LLIN Durability Monitoring in Madagascar 2015-2017

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1 Executive Summary

During a mass Long Lasting Insecticide Treated Net (LLIN) distribution campaign in Madagascar from October 2015 to November 2015, which took place in 92 of Madagascar's 112 districts, three types of LLIN were distributed: PermaNet 2.0®, Yorkool®, DawaPlus®. A cohort study on PermaNet 2.0® was conducted in four malaria endemic districts: Ankazobe, Mananjary, Antsohihy and Toliary II. This cohort study was conducted over three rounds, at 3-6 months, 12 months and 24 months after the mass distribution. In addition, as recommended by the President's Malaria Initiative (PMI) and the National Malaria Control program (NMCP), Yorkool® was distributed in Manja and Beloha districts, and DawaPlus® was distributed in Sambava and Vondrozo districts at the evaluation process - 24th months after mass distribution. The present study was conducted similarly to the 2013 study, which examined the BestNet Netprotect®, Royal Sentry® and Yorkool® LLIN, for which results are available in the 2013 Net Durability Report.

The objectives of the recent study were to measure survival of the nets through analyzing the integrity hole indexes and bioassays of the LLINs. The results of this study will help Madagascar's national malaria program and aid the government in determining the most appropriate mosquito net for future procurement.

Of the 1300 nets enrolled for the cohort study at 6th month, only 593 were found after the 24th month. The reasons for net losses were: given away or stolen (36.6%) or destroyed or used otherwise (25%), with the remainder thrown away. At both baselines, 600 households were selected, with only 484 retained to the last phase of the study (October - November 2017). Reasons on household attrition were: households moved to other places, houses being abandoned, or household members being absent.

In the South Districts, survivorship declined significantly for the last two periods: from 84.4% [95%CI(81.1-87.8]) at 12thmonth to 45.0% [95%CI(40.6-49.6)] at 24thmonth for Toliary II, and from 86.1% [95%CI(83.3-90.4)] at 12thmonth to 43.4% [95%CI(38.7-48.1)] at 24thmonth in Mananjary. Ankazobe and Antsohihy presented higher survivorship around 73.6% and 77% after 24 months of mass distribution campaign. The LLIN estimated median survival time was higher in the North and Center Districts, at 4 years in Ankazobe and 6 years in Antsohihy. This estimation is significantly lower In Mananjary and Toliary II, at 1.85 and 1.87 years respectively.

For the four additional brands evaluated at the 24thmonth mark, the highest proportion of households that were still in possession of all nets received from the campaign was in Beloha (Yorkool®) at 84.0%. This proportion was at 49.3% in Sambava (DawaPlus®), 56.7% in Manja (Yorkool®), and 68.0% in Vondrozo (DawaPlus®). The district with the highest proportion of serviceable net based on having a proportionate hole index (pHI) less or equal to 642 (defined as net in good condition or damaged) was Sambava (DawaPlus®) at 74.1% [95%CI(64.0-82.1)], but low in Vondrozo (DawaPlus®), at 47.7% [95%CI(47.7-63.1)].

Bioassays were carried out according to WHO protocol using an *Anopheles arabiensis* strain susceptible to deltamethrin reared in the insectary of the *Institut Pasteur de Madagascar*. The Three brands of nets tested were: PermaNet 2.0®, DawaPlus®, and Yorkool®. PermaNet 2.0® was tested at baseline (new nets coming from packaging), and at three/six, 12 and 24 months of use while DawaPlus®, and Yorkool® were tested after 24 months of use only. PermaNet 2.0® nets were collected form Ankazobe, Antsohihy, Mananjary and Toliary II district while DawaPlus® were collected from Sambava and Vondrozo districts and Yorkool® from Beloha and Manja districts. A total of 30 nets per district per round was tested.

The average mosquito mortality for the new nets was 98.6%. After three or six months of use (depending on the cohort), the average mosquito mortalities for the nets surpassed the WHO threshold (≥80.0%) in all study sites. After 12 months use, among 120 nets tested, only 13 nets were considered as effective nets (having mosquito mortality above 80%): two nets were collected in Ankazobe, four nets in Antsohihy, three nets in Mananjary and four nets in Toliary II.

After 24 months of use, the average mortality was far below the WHO threshold. Mortality with DawaPlus® was 15.7% and 15.2% in Sambava and Vondrozo, respectively. With PermaNet 2.0®, mortality was 32.5%, 28.9%, 21.0% and 30.4% in Ankazobe, Antsohihy, Mananjary and Toliary II, respectively. Mosquito mortality with Yorkool was 23.1% and 12.3% in Beloha and Manja respectively.

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2 Acknowledgements

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3 Background

Madagascar, an island composed of 22 regions with approximately 22 million inhabitants in southeastern Africa, is separated from Africa by the Mozambique Channel. Most of the rural areas are not accessible by car as the roads are in poor condition. These situations affect the logistics of ongoing sustained distribution of mosquito nets in Madagascar. Madagascar's geography results in a tropical climate characterized by a rainy season (November-March) and a dry season (April-October), the length of which varies from one region to another. This results in an added layer of complexity, when certain areas are different to access, and the epidemiology of malaria and the vector varies drastically.

Malaria prevention with long-lasting insecticidal mosquito nets (LLIN), a highly effective and cost-efficient intervention, has seen a tremendous scale-up in sub-Saharan Africa in recent years. As many countries have now achieved high coverage of LLINs and are approaching the WHO's universal coverage target of one net for every two people of the population at risk[1], the question of how these successes can be sustained becomes the focus of discussion. Madagascar, however, is lagging behind this goal – as only 44% of households have one LLIN per two people (Malaria Indicator Survey (MIS) 2016). Further, especially in the context of Madagascar, the importance of LLIN durability and the "average useful life" of a net is increasingly recognized as critical factors for malaria program design, as these determine the frequency at which nets need to be replaced and the type of net to be procured. This is reflected in the WHO guidelines for the monitoring of LLIN in the field, which recommends that countries routinely monitor net durability.

Several reports, including a limited PMI-supported assessment of net durability on LLINs three years post-delivery, indicate a rapid decline in net survivorship in Madagascar. This highlights the need to establish LLIN monitoring activities similar to those done following the mass campaign distribution in 2013, to justify, quantify, and prioritize future replacement needs. This includes analysis of the bioassay, as WHO guidelines state that LLINs should have adequate insecticidal activity after 20 standard washes and a minimum of 3 years under routine use in the field.

Net durability monitoring is concentrated on three indicators: net survivorship, which is the percentage of nets still present and in use in the household to which they were distributed; physical integrity, a quantification of the size and the number of holes in the LLIN; and bio-efficacy, a measure of LLIN's insecticidal effect.

[1]Source: Revised recommendations for achieving universal coverage with long-lasting insecticidal nets in malaria control. Page5. Geneva, Switzerland. October 2017. Global Malaria Program. WHO.

Following the mass campaign in 2015, which took place between 28th September and 12th October, a net durability study was conducted in four endemic regions that received Permanet 2.0®. This report presents results of the three rounds at 3-6 month, 12 months and 24 months.

4 Research objectives

The objectives of the study were:

1. To assess the physical durability (survivorship and physical integrity) of the three brand nets namely Permanet2.0® manufactured by Vestergaard, DawaPlus® manufactured by TanaNet and Yorkool® manufactured by Tianjin Yorkool. All the three brands are pretreated with deltamethrin and made of polyester fiber. Those LLIN were distributed in 92 out of 112 health districts, over a three-year period.

2. To assess the bio-efficacy of the nets collected from the field.

3. To compare the durability across the different locations and identify major determinants of field performance.

The study's secondary objective was to describe major behavioral and demographic aspects of net care and repair and their impact on insecticidal and physical durability.

During the LLIN mass campaign 2015: 76% are Permanet 2.0® branded LLIN, 10% are Yorkool® branded LLIN and 14% are DawaPlus® branded LLIN. Only the Permanet 2.0® brand LLIN was evaluated at baseline, 6th and 12th month. The other two brands, Yorkool® and DawaPlus® LLIN were added in the evaluation process at 24th month as per the national malaria program and PMI recommendation in order to have a big picture of the net durability of all brands distributed during the mass campaign.

5 Methods

This study followed a cohort design and was implemented in four Districts that obtained nets through a mass distribution campaign held in 2015. Within 3-6 months following the mass campaign, a representative sample of 1,300 campaign nets from study locations were identified through a cluster household survey, with all campaign nets from consenting households forming the study cohort. These nets were then labeled with a unique identifier and their presence and physical condition in the house were assessed during three rounds of annual surveys as well as household characteristics, use, care, and net behaviour. At each assessment stage (3-6, 12, and 24 months), sub-samples of campaign nets were selected for insecticide effectiveness testing (bio-assays). The new Permanet 2.0® was also tested for bioassay efficacy and considered as a positive control.

The study was carried out in eight districts:

Four districts selected for Permanet 2.0® brand net: Antsohihy, Ankazobe, Mananjary and Toliary II.

Additional four districts selected for DawaPlus® brand net: Sambava and Vondrozo and for Yorkool® brand net: Manja and Beloha.

5.1 Sites

The eight study districts were selected following malaria epidemiology and socio-ecological profiles – with these districts representing areas with high, moderate, and low malaria transmission potential and areas with significantly different climatic or socio-demographic characteristics. The sampling unit was the household and in each household all nets were selected.

Table 1: Summary of the study sites and the sampling

Transmission zone	**Brand net**	**District**	**Campaign net period**	**Data collection period**
Perennial transmission	Permanet 2.0®	Mananjary (150 households)	September	6 - 12 and 24 months post campaign
Long transmission	Permanet 2.0®	Antsohihy (150 households)	September	6 - 12 and 24 months post campaign
Long transmission	Permanet 2.0®	Toliary II (150 households)	December	3 - 12 and 24 months post campaign
Seasonal and short transmission	Permanet 2.0®	Ankazobe (150 households)	September	6 -12 and 24 months post campaign
Long transmission	Yorkool®	Manja (150 households)	September	24 months post campaign
Seasonal	Yorkool®	Beloha (150 households)	September	24 months post campaign
Perennial transmission	DawaPlus®	Sambava (150 households)	September	24 months post campaign
Seasonal	DawaPlus®	Vondrozo (150 households)	September	24 months post campaign

For Toliary II site, the mass campaign distribution took place in December- slightly different from the three other sites with the Permanet 2.0® net. The first, second, and third rounds of data collection had been indeed implemented at 3, 12 and 24 months after the campaign respectively for these other Permanet 2.0® sites. For the three remaining sites selected for Permanet 2.0®, the first, second and third rounds of data collection were held at 6, 12 and 24 months post campaign respectively. For the descriptive analysis and all mention of first round of data collection 6th month time reference is used for the four sites to standardize reading and avoid confusion while specifying that the baseline survey for Toliary II happened 3 months after mass campaign.

In total 15 Fokontany (enumeration area) per site were randomly selected using the PPS (probability proportional to size) method. In each Fokontany, 10 households were sampled for bioassay testing. Within each Fokontany, a census conducted to map all households was used as a sampling frame to select these 10 households. Only households having received nets from the mass campaign were listed in the sampling frame.

The tracking of the Permanet 2.0 brand for the three rounds of data collection was made possible due to tagging of selected nets as baseline. Additionally, GPS coordinates were recorded during the first round of data collection at 6 months, in order to facilitate identification of the selected households and the tagged net for the next survey round. For follow up visits, the presence of the LLIN was verified visually in all selected households.

For the LLINs collected for the bioassay testing, two nets per Fokontany were randomly selected. In addition, 10 new nets from the Permanent 2.0® brand were sent to IPM for bioassay testing upon arrival to the country.

5.2 Analysis

The analyses included examination of the LLIN's integrity, survivorship, and insecticide activity.

5.2.1 Integrity and Survivorship

Upon examining the nets, holes in the nets were looked for, and if found, categorized into four distinct groups as per the WHO guidelines. The following categories were used, and were described in the following way to the interviewers:

- Category 1 – < thumb (0.5-2.0cm) (holes <0.5 cm ignored)
- Category 2 – > thumb < fist' (2-10 cm)
- Category 3 – > fist < head' (10-25 cm)
- Category 4 – > head' (>25 cm)

According to WHO recommendations, the calculation of the LLIN's physical integrity, proportional hole index (pHI)was calculated using formula 1, allowing for weighting of holes based on size.

*(1) pHI = (size 1 holes) + (size 2 holes * 23) + (size 3 holes * 196) + (size 4 holes * 578)*

Based on the value obtained from pHI, the nets were categorized as: Good (pHI values 0-64); Damaged (pHI values 65-642); and beyond repair (pHI values >643). Good or damaged mean that the nets are still serviceable.

Survival was then calculated using formula 2:

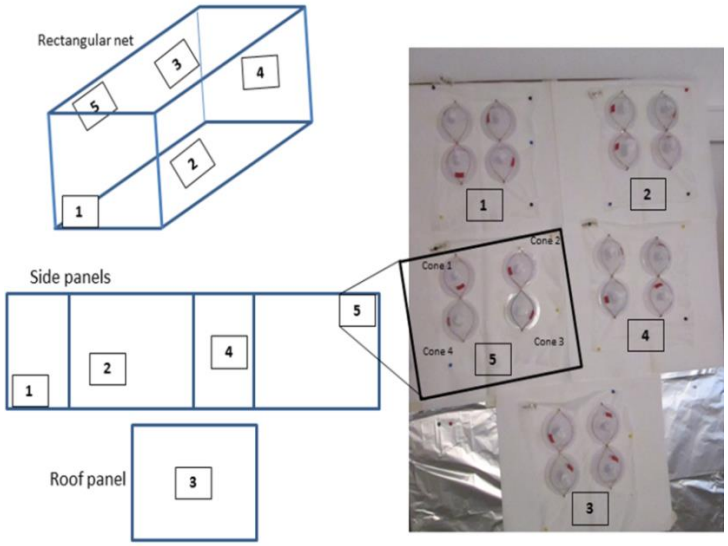
(2) $$Survival = \frac{(nets\ still\ present\ at\ the\ time\ of\ follow\ up\ visit) X (the\ proportion\ of\ serviceable\ nets)}{(number\ of\ original\ nets\ not\ given\ away)}$$

5.2.2 Insecticidal activity

Standard WHO cone bioassays were performed with a fully susceptible laboratory strain of *Anopheles arabiensis* mosquito to assess the bio-efficacy of LLINs as recommended by the WHO pesticide evaluation scheme (WHOPES) (WHOPES, 2013). For each LLIN, five 25"x25" sub-samples were cut from randomly selected LLINs for cone tests. The sub samples were cut from the four sides of the net (Figure 1). Then, each sub-sample was placed in an aluminum foil envelope, labeled, and kept individually in a +4°C refrigerator prior to conducting the bio-assay. For each individual sub-sample, four cone tests were conducted simultaneously, following standard WHO procedure (WHOPES, 2013). Five non-blood-fed, two-to-five-days-old female *An. arabiensis* were introduced into each cone and exposed to LLINs samples for three minutes before being transferred to paper cups covered with neutral netting. These were then held for 24 hours at 28°C and 80% humidity with access to 10% sugar solution. Knock-down (KD) was recorded at 60 minutes post-exposure, and mortality was recorded 24hours post-exposure. By following this methodology, a total of 100 mosquitoes were tested for each net. On each day of testing, four cones, each with 10 *An. arabiensis*, were fixed on a non-impregnated net as a negative control. If the mortality in the control was <10% for a given day, the data were adjusted using Abbott's formula (Abbott, 1925). If the mortality in the control was >10%, all the tests for that day were repeated. A LLIN was considered as effective if the mortality was up to the WHO threshold of 80% or the KD up to the WHO threshold of 95% (WHOPES, 2013).

Three brands of nets were tested: PermaNet 2.0®, DawaPlus®, and Yorkool®. PermaNet 2.0® was tested at baseline (new nets coming from packaging), three/six, 12 and 24 months of use, while DawaPlus® and Yorkool® were tested at 24 months of use. PermaNet 2.0® were collected form Ankazobe, Antsohihy, Mananjary and Toliary II districts while DawaPlus® were collected from Sambava and Vondrozo districts and Yorkool® from Beloha and Manja districts. A total of 30 nets per district per round were tested.

Figure 1. Sampling locations on a rectangular type bed net and bioassay



5.3 Ethical Clearance

This study was reviewed by both the CDC in Atlanta and Madagascar's local ethics board and was deemed exempt on the grounds of quality improvement. Informed consent was sought for all participants in this study.

6 Results on cohort district receiving Permanet 2.0®

6.1 Sample description and net possession

As shown in the table 2, the total nets reported as received from the campaign by selected households was 1,440 LLIN. At 6 month, 1,300 LLIN had been found and were tagged for follow-up visit. Only 992 LLIN had been found at 12thmonth, and 534 LLIN at 24thmonth.Substantialloss is noted in Toliary II, with a significant loss from 341 at 6thmonth, 251 at 12thmonth, and to 93 at 24thmonth. At follow up visits, some households were not found as they moved to another place or they were absent during data collection timeline. The initial selection at 6thmonth was 600 households for the total of the 4 districts but only 484 households were identified at 24thmonth.

Table 2: Sample description and net possession

Location	Household selected			Original nets received from campaign	Net still in cohort		
	6 months	12 months	24 months		6 months	12 months	24 months
Ankazobe	150	145	132	362	327	264	185
Mananjary	150	140	118	344	315	248	115
Antsohihy	150	143	116	365	317	229	150
Toliary II	150	139	118	369	341	251	93
Total	600	567	484	1,440	1,300	992	543

**Household absent or moved to another place outside the commune*

6.2 Net Use and Ownership

6.2.1 Net ownership

To improve net use, the household is encouraged to hang the net to be ready for use when someone is going to sleep at night.Net hanging varied from 59.2% [95%CI(53.8-64.4)] at 6th month in Toliary II to 33.5% [95%CI(24.0-44.6)] at 24th month in Ankazobe. At 24thmonth, as shown in the table 3, the percent of net hanged remained relatively low: 33.5% [95%CI(24.0-44.6)] in Ankazobe compared to 54.7% [95%CI(46.1-63.0)] in Antsohihy. There was no significant difference between rounds. For nets taken down or stored, at 6thmonth, household behavior presented significant difference for two sites Ankazobe 43.7% [95%CI(37.2-50.5)] and Toliary II 31.7% [95%CI(27.6-36.0)].

Additionally, in Toliary II, the percent of nets taken down or stored increased significantly from 31.7% [95%CI(27.6-36.0)] at 6thmonth to 47.3% [95%CI(36.8-58.1)] at 24thmonth. There was a consistently low number of nets still in the package, with the number decreasing over time with no statistical difference between sites and round (Table 3).

Table 3: Hanging and storage of campaign nets from cohort

Site	Round	N	Hanging	Taken down or stored	Still in package
Ankazobe	6th month	327	43.7 (36.4,51.3)	43.7 (37.2,50.5)	12.5 (9.2,16.9)
	12th month	264	38.6 (31.1,46.7)	49.2 (41.2,57.3)	12.1 (6.9,20.3)
	24th month	185	33.5 (24.0,44.6)	63.8 (49.3,76.1)	2.7 (0.3,19.2)
Mananjary	6th month	315	53.0 (43.7,62.2)	40.6 (31.4,50.6)	6.4 (2.6,14.9)
	12th month	248	54.8 (46.4,63.0)	39.1 (30.8,48.1)	6.1 (2.5,14.2)
	24th month	115	53.9 (40.9,66.4)	46.1 (33.6,59.1)	0.0 (.)
Antsohihy	6th month	317	50.5 (39.4,61.5)	45.7 (35.3,56.6)	3.8 (1.1,11.8)
	12th month	229	46.3 (37.3,55.5)	34.9 (25.9,45.3)	18.8 (10.6,31.1)
	24th month	150	54.7 (46.1,63.0)	45.3 (37.0,53.9)	0.0 (.)
Toliary II	6th month	341	59.2 (53.8,64.4)	31.7 (27.6,36.0)	9.1 (5.0,15.8)
	12th month	251	59.0 (51.3,66.2)	37.9 (31.0,45.2)	3.2 (1.2,8.5)
	24th month	93	52.7 (41.9,63.3)	47.3 (36.8,58.1)	0.0 (.)

6.2.2 Net use

There is no significance difference on net use the night preceding the survey between districts and rounds. Data from the three rounds provided an average of 52% in Ankazobe, 64% in Mananjary, 57% in Antsohihy, and 70% in Toliary II. As expected, the proportion reporting using a net every night followed the same pattern observed for net use during the previous night following the survey (Table 4).

Table 4. Frequency of use of the campaign net

Site	Round	N	Used last night	Used every night (last week)
Ankazobe	6th month	327	56.9 (48.2,65.2)	54.7 (45.6,63.6)
	12th month	264	53.4 (44.6,62.0)	48.5 (39.7,57.4)
	24th month	185	46.0 (38.2,53.9)	41.1 (32.3,50.4)
Mananjary	6th month	315	64.8 (55.5,73.1)	61.9 (52.2,70.7)
	12th month	248	63.7 (55.5,71.2)	62.1 (53.2,69.0)
	24th month	115	63.5 (48.8,78.1)	62.9 (44.3,78.4)
Antsohihy	6th month	317	53.3 (42.1,64.2)	51.7 (40.1,63.2)
	12th month	229	52.4 (43.0,61.6)	50.2 (41.4,59.0)
	24th month	150	66.0 (58.3,72.9)	63.3 (55.4,70.7)
Toliary II	6th month	341	70.4 (63.6,76.4)	63.9 (57.5,69.9)
	12th month	251	74.9 (67.5,81.1)	69.7 (61.8,76.6)
	24th month	93	65.9 (45.9,81.1)	63.4 (43.2,79.8)

Net use among children under 5 years remained consistently low over time across all districts. At 12thmonth, the proportions presented significant difference between Mananjary 25.4%[95%CI(19.6-32.3)] which was slightly higher and Antsohihy 11.8% [95%CI(7.3-18.6)]. Among older children, use of LLIN remained low between 10 and 25%, and remained unchanged for the duration of the study. Among adolescents, the net use the previous night presented significant difference between Ankazobe 14% [95%CI(9.6-20.0)] and Toliary II 28.7% [95%CI(23.4-34.6)] two times higher at 12thmonth. We noted the same trend at 24thmonth for the same group with the same districts, 14.6% [95%CI(10.3-20.2)] in Ankazobe and 32.3% [95%CI(21.5-45.3)] in Toliary II. With the same indicator, there is no significant changes between rounds for the three groups (children under five years, older child between 5-9 years and adolescent 10-19 years). At all time points, adults represented the highest proportion of those sleeping under nets, with this number at 24thmonth being 34.1% in Ankazobe, 42.6% in Mananjary, 39.3% in Antsohihy and 30.1% in Toliary II (Table 5).

Table 5: Use of nets by age ranges

Site	Round	N	Child under 5 years	Older child (5-9years)	Adolescent (10-19years)	Adult
Ankazobe	6th month	327	16.5 (11.8,22.6)	12.5 (8.2,18.7)	22.0 (17.4,27.4)	38.5 (32.2,45.3)
	12th month	264	18.9 (15.5,23.0)	16.3 (11.3,22.9)	14.0 (9.6,20.0)	41.3 (34.8,48.1)
	24th month	185	13.5 (9.0,19.9)	11.9 (8.2,16.9)	14.6 (10.3,20.2)	34.1 (28.5,40.1)
Mananjary	6th month	315	24.4 (20.0,29.6)	22.2 (16.5,29.3)	27.3 (21.1,34.6)	46.0 (39.7,52.5)
	12th month	248	25.4 (19.6,32.3)	24.6 (18.5,31.9)	27.0 (20.9,34.2)	45.6 (39.5,51.8)
	24th month	115	22.6 (16.2,30.7)	25.2 (18.4,33.5)	27.8 (16.4,43.1)	42.6 (31.6,54.4)
Antsohihy	6th month	317	15.1 (10.4,21.5)	11.4 (7.7,16.4)	19.2 (12.8,27.9)	34.1 (28.2,40.5)
	12th month	229	11.8 (7.3,18.6)	16.2 (10.8,23.5)	21.8 (15.3,30.1)	25.8 (20.0,32.5)
	24th month	150	15.3 (9.9,23.1)	19.3 (14.1,26.0)	22.7 (18.0,28.1)	39.3 (31.1,48.2)
Toliary II	6th month	341	27.9 (21.6,35.1)	20.5 (16.2,25.6)	27.0 (21.6,33.1)	46.9 (42.0,51.9)
	12th month	251	27.5 (21.0,35.1)	23.9 (18.6,30.2)	28.7 (23.4,34.6)	49.0 (43.5,54.5)
	24th month	93	17.2 (10.8,26.4)	23.7 (14.1,37.0)	32.3 (21.5,45.3)	30.1 (20.7,41.5)

* *Age 0-9 years; ** includes adolescents 10-19*

6.3 Survivorship and durability of campaign nets

6.3.1 Net Loss

Severe and significant net attrition took place over the study in two districts, Mananjary and Toliary II. In Mananjary, the proportion of households that still had possession of all the nets they received from the campaign decreased from 79.3% [95%CI(72.8-84.6)] at 6thmonths to 30.5% [95%CI(22.6-39.7)] at 24thmonths while in Toliary II, this proportion declined from 78% [95%CI(70.9-88.3)] to as low as 18.6% [95%CI(14.1-24.2)] in the same period. In Ankazobe and Antsohihy, there was no significant decrease on the number of households that still in possession of all nets for the three rounds.

Then net being given away to relatives was the main reason for net loss across all the districts. This practice was observed mainly at the 12th month in Toliary II, 78.8% [95%CI(63.2-88.9)] compared to 16.7% [95%CI(8.6-29.8)] and 40.3% [95%CI(27.3-54.7)] at 6th month and 24th month respectively.

Table 6: Lost net from campaign

Site	Ankazobe			Mananjary			Antsohihy			Toliary II		
	6th month N=150	12th month N=145	24th month N=132	6th month N=150	12th month N=140	24th month N=118	6th month N=150	12th month N=143	24th month N=116	6th month N=150	12th month N=139	24th month N=118
	% (95 CI)	% (95 CI)	% (95 CI)	% (95 CI)	% (95 CI)	% (95 CI)	% (95 CI)	% (95 CI)	% (95 CI)	% (95 CI)	% (95 CI)	% (95 CI)
Proportion of household who are still in possession of all the nets they received from the campaign	77.3 (65.8,85.8)	59.3 (55.3,63.2)	55.3 (42.1,67.8)	79.3 (72.8,84.6)	75.7 (71.4,79.6)	30.5 (22.6,39.7)	65.3 (56.5,73.2)	52.5 (40.2,64.4)	44.8 (33.0,57.2)	78.0 (70.9,83.8)	54.7 (46.7,62.4)	18.6 (14.1,24.2)
Main reason for the loss of the campaign net among all net lost												
	N=39	N=73	N=66	N=39	N=44	N=142	N=69	N=111	N=93	N=38	N=88	N=179
	%	%	%	%	%	%	%	%	%	%	%	%
Net was stolen	5.7 (1.3,21.5)	3.5 (0.4,26.7)	2.1 (0.2,18.1)	0.0 (.)	8.8 (2.4,27.7)	11.1 (2.9,34.5)	1.9 (0.2,9.3)	6.9 (2.3,19.1)	1.6 (0.2,12.6)	6.1 (1.3,24.5)	1.5 (0.2,13.0)	7.3 (3.1,16.6)
Destroyed accidentally	5.7 (0.6,37.9)	0.0 (.)	0.0 (.)	0.0 (.)	5.3 (1.5,16.7)	8.9 (3.1,22.9)	3.8 (1.2,11.5)	5.6 (2.1,13.9)	26.6 (15.1,42.3)	40.4 (29.4,52.4)	4.5 (1.4,13.8)	47.0 (35.0,59.3)
Given away to relatives	80.0 (50.3,94.1)	79.3 (52.1,93.1)	79.2 (55.8,92.0)	78.6 (56.9,91.1)	66.7 (51.2,79.2)	62.4 (37.6,82.0)	57.7 (44.6,69.8)	62.5 (48.9,74.4)	56.3 (41.9,69.6)	16.7 (8.6,29.8)	78.8 (63.2,88.9)	40.3 (27.3,54.7)
Given away to others	0.0 (.)	3.5 (0.4,26.7)	2.1 (0.2,17.4)	7.1 (0.8,41.9)	5.3 (1.5,17.4)	0.0 (.)	1.3 (0.1,10.4)	4.2 (0.8,18.3)	0.0 (.)	4.4 (1.5,12.3)	0.0 (.)	1.3 (0.3,5.5)
Thrown away	0.0 (.)	6.9 (1.1,34.0)	0.0 (.)	0.0 (.)	1.8 (0.2,13.3)	0.0 (.)	0.0 (.)	0.0 (.)	12.5 (6.7,22.3)	9.6 (4.6,19.3)	1.5 (0.2,11.2)	0.0 (.)
Used for another purpose	5.7 (1.2,23.3)	0.0 (.)	14.6 (4.3,39.3)	14.3 (4.9,35.1)	0.0 (.)	4.4 (0.6,27.8)	1.3 (0.2,9.3)	1.4 (0.2,11.7)	3.1 (0.7,12.3)	18.4 (11.2,28.9)	1.5 (0.2,11.9)	0.0 (.)

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6.3.2 Physical damaged and pHI indicator

The study measured the number and the size of holes following WHO definition (see methods section). The proportion of campaign nets with holes greater than 0.5cm increased from 14.4% [95%CI(10.7-19.1)] at 6thmonth to 69.7%[95%CI(64.1-74.8)] at 24thmonths in Ankazobe, while the same proportion increased from 35.6% [95%CI(25.9-46.6)] to 83.6%[95%CI(68.6-92.3)] in Mananjary over the same period. Similarly, the proportion of nets with holes greater than 0.5cm increased from 20.5%[95%CI(13.4-30)] to 74%[95%CI(63.3-82.5)] between 6thand 24thmonth in Antsohihy. In Toliary II, about 28.7%[95%CI(23.4-34.8)] of campaign nets had holes greater than 0.5cm at 6thmonth increasing significantly to 83.9%[95%CI(73.2-90.8)]at 24th month (Table 7).

The most common holes seem to be the 0.5-2.0 cm sizes, followed by 2-10 cm across all study districts.

About a third of all nets in each district were considered damaged i.e. with proportionate hole index (pHI) of 65-642. The study examined serviceable nets by combining those in good condition and damaged nets having a pHI less than 642. Overall, the proportions of nets that were serviceable were above 75% across all district. In Mananjary the proportion of serviceable nets declined from 97.1% [95%CI(93.8-98.7)] to 74.8% [95%CI(62.5-84.1)] between 6thand 24thmonth points, while in Ankazobe this proportion declined from 100% to 88.7% [95%CI(80.9-93.5)]over the same period. Similarly, in Antsohihy, the proportion of serviceable nets declined from 98.7% [95%CI(96.8-99.5)] to 80% [95%CI(70-87.3)] at 6thand 24thmonth respectively, and in Toliary II this proportion declined from 98% [95%CI(93.8-99.3)] at 6thmonth to 81.7% [95%CI(69.1-89.9)]at 24th month (Table 7).

Table 7: Physical condition (integrity) of surviving cohort nets (pHI=proportionate Hole Index)

		Ankazobe			Mananjary			Antsohihy			Toliary II		
		6th month N=327	12th month N=264	24th month N=185	6th month N=315	12th month N=248	24th month N=115	6th month N=317	12th month N=229	24th month N=150	6th month N=341	12th month N=251	24th month N=93
		% (95 CI)	% (95 CI)	% (95 CI)	% (95 CI)	% (95 CI)	% (95 CI)	% (95 CI)	% (95 CI)	% (95 CI)	% (95 CI)	% (95 CI)	% (95 CI)
Campaign net with holes ≥0.5cm		14.4 (10.7,19.1)	53.8 (48.1,59.4)	69.7 (64.1,74.8)	35.6 (25.9,46.6)	63.6 (49.8,75.5)	83.6 (68.6,92.3)	20.5 (13.4,30.0)	57.2 (44.2,69.3)	74.0 (63.3,82.5)	28.7 (23.4,34.8)	71.7 (63.1,79.0)	83.9 (73.2,90.8)
Proportion of net with holes by													
Hole size category	[0.5-2.0[cm	11.3 (8.1,15.6)	48.9 (39.9,57.9)	63.2 (53.4,72.1)	29.2 (20.5,39.8)	60.1 (49.9,69.4)	78.3 (68.6,85.6)	17.0 (11.8,23.9)	54.6 (42.7,66.0)	72.0 (60.3,81.3)	22.6 (17.4,28.8)	65.7 (55.9,74.4)	81.7 (71.0,89.1)
	[2-10[cm	9.2 (5.7,14.5)	39.0 (31.1,47.5)	55.1 (46.0,64.0)	24.4 (19.1,30.7)	51.2 (41.9,60.4)	70.4 (62.2,77.6)	16.1 (10.1,24.6)	42.4 (33.1,52.2)	64.7 (55.1,73.2)	20.8 (16.3,26.2)	53.8 (45.6,61.8)	71.0 (55.5,82.7)
	[10-25] cm	1.8 (0.8,4.4)	9.8 (7.1,13.5)	21.1 (14.5,29.6)	6.7 (4.1,10.6)	19.0 (13.5,26.0)	37.4 (26.3,50.1)	5.4 (2.8,9.9)	16.6 (10.7,24.8)	34.0 (25.1,44.2)	5.6 (3.6,8.5)	16.3 (11.3,23.0)	30.1 (19.4,43.6)
	> 25 cm	0.3 (0.0,2.5)	2.3 (0.7,7.0)	9.2 (4.7,17.4)	1.9 (0.8,4.5)	4.4 (2.3,8.4)	13.0 (7.7,21.2)	1.3 (0.5,3.3)	5.7 (3.6,8.8)	10.0 (5.9,16.3)	2.1 (0.6,7.3)	7.2 (3.8,13.0)	10.8 (6.1,18.2)
Hole index (pHI)													
pHI	Good: pHI Є [0-64]	96.6 (93.8,98.2)	78.4 (71.9,83.8)	60.5 (51.5,68.9)	86.0 (79.6,90.7)	60.4 (46.3,73.0)	40.9 (29.8,53.0)	89.6 (83.8,93.5)	73.4 (63.1,81.6)	48.7 (38.3,59.2)	89.7 (85.0,93.1)	63.4 (53.6,72.1)	45.2 (31.0,60.1)
	Damaged: pHI Є [65-642]	3.4 (1.8,6.2)	16.3 (11.5,22.5	28.1 (20.7,36.9)	11.1 (6.8,17.7)	30.0 (23.3,37.8)	33.9 (23.9,45.6)	9.2 (5.7,14.4)	17.5 (12.1,24.6)	31.3 (24.3,39.4)	8.2 (5.7,11.8)	27.5 (20.2,36.2)	36.6 (29.0,44.9)
	Too torn: pHI ≥ 643	0.0 (.)	5.3 (2.7,10.0)	11.4 (6.5,19.1)	2.9 (1.3,6.2)	9.6(4.3,20.0)	25.2 (15.9,37.5)	1.3 (0.5,3.3)	9.2 (5.6,14.8)	20.0 (12.7,30.0)	2.1 (0.6,6.2)	9.2 (4.6,17.3)	18.3 (10.1,30.9)
Serviceable (pHI≤642)		100.0 (.)	94.7 (90.0,97.3)	88.7 (80.9,93.5)	97.1 (93.8,98.7)	90.3 (83.9,94.3)	74.8 (62.5,84.1)	98.7 (96.8,99.5)	90.8 (85.2,94.4)	80.0 (70.0,87.3)	98.0 (93.8,99.3)	90.8 (82.7,95.4)	81.7 (69.1,89.9)

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6.3.3 Net Survivorship

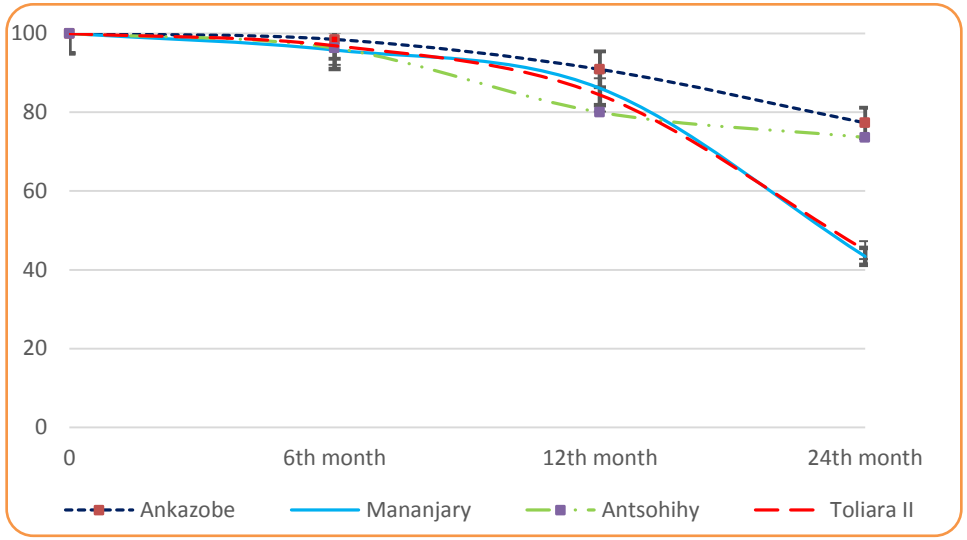
Throughout all districts, survivorship declined over time at an exponential rate, with the most dramatic decline being in Mananjary and Toliary II (Fig. 2). In Toliary II, survivorship declined from 84.4% [95%CI(81.1-87.8)]at 12thmonth to 45.0% [95%CI(40.6-49.6)] at 24thmonth. Similarly, survivorship also sharply declined in Mananjary, declining from 86.1% [95%CI(83.3-90.4)]at 12thmonth to 43.4% [95%CI(38.7-48.1)] at 24thmonth. Ankazobe and Antsohihy presented higher survivorship, at77.3% [95%CI(73.3-81.4)] and 73.6% [95%CI(67.6-79.6)] for both sites after 24thmonth of mass distribution campaign (Table 8).

Table 8: Proportion of net survivorship up to three rounds of data collection

Site	6th month		12th month		24th month	
	N	%	N	%	N	%
Ankazobe	327	98.5 (98.5,98.5)	264	90.9 (88.3,93.5)	185	77.3 (73.3,81.4)
Mananjary	315	95.9 (94.1,97.8)	248	86.1 (83.3,90.4)	115	43.4 (38.7,48.1)
Antsohihy	317	96.3 (95.1,97.5)	229	80.0 (76.7,83.3)	150	73.6 (67.6,79.6)
Toliary II	341	96.9 (95.3,98.2)	251	84.4 (81.1,87.8)	93	45.0 (40.6,49.6)

Numerator is the number of net present at round (x) multiplied by the proportion of net serviceable
The denominator is all net originally received and not yet given away

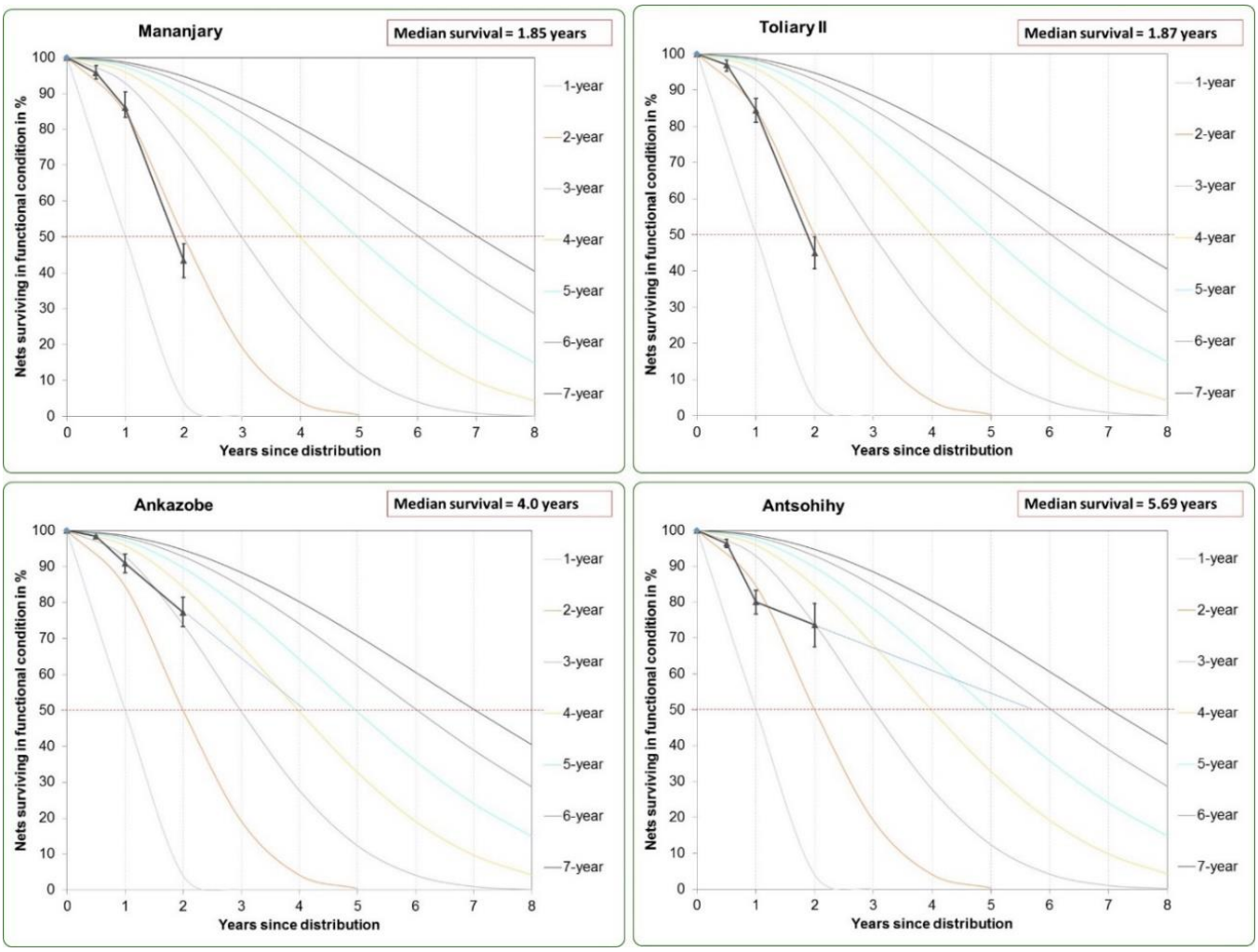
Figure 2. Survivorship



6.3.4 Median Survival Time

In Mananjary and Toliary II, under 50% of nets survived till 2 years, with median survival time at 1.85 years and 1.87 years respectively. In the others districts, Ankazobe and Antsohihy, median survival time is in excess of 4 years (4.0 years and 5.69 years) (Fig. 3).

Figure 3. Median survival time



6.3.5 Net care and repair

When examining education and knowledge on LLIN care, the proportion of households receiving information on use, care and repair of mosquito nets in the last 6 months preceding the survey declined significantly for two districts: Ankazobe from 42% [95%CI(27.5-58)] at the 6th month to 12.1% [95%CI(7.0-20.0)] at the 24th month, and Antsohihy from 67.3% [95%CI(54.4-78)] to 32.8% [95%CI(23.3-43.8)] for the same periods. However, in Ankazobe, the proportion of households that could cite the recommended way (gently in a basin and mild soap) to wash mosquito net significantly improved from 73.3% [95%CI(61.9-82.3)] at 6th month to 95.9% [95%CI(91.3-98.1)] at the 12th month and stayed stable at the 24thmonth. Other districts followed similar trends except for Antsohihy with no significant changes over time (Table 10).

Households having campaign net with holes increased significantly, from 27.5% [95%CI(21.9-34.0)] at 6thmonth to 80.7% [95%CI(70.7-87.9)]in the 24thmonth in Ankazobe; from 56.7% [95%CI(48.5-64.5)] to 94.9% [95%CI(81.6-98.7)] in Mananjary; from 28.9% [95%CI(20.0-39.7)] to 83.3% [95%CI(69.2-91.8)] in Antsohihy; and from 51.3% [95%CI(40.1-62.4)] to 90.5% [95%CI(80.7-95.6)] in Toliary II, for the same periods (Table 10).

There was a significant improvement for the proportion of households that have already repaired holes in campaign nets between the 6th and 24thmonth mark in Ankazobe from 0% [95%CI(0.0-0.0)] to 8.8% [95%CI(4.0-18.1)], and from 0% [95%CI(0.0-0.0)] to 10.4% [95%CI(6.6-16.1)] in Antsohihy. The other districts did not have any significant changes (Table 10).

Table 10: Household experience with repair of any nets

Site	Round	N	Household that received any information on use and care and repair of mosquito nets in the last 6 months	Could cite the recommended way to wash mosquito net*	Household having campaign net with holes	Household that have already repaired hole on campaign net
			%	%	%	%
Ankazobe	6th month	150	42.0 (27.5,58.0)	73.3 (61.9,82.3)	27.5 (21.9,34.0)	0.0 (0.0,0.0)
	12th month	145	32.4 (21.0,46.3)	95.9 (91.3,98.1)	66.2 (56.6,75.1)	4.3 (2.2,8.2)
	24th month	132	12.1 (7.0,20.1)	98.5 (94.0,99.6)	80.7 (70.7,87.9)	8.8 (4.0,18.1)
Mananjary	6th month	150	44.0 (37.1,51.2)	84.7 (74.0,91.5)	56.7 (48.5,64.5)	0.7 (0.1,6.2)
	12th month	140	26.4. (14.1,44.0)	92.9 (86.6,96.3)	86.3 (75.5,92.7)	6.7 (3.2,14.0)
	24th month	118	37.3 (21.4,56.5)	98.3 (91.9,99.7)	94.9 (81.6,98.7)	11.5 (4.4,27.0)
Antsohihy	6th month	150	67.3 (54.5,78.0)	86.0 (75.5,92.5)	28.9 (20.0,39.7)	0.0 (0.0,0.0)
	12th month	143	27.3 (19.0,37.5)	90.9 (81.8,95.7)	68.3 (54.5,79.4)	3.2 (1.2,8.0)
	24th month	116	32.8 (23.3,43.8)	97.4 (92.5,99.1)	83.3 (69.2,91.8)	10.4 (6.6,16.1)
Toliary II	6th month	150	45.3 (32.4,59.0)	68.7 (54.1,80.3)	51.3 (40.1,62.4)	3.3 (1.2,8.8)
	12th month	139	33.1 (24.8,42.6)	89.9 (78.3,95.7)	87.1 (76.8,93.2)	4.3 (1.7,10.5)
	24th month	118	51.7 (40.6,62.7)	98.3 (92.7,99.6)	90.5 (80.7,95.6)	5.9 (3.3,10.5)

6.3.6 Washing methods

At 24th month mark, over 91% of all nets monitored had already been used across all the four districts. At 6th month mark, the proportion of nets reported washed at least once in the last 6 months was lower in Toliary II 47.6% [95% (38.8-56.6)] compared to the two other districts Mananjary 70.8% [95%CI(60.1-79.6)] and Antsohihy 77.5% [95%CI(68.0-84.8)]. For Ankazobe and Toliary II, about 1 in 2 nets was washed at 6th month. This proportion increased significantly to at over 70% at either 12th and 24th month points in both districts. In Mananjary and Antsohihy, the proportion of nets washed was high and remained unchanged during the study. The reported drying method was predominantly on outdoor drying lines for the four districts. The proportion increased from 32.3% [95%CI(18.0,50.8)] at 6th month to 62.4% [95%CI(55.9-68.9)] at 24th month in Ankazobe. There were no significant changes between districts and time for the three remaining districts (Table 11). Predominantly and consistently over time, most nets were washed using a bar of soap (Table 11) – ranging from 70.4% [95%CI(55,25.5)] in Mananjary at the 12th month mark to 95.2% [95%CI(84.3-98.7)] in Toliary II at the 24th month mark.

Table11: Net wash and care

	Ankazobe			Mananjary			Antsohihy			Toliary II		
	6th month N=327	**12th month N=264**	**24th month N=185**	**6th month N=315**	**12th month N=248**	**24th month N=115**	**6th month N=317**	**12th month N=229**	**24th month N=150**	**6th month N=341**	**12th month N=251**	**24th month N=93**
	%	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
Proportion of net that has already been used	71.3 (65.7,76.3)	84.9 (78.3,89.7)	94.1 (81.4,98.3)	74.9 (64.3,83.2)	84.4 (70.4,92.5)	93.1 (83.9,97.2)	70.0 (64.0,75.4)	82.1 (72.9,88.7)	91.3 (78.9,96.7)	80.1 (72.8,85.8)	89.6 (82.7,94.0)	92.5 (72.1,98.3)
Proportion of net that has been washed at least once in the last 6 months among all net that has already been used	N=233	N=224	N=174	N=236	N=211	N=108	N=222	N=188	N=137	N=273	N=225	N=86
	%	%	%	%	%	%	%	%	%	%	%	%
	52.4 (42.1,62.5)	81.7 (74.7,87.1)	77.6 (69.7,83.9)	70.8 (60.1,79.6)	84.8 (74.1,91.6)	93.5 (79.4,98.2)	77.5 (68.0,84.8)	93.1 (80.8,97.7)	84.7 (77.9,89.6)	47.6 (38.8,56.6)	90.2 (84.8,93.8)	84.9 (75.3,91.2
Drying method of the net	N=124	N=206	N=165	N=169	N=186	N=105	N=179	N=182	N=122	N=132	N=208	N=84
	%	%	%	%	%	%	%	%	%	%	%	%
Outside on the ground	47.6 (38.3,57.0)	2.4 (0.7,7.7)	9.1 (4.6,17.0)	10.1 (3.2,27.3)	8.1 (2.9,20.5)	9.5 (4.2,20.3)	0.6 (0.1,4.9)	7.1 (2.6,18.3)	12.3 (7.1,20.4)	3.8 (0.9,14.9)	10.6 (4.5,23.0)	19.1 (12.3,28.3)
Outside on line	32.3 (18.0,50.8)	40.8 (29.7,52.9)	62.4 (55.9,68.9)	64.5 (47.0,78.8)	71.5 (56.8,82.7)	77.1 (61.5,87.7)	96.7 (89.2,99.0)	91.2 (77.9,96.8)	79.5 (66.2,88.5)	62.1 (44.4,77.1)	80.3 (69.3,88.0)	65.5 (57.9,72.3)
Outside bush or fence	10.5 (5.7,18.6)	30.6 (24.4,37.6)	13.3 (8.1,21.2)	23.7 (12.6,40.0)	14.5 (8.0,25.0)	12.4 (4.4,30.2)	2.2 (0.4,12.4)	1.1 (0.2,5.6)	0.8 (0.1,7.2)	18.9 (8.9,35.7)	8.7 (4.3,16.7)	11.9 (5.0,25.6)
Inside	9.7 (4.5,19.5)	26.2 (14.3,43.1)	15.2 (7.2,29.3)	1.8 (0.4,8.5)	5.9 (2.2,14.8)	1.0 (0.1,7.5)	0.6 (0.1,5.5)	0.6 (0.1,5.6)	7.4 (2.7,18.5)	15.2 (6.9,30.1)	0.5 (0.1,4.2)	3.6 (0.4,25.6)
Proportion of the soap used for the last wash	%	%	%	%	%	%	%	%	%	%	%	%
Soap bar	78.2 (59.2,89.9)	80.1 (74.6,84.)	86.1 (76.3,92.2)	69.8 (60.8,77.6)	70.4 (55,25.5)	84.8 (71.9,92.4)	81.6 (3.6,25.5)	84.6 (74.3,91.3)	83.6 (65.6,93.2)	71.2 (50.4,85.8)	83.2 (70.5,91.1)	95.2 (84.3,98.7)
Detergent (OMO etc.)	12.1 (3.9,31.6)	11.7 (6.8,19.1)	12.1 (5.9,23.4)	24.9 (17.0,34.8)	16.1 (9.7,25.6)	15.2 (7.6,28.1)	16.2 (7.1,32.9)	11.0 (3.6,25.5)	16.4 (6.8,34.4)	24.2 (12.4,42.0)	10.1 (3.6,25.5)	4.8 (1.3,15.7)
Bleach	0.0	0.0	0.0	0.6 (0.1,5.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mix	9.7 (3.6,23.3)	8.3 (4.3,15.0)	1.8 (0.4,8.1)	4.7 (1.7,12.7)	13.4 (6.9,24.6)	0.0	2.2 (06,7.9)	4.4 (1.2,15.0)	0.0	4.5 (1.0,18.1)	6.7 (2.6,16.2)	0.0

7 Net loss and physical integrity for the DawaPlus® and Yorkool® brands in the additional districts at 24th month

7.1 Net loss

The district with the highest proportion of households still in possession of all the nets received from the campaign is Beloha, with 84.0% [95%CI(70.2-92.1)]. In the other three districts, the proportion is 49.3% [95%CI(37.2% - 61.5%)] in Sambava, 56.7% [95%CI(48.5% - 64.5%)] in Manja, 68.0% [95%CI(60.1% - 75.0%)]in Vondrozo (Table 12).

In three of the districts, main reason for the loss of the campaign net was that it was given away to relatives: 48.5% in Manja, 59.3% in Sambava and 57.3% in Vondrozo. In Beloha, the predominant reason for loss was that nets were destroyed accidentally (67.7%).

Table12: Lost nets from campaign

Site	Manja	Sambava	Beloha	Vondrozo
	N=150	**N=150**	**N=150**	**N=150**
	% (95 CI)	**% (95 CI)**	**% (95 CI)**	**% (95 CI)**
Proportion of household who are still in possession of all the nets they received from the campaign	56.7 (48.5,64.5)	49.3 (37.2,61.5)	84.0 (70.2,92.1)	68.0 (60.1,75.0)
Main reason for the loss of the campaign net among all net lost				
	N=130 %	N=145 %	N=34 %	N=89 %
Net was stolen	0.8	0.0	0.0	2.2
Destroyed accidentally	42.3	10.3	67.7	28.1
Given away to relatives	48.5	59.3	5.9	57.3
Given away to others	0.8	7.6	0.0	3.4
Thrown away	1.5	6.2	17.7	3.4
Used for another purpose	5.4	16.6	8.8	5.6

7.2 Physical damaged and pHI indicator

For the four additional districts where Yorkool® and DawaPlus® were assessed, the proportion of nets with holes greater than 0.5cm was over 69%. In the districts receiving DawaPlus®, the proportion was more striking in Vondrozo, at 90.9% [95%CI(81.9-95.6)] compared to 68.7% [95%CI(56.1-78.9)] in Sambava.(Table 13).There is no significant difference between the two districts receiving Yorkool® brand, Manja and Beloha(Table 13).The most predominant hole category was 0.5-2.0 cm and 2-10 cm in the four districts Again among the DawaPlus® districts, the hole category between 2 and 10 cm was more prevalent in Vondrozo 91.7% [95%CI(86.3-95.1)] compared to 70.8% [95%CI(61.7-78.5)] in Sambava (Table 13).The proportion of serviceable net with pHI<=642 was higher in Sambava 74.1% [95%CI(64.0-82.1)] compared to 55.6% [95%CI(47.7-63.1)] in Vondrozo (Table 13), both receiving DawaPlus® brand net. No significant difference was observed between the two Yorkool® districts.

Table13: Physical condition (integrity) of surviving cohort nets

		Manja	**Sambava**	**Beloha**	**Vondrozo**
		N=182	**N=185**	**N=148**	**N=252**
		% (95 CI)	**% (95 CI)**	**% (95 CI)**	**% (95 CI)**
Campaign net with holes ≥0.5cm		80.7. (71.5,87.6)	68.7 (56.1,78.9)	77.0 (62.3,87.2)	90.9 (81.9,95.6)
Proportion of net with holes by		%	%	%	%
Hole size category	[0.5-2.0[cm	85.7 (79.2,90.4)	80.0 (69.2,87.7)	75.0 (61.5,85.0)	93.3 (75.6,98.4)
	[2-10[cm	81.9 (76.9,85.9)	70.8 (61.7,78.5)	75.0 (61.2,85.1)	91.7 (86.3,95.1)
	[10-25] cm	43.4 (34.1,53,2)	38.9 (32.3,46.0)	52.7 (40.7,64.4)	59.1 (52.6,65.3)
	> 25 cm	14.8 (8.3,25.1)	19.5 (12.3,29.4)	29.1 (19.6,40.7)	24.6 (20.4,29.4)
Hole index (pHI)		%	%	%	%
pHI	Good: pHI Є [0-64]	30.8 (24.0,38.4)	43.2 (32.4,54.8)	28.8 (18.6,41.7)	17.1 (11.6,24.4)
	Damaged: pHI Є [65- 642]	42.3 (33.1,52.1)	30.8 (23.3,39.5)	30.8 (23.6,39.1)	38.5 (32.2,45.2)
	Too torn: pHI ≥ 643	26.9 (17.6,38.8)	26.0 (17.9,36.0)	40.4 (30.6,51.0)	44.4 (36.9,52.3)
Net Integrity		% (95 CI)	% (95 CI)	% (95 CI)	% (95 CI)
Serviceable (pHI≤642)		73.1 (61.2,82.4)	74.1 (64.0,82.1)	58.8 (48.2,68.6)	55.6 (47.7,63.1)

8 Insecticidal effectiveness of nets

Results from bioassays on new nets and nets after three/six, 12 or 24 months of use are presented in tables 14 and 15. The average mosquito mortalities on new nets coming from packaging was 98.6%. After three or six months of use (depending on the cohort), the average mosquito mortalities surpassed the WHO threshold (≥80.0%) in all study sites. Average vector mortalities were 98.9%, 95.0%, 97.9% and 96.9% in Ankazobe, Antsohihy, Mananjary and Toliary II, respectively. After 12 months of use, average mortalities were 60.4%, 70.5%, 50.8% and 60.7% in Ankazobe, Antsohihy, Mananjary and Toliary II, respectively. Mosquito mortality in the negative control was always under 5%.

Mortality of *An. Arabiensis* at baseline, after three/six months of use, and after 12 months of use, is presented in Figure 4, and show decreasing mortality rates over time. After three or six months of use, the mosquito mortality ranged between 82% and 100% (Figure 5). After 12 months of use, among 120 nets tested, only 13 nets were considered as effective nets (with mosquito mortality above 80%): 2 nets were collected in Ankazobe, 4 nets in Antsohihy, 3 nets in Mananjary and 4 nets in Toliary II (Figure 6).

After 24 months of use, the average mortality was far below the WHO threshold (Figure 7). Indeed, mortality with DawaPlus® was 15.7% and 15.2% in Sambava and Vondrozo, respectively. With PermaNet 2.0®, mortality was 32.5%, 28.9%, 21.0% and 30.4% in Ankazobe, Antsohihy, Mananjary and Toliary II, respectively. Mortality with Yorkool was 23.1% and 12.3% in Beloha and Manja respectively (Table 15).

Table 14. Results from net bioassays at baseline and after three/six and 12 months of use

		Locality							
		Ankazobe		Antsohihy		Mananjary		Toliary II	
Net age	Baseline	3 months	12 months	3 months	12 months	3 months	12 months	3 months	12 months
No. Collected nets	30	30	30	30	30	30	30	30	30
Average KD %	76,8	62,1	46,4	74,1	62,3	60,8	36,6	64,6	34,4
sd KD %	20,2	7,7	25,4	17,2	33,9	6,1	28,1	11	27,6
Average mortality %	98,6	98,9	60,4	95,0	70,5	97,9	50,8	96,9	60,7
sd mortality %	5,0	5,3	19,7	8,9	17	6,9	24,8	7,8	22,2

Table 15. Results from net bioassaysafter24 months of use

Net brand	DawaPlus		PermaNet 2.0				Yorkool	
Locality	Sambava	Vondrozo	Ankazobe	Antsohihy	Mananjary	Toliary II	Beloha	Manja
No. Collected nets	30	30	30	30	30	30	30	30
Average KD %	49,2	30,4	59,5	53,6	33,6	53,1	30,9	38,2
sd KD %	34,4	26,8	30,9	29,7	28,7	32,7	32,0	33,4
Average mortality %	15,7	15,2	32,5	28,9	21,0	30,4	23,1	12,3
sd mortality %	19,0	20,1	30,0	27,0	23,1	31,4	30,2	19,1

Figure 4. Percentage of mortality of *An. arabiensis* after 24hours of exposition on new nets(Month = 0), on nets after three/six months of use (Month=3) and after12 months of use (Month=12)

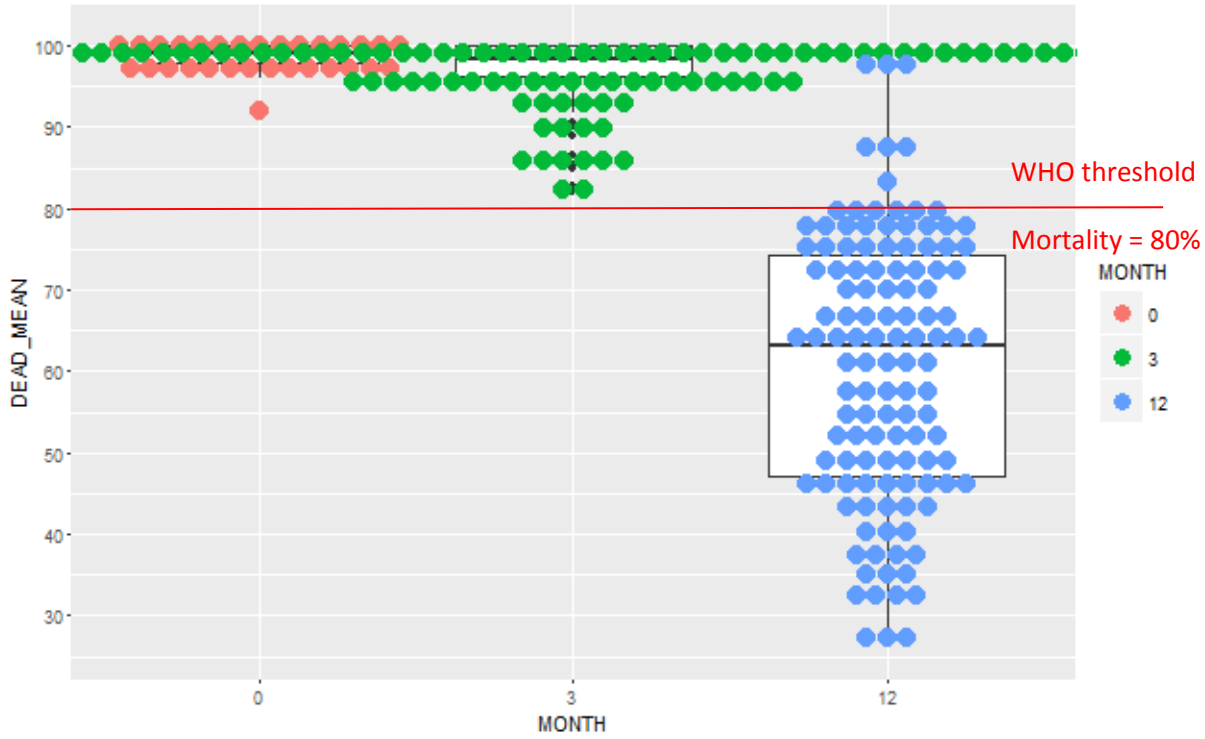


Figure 5. Percentage of mortality of *An. arabiensis* exposed on nets after three/six months of use, by locality

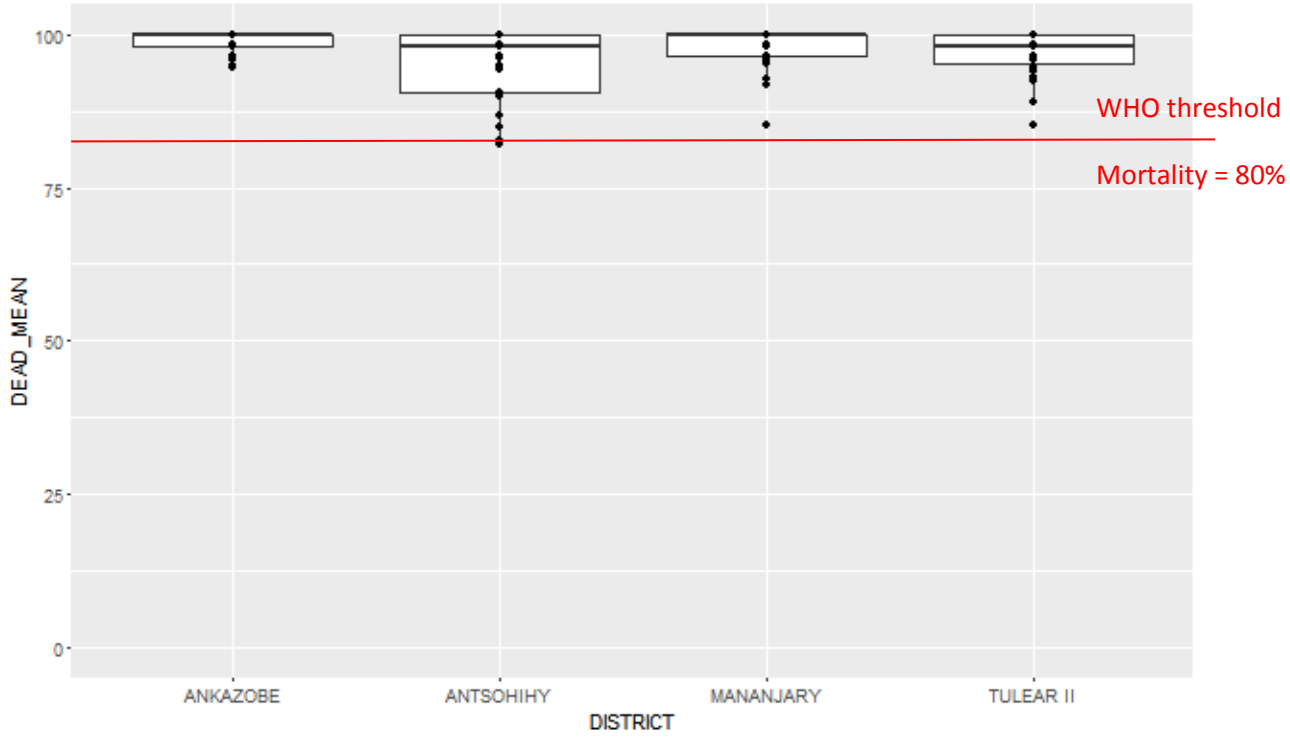


Figure 6. Percentage of mortality of *An. arabiensis* exposed on nets after 12 months of use, by locality

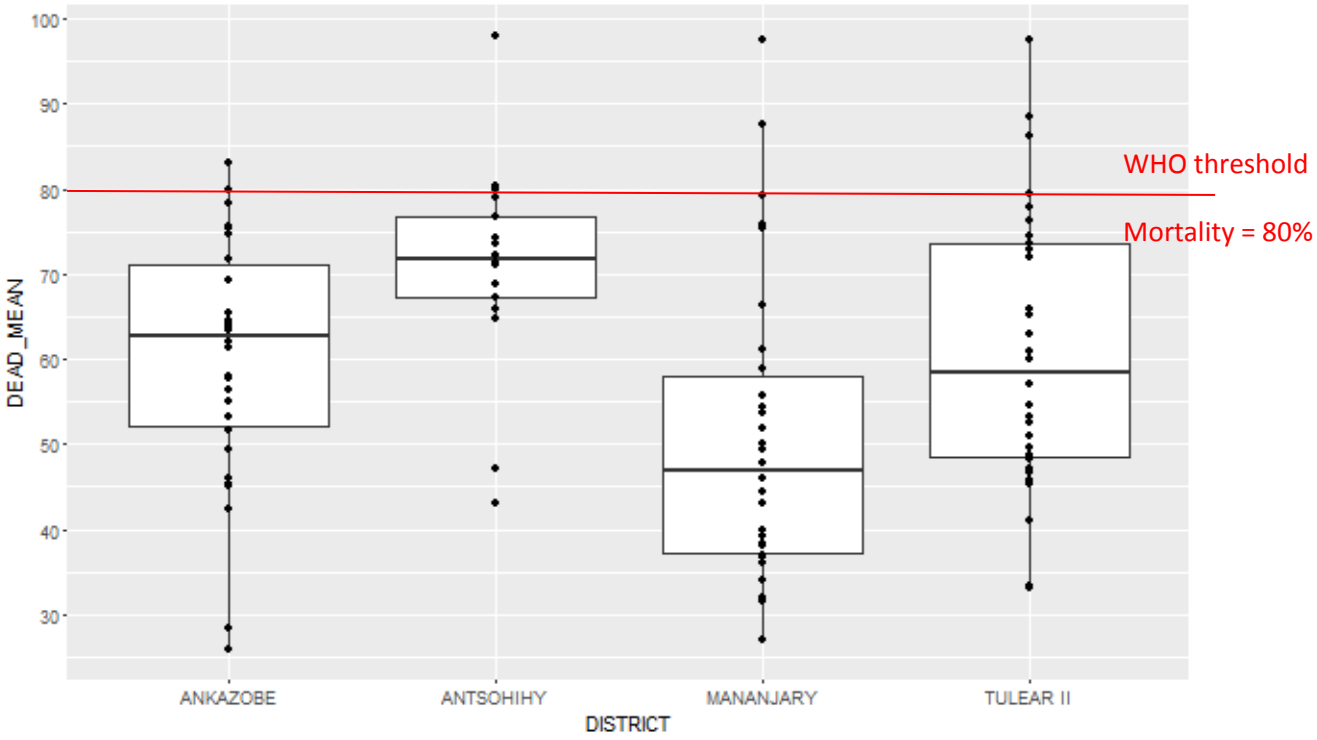
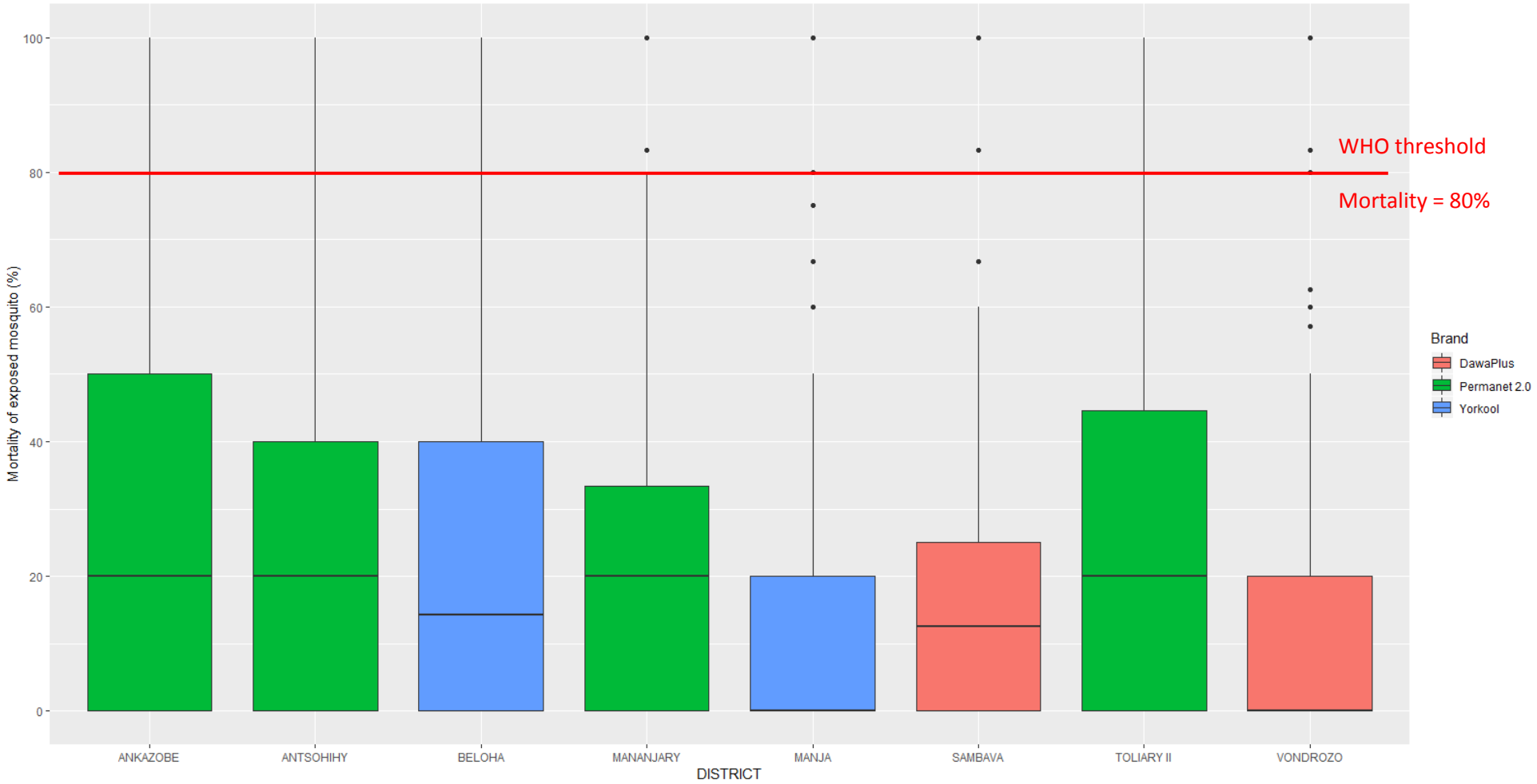


Figure 7. Percentage of mortality of *An. arabiensis* exposed on nets after 24 months of use, by locality



9 Recommendations

As the results of the bioefficacy of nets distributed during the campaign were obtained only from the four PermaNet districts, Yorkool two districts, and two Dawaplus districts, Net sampling in other districts throughout Madagascar following the next distribution program is necessary. This will allow program staff to have a better picture of the bioefficacy of nets throughout the nation. Moreover, in Madagascar, the main strategy of net distribution is by mass campaign every three years, problematic given that the bioefficacy effectiveness of the nets is lost 12 months after distribution. A change in distribution strategy by replacing mass distribution campaigns with continuous distribution may remedy this problem, as well as problems regarding loss and theft. In addition, it may be impactful to conduct in-depth studies to understand why the effectiveness of mosquito nets used in Madagascar is shorter than effectiveness declared by the manufacturers. This in-depth study may also answer questions surrounding why that survivorship and physical durability are better in the North/Center regions compared to the South, with the hope that the study will show how proper net care can be promoted in the South – particularly with messages on drying and washing.

10 References

- World Health Organization. Guidelines for laboratory and field-testing of long-lasting insecticidal nets (World Health Organization, Geneva, 2013).
- Randriamaherijaona S., Velonirina HJ., Boyer S. Susceptibility status of Anopheles arabiensis (Diptera: Culicidae) commonly used as biological materials for evaluations of malaria vector control tools in Madagascar. Malar. J. (2016) 15:338.
- National Strategic plan 2018-2022

11 Annex

Additional results related to Sambava (DawaPlus®), Manja (Yorkool®), Beloha (Yorkool®) and Vondrozo (DawaPlus®)

1.1 Summary of the study sites and the sampling (additional districts)

Transmission zone	**District**	**Campaign net period**	**Data collection period**
Perennial transmission	Sambava	September	24-month post campaign
Long transmission	Manja	September	24-month post campaign
Long transmission	Beloha	September	24-month post campaign
Long transmission	Vondrozo	September	24-month post campaign

1.2.Net care and repair (additional district)

Site	Round	N	Household that received any information on use and care and repair of mosquito nets in the last 6 months	Could cite the recommended way to wash mosquito net*	Household having campaign net with holes	Household that have already repaired hole on campaign net
			%	%	%	%
Manja	24th month	150	5.3 (2.2,12.3)	87.3 (81.1,91.7)	92.4. (85.2,96.2)	16.7 (10.3,25.8)
Sambava	24th month	150	28.0 (20.3,37.3)	87.3 (74.6,94.2)	89.7 (82.6,94.2)	5.3 (2.7,10.3)
Beloha	24th month	150	27.3 (19.1,37.5)	99.3 (95.0,99.9)	80.6 (68.5,88.8)	8.7 (4.8,15.3)
Vondrozo	24th month	150	7.3 (3.3,15.6)	68.7 (59.4,76.7)	98.6 (95.4,99.6)	13.3 (10.6,16.7)

**the recommended way to wash a mosquito net: Gently, in a basin, with mild soap*

1.3-Net wash and care (additional district)

Site	Manja	Sambava	Beloha	Vondrozo
	24th month N=182	24th month N=185	24th month N=148	24th month N=252
	%	%	%	%
Proportion of net that has already been used	98.4 (92.8,99.6)	95.1 (85.7,98.5)	100.0 (.,.)	98.0 (91.9,99.6)
	N=179	N=176	N=148	N=247
	%	%	%	%
Proportion of net that has been washed at least once in the last 6 months among all net that has already been used	96.7 (91.5,98.7)	84.7 (68.2,93.4)	89.9 (77.8,95.7)	93.5 (87.7,96.7)
Drying method of the net	N=175	N=167	N=136	N=238
	%	%	%	%
Outside on the ground	2.3 (0.6,8.2)	0.6 (0.1,6.2)	19.9 (15.6,24.9)	8.8 (4.8,15.6)
Outside on line	61.1 (46.2,74.2)	94.6 (87.3,97.8)	50.0 (43.2,56.8)	63.9 (49.0,76.5)
Outside bush or fence	34.9 (23.2,48.5)	4.2 (1.5,11.3)	30.1 (22.3,39.4)	27.3 (17.5,40.0)
Inside	1.7 (0.5,5.9)	0.6 (0.1,5.6)	0.0	0.0
Proportion of the soap used for the last wash	%	%	%	%
Soap bar	25.7 (15.7,39.2)	76.1 (67.9,82.7)	38.2 (24.7,54.9)	75.2 (59.2,86.4)
Detergent (OMO etc.)	63.4 (52.1,73.5)	22.2 (15.3,30.9)	58.8 (44.2,72.1)	7.6 (5.9,9.7)
Bleach	0.0	0.0	0.0	16.8 (7.0,35.2)
Mix	10.9 (5.8,19.6)	1.8 (0.2,11.8)	2.9 (0.9,9.0)	0.4 (0.1,3.0)

1.4. Frequency of use of the campaign net the week before the survey (additional district)

Site	Round	N	Used the net at least 5 nights out of 7 during the previous week (%)
Manja	24th month	179	89.9
Sambava	24th month	176	78.4
Beloha	24th month	148	87.8
Vondrozo	24th month	247	87.5