(s)	N/A	27.7%	42.5%	42.7%
Used by adult(s) only	N/A	66.2%	50.0%	53.1%

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 15). 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. Data for these indicators was captured at baseline and endline study rounds. Data on use of ITNs at the population level is only available for the endline study round.

By both measures, access to all ITNs and cohort ITNs decreased from baseline to 36-months in all study sites. At 36-months, household and population access to cohort ITNs differed between sites and was highest in Maintirano (28% and 47% in Maintirano, 12% and 31% in Farafangana, 9% and 25% in Bekily, and 8% and 26% in Fort Dauphin; $p<0.001$ for household access, $p=0.002$ for population access). Although measures of cohort ITN access differed between sites, population cohort ITN use was similar (26% across all sites). Household access to other ITNs was highest in Maintirano (22% in Maintirano, 13% in Farafangana, 8% in Bekily, and 4% in Fort Dauphin; $p=0.008$), while population access to other ITNs was relatively high in both Farafangana and Maintirano (47% in Farafangana, 44% in Maintirano, 31% in Bekily, and 16% in Fort Dauphin; $p<0.001$). Population use of other ITNs differed between sites and was lowest in Fort Dauphin (17% in Fort Dauphin, 51% in Farafangana, 35% in Bekily, and 43% in Maintirano; $p<0.001$).

The ratio of population-level ITN use to population-level ITN access is known as the use:access ratio. This ratio gives an estimate of the proportion of the population using nets, among those that have access to one within their household. Use:access values of 0.8 and above are considered good. At 36-months, the use:access ratio considering all ITNs was classified as good for all study sites, with values greater than 1.0 in Farafangana, Bekily and Fort Dauphin, indicating that ITNs were being used by more than 2 people on average. The result in Maintirano was lower (0.85). For all sites, use of non-cohort ITNs given access was equal to or higher than use of cohort ITNs given access. The use:access ratio does not consider the physical integrity of the ITNs. Maintirano and Farafangana, the two sites with the lowest use:access ratio for cohort ITNs, are the two sites with the highest proportion of damaged cohort ITNs (see Table 17, under Durability of Cohort ITNs).

TABLE 15: HOUSEHOLD AND POPULATION ITN ACCESS AND USE

	Baseline	36 months
Farafangana		
Household access	**N=210**	**N=143**
All ITNs	80.5%	38.5%
Campaign cohort ITNs (DawaPlus 2.0)	34.8%	11.9%
Other ITNs	15.7%	12.6%
Population access	**N=1,309**	**N=940**
All ITNs	93.6%	70.7%
Campaign cohort ITNs (DawaPlus 2.0)	70.4%	31.1%
Other ITNs	50.3%	46.6%
Population use	**N/A**	**N=940**
All ITNs	N/A	79.1%
Campaign cohort ITNs (DawaPlus 2.0)	N/A	28.0%
Other ITNs	N/A	51.4%
Use:access ratio	**N/A**	**N=940**
All ITNs	N/A	1.12
Campaign cohort ITNs (DawaPlus 2.0)	N/A	0.90
Other ITNs	N/A	1.10
Bekily		
Household access	**N=224**	**N=92**
All ITNs	57.1%	28.3%
Campaign cohort ITNs (DawaPlus 2.0)	42.0%	8.7%
Other ITNs	8.9%	7.6%
Population access	**N=1,092**	**N=528**
All ITNs	76.2%	51.5%
Campaign cohort ITNs (DawaPlus 2.0)	68.1%	24.6%
Other ITNs	17.9%	30.5%
Population use	**N/A**	**N=528**
All ITNs	N/A	58.0%
Campaign cohort ITNs (DawaPlus 2.0)	N/A	23.3%
Other ITNs	N/A	35.4%
Use:access ratio	**N/A**	**N=528**
All ITNs	N/A	1.13
Campaign cohort ITNs (DawaPlus 2.0)	N/A	0.95
Other ITNs	N/A	1.16
Maintirano		
Household access	**N=154**	**N=65**
All ITNs	85.7%	56.9%
Campaign cohort ITNs (DawaPlus 2.0)	66.9%	27.7%
Other ITNs	32.5%	21.5%
Population access	**N=666**	**N=283**
All ITNs	93.2%	74.9%
Campaign cohort ITNs (DawaPlus 2.0)	81.4%	46.6%

Other ITNs	46.7%	43.5%
Population use	**N/A**	**N=283**
All ITNs	N/A	63.6%
Campaign cohort ITNs (DawaPlus 2.0)	N/A	20.8%
Other ITNs	N/A	42.8%
Use:access ratio	**N/A**	**N=283**
All ITNs	N/A	0.85
Campaign cohort ITNs (DawaPlus 2.0)	N/A	0.45
Other ITNs	N/A	0.98
	12 months	**36 months**
Fort Dauphin*		
Household access	**N=209**	**N=113**
All ITNs	36.8%	19.5%
Campaign cohort ITNs (PermaNet 2.0)	33.5%	8.0%
Other ITNs	4.3%	4.4%
Population access	**N=962**	**N=586**
All ITNs	65.5%	39.9%
Campaign cohort ITNs (PermaNet 2.0)	61.6%	25.6%
Other ITNs	7.6%	15.7%
Population use	**N/A**	**N=586**
All ITNs	N/A	44.5%
Campaign cohort ITNs (PermaNet 2.0)	N/A	27.6%
Other ITNs	N/A	16.9%
Use:access ratio	**N/A**	**N=586**
All ITNs	N/A	1.12
Campaign cohort ITNs (PermaNet 2.0)	N/A	1.08
Other ITNs	N/A	1.08

* The first round of data collection in Fort Dauphin was the 12-month survey.

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 16 and Figure 7 presents results for the attrition of cohort nets at baseline, 12-, 24- and 36-month rounds. Of the 510 cohort nets in Farafangana, 418 nets in Bekily, and 353 nets in Maintirano enrolled at baseline, 423, 306, and 198 nets respectively were included in the attrition calculation at 36-months. In Fort Dauphin, 369 cohort nets were enrolled at 12-months (the first round of data collection in Fort Dauphin) and 326 of these nets were included in the 36-month attrition calculation. 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 survey round in case they reappear in the household. Campaign cohort nets that were given to family elsewhere before the baseline survey (12-month survey in Fort Dauphin) were not tagged and are considered as given away to others (two nets in Maintirano, one net in Fort Dauphin).

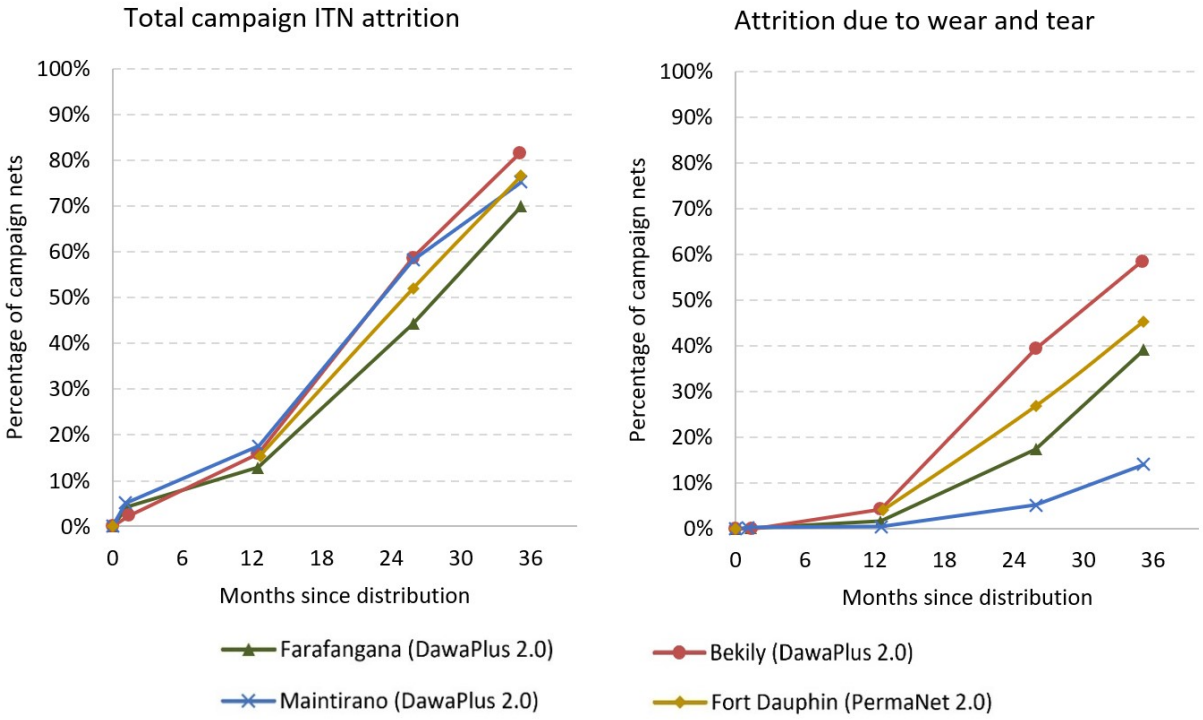
Total cohort ITN all-cause attrition increased from 4% at baseline to 70% at 36-months in Farafangana, from 2% to 82% in Bekily, and from 5% to 75% in Maintirano. In Fort Dauphin, all-cause attrition increased from 15% at 12-months to 77% at 36-months. At 36-months, differences in total attrition between study sites were significant (p=0.028) as were differences in attrition from nets given away to others (p<0.001) and from nets being discarded (also known as attrition due to wear and tear, p<0.001). Attrition due to wear and tear at 36-months was highest in Bekily (58.5%) and lowest in Maintirano (14.1%). In Farafangana, Bekily and Fort Dauphin, the most common reason for attrition was nets being discarded (39%, 59%, and 45%), while the most common reason in Maintirano was nets given away to others (40%). The second most common reason for attrition was given away to others in Farafangana and Fort Dauphin (19% and 23%) and lost for other/unknown reason in Bekily and Maintirano (14% and 21%).

TABLE 16: CAMPAIGN COHORT ITN ATTRITION

	Baseline	12 months	24 months	36 months
Farafangana	**N=510**	**N=402**	**N=411**	**N=423**
Total campaign ITN all-cause attrition	4.3%	12.9%	44.3%	70.0%
ITNs given away to others	4.1%	6.6%	15.1%	19.1%
ITNs discarded	0.2%	1.7%	17.5%	39.2%
ITNs lost for other/unknown reason	0.0%	9.2%	11.7%	11.6%
Bekily	**N=418**	**N=315**	**N=317**	**N=306**
Total campaign ITN all-cause attrition	2.4%	15.9%	58.7%	81.7%
ITNs given away to others	2.4%	4.6%	6.6%	9.5%
ITNs discarded	0.0%	4.3%	39.4%	58.5%
ITNs lost for other/unknown reason	0.0%	9.5%	12.6%	13.7%
Maintirano	**N=353**	**N=204**	**N=194**	**N=198**
Total campaign ITN all-cause attrition	5.1%	17.6%	58.2%	75.3%
ITNs given away to others	4.8%	16.7%	35.6%	40.4%
ITNs discarded	0.3%	0.5%	5.2%	14.1%
ITNs lost for other/unknown reason	0.0%	7.2%	17.5%	20.7%
Fort Dauphin	**N/A**	**N=369**	**N=353**	**N=326**
Total campaign ITN all-cause attrition	N/A	15.4%	52.1%	76.7%
ITNs given away to others	N/A	7.9%	17.3%	22.7%
ITNs discarded	N/A	4.1%	26.9%	45.4%
ITNs lost for other/unknown reason	N/A	3.5%	7.9%	8.6%

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 ≤ 0.01m^2)
Serviceable:	pHI ≤ 642 (total hole surface area ≤ 0.1 m^2)
Torn:	pHI > 642 (total hole surface area > 0.1m^2)

Table 17 presents the physical integrity results of nets that were in the household at each survey round (nets that were in the household but were temporarily unavailable due to being washed or were locked away were not included in the assessment). The proportion of cohort nets with any holes increased from 9% at baseline to 95% at 36-months in Farafangana, from 2% to 88% in Bekily, from 6% to 91% in Maintirano, and from 68% (at 12-months) to 88% in Fort Dauphin. At 36-months, the proportion of cohort nets with any holes was similar between study sites (91% across all sites). The proportion of remaining nets classified as "serviceable" based on their physical integrity differed significantly across sites and ranged from 47% to 88% (55% of nets in Farafangana, 88% in Bekily, 47% in Maintirano, and 74% in Fort Dauphin; p<0.001).

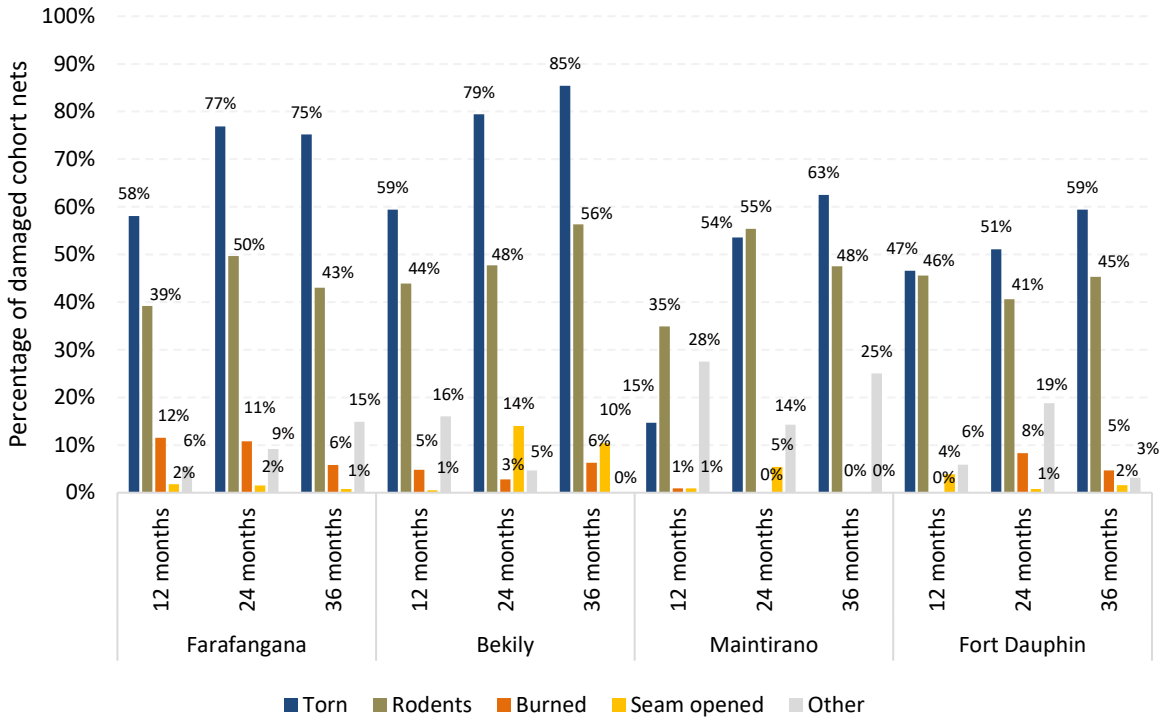
TABLE 17: PHYSICAL INTEGRITY OF OBSERVED CAMPAIGN COHORT ITNS

	Baseline	12 months	24 months	36 months
Farafangana	**N=488**	**N=347**	**N=223**	**N=127**
Cohort ITN with any holes	8.8%	61.4%	89.7%	94.5%
ITNs classified as "Good"	98.2%	56.2%	27.4%	18.9%
ITNs classified as "Too torn"	0.6%	16.4%	35.4%	44.9%
ITNs classified as "Serviceable"	99.4%	83.6%	64.6%	55.1%
Among ITNs with any holes:	N=43	N=213	N=200	N=120
Median pHI for ITNs with any holes	25.0	246.0	435.5	592.0
Bekily	**N=408**	**N=264**	**N=130**	**N=56**
Cohort ITN with any holes	1.5%	70.1%	83.1%	87.5%
ITNs classified as "Good"	99.0%	58.0%	63.8%	57.1%
ITNs classified as "Too torn"	0.0%	17.0%	10.8%	12.5%
ITNs classified as "Serviceable"	100.0%	83.0%	89.2%	87.5%
Among ITNs with any holes:	N=6	N=185	N=108	N=49
Median pHI for ITNs with any holes	73.0	149.0	52.5	64.0
Maintirano	**N=335**	**N=165**	**N=79**	**N=43**
Cohort ITN with any holes	6.3%	66.1%	82.3%	90.7%
ITNs classified as "Good"	99.1%	64.8%	39.2%	23.3%
ITNs classified as "Too torn"	0.0%	10.9%	25.3%	53.5%
ITNs classified as "Serviceable"	100.0%	89.1%	74.7%	46.5%
Among ITNs with any holes:	N=21	N=109	N=65	N=39
Median pHI for ITNs with any holes	3.0	80.0	320.0	937.0
Fort Dauphin	**N/A**	**N=312**	**N=167**	**N=73**
Cohort ITN with any holes	N/A	67.9%	87.4%	87.7%
ITNs classified as "Good"	N/A	59.9%	40.1%	32.9%
ITNs classified as "Too torn"	N/A	13.8%	32.9%	26.0%
ITNs classified as "Serviceable"	N/A	86.2%	67.1%	74.0%
Among ITNs with any holes:	N/A	N=212	N=146	N=64
Median pHI for ITNs with any holes	N/A	127.5	341.0	232.0

To understand the ways in which nets were damaged in real-life conditions, prior to the hole assessment respondents were asked what causes the holes in their nets. The responses are captured in Figure 8 (baseline figures are not presented because the low number of nets with any holes are not directly comparable to those during subsequent study rounds).

The two most commonly reported damage mechanisms across study sites and survey rounds were tears and damage reportedly caused by rodents. At 36-months, the proportion of nets reportedly damaged by tears and rodents was similar between districts and was reported for 71% and 47% of damaged cohort nets. Although relatively uncommon across sites, damage from seams opening was reported for a higher proportion of damaged nets in Bekily (10% in Bekily, 1% in Farafangana, 0% in Maintirano, and 2% in Fort Dauphin; p=0.005) Damage from other reasons was more common in Farafangana and Maintirano (15% in Farafangana, 25% in Maintirano, 0% in Bekily, and 3% in Fort Dauphin) and included damage reportedly caused by insects, pests, mold and general net material deterioration.

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



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

Table 18 reports the proportion of cohort ITNs surviving and in serviceable condition at each study round. At baseline and 12-months, net survival was similar across study sites. At 24-months, cohort net survival was approximately 20 percentage points higher in Maintirano (66%) compared to in the other study sites (49% in Farafangana, 46% in Bekily, and 43% in Fort Dauphin; p=0.002). At 36-months, cohort net survival was slightly higher in Maintirano (28%) compared to in Farafangana (24%), Bekily (21%) or Fort Dauphin (24%), however the difference between sites was not statistically significant (p=0.658). Survival of cohort nets ever-used and present was higher in Bekily (87%) and Fort Dauphin (74%) compared to in Farafangana (53%) and Maintirano (44%) at 36-months (p<0.001).

TABLE 18: CAMPAIGN COHORT ITNS SURVIVING IN SERVICEABLE CONDITION

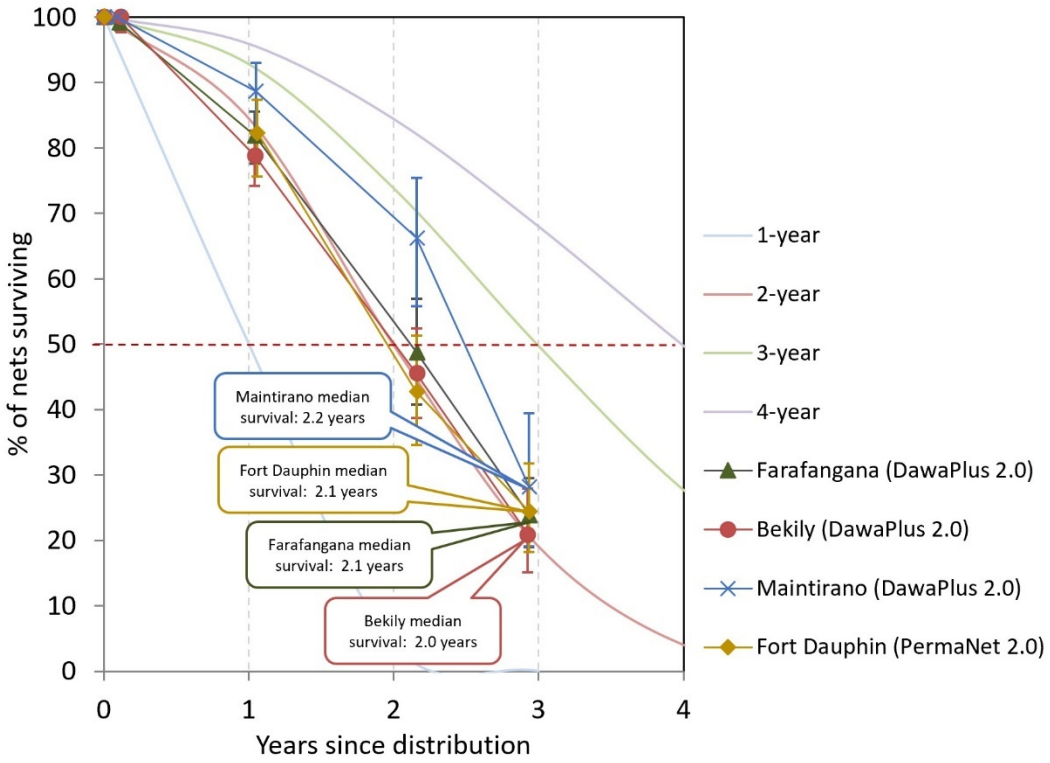
	Baseline	12 months	24 months	36 months
Farafangana				
All cohort nets*	N=489	N=354	N=295	N=293
Survival estimate	99.2%	81.9%	48.8%	23.9%
95% CI	98.0%-99.7%	77.6%-85.6%	40.8%-56.9%	19.0%-29.5%
Cohort nets ever-used and present	N=203	N=284	N=217	N=122
Survival estimate	99.0%	80.6%	63.6%	53.3%
95% CI	96.0%-99.8%	75.5%-84.9%	54.4%-71.9%	44.1%-62.2%
Bekily				

All cohort nets*	N=408	N=278	N=255	N=235
Survival estimate	100.0%	78.8%	45.5%	20.9%
95% CI	--	74.2%-82.7%	38.7%-52.4%	15.2%-27.9%
Cohort nets ever-used and present	N=198	N=219	N=120	N=54
Survival estimate	100.0%	80.8%	88.3%	87.0%
95% CI	--	74.5%-85.9%	77.1%-94.4%	70.7%-94.9%
Maintirano				
All cohort nets*	N=336	N=166	N=89	N=71
Survival estimate	99.7%	88.6%	66.3%	28.2%
95% CI	97.7%-100.0%	81.9%-93.0%	55.8%-75.4%	19.1%-39.5%
Cohort nets ever-used and present	N=135	N=136	N=76	N=41
Survival estimate	100.0%	86.8%	75.0%	43.9%
95% CI	--	78.6%-92.1%	62.3%-84.5%	29.3%-59.6%
Fort Dauphin				
All cohort nets*	N/A	N=327	N=262	N=221
Survival estimate	N/A	82.3%	42.7%	24.4%
95% CI	N/A	75.6%-87.4%	34.6%-51.3%	18.3%-31.8%
Cohort nets ever-used and present	N/A	N=281	N=158	N=72
Survival estimate	N/A	84.7%	66.5%	73.6%
95% CI	N/A	80.1%-88.4%	58.6%-73.5%	64.4%-81.1%

* 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 on the 36-month data, the estimated median useful life for DawaPlus 2.0 nets in Bekily is 2.0 years, in Farafangana 2.1 years, and in Maintirano 2.2 years, and for PermaNet 2.0 nets in Fort Dauphin is 2.1 years.

FIGURE 9: ESTIMATED ITN SURVIVAL



Error bars show 95% confidence intervals.

Table 19 presents the 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 DawaPlus 2.0 nets is 2.1 years in Farafangana, 2.0 years in Bekily, 2.5 years in Maintirano, and 2.1 years for PermaNet 2.0 nets in Fort Dauphin.

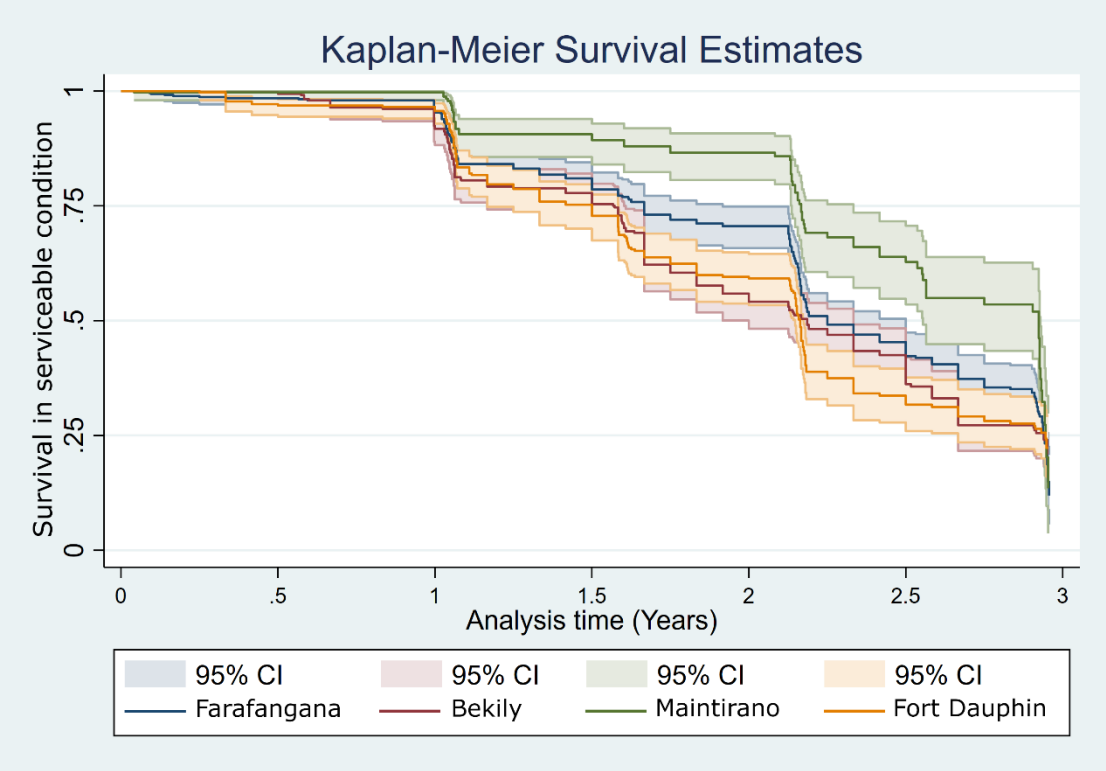
TABLE 19: ESTIMATED MEDIAN SURVIVAL OF ITNS IN YEARS USING DIFFERENT METHODS

	12 months	24 months	36 months
Farafangana (DawaPlus 2.0)	**N=354**	**N=295**	**N=293**
Estimated from Figure 9	1.9	2.1	2.1
Calculated from last two data points* (95% CI)	-	-	2.1 (1.9-2.2)
Bekily (DawaPlus 2.0)	**N=278**	**N=255**	**N=235**
Estimated from Figure 9	1.8	2.0	2.0
Calculated from last two data points* (95% CI)	-	-	2.0 (1.8-2.2)
Maintirano (DawaPlus 2.0)	**N=166**	**N=89**	**N=71**
Estimated from Figure 9	2.6	2.5	2.2
Calculated from last two data points (95% CI)	-	-	2.5 (2.3-2.7)
Fort Dauphin (PermaNet 2.0)	**N=327**	**N=262**	**N=221**
Estimated from Figure 9	2.0	2.0	2.1
Calculated from last two data points* (95% CI)	-	-	2.1 (1.9-2.3)

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

When data were analyzed as survival analysis in a Kaplan-Meier plot (Figure 10), DawaPlus 2.0 ITNs in Maintirano showed higher survival compared to DawaPlus 2.0 nets in Farafangana and Bekily, and PermaNet 2.0 nets in Fort Dauphin (p<0.001).

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



3.5 INSECTICIDAL EFFECTIVENESS AND CONTENT OF CAMPAIGN NETS

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

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

Chemical content analysis was conducted by CDC on 10 samples selected at random from the 30 bioassay ITNs withdrawn for each brand at each round. Chemical content results are presented as summary statistics for active ingredients in mg/m² units.

Bioassay results for DawaPlus 2.0 and PermaNet 2.0 nets tested on arrival in Madagascar are shown in Table 20 and Figure 11. Results for nets sampled at baseline,12-months, 24-months, 36-months are shown in Table 21 and Figure 12. ITN samples were tested against a fully susceptible lab strain of *An. arabiensis*.

On arrival in Madagascar, 100% of sampled DawaPlus 2.0 nets were optimally effective and 87% of sampled PermaNet 2.0 nets were optimally effective (Table 20). Only three DawaPlus 2.0 samples and two PermaNet

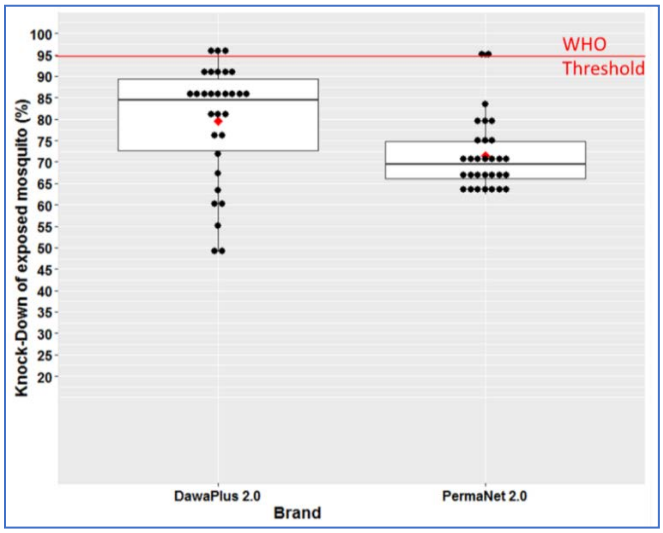
2.0 samples passed the WHO threshold of 95% for 60-minute knock down, but all 30 DawaPlus 2.0 and 26/30 PermaNet 2.0 samples surpassed the WHO threshold of 80% for 24-hour mortality (Figure 11).

TABLE 20: CONE BIOASSAY RESULTS FROM NETS ON ARRIVAL

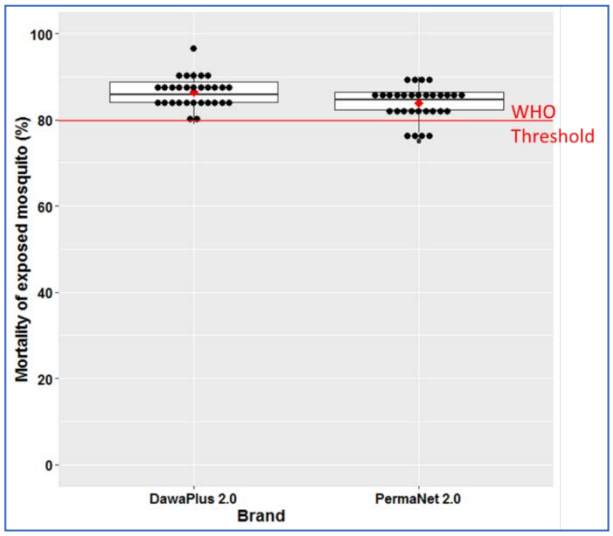
	DawaPlus 2.0	PermaNet 2.0
	N=30	N=30
Knock down 60 minutes		
Mean (95% CI)	79.5% (74.3%-84.6%)	71.5% (68.3%-74.7%)
Median [IQR]	84.4% [72.7%-89.3%]	69.6% [66.2%-74.8%]
Mortality 24 hours		
Mean (95% CI)	86.5% (85.1%-87.8%)	83.9% (82.4%-85.3%)
Median [IQR]	86.0% [84.1%-88.9%]	84.6% [82.4%-86.5%]
Optimal effectiveness		
Estimate (95% CI)	100% (--)	86.7% (68.4%-95.6%)
Minimal effectiveness		
Estimate (95% CI)	100% (--)	100% (--)

FIGURE 11: BOX PLOT OF ITN CONE BIOASSAY RESULTS FROM NETS ON ARRIVAL

Knock down 60 minutes



Mortality 24 hours



DawaPlus 2.0 nets sampled from the three sites during the baseline round also showed full optimal effectiveness (Table 21, Figure 12). However, insecticidal effectiveness declined sharply from baseline to 12-months and continued to decline to 24-months (with the percentage of nets achieving optimal effectiveness reaching 0% in Farafangana, 7% in Bekily, 3% in Maintirano and 3% in Fort-Dauphin at 24-months). The same trend was seen for minimal effectiveness of nets between 12-months and 24-months (50% to 11% in Farafangana, 50% to 23% in Bekily, from 63% to 20% in Maintirano and from 47% to 30% in Fort-Dauphin). Surprisingly, mean knock down and mortality results both increased for samples tested at 36-months contrary to the previous trend. Mean mortalities at 36-months were below the WHO threshold, at 44.5%, 37.3%, 35.5% and 47.7% for Bekily, Farafangana, Maintirano and Fort Dauphin respectively. The improvement recorded between 24- and 36-months resulted in an increase in the percentage of sampled nets meeting the optimal and minimal effectiveness criteria between the 24- and 36-month round in the four sites. For the PermaNet 2.0, for example,

the values rose from 3.3% to 43.3% for optimal effectiveness and from 30% to 86.7% for minimal effectiveness, increases of 40 and 50 points respectively.

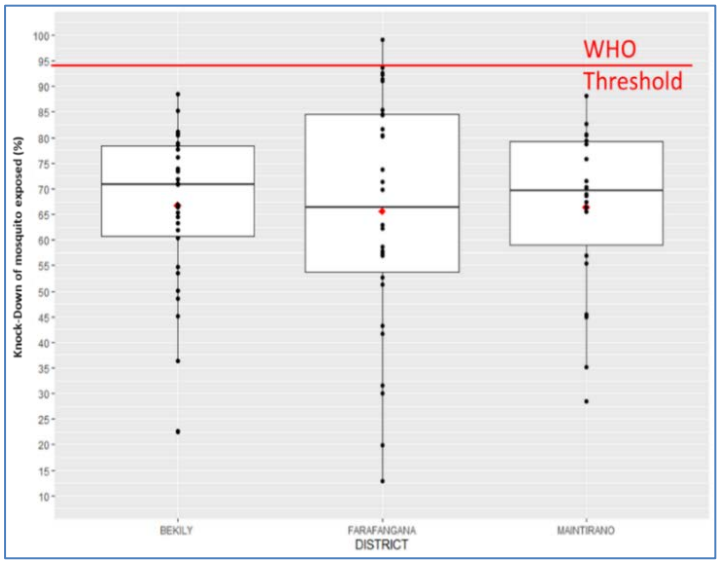
TABLE 21: CONE BIOASSAY RESULTS AT BASELINE, 12- , 24-, AND 36-MONTHS

	Baseline	12 months	24 months	36 moths
Farafangana	**N=30**	**N=30**	**N=30**	**N= 30**
Knock down 60 minutes				
Mean (95% CI)	65.6% (57.0%-74.3%)	62.6% (54.2%-71.1%)	31.2% (22.1%-40.3%)	82.5% (76.9%-88.0%)
Median [IQR]	66.4% [53.7%-84.5%]	66.3% [50.7%-79.8%]	24.2% [9.3%-50.5%]	84.8% [78.5%-93.4%]
Mortality 24 hours				
Mean (95% CI)	84.5% (83.5%-85.4%)	43.3% (36.5%-50.2%)	24.0% (17.2%-30.6%)	37.3% (30.1%-44.6%)
Median [IQR]	83.8% [82.2%-87.0%]	47.6% [28.0%-55.3%]	15.8% [11.6%-38.1%]	33.4% [22.0%-50.2%]
Optimal effectiveness				
Estimate (95% CI)	100% (--)	6.7% (1.2%-23.5%)	0.0% (--)	23.3% (10.6%-42.7%)
Minimal effectiveness				
Estimate (95% CI)	100% (--)	50.0% (33.2%-66.8%)	11.0% (2.6%-27.7%)	83.3% (65.0%-93.7%)
Bekily	**N=22**	**N=30**	**N=30**	**N=30**
Knock down 60 minutes				
Mean (95% CI)	66.7% (61.1%-72.5%)	58.3% (48.5%-68.1%)	45.8% (34.7%-56.9%)	88.9% (83.8%-93.9%)
Median [IQR]	71.0% [60.8%-78.4%]	57.6% [35.6%-86.6%]	48.0% [22.0%-67.9%]	95.0% [87.0%-97.3%]
Mortality 24 hours				
Mean (95% CI)	84.0% (82.9%-85.1%)	45.9% (36.4%-55.3%)	29.0% (21.2%-36.7%)	44.5% (36.2%-52.8%)
Median [IQR]	83.7% [82.4%-85.1%]	39.8% [23.4%-58.1%]	21.1% [13.5%-42.1%]	46.3% [23.3%-55.0%]
Optimal effectiveness				
Estimate (95% CI)	100% (--)	16.7% (6.3%-35.5%)	6.7% (1.2%-23.5%)	50.0% (33.2%-67.0%)
Minimal effectiveness				
Estimate (95% CI)	100% (--)	50.0% (33.2%-66.6%)	23.3% (10.6%-42.7%)	83.3% (64.5%-94.0%)
Maintirano	**N=22**	**N=30**	**N=30**	**N=30**
Knock down 60 minutes				
Mean (95% CI)	66.4% (59.3%-73.5%)	65.1% (55.0%-75.1%)	36.8% (25.7%-47.8%)	86.1% (81.9%-90.2%)
Median [IQR]	69.6% [59.1%-79.3%]	68.6% [49.5%-88.5%]	29.0% [7.4%-64.6%]	89.7% [80.5%-93.1%]
Mortality 24 hours				
Mean (95% CI)	85.0% (83.9%-86.0%)	50.8% (42.7%-59.0%)	21.2% (13.7%-28.6%)	35.5% (28.4%-42.6%)
Median [IQR]	84.8% [83.8%-86.8%]	52.6% [40.5%-67.0%]	13.4% [8.2%-30.7%]	33.5% [20.1%-47.8%]
Optimal effectiveness				
Estimate (95% CI)	100% (--)	13.3% (4.4%-31.6%)	3.3% (0.2%-19.1%)	16.7% (6.3%-35.5%)
Minimal effectiveness				
Estimate (95% CI)	100% (--)	63.3% (44.0%-79.5%)	20.0% (8.4%-39.1%)	86.7% (68.4%-95.6%)
Fort Dauphin	**N/A**	**N=30**	**N=30**	**N=30**
Knock down 60 minutes				
Mean (95% CI)	N/A	53.7% (44.0%-63.4%)	49.9% (39.0%-60.7%)	88.0% (83.2%-92.8%)
Median [IQR]	N/A	55.8% [35.9%-68.7%]	56.4% [23.6%-74.6%]	91.0% [85.4%-96.5%]
Mortality 24 hours				
Mean (95% CI)	N/A	44.5% (35.1%-53.9%)	25.8% (18.4%-33.1%)	47.7% (40.0%-55.4%)

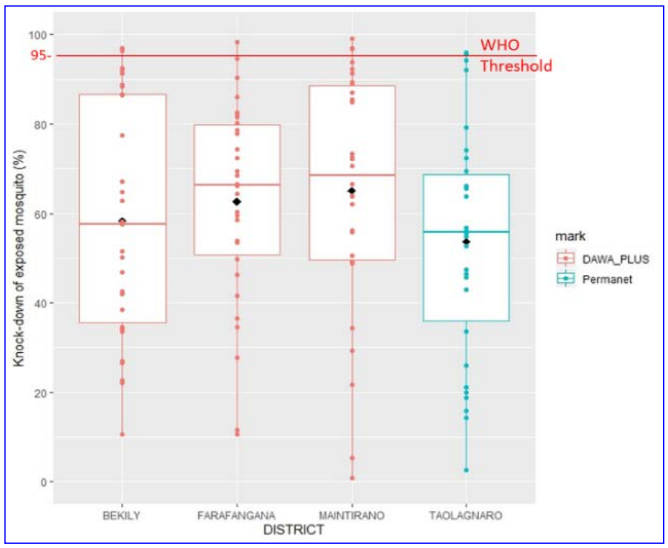
Median [IQR]	N/A	41.1% [25.6%-67.3%]	20.7% [9.7%-39.5%]	49.2% [29.6%-60.9%]
Optimal effectiveness				
Estimate (95% CI)	N/A	10% (2.6%-27.7%)	3.3% (0.2%-19.1%)	43.3% (26.0%-62.3%)
Minimal effectiveness				
Estimate (95% CI)	N/A	46.7% (28.8%-65.4%)	30.0% (2.6%-27.7%)	86.7% (64.4%-95.6%)

FIGURE 12: BOX PLOT OF ITN CONE BIOASSAY RESULTS AT BASELINE, 12-, 24-, AND 36-MONTHS

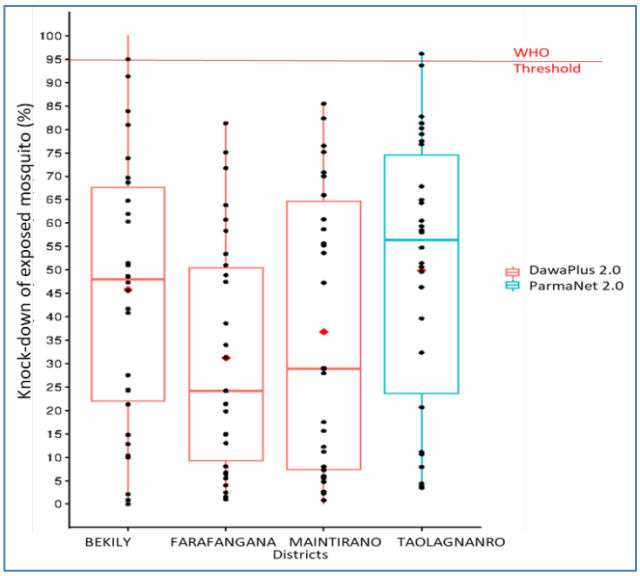
Knock down 60 minutes - baseline



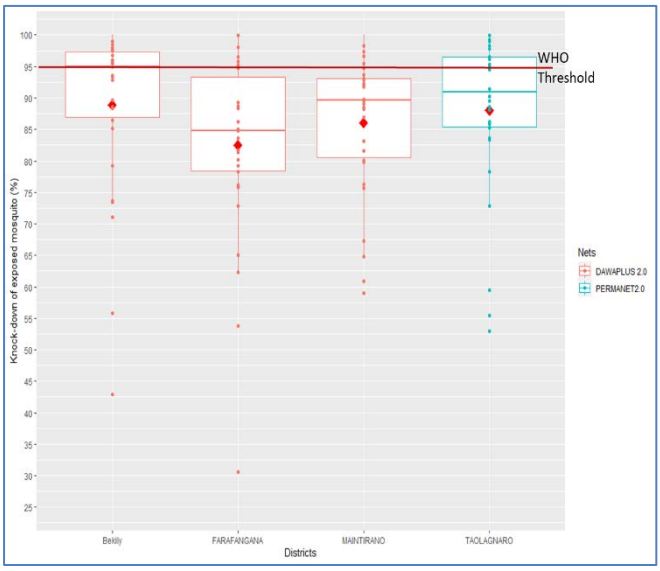
Knock down 60 minutes - 12-months



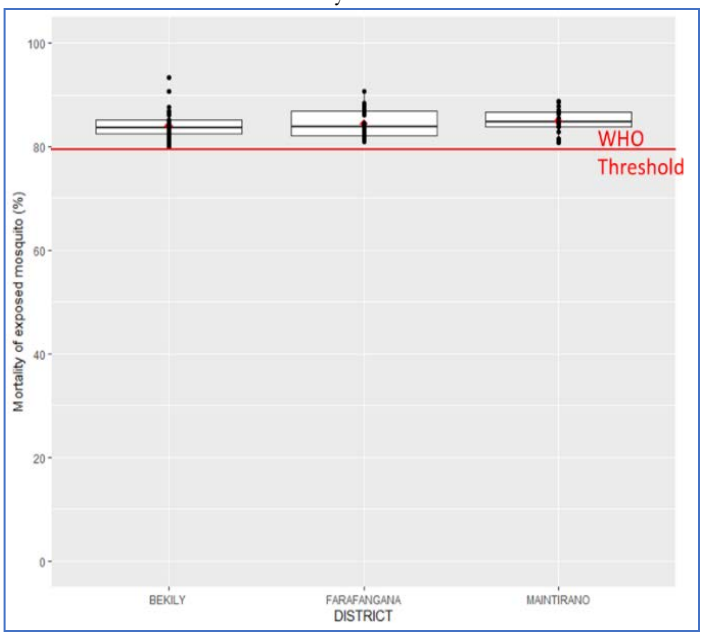
Knock down 60 minutes - 24-months



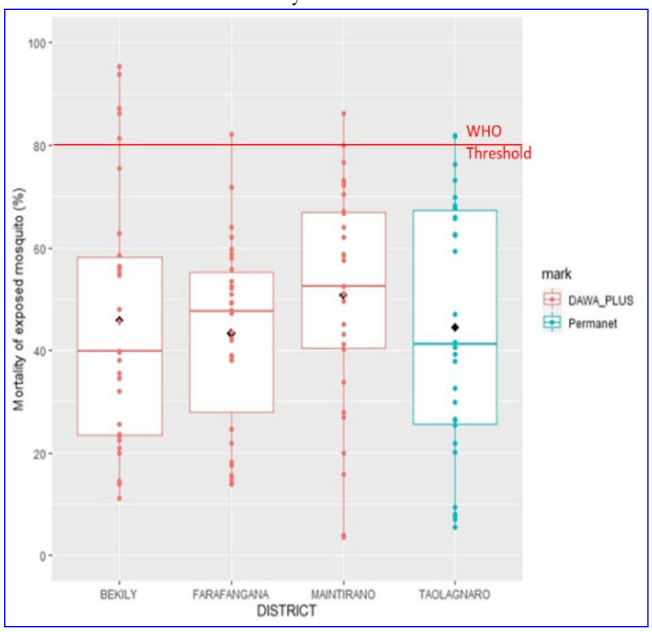
Knock down 60 minutes - 36-months



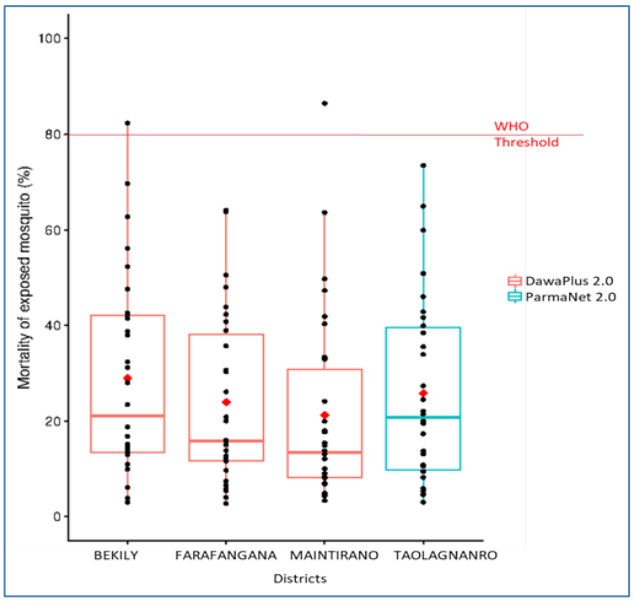
Mortality - baseline



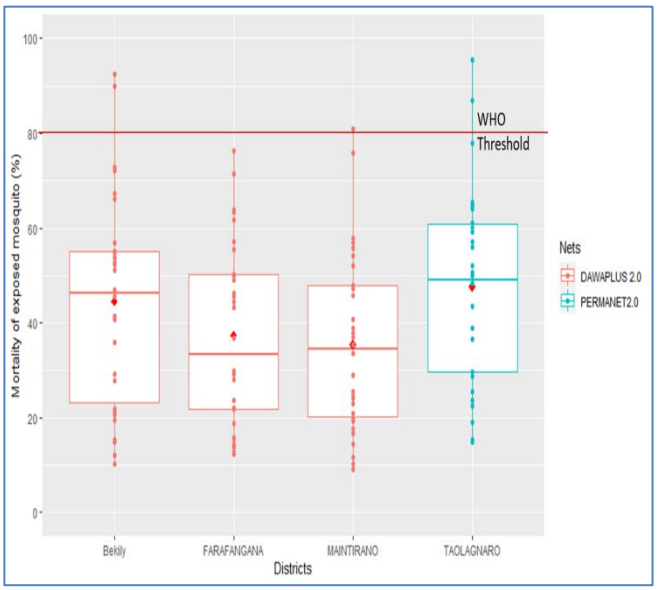
Mortality - 12-months



Mortality - 24-months



Mortality - 36-months



Results from WHO cone bioassays: box plots show data points (multiple black or red dots), the median (straight line across box), the mean (single red or black dot), interquartile range (box), adjacent values (whiskers) and outliers, lines represent WHO optimal effectiveness thresholds for knock-down (kd60, 95%) and mortality (mortality, 80%).

Among the 120 ITNs withdrawn for bioassays at 36-months, 39 nets were identified as cohort nets by household respondents but the nets themselves had lost their unique ID and/or label between fieldwork at 24- and 36-months. Mean 24-hour mortality results were calculated for the restricted subset of 81 labelled ITNs and compared against the results for the full sample using the t-test for results from each site (Table 21A). Differences in mean mortality were not statistically significant at the conventional 5% level.

TABLE 21A: CONE BIOASSAY MORTALITY RESULTS FOR SAMPLES AT 36-MONTHS BY COHORT LABEL STATUS

	Nets with label		All nets		
Districts	**No**	**Mean Mortality**	**No**	**Mean Mortality**	**p-value (t-test)**
Bekily	22	48.0	30	46.5	0.6234
Farafangana	27	36.9	30	37.3	0.9236
Maintirano	13	38.3	30	35.5	0.6152
Fort Dauphin	19	55.7	30	47.7	0.1566

Chemical content results from CDC for DawaPlus 2.0 nets on arrival are presented in Table 22. DawaPlus 2.0 (distributed in Farafangana, Bekily and Maintirano) is manufactured with 80 mg/m² of deltamethrin, while PermaNet 2.0 (Fort Dauphin) is manufactured with 55 mg/m² of deltamethrin. DawaPlus 2.0 nets tested on arrival had a mean 65.9 mg/m² of deltamethrin, corresponding to an 18% loss compared to the manufacturer target dose.

TABLE 22: CHEMICAL CONTENT RESULTS FROM NETS ON ARRIVAL

	On arrival
DawaPlus 2.0 (deltamethrin, 80mg/m²)	**N=30**
Mean	65.91
Median	63.93
Minimum	57.12
Maximum	77.51

Results for each district surveyed at baseline, 12-months, 24-months, and 36-months are presented in Table 23 and Figure 13 (in Figure 13, results for nets on arrival are *0 Month New Nets* and results for the baseline survey appear under the study site name). Chemical content testing occurred on subsamples of 10 randomly selected ITNs from the pool of 30 ITNs withdrawn at each site for each round. At 36-months, out of the 40 nets sent to CDC, 15 nets were presented without labels, thus data analysis was conducted on the 25 nets with labels as well as all 40 nets with or without labels.

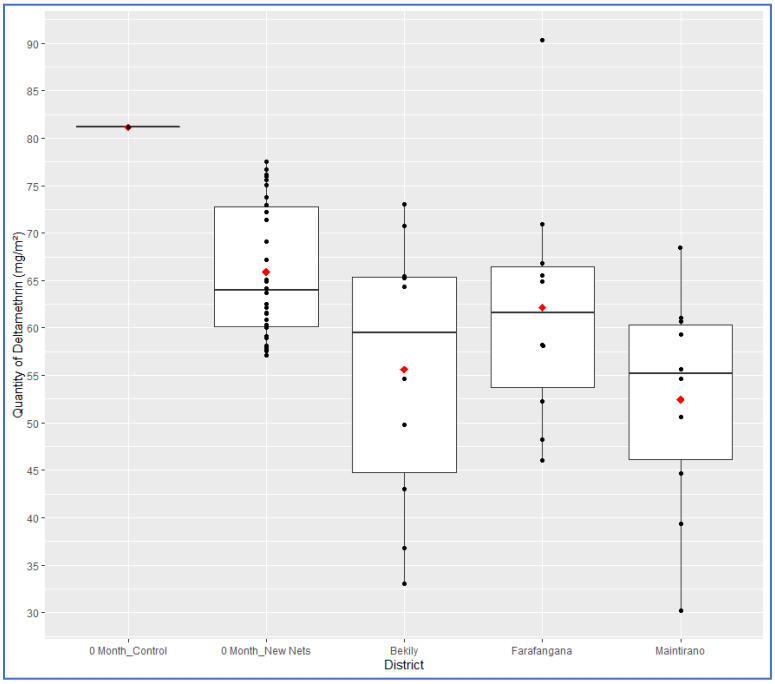
After 24 months of field use, the mean deltamethrin content of DawaPlus 2.0 net samples was 10.6 mg/m² for Farafangana, 5.9 mg/m² for Bekily and 13.4 mg/m² for Maintirano; the mean content of PermaNet 2.0 samples from Fort Dauphin was 17.5 mg/m² (Table 23). These values corresponded to a loss of chemical content of 68% (Fort Dauphin), 83% (Maintirano), 87% (Farafangana) and 93% (Bekily) compared to the manufacturer target doses of deltamethrin. This represented only a small increase (2 percentage points) in content loss between 12- and 24-months for DawaPlus 2.0 samples from Maintirano, but a substantially larger loss in the other sites (between 15 and 29 percentage points). At 36 months, the mean deltamethrin content of DawaPlus 2.0 distributed in Farafangana was 22.9 mg/m², 17 mg/m² in Bekily, and 31 mg/m² in Maintirano and the mean concentration of deltamethrin in PermaNet 2.0 distributed in Fort Dauphin was 12 mg/m². The 36 months results corresponded to a loss of chemical content of 43% (Maintirano), 58% (Farafangana), 69% (Bekily), and 86% (Fort Dauphin) compared to the manufacturer target doses. Analysis restricted to the 25 labeled samples produced mean values similar to the main analysis for Farafangana and Bekily, but larger differences in Maintirano (59.9 mg/m² in restricted analysis compared to 31.3 mg/m² with the full data) and Fort Dauphin (22.2 mg/m² in restricted analysis compared to 11.6 mg/m² with the full data). Further interpretation is made difficult by the small sample sizes involved.

TABLE 23: CHEMICAL CONTENT RESULTS AT BASELINE, 12-MONTHS, 24-MONTHS, AND 36-MONTHS

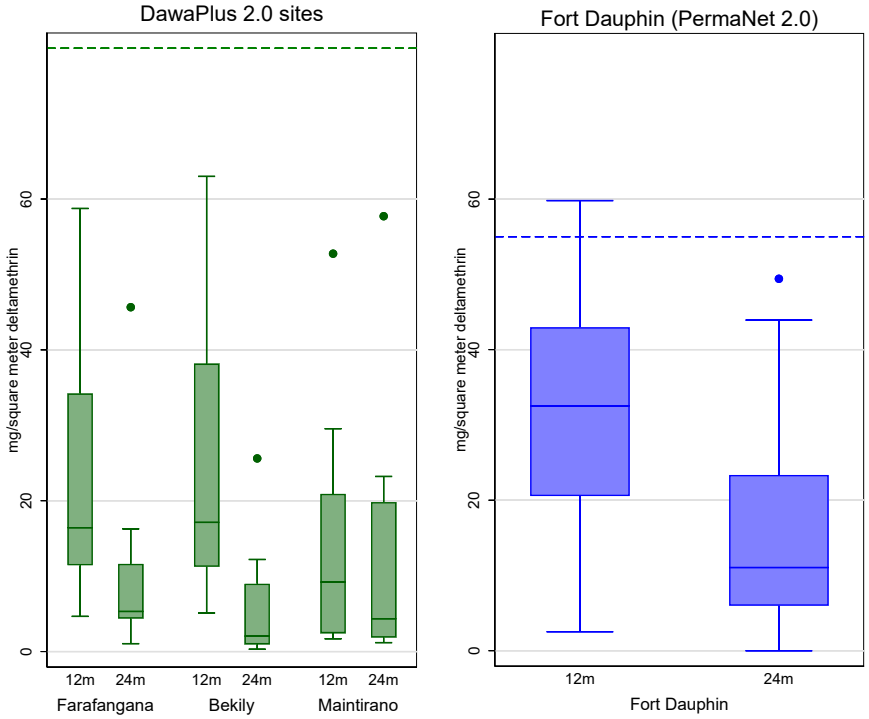
	Baseline	12 months	24 months	36 months
Farafangana (DawaPlus 2.0 deltamethrin, 80mg/m²)	**N=10**	**N=10**	**N=10**	**N=10**
Mean	62.14	22.17	10.56	22.9
Mean of labeled net samples (36-month)	N/A	N/A	N/A	22.0 (n=8)
Median [IQR]	61.57	16.4 [11.4-34.2]	5.3 [4.4-10.8]	22.2 [13.7-28.4]
Median [IQR] of labeled net samples	N/A	N/A	N/A	22.0 [14.3-28.2]
Minimum	46.04	4.70	1.05	8.1
Maximum	90.36	58.70	45.66	40.3
Bekily (DawaPlus 2.0 deltamethrin, 80mg/m²)	**N=10**	**N=10**	**N=10**	**N=10**
Mean	55.62	26.42	5.92	17.3
Mean of labeled net samples (36-month)	N/A	N/A	N/A	19.2 (n=7)
Median [IQR]	59.51	17.1 [11.3-38.2]	2.1 [1.1-7.9]	16.1 [13.2-19.0]
Median [IQR] of labeled net samples	N/A	N/A	N/A	15.2 [13.6-21.4]
Minimum	33.07	5.10	0.31	1.0
Maximum	73.04	63.00	25.61	45.4
Maintirano (DawaPlus 2.0 deltamethrin, 80mg/m²)	**N=10**	**N=10**	**N=10**	**N=10**
Mean	52.47	15.02	13.35	31.3
Mean of labeled net samples (36-month)	N/A	N/A	N/A	59.9 (n=5)
Median [IQR]	55.17	9.2 [2.4-20.9]	4.4 [2.4-18.7]	6.4 [1.4-12.3]
Median [IQR] of labeled net samples	N/A	N/A	N/A	12.5 [11.6-133.8]
Minimum	30.20	1.70	1.19	0
Maximum	68.50	52.80	57.72	138.3
Fort Dauphin (PermaNet 2.0 deltamethrin, 55mg/m²)	**N/A**	**N=10**	**N=10**	**N=10**
Mean	N/A	33.47	17.5	11.6
Mean of labeled net samples (36-month)	N/A	N/A	N/A	22.2 (n=5)
Median [IQR]	N/A	32.5 [20.5-43.0]	11.1 [6.5-22.5]	2.5 [0.9-22.3]
Median [IQR] of labeled net samples	N/A	N/A	N/A	25.7 [11.8-28.6]
Minimum	N/A	2.50	0	0.4
Maximum	N/A	59.80	49.42	41.8

FIGURE 13: BOX PLOT OF ITN CHEMICAL CONTENT RESULTS FROM NETS ON ARRIVAL, AT BASELINE, 12-, 24-, AND 36-MONTHS

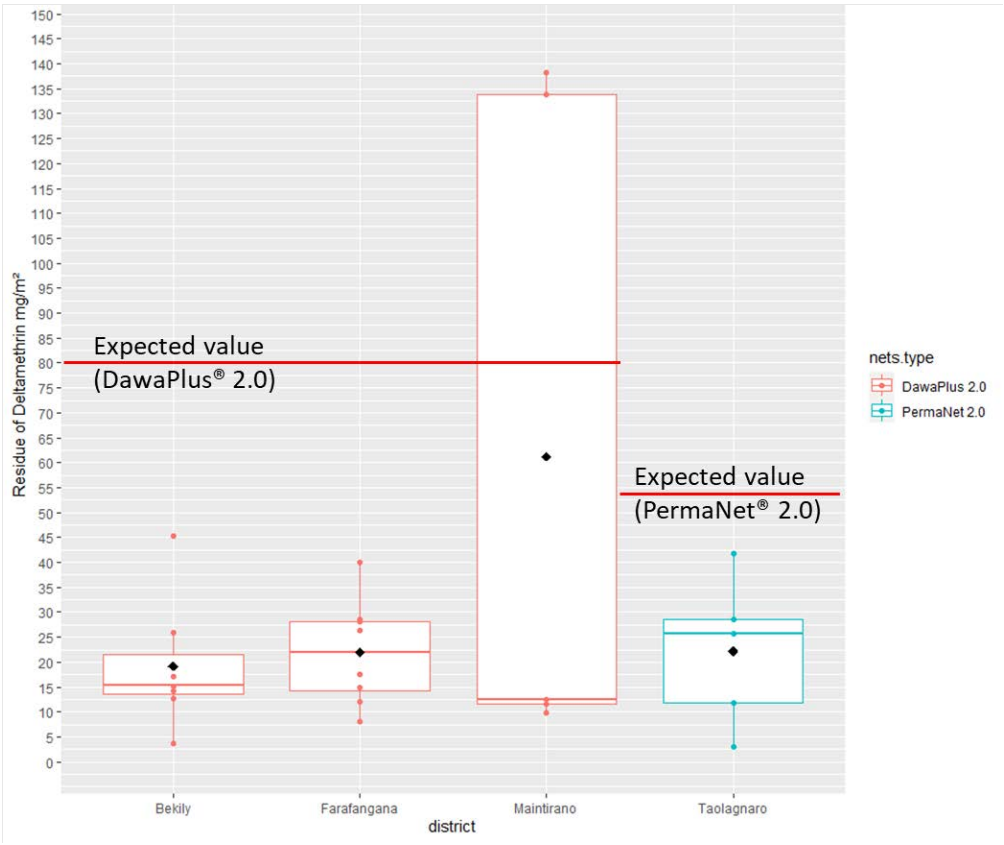
A: On arrival and baseline



B: At 12 and 24 months



C: At 36 months (among labeled samples)



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

Tables 24-26 present details of reported handling and use for the ITNs undergoing bioassay and chemical analysis for each survey period. Overall, nets collected for bioassay were very similar to cohort nets. At 36-months, net location (hanging, not hanging, stored) sleeping place (bed, mattress, mat/ground), net users (children only, adults only, children/adults sharing), net use, and washing practices (washing frequency, use of detergent/bleach) were similar for bioassay nets and cohort nets not sampled for bioassay analysis. Differences in bioassay nets between districts were similar to differences observed in cohort nets between districts.

TABLE 24: HANDLING OF BIOASSAY TEST ITNS

	12 months	24 months	36 months
Farafangana			
Location found	N=30	N=30	N=29
Hanging and folded or tied	3.3%	26.7%	79.3%
Hanging loose	80.0%	56.7%	17.2%
Not hanging	6.7%	13.3%	3.4%
Stored unpacked	10.0%	3.3%	0.0%
Stored in package	0.0%	0.0%	0.0%
Type of sleeping space (if used)	N=30	N=30	N=29
Bed	40.0%	33.3%	13.8%
Mattress	0.0%	0.0%	3.4%

Mat/Ground	60.0%	66.7%	82.8%
Net users	N=26	N=29	N=27
Child(ren) only	38.5%	13.8%	7.4%
Child(ren) and adult(s)	38.5%	65.5%	59.3%
Adult(s) only	23.1%	20.7%	33.3%
Bekily			
Location found	N=29	N=30	N=32
Hanging and folded or tied	6.9%	10.0%	25.0%
Hanging loose	55.2%	73.3%	68.8%
Not hanging	34.5%	13.3%	0.0%
Stored unpacked	3.4%	3.3%	6.3%
Stored in package	0.0%	0.0%	0.0%
Type of sleeping space (if used)	N=29	N=30	N=32
Bed	37.9%	33.3%	15.6%
Mattress	6.9%	6.7%	15.6%
Mat/Ground	55.2%	60.0%	68.8%
Net users	N=28	N=30	N=32
Child(ren) only	21.4%	16.7%	12.5%
Child(ren) and adult(s)	57.1%	60.0%	37.5%
Adult(s) only	21.4%	23.3%	50.0%
Maintirano			
Location found	N=30	N=30	N=30
Hanging and folded or tied	10.0%	50.0%	46.7%
Hanging loose	86.7%	23.3%	23.3%
Not hanging	3.3%	6.7%	3.3%
Stored unpacked	0.0%	16.7%	26.7%
Stored in package	0.0%	3.3%	0.0%
Type of sleeping space (if used)	N=30	N=30	N=29
Bed	36.7%	56.7%	55.2%
Mattress	26.7%	20.0%	20.7%
Mat/Ground	36.7%	23.3%	24.1%
Net users	N=29	N=29	N=21
Child(ren) only	37.9%	10.3%	9.5%
Child(ren) and adult(s)	37.9%	62.1%	42.9%
Adult(s) only	24.1%	27.6%	47.6%
Fort Dauphin			
Location found	N=29	N=30	N=28
Hanging and folded or tied	3.4%	33.3%	50.0%
Hanging loose	75.9%	36.7%	21.4%
Not hanging	17.2%	13.3%	10.7%
Stored unpacked	0.0%	16.7%	17.9%
Stored in package	3.4%	0.0%	0.0%
Type of sleeping space (if used)	N=26	N=27	N=28
Bed	50.0%	66.7%	46.4%

Mattress	11.5%	14.8%	14.3%
Mat/Ground	38.5%	18.5%	39.3%
Net users	N=26	N=26	N=24
Child(ren) only	11.5%	11.5%	0.0%
Child(ren) and adult(s)	50.0%	65.4%	66.7%
Adult(s) only	38.5%	23.1%	33.3%

TABLE 25: REPORTED USE OF BIOASSAY TEST ITNS

	12 months	24 months	36 months
Farafangana	N=30	N=28	N=29
Used last night	80.0%	92.9%	93.1%
Used last week	N=30	N=30	N=29
Every night	76.7%	93.3%	93.1%
Most nights (5-6 nights)	16.7%	0.0%	0.0%
Some nights (1-4 nights)	0.0%	3.3%	3.4%
Not used last week	6.7%	3.3%	3.4%
Never used	0.0%	0.0%	0.0%
Don't know	0.0%	0.0%	0.0%
Seasonal use	N=30	N=29	N=29
Equally in rainy and dry seasons	100.0%	96.6%	100.0%
Mainly rainy season	0.0%	3.4%	0.0%
Rainy season only	0.0%	0.0%	0.0%
Not used	0.0%	0.0%	0.0%
Bekily	N=29	N=30	N=32
Used last night	89.7%	100.0%	100.0%
Used last week	N=29	N=30	N=32
Every night	96.6%	90.0%	87.5%
Most nights (5-6 nights)	0.0%	10.0%	9.4%
Some nights (1-4 nights)	0.0%	0.0%	3.1%
Not used last week	0.0%	0.0%	0.0%
Never used	3.4%	0.0%	0.0%
Don't know	0.0%	0.0%	0.0%
Seasonal use	N=29	N=30	N=32
Equally in rainy and dry seasons	93.1%	90.0%	96.9%
Mainly rainy season	3.4%	10.0%	3.1%
Rainy season only	3.4%	0.0%	0.0%
Not used	0.0%	0.0%	0.0%
Maintirano	N=29	N=30	N=30
Used last night	93.1%	90.0%	70.0%
Used last week	N=30	N=30	N=30
Every night	90.0%	83.3%	70.0%
Most nights (5-6 nights)	10.0%	3.3%	0.0%
Some nights (1-4 nights)	0.0%	6.7%	6.7%
Not used last week	0.0%	6.7%	20.0%

Never used	0.0%	0.0%	3.3%
Don't know	0.0%	0.0%	0.0%
Seasonal use	N=30	N=30	N=30
Equally in rainy and dry seasons	96.7%	86.7%	100.0%
Mainly rainy season	0.0%	10.0%	0.0%
Rainy season only	3.3%	3.3%	0.0%
Not used	0.0%	0.0%	0.0%
Fort Dauphin	N=28	N=29	N=28
Used last night	89.3%	89.7%	85.7%
Used last week	N=28	N=29	N=28
Every night	78.6%	86.2%	82.1%
Most nights (5-6 nights)	7.1%	6.9%	7.1%
Some nights (1-4 nights)	0.0%	3.4%	0.0%
Not used last week	10.7%	3.4%	10.7%
Never used	0.0%	0.0%	0.0%
Don't know	3.6%	0.0%	0.0%
Seasonal use	N=29	N=30	N=28
Equally in rainy and dry seasons	93.1%	93.3%	92.9%
Mainly rainy season	3.4%	6.7%	7.1%
Rainy season only	0.0%	0.0%	0.0%
Not used	3.4%	0.0%	0.0%

TABLE 26: REPORTED WASHING OF BIOASSAY TEST ITNS

	12 months	24 months	36 months
Farafangana	N=30	N=30	N=29
Ever washed	86.7%	96.7%	93.1%
Washes in the last six months among all nets (if known)	N = 28	N = 30	N = 29
Mean	2.14	3.37	3.10
Median	2.0	3.0	2.0
Washes in the last six months among washed nets	N = 24	N = 29	N = 27
Mean	2.50	3.48	3.33
Median	2.0	3.0	2.0
Soap used for last wash	N=26	N=29	N=29
Soap bar	84.6%	82.8%	69.0%
Detergent or bleach	15.4%	6.9%	24.1%
Mix	0.0%	10.3%	0.0%
None	0.0%	0.0%	0.0%
Don't know	0.0%	0.0%	6.9%
Where dried after last wash	N=26	N=29	N=27
Shade	76.9%	62.1%	81.5%
Sun	23.1%	37.9%	18.5%
Don't know	0.0%	0.0%	0.0%

Bekily	N=29	N=30	N=32
Ever washed	96.6%	96.7%	100.0%
Washes in the last six months among all nets (if known)	N = 28	N = 28	N = 32
Mean	3.61	2.75	4.00
Median	3.0	2.5	3.0
Washes in the last six months among washed nets	N = 27	N = 27	N = 32
Mean	3.74	2.85	4.00
Median	3.0	3.0	3.0
Soap used for last wash	N=28	N=29	N=32
Soap bar	14.3%	34.5%	37.5%
Detergent or bleach	78.6%	65.5%	59.4%
Mix	0.0%	0.0%	3.1%
None	7.1%	0.0%	0.0%
Don't know	0.0%	0.0%	0.0%
Where dried after last wash	N=27	N=27	N=32
Shade	85.2%	85.2%	81.3%
Sun	14.8%	14.8%	18.8%
Don't know	0.0%	0.0%	0.0%
Maintirano	N=30	N=30	N=30
Ever washed	100.0%	96.7%	100.0%
Washes in the last six months among all nets (if known)	N = 21	N = 29	N = 30
Mean	5.24	11.45	5.77
Median	4.0	12.0	4.0
Washes in the last six months among washed nets	N = 21	N = 28	N = 30
Mean	5.24	11.86	5.77
Median	4.0	12.0	4.0
Soap used for last wash	N=30	N=29	N=30
Soap bar	60.0%	58.6%	50.0%
Detergent or bleach	33.3%	41.4%	46.7%
Mix	6.7%	0.0%	3.3%
None	0.0%	0.0%	0.0%
Don't know	0.0%	0.0%	0.0%
Where dried after last wash	N=29	N=29	N=30
Shade	55.2%	41.4%	50.0%
Sun	44.8%	58.6%	50.0%
Don't know	0.0%	0.0%	0.0%
Fort Dauphin	N=29	N=30	N=28
Ever washed	93.1%	100.0%	100.0%
Washes in the last six months among all nets (if known)	N = 28	N = 30	N = 28
Mean	4.29	4.27	7.07
Median	3.0	3.0	5.5
Washes in the last six months among washed nets	N = 26	N = 30	N = 28
Mean	4.62	4.27	7.07

Median	3.0	3.0	5.5
Soap used for last wash	N=27	N=30	N=28
Soap bar	44.4%	46.7%	60.7%
Detergent or bleach	48.1%	46.7%	25.0%
Mix	3.7%	6.7%	3.6%
None	3.7%	0.0%	10.7%
Don't know	0.0%	0.0%	0.0%
Where dried after last wash	N=26	N=29	N=28
Shade	61.5%	55.2%	85.7%
Sun	34.6%	41.4%	14.3%
Don't know	3.8%	3.4%	0.0%

4. CONCLUSIONS

4.1 SUMMARY OF FINDINGS

This durability monitoring study included ITNs that were distributed during the 2018 campaign in four districts spread geographically across Madagascar: Farafangana on the Southeast coast, Maintirano on the West coast, Bekily in the South, and Fort Dauphin on the Southeast coast. DawaPlus 2.0 ITNs were monitored in Farafangana, Maintirano and Bekily, and PermaNet 2.0 ITNs were monitored in Fort Dauphin. The study districts represented settings with varying climactic conditions and malaria transmission, as well as varying levels of population access to ITNs. At baseline, the study team successfully recruited a total of 1,650 ITNs to study cohorts in each district (including campaign nets reported as lost before the baseline round). For the 36-month round, the study teams visited 517 households across the four districts and recorded 308 cohort ITNs still present (127 in Farafangana, 56 in Bekily, 49 in Maintirano, and 76 in Fort Dauphin).

At 36-months, total cohort ITN attrition was 70% in Farafangana, 82% in Bekily, 75% in Maintirano, and 77% in Fort Dauphin, with a range of only 12 percentage points across sites. In contrast, attrition due to wear and tear varied from 14% in Maintirano to 59% in Bekily, a range of 45 percentage points. ITN attrition in Maintirano was most commonly due to nets being given away to others (40%), a practice that was much less common in other settings (23% in Fort Dauphin to 10% in Bekily). Between 12- and 36-months, increases in attrition due to wear and tear were approximately linear in all settings except Farafangana, where the increase in loss was greater between 24- and 36-months (22%) compared to between 12- and 24-months (16%).

The physical integrity of ITNs remaining in the household generally declined from one round to the next in all sites, with the proportion of ITNs classified as "serviceable" monotonically declining in Farafangana and Maintirano between baseline and endline. However, this indicator increases in Bekily between 12- and 24-month and 24- and 36-month rounds, and in Fort Dauphin between the 24- and 36-month rounds. The median pHI values declined during the same period. Bekily and Fort Dauphin reported the two highest levels of attrition due to wear and tear, and together, these data suggest that households in these districts were discarding nets with relatively lower levels of damage compared to those in Farafangana and Maintirano, and thus their remaining nets were in relatively better physical condition. The median pHI value in Maintirano at 36-months was 937, much greater than the cut-off for a net to be classified as torn (pHI>642) and indicating that more than half (54%) of the remaining nets in this site were in very poor condition.

Considering attrition and physical integrity data together, settings with high levels of attrition due to wear and tear tended to have a higher proportion of remaining nets in serviceable condition (Bekily and Fort Dauphin), while those with lower levels of attrition due to wear and tear tended to have poorer physical integrity outcomes (Farafangana and Maintirano). As a result, the proportion of cohort nets that survived in serviceable condition at 36-months was similar across the four settings: 24% in Farafangana, 21% in Bekily, 28% in Maintirano, and 24% in Fort Dauphin (a range of 7 percentage points). These values correspond to an estimated median life for DawaPlus 2.0 of 2.1 years in Farafangana, 2.0 years in Bekily, 2.5 years in Maintirano, and 2.1 years for PermaNet 2.0 in Fort Dauphin.

The presence of non-cohort nets in study households varied over time. Availability of non-cohort nets in the three DawaPlus 2.0 sites decreased between baseline and 12-month rounds, before increasing between 12- and 24-month rounds to a level of availability similar to or greater than baseline. At 36-months, non-cohort net availability among households remaining in the study ranged from 56% in Fort Dauphin to 89% in Farafangana. In absolute terms, there were nearly twice as many non-cohort nets than cohort nets in the study area at 36-months (256 versus 127 in Farafangana, 92 versus 56 in Bekily, 106 versus 49 in Maintirano, and 107 versus 76

in Fort Dauphin). Community continuous distribution was an important source of non-cohort nets in Farafangana (33% of all non-cohort nets) and Bekily (75%). In Maintirano and Fort Dauphin, distribution through the private sector was the source of 49% and 33% of non-cohort nets, respectively.

Institut Pasteur de Madagascar conducted WHO cone bioassays on DawaPlus 2.0 and PermaNet 2.0 ITNs on arrival in Madagascar, and on field samples withdrawn by the study teams at each study round. ITN samples were tested against a fully susceptible lab strain of *An. arabiensis*. Samples tested on arrival in country showed 100% optimal effectiveness of DawaPlus 2.0 but only 87% optimal effectiveness for PermaNet 2.0. These samples failed to meet the 95% WHO threshold for 60-minute knock-down (KD60) (79.5% for DawaPlus 2.0 vs 71.5% for PermaNet 2.0) and mean KD60 values remained under the WHO threshold for samples from both brands when tested 12- and 24-months after distribution. Samples tested on arrival showed mean 24-hour mortality results above the WHO threshold of 80% (86.5%, DawaPlus 2.0; 83.9%, PermaNet 2.0), mean mortality at 12-months ranged from 43-51% and mean mortality at 24-months ranged from 21-29%. At 24-months after distribution, the proportion of net samples meeting the threshold for optimal effectiveness was less than 7%. There is some evidence that PermaNet 2.0 ITNs (30% minimally effective) performed better than DawaPlus 2.0 ITNs (≤ 23% minimally effective in the three other sites). At the 36-month, contrary to the trend previously observed up to 24th month, an increase in mortality was seen in the four locations resulting in an increase in the optimal and minimal effectiveness.

CDC Atlanta conducted chemical residue testing on netting taken from the field samples withdrawn by the study teams. Chemical content results for nets on arrival are only available for DawaPlus 2.0 samples and the mean deltamethrin content was 65.9 mg/m², corresponding to a 18% reduction compared to the manufacturer target dose of 80 mg/m². At 12 months, the mean deltamethrin content in DawaPlus 2.0 samples ranged from 15.0 mg/m² to 26.4 mg/m², corresponding to a 67-81% reduction from the target dose. Chemical content analysis on 10 PermaNet 2.0 samples at 12 months recorded a mean deltamethrin content of 33.5 mg/m², corresponding to a 39% reduction from the manufacturer target dose of 55 mg/m². At 24-months, the mean deltamethrin content of DawaPlus 2.0 net samples corresponded to a loss of chemical content of 83% (Maintirano), 87% (Farafangana) and 93% (Bekily) compared to the manufacturer target doses. For PermaNet 2.0 samples from Fort Dauphin the recorded loss was 68%. The mean chemical contents of DawaPlus 2.0 samples tested at 36-months, were higher than those recorded at 24-months. This aligns with the higher knockdown and mortality results from the bioassay tests and supports the hypothesis that cohort nets still present in households after 36 months had received better care than those withdrawn during earlier rounds. However, the PermaNet 2.0 samples from Fort Dauphin recorded greater loss than at 36-months, contrary to the improvement seen in the bioassay results for this site. The mean residual quantity of deltamethrin on DawaPlus 2.0 net samples was 17 mg/m² in Bekily, 23 mg/m² in Farafangana and 31 mg/m² in Maintirano. Deltamethrin content was 12 mg/m² for PermaNet 2.0 samples in Fort Dauphin. The 36-month chemical content results correspond to a loss of chemical content of 43% (Maintirano), 58% (Farafangana), 69% (Bekily), and 86% (Fort Dauphin) compared to the manufacturer target doses.

4.2 KEY CHALLENGES AND LESSONS LEARNED

This study was the third time the implementing fieldwork team (PSI Madagascar) had conducted a durability monitoring study and, as such, challenges to efficient implementation were limited throughout the life of the study.

Prior to baseline, the implementation team was able to draw on its database of research associates located across the country for field team selection. However, few listed individuals were from or familiar with the areas around Bekily and Maintirano districts. Local knowledge for these districts was important due to the specific language and dialects used locally. PSI staff located close to these areas recruited new data collectors from Bekily and Maintirano who were brought to Antananarivo for training to ensure that all districts were supported by teams knowledgeable of the area and local dialect.

The most significant challenge during baseline activities was the adverse security situation in Melaky region, home to Maintirano district. Unrest and banditry eventually meant that fieldwork in the site was halted after 11 of the planned 15 clusters had been completed. After the locality was attacked by bandits, a decision was made to halt data collection in Maintirano for the safety of the field team and study materials. This resulted in a smaller ITN cohort from Maintirano than planned. During the 12-, 24- and 36-month study rounds, the Maintirano team worked in close collaboration with local law enforcement and government security officials before and during field activities in the region to ensure study clusters were safe before travelling and conducting fieldwork.

For the 12-month survey round, Fort Dauphin was added to the set of monitoring sites. During household enumeration in the new study clusters in Fort Dauphin, it transpired that some clusters had received Yorkool branded ITNs rather than PermaNet 2.0 ITNs. As had been seen previously in Madagascar and in previous durability monitoring studies elsewhere, information available to the study team during study planning did not always accurately reflect the actual distribution. The field team collected additional data from *fokotany* (cluster) chiefs and local health centers to identify which fokontany had received the PermaNet 2.0 brand and which had received Yorkool branded ITNs. In total, seven of the 15 pre-selected clusters received Yorkool ITNs, and these clusters were replaced by the field team within Fort Dauphin by matching on cluster population size with a cluster known to have received only PermaNet 2.0 ITNs.

Due to the longer period between the ITN distribution and the first round in Fort Dauphin, compared to the DawaPlus 2.0 sites, there is the potential for increased recall bias of campaign nets received and campaign nets lost since the campaign. However, indicator values from the first round of data in Fort Dauphin fall within the range of comparable data collected from the original three study sites and give no indication of systematic bias due to a longer initial recall period.

Before the start of the 24-month round, the COVID-19 pandemic spread throughout Madagascar and the rest of the world causing data collection to occur six weeks later than originally planned. To ensure no further delays to data collection, VectorLink implemented several COVID-19 mitigation measures to protect the data collection teams and the study communities. By the 24-month study round, implementation challenges had been minimized and both the 24- and 36-month study rounds were conducted successfully, following COVID-19 mitigation measures, with the engagement and support of district level officials, chiefs, and community members.

During the 36-month round, field teams were challenged by having to withdraw cohort ITNs for laboratory analysis from a relatively small cohort of remaining ITNs. All withdrawn ITNs were confirmed by households to be part of the study cohort, but some nets had lost their unique cohort ID (the value written on the label had faded or the label had come off the net). Analysis of bioassay and chemical testing results was performed using the full sample of withdrawn nets, and in a secondary analysis restricted to those nets with a unique ID present on the net label. Results from the two analyses were consistent for bioassays and largely unchanged for chemical content testing, though the small sample size makes interpretation of differences difficult. Future studies should continue to emphasize during interviewer training that every net collected for laboratory analysis must have a visible cohort label or ID.