Options and considerations for maintaining universal coverage and use of long-lasting insecticidal nets (LLIN) in sub-Saharan Africa

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Prof. Dr. Jörg Schibler

Dekan

In memory of Idrissa Dante, who first told me “il faut être utile”.

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List of abbreviations

ACT	Artemisinin Combination Therapy
AIDS	Acquired Immune Deficiency Syndrome
AMP	Alliance for Malaria Prevention
ANC	Ante-Natal Care
BCC	Behaviour Change Communication
CBOs	Community Based Organizations
CCOP	Communication Community of Practice
CD	Continuous distribution
CHW	Community Health Worker
DDT	Dichlorodiphenyltrichloroethane
DHS	Demographic and Health Surveys
DRC	Democratic Republic of Congo
EPI	Expanded Programme on Immunization
FANTA	Food and Nutrition Technical Assistance project
FGD	Focus Group Discussions
GFATM	Global Fund for AIDS, Tuberculosis and Malaria
GHS	Ghana Health Service
HBM	Health Belief Model
HIV	Human Immuno-deficiency Virus
HWG	Harmonization Working Group
IFRC	International Federation of the Red Cross and Red Crescent Societies
IMBP	Integrative Model of Behavioural Prediction
IPC	Inter-Personal Communication
IPTp	Intermittent preventive treatment for pregnant women
IQR	Inter-Quartile Range
IRB	Institutional Review Board
IRS	Indoor Residual Spraying
ITN	Insecticide-Treated Net
JHSPH	Johns Hopkins Bloomberg School of Public Health
JHU	Johns Hopkins University
JHUCCP	Johns Hopkins University Center for Communication Programs
LGA	Local Government Area
LLIN	Long-Lasting Insecticidal Nets
LQAS	Lot Quality Assurance Sampling
MAP	Malaria Atlas Project
MEDA	Mennonite Economic Development Associates
MERG	Malaria Monitoring and Evaluation Reference Group
MICS	Multiple Indicator Cluster Surveys
MIS	Malaria Indicator Surveys
MSD	Medical Stores Department

NBS	National Bureau of Statistics
NGOs	Non-Governmental Organizations
NMCP	National Malaria Control Programme
PCA	Principal Component Analysis
pHI	proportionate Hole Index
PMI	President's Malaria Initiative
PSI	Population Services International
PYP	Person-Years-of-Protection
RBM	Roll Back Malaria
RCH	Reproductive and Child Health
SDC	Swiss Agency for Development and Cooperation
THMIS	Tanzania HIV and Malaria Indicator Survey
TMTL	Textile Manufacturers of Tanzania Limited
TNVS	Tanzania National Voucher Scheme
TRA	Theory of Reasoned Action
U5CC	Under 5 Catch-Up Campaign
UCC	Universal Coverage Campaign
UNCST	Uganda National Council of Science and Technology
USAID	United States Agency for International Development
USD	US Dollars
VCWG	Vector Control Working Group
WHO	World Health Organization
WHOPES	World Health Organization Pesticide Evaluation Scheme
ZMCP	Zanzibar Malaria Control Programme

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Summary

Malaria causes over 600,000 deaths annually, primarily among young children in sub-Saharan Africa, comprising a large proportion of the disease burden. Long lasting insecticidal nets (LLIN) are the primary vector control measure to prevent malaria, reducing malaria cases by 50% when used at high rates. However, high use rates (over 80%) first require high rates of intra-household availability of LLIN. Currently, mass campaigns are the primary channel for distributing LLIN to achieve universal coverage, but fail to maintain high levels of intra-household access to LLIN between campaigns. Identifying ways to maintain consistent high rates of intra-household access and ways to sustain high rates of use are crucial to achieving declines in malaria burden.

The aim of this thesis was to improve the evidence-based development of continuous ITN distribution strategies in malaria endemic countries, through a better understanding of the options for distribution channels, and through an improved understanding of determinants of net use and the impact of behaviour change communication. Quantitative and qualitative methodologies were used to model outcomes of combinations of continuous distribution channels, assess the reasons behind continued LLIN use in reduced-burden areas of Tanzania, apply the revised universal coverage indicators in Nigeria and to 41 DHS and MIS surveys to recalculate the net use gap, explore the determinants of discarding or giving away LLINs, and to evaluate the impact of a behaviour change communication intervention on LLIN care and repair behaviours and median net lifespan.

These results showed that for continuous distribution strategies, over a ten year period there is a significant amount of excess LLIN distributed through mass campaigns, and that program and overall costs can be made more efficient by distributing the optimal number of nets through a combination of continuous distribution channels that reach the majority of the at-risk population. In the case of Tanzania, ANC and EPI distribution plus a school channel delivering nets each year to pupils in every other class of primary and secondary school was most likely to sustain universal coverage.

Qualitative data collected in Zanzibar and Bukoba (Tanzania) demonstrated that the perceived risk of malaria had decreased among the respondents, and malaria control interventions were credited for the decline, although malaria was still considered a significant threat. Participants' conceptualization of risk and aspects of comfort (getting a good night's sleep, avoiding biting pests) appeared to play a large role in personal decisions to use nets consistently or not. Barriers to comfort (feeling uncomfortable or trapped; perceived difficulty breathing, or itching/rashes) were frequently cited as reasons not to use a net consistently. These data offer a strong way forward for messaging to maintain LLIN use even as malaria burden decreases, by focusing on the non-malaria benefits of LLIN use.

We also applied the universal coverage indicators validated in 2013 to the Nigeria 2010 MIS to illustrate their utility for LLIN program planning. States with a recent mass campaign had ownership rates of 75% overall, but a considerable intra-household ownership gap remained, with 66% of households with any ITN not having enough for every family member. In contrast, the analysis comparing actual against potential use showed that ITN utilization was good overall with only 19% of people with access not using the ITN, but with a significant difference between the North, where use was excellent (use gap 11%), and the South (use gap 36%) indicating the need for enhanced behaviour change communication in Southern Nigeria.

When we expanded the comparisons of intra-household (or population) access and LLIN use to 41 DHS and MIS surveys from 2005-2012, the median proportion of users compared to those with access was high, at 82.1%. Even at population access levels below 50%, a median 80.6% used an ITN given they had access, and this rate increased to 91.2% for access rates above 50%. Linear regression of use against access showed that 89.0% of household members with access to nets used them the night before, demonstrating that the previously conceived gap between ownership and use was a poor comparator, and that the gap was primarily driven by lack of intra-household access. BCC programs can now begin to use these indicators to further pinpoint areas or household characteristics that require additional behaviour change, and allocate resources according to specific needs.

We examined 14 household surveys from Ghana, Senegal, Nigeria and Uganda to assess the determinants of discarding nets, and the degree to which households give away nets to other households after a mass campaign, or use LLINs for other purposes than sleeping. Intra-household re-allocation of nets was sensitive to current household net ownership and the time elapsed since mass distribution. These factors can be addressed programmatically to further facilitate reallocation within a given community. The overwhelming majority of nets were used for malaria prevention. Of the repurposed nets (<1% overall), the majority were already considered too torn, indicating they had already served out their useful life for malaria prevention. National programs and donor agencies should remain confident that overall, their investments in LLIN are being appropriately used.

Finally, we planned, implemented, and evaluated a BCC intervention intended to promote care and repair behaviours to extend net life. Exposure to the intervention was strongly correlated with increased positive attitude towards care and repair, and increases in attitude were positively correlated with observed net repairs, and with the proportion of nets in serviceable condition. Estimated median net lifespan was approximately one full year longer for nets in households with a positive attitude compared to negative attitude towards care and repair. Care and repair messages are easily incorporated into existing malaria BCC platforms, and will help contribute to improved net condition, providing more protection from malaria.

This thesis demonstrates that high rates of use of LLIN are the norm rather than the exception, and that use is primarily driven by intra-household access – that is, households having enough nets for their family members. Reaching and maintaining high levels of access will require concerted efforts to determine the best continuous distribution strategy based on a given country (or region's) operational capacity to deliver nets, and mass campaigns are by no means obsolete. Program planners must take into account the best options for continuous distribution of nets through optimal channels, as delivering the correct number of nets will eventually lead to cost savings over time, as excess nets are minimized, and replacement occurs when nets are needed, rather than at pre-determined intervals. Behaviour change communication has already contributed to high LLIN use rates, and has been demonstrated herein to significantly impact median net lifespan. National plans that optimize both distribution strategies and accompanying BCC strategies will be necessary to ensure continuing protection of all individuals at risk of malaria, and to maximize investments.

1 Introduction

1.1 Malaria

Malaria is a parasitic disease caused by four species of *Plasmodium*, transmitted by several species of female anopheles mosquitoes. *P. falciparum* is the predominant species in sub-Saharan Africa, and responsible for the majority of severe and fatal malaria cases worldwide, while *P. vivax, P. ovale*, and *P. malariae* are found throughout the globe in more temperate areas, and contribute greatly to overall morbidity, although not mortality of the disease. Female anophelines ingest gametocytes during a blood meal from an infected person, whereupon the parasites undergo sexual reproduction in the mosquito midgut, and travel to the mosquito's salivary glands. From this point the female mosquito can transmit sporozoites during her next blood meal to a new human host. Sporozoites travel through the bloodstream to the liver, where they mature and reproduce as merozoites for about a week, bursting open liver cells to return back into the bloodstream, where they infect red blood cells. Clinical disease occurs during this erythrocytic period, and occurs no earlier than 7 days after initial infection, and ranges depending on the parasite species, with *P. falciparum* having the shortest incubation period of 8-11 days. The length of the developmental stage in the mosquito (extrinsic incubation period) ranges from 8-30 days or more, depending on host species and the ambient temperature. *P.* vivax may take as little as 8 days, while *P. falciparum* averages 11-21 days (Boyd 1932). This period has important implications for vector control specifically with LLINs.

Simple malaria is characterized by high fever, chills, malaise, nausea, headache, body pains, and diarrhea (Warrell *et al*. 2002), while severe malaria is a complex disorder, including severe anemia, coma, respiratory distress, convulsions, circulatory collapse, jaundice, and hemoglobinuria (World Health Organization 2000; Mackintosh *et al*. 2004). Severe and cerebral malaria can have lasting consequences, including cerebral palsy, speech and cognitive impairment, blindness, and epilepsy (Murphy *et al*. 2001).

Children under five bear the highest burden of malaria; the majority of mortality falls in this age category, particularly in sub-Saharan Africa. Neonates and infants benefit from some conferred maternal immunity, although this fades within six months, putting children between 6 and 36 months at a high risk of mortality in highly endemic areas (Warrell *et al*. 2002). Pregnant women are also more vulnerable than their non-pregnant counterparts, especially in their first pregnancy. Malaria carries a high risk of abortion, stillbirth and maternal mortality in low and unstable transmission areas;

in high transmission areas, low-birth weight and resulting impact on child survival are the main complications. Worldwide, approximately 600,000 individuals die of malaria each year (World Health Organization 2013c).

1.2 Malaria Vector Ecology

Prevention of malaria has focused on reducing contact between infectious mosquitoes and human hosts. *Anopheles gambiae* is the primary vector for *P. falciparum* in sub-Saharan Africa, and is endophagic and endophilic (Sinka *et al*. 2012). *Anopheles funestus* is the other major malaria vector in Africa, and is likewise endophagic and endophilic, with peak biting period occurring after 22:00. Both species exhibit some outdoor biting and resting. By contrast the third major vector, *Anopheles arabiensis*, is both anthropophilic and zoophilic as well as exophilic, posing potential problems for indoor control measures. Their peak biting times can be in the early evening, around 19:00, and the early morning (3:00) (Sinka *et al*. 2012). All three are found throughout sub-Saharan Africa, with *A. Arabiensis* concentrated in areas of lower rainfall such as the drier savannah areas (Coetzee *et al*. 2000).

The indoor resting biting and resting behaviour of the dominant vectors makes them particularly susceptible to insecticides used indoors, whether through the application of insecticide to walls via indoor residual spraying, or embedded in/applied to the fibres of mosquito nets. However, the small percentage of outdoor biting vectors remain a source of residual transmission.

1.3 Malaria Prevention

Early efforts in the first part of the 20th century included elimination of mosquito breeding sites through drainage and larviciding with oil and Paris Green. Screening, prophylactic quinine, and environmental engineering to eliminate breeding sites were successful for a time in Panama under Gorgas, and in the Malaya rubber plantations under Watson (Packard 2011). Quinine campaigns prior to World War I in Italy were successful at reducing mortality, but not morbidity, as they had almost no effect on transmission. During World War II DDT was developed and catalysed investment in development of spray equipment, including via aerial delivery. With the success of a DDT program in Sicily and Cyprus, large scale control programs began relying on indoor house spraying with DDT in Ceylon, India, and Venezuela in 1946 (Packard 2011). From the early 1950’s through the 1969, indoor spraying was the primary tool in the fight against malaria, under the WHO Malaria Eradication Programme. However, declines in malaria were not sustained, and malaria resurged in the tropical countries, many of whom had been spraying continuously for ten years.

By 1969, 56 species of anophelines were known to be resistant to DDT, and work began to assess and use other types of insecticides, including other organophosphates, carbamates, and pyrethroids. The costs of these insecticides were significantly higher, and cost-cutting strategies tended to result in less effective spray programs (Packard 2011).

Untreated mosquito nets had been used to prevent night-time biting pests for centuries but were not considered effective as a widespread tool for vector control until the early 1980's, when technologies were developed to treat them with insecticides. Small-scale trials showed that ITNs were associated with significant reductions in malaria morbidity in African, Asian, and Latin American populations (Ranque *et al*. 1984; Rozendaal 1989; Bermejo *et al*. 1992). Large randomized controlled trials in the 1990's confirmed the efficacy of ITNs at reducing malaria cases throughout a range of endemicity zones (Lengeler 2004; Phillips-Howard *et al*. 2003). A Cochrane review in 2004 laid the foundation for scale-up of ITNs as the main vector control tool, concluding that use of ITNs reduces the number of malaria cases by 50%, saving 5.5 lives for every 1000 children using a net (Lengeler 2004). Early ITNs were treated manually by dipping them into insecticide; this process required retreatment campaigns every six months, and these were relatively unsuccessful. Later in the 2000's long-lasting insecticidal nets (LLIN), which did not need retreatment and whose insecticide was specified to last through at least 20 washes, began to be manufactured and sold at subsidized prices, and distributed to pregnant women and young children through antenatal care visits and immunization clinics. In December 2002, the first mass campaign was conducted in a rural district of Ghana, where ITNs were distributed to all children attending a measles vaccination campaign (Grabowsky *et al*. 2007). In 2003 Zambia also conducted a limited mass ITN campaign integrated with measles vaccination campaign, delivering 75,000 nets to all children under five years old (Grabowsky *et al*. 2005). The first nation-wide mass campaign was conducted in Togo in 2004 targeting children under five, contributing to a reduction in severe anaemia and clinical malaria in southern districts, but not in the northern district (Terlouw *et al*. 2010). Other early mass campaigns were linked with door-to-door vaccination campaigns, as the target groups were complementary.

1.4 ITN vs IRS

Large scale IRS programs using DDT were, as earlier described, the focus of the Global Malaria Eradication Campaign of the 1950's and 1960's. After the failure of the campaign, IRS was no longer widely used as a vector control strategy, but was still maintained by some public health programs and particularly among private companies for employee protection in a wide range of areas. IRS both repels mosquitoes from houses and kills resting mosquitoes, and requires very high levels of community coverage in order to be effective enough to provide significant reductions in malaria transmission, with programs aiming to spray 90% of targeted households. Spraying occurs between one and three times per year depending on the insecticide used and the transmission patterns of the area (Pluess *et al*. 2010). While both ITN and IRS provide similar health benefits, cost differences in the insecticides themselves, combined with the need for multiple spray rounds per year in some areas, make IRS much more expensive per child death averted than ITNs (Yukich *et al*. 2008). However, ITNs currently are produced with only a single class of insecticide (pyrethroids), leading to significant concerns of the development of insecticide resistance. Current IRS programs, which expanded during the first part of the President's Malaria Initiative in Africa in the late 2000's, were using primarily pyrethroid insecticides, but due to growing vector resistance, many are now switching to other classes, mainly carbamates and organophosphates (President's Malaria Initiative 2014).

1.5 Universal coverage with LLIN

The call for universal coverage with malaria prevention interventions was launched in 2008 by UN Secretary-General Ban Ki-moon. Insecticide-treated net[1] (ITN) distribution up to this point had concentrated on the most vulnerable target groups, pregnant women and children under five, using a mix of distribution models, including campaigns, voucher systems, routine distribution via ANC and EPI clinics, and social marketing (Kilian *et al*. 2010).

With the new target of universal coverage, focusing exclusively on these vulnerable groups was no longer appropriate, and scale-up campaigns began to be implemented to reach the general population.

[1] Insecticide-treated net is a category that includes long-lasting insecticidal nets (LLIN); the terms "net", "ITN" and "LLIN" are used somewhat interchangeably in practice as well as in this document, since the vast majority of nets distributed in sub-Saharan Africa since 2006 have been LLIN.

These universal coverage campaigns aimed to deliver 1 LLIN for every 2 people, with a mix of operational strategies to achieve this at household level. Significant support for these campaigns was obtained through the Global Fund for AIDS, Tuberculosis and Malaria (GFATM) grants, and planning and implementation support was channelled through the RBM Harmonization Working Group (for proposal and planning support) and via the Alliance for Malaria Prevention (AMP), a working group devoted to campaign implementation.

Meanwhile, studies were underway that estimated the average lifespan of LLINs in the field. Manufacturers' studies and WHOPES criteria varied somewhat, with an agreed-upon planning average lifespan of 3 years (Roll Back Malaria Harmonization Working Group 2011). Observations in the field found nets lasting less than this before becoming too torn to use (Allan *et al*. 2012), or much longer than 3 years, depending on field conditions, household practices, and the textile material (Kilian 2010; Kilian *et al*. 2011). While the lifespan of any particular net was impossible to predict, for planning purposes 3 years became the cut-off beyond which nets were deemed unusable, and required replacement. Countries wrote Global Fund proposals that included universal coverage campaigns every three years as a result.

Implementing campaigns every three years ignores the fact that new children are born, new sleeping spaces are created within households, and nets wear out before their average lifespan is over. Maintaining universal coverage is not as simple as planning a campaign every three years; it requires some form of continuous distribution channel to be operating so that families can acquire replacements nets when they need them. To this end, the RBM Vector Control Working Group drafted a Consensus Statement on Continuous Distribution to highlight these points (Roll Back Malaria Vector Control Working Group 2011).

Thus far, continuous distribution channels have primarily focused on the previously targeted groups of pregnant women and children under five by distributing nets through routine ANC and EPI services. These populations are easy to reach through routine services and easy to identify in the context of mass/community distributions. Delivering nets continuously to the general population is a much tougher proposition, as verifying the need for new or replacement nets at household level is extremely difficult to operationalize. Opportunities to reach households through other channels such as schools or community based distribution are promising but remain to be evaluated for effectiveness at sustaining coverage.

1.6 Problems with calculating net use

When the WHO and RBM goals focused on vulnerable populations of children under five and pregnant women, net use indicators correctly focused on usage of nets the previous night by these groups. However, at the time, the 'net use gap' was discussed comparing use by these groups against ownership of at least one net. More than anything, the "gap" illustrated the failure of ANC and EPI delivery channels to scale up ownership. In 2003, households in sub-Saharan Africa had an average of around 1.8 nets (Korenromp *et al*. 2003), not enough to ensure use by multiple under-fives, but perhaps enough for a woman and her infant. As mass campaign distributions rolled out over sub-Saharan Africa ownership rates rose and under-five usage rates rose with them. The 'gap', however, remained as a simple comparison of two very different indicators:

Figure 1.1: Apples and oranges: comparison of WHO/RBM ownership and use indicators. Note that denominators are not the same and therefore not comparable.

Coverage (ownership)	**Use**
# of households with at least one ITN	# of <5s who slept under an ITN the previous night
# of total households in the survey	# of total <5s in the survey

The gap between ownership and use was largely interpreted to indicate that not enough nets were being distributed, but many program planners felt this meant that there were nets not being used, and a number of international meetings were organized in the late 2000's to look at the problem of net use vs ownership. Were nets the wrong shape, size or colour? Was it too hot? Did people not know how to hang the nets properly? Was malaria not seen as a serious illness?

In 2008 the call for universal coverage was made and larger-scale, universal coverage distributions commenced, targeting the general population and aiming to provide one net for every two people. Work by Eisele (Eisele *et al*. 2009) on surveys from 2003-2006 showed that unsurprisingly, children's net use was most strongly and consistently predicted by net ownership, and that having enough nets in the household made it possible for people to use nets. However, the problem of differing denominators persisted, as the comparison was still being made between the percent of households with at least one net, and the percent of under-fives or pregnant women sleeping under a net. In part this was due to the fact that the RBM indicators remained focused on these indicators, and reports and studies duly reported on them. But the indicators did not take into account any information about household members or sleeping spaces, and without comparing household ownership of insecticide-treated nets (ITN) to these, it is not possible to determine whether the net gap was caused by behavioural factors or by the lack of opportunity to use a net.

Compounding this problem was the tendency at the time to present graphs showing net use by under-fives and net ownership of at least one net (World Health Organization 2008; World Health Organization 2009; World Health Organization 2010). This reinforced the perception that the 'net use gap' was larger than it was, and that there were serious obstacles to net use (other than ownership). Vanden Eng *et al*. (Vanden Eng *et al*. 2010) introduced a framework that made use of the standard indicators to address this problem, separating non-use of nets into three categories: children living in households without an ITN, those living in households that owned nets but did not hang them, and those living in households that hung nets but did not use them. Still, this approach was not widely taken up, and did not provide any insight on the reasons for not hanging, or not using nets within the household.

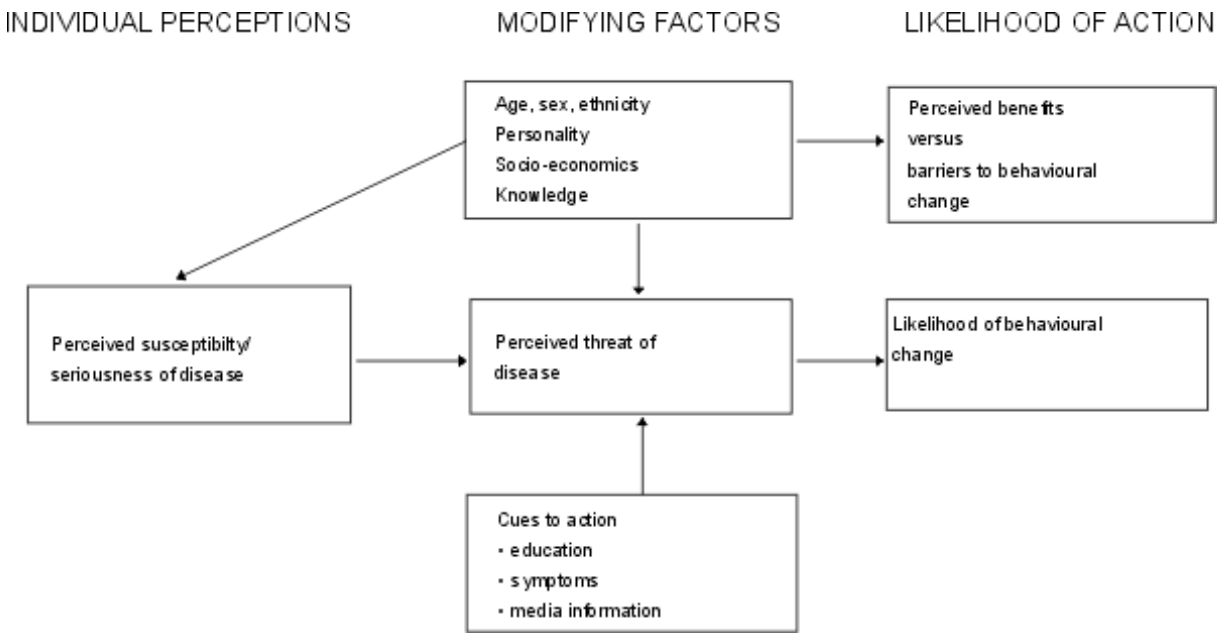
In 2009 the Roll Back Malaria Monitoring and Evaluation Reference Group (MERG) began the process of revising the universal coverage indicators, which were finalized in June 2011 and for which the final document was published only in June 2013 (MEASURE Evaluation *et al*. 2013). The two new indicators include an intra-household access indicator, the percent of households with at least one ITN for every two people, and the percent of the population with access to an ITN in their household. The second indicator measures the proportion of the population that potentially could have used an ITN the previous night, assuming that each ITN is used by 2 people. The first indicator can be directly compared to the existing ownership indicator of at least 1 net to understand the gap between households that have some nets and households that have enough nets. The second indicator can be directly compared to the existing use indicator, as it compares the proportion of people who could have used a net against the proportion of people who did in fact use a net (the previous night). The denominators are the same and the net use gap now reflects only behavioural factors, not an insufficient number of nets for the household.

1.7 Determinants of net use and gaps in the evidence base

In efforts since 2006 to investigate behavioural determinants of the net use gap, the focus was mainly on variables available for analysis in the large household surveys (Malaria Indicator Surveys (MIS), Demographic and Health Surveys (DHS), and Unicef's Multiple Indicator Cluster Surveys (MICS)). Seasonality was an issue and could be measured or estimated when comparing net use rates when surveys were done in the same country at different times of year (Korenromp *et al*. 2003; Thwing *et al*. 2008; Eisele *et al*. 2010). In 2009 Senegal MIS a question about net use year-round was added, perhaps one of the first times that net use other than just the previous night was explored (Thwing 2010, preliminary report). The results shed light on net use patterns around the year during hot, wet, dry and rainy seasons, and provided a baseline to compare efforts to improve consistent net use in subsequent surveys. In 2011 Liberia included a question on exposure to malaria messages in its MIS; Uganda and Zambia did the same in the 2011 MIS. Few surveys asked for the reasons for not using a net, or attempted to explore more distal determinants of net use or the rationale behind the barriers (Pulford *et al*. 2011). A review by Pulford *et al.* in 2011 summarized findings from 2000-2010, focusing on reasons for non-use of nets when they are available. The most cited reasons were feeling hot or uncomfortable under the net, followed by a lack of mosquitoes, but the authors cautioned that the evidence base was too thin and that "minimal dedicated attention" had been paid to the reasons for not using nets. Without these types of questions in the large household surveys, any evidence on non-access determinants of net use was perceived as anecdotal by members of the RBM MERG and donor agencies.

For any given behaviour there are a variety of determinants that influence the behaviour – some more important than others, many depending on the context. A number of theories of behaviour change and conceptual models exist that describe net use and its determinants. The Health Belief Model (Rosenstock 1974; Janz *et al*. 1984) is one of the most widely used models in public health, and is composed of perceived risk, benefits, barriers, and cues to action (Figure 1.2). Later versions of the Health Belief Model include self-efficacy.

Figure 1.2: The Health Belief Model



In the MIS, DHS and MICS, information about age, sex, ethnicity, socioeconomic status, level of education, and sometimes knowledge was collected. Information on other elements of the Health Belief Model such as self-efficacy, perceived threat (susceptibility as well as severity of the disease) and perceived benefits and barriers was rarely, if ever collected, except by programmatic (generally subnational) surveys. Malaria therefore lacks the robust evidence base that family planning and HIV currently enjoy. Decades of behavioural research in these two areas have provided an evidence base that allows researchers to test whether theories like the Health Belief Model fit the data, or whether other theories or principles (theory of reasoned action; integrative model of behavioural prediction, social ecological model) might better explain how individuals make decisions and are influenced by their family, friends, media influences, and changing social environments. Malaria behaviour change programs therefore currently operate using assumptions from the family planning and HIV behavioural theory literature, which may or may not be entirely similar.

Malaria-specific research has shown that use of nets is driven by a variety of factors, including first and foremost the availability of nets within the household (Eisele *et al*. 2009), and then by mosquito density, seasonality, risk perception, social factors, and practical issues (MacCormack *et al*. 1986; Winch *et al*. 1994; Thomson *et al*. 1996; Binka *et al*. 1996; Frey *et al*. 2006; Thwing *et al*. 2008; Toé *et al*. 2009; Baume *et al*. 2009; Ng'ang'a *et al*. 2009; Widmar *et al*. 2009; Atkinson *et al*. 2009; Pulford *et al*. 2011; Beer *et al*. 2012). Non-use of nets has been most often reported due to a perceived lack of mosquitoes and discomfort, generally due to heat (Pulford *et al*. 2011). Physical factors like simply being present the night of the survey and sleeping space arrangements also matter. Sleeping inside and outside during the night, shifting sleeping arrangements within households, and sleeping near kitchen areas are important determinants of use (Toé *et al*. 2009; Baume *et al*. 2009). Repositioning nets throughout the day and evening is an inconvenience that can overcome even the best of intentions. Some nets are not long enough to reach underneath beds, or they are too confining. In addition to these structural factors, fears and attitudes play an extremely strong role, but one that is hard to quantify. Some users are afraid of the insecticide (Baume *et al*. 2009), and feelings of hotness or claustrophobia are common (Binka *et al*. 1996; Binka *et al*. 1997; Alaii *et al*. 2003; Korenromp *et al*. 2003; Frey *et al*. 2006; Pulford *et al*. 2011).

Following successful malaria control campaigns, or during low transmission season when the risk of malaria is reduced, it is still critical that individuals continue preventive efforts. There is a considerable gap in the evidence regarding appropriate and effective messaging during periods of low malaria risk, either because of seasonal changes in malaria risk or because of the effectiveness of malaria interventions. It is largely unclear how to motivate populations who perceive that malaria is no longer a major threat. This is an important issue to address as malaria prevention efforts approach the elimination of the disease in certain regions and countries. As nuisance biting and perception of mosquito density are known to predict net use, it may be possible to maintain good habits of net use by focusing on this particular benefit, even as transmission itself declines.

1.8 Maintaining nets in good condition

As important as delivering nets at the right time is for maintaining universal coverage, perhaps equally important is maintaining nets in good condition for as long as possible in the home. LLIN still provide protection against malaria when torn, due to the repelling and killing effect of the insecticide, but it is hypothesized that their protective capacity diminishes as the number and size of holes in the net grows. It is well known that LLIN are subject to many stressors at the household level, from regular wear and tear from being tucked in and used, stretching and wear during washing, pulling and tugging by children, snagging on rough bedframes, hanging nails, and walls, etc. Rats are observed to remove pieces of netting material for their nests, and candles, kerosene lanterns, and hot embers from cooking fires contribute to burns and melting of the netting material (Kilian *et al*. 2008; Batisso *et al*. 2012; Loll *et al*. 2013; Loll *et al*. 2014; Hunter *et al*. 2014).

Durability studies for LLIN have found that nets can persist in varying conditions for varying lengths of time, all somewhat close to the average 3-year lifespan (Atieli *et al*. 2010; Tsuzuki *et al*. 2011; Batisso *et al*. 2012; Mejia *et al*. 2013; Wills *et al*. 2013; Mutuku *et al*. 2013; Okumu *et al*. 2013), but ranging anywhere from six months (Hoibak 2010) to seven or more years (Tami *et al*. 2004). Environment does seem to play a significant role: Allan *et al.* (Allan *et al*. 2012) found the physical condition of polyester nets in Eastern Chad to be much poorer than would have been expected from similar nets seen in the more moderate climate of Western Uganda (Kilian *et al*. 2008). Insecticide retention also diminishes over time to varying degrees, as shown in Ghana, where only 14.7% of ITNs retained full insecticidal strength after 38 months in the field measured with both residual insecticide concentration and cone bioassays (Smith *et al*. 2007). However, other studies report that knockdown and mortality remain high even after many years in the field (Graham *et al*. 2005; Gimnig *et al*. 2005; Maxwell *et al*. 2006; Kilian *et al*. 2008; Kweka *et al*. 2011; Tsuzuki *et al*. 2011).

By far the most important factor for net durability is the decision to discard the net, which is one made entirely by the household and subject to several other influences, including availability of a replacement net, condition of the current net, household needs, and perceived malaria risk, as shown in the conceptual model below. Qualitative studies indicate that household perceptions of when a net is no longer useful are highly subjective: nets were kept even when extremely torn in one study (Loll *et al*. 2014), and discarded when they only had a few small holes in others (Hoibak 2010; Batisso *et al*. 2012).

Improvements in the net textile itself are possible, and studies have shown that the knitting pattern can have a significant impact on how easily the net tears, and whether it continues to unravel once a small hole is made (Skovmand *et al*. 2011). However, given current procurement practices that focus on lowest price per net delivered, and rely solely on the existing WHO bursting strength criteria, there is no financial incentive for manufacturers to produce more durable LLIN, as nearly any improvement in the textile fibers themselves would result in increased cost. Therefore, given that household behaviours offer the greatest potential for extending LLIN lifespan, it is important to test BCC strategies to encourage proper maintenance and care of nets, and their repair when holes do develop. A single case study from the Gambia in 2006 describes this type of BCC intervention, and found that a community-led intervention increased the prevalence of repairs of holes (Panter-Brick *et al*. 2006). Subsequent formative research into net care and repair attitudes and practices in Senegal, Mali, Nigeria, and Uganda found that repair behaviours were not common prior to BCC interventions, but that participants saw no particular challenges to repair other than their own lack of time or inclination to repair nets (Loll *et al*. 2013; Loll *et al*. 2014; Hunter *et al*. 2014; Scandurra *et al*. 2014). Respondents tended to judge others whose nets were not in good condition as lazy or irresponsible, and valued the aesthetics of a properly maintained net. Nonetheless, they also acknowledged that nets inevitably develop holes, and expressed uncertainty about their own ability to delay this eventual decline (Scandurra *et al*. 2014).

Should improvements in net durability be possible via BCC interventions, the time period between major mass distributions (whether campaign or school-based) could in theory be extended, leading to overall cost savings for program planners and donor agencies.

Based on the above considerations, we undertook several studies to explore options for sustaining universal coverage, identifying key determinants of net use, and extending the useful lifespan of nets.

2 Goals and Objectives

2.1 Goal

To improve the evidence-based development of continuous ITN distribution strategies in malaria endemic countries, through a better understanding of the options for distribution channels, and through an improved understanding of determinants of net use and the impact of behaviour change communication.

2.2 Objectives

1. To model the potential coverage achieved and costs of different options for continuous ITN distribution in Tanzania
2. To explore perceptions of risk and factors influencing net use in low or lower-transmission settings in two communities in Tanzania.
3. To recalculate the gap between ITN ownership and ITN use using updated universal coverage indicators across sub-Saharan Africa.
4. To investigate the factors associated with households that give away nets following mass distribution campaigns in sub-Saharan Africa.
5. To assess the impact of a behaviour change intervention in Nasarawa State, Nigeria, promoting care and repair of ITNs on care and repair behaviours as well as on the number and size of holes in ITNs.

3 Analysing and recommending options for maintaining universal coverage with LLINs – the case of Tanzania in 2011

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3.1 Abstract

Tanzania achieved universal coverage with long-lasting insecticidal nets (LLINs) in October 2011, after three years of free mass net distribution campaigns and is now faced with the challenge of maintaining high coverage as nets wear out and the population grows. A process of exploring options for a continuous or “Keep-Up” distribution system was initiated in early 2011. This paper presents for the first time a comprehensive national process to review the major considerations, findings and recommendations for the implementation of a new strategy.

Stakeholder meetings and site visits were conducted in five locations in Tanzania to garner stakeholder input on the proposed distribution systems. Coverage levels for LLINs and their decline over time were modelled using NetCALC software, taking realistic net decay rates, current demographic profiles and other relevant parameters into consideration. Costs of the different distribution systems were estimated using local data.

LLIN delivery was considered via mass campaigns, Antenatal Care-Expanded Programme on Immunization (ANC/EPI), community-based distribution, schools, the commercial sector and different combinations of the above. Most approaches appeared unlikely to maintain universal coverage when used alone. Mass campaigns, even when combined with a continuation of the Tanzania National Voucher Scheme (TNVS), would produce large temporal fluctuations in coverage levels; over 10 years this strategy would require 63.3 million LLINs and a total cost of $444 million USD. Community mechanisms, while able to deliver the required numbers of LLINs, would require a massive scale-up in monitoring, evaluation and supervision systems to ensure accurate application of identification criteria at the community level. School-based approaches combined with the existing TNVS would reach most Tanzanian households and deliver 65.4 million LLINs over 10 years at a total cost of $449 million USD and ensure continuous coverage. The cost of each strategy was largely driven by the number of LLINs delivered.

The most cost-efficient strategy to maintain universal coverage is one that best optimizes the numbers of LLINs needed over time. A school-based approach using vouchers targeting all students in Standards 1, 3, 5, 7 and Forms 1 and 2 in combination with the TNVS appears to meet best the criteria of effectiveness, equity and efficiency.

3.2 Background

Between 2009 and 2011 Tanzania implemented two mass long-lasting insecticide-treated bed net (LLIN) distribution campaigns with the goal of achieving universal coverage nationwide: the under-five catch up campaign (U5CC) and the universal coverage campaign (UCC). Approximately 27 million LLINs were distributed during the two campaigns, leading to large increases in household ownership and usage (Renggli *et al*. 2013). Reaching universal coverage through campaigns represents a "catch-up" strategy according to the Consensus Statement of the Roll Back Malaria Vector Control Working Group (VCWG) (Roll Back Malaria Vector Control Working Group 2011). However, it is well recognized that once countries reach universal coverage they need to implement new strategies to maintain the high coverage levels: "Keep-Up" strategies. New households require new nets and lost or worn out nets need to be replaced.

Tanzania introduced the Tanzania National Voucher Scheme (TNVS) in 2004 to distribute nets to pregnant women and infants. During the period of the recent campaigns the TNVS distributed roughly 5.4 million nets. The TNVS has been extensively described in terms of operations and cost-effectiveness (Mushi *et al*. 2003; Magesa *et al*. 2005; Tami *et al*. 2006; Mulligan *et al*. 2008; Hanson *et al*. 2009; Njau *et al*. 2009; Marchant *et al*. 2010; Gingrich *et al*. 2011). Vouchers obtained by pregnant women and mothers of infants coming for measles vaccination through routine clinic visits can be redeemed for reduced price nets at participating retailers. Top-ups paid by women and mothers initially ranged from about TZS700 to over TZS1,500 ($0.65-$1.38 at 2005 rates) depending on the size of the selected net (Hanson 2005). In late 2006 the voucher value was increased to TZS3,250 ($2.60 at 2006 rates) and the infant voucher was introduced. By 2008, the average top-up had reached over TZS2,300 ($1.95 at 2008 rates) (Marchant 2008). In October 2009 the existing voucher was replaced by a new voucher with a fixed top-up of TZS500 ($0.38 in 2009 and $0.32 in 2012). However, the TNVS does not provide enough nets annually to maintain universal coverage, hence the need for defining and implementing additional "Keep-Up" strategies. This paper describes the results of a comprehensive process of stakeholder meetings, in-depth interviews and cost and coverage modelling to identify options for maintaining universal coverage in Tanzania. This work was carried out also considering that the current funding for malaria control at global level is plateauing and potentially declining (World Health Organization 2011b); hence new strategies must be both effective and efficient.

3.3 Methods

3.3.1 Qualitative methods

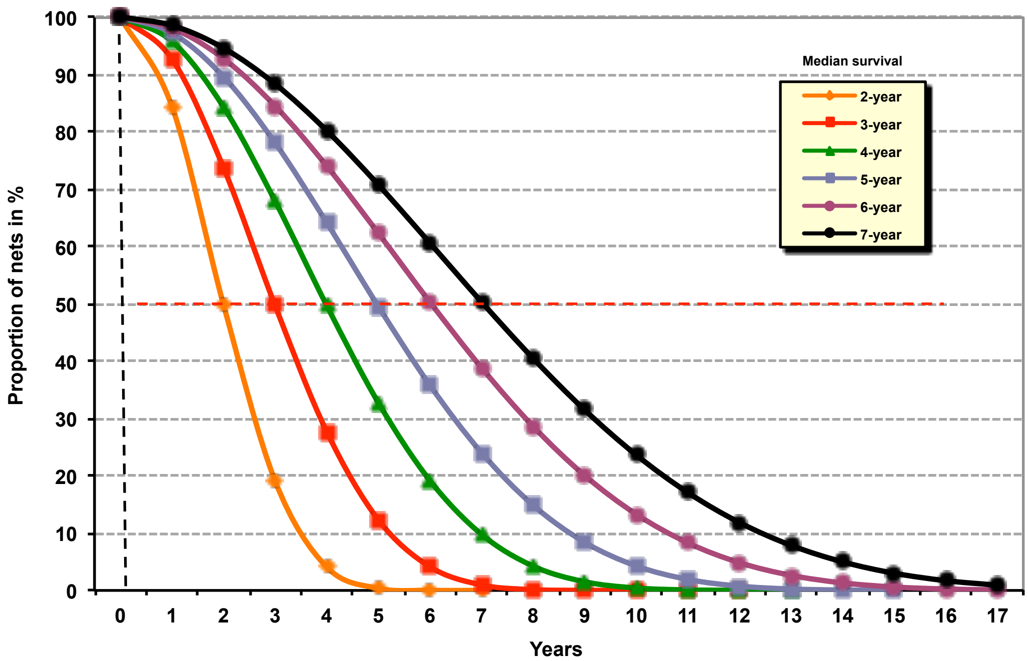
A series of bilateral and multilateral stakeholder meetings was held in Dar es Salaam, Morogoro, Mtwara, Mwanza and Arusha, reflecting a variety of transmission zones and combinations of malaria control interventions. Field visits and in-depth interviews were conducted in each zone with participating TNVS clinics and retailers along with local government officials, council health management teams, district medical officers and malaria focal persons. Stakeholder meetings were designed to elicit inputs on the operational feasibility of each of the options for additional channels and to identify potential bottlenecks and barriers at both government and community level to successful implementation. Interviews with retailers and net manufacturers focused on retailers' experience under the TNVS and their current business practices. These meetings took place between 1 and 24 June, 2011. An additional file, Table 3.1 describes the details of stakeholder meeting attendees, interviewees and site visits.

3.3.2 Modelling and costing methods

The term "coverage" is defined here as it is used within the National Malaria Control Programme of Tanzania (NMCP), to mean use of nets by the general population. "Ownership" is defined as household ownership of a specified number of nets per household, or net to occupant ratio. Unless otherwise noted, this is the standard Roll Back Malaria (RBM) indicator of at least one LLIN per household.

Net ownership and coverage levels were modelled using the NetCALC software developed on a Microsoft Excel platform (available at networksmalaria.org). NetCALC projects LLIN coverage at a given point in time as a simple compartmental model based on the number of nets available for use at that time which in turn is the sum of all nets remaining from annual net cohorts distributed assuming an S-shaped loss-function (Figure 3.1). This loss function is built on data and observations on the longevity of LLINs in the field (Kilian *et al*. 2008; Kilian 2010; Briet *et al*. 2012) which was then mathematically described, allowing the user to select a variety of median survival times with the default set at three years. The relationship between the mean number of nets per net-owning household and the mean number of nets per household considering all households was defined by relating the range of coverage rates from several household surveys in Uganda and the mean number of nets per net-owning households and calculating the corresponding ratio of nets to households. Plotting the results showed a curvilinear function. This relationship was modelled in STATA using a fractional polynomial regression (the fracpoly command) and a correction factor was added to account for variations in average household size from country to country. Thus NetCALC is able to translate the remaining number of nets into a value for household net coverage (expressed as the percentage of households owning at least one LLIN) via this formula. The correction factor in the formula also ensures that 100% household coverage with at least one LLIN is equivalent to the population divided by 1.8 (Kilian *et al*. 2010), which is the World Health Organization (WHO) and RBM recommendation for the number of insecticide-treated nets (ITNs) needed for universal coverage (World Health Organization 2011b). Hence, by inputting population parameters, the expected mean lifespan of local LLINs, and numbers of LLINs distributed, NetCALC estimates ownership (at least one LLIN per household) over a set time period.

Figure 3.1: Decay curves used to model net longevity in NetCALC (Kilian).



Models were implemented using NetCALC's Free Modeling module to allow for complete control over the numbers of nets assumed to be delivered in the "Keep-Up" system. The numbers of nets delivered using the continuous supply systems of the TNVS were estimated utilizing the continuous Antenatal Care-Expanded Programme on Immunization (ANC/EPI) modules. Base scenarios utilized a mean lifespan of three years for all LLINs distributed (all nets distributed in the U5CC and UCC campaigns and since October 2009 under TNVS have been Olyset™ polyethylene nets produced by A to Z Textile Mills Ltd in Arusha (Bonner *et al*. 2011). Details of model inputs and outputs are included as a web appendix.

3.3.3 Population structure and population protected

The population structure used in the model is based on that of Tanzania with an estimated population of 43.2 million in 2010, 17% of whom are children under five and 47.4% under 15 years of age based on the Tanzania National Bureau of Statistics (NBS) projections from the 2002 Census. The average household size was assumed to be five persons and this was treated as invariant over time (National Bureau of Statistics (NBS) [Tanzania] *et al*. 2011). A population growth rate of 3.0% per annum was assumed (UN Statistics Division 2010). School enrolment figures were derived from Tanzanian National Enrolment Management Information System Statistics (Ministry of Education and Vocational Training 2011). Other inputs were estimated based on the 2010 Tanzania Demographic and Health Survey (National Bureau of Statistics (NBS) [Tanzania] *et al*. 2011).

3.3.4 Time frame

Inputs of LLINs were estimated over the period 2009-2021 inclusively, however, only additional nets beyond the mass campaigns and TNVS deliveries through 2011 were included in the analysis of cost, LLIN needs and cost-effectiveness. In order to accurately estimate current coverage levels and net ages nationwide it was necessary to include nets that had been delivered before the decision point of June 2011. However, nets that had either already been delivered or were planned for delivery were considered as “sunk-costs” and not included in the decision analysis.

3.3.5 Net inputs

Numbers of LLINs distributed in Tanzania through the TNVS were assumed to increase only in proportion to population growth, until the end of 2011. Inputs of LLINs during the U5CC Campaign and a completed UCC were estimated based on information from the Tanzania NMCP and included in the model in the year of actual (or planned) distribution (Renggli *et al*. 2013; Bonner *et al*. 2011). TNVS inputs were estimated based on the assumption of 95% coverage of ANC and first EPI vaccinations (National Bureau of Statistics (NBS) [Tanzania] *et al*. 2011), 90% success at vouchers being received by the target groups and 80% redemption rate based on current data from the Mennonite Economic Development Associates (MEDA), the non-governmental organization implementing the voucher distribution and redemption component of the TNVS (Faith Patrick, pers comm, June 2011). Expansion of the voucher system beyond the current year assumed 90% of target groups would receive a voucher and that 80% would redeem them, consistent with estimated voucher redemption rates, but higher than historical redemption rates when the “top-up” associated with voucher redemption was higher in real and nominal terms than currently. Based on previous campaign success in reaching targeted households, direct delivery of nets through campaigns or other distribution assumed that 80% of targeted groups would receive nets (Renggli *et al*. 2013; Bonner *et al*. 2011; Centers for Disease Control and Prevention (CDC) 2005; Grabowsky *et al*. 2005; Grabowsky *et al*. 2007; Thwing *et al*. 2008; Kulkarni *et al*. 2010; Hightower *et al*. 2010; Terlouw *et al*. 2010; Thwing *et al*. 2011).

LLIN needs

The Tanzania NMCP has established a target of 80% LLIN use within the general population. To account for a probable small but persistent gap between ownership and use over the 10-year period, stakeholders estimated at the first stakeholder meeting in Dar es Salaam that a 7% disparity could serve as a standard adjustment for non-use. This was included in the modelling so that outputs would indicate whether or not Tanzania would meet its target of 80% LLIN use. In order to maintain coverage at this level the minimum number of additional LLIN per year from 2012 to 2021 was estimated. The coverage target was calculated based on the total number of person-years in Tanzania over the period 2012 to 2021 and the proportion of all person-years over the same period in which a net was used. Success at meeting the NMCP target resulted when at least 80% of all possible person-years over the period were protected.

Cost and cost-effectiveness

Cost modelling used data from various sources, including the NMCP of Tanzania, published literature, and financial records and reports of implementing partners of the NMCP. Conversions to USD from TZS were made using an exchange rate for 2011 (TZS1,500 per USD), the prevailing exchange rate at the time of the study. All costs were projected into the future assuming constant dollars and adjusted to present value in 2012 using a 3% discount rate as is common in the economic evaluation literature. All cost analyses took a provider perspective and costs were purely financial. Only costs related to actual financial outlays by donor agencies or the NMCP of Tanzania were included. Commodity costs for nets were assumed not to vary over time, but were related to scale in the mass distribution campaign models (where the largest procurements would occur), so that larger purchase quantities of nets resulted in lower per-net prices. The relationship between purchase volume and LLIN procurement cost was estimated based on LLIN tender data from past procurements in

Tanzania. In commercial sales scenarios, sales levels were estimated based on historical sales records from the Strategic Social Marketing for expanding the Commercial Market of ITNs in Tanzania (SMARTNET) programme adjusted for population size and subsidy levels using existing price elasticity estimates (Gingrich *et al*. 2011). Costs to users were not included in total costs as only purely provider costs were considered in the cost analysis. The implications of varied user costs were included in the sense that various levels of voucher redemption and sales volumes related to top-ups and market price were considered.

The costs of voucher distribution were assumed to be similar to the current TNVS. Direct net distribution assumed the same costs as for past campaign distributions. Other than the purchase quantity efficiencies assumed in the mass distribution models, economies of scale were not included. The evidence of scale efficiencies in LLIN distribution is limited and no data to base such a model on currently exists (Yukich *et al*. 2008). Similarly, no economies of scope were assumed in the modelling of combination approaches. In costing the options, campaign or physical net distribution costs included campaign-specific behaviour change communication (BCC) activities and follow up “hang-up” activities. However, no unlinked BCC activities were included either for campaigns or any other distribution system. Denominators for cost-effectiveness ratios were estimated in terms of the total person-years covered over the period 2012-2021.

Sensitivity analysis

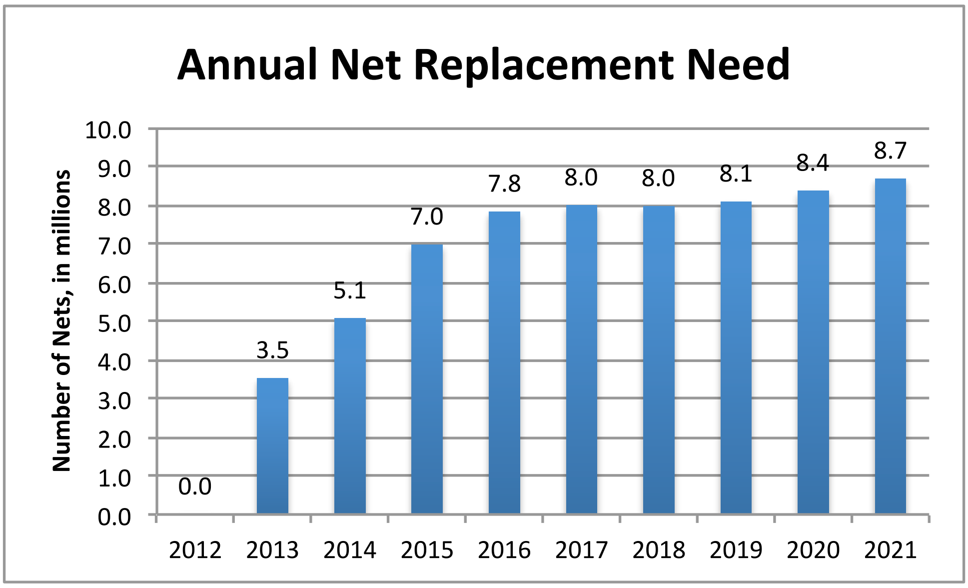
One-way sensitivity analyses were conducted on net lifetimes, costs of delivery systems and net procurement prices, usage rates and discount rates. Multiway or scenario analyses were also conducted to estimate the effects of varying multiple parameters on the number of LLINs needed, total costs and cost-effectiveness.

3.4 Results

3.4.1 Numbers of LLINs required for meeting universal coverage targets in Tanzania

Under the base scenario an average of 7.9 million LLINs per year (2012-2021) were required to meet NMCP targets of maintaining 80% coverage (Figure 3.2). Relatively few nets were needed in the first years (2012-2013) due to the large numbers of nets already present from recent mass campaigns. After 2013, however, there was a need for a significant increase in scale. Sensitivity analysis indicated that both the size and timing of the increase in delivery was highly dependent on the assumed lifetime of nets delivered in the two mass campaigns and to a lesser extent the number of LLINs delivered through the TNVS. Assuming a constant lifetime of nets over the period, the number of LLINs needed in each year after the programme's initial expansion grew in direct proportion to population growth.

Figure 3.2: Annual net replacement need for Tanzania, 2012-2021.



3.4.2 Stakeholder preferences for "Keep-Up" strategies

An ideal "Keep-Up" strategy, as defined through stakeholder meetings and in consultation with the NMCP, would maintain usage of LLINs at 80% or more of the general population of Tanzania and be equitable in terms of access to LLINs. It would additionally have minimal geographic and temporal gaps in coverage, so that spatial coverage is maintained over time throughout all communities, in order to provide the significant community effects (which have been measured at >50% household coverage in Kenya (Hawley *et al*. 2003) and shown to exceed individual protection at levels over 40% in a mathematical model (Killeen *et al*. 2007)). Further, the system should not oversupply nets to households or be excessively costly and burdensome to manage and administer. It would also put some degree of responsibility on households to acquire nets, either through effort (travel, self-registration, et.) or through paying a small portion of the cost of the net as is currently done through the TNVS. The system would also encourage fair competition among manufacturers to improve quality and reduce costs. In an ideal system a choice of nets (in terms of size, fabric and colour) would also be available to the consumer.

At all the stakeholder meetings, priority groups were identified fairly consistently, and included pregnant women, under-fives, the elderly (over 60), the disabled, orphans and street children, people living with HIV/AIDS and tuberculosis, the poor, widows and widowers, and victims of floods/fire and other disasters.

Possible net distribution options are described systematically in the following sections, first by presenting the results of stakeholder discussions, and then by modelling number of nets and cost of the approach. Single interventions are examined first, and the most attractive combinations follow.

3.4.3 Single interventions

Repeated mass campaigns, the TNVS alone, health-facility distribution of nets, community distribution of nets or vouchers, school-based distribution of nets or vouchers, and commercial sector options were analysed individually first as future options for the "Keep-Up" strategy. Table 3.2 in the additional files summarizes these options.

3.4.3.1 Future option 1: Repeated mass campaigns

Tanzania has conducted two mass LLIN distribution campaigns: the 2009-2010 U5CC and the 2010-2011 UCC). Completed in November 2011, these campaigns distributed 27 million nets with an estimated financial cost of $7.07 per net for the U5CC (Bonner *et al*. 2011) and $5.90 per net for the UCC (Renggli *et al*. 2013). Over a 10-year period around 61.5 million nets would be needed to conduct a UCC every three years, accounting for population growth. Given the scale and complexity of implementation, any future UCC is likely to be conducted in rolling stages with specific regions or zones covered sequentially – as was done for the 2010-2011 campaign. While in the national aggregate this strategy would provide protection to approximately 80% of all of the person-years at risk over 2012-2021, the fluctuation in coverage would be fairly large in individual locations, with predicted LLIN use at any location varying from 93% of the population at peak periods (just after completion of distribution) to as low as 20% in periods between campaigns.

Figure 3.3 illustrates modelled results of conducting a rolling universal coverage campaign, segmenting Tanzania into six zones each with a campaign every three years on a six-month rotation schedule (campaign sizes are adjusted for population growth). Figure 3.4 illustrates modelled results of coverage for Southern Zone, which was one of the first zones to complete universal coverage, but (in this model) one of the last to receive the second universal coverage distribution, resulting in a significant loss of coverage between distributions.

Figure 3.3: Rolling Universal Coverage Campaign every three years - National Coverage.

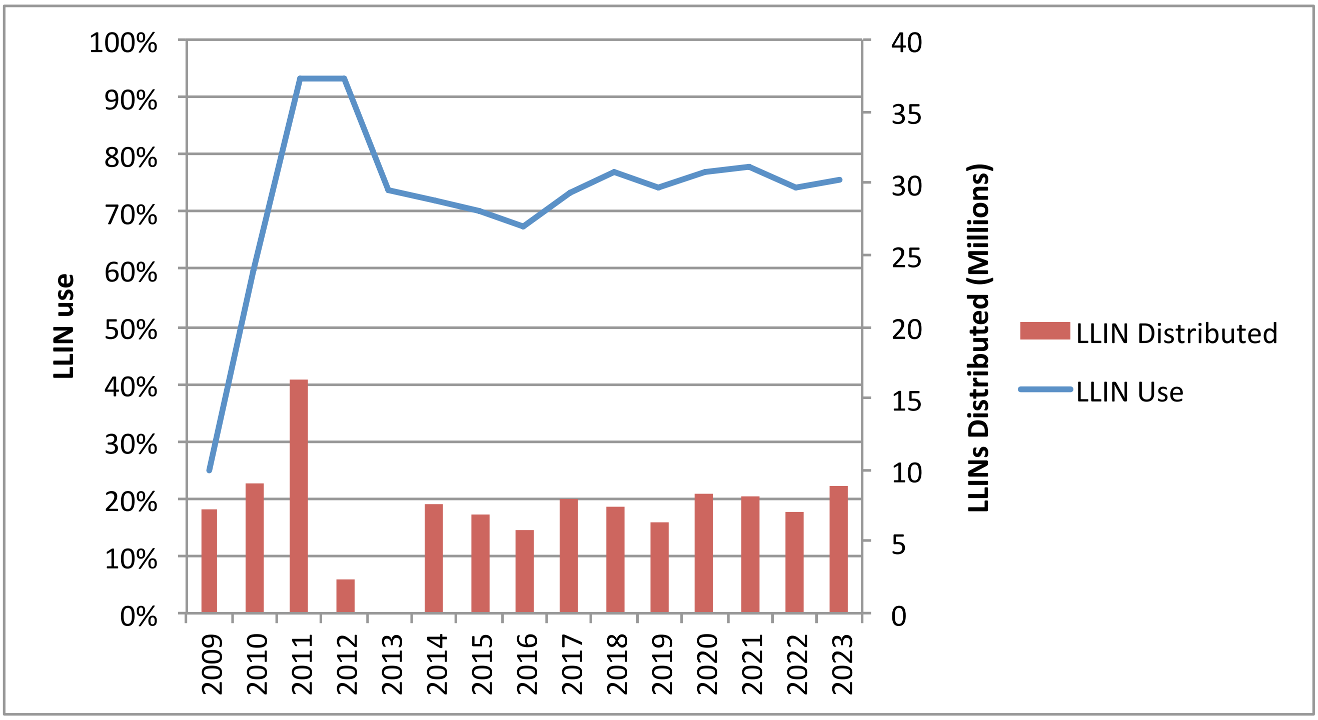
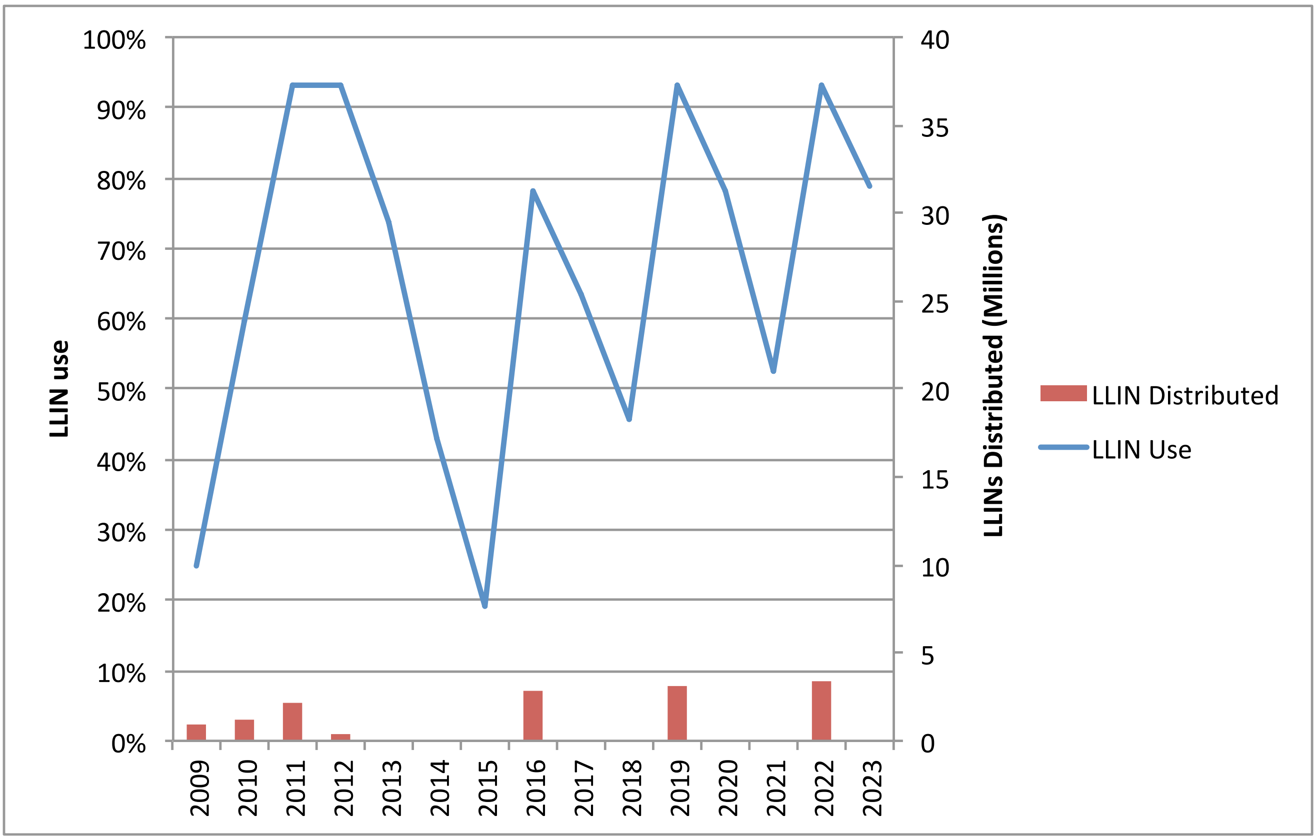


Figure 3.4: Rolling Universal Coverage Campaign every three years - Southern Zone. Southern Zone is last to receive a second campaign under the model, thus the decline in coverage is most extreme in this area.



3.4.3.2 Future option 2: Tanzania National Voucher Scheme (TNVS)

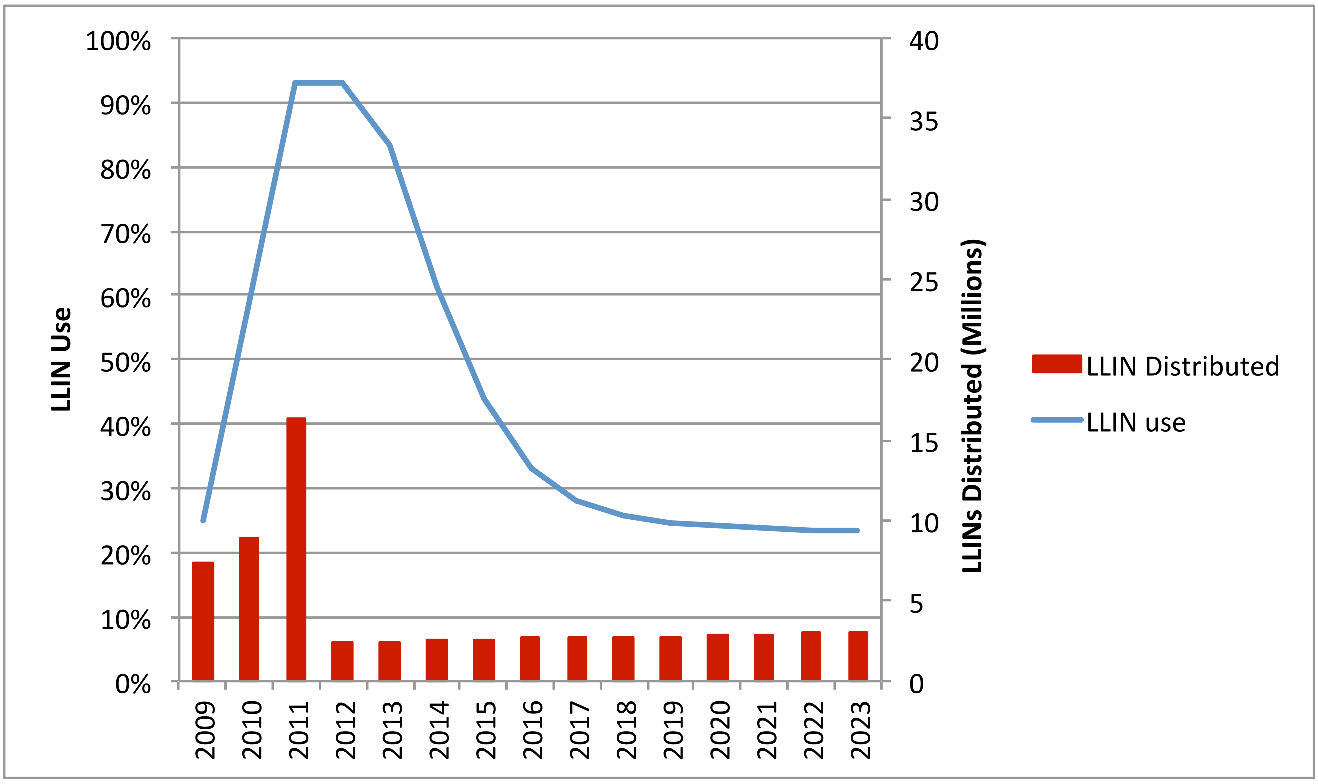
At current levels, the TNVS distributes about 1.5-1.6 million nets per year. MEDA projections assume that 90% of pregnant women and infants attend ANC and EPI and that 85% of pregnant women (80% for the infant voucher) then redeem their respective vouchers, putting the potential throughput at 2.64 million nets per year starting in 2012 (MEDA, pers comm). The network of retailers is currently quantified at 5,426 retailers (confirmed as of June 2011). A total of 4,428 out of a possible 4,891 Reproductive and Child Health (RCH) clinics participate, including some private clinics (Mennonite Economic Development Associates 2011). By continuing the TNVS over the next several years coverage can be maintained at high levels at least until the end of 2013, when additional channels would need to be added in order for coverage not to drop below acceptable levels (by 2014 ownership would fall below 70%).

Interviews with retailers indicated that tying up large amounts of working capital with slow-moving stocks of TNVS nets has been difficult. If turnover were faster the small TZS500 profit from top-up payment by women could become more attractive. The financial and opportunity costs of stocking LLINs were described by retailers, who noted that consumer goods such as soap or food items take up less shelf space and sell in greater volume, bringing in greater profits than bulky LLINs. However, retailers also reported that they felt they were “providing a service” to pregnant women and mothers of young children by stocking nets and that they enjoyed this aspect of the programme. The majority of those interviewed were selling many other products in their shops; LLINs were only a small part of their total sales.

The model used the assumptions that vouchers reach 90% of the beneficiaries attending clinics and that 80% of vouchers are redeemed, based on 2010 Demographic and Health Survey (DHS) findings that 96% of women attend ANC at least once and measles coverage is 85%, and on MEDA’s voucher redemption records from early 2011. Coverage models based on these rates indicate that TNVS by itself would maintain national coverage with LLINs at around 25%.

Figure 3.5 describes coverage achieved by maintaining the TNVS in the absence of other distribution channels. Over 10 years this option would require 26.5 million LLINs at a total cost of $182 million, and would provide 45% of total person-years of protection, at a cost per person-year protected of $0.99.

Figure 3.5: TNVS maintained alone



3.4.3.3 Future option 3: Ante-Natal Care (ANC) and Expanded Programme for Immunization (EPI) delivery of nets

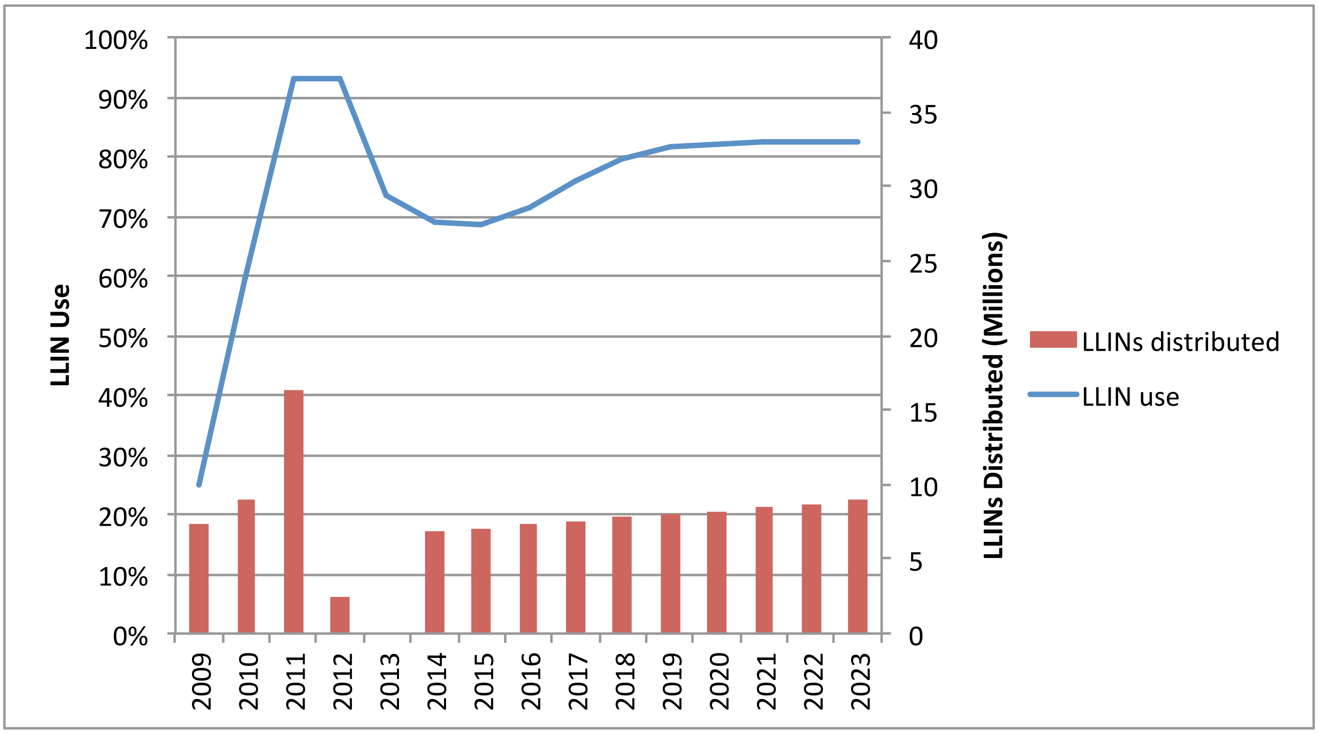
A third possibility for delivery of nets to pregnant women and infants would be to distribute free nets directly to beneficiaries through RCH/EPI clinics. Assumptions in the model kept 90% attendance rate at RCH clinics, and assumed that 80% of those attending will receive a net, as LLINs are more difficult to transport and store than vouchers. While this slightly increased coverage in the model, by eliminating the redemption gap, the overall gains in ownership and use appear to be modest. Over 10 years this option would require 29.5 million LLINs at a total cost of $212 million, and would provide 48% of total person-years of protection, at a cost per person-year protected of $1.10.

3.4.3.4 Future option 4: Community vouchers or nets

With a 'community voucher', community members would identify households in need of replacement nets and issue them vouchers to be redeemed at participating retailers. This approach could in principle deliver the number of LLINs per year set by the programme at any desired level. The system would need to be capped at the number needed to fulfil all replacement needs with some allowance for loss during and immediately after delivery. Community delivery of nets or vouchers was initially a popular option during discussions, as both mechanisms could potentially fill the gaps needed to replace nets and maintain universal coverage. However, a number of potentially significant challenges were cited during discussions, including the difficulty of verifying household need on a regular basis, costs of motivating community volunteers to conduct household outreach to assess need, concerns about favouritism for certain households over others (particularly related to hard-to-reach areas, or based on political affiliations). While stakeholders suggested trading in old nets for new nets as an option to verify household need, they also concluded that this would result in rewarding households that did not take good care of their LLINs. Making vouchers available to the general population at health clinic level was also discussed, and determined to be less desirable again due to difficulties of verifying household need and due to the additional burden that would be placed on health care workers. Conducting regular household registration to identify sleeping spaces that lacked nets was a third option. However, none of the stakeholders thought that this household registration could be accomplished on a volunteer basis; compensating the efforts of local officials or community volunteers who help identify household needs would become significant at scale.

The model (Figure 3.6) assumed that community vouchers cover 90% of the need for full replacement of nets and that there would be an 80% redemption rate. Community delivery of nets assumed that 80% of households would receive nets. Over 10 years this option would each require 62.7 million LLINs at a total cost of $477 million (for a community voucher programme) or $432 million (if free net distribution was used), and would provide 78% of total person-years of protection, at a cost per person-year protected of $1.52 (vouchers) or $1.39 (free nets).

Figure 3.6: Full-scale Community Voucher



3.4.3.5 Future option 5: School vouchers or direct school net delivery

Distribution of vouchers or free LLINs through school registration is another interesting option as a component of a strategy to maintain universal coverage. Enrolment at the primary school level in Tanzania is generally high, with all but two regions reporting net enrolment rates greater than 90% (Ministry of Education and Vocational Training 2011). Additionally, roughly 30% of the population of the country is between five and 15 years of age and is thus eligible for primary school enrolment and at least 62% of households have a current resident of primary school age (National Bureau of Statistics (NBS) [Tanzania] *et al*. 2011). This strategy would not reach households who have no school-age children or households that cannot or do not send their children to school, unless there is inter-household redistribution of LLINs (for which there is no evidence to date). Enrolment is the highest for Standard 1 and falls in each subsequent year as students drop out of the school-attending population. Primary school enrolment rates remain much higher than secondary school and thus would likely be the primary target of any net distribution strategy. Results of stakeholder discussions confirmed that beneficiary identification is clear and simple as only students enrolled in school would be eligible and teachers and school health officials could facilitate distribution and monitoring. Stakeholders noted that since households already need to pay for school fees and uniforms at the beginning of the school year, the additional expense of a voucher could pose a barrier to school enrolment, and might be expected to reduce voucher redemption rates. On the other hand, receipt of vouchers could alternatively incentivize enrolment and thus potentially boost enrolment levels.

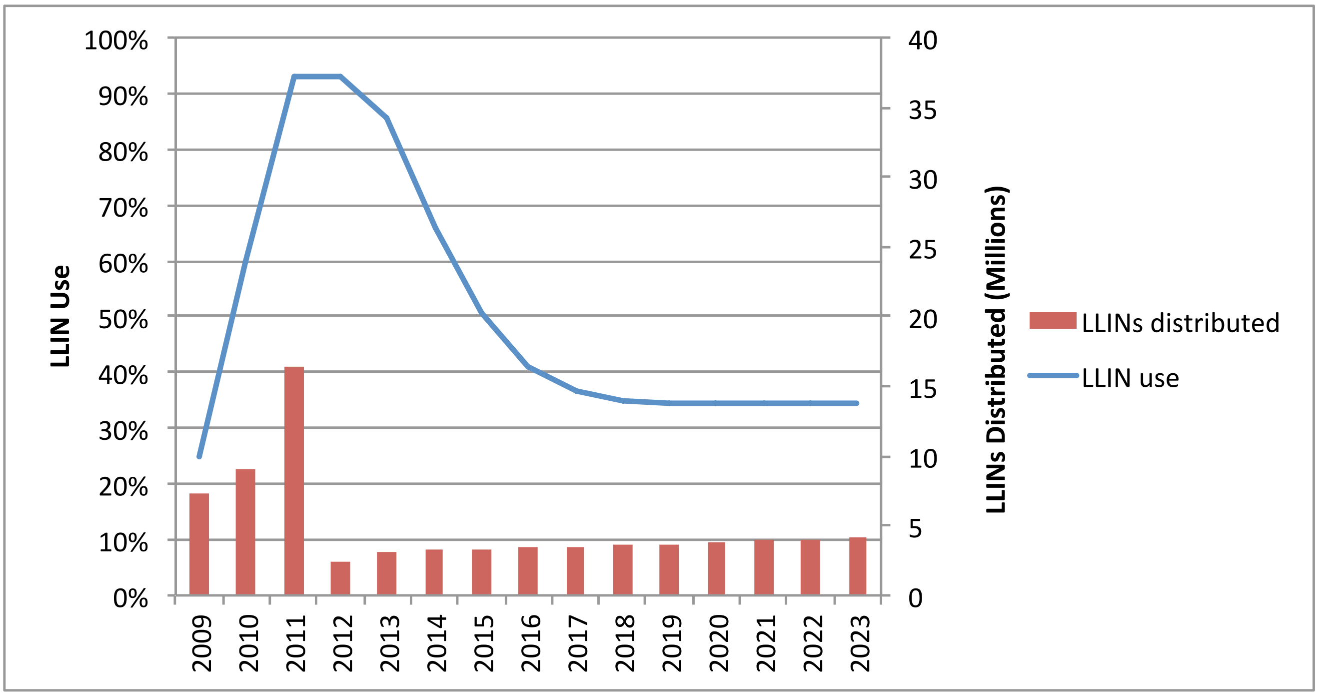
In Tanzania, as of 2010, there were approximately 8.4 million primary school enrollees. Delivery of vouchers to 90% of all enrollees (with an 80% redemption rate) would lead to the delivery of approximately 6.2 million LLINs per year into households in Tanzania, falling short of total net replacement need. However, this approach might also be used to complement other strategies including the ongoing TNVS, or a community level distribution mechanism (discussed below under the heading of "combinations"). Modelling the delivery via vouchers to all primary school students each year would require 56.7 million LLINs at a total cost of $389 million, resulting in 73% of all person-years protected with a cost of $1.32 per person-year-protected. If free nets were provided instead, due to slight gains in delivery success, 67.3 million LLINs would be required at a total cost of $466 million, resulting in 83% of all person-years protected at a cost of $1.41 per person-year protected (Table 3.2, additional files).

3.4.3.6 Future option 6: Commercial sector distribution

Very little information exists publicly which can be used to predict the demand for population-wide subsidized sales of LLINs in Tanzania. However, the history of the SMARTNET programme (2002-2007) provides clear evidence that sales could reach more than 1.5 million nets annually with a net price of TZS3,000-5,000 or roughly $2.63 to $4.39 (unpublished data, Population Services International/Tanzania (PSI)). Additionally, a recent study estimated the demand for the pregnant woman voucher and infant voucher redemptions for LLINs at various top-up prices for different socio-economic quintiles (Gingrich *et al*. 2011). The information from these two sources was used to estimate demand for LLINs on the commercial market at various subsidized retail prices. The accuracy of results modelled here is highly speculative due to the limited evidence base on both general population price elasticity of demand and historical sales volumes for similar (LLIN) products.

Figure 3.7 illustrates the model results of making LLINs available through the retail network to the general population at a highly subsidized retail price of TZS500 ($0.32). Costs of such an approach were modelled based on the current mechanism for providing subsidies to beneficiaries per net sold through the TNVS. At various retail prices more substantial amounts of the manufacture and distribution costs have been assumed to be passed along through retailers to manufacturers and thus subsidy amounts are assumed to be lower at higher top-up prices. (For the results of the extended analysis see accompanying spreadsheet models). This model in its base scenario estimates that approximately three million LLINs could be delivered each year via this mechanism, or roughly 38% of expected replacement need. Over 10 years this option would require 33.4 million LLINs at a total cost of $214 million, and would provide 52% of total person-years of protection, at a cost per person-year protected of $1.00.

Figure 3.7: Commercial sector subsidized sales at TZS500 per net.



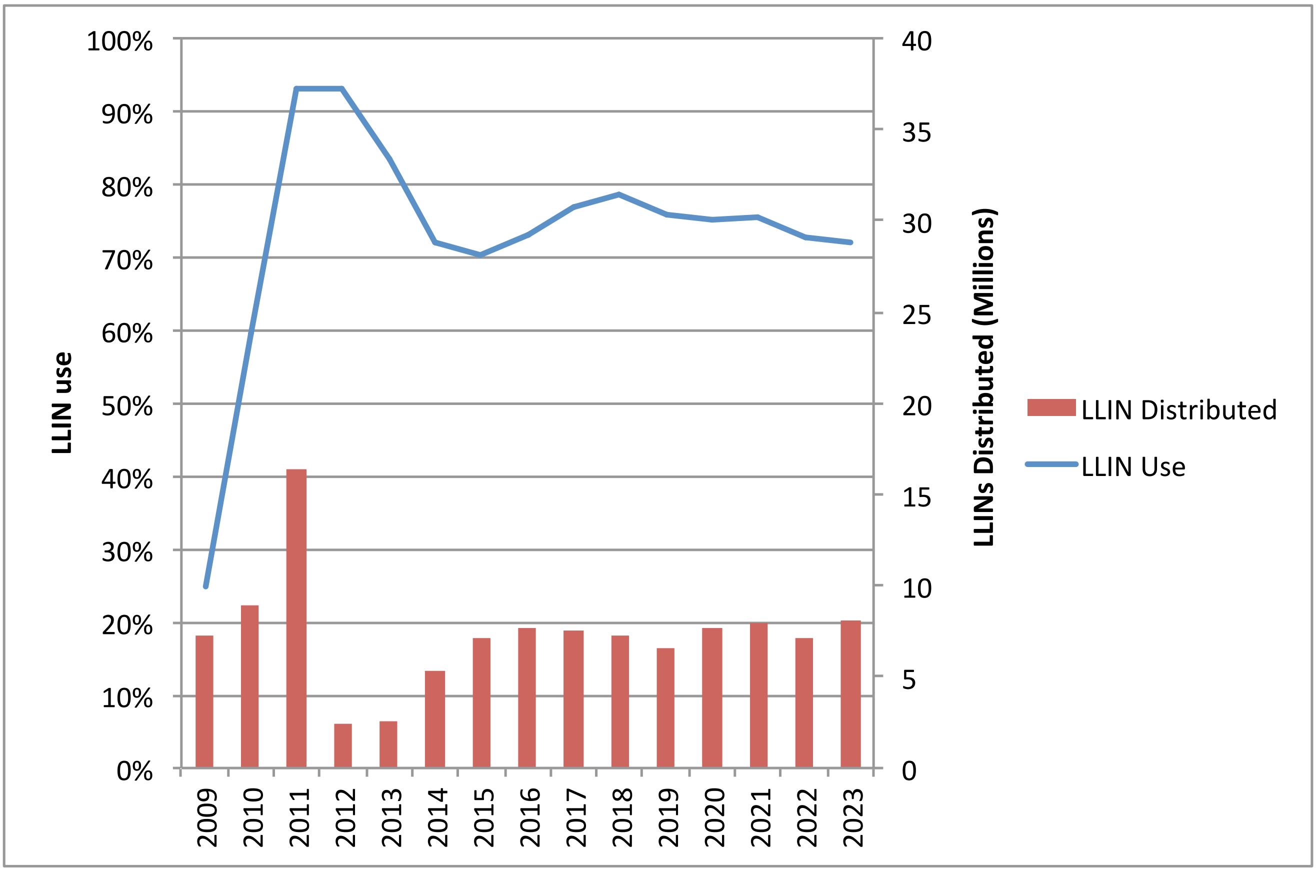
3.4.4 Combinations of options

To model combinations of different mechanisms, overall net inputs from individual channels were combined to estimate final coverage levels. Some delivery systems were modelled on alternative scales in order to avoid oversupplying nets. There was strong support among stakeholders to maintain the TNVS and to combine it with an additional channel. Given current experience with the Medical Stores Department (MSD) supply chain, stakeholders generally agreed that switching from the voucher scheme to a direct delivery of nets via ANC and EPI would likely result in frequent net stock outs, reducing the success of this strategy. Therefore, three potential combinations are modeled here that each include maintaining the TNVS: TNVS plus rolling mass distribution campaigns; TNVS plus school-based distribution; and TNVS plus school and community-based distribution. These options are summarized in Table 3.2 in the additional files. At this stage, the TNVS represents a working model for a "Keep-Up" mechanism, with a high level of recognition and acceptance, and it would be highly risky not to include this strategy in future plans.

3.4.4.1 Combination 1: TNVS plus rolling mass campaigns

The combination of the TNVS with repeated mass campaigns for universal coverage on a three or five-year cycle (assuming a three-year net lifespan) yields universal coverage periodically, but the number of nets delivered by the TNVS fails to supply enough LLINs to ensure local full coverage between such campaigns, even in a rolling campaign scenario (Figure 3.8). On a five-year campaign cycle usage rates would fall to under 50% between campaigns. A three-year cycle combined with the TNVS could potentially maintain universal coverage locally throughout the period, although this strategy results in the delivery of approximately 20 million excess LLINs, due to oversupply in the years that the campaigns are implemented.

Figure 3.8: National coverage for TNVS plus three-year rolling UCC.

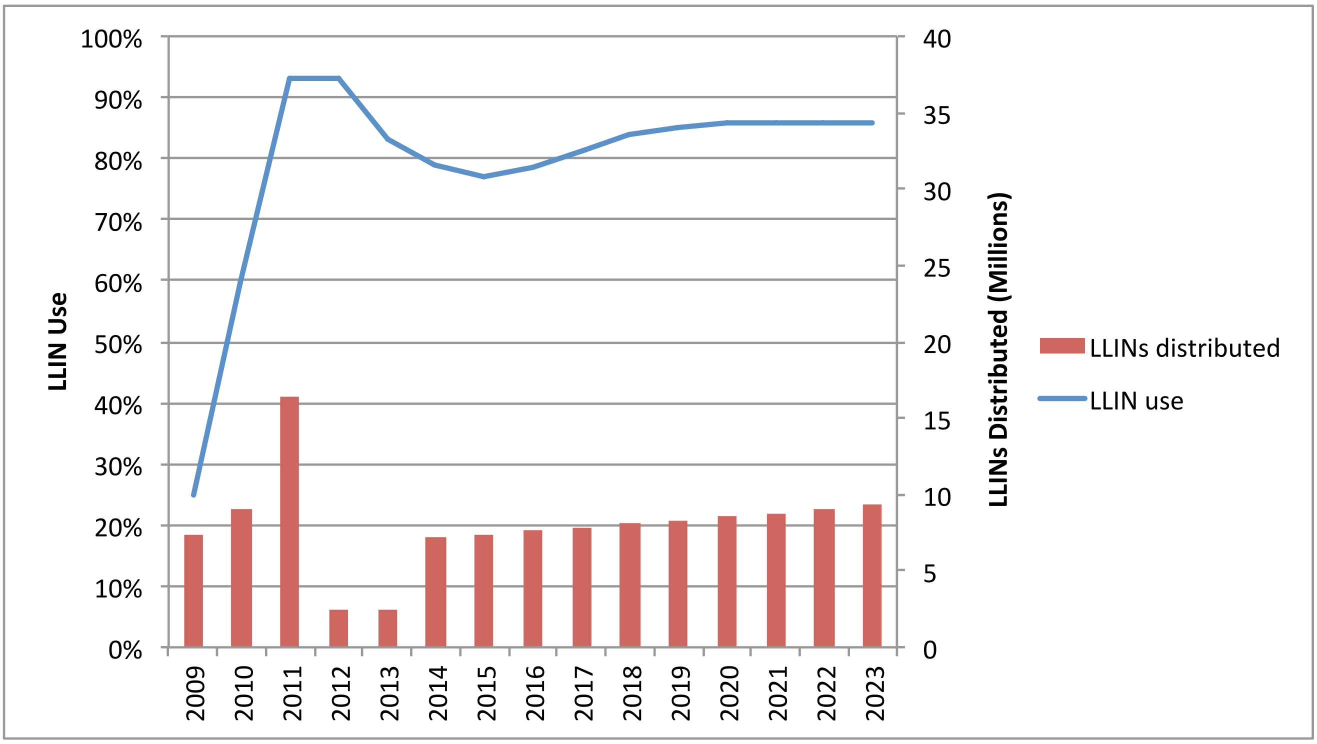


Over 10 years this combination would require 63.3 million LLINs at a total cost of $444 million, and would provide 82% of total person-years of protection, at a cost per person-year protected of $1.35, and a per-net cost of $7.01.

3.4.4.2 Combination 2: TNVS plus school voucher

Figure 3.9 illustrates the combination of the TNVS with a school voucher distributed each year in Standards 1, 3, 5, 7 and Forms 1 and 4. Distributing nets to all primary school students would result in an oversupply of nets; distributing nets to students every second year achieves the overall goal but assumes that within households nets will be shared among family members not of school age, and allow for replacement of the oldest nets in the household as the student moves through school. Targeting pregnant women and infants through the TNVS, and students in these school grades leads to a sustained coverage of about 82%. Beneficiary identification is straightforward for reasons mentioned earlier. The use of vouchers for schools consolidates administration of the programme into one activity, rather than working with multiple mechanisms in which vouchers are combined with a separate free net distribution. Over 10 years the combination of TNVS plus a school voucher would require 65.4 million LLINs at a total cost of $449 million, and would provide 82% of total person-years of protection, at a cost per person-year-protected of $1.34, and a per-net cost of $6.87.

Figure 3.9: TNVS plus limited school voucher.

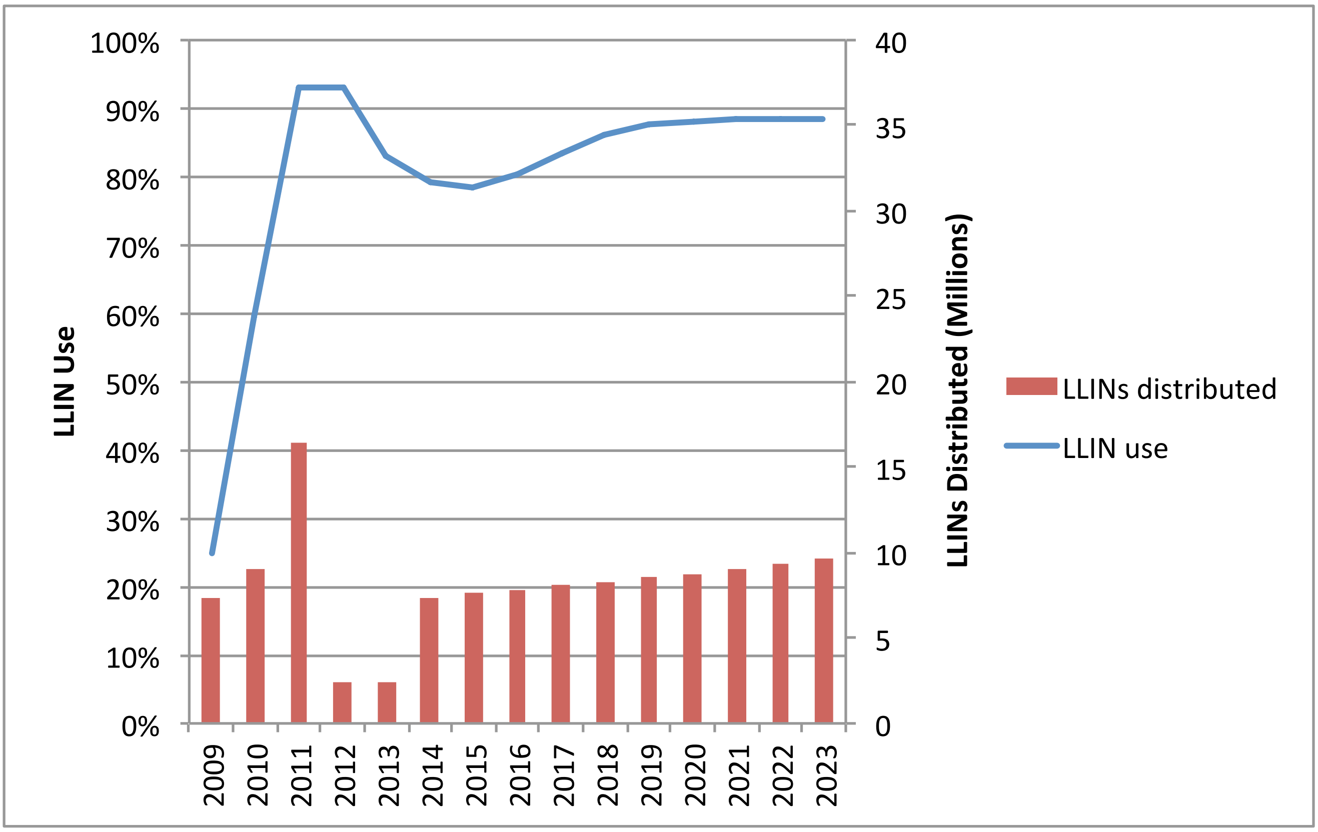


3.4.4.3 *Combination 3: TNVS plus school voucher plus community voucher*

Figure 3.10 illustrates the combination of the TNVS, a more limited school voucher (given to Standards 1, 4, 7 annually) and a limited community voucher (to supply two million LLINs in 2014). In modelling this approach the TNVS plus the limited school voucher would still require substantial input to maintain universal coverage as defined by NMCP, and the community voucher has been scaled to meet the remaining need. Criteria for identifying the households would need to be developed. One possible avenue for such would be to target the remaining ~16% of households in Tanzania that have neither a pregnant woman nor any children under 15 years of age. Over 10 years this combination would require 69 million LLINs at a total cost of $520 million, and would provide 85% of total person-years of protection, at a cost per person-year-protected of $1.52, and a per-net cost of $7.54.

Summary modelling results are included in the additional files as Table 3.2.

Figure 3.10: TNVS plus limited school voucher plus limited community voucher.



3.5 Discussion

3.5.1 Community delivery of nets

The most significant difficulty presented by the community-based distribution approach is how to define and identify households that qualify for a new net or voucher in an equitable and implementable manner. Criteria for identifying these households would need to be transparent and consistently applied; reporting and supervision would likely need to be intensive in order to meet donor reporting requirements showing that the system is reaching the right households. At the same time, communities should have some leeway in determining the most needy households. Verification that new nets are needed at the household level may be difficult; an alternative is to institute a net replacement programme where worn nets are exchanged for new ones. However, such a system might reward households that wear their nets out more quickly.

Community-based distribution could provide a more continuous distribution mechanism but likely at a slightly higher cost per net delivered, due to smaller and more frequent deliveries to village level (if direct distribution is used), and an expansion of the monitoring system being required. Semi-annual or quarterly net distribution is recommended for direct deliveries or continuous voucher availability. A voucher, particularly if the top-up is increased slightly, may provide a limiting factor to reduce the number of households that obtain more nets than they need. A steady supply of vouchers would need to be issued over the course of the year with caps at a village level to avoid rapid depletion of capital from the programme for voucher redemption (this could be estimated based on UCC registration numbers, but growth rates for specific village/ward levels may be highly variant due to dramatic differences in migration and urbanization rates; registries would need to be updated regularly to ensure adequate supply volumes if nets rather than vouchers are delivered to households). A retailer scale-up programme would also be necessary if a voucher mechanism is used. To ensure that criteria for voucher or net allocation are met at the village level a significant investment in the supervision system will be necessary.

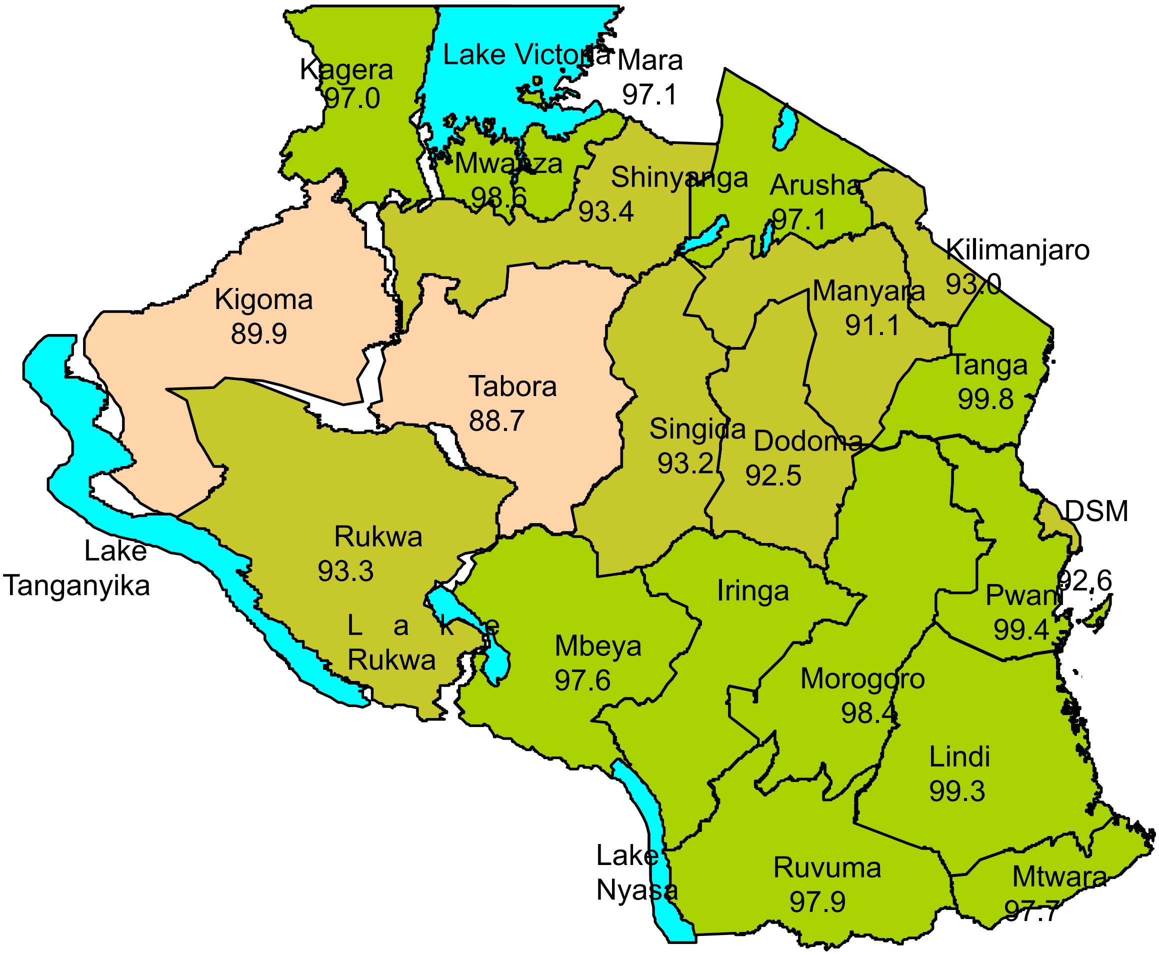
3.5.2 School-based distribution

Collaborations between the health and education system are not new; health staff within the school system have also implemented Vitamin A, mebendazole and praziquantel campaigns. Collaboration could be coordinated through District School Health Coordinators and School Health Committees as with these other campaigns. Logistically, vouchers would be easier to distribute than nets, and this system would enable the retail networks to expand stocks, potentially making this a more attractive option as volumes of net sales increase, as well as to allow options for net choice which might not be possible with direct LLIN distribution through schools. Distribution of free nets at schools could be done all at once but would require significant storage and management logistics. Any school-based distribution option must take into consideration the logistical burden on school staff.

The timing of distribution is also important. Distributing large numbers of vouchers at the beginning of the school year would mean that retailers would require large stocks of nets at one time. It may be preferable to distribute vouchers to school children more or less evenly throughout the year, perhaps by grade level, in order for retailers to maintain a steady level of stock, as they may be unable to scale up to meet demand by all students at once.

Retailers have largely set up around the clinics to capture the maximum number of vouchers as they are issued. As the current network is rather saturated, having the schools as an additional voucher distributing point creates the possibility to bring in new retailers who can situate themselves close to schools. However, the challenge will be to have them in place at the start of implementation of the strategy, as few may be willing to take the risk of investment before seeing the vouchers actually distributed. Additionally, consideration of school attendance and enrolment rates, the latter of which are high in Tanzania (Figure 3.11) should take into account the fraction of children that attend boarding schools and thus would return home irregularly and thus not deliver nets the household. This was not considered in the estimates included in the paper and this is a potential limitation of this research.

Figure 3.11: Primary school enrolment by region (2010).



3.5.3 Commercial sector

While Tanzania previously had multiple brands of locally made ITNs bundled with insecticide treatment kits available at both full retail and subsidized prices, the NMCP switched to LLINs in 2009, and Tanzania ceased importation of retreatment kits by 2010. Textile Manufacturers of Tanzania Limited (TMTL) and Moshi Textile Mills Limited (Motex) ceased production of untreated polyester nets in July 2009 and March 2010 respectively. The remaining Tanzanian net manufacturers, A-Z and Sunflag, were expected to run out of bundled polyester nets due to lack of available insecticide retreatment kits by September 2011 (PSI/Tanzania 2011).

It is not clear whether there is a significant market for unsubsidized LLINs outside urban areas. Internationally recognized, WHOPES-recommended LLINs (manufactured by A-Z, BASF, Vestergaard Frandsen and BestNet) are available on the Tanzanian commercial market in small quantities but these remain an insignificant portion of the LLINs available in country.

Due to the highly limited information on demand at various prices, it is difficult to predict the coverage that would result from a manufacturer subsidy. However, evidence suggests that such a system would not be equitable except at an extremely low retail price, and retailers are unlikely to accept a recommended retail price of TZS500 given their current dissatisfaction with this margin under the TNVS (Gingrich *et al*. 2011). Current information on the equity of the TZS500 voucher is not yet available. Even if nets are highly subsidized at manufacturer level, as nets move through the retail chain, prices are likely to rise to a level beyond the ability to pay for a large proportion of Tanzanian households.

3.5.4 Combinations

Many of the proposed individual mechanisms for LLIN “Keep-Up” will likely fail to deliver adequate numbers of LLINs to maintain universal coverage. Combination approaches to net delivery have been tried previously in some settings including PSI’s “Malawi model” that combined traditional social marketing with highly subsidized nets delivered to pregnant women and children under five through ANC-EPI clinics in Malawi (Stevens *et al*. 2005; Chavasse *et al*. 2001) Kenya’s mix of ANC distribution, subsidized nets and campaigns has been described elsewhere (Hightower *et al*. 2010; Guyatt *et al*. 2002; Noor *et al*. 2007; Tilson 2007; Wacira *et al*. 2007). In the Tanzanian “Keep-Up” context combinations of approaches may allow the achievement of LLIN delivery on the scale needed to maintain universal coverage and at the same time allow for the targeting of different households based on the targeting criteria of each selected channel.

Special attention needs to be paid to the overlap of households targeted by various channels in combined approaches. NetCALC assumes inter-household reallocation and thus approaches that focus on specific target groups may appear in the model to increase population level coverage even though in reality nets would concentrate within households in the absence of such reallocation. Some combinations such as TNVS plus primary school vouchers may deliver nets to the same household and as such NetCALC may overestimate coverage results based on the overlap. This targeting of households through multiple channels may be seen as both an advantage and disadvantage of using combined approaches depending on the demographics of the country and the various channels chosen in combination.

3.5.5 TNVS plus rolling campaigns

Tanzania has already combined universal campaigns with ongoing TNVS; preliminary evidence (MEDA, pers comm) indicates that the mass distribution campaigns did not significantly dampen the demand for voucher redemption, despite predictions to the contrary, indicating that it may be possible to combine free LLIN delivery with a subsidized system in this context. In this model, national coverage remains high and the costs of this strategy are comparatively low, though local coverage levels will still fluctuate greatly between distributions.

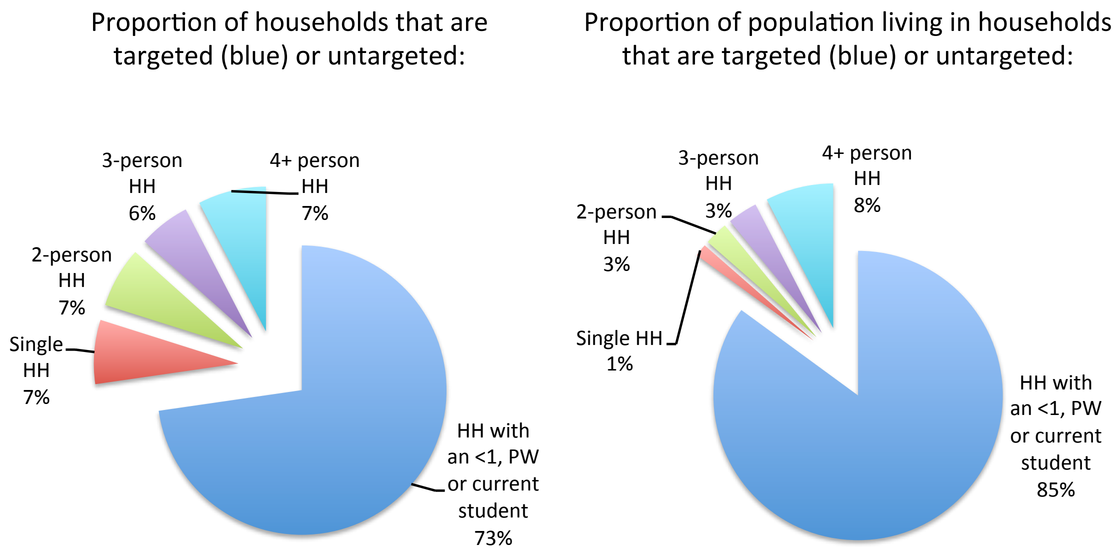
A continuous rolling campaign by zone would require a dedicated campaign team. This would be preferable to adding campaign planning to the existing workload of already busy NMCP and implementing partner staff.

Mass campaigns need to remain a tool in the arsenal of the Tanzania NMCP, but are better suited for emergency "catch-up" situations when national or sub-national areas have fallen below target levels of ownership and use of LLINs and will not recover using the country's "Keep-Up" strategy; during epidemics or emergency situations, or alternatively for the regular coverage of institutional sleeping spaces such as boarding schools, prisons, hospitals and military camps.

3.5.6 TNVS plus school-based distribution

The TNVS plus a school-based method of delivery has the potential to reach a large majority of households, shown in Figure 3.12. Approximately 73% of households, representing 85% of the population, include a currently pregnant woman, an infant (under one year) or a current student (National Bureau of Statistics (NBS) [Tanzania] *et al*. 2011). The remaining untargeted households are split evenly among single-person households (7% of all households and 1% of the population), two-person households (7% of all households and 3% of the population), three-person households (6% of all households and 3% of the population), and households with four or more people (8% of all households and 8% of the population). Of the single-person households, roughly two-thirds (65%) are male. Of the two-person households, 73% are male-female households, split 44/56 between couples under and over age 40. Roughly two-thirds of the larger untargeted households have one to three children between the ages of one and five, and thus would have recently been eligible for the TNVS (both the pregnant woman and the infant voucher). These households would be expected to move into the targeted category as the children reach school age.

Figure 3.12: Proportion of targeted and untargeted households and population living in them. The school voucher + TNVS approach would reach the 73% of households (left) that have at least one member of the target groups. Because the untargeted households are smaller in size than targeted households, a greater proportion of the population (85%) is reached through this combination.



The combination of the TNVS plus school voucher distribution is the only option with a clear and straightforward identification mechanism for beneficiary households that could also supply nets on a continuous basis, avoiding significant drops in coverage. While scaling up retailer stocks to meet the increased demand would require significant initial seed investment, and the logistics of voucher distribution through the school system remain to be developed in detail, the advantages of this option make it a promising one for reaching a large proportion of households within Tanzania with replacement nets.

3.5.7 TNVS plus community-based distribution

TNVS plus a community distribution has the potential to reach 100% of households – but given geographic barriers in remote areas, bias favouring households that are more central to the distribution site or voucher holder, political considerations, and the good but varied success of the UCC and hang-up campaigns at reaching all households with the correct number of nets, 100% coverage of all households is not guaranteed under such a mechanism.

3.5.8 Choice

While the majority of stakeholders expressed desire to have a range of choices available for nets (for size, shape, material and colour), incorporating choice of nets within the retail sector on multiple parameters would likely require massive working capital injections in order to ensure availability of a variety of options at each retail location. Vouchers do offer an obvious mechanism for incorporation of choice compared with direct net delivery, and this process is simplified when the voucher represents a fixed value and the consumer provides a top-up that corresponds with the difference in price of their preferred net.

3.5.9 Scaling up LLIN stocks at retailer level

Initial seed funding from the President's Malaria Initiative (PMI) and A-Z was used in 2010-11 to increase working stocks of nets for around 3,000 retailers, using a "buy five get 10 free" programme, in which PMI and A-Z each provided five free nets to retailers who purchased five themselves. This fund has been exhausted and the newer and smaller retailers interviewed found it difficult to finance scale-up due to shortage of working capital. Even though a large number of retailers reported working capital as their utmost constraint for business expansion, a close analysis of their business showed that they lack basic business management skills like record keeping, stock planning, cash management, etc, that are crucial for managing their businesses. There is, therefore, a need to provide training to retailers in addition to any potential credit mechanism.

If school or community vouchers are issued only once or twice per year, retailers would need significant capital in order to scale up stock levels to meet the large demand for nets immediately following the voucher distribution. If voucher distribution is more evenly spaced throughout the year, demand is likely to be lower on average and more consistent, and retailers would require a smaller amount of capital in order to scale up stocks of LLINs to meet demand.

3.5.10 Behaviour change communication and net durability

Net durability is comprised of the bio-availability of insecticide on the net over time, the net's physical condition (holes, tears, burns, etc), and perhaps most importantly, the perception of the user about their net's usefulness. BCC was cited in every stakeholder meeting as a key component of any "Keep-Up" strategy, to stimulate demand for nets and encourage consistent use throughout the year. Along with improvements in the physical durability of LLINs, "care and repair" messaging also has the potential in theory to increase the useful life of nets, although by how many months remains to be quantified. Should LLIN effective lifetimes be substantially longer than under the base scenarios, net replacement needs could be substantially lower. This factor is one of the largest cost drivers in the modelling exercise. If mean lifespan is two years, 89 million nets would be needed; if mean lifespan is three years, 63 million nets would be needed; a mean lifespan of four years would require 51 million nets over 10 years. Textile improvements and BCC activities that could significantly extend the life of LLINs should be explored and evaluated.

3.5.11 Population estimates

Experience from the recent mass campaigns indicates that Tanzania's 2002 Census figures and subsequent projections by the National Bureau of Statistics may be underestimating the population by as much as 15% (Bonner *et al*. 2011). This represents a significant difference with implications for procurement and planning. In the estimates presented here NBS population projections are used, but planning committees should consider including room for this level of population variance in final budgets.

3.6 Conclusions

The "Keep-Up" strategy that is most cost-efficient to maintain universal coverage will be the strategy that best optimizes the numbers of nets needed over time, while maintaining universal coverage of LLINs. Based on the modelling and costing shown here, in combination with the qualities of a desirable system identified by stakeholders, it appears that a TNVS targeting pregnant women and infants plus school-based voucher distribution (to Standards 1, 3, 5, 7, and Forms 1 and 4) is the best strategic option. The strategy has a very clear and simple identification strategy, the ability to reach 85% of the population when combined with the TNVS, and could be clearly monitored. A modified version of this approach whereby physical nets are distributed to these students, rather than vouchers, is now being piloted in 20 districts in the country to assess field effectiveness, and to examine in particular whether targeted households redistribute excess nets to untargeted households. Repeated mass campaigns and some level of private sector delivery remain strong potential back-up strategies in the event of failure of the selected "Keep-Up" strategies.

3.7 Competing Interests

The authors declare that they have no competing interests. At the time of the fieldwork, Nick Brown was head of the ITN Cell at the Tanzania NMCP. He is currently employed by A-Z Textile Mills Ltd.

3.8 Authors' contributions

HMK led the fieldwork and drafted the manuscript; JOY conducted the modelling and fieldwork and contributed to the manuscript; AM conducted fieldwork and contributed to the manuscript. RM, NB and CL contributed to the study design. AK designed the NetCALC tool. All authors read, edited and approved the final manuscript.

3.9 Acknowledgements

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3.10 Additional Files

Table 3.1: Interviews and stakeholder participation, by location

Table 3.1 summarizes the number and types of stakeholders consulted through meetings and interviews during the fieldwork, by location.

Table 3.1: Interviews and stakeholder meeting participation

	Dar es Salaam	Morogoro	Mtwara	Mwanza	Arusha	Dar es Salaam (second meeting)	Dar es Salaam Final	Total
Number of regions participating in zonal stakeholder meetings	1	3	3	7	4	1	8	18
Number of participants[o] at the zonal stakeholder meeting	36	~35[a]	~35[a]	46	47	26*	41	225
Number of district field visits		1	1	2	2	3*		9
Number of RCH clinics visited		1	1	2	2			6
Number of retailers interviewed		2	3	2	2	2*		11
Number of net manufacturers interviewed	1	1		1	3			6
Number of CBOs and Tanzanian NGOs interviewed	2		1	2				5
Donor agencies interviewed	5							5
International NGOs interviewed	6							6

[o] Participants included regional and district medical officers, reproductive and child health clinic nurses, regional and district malaria focal persons, council health management team members, district executive directors, regional administrative secretaries, municipal executive officers, village executive officers, principal health officers, retailers, community members, implementing partner staff, national malaria control programme staff, net manufacturers and distributors, and in Dar es Salaam, implementing partner staff, donor agencies and other NGOs.

[a] Attendance sheets were lost and exact numbers are not known.

* Field visits were not conducted but district municipal council members and retailers from Temeke, Kinondoni, and Ilala were consulted during a separate stakeholders meeting.

Table 3.2 summarizes results of NetCALC modelling over the period of 2012-2021 for various options for maintaining universal coverage. All options mentioned in the paper are presented here and described in % of person-years-of-protection (PYP) obtained, number of LLINs required, total cost in USD, cost per LLIN, cost per PYP, and number of excess LLIN delivered for each option

Table 3.2: Summary results of LLIN coverage and usage modelling over period 2012-2021. All costs in 2011 USD.

Distribution System	% of person-years protected (PYP) 2012-2021	# LLIN delivered (millions)	Total Cost (million USD)	Cost per LLIN[1]	Cost per PYP	Excess LLIN (millions)[2]
Tanzania National Voucher Scheme (TNVS)/Antenatal Care-Expanded Programme on Immunization (ANC-EPI)-based approaches						
TNVS only	45%	26.5	$182	$6.87	$0.99	2.7
ANC-EPI net distribution	48%	29.5	$212	$7.19	$1.10	2.9
Universal Coverage Campaign (UCC)-based approaches						
UCC (3 year cycle)	77%	61.5	$406	$6.59	$1.32	11.6
UCC (5 year cycle)	54%	47.0	$249	$5.30	$1.18	2.7
Community-based approaches						
Community voucher	78%	62.7	$477	$7.61	$1.52	2.7
Community nets	78%	62.7	$432	$6.89	$1.39	2.7
Household net card/voucher (1 per household per year)	78%	62.4	$475	$7.61	$1.52	2.7
School-based approaches						
Large Scale School[3] Voucher	73%	56.7	$390	$6.87	$1.32	2.7
Large Scale School Nets	83%	67.4	$466	$7.00	$1.41	2.7
Commercial sector-based approaches						
Subsidized sales[4] TZS500	52%	33.4	$214	$6.40	$1.00	2.7
Subsidized sales TZS1,000	49%	30.3	$188	$6.18	$0.93	2.7
Mixed Top Up Sales (mixed subsidized sales)	52%	33.4	$209	$6.26	$0.97	2.7
Combination approaches						
Two-way combinations						
UCC (3-year cycle) + TNVS	82%	63.3	$444	7.01	$1.35	6.2
UCC (5-year cycle) + TNVS	75%	71.1	$432	$6.06	$1.45	12.9

Distribution System	% of person-years protected (PYP) 2012-2021	# LLIN delivered (millions)	Total Cost (million USD)	Cost per LLIN[1]	Cost per PYP	Excess LLIN (millions)[2]
TNVS + Limited School Voucher	82%	65.4	$449	$6.87	$1.34	2.7
TNVS + Large School Voucher	93%	86.9	$597	$6.87	$1.57	37.0
Commercial (subsidized) + TNVS	76%	58.0	$386	$6.65	$1.23	3.2
Commercial (subsidized) + School (Limited)	77%	58.8	$391	$6.65	$1.24	0.2
Commercial (subsidized) + Community Voucher (limited)	86%	68.2	$453	$6.64	$1.29	4.2
	Three-way combinations					
TNVS + School Voucher (Limited)+ Community voucher (limited)	85%	69.0	$520	$7.54	$1.52	2.7
Commercial (subsidized) + TNVS + School (limited)	93%	85.8	$577	$6.72	$1.51	33.5
	Four-way combinations					
Commercial (subsidized) + TNVS + School (limited) + Community (limited)	93%	111.5	$799	$7.17	$2.12	106.1

1. Cost per LLIN is the average cost per LLIN delivered over the period 2012-2021
2. Excess LLIN = the number of LLIN delivered in excess of need for full coverage and is calculated on an annual basis, the number shown refers to the entire period 2012-2021
3. School = School voucher unless otherwise noted (limited refers to vouchers given only to certain classes while large scale refers to delivery to all primary school students
4. Commercial (subsidized) = Manufacturer Subsidy

4 A good night's sleep and the habit of net use: perceptions of risk and reasons for bed net use in Bukoba and Zanzibar

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4.1 Abstract

Intensive malaria control interventions in the United Republic of Tanzania have contributed to reductions in malaria prevalence. Given that malaria control remains reliant upon continued use of long-lasting insecticidal bed nets (LLINs) even when the threat of malaria has been reduced, this qualitative study sought to understand how changes in perceived risk influence LLIN usage, and to explore in more detail the benefits of net use that are unrelated to malaria.

Eleven focus group discussions were conducted in Bukoba Rural District and in Zanzibar Urban West District in late 2011. Participants were males aged 18 and over, females between the ages of 18 and 49, and females at least 50 years old.

The perceived risk of malaria had decreased among the respondents, and malaria control interventions were credited for the decline. Participants cited reductions in both the severity of malaria and in their perceived susceptibility to malaria. However, malaria was still considered a significant threat. Participants' conceptualization of risk appeared to be an important consideration for net use. At the same time, comfort and aspects of comfort (getting a good night's sleep, avoiding biting pests) appeared to play a large role in personal decisions to use nets consistently or not. Barriers to comfort (feeling uncomfortable or trapped; perceived difficulty breathing, or itching/rashes) were frequently cited as reasons not to use a net consistently. While it was apparent that participants acknowledged the malaria-prevention benefits of net use, the exploration of the risk and comfort determinants of net use provides a richer understanding of net use behaviours, particularly in a setting where transmission has fallen and yet consistent net use is still crucial to maintaining those gains.

Future behaviour change communication campaigns should capitalize on the non-malaria benefits of net use that provide a long-term rationale for consistent use even when the immediate threat of malaria transmission has been reduced.

4.2 Background

The recent scale-up of malaria control interventions in Tanzania has dramatically reduced the risk of malaria in many regions. Given that malaria control is reliant upon continued use of long-lasting, insecticidal bed nets (LLINs) even when the threat of malaria has been reduced, this study aimed to explore factors at play when perceived threat is low, and how net use might be promoted when fear appeals are no longer effective. Through the use of qualitative methods, this study sought to understand how changes in perceived risk influence LLIN usage, and to explore in more detail the benefits of net use that are unrelated to malaria.

Between 2008 and 2011, mainland Tanzania experienced a significant reduction in malaria parasitaemia due in large part to a comprehensive and well-implemented malaria control programme. The National Malaria Control Programme (NMCP) conducted two mass campaigns with LLINs, first targeting children under five (Bonner *et al*. 2011) and then the general population (West *et al*. 2012; Renggli *et al*. 2013), conducted indoor residual spraying (IRS), scaled-up access to artemisinin combination therapy (ACT) and intermittent preventive treatment for pregnant women (IPTp) and carried out large scale, social and behaviour change communication efforts (President's Malaria Initiative 2012). Zanzibar's parasitaemia rates have fallen significantly since 2004, thanks to the introduction of ACT in 2003, ad-hoc LLIN campaigns in 2005–6 and 2008, and yearly IRS since 2006 (Bhattarai *et al*. 2007; Aregawi *et al*. 2011). The recent Malaria Indicator Surveys showed that in Zanzibar, malaria prevalence stood at 0.8% in 2007 and remained less than 1.0% in the 2011–12 THMIS. In Kagera Region, prevalence fell from 41.1% in 2007–8 to 8.5% in 2011–12. LLIN ownership in both areas was high with use rates lower in Zanzibar (Table 4.1) (TACAIDS Tanzania Commission for ADS, ZAC Zanzibar AIDS Commission, NBS National Bureau of Statistics, OCGS Office of the Chief Government Statistician and Macro International, INC 2012).

Table 4.1: Long-lasting insecticidal bed net ownership and use in study sites from 2011-2012 Tanzania HIV-AIDS and Malaria Indicator Survey

	Ownership of at least one net/LLIN	**Average number of nets per household (any net/LLIN)**	**Use of net/LLIN (general population)**	**Use of LLIN among households with at least 1 LLIN**
Kagera Region (n=445)	94.2%/91.9%	2.3/2.1	70.7% / 66.9%	72.6%
Zanzibar (Unguja) (n=141)	84.3%/65.5%	2.3/1.6	57.6% / 36.7%	58.6%

Note: Fieldwork for the 2011–2012 THMIS was done concurrently with the fieldwork for this study

The use of nets is driven by a variety of factors, including first and foremost the availability of nets within the household (Eisele *et al*. 2009), and then by mosquito density, seasonality, risk perception, social factors, and practical issues (MacCormack *et al*. 1986; Winch *et al*. 1994; Toé *et al*. 2009; Baume *et al*. 2009; Ng'ang'a *et al*. 2009; Widmar *et al*. 2009; Atkinson *et al*. 2009; Pulford *et al*.

2011; Beer *et al*. 2012). Non-use of nets has been most often reported to be due to perceived low mosquito density and to discomfort, generally due to heat (Pulford *et al*. 2011). Net use messaging in Tanzania and in many other countries has focused almost entirely on the prevention of malaria as the key reason to use nets. Key messages that have focused on the threat of the disease may no longer resonate with populations who do not perceive malaria to be a significant danger. If prevention of malaria is the sole message promoting net use, little remains to encourage individuals to use their nets in a context of reduced malaria incidence. There is a considerable gap in the evidence regarding appropriate and effective messaging during periods of low malaria risk. It is largely unclear how to motivate populations who perceive that malaria is no longer a major threat. This is an important issue to address as malaria prevention efforts approach the elimination of the disease in certain regions and countries.

Elements of the Health Belief Model (HBM) (Janz *et al*. 1984; Rosenstock 1974) and the Theory of Reasoned Action (TRA) (Fishbein *et al*. 1975; Azjen *et al*. 1980) were used to develop the conceptual model for this study (Figure 4.2) and the discussion guides. Beer *et al*. demonstrate effectively that HBM can be used to interpret net use behaviours in the context of reduced risk in Zanzibar (Beer *et al*. 2012). Constructs from the HBM included perception of risk (composed of perceived susceptibility and perceived severity of illness), self-efficacy, perceived benefits, perceived barriers, and cues to action (such as presence of mosquitoes). According to the HBM, an individual will take preventive action if they believe that action will prevent illness and if they have the desire to avoid that illness. The TRA states that individuals make decisions based on subjective norms, attitudes and beliefs about the outcome of an action, which lead to intention to perform behaviour and subsequently the behaviour itself.

This article expands on the recent studies that explored perceptions of malaria and bed net use after a reduction in malaria incidence during interviews conducted in Zanzibar in 2007 and 2012, respectively (Beer *et al*. 2012; Bauch *et al*. 2013), by focusing on how non-malaria benefits of nets are perceived by those living in areas of reduced malaria transmission, and how these findings inform message development for behaviour change communication interventions.

4.3 Methods

4.3.1 Study population

This research was comprised of 12 focus group discussions (FGD) with purposively sampled participants in Bukoba Rural and Zanzibar. However, one of the FGD recordings had technical problems and could not be recovered. Therefore, the results presented report on data gleaned from 11 FGDs. In each of the two sites, participants were purposively sampled by age, sex and net user status. Each site had focus groups with men aged 18–49, women aged 18–49, and women over the age of 50 years. Older women were selected as a separate focus group distinction since they would be better able to talk about changes in malaria risk, net availability and net use over time. All study participants were residents of Bukoba Rural or Zanzibar. Focus group sizes ranged from seven to 11 participants and a total of 35 men and 60 women participated in the FGDs.

4.3.2 Study sites

Bukoba Rural and Zanzibar were chosen as study sites due to their significant malaria efforts, in particular the mass net distribution and indoor residual spraying campaigns over the past six years. For the four months prior to fieldwork, Bukoba Rural had its universal coverage campaign and subsequent Hang Up visits to provide nets and promote their use. In both sites, heavy rains fall from March to May and short rains from September to November in Zanzibar (October to December in Bukoba); hot season occurs in December (Zanzibar), January and February (Bukoba). In Kagera, three wards within Bukoba Rural District were selected (Kikomero, Rutete and Butelankuzi); in Zanzibar, two shehia in Zanzibar Urban District (Mkele, classified as rural, and Mlandege, an urban site) were selected.

4.3.3 Procedures

Data was collected from 29 November to 6 December, 2011 by a team of four data collectors trained on study design, aims of the study and ethical treatment of participants, using pretested, semi structured interview guides. In Bukoba Rural, the District Malaria Focal Person, village chairpersons and community volunteers conducting Net Hang-Up visits worked with the study team to identify households that owned at least one net and used, or did not use nets. In Zanzibar, the Zanzibar malaria control programme official plus the Sheha (lowest government officials) identified households. Potential participants were screened using a recruitment/screening tool. Interviews were conducted in

Swahili. Interviewers were trained to distinguish between malaria fever (*homa ya malaria*) and non-malaria fever (*homa isiyokuwa ya malaria*) as Kiswahili words for fever and for malaria have been previously shown to be context-dependent (Winch *et al*. 1994). Transcripts confirmed that participants made this distinction. Discussions touched on other types of fever (*homa*) but these findings relate to *homa ya malaria*.

4.3.4 Data analysis

FGDs were audio recorded, transcribed verbatim, and translated into English. Transcripts were coded in Atlas.ti version 6.2 software using a hybrid approach of inductive and deductive coding. One individual coded all of the transcripts and an analysis team assessed outcomes of interest by region, sex, and user status.

4.3.5 Ethical considerations

Ethical approval for this study was obtained from both the Johns Hopkins University School of Public Health Institutional Review Board in Baltimore, MD, USA and the University of Dar es Salaam Directorate of Research and Publications. Participants provided oral consent prior to participating in the study. No personal identifiers were recorded or transcribed.

4.4 Results

4.4.1 Perceived risk of malaria

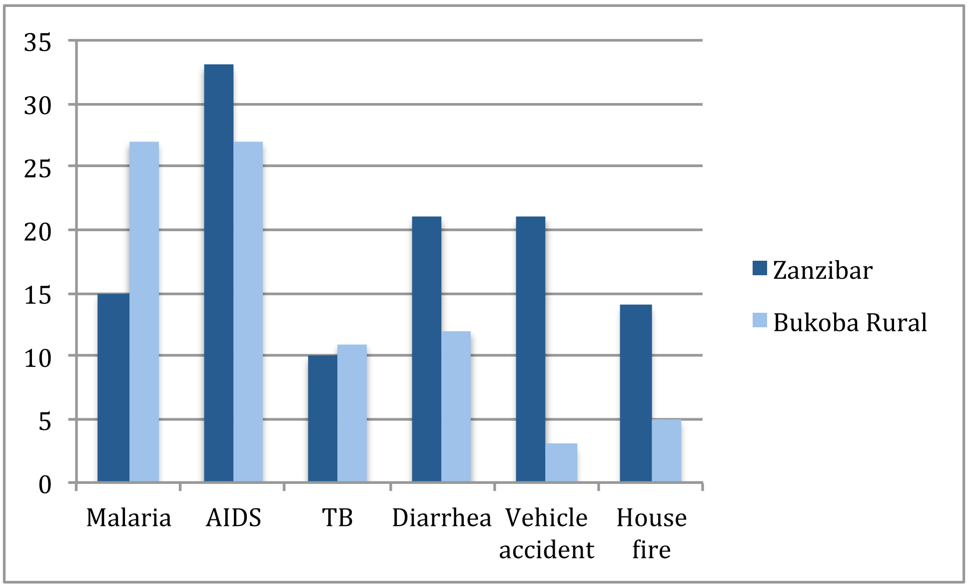
As described in Witte's Extended Parallel Process Model (Witte 1992) and in the HBM (Rosenstock 1974), perceived risk is composed of both the perceived severity of the risk and the perceived susceptibility to the risk. Perceived severity of the threat is the danger that malaria poses; perceived susceptibility is informed by the perceived probability of getting malaria, or developing severe malaria. Participants spoke about changes in both severity of the risk of the malaria as well as their own susceptibility.

To first situate perceived susceptibility of malaria compared to other diseases or calamities, participants were asked to sort various diseases (malaria, HIV, diarrhoea, tuberculosis) known to be important health problems (Kinung'hi *et al*. 2010) or other calamities (house fire, vehicle accidents) as having either a ‘high chance’ of happening or a ‘low chance’ of happening. Participants in Bukoba Rural tended to agree that malaria and HIV had a high chance of occurring. Tuberculosis, diarrhoea, vehicle accidents and house fires were generally rated as ‘low chance’ or ‘less likely’ to occur. In Zanzibar, however, malaria was rated as ‘low chance’ by two of the five groups. HIV remained a high chance occurrence, along with vehicle accidents.

> *“Malaria according to what I think it has a high chance because despite the fact that there is no severe malaria but every day you will hear this one has malaria and this one has malaria; so in short I think that it has a high chance of happening.”(Older female, Zanzibar)*

Participants were asked to rank the diseases or calamities rated as ‘high chance’ of occurrence. Participants interpreted this to mean a ranking of most worrisome to occur to the least worrisome. Scores of 6 (most worrisome) through 1 (least worrisome) were assigned to the rankings, and to account for the ‘low chance’ ratings, these items were given a −1 score. Malaria and HIV were perceived as the most worrisome, as shown in Figure 4.1. Zanzibari participants rated malaria lower than HIV and vehicle accidents, citing reductions in malaria.

Figure 4.1: Summed rankings of diseases and calamities, by study site



4.4.2 Reduction in overall risk

To understand the respondents’ perceptions of risk both in the past and at the time of the interview, discussion groups were asked about how fevers “nowadays” compared to “in the past’. Only a few participants felt that malaria had in fact increased or become more severe over recent years. These were mainly older men or women, who felt that this increase was due to a loss of earlier immunity, gained through diet or traditional medications. Another noted that while the occurrence of malaria may not have increased, the disease itself had become more severe. However, the few examples of increased sense of risk were greatly outweighed by the number of responses expressing an overall reduction in perceived malaria risk. Many respondents specifically noted a reduction in severe malaria or convulsions (*degedege* in Swahili) as evidence for the decline. Respondents cited the availability of LLINs, indoor spraying, and quality drugs at the health facilities, behaviour change communication, and sanitation improvements as the primary reasons for the decline in both severe and non-severe malaria.

> *R: "To say the truth I see malaria has decreased because I am talking about a ward in my village and I am a secretary of a women's group. Most of times there were many children's deaths during rainfall but this time they are few." (Older female, Bukoba Rural)*
>
> *R: "We fear it but not like in the past."*
>
> *I: What are reasons behind that?*
>
> *R: "We sleep under nets everyday and there are drugs to treat the disease. If you are sick and you go to a dispensary you'll be given treatment like Alu [artemether-lumefantrin] tabs, septrin, paracetamol and if it's a child s/he will be given quinine injections and then s/he may recover." (Female, Bukoba Rural)*
>
> *R1: "It is not the same as in the past, people didn't bother about malaria in the past but now they are using mosquito nets properly because they want to prevent themselves from getting sick. They have changed.*
>
> *R6: They have changed because in the past we used local herbs when we suffered from malaria…now we go to hospital for treatment." (Female, Bukoba Rural)*

Health education was cited as playing a part in the change in risk. Participants noted that in the past, people often went first to traditional healers, and then to the hospital when those treatments did not work. Now, "everyone understands" that they should go to the hospital quickly.

> *R: "Because in the past people did not understand the need of rushing to the hospital and many did not know that diseases could be treated at the hospital. Some were preventing others*

to go to hospital because they believed that children might die after being injected or given oral medicines. But as we are being educated then we came to know that when a child develops convulsions and hurried to a hospital, she gets well quickly after being infused with some medicines. Therefore right now many people have understood that convulsions are coming from malaria. In the past we used to call it Ezabo in Haya language, we did not know it was malaria." (Older female, Bukoba Rural)

R: "The danger was significant because we had no knowledge and few people used nets and when they didn't go to hospital when someone got sick, they used local herbs such as neem and others. Now when someone gets sick they rush to hospital, Alhamdulillah, he gets treatment and recovers." (Female, Zanzibar)

4.4.3 Nets cannot prevent all bites

Response efficacy, or the respondents' perceived efficacy of the LLIN at preventing malaria, was reduced or limited in several circumstances. Staying outside during the evening, or needing to travel or work and not having a net were recognized as potential opportunities to be bitten by mosquitoes and develop the disease. "There are many that are using bed nets but they still suffer from malaria", noted one participant (older female, Bukoba Rural). Others echoed those sentiments, noting that some people never used nets but never fell ill, while others used nets and continued to get sick. Respondents also noted that the insecticide wears out, citing a need for new nets or for the retreatment kits (Ngao) that had been socially marketed for several years prior.

R: "[Malaria] is not preventable, you may find that at my place I am using a bed net but when I am travelling using a boat or bus the mosquitoes are biting me and I do not have protection so I will get malaria." (Older female, Bukoba Rural)

R3: "I think that it has decreased a bit, malaria has decreased. Everyone has their own understanding, I can say that malaria has decreased and I keep on protecting myself, do you understand me, because if this mosquito has died that was born yesterday, the day after tomorrow there comes another one…because of this issue with the mosquito I don't think if malaria will be eradicated. What you can only do is to protect yourself from them but saying that they will leave completely they will not leave, because when they die there are others that are born, and then they die, and then new ones are born." (Female, Zanzibar)

4.4.4 Perception of risk complicated by rapid diagnostic tests

In the Zanzibar focus groups, the participants discussed the confusion arising from malaria testing, and the uncertainty of whether or not they had malaria and how it should be treated. Rapid diagnostic tests are widely available and used in both public and private clinics throughout Tanzania. Respondents expressed impatience with doctors who told them they did not have malaria, when the participants felt that they did. In some cases the participants sought out malaria treatment despite the doctor's advice; in other cases, the doctors themselves provided malaria treatment even when malaria test results were negative.

> *R: "I would like to contribute there that when you go to the hospital, all the hospitals private ones and government ones you are told that you do not have malaria when you are tested for malaria but I am surprised that some of the doses are for malaria."*
>
> *I: Which doses?*
>
> *R: "If you will be given, first of all now there are combination medications for malaria and it has a name written in green I do not know what, when you go there you are given while you do not have malaria and those medication for malaria despite the fact that you have been tested and they said you do not have malaria they still give you those medications for malaria." (Female, Zanzibar)*

Repeated negative test results contributed to a reduced perceived need for malaria preventive behaviours.

> *"I think now the usage of nets have decreased because there are few mosquitoes and when people go to hospitals to test for malaria, they are always found negative. When you feel joint pains, headache or fevers and then you go for a malaria test, the results are always negative though they'll give you anti-malarials, so because of this the usage of nets has decreased." (Male, Zanzibar)*

4.4.5 Seasonal variations in perceived risk

In addition to the distinctions made between risk of malaria over the past few years, participants noted that malaria risk continues to change throughout the year. This has been more fully explored by Winch (Winch *et al*. 1994) but the link between seasons, weather and risk of malaria and anaemia remains strong according to some of the participants, particularly the older men and women. In addition, participants generally linked an increase in mosquitoes to an increase in malaria. November to December and June to July were months in which "mosquitoes are many" (Older females, Bukoba Rural).

In both study sites, but particularly in Bukoba, several respondents noted that hot seasons were in fact the time of highest malaria risk. Respondents attributed malaria to the hot weather and to wind, stating that mosquitoes bred during the rainy season and then commenced biting or "woke up" once it became sunny and dry. In Bukoba, respondents noted that they were "more afraid" of malaria during the months of May to August, the "sunny season" that follows the rainy season; "in June children usually fall sick and you find many sick children when you go to hospital" (Older female, Bukoba Rural). The perception that malaria risk was highest during the rainy season was more common in Zanzibar.

4.4.6 Benefits of net use

While respondents agreed that malaria prevention was one of the main reasons for using nets, many also stated that there was no reason to stop using them just because the risk of malaria had apparently decreased. Rather, participants expressed that they were more motivated to use nets, in order to maintain its protective benefit from malaria, but also because they now found that LLIN use had become a habit, and that sleeping without a net contributed to worries and to a sense of discomfort. Respondents also stated that IRS campaigns did not reduce their need to use nets; behaviour change communication (BCC) campaigns had instructed them to keep on using the nets after spraying, and that the dual protection provided by the spray and the net were seen as complementary rather than duplicative.

> *R: "When you use mosquito net then the possibility of being bitten by mosquitoes is small so as the chance of developing malaria. But if you don't use a net then the possibility is big." (Male, Zanzibar)*

Respondents mentioned the reduction in cases of malaria as both motivating and demotivating for net use. Some mentioned that it encouraged net use because community members had seen how well nets worked at preventing malaria and continued using them to remain safe from the disease. Other respondents indicated that the decrease in malaria prevalence had decreased net use in the community, because people no longer thought that malaria was a problem. This issue was even debated within the same focus group discussions.

> *R1: "I think now the usage of nets have decreased because there are few mosquitoes and when people go to hospitals to test for malaria, they are always found negative. When you feel joint pains, headache or fevers and then you go for a malaria test, the results are always negative though they'll give you anti malarials, so because of this the usage of nets has decreased."*
>
> *R2: "Also not all people stopped using nets. Others after seeing that malaria cases have decreased, they have increased the frequencies of sleeping under a net so as to avoid infections completely. Also in my opinion I think we should continue to use the nets more and or spraying the insecticides more so as to kick malaria away." (Males, Zanzibar)*

4.4.7 Comfort and discomfort of nets

The non-malaria-related benefits of net use focused on the comfort of net use; these were the more salient subjective factors mentioned by respondents. Respondents indicated that increased comfort when sleeping under nets was a motivating factor for net use. Nets were said to prevent nuisance biting from insects and pests, provide warmth and contribute to getting a good night's sleep.

The most commonly mentioned benefit of net use and IRS was the prevention of bites and interactions with pests in the household. Next to considerations of the prevention of malaria and illness, comfortable sleep was the most commonly cited benefit of net use. Ticks, mosquitoes, fleas, lice and bedbugs were very commonly mentioned pests that could be avoided. However, respondents also noted the protective effect of nets against other pests such as cockroaches, snakes, rats, centipedes, ants, houseflies, lizards, spiders, and even cats.

> *R: "It is not just for the mosquitoes, there are spiders, there are insects of every kind that will always be there every kind of insect. Even that cat may be looking for rats but when it enters inside the room, the cat cannot pass there to go catch a rat. It has to go to the other side. If you are not sleeping inside a bed net, the cat will scratch you." (Female, Zanzibar)*

Many respondents indicated that this prevention of nuisance biting and pests was instrumental in helping them to achieve a good night's sleep, or usingizi mwororo. They defined a good night's sleep as sleep without disturbance. Many respondents linked the deep sleep to feeling healthy, energized and well-rested during the following day. As a respondent noted, “It helps people to have good health and when they wake up, they don’t feel exhausted.” (Female, Bukoba Rural). Most, but not all, respondents in both sites indicated that a mosquito net is a factor that can help them to get good, deep sleep. They expressed that the net keeps mosquitoes and other pests away from them while sleeping and allows them to sleep soundly.

> *R: “For those who are using the mosquito nets, it is true that it helps you to have a good sleep. For most people, when a mosquito bites you, the sleep disappears. When you are sleeping under a net, you get good sleep and everything is fine.” (Male, Bukoba Rural)*
>
> *I: “What do you mean when you say ‘usingizi murua, mnono or mwanana’*
>
> *R9: The kind of sleep with no worries*
>
> *I: What do you mean?*
>
> *R: To sleep without being disturbed by mosquitoes or bedbugs.*
>
> *I: And how can a bed net cause you to have ‘usingizi mwororo’?*
>
> *R8: Because the bed net finishes all the insects so you sleep luxuriously.”*
>
> *(Male, Bukoba Rural)*

A good night’s sleep was also characterized by a lack of worry about getting bitten by mosquitoes and developing malaria. Not only are individuals able to sleep soundly without the nuisance of being bitten, but they are freed from the fear of what consequences the bites might have.

> *R: “Be it the dry or rainy season when mosquitoes enter the house I was not worried that they might bite me because I was sleeping under the net.” (Male, Bukoba Rural)*
>
> *R: “They like to sleep inside the bed net because you do not have to worry about getting sick.” (Male, Bukoba Rural)*

One individual who did not like nets acknowledged that she could not sleep without one. The discomfort of mosquitoes outweighed the discomfort of feeling hot.

> *R: “I do not like it even a little bit but there are mosquitoes making it impossible to sleep without a bed net.*

I: Why don't you like it mama?

R: I was not used to it and it is hot sleeping in it." (Older female, Zanzibar)

4.4.8 Net use as a habit

Some respondents discussed the importance of continuous use of nets to maintain good sleep. They mentioned becoming accustomed to the net and the challenges of sleeping without one.

R: "When you are used to sleeping under a mosquito net, then that comfort would cease the moment that you stop using it because you will be disturbed by mosquitoes. Once you are used to it, then you can't stop using the net." (Male, Zanzibar)

R: "For me I see a mosquito net as a blanket and I am used to it." (Older female, Bukoba Rural)

Respondents in both sites talked about developing a habit of consistent net use. When asked their reasons for using nets, they simply mentioned that they were "used to it." While it was not completely clear how this habit was formed, in many cases it seemed to be a result of the positive outcomes associated with undisturbed sleep. In developing this habitual net use, they have become accustomed to nets and consider it a necessary part of life. Building this culture of net use is ideal for maintaining consistent net use throughout fluctuations in perceived risk.

"Though malaria has greatly decreased, there are insects which affect our sleep like cockroaches and non-malarial mosquitoes. We have to put a mosquito net and when you are used to it, then you can't sleep without it because you will definitely feel naked." (Male, Zanzibar)

R: They are still using the mosquito nets because of being used to them. I am already used to it. We started to use mosquito nets because of protecting ourselves against mosquitoes and therefore we are already used to them." (Older female, Bukoba rural)

R: Children and adults, all of them [are using bed nets] and without a bed net you cannot sleep. Mosquitoes are still there, now as they are saying that malaria is not present but mosquitoes are still there and without a bed net you cannot sleep and your children you cannot put him/her without a bed net, it is a must that your child gets a bed net and even you will not be able to sleep without a bed net." (Older female, Zanzibar)

4.4.9 Advice for friends

In order to understand the words and arguments that Tanzanian individuals would use to convince others to use nets, the interviewers asked respondents what they would say to a friend that did not sleep under a mosquito net. Respondents reiterated benefits regarding malaria prevention, comfort and getting good sleep as persuasive arguments.

> *"I will convince my friend to use a mosquito net by telling her the effects of malaria and the benefits of using mosquito nets… The effects of malaria are recurrent sufferings, deaths and then when you go to hospital you use money and your activities become affected because when you suffer from malaria, you cannot do any work. The benefit of mosquito nets is that when you sleep under it you get a good and deep sleep, you don't contract malaria, you don't get bitten by mosquitoes and snakes or rats won't fall down on you. Those are the benefits." (Female, Bukoba Rural)*

> *"For example if I know that you don't use a net I'll come to you straight and I'll ask you if you are using a net. If you say no then I'll ask you if you have one and if you have one then I'll ask you why don't you use the net… you will give me your reasons but I'll ask you again during the times when you are not sleeping under a net do you sleep well… Even if you sleep well I'll ask you again when was the last time you were sick… If you reply then I'll advise you to use a net because there a lot of mosquitoes and you shouldn't be satisfied because of the indoor residual spraying or other insecticides you use because not all insects die during the process so when you sleep they might bite you spreading the infection thus using a net helps you in avoiding them." (Male, Zanzibar).*

Some participants suggested that they would advise their friends to acquire a net or assist them with learning how to hang or use it. The various arguments presented by the respondents included considerations about knowledge promotion, net acquisition, sleeping well at night, malaria prevention and nuisance insect prevention.

4.4.10 Barriers to net use

To facilitate analysis, barriers to net use were coded as 'subjective' or 'objective'. Subjective barriers were primarily attitudinal. Objective barriers were primarily structural, such as someone being away from home or if the net was not available.

Subjective barriers to net use were mainly related to discomfort, either due to heat or insecticide. Participants noted that nets made them feel 'squeezed', 'uncomfortable', 'hot', and 'itchy'. A small number of participants, mainly older women, complained that LLINs made it difficult to breathe. Hot weather exacerbated discomfort. Several participants also noted the challenges of waking up in the night and untucking the net in order to go urinate, seen as particularly challenging for elderly and pregnant populations. Participants also cited fear of burning nets with oil lamps or candles, the difficulty of using a net with grass mats, and not having enough nets for all members of the family, particular older children of different sexes who could not share the same sleeping space. Men in Bukoba Rural described a rumour of fertility problems caused by the insecticide from IRS and/or nets.

Objective barriers included being away from home, and having a net still damp from recent washing. Funerals presented a particular challenge for net use. Respondents indicated that they travel to participate in funerals, sleeping outside in their clothes, with just a blanket or sheet to cover themselves. Respondents noted the logistical challenges of attaching the net in an open area with no beds or mattresses, amidst an outdoor crowd, while others said it was common for people to stay awake all night. Others stated that it would be inappropriate to use a net at a funeral, since others would remain unprotected. Both men and women recognized the danger that lack of net use at funerals presented and noted the large crowds and the opportunities for transmission.

> *R: "For example it happens that you have a funeral at your house and you have nets just enough for your family then it is inhuman to sleep under a net leaving the guests sleeping outside without nets." (Male, Zanzibar)*
>
> *R: "We do not use nets at all in that occasion. When we go to funerals, we sleep outside and a bit fire is lit. Would you fix a net there? If there are any mosquitoes, then they will do their job perfectly." (Male, Bukoba Rural)*
>
> *"[At] that wake (mkesha) people will be dancing they will not be covering themselves with bed nets." (Female, Zanzibar)*

4.4.11 Alternative uses of nets

As risk of malaria decreases it is possible that nets may be perceived as more useful for alternative uses than for malaria protection. A small number of people in both study sites discussed the repurposing of nets in their community for agriculture rather than for malaria prevention. Alternative uses of nets included protecting gardens, enclosing poultry, fishing, and collecting flying ants.

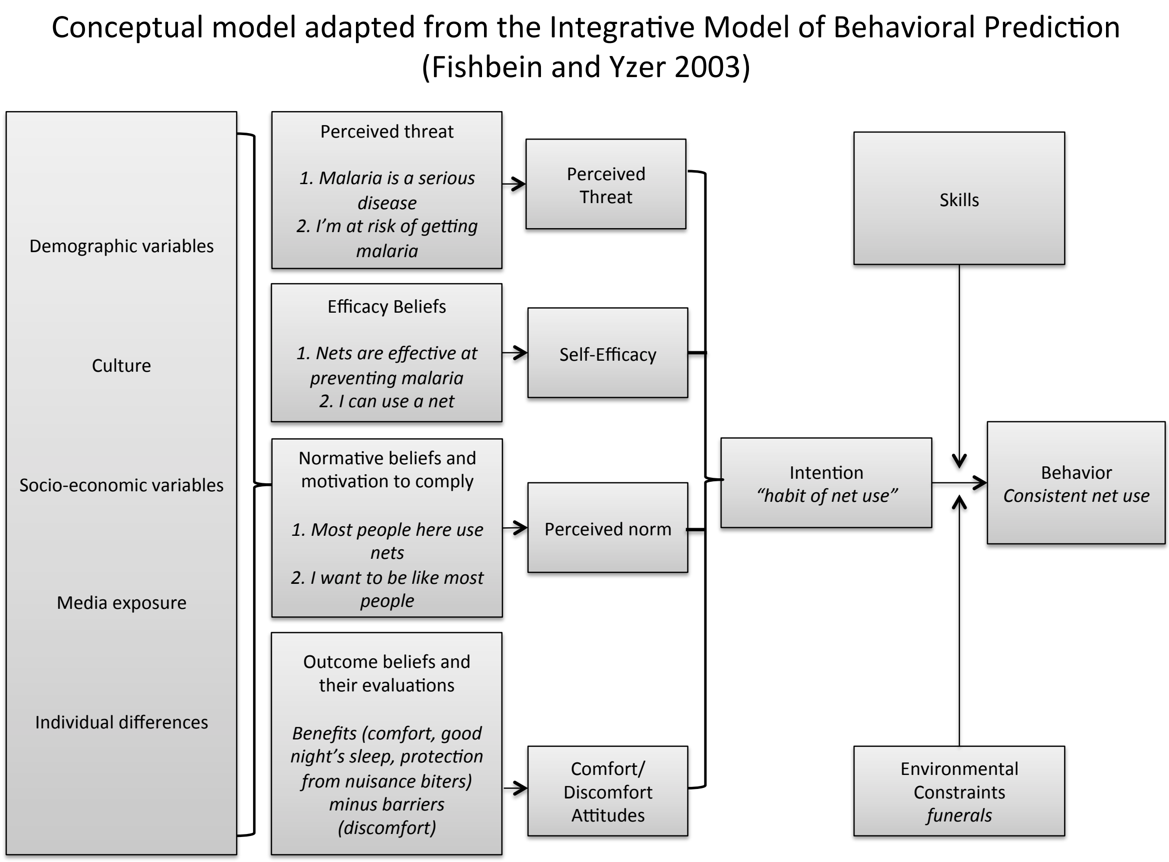
Respondents noted that older, torn nets were primarily the ones that were repurposed. Only one of the 95 participants described the repurposing of a new net for an alternative use. In both Bukoba Rural and Zanzibar community leaders and Shehas had sanctioned those who misused nets by imposing fines or other punishments.

> *R: "When a mosquito net is torn or used up…my fellows usually use the torn one to make chicken huts by placing them on top. (Older female, Bukoba Rural)*
>
> *R: "Others use the nets for fencing paddy fields but some use them in vegetable gardens…while I have already reported to the Sheha that, this net of mine has already been worn out. In that case I will give you a new one and the old one I use for fencing my vegetables.*
>
> *I: What would the Sheha say if he finds out you have used the net for fencing?*
>
> *R: Ahaha he knows that the net had already worn out.*
>
> *I: Won't he take any measures because you are using the net inappropriately?*
>
> *R: it is because the net was worn out." (Female, Zanzibar)*

4.5 Discussion

The conceptual model below (Figure 4.2) is adapted from the Integrative Model of Behavioural Prediction (IMBP) (Yzer2012), which combines variables of two well-known theories: the HBM (Janz *et al*. 1984; Rosenstock 1974), and the TRA (Fishbein *et al*. 1975; Azjen *et al*. 1980). The IMBP has the advantage of including intention to act, linked here with developing a habit of net use. The TRA and IMBP include normative beliefs (subjective norms and motivation to comply), which remain in this model but did not appear to play a significant role in respondents' reasons for net use. Theoretical models are useful to inform message conceptualization, as messages that target the most important determinants of behaviour are more likely to be effective (Fishbein *et al*. 2003).

Figure 4.2: Conceptual model for messaging in reduced transmission zones - adapted from the integrative model of behavioural prediction of Fishbein and Yzer



To summarize, the model, demographic variables, culture, socio-economic variables, media exposure, and individual differences play a role in individuals' perceived threat, efficacy beliefs, normative beliefs, and outcome beliefs. Perceived threat, efficacy, norms, and outcome beliefs (here relating primarily to elements of comfort and discomfort) combine to influence intention to act, or the habit of net use. Intention is modified by skills (a relatively minor element, related to hanging nets) and by environmental constraints such as funerals or other structural barriers; finally leading to the behaviour itself, consistent or habitual net use.

Results from this study show that perceived risk of malaria has decreased among the respondents, particularly in Zanzibar, and that malaria control interventions are credited for the decline. In Zanzibar these findings confirm results from two recently published papers on perceived malaria risk (Beer *et al*. 2012; Bauch *et al*. 2013). Participants cited a reduction in the severity of malaria, that is, the number and frequency of severe cases or deaths from malaria in their communities and families, as well as a reduction in their perceived susceptibility to malaria. Decreases in both severity and susceptibility were attributed to the availability of LLINs and various drugs at health facilities, particularly Alu, as well to the IRS campaigns, improvements in sanitation and standing water, and improved education on the part of the population about malaria and its prevention.

Respondents expressed a sense of control over malaria "nowadays" as compared to "in the past", again citing the availability of drugs and LLINs. The perceived response efficacy of these malaria control interventions was quite high; respondents agreed that nets in particular worked well at reducing mosquito bites, although several noted that there are still moments in the evenings or while travelling that net use is not possible and mosquitoes remain a threat. Respondents also felt confident that malaria drugs, in particular the first line ACT, artemether-lumefantrine or Alu, would be available at health centres and that they could access them there. This combination of perceived response efficacy, or belief in the effectiveness of the tool, and respondents' own perceived self-efficacy at using nets, accepting IRS, and accessing drugs fits with the HBM where these two elements are the components of perceived self-efficacy.

Receiving negative diagnostic tests multiple times is likely to contribute to the sense of decreased risk of malaria. Willingness to trust the results of diagnostic tests is an important concern as malaria control efforts are scaled up, and represent a concrete example of the challenges that can arise when personal risk assessment is corroborated or overturned. Receiving a negative test result when symptoms indicate malaria also leads to cognitive dissonance for both providers and for patients or caretakers. One way that people resolve cognitive dissonance is to discount the effectiveness of the test itself, and as seen above, it appears common that patients continue to ask for malaria treatment and even doctors sometimes provide it despite the negative test results. In the absence of clear protocols or additional diagnostics for other causes of fever, this confusion is likely to remain a problem, even in environments like Zanzibar where parasitaemia rates among under five-year-olds are less than 1%. In addition, unnecessary treatment of suspected malaria is an inefficient use of resources.

Barriers to net use were in line with a recent review of reasons for not using nets (Pulford *et al*. 2011; Beer *et al*. 2012); discomfort from heat or feeling closed in were the most cited reasons. While wind-tunnel testing has shown that it is not in fact hotter or more humid inside a net, decreases in airflow do occur and can increase discomfort (von Seidlein *et al*. 2012). Perceived discomfort caused by insecticide, fear of the net catching fire, and the annoyance of getting in and out of the net during the night were the other most commonly cited reasons for not using a net. Older male respondents in Bukoba Rural expressed the fear of insecticide causing infertility or impotence; similar rumours were reported in Mara and Mwanza regions related to the IRS campaign (Kaufman *et al*. 2012).

The role of comfort in net use appears to be important among respondents in this study. Aside from malaria prevention, the main reason for sleeping under nets was because they provided comfortable sleep, and this was a key factor in consistent use of nets. Nets prevent nuisance biting from mosquitoes and other pests, and provide warmth during cold season. Respondents repeatedly expressed that they had become used to nets or were in the habit of using them. Programme planners speak of building a 'net culture', although this concept remains ill defined. A majority of people who believe that they cannot sleep without a net is almost certainly a key component of a net culture. Building habits of consistent net use despite variations in temperature and mosquito density is possible, as has been seen here.

Recent research has tended to focus on identifying the barriers to net use (Pulford *et al*. 2011; Beer *et al*. 2012) or the malaria-related benefits of net use (Bauch *et al*. 2013), perhaps assuming that malaria prevention is reason enough. These findings indicate that non-malaria benefits do exist and may be exploited for developing messages to improve consistent net use.

4.5.1 Recommendations for messaging as malaria risk declines

The interplay of perceived risk and comfort modulate net use behaviours in the study areas. Messaging to promote net use in areas like Bukoba Rural and Zanzibar should focus on highlighting these non-malaria benefits of net use as well as the preventive benefits; making an LLIN an essential component of a 'good night's sleep' rather than simply a tool to prevent malaria may further entrench Tanzania's net culture. Messages should also promote nets' ability to protect the user from a wide variety of nuisance biting insects and pests. A good night's sleep message can be extended further: a good night's sleep enables a productive day at work or school, and ensuring good sleep over the long term could improve overall performance of a student at school or facilitate adults' ability to perform their jobs well and provide for their families. Preferred channels of communication were not addressed in this study, but might include radio, health committee talks, schools, and mosques as described in Bauch *et al.* (Bauch *et al*. 2013).

Perception of risk is complex and multifaceted, comprised of individuals' assessments of their susceptibility, the severity of the disease, and how effectively the individual feels they can access prevention or treatment options. Focusing messaging solely on aspects of risk may be difficult to do in a way that resonates with a large number of people, as risk is too idiosyncratic to be targeted with a broad message, and concentrating BCC around malaria risk is likely to induce message fatigue. Those individuals who do not feel themselves at risk, or do not feel they have the means to manage the risk, are more likely to reject BCC messages on risk, as described in Witte's Extended Parallel Process Model (Witte 1992). Messages that highlight the comfort aspects of nets and net use, however, have the potential to improve consistent net use among those who already believe that nets provide a degree of comfort, and provide a stronger rationale for those who are currently weighing the discomfort of net use from hotness or claustrophobia against the benefits of sound sleep and freedom from worries about malaria.

While the findings from this study are not generalizable due to the qualitative nature and the specific environments of the study sites, it is nonetheless important to consider that these types of non-malaria benefits of net use are likely to be important for net use in other countries or regions where malaria transmission is falling and LLINs remain important tools to maintain those gains. Messages may work to bolster net use in low-transmission or low-risk seasons such as the dry season or hot season, even in areas where malaria transmission has not yet been noticeably reduced. Findings from Bukoba Rural and Zanzibar may provide clues for other countries or regions that are facing the challenge of maintaining protective behaviours as malaria transmission and the threat of severe malaria fall. Zanzibar is in a pre-elimination phase while Kagera remains in a control phase, and both regions may stay in these phases for decades or more before being able to progress to the next phase (Smith *et al*. 2011), assuming sufficient funding is made available. Continued use of LLINs will be a crucial tool in making progress towards these goals. Targeted messages that support consistent net use, for populations in reduced-transmission zones, must be identified in order to support malaria prevention efforts.

4.5.2 Limitations

The data collected were qualitative in nature and as such, the specific findings cannot be generalized to other contexts. However, the data does provide programme implementers with a framework for considering risk/benefit calculations related to net use. Secondly, while the study was initially designed to enable a doer/non-doer analysis, these groups were actually less distinct than initially thought. Many of the respondents' net use statuses fluctuated seasonally and based on the availability of nets. Therefore, the doer/non-doer analysis was not a useful distinction.

This study also had some logistical challenges that may have affected the results. Zanzibar participants were from two shehia in a single (large) district, Urban West. One FGD had technical problems and was not recovered nor included in this analysis. While saturation appeared to be reached within the other 11 focus groups, it is possible that the remaining group of older Zanzibari women or participants from other parts of the island would have provided additional perspective.

4.6 Conclusion

Results showed that perceived risk of malaria has decreased among the respondents, and that malaria control interventions are credited for the decline. Participants cited reductions in both the severity of malaria and in their perceived susceptibility to malaria. However, malaria was still considered a significant threat. Participants' conceptualization of risk appeared to be an important consideration for net use; net use was cited as a way to reduce one's personal risk of malaria as well as a major contributor to the overall reduction of malaria in both regions. At the same time, comfort and aspects of comfort (getting a good night's sleep, avoiding nuisance biters) appeared to play a large role in personal decisions to use nets consistently or not. Barriers to comfort (feeling uncomfortable or trapped; perceived difficulty breathing, or itching/rashes) were frequently cited as reasons not to use a net consistently. While it was apparent that participants acknowledged the malaria-prevention benefits of net use, the exploration of the risk and comfort determinants of net use provides a richer understanding of net use behaviours, particularly in a setting where transmission has fallen and yet consistent net use is still crucial to maintaining those gains. Future behaviour change communication campaigns should capitalize on the non-malaria benefits of net use that provide a long-term rationale for consistent use even when the immediate threat of malaria transmission has been reduced.

4.7 Authors' contributions

HK designed the study and interview guides, analysed the data, and drafted the manuscript; DL contributed to the interview guides, conducted analysis, and drafted portions of the manuscript; DR contributed to study design, and interview guides, supervised data collection, data processing and preliminary data analysis. AA facilitated fieldwork in Zanzibar and provided perspective on the analysis. All authors read and approved the final manuscript.

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5 Universal coverage with insecticide-treated nets – applying the revised indicators for ownership and use to the Nigeria 2010 malaria indicator survey data

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5.1 Abstract

Until recently only two indicators were used to evaluate malaria prevention with insecticide-treated nets (ITN): "proportion of households with any ITN" and "proportion of the population using an ITN last night". This study explores the potential of the expanded set of indicators recommended by the Roll Back Malaria Monitoring and Evaluation Reference Group (MERG) for comprehensive analysis of universal coverage with ITN by applying them to the Nigeria 2010 Malaria Indicator Survey data.

The two additional indicators of "proportion of households with at least one ITN for every two people" and "proportion of population with access to an ITN within the household" were calculated as recommended by MERG. Based on the estimates for each of the four ITN indicators three gaps were calculated: i) households with no ITN, ii) households with any but not enough ITN, iii) population with access to ITN not using it. In addition, coverage with at least one ITN at community level was explored by applying Lot Quality Assurance Sampling (LQAS) decision rules to the cluster level of the data. All outcomes were analysed by household background characteristics and whether an ITN campaign had recently been done.

While the proportion of households with any ITN was only 42% overall, it was 75% in areas with a recent mass campaign and in these areas 66% of communities had coverage of 80% or better. However, the campaigns left a considerable intra-household ownership gap with 66% of households with any ITN not having enough for every family member. In contrast, the analysis comparing actual against potential use showed that ITN utilization was good overall with only 19% of people with access not using the ITN, but with a significant difference between the North, where use was excellent (use gap 11%), and the South (use gap 36%) indicating the need for enhanced behaviour change communication.

The expanded ITN indicators to assess universal coverage provide strong tools for a comprehensive system effectiveness analysis that produces clear, actionable evidence of progress as well as the need for specific additional interventions clearly differentiating between gaps in ownership and use.

5.2 Background

Until recently the two main indicators recommended for the assessment of progress in malaria prevention with insecticide-treated nets (ITN) have been the "proportion of households owning at least one ITN" and the "proportion of children under five (or pregnant women) sleeping under an ITN the previous night" (Roll Back Malaria 2009). These indicators have been used to monitor progress in the early years (Korenromp *et al*. 2003) as well as following the scale-up of mass distributions of ITN around 2005 (Eisele *et al*. 2009; Thwing *et al*. 2008; Hightower *et al*. 2010; Hetzel *et al*. 2012) and consistently found a considerable gap between ownership of at least one ITN at household level and actual use of ITN by children which has often been interpreted as a failure to convince people to use available nets and triggered calls for better behavioural change communication (BCC) programmes (Korenromp *et al*. 2003) and/or assistance in hanging the nets (Macintyre *et al*. 2011). While undoubtedly there is need for BCC programmes to strengthen net use and strategies have been developed for these (Panter-Brick *et al*. 2006), it has been pointed out as early as 2009 by Eisele and colleagues that the most important determinant of use is ownership of enough ITN, and that BCC programmes should address the gap that remains once sufficient intra-household access to ITN has been achieved (Eisele *et al*. 2009). This was confirmed by Hetzel *et al.* in Papua Guinea who observed that 99.5% of household members not using a net did not have access to one within the household (Hetzel *et al*. 2012) and pointed to the need to better differentiate between a lack of ITN within the household and the behavioural failure to use a net that was available.

A first step in this direction was suggested by Vanden Eng and colleagues in 2010 by proposing to categorize the population of children under five into four categories namely those living in households that: i) do not own any ITN; ii) own but did not hang an ITN; iii) own and hang but not use an ITN; and iv) those children actually using an ITN (Vanden Eng *et al*. 2010). The limitation of this approach was that it still did not distinguish whether a person actually had access to an ITN within the household as categories ii) and iii) refer to non-use without confirmation that enough ITN are available. A revision of recommended indicators was then considered by the "Survey and Indicator Task Force" of the Roll Back Malaria Monitoring and Evaluation Reference Group (MERG) which in June 2011 recommended two additional core ITN indicators (Roll Back Malaria Partnership 2011): the "proportion of households with at least one ITN for every two people" which is considered to be enough to cover all household members (World Health Organization 2007), and the "proportion of the population that has access to an ITN within the household" and supplied detailed descriptions on how these indicators should be calculated (Measure DHS 2012). The first indicator is to be used in conjunction with the previous indicator "proportion of households with at least one ITN" to better define the ownership gap, i.e. households with no or insufficient ITN. The second is intended to define the use gap, i.e. that part of non-use that is not explained by the absence of a usable ITN and hence open to a BCC intervention. The indicator of "access of population to ITN" has been used as a key evaluation tool in the 2012 World Malaria Report by WHO (World Health Organization 2012) and Bennett and colleagues applied the indicator of "at least one ITN for every two people" to an evaluation exercise in Sierra Leone (Bennett *et al*. 2012); however, in general these new indicators have not yet been broadly used.

This study applies the newly recommended indicators for the evaluation of ITN programs to the data set from the Malaria Indicator Survey of Nigeria 2010 (National Population Commission Nigeria *et al*. 2012) in order to explore and demonstrate their usefulness, hoping to stimulate wider utilization among malaria programme managers and public health practitioners.

5.3 Methods

5.3.1 Data set

The Nigeria Malaria Indicator Survey (MIS) was commissioned by the National Malaria Control Programme and carried out by the National Population Commission with support from a number of partners from the Roll Back Malaria (RBM) partnership between October and December 2010, with the objective to provide a nationally representative picture of the coverage of key malaria interventions as well as the current levels of malaria parasitaemia in children (National Population Commission Nigeria *et al*. 2012). The protocol and questionnaire followed closely those recommended for MIS by the RBM Monitoring and Evaluation Reference Group (MEASURE Evaluation *et al*. 2013) The six geopolitical zones of the country (Figure 5.1) were defined as the sampling domains targeting 1,000 households per zone, 6,000 in total. Based on the 2006 National Population Census 40 clusters, defined as census Enumeration Areas, were selected per zone using sampling probability proportionate to population size and within each cluster 25 households were selected by simple random sampling.

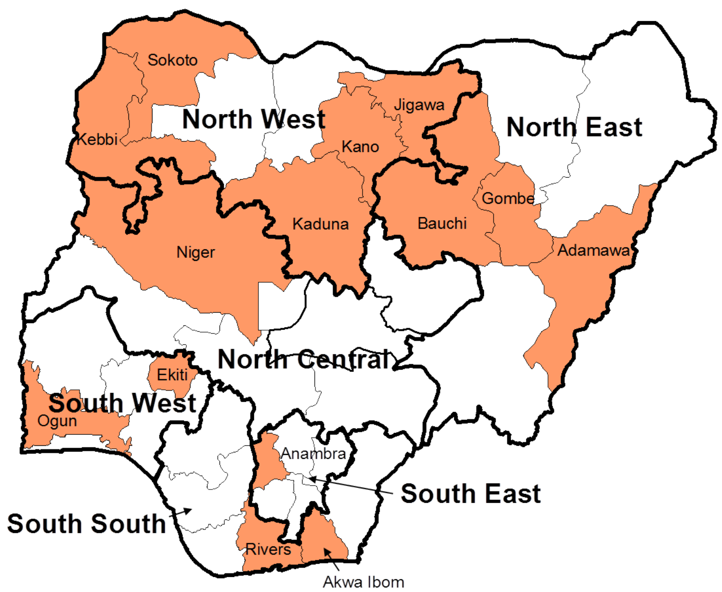
The data set was downloaded with permission from the Measure DHS website and all data preparations and analyses were done using Stata 11.2 software (Stata Corp, College Station, Texas, USA).

5.3.2 Calculation of indicators for universal ITN coverage

Of the four recommended indicators for assessment of universal coverage with ITN (Roll Back Malaria Partnership 2011), two use the household as the unit of observation while the other two use the *de facto* population, i.e. all people present in the household the night preceding the survey. The two household related indicators are:

- Proportion of households with at least one ITN where the numerator consists of all households that own at least one mosquito net that was either identified as a long-lasting insecticidal net (LLIN) by the brand label or that was treated with insecticide within the past 12 months (Roll Back Malaria Partnership 2011) and the denominator is the total of sampled households.
- Proportion of households with at least one ITN for every two people where the numerator comprises all households where the ratio between number of ITN owned and the number of de-jure members of that household, i.e. usual members excluding visitors, is 0.5 or higher and the denominator is the total of sampled households.

Figure 5.1: Map of Nigeria, indicating the six geopolitical zones (thick border) and the States where an ITN mass campaign had already taken place before the survey (shaded areas).



The two population-based indicators are:

- Proportion of population with access to ITN within the household where the numerator includes all de facto household members in the sample who had access to an ITN assuming each ITN was used by two people and the denominator is the de facto population in the sample. The calculation of the numerator was done in two steps as recommended by MERG (Measure DHS 2012): first, an intermediate variable of "potential ITN users" was created by multiplying the number of ITN in each household by the factor two. In order to correct for households with more than one net for every two people the potential ITN users were set equal to the de facto members in that household if the potential users exceeded the number of people in the household; second, the access indicator was calculated by dividing the potential ITN users by the number of de facto members for each household and determining the overall sample mean of that fraction.
- Proportion of population sleeping under an ITN the previous night where the numerator comprises all *de facto* members identified as one of the users of an ITN based on the listings of member's line numbers in the net roster of the questionnaire and the denominator is the *de facto* population in the sample.

Two additional indicators were calculated to aid interpretation of the ownership and use gaps:

- The "proportion of households with at least 1 ITN for every two people among households owning any ITN" measuring the saturation with ITN for households with any ITN. The inverse (1-p) then describes the intra-household ownership gap and can be contrasted with the spatial ownership gap, i.e. the proportion of all households that have no ITN at all.
- The "proportion of population sleeping under an ITN the previous night among those with access". Because the method of calculating the access indicator does not allow allocation of access to specific individuals within the household this indicator was calculated for the overall sample or sub-groups by dividing the number of people with access, obtained by applying the weighted proportion with access to the total of the population in the sample or sub-group, by the respective *de facto* population. The confidence interval was obtained by first calculating the exact binomial 95% confidence interval of the proportion and then inflating it by the design effect, i.e. the ratio of the crude and adjusted 95% confidence interval for the access estimate. The inverse of this indicator (1-p) is taken as the use gap.

5.3.3 Data analysis

All data analysis was done applying the sampling weights provided in the original data set and adjusting confidence intervals of estimates for the design effect by using the suite of "svy" commands in Stata. Estimates of the four relevant indicators for universal coverage with ITN were disaggregated by residence (urban–rural), wealth quintiles, the six geopolitical zones as well as a North–South grouping of these zones and whether or not the household was in a state where a mass distribution campaign had already taken place in the 18 months preceding the survey (Figure 5.1) based on the information provided by the National Malaria Control Programme.

The wealth index was based on household assets and obtained by principle component analysis (Measure DHS 2012) and quintiles were calculated separately for the urban and rural strata in order to adjust for differences between them. The concentration index was used as a measure of equity (Kakwani *et al*. 1997) with the value 0 representing perfect equity, +1 maximum pro-rich and −1 maximum pro-poor inequality.

Given that universal coverage with ITN aims at reduction of malaria transmission and hence a community mass effect, cluster level analysis of ITN ownership was done using a Lot Quality Assurance Sampling (LQAS) based approach as previously described by Biedron *et al.* (Biedron *et al*. 2010) where the cluster (Enumeration Area) is considered as the "lot". For each ITN ownership indicator the outcome of whether a defined target level of coverage was reached or not was determined by comparing the actual number of "successes" in the cluster against the decision rule. Decision rules were determined based on the target level ranging from 40% to 90% and using a 20-percentage point margin for the minimally acceptable performance (e.g. 60% for the 80% target etc.) They were obtained from the web-based "LQAS Sampling Plan Calculator" provided by the Food and Nutrition Technical Assistance project (FANTA II) (). Because the sample size for each cluster was not always 25, decision rules were determined for each possible sample which ranged from 15 to 26 with 83.5% of clusters having a sample size of 24, 25 or 26.

Unless otherwise indicated statistical significance testing applied the Pearson design-based F-statistic for proportions and maximum likelihood logistic regression for multivariate analysis.

5.4 Results

5.4.1 The sample

Out of the 240 sampled clusters one was not accessible (National Population Commission Nigeria *et al*. 2012) so that a total of 239 clusters from all 37 states (including the Federal Capital Territory) with 5,890 households (98.2% of target) were included in the final sample. Overall 29.2% (95% confidence interval (CI) 23.3, 35.9) of households were in urban areas with a higher proportion in the South (36.8%) than in the North (22.3%, $p = 0.03$). The de-jure population in the sample was 30,336 with a mean of 4.5 per household in the North and 5.8 in the South and the *de facto* population was 30,088, of which 22.1% were children under-five in the North and 18.0% in the South ($p < 0.0001$). Households headed by a female contributed 24.9% in the South and 6.7% in the North ($p < 0.0001$). Ownership of household assets was generally higher in the South with 76.9% owning a mobile phone, 73.4% a radio and 57.9% a television while the respective figures in the North were 44.2%, 64.5% and 23.9% respectively. Interestingly, even among the poorest wealth quintile 34.4% in the South and 15.0% in the North owned a mobile phone. A full description of the socio-economic and demographic characteristics is given in the survey report (National Population Commission Nigeria *et al*. 2012).

5.4.2 ITN ownership

5.4.2.1 Type of nets owned

Among the sampled households a total of 5,169 mosquito nets were found and assessed. The vast majority of these nets were long-lasting insecticidal nets (LLIN), 95.9% in areas with the recent mass campaign (Figure 5.1) and 90.7% in areas without campaign. Permanet® was the most common LLIN brand (46.7%) followed by Olyset® (30.8%) while others only had a share of 3.5% to 7.0%. Only 7 nets (0.2%) were reported to have been treated with insecticide within the last 12 months and could be considered an ITN while untreated nets contributed 5.5% of the nets in the sample.

5.4.2.2 Source of nets

Not surprisingly, in states with a recent ITN mass campaign 89.7% (95% CI 82.8, 94.0) of nets were obtained for free from the public sector and among these 81.5% were reported received from the campaign, 17.0% from health facilities and 1.6% from hospitals. In campaign areas 7.6% of nets were obtained from the retail market and the remaining 2.7% from private health facilities or faith-based institutions. In contrast, in the areas where the campaign was yet to be done the majority of nets (53.2%, 95% CI 42.6, 63.6) were obtained from the retail market although this was much more common in the North (69.9%, 95% CI 58.3, 79.4) than in the South (23.1%, 95% CI 17.0, 30.6, $p < 0.0001$). Sources were mainly open markets (88.7%) and hawkers (5.7%) while shops or supermarkets (3.5%), Patent Medicine Vendors (1.1%) and pharmacies (0.9%) played a minor role and here the pattern between North and South was similar. Even among the nets bought from the retail market 84.9% were LLIN (86.8% in the North, 72.7% in the South, $p > 0.05$), showing that these types of nets now dominate the market. In states without recent campaign the nets obtained from the public sector were in 62.9% from health facilities or hospital and 37.1% from previous campaigns.

Overall, 10.2% (95% CI 7.9, 13.1) of households owned a net obtained from the retail market and surprisingly this rate was highest in the two poorest wealth quintiles 16.0% (95% CI 11.4, 21.8) compared to the upper three with 5.9% (95% CI 4.8, 7.2, $p < 0.0001$). However, the median reported price paid for an LLIN from the market increased with increasing wealth quintile from Naira 500 for the lowest two wealth quintiles to Naira 600 for the mid-quintile and Naira 800 for the wealthiest.

5.4.2.3 Ownership coverage

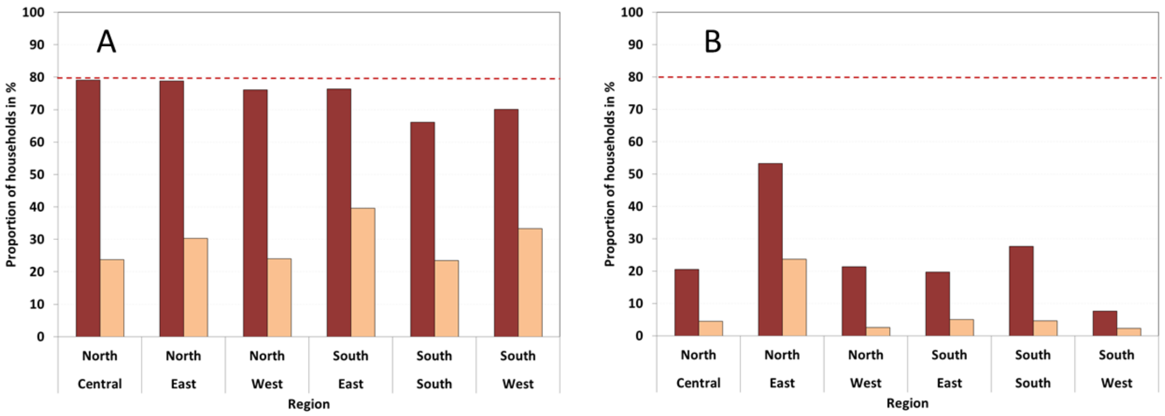
Results for the ownership indicators for ITN are presented by background characteristics in Table 5.1 and for geopolitical zones with and without recent campaign in Figure 5.2. Overall the household ownership of at least one ITN was only 42.0% with significant variations between zones and higher rates in the North (Table 5.1) but these differences were driven by whether or not a campaign had recently taken place in the state and this was more frequent in the North (Figure 5.1). In the campaign areas 74.5% of households had at least one ITN and 52.0% (95%CI 47.3, 56.6) owned at least two ITN, the target during the campaigns. In non-campaign states these rates were only 22.3% and 9.5% respectively. Considering results by zones taking into account the campaign status (Figure 5.2) shows that in all but the South-South (66.2%) and South-West (79.0%) the target of 80% ownership of at least one ITN was reached, while only the North-East (53.3%) showed coverage above 30% in the non-campaign areas.

Distribution of any ITN ownership was very equitable with a concentration index of −0.002 (95% CI −0.016, 0.012) for areas with recent campaign and actually slightly pro-poor in areas without a recent campaign with a concentration index of −0.55 (95% CI −0.089, -0.021). The proportion of households with enough ITN for every household member, i.e. at least one ITN for every two people, was low even in the states with a recent campaign (27.2%) but again very equitable in the campaign areas, concentration index 0.035 (95% CI −0.002, 0.072), and pro-poor in the non-campaign areas, concentration index −0.184 (95% CI −0.257, -0.112).

Table 5.1: ITN Ownership, Nigeria 2010 MIS

Background characteristic	Households with at least 1 ITN % (95% CI)	Households with at least 1 ITN for every 2 people % (95% CI)	Households with at least 1 ITN for every 2 people if any ITN % (95% CI)	Number of households
Residence				
Urban	33.3% (26.2, 40.6)	11.5% (8.5, 15.4)	34.6% (29.7, 39.9)	1942
Rural	45.6% (39.8, 51.4)	15.3% (12.7, 18.3)	33.5% (30.2, 37.1)	3948
Zone				
North Central	32.1% (22.4, 43.4)	8.3% (4.9, 13.7)	28.9% (18.5, 34.9)	994
North East	64.5% (54.1, 73.6)	26.6% (20.7, 33.6)	41.2% (35.4, 47.3)	968
North West	58.3% (47.3, 68.5)	17.1% (12.7, 20.1)	29.3% (24.1, 35.1)	1009
South East	32.3% (23.6, 42.4)	12.7% (7.8, 20.1)	39.5% (30.3, 49.4)	997
South South	43.9% (35.5, 52.6)	12.6% (9.1, 15.8)	28.6% (23.0, 35.0)	1007
South West	21.2% (12.0, 34.6)	9.1% (5.1, 15.8)	42.8% (37.2, 48.5)	915
Region				
North	52.0% (45.5, 58.4)	17.0% (14.1, 20.4)	32.8% (29.1, 36.6)	2971
South	30.9% (25.0, 37.4)	11.0% (8.4, 14.4)	35.7% (31.5, 40.2)	2919
ITN campaign				
Yes	74.5% (70.1, 78.4)	27.2% (24.2, 30.5)	36.5% (33.0, 40.3)	2273
No	22.3% (18.8, 26.3)	6.3% (4.7, 8.4)	28.4% (23.6, 33.4)	3617
Wealth quintile				
Lowest	46.8% (38.3, 55.5)	16.6% (12.4, 21.8)	35.5% (29.6, 41.8)	1177
Second	40.9% (34.3, 48.0)	13.5% (10.7, 17.0)	33.0% (27.5, 39.1)	1178
Third	45.2% (38.9, 51.7)	16.1% (12.3, 20.7)	35.5% (29.9, 41.5)	1178
Fourth	36.0% (30.5, 41.8)	10.1% (7.7, 13.1)	28.1% (23.2, 33.5)	1178
Highest	39.9% (33.4, 46.9)	14.1% (10.7, 18.3)	35.3% (29.6, 41.4)	1179
Total	**42.0% (37.6, 46.5)**	**14.2% (12.1, 16.5)**	**33.8% (31.0, 36.8)**	**5890**

Figure 5.2: Household ownership of ITN. Showing ownership of at least one ITN (dark bars) and at least one ITN for every two people (light bars) for areas that did (A) or did not (B) have a recent mass campaign. Red dashed line represents the national target.



One third of those households that owned any ITN (33.8%) also had enough ITN for all household members and this was surprisingly constant across those background characteristics included in Table

5.1 and varied only marginally between campaign (36.5%) and non-campaign areas (28.4%, p=0.01). It did, however, vary significantly with household size. Overall the proportion of households with enough ITN for all was 24.5% if household size was four or less persons while only 5.1% for households with five or more members which comprised 58.1% of all sampled households ($p < 0.00001$). Similarly, in areas with recent campaigns 51.8% of households had enough ITN for all if there were four or fewer members compared to 9.5% for households with five or more ($p < 0.0001$).

When the ITN ownership coverage at the cluster (Enumeration Area) is considered 93.5% of the 92 clusters in states with recent campaigns were estimated to have reached at least the 50% coverage level and two-thirds (66.3%) the 80% threshold (Table 5.2). When the criterion of at least two ITN was applied 71.7% of the clusters reached the 50% level and only 22.8% the 80% threshold while in only 22.3% of the clusters did the proportion of households with at least one ITN for every two people reach 50%. Not surprisingly, the corresponding rates among the 147 clusters without recent campaign were very low not even reaching 20% for coverage with at least 50% of households with any ITN.

Table 5.2: ITN coverage reached at cluster (Enumeration Area) level

Coverage at cluster level	Proportion (%) of clusters reaching coverage level					
	At least one ITN		At least two ITN		One ITN for every two people	
	No Campaign	Campaign	No Campaign	Campaign	No Campaign	Campaign
40%	26.5	97.8	8.2	83.7	6.8	39.2
50%	17.0	93.5	6.8	71.7	2.7	22.3
60%	13.6	88.0	6.1	56.2	2.0	13.0
70%	8.2	77.2	3.4	37.0	0.7	3.2
80%	5.4	66.3	2.0	22.8	0.0	0.0
90%	3.4	42.4	0.0	9.8	0.0	0.0

5.4.3 ITN use

Three quarters of the nets found in the households were observed hanging over a sleeping place, 75.5% (95% CI 72.5, 78.7), and 76.8% (95% CI 73.5, 79.9) were reported as having been used the previous night of which use could be confirmed in 99.3% by the detailed list of net users resulting in a net use rate of 76.4% (95% CI 73.0, 79.4). In a multivariate logistic regression model the strongest predictor of a net being used the previous night was, not surprisingly, whether the net was hanging (adjusted Odds Ratio (OR) 40.00, 95% CI 25.70, 62.26). However, use of the net was also significantly associated with the Northern region (OR 3.30, 95% CI 2.08, 5.22), net being obtained from the retail market (OR 2.58, 95% CI 1.26, 5.26) and recent mass campaign (OR 2.16, 95% CI 1.28, 3.63) but did not vary by net type (LLIN vs. untreated), age of net or urban residence. Interestingly, net use was highest among nets from the poorest wealth quintile continuously decreasing with increasing wealth ($p = 0.01$ for linear trend) with an OR of 0.39 (95% CI 0.22, 0.67) for the wealthiest compared to the poorest and a concentration index of −0.080 (95% CI −0.088, -0.070).

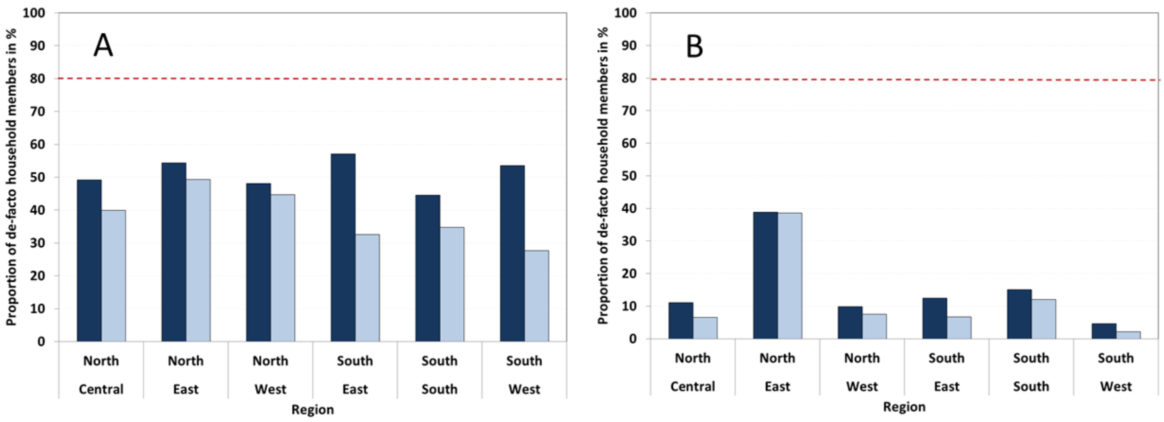
Net use indicators by the *de facto* population are presented in Table 5.3 by background characteristics and in Figure 5.3 by zone and campaign status. At national level only 28.7% of the population had access to an ITN within the household and this rate increased to 50.0% in areas with a recent campaign. It did not significantly differ by wealth quintiles ($p = 0.7$) or urban residence ($p = 0.2$) and was only marginally higher in the North ($p = 0.03$), essentially driven by a high access rate in the NorthEastern states where no campaign had taken place (see Figure 5.3).

The proportion of the population actually using an ITN the previous night was 23.3%, only slightly lower than the access rate indicating a generally high level of use among those with access. Indeed, when the indicator “proportion of ITN users among those with access” is considered (Table 5.3), 81.2% actually used an ITN. Use among those with access was significantly higher in the North and decreased with increasing wealth quintile, from 93.6% among the poorest to 62.1% among the wealthiest, but did not differ by urban residence or campaign status.

Table 5.3: Access to and use of ITN

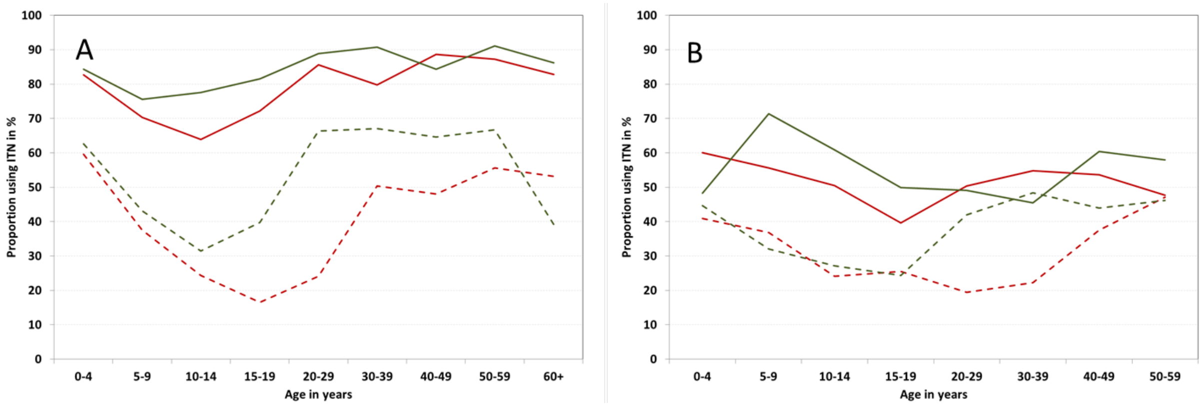
Background characteristic	**People with access to ITN within household % (95% CI)**	**People who slept under ITN last night % (95% CI)**	**People who used ITN if access % (95% CI)**	**Population (*de facto)***
Residence				
Urban	23.3% (18.5, 29.0)	16.5% (12.6, 21.4)	70.8% (59.5, 82.1)	9190
Rural	30.6% (26.5, 35.1)	25.7% (22.1, 29.8)	84.0% (77.1, 89.7)	20,898
Zone				
North Central	19.8% (13.5, 28.1)	14.2% (8.9, 21.9)	71.7% (53.1, 90.3)	5171
North East	46.5% (38.7, 54.5)	43.9% (35.8, 52.3)	94.4% (88.9, 99.9)	5492
North West	34.5% (26.8, 43.0)	31.5% (24.5, 39.7)	91.3% (82.9, 99.7)	6143
South East	22.9% (16.2, 31.3)	12.7% (8.6, 18.3)	55.4% (36.3, 74.7)	4648
South South	27.3% (21.6, 33.8)	21.4% (16.8, 27.0)	78.4% (67.7, 89.1)	4927
South West	16.5% (8.7, 28.9)	8.4% (3.6, 18.3)	50.8% (17.2, 84.4)	3707
Region				
North	33.6% (28.9, 38.6)	30.0% (25.5, 34.8)	89.3% (84.0, 94.4)	16806
South	21.7% (17.2, 27.0)	13.9% (10.8, 17.6)	64.1% (58.8, 69.3)	13282
ITN campaign				
Yes	50.0% (46.7, 53.3)	41.3% (37.9, 44.8)	82.6% (79.1, 86.1)	12642
No	14.0% (11.3, 17.2)	10.9% (8.3, 14.2)	75.7% (65.4, 86.0)	17446
Wealth quintile				
Lowest	31.7% (25.0, 39.1)	29.7% (23.1, 37.3)	93.6% (87.0, 99.9)	6311
Second	28.8% (24.3, 33.7)	24.5% (20.7, 28.7)	85.1% (76.8, 93.4)	6052
Third	31.0% (26.2, 36.3)	24.9% (20.3, 30.3)	80.3% (72.2, 88.4)	6121
Fourth	25.6% (21.8, 29.9)	19.7% (16.1, 23.8)	76.9% (69.6, 84.2)	5691
Highest	25.1% (20.4, 30.4)	15.6% (12.5, 19.3)	62.1% (50.7, 73.5)	5913
Total	**28.7% (25.4, 32.2)**	**23.3% (20.5, 26.3)**	**81.2% (75.8, 86.6)**	**30,088**

Figure 5.3: Population access and use. Showing access to ITN (dark bars) and use of ITN (light bars) for areas that did (A) or did not (B) have a recent mass campaign. Red dashed line represents the national target.



Considering only the population from households with any ITN, use also clearly differed by age, gender and supply of ITN at household level as shown in Figure 5.4 separately for the Northern and the Southern zones. Except for the youngest two and the oldest age groups there was a significant gender gap in ITN use in the North for people from households with any but not enough ITN for every member with use among women much higher than among men and particularly low use rates for both at ages 10 to 19 years. For the population in households that did have enough ITN for everybody use was not only much higher ranging between 75% and 90% for women and 65% and 90% for men, but the differences by age and gender were much reduced although statistically still significant in a multivariate model ($p = 0.006$ for gender, $p = 0.002$ for age). In the South gender differences were non-existent at younger ages if not enough ITN were available but very clearly favoured women between ages 20 and 49. The most striking difference to the North was the lack of dramatic increase once enough ITN were available in the household with use rates generally not exceeding 60% even though the age curve was more straightened, i.e. there were particular gains in the least using age groups (10–19 years of age). As with the North, gender (0 = 0.01) and age ($p < 0.0001$) remained significant predictors of ITN use in the regression model even when sufficient ITN were available. In a joint model (North and South) of the population living in households with at least one ITN that adjusted for age, urban residence and wealth quintiles having sufficient ITN for all members was the strongest positive predictor of use (OR 3.46, 95% CI 2.88, 4.15) followed by residence in the Northern zones (OR 1.58, 95% CI 1.27, 1.98) and being female (OR 1.48, 95% CI 1.35, 1.63) while strong negative associations were found for being between age 10 and 19 (OR 0.40, 95% CI 0.36, 0.46) and belonging to the highest wealth quintile (OR 0.44, 95% CI 0.31, 0.61).

Figure 5.4: ITN use by age, gender, and ITN supply. (A) Northern zones; (B) Southern zones. Solid line population from households with at least one ITN for every two people; dashed line population from households with any but not enough ITN; red male, green female.



5.4.3.1 Ownership and use gaps

Taking the inverse of the ownership and use coverage allows defining the respective gaps, i.e. the proportion of households that own no or insufficient nets and the proportion of the population that could have but did not use an ITN the previous night. These gaps are presented in Table 5.4 and show that although the spatial coverage gap (no ITN at all) was still significant at national level with 58.0%, it was actually quite small for those areas where a mass campaign had already been implemented (25.5%) while the intra-household gap, i.e. the level of insufficient ITN ownership among households owning any ITN was quite large (66.2%). The intra-household gap varied little across background characteristics and was only 8-percentage points higher in areas without recent campaign (63.5% vs. 71.6%, p = 0.01). However, the intensity of the intra-household gap, i.e. the number of "missing" ITN, clearly differed between campaign and non-campaign areas as households with any but not enough ITN owning on average 1.56 ITN (95% CI 1.44, 1.67) compared to 1.90 (95% CI 1.69, 2.12) in households with at least one ITN for every two people in the non-campaign areas and 1.96 ITN (95% CI 1.87, 2.05) compared to 2.20 (95% CI 2.08, 2.32) respectively in the campaign areas. In contrast, the use gap when only considering those that actually could have used an ITN was quite small overall (18.8%) and ITN utilization based on this criterion was particularly good in the North (gap 10.7%) and among the poorest wealth quintile (gap 6.4%) but low in the South (gap 35.9%).

Table 5.4: Ownership and use gaps

Background characteristic	Ownership gap		Use gap
	Households with no ITN % 95% CI)	Households with insufficient ITN if any ITN % (95% CI)	People with access not using ITN % (95% CI)
Residence			
Urban	66.7% (59.4, 73.8)	66.6% (60.1, 70.3)	29.2% (17.9, 40.4)
Rural	54.4% (51.4, 60.2)	66.5% (62.9, 69.8)	16.0% (10.3, 22.9)
Zone			
North Central	67.9% (56.6, 77.6)	71.1% (65.1, 81.5)	28.3% (9.7, 46.9)
North East	35.5% (26.4, 45.9)	58.8% (52.7, 64.6)	5.6% (0.1, 11.1)
North West	41.7% (31.5, 52.7)	70.7% (64.9, 75.9)	8.7% (0.3, 17.1)
South East	67.8% (57.6, 76.4)	60.5% (50.6, 69.7)	44.6% (25.3, 63.7)
South South	56.1% (47.4, 64.7)	71.4% (65.0, 77.0)	21.6% (10.9, 32.3)
South West	78.8% (65.4, 88.0)	57.2% (51.5, 62.8)	49.2% (15.6, 82.8)
Region			
North	48.0% (41.6, 54.5)	67.2% (63.4, 70.9)	10.7% (5.6, 16.0)
South	69.1% (62.6, 75.0)	64.3% (59.8, 68.5)	35.9% (30.7, 41.2)
ITN campaign			
Yes	25.5% (21.6, 29.9)	63.5% (59.7, 67.0)	17.4% (13.9, 20.9)
No	77.7% (73.7, 81.2)	71.6% (66.6, 76.4)	24.3% (14.0, 34.6)
Wealth quintile			
Lowest	53.2% (44.5, 61.7)	64.5% (58.2, 70.4)	6.4% (0.1, 13.0)
Second	59.1% (52.0, 65.7)	67.0% (60.9, 72.5)	14.9% (6.6, 23.2)
Third	54.8% (48.3, 61.1)	64.5% (58.5, 70.1)	19.7% (11.6, 27.8)
Fourth	64.0% (58.2, 69.5)	71.9% (66.5, 76.8)	23.1% (15.8, 30.4)
Highest	60.1% (53.1, 66.6)	64.7% (58.6, 70.4)	37.9% (26.5, 49.3)
Total	**58.0% (53.5, 62.4)**	**66.2% (63.2, 69.0)**	**18.8% (13.4, 24.2)**

5.5 Discussion

The primary purpose of this study was to demonstrate the application of the recently revised and expanded indicators for universal coverage with ITN (Roll Back Malaria Partnership 2011; Measure DHS 2012) and explore their capacity to differentiate between the lack of ITN within the communities and households referred to as ownership gap, and the inability or unwillingness to use an ITN that actually is available referred to as use gap. Based only on the previously recommended core ITN indicators of “proportion of households with any ITN” and “proportion of population (or sub-groups) using an ITN last night” (Roll Back Malaria 2009) the results of the 2010 MIS for Nigeria show overall ITN ownership of 42% of households and 23% of the population using an ITN the previous night. When only areas with a recent mass distribution campaign of ITN are considered, 75% of households owned at least one ITN and 41% of the population used an ITN. In both cases the use estimate is only slightly more than half that of the ownership estimate suggesting a significant gap between owning and using an ITN. Such gaps have frequently been interpreted primarily as a lack of ability or willingness to use nets (Korenromp *et al*. 2003; Macintyre *et al*. 2011; Ye *et al*. 2012; Atieli *et al*. 2011), although authors have also highlighted the need to clearly distinguish between the lack of nets and failure to use when available (Eisele *et al*. 2009; Hetzel *et al*. 2012; Pulford *et al*. 2011) both of which are included in this gap. To more precisely address the use gap some analyses have restricted data to only households owning at least one net or ITN (Macintyre *et al*. 2011; Ankomah *et al*. 2012; Graves *et al*. 2011) but this still leaves intra-household net density as a significant determinant (Graves *et al*. 2011) because some household members will still be without access. An alternative approach is to consider the net as the unit of observation (Baume *et al*. 2008; Baume *et al*. 2009; Ordinioha 2012) which allows a detailed look at reasons for non-use (including the physical condition of the net) but does not allow an estimate of the intra-household ownership gap at the same time. A more comprehensive evaluation framework which includes aspects of ownership and use by disaggregating the population into four categories of potential access has been suggested by Vanden Eng (Vanden Eng *et al*. 2010). However, this approach only allows the identification of persons who have at least one net or ITN in their household but this does not necessarily imply that they had access if there are not enough nets for all.

In contrast, the application of the set of four ITN indicators recommended by MERG (Roll Back Malaria Partnership 2011) and subsequent indicators of the ownership and use gaps to the Nigeria 2010 MIS data allows a much more detailed picture of the situation which clearly identifies where the successes and shortcomings are.

First, spatial coverage, i.e. proportion of households with at least one ITN, while overall only moderately high with 42%, was very close to the national target of 80% in areas that did have a mass distribution of ITN, leaving a gap if only 26% of households without any ITN (Table 4). Furthermore, using an LQAS-based assessment of each survey cluster shows that in the campaign areas almost all communities (94%) had at least 50% of households covered with at least one ITN and two thirds of the communities had an 80% coverage or better. This suggests that the target of universal spatial coverage and reduction of malaria transmission through a mass effect has been achieved by the campaigns as community level coverage as low as 50% has been shown in models to provide protection beyond the individual net users (Killeen *et al*. 2007). Such mass effect is likely to have significantly contributed to the reduced malaria parasitemia prevalence observed in children in communities with a recent campaign compared to those without campaign in a secondary analysis of the Nigeria 2010 MIS data set recently presented by Kyu and colleagues (Kyu *et al*. 2013).

Second, the analysis shows that there remained a considerable gap in the intra-household saturation with ITN, as overall 66% of households that owned any ITN did not have enough ITN for every household member, i.e. at least one ITN for every two people. This intra-household ownership gap was surprisingly constant across all background variables (Table 4) and notably did not differ much between areas with a recent campaign (63%) and no campaign (72%). However, this comparison can be somewhat misleading as the indicator only identifies the proportion of households with any gap but does not specify how big this gap is. Analysis of the mean number of ITN owned by these households showed that in campaign areas the magnitude of the gap was much smaller, with a mean of 1.96 compared to 1.56 in non-campaign areas. Nonetheless, the intra-household ownership gap remains the most critical deficit after the mass campaigns and this is caused by the NMCP strategy of limiting the number of ITN given per household to two irrespective of family size (Ye *et al*. 2012; Kyu *et al*. 2013) which implied that the 58% of households in the campaign areas that had five or more members did, by definition, not get enough ITN. However, this was by design and it was clear that some additional, continuous distribution of ITN has to be established in any case to sustain universal coverage as has been emphasized by several authors (Thwing *et al*. 2008; Hightower *et al*. 2010; Hetzel *et al*. 2012; Bennett *et al*. 2012; Ye *et al*. 2012) and is recommended by WHO (World Health Organization 2007). Such continuous distribution strategies are already being implemented or piloted in Nigeria through health services, schools, the communities and the retail market (E. Baba, personal communication).

Third, using the newly recommended ITN access indicator allows differentiating in the analysis between non-use due to lack of nets and behaviour driven non-use if the person actually could have used an ITN. The results indicate that overall ITN utilization was high with only 19% of those with access not using an ITN the previous night which is very good considering that some nets are not available all nights due to washing or temporary use at other locations (Pulford *et al*. 2011). Furthermore, the analysis shows a clear difference between the Northern and Southern geopolitical zones in Nigeria with excellent use in the North (use gap 11%) but a considerable lack of utilization in the South (use gap 36%) implying that interventions targeting behavioural change and building of a net culture need to be strengthened in the Southern part of the country. The description of the use gap is further enhanced by the analysis of ITN use by age, gender and supply situation of the household (Figure 5.4) showing not only the difference between the North and the South but also that the lower use among older children and young adults which has been also found in many other settings (World Health Organization 2012; Bennett *et al*. 2012; Graves *et al*. 2011) is dramatically reduced once enough ITN are available in the household, i.e. they are not primarily behaviour driven. This phenomenon has also been observed in Sierra Leone (Bennett *et al*. 2012). In contrast, the higher use rate of females compared to males, especially in early adulthood, which is also well described in the literature (Bennett *et al*. 2012; Graves *et al*. 2011; Garley *et al*. 2013; Stevens *et al*. 2013) appears to remain in Nigeria even when sufficient nets are available. This can be interpreted as a success of the campaign to emphasize the importance of women's protection from malaria during the reproductive years.

There are two major strengths of the revised ITN indicators for the assessment of universal coverage. The first is that none of the added indicators requires changing the existing standard questionnaire modules, which allows ownership and use gaps to be easily calculated from historical data, as well as allowing analysis of trends in these specific gaps over time. The second strength is that the combination of the four indicators now allows a comprehensive analysis of malaria prevention programmes with ITN in the sense of "systems effectiveness" previously described by Tanner and colleagues (Tanner *et al*. 1993). This approach looks at the programme success as a cascade of dependent steps of coverage and utilization that ultimately result in the "community effectiveness". In this case it would be the progress from spatial household ownership coverage with "at least one ITN" to the "ITN use the previous night" by the general population as seen in the combination of Figure 5.3 and Figure 5.4. However, there is one difference to the approach originally suggested by Tanner *et al.* in that there is a change of denominator in the cascade from households to population making a direct comparison of these steps impossible.

There is one important limitation to the access indicator: because it is based on the ratio between number of persons and ITN at household level the indicator does not allow the determination of who among the family members has access to an ITN if there are not enough for all, meaning that comparisons between access and use cannot be done at individual level but only at the level of the overall sample or sub-groups. It also means that the calculation of the use gap estimate, i.e. the difference between access and use, and the confidence interval have to be calculated manually as suggested in this study. This, however, does not really limit the usefulness of the access indicator as a critical tool in the comprehensive analysis of the different aspects of universal coverage with ITN and the limitation can in part be overcome by using the population living in houses with sufficient ITN, who by definition should all have access to an ITN, to analyse changes in utilization by age, gender or other variables as a function of access.

The revision of the ITN indicators was initiated in 2010 and finalized in 2011. However, to date these indicators have only been broadly applied by the WHO World Malaria Report (World Health Organization 2012) and in unpublished reports from post-campaign surveys while in the more recent publications they have only partially been applied (Bennett *et al*. 2012) or not at all (Ye *et al*. 2012; Atieli *et al*. 2011; Stevens *et al*. 2013). Given the proven usefulness of the expanded ITN indicators there appears to be an urgent need to rapidly introduce them to a wider audience and particularly to build capacity among programme staff to appropriately utilize them.

5.6 Conclusions

The revised and expanded ITN indicators to assess universal coverage provide researchers, managers and the public health community in general with strong tools for a comprehensive situation analysis in the sense of a "systems effectiveness" approach that produces clear, actionable evidence of progress as well as the need for specific additional interventions by clearly identifying the ownership and use gaps.

5.7 Author's contributions

AK, HK, ML developed the concept of the study, AK undertook the data analysis and all co-authors participated in data interpretation. Initial manuscript was drafted by AK with all co-authors contributing to final version. All authors read and approved the final manuscript.

5.8 Acknowledgements

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6 Recalculating the net use gap: a multi-country comparison of ITN use versus ITN access

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6.1 Abstract

Use of insecticide treated nets is widely recognized as one of the main interventions to prevent malaria and high use rates are a central goal of malaria programs. The gap between household ownership of at least one ITN and population use of ITN has in the past been seen as evidence for failure to achieve appropriate net use. However, past studies compared net use with ownership of at least one net, not access to sufficient nets within households. This study recalculates the net use gap in recent large household surveys using the comparison indicator of 'access to nets within the household' as now recommended by Roll Back Malaria and the World Health Organization.

Data from 41 Demographic Health Surveys (DHS) and Malaria Indicator Surveys (MIS) (2005-2012) in sub-Saharan Africa were used. For each dataset three indicators were calculated: population access to ITN, population use of ITN, and household ownership of at least one ITN. The ITN use gap was expressed as the difference between one and the ratio of use to access.

The median proportion of users compared to those with access was high, at 82.1%. Even at population access levels below 50%, a median 80.6% used an ITN given they had access, and this rate increased to 91.2% for access rates above 50%. Linear regression of use against access showed that 89.0% of household members with access to nets used them the night before.

These results clearly show that previous interpretations of the net use gap as a failure of behavioural change communication interventions were not justified and that the gap was instead primarily driven by lack of intra-household access. They also demonstrate the usefulness of the newly recommended ITN indicators; access to an ITN within the household provides a much more accurate comparison of ITN use than ownership.

6.2 Introduction

Use of insecticide treated nets (ITN) is widely recognized as one of the main interventions to prevent malaria and high use rates are a central goal of malaria programs. The two main indicators to assess outcomes have been household ownership of at least one ITN and population use of ITN the previous night. Consistently, evaluations have found a significant gap between these indicators with ITN use always much lower than ownership of at least one ITN (Korenromp *et al*. 2003; Macintyre *et al*. 2006; Belay *et al*. 2008; Baume *et al*. 2008; Githinji *et al*. 2010; Rickard *et al*. 2011; Atieli *et al*. 2011; Macintyre *et al*. 2011; Deressa *et al*. 2011; Garley *et al*. 2013) and this has been interpreted as evidence of failure to achieve appropriate net use or as a failure of behaviour change communication (BCC) to adequately improve ITN use rates (Macintyre *et al*. 2006; Afolabi *et al*. 2009; Ndjinga *et al*. 2010; Deribew *et al*. 2012). Even very recent publications have continued in this trend (Loha *et al*. 2013; Stevens *et al*. 2013) calling for more educational campaigns to close the entire assumed gap. However, the comparison of ownership to use is misleading and inaccurate for two reasons: first, the denominators of the two indicators are different; second, the ownership indicator does not account for insufficient intra-household net saturation, i.e. some household members will not able to use an ITN simply because it is not there, irrespective of motivation to use.

ITN use is affected by many factors, including seasonal perception of risk, mosquito biting density, perceived comfort, household composition, physical space constrictions (Winch *et al*. 1994; Agyepong *et al*. 1999; Fernando *et al*. 2009; Toé *et al*. 2009; Gunasekaran *et al*. 2009; Iwashita *et al*. 2010; Pulford *et al*. 2011), and in some cases where a variety of nets are available, net preferences (Grietens *et al*. 2013; Baume *et al*. 2009; Baume *et al*. 2011). However, several authors have pointed out that the main reason for non-use is lack of access to a net (Hetzel *et al*. 2012) and having enough nets for all within a household is the strongest determinant of net use (Eisele *et al*. 2009; Bowen 2013). Accordingly, adjustments were made for ownership of nets within the household by restricting analysis to net-owning households (Eisele *et al*. 2009; Rickard *et al*. 2011) or including the variable of at least one ITN for every two household members (Bennett *et al*. 2012). Vanden Eng (Vanden Eng *et al*. 2010) introduced a framework of four categories assessing whether individuals were living in households where a) nets were not owned, b) nets were owned but not hung, c) nets were hung but not used, or d) nets were used, in an effort to specify whether non-use of nets was behaviour- or access-driven. However, this framework still did not account for whether there were enough nets in the household. Thwing (Thwing *et al*. 2011) and West (West *et al*. 2012) reported on the percentage of households with enough nets to cover all sleeping spaces, but did not conduct use analysis for these households. The most recent suggestion is presented by Singh *et al.* (Singh *et al*. 2013) in a review of ITN use during pregnancy which introduces the indicator "use of an available net" which here refers to ITN use by a pregnant woman if the household owns at least one ITN. However, none of these approaches is able to clearly define the behavioural part of the gap between ownership and use as they fail to clearly define access to a net or ITN within the household.

Acknowledging the shortcomings of the existing two indicators for ITN programs, the RBM Monitoring and Evaluation Reference Group (MERG) reviewed them in 2010 and in 2011. The group recommended the addition of two new indicators (MEASURE Evaluation *et al*. 2013), namely the proportion of households with one ITN for every two people ("household access") and the proportion of the population with access to an ITN within the household (here referred to as "population access" or simply "access") with the assumption that an ITN protects on average two people. These new indicators allow for direct comparison against household ownership and population use, respectively, aligning with best practice for using appropriate comparators for assessing health program implementation (Tanahashi 1978). Kilian and colleagues (Kilian *et al*. 2013a) recently described in detail how these indicators can be applied for a comprehensive ITN program analysis using Nigeria as an example. Recent WHO World Malaria Reports also presented a generalized analysis of population ITN use compared to population ITN access (World Health Organization 2010; World Health Organization 2011b; World Health Organization 2012; World Health Organization 2013c). The aim of the present study was to recalculate the net use gap – the relationship between access and use rather than ownership and use – using data sets from the last seven years and the updated comparison indicator of 'access to nets within the household' as recommended by RBM and WHO.

6.3 Methods

Data from 41 DHS and MIS surveys (2005-2012) in sub Saharan Africa were used which were downloaded with permission from the Measure DHS web site. For each dataset three indicators were calculated: individual access to ITN within the household, individual use of ITN the previous night, and household ownership of at least one ITN. The ratio of population ITN use to population ITN access within the household was calculated and is referred to here as the use:access ratio. The ITN use gap is therefore calculated as 1 minus the use:access ratio. The ITN variables were used rather than LLIN due to the fact that in the earlier surveys some conventionally treated nets were still present. The majority of ITNs in this analysis, however, are LLIN.

Data management and analysis was done using STATA version 12 (STATA Corporation, College Station, Texas, USA) or Excel 2010 (Microsoft Corporation, Seattle, Washington, USA). All analyses accounted for survey design including sampling weights where applicable using the survey command family in STATA.

The survey indicator of access to ITN within the household was calculated from the datasets of individual household members as recommended by MERG (MEASURE Evaluation *et al*. 2013). First, an intermediate variable of "potential ITN users" was created by multiplying the number of ITN in each household by a factor of 2.0. In order to adjust for households with more than one net for every two people, the potential ITN users were set equal to the *de facto* population in that household if the potential users exceeded the number of people in the household. Second, the population access indicator was calculated by dividing the potential ITN users by the number of *de facto* members for each household and determining the overall sample mean of that fraction.

Use of an ITN the previous night was calculated for each *de facto* member of the household, i.e. those present in the house the previous night, as recommended by MERG using the listings of net users from the net roster (MEASURE Evaluation *et al*. 2013). Household ownership of at least one ITN was also calculated for each dataset based on the number of ITN observed in the household and defining an ITN as a long-lasting insecticidal net (LLIN) identified by its label or a net that was treated with an insecticide within the last 12 months.

Linear regression was used to describe the relationship between use, ownership and access and in order to acknowledge the fact that no use is possible without access or ownership, all models were run with a “no constant” constraint.

6.4 Results

Details of the 41 datasets are provided in Table 6.1. Surveys were conducted between 2005 and 2012, and consisted of 28 DHS (57%), twelve MIS (41%), and one Anaemia and Parasitemia Survey. A total of 28 countries in sub-Saharan Africa were represented, with sixteen surveys (39%) from West Africa, fourteen (34%) from East Africa, five (12%) from Central Africa and six (15%) from Southern Africa.

The range of values for household ownership of ITN was from 3.5% (Guinea 2005) to 90.9% (Tanzania 2011). Median proportion of the *de facto* population with access to an ITN within the household was 31.6%, ranging from 1.5% (Guinea 2005) to 74.5% (Tanzania 2011). Use of an ITN the previous night ranged from 0.3% (Swaziland 2006) to 68.4% (Tanzania 2011). The ratio of use to access ranged from 0.11 (Swaziland 2006) to 1.19 (Madagascar 2011).

Table 6.1: Access, use, and ownership of ITNs by survey

Country | Survey | Year	% of households owning at least 1 ITN	% of population with access to an ITN within their own household	% of population that used an ITN the previous night	Ratio of use to access
Angola MIS 2006-2007	27.5%	14.5%	11.9%	0.82
Angola MIS 2011	34.5%	19.0%	18.9%	0.99
Benin DHS 2006	24.5%	14.7%	14.7%	1.00
Burkina Faso DHS 2010	56.9%	36.1%	31.5%	0.87
Burundi DHS 2010	52.0%	39.1%	37.8%	0.97
Burundi MIS 2012	66.0%	46.0%	48.6%	1.06
Cameroon DHS 2011	36.4%	10.8%	7.6%	0.71
Cote d'Ivoire DHS 2012	71.7%	49.0%	33.2%	0.68
DRC DHS 2007	9.2%	4.2%	4.3%	1.03
Gabon DHS 2012	44.1%	26.9%	26.7%	0.99
Ghana DHS 2008	41.7%	30.1%	20.9%	0.69
Guinea DHS 2005	3.5%	1.5%	1.1%	0.77
Kenya DHS 2008	55.7%	42.3%	35.1%	0.83
Liberia MIS 2009	47.2%	25.4%	22.8%	0.90
Liberia MIS 2011	49.7%	30.8%	32.1%	1.04
Madagascar DHS 2008	57.0%	34.7%	36.6%	1.05
Madagascar MIS 2011	80.5%	57.3%	68.4%	1.19
Malawi DHS 2010	56.8%	37.6%	29.0%	0.77
Malawi MIS 2012	55.0%	37.2%	40.9%	1.10
Mali Anemia & Parasitemia 2010	85.9%	61.6%	56.2%	0.91
Mali DHS 2006	50.0%	29.7%	21.4%	0.72
Mozambique DHS 2011	54.7%	37.0%	29.4%	0.80
Namibia DHS 2006	20.2%	12.8%	5.5%	0.43
Niger DHS 2006	43.0%	19.6%	4.4%	0.22
Nigeria DHS 2008	8.0%	4.8%	3.2%	0.68
Nigeria MIS 2010	41.5%	28.7%	23.3%	0.81
Rwanda DHS 2007-2008	55.6%	38.1%	39.7%	1.04
Rwanda DHS 2010	82.0%	64.2%	57.7%	0.90
Sao Tome Principe DHS 2008	60.8%	51.0%	45.9%	0.90
Senegal DHS 2010	66.2%	38.1%	28.9%	0.76
Senegal MIS 2008	60.4%	34.9%	22.9%	0.66
Sierra Leone 2008 DHS	36.6%	18.8%	19.2%	1.02
Swaziland DHS 2006	4.4%	2.3%	0.3%	0.11
Tanzania DHS 2010	63.8%	46.6%	45.1%	0.97
Tanzania THMIS 2007-2008	39.2%	25.4%	20.3%	0.80
Tanzania THMIS 2011	90.9%	74.5%	68.4%	0.92
Uganda DHS 2011	59.8%	44.7%	35.0%	0.78
Uganda MIS 2009	46.7%	31.6%	25.6%	0.81
Zambia DHS 2007	53.3%	33.9%	23.0%	0.68

Zimbabwe DHS 2005-2006	9.1%	4.8%	2.4%	0.50
Zimbabwe DHS 2010	28.8%	20.2%	8.7%	0.43
Mean	**47.1%**	**31.2%**	**27.0%**	**0.81**
Median	**50.0%**	**31.6%**	**25.6%**	**0.82**

Ownership of ITNs was consistently higher than population access and population use, while access and use tracked more closely as illustrated in Figure 6.1. Regression analysis showed that there was a close, linear relationship between access and ownership (Figure 6.2, $p<0.0001$, R-squared 0.98) with a regression coefficient of 0.68.

Figure 6.1: Ownership, access and use of ITNs for all datasets. Survey results are ordered by ownership. Previously, the visual gap between ownership (dark line) and use (dashed line) made it seem as though the use gap was vast. When use is compared to access (gray line), however, a much closer relationship – and narrower gap – is immediately apparent.

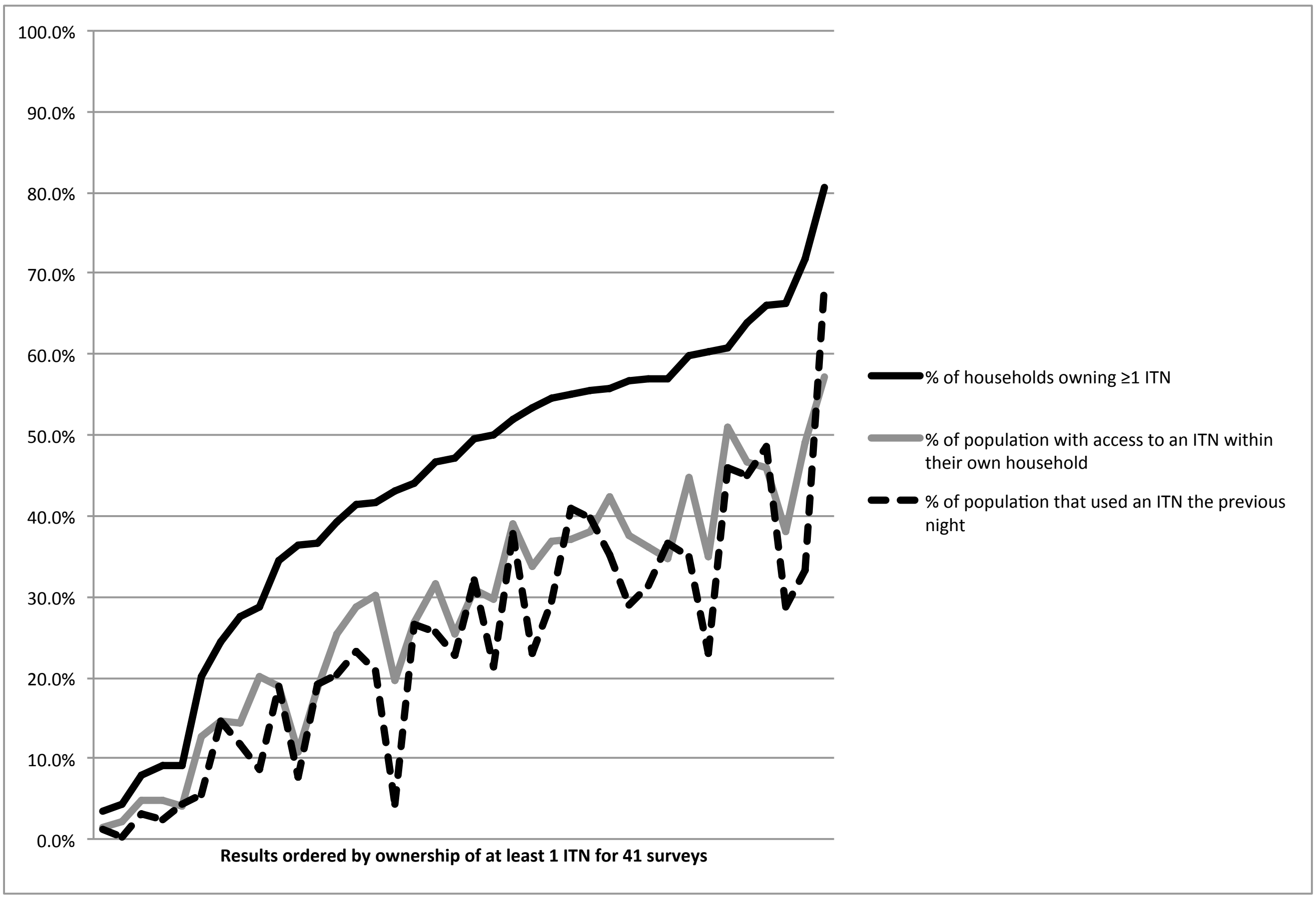
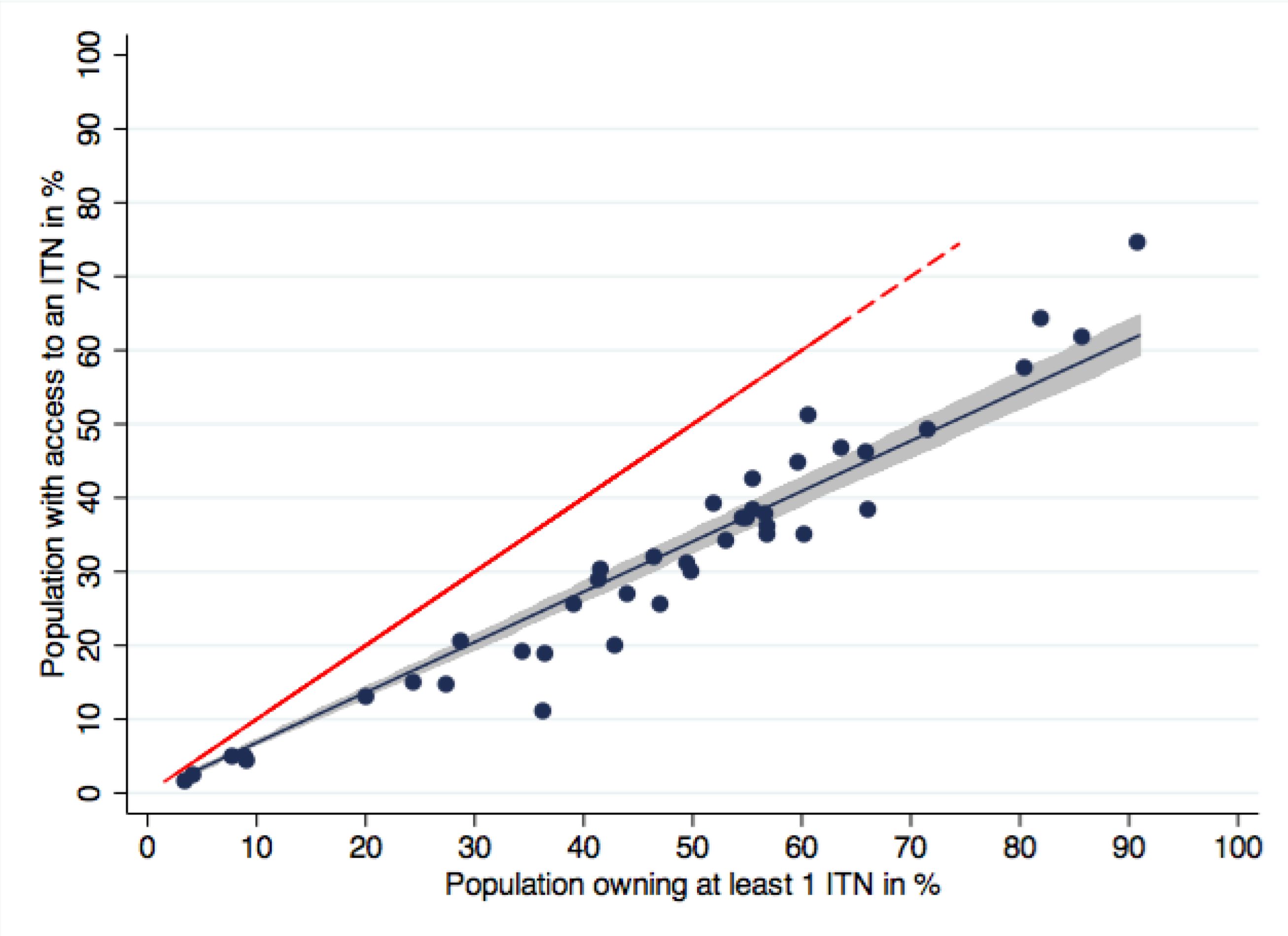


Figure 6.2: Population with access to an ITN within the household compared to ownership of at least one ITN. Blue dots represent the data points for data sets, the blue line the regression function (fitted values). Shaded area is the 95% confidence interval of the fitted values of population with access to an ITN within the household. Red dashed line represents the equity line where ownership is equal to access. On average, population access was 32% lower than household ownership. Coefficient 0.68, R^2=0.98, p<0.001.



6.4.1 The ratio of use to access

Overall the median proportion of ITN users compared to those with access within the household was high, at 82.1% (Interquartile Range 70.7% to 99.2%) with ten surveys (24%) showing proportions below 70% (range 11.2% to 69.4%) and another eight surveys with a result above 100% (range 102% to 119%) indicating that mean users per net exceeded 2.0 in these cases. Even at population access levels below 50%, a median 80.6% used an ITN given they had access, and this rate increased to 91.2% for access rates >50%. Linear regression of ITN use against access showed an estimated use of 89.0% (95% CI 84.0-93.9) given access (Figure 6.3) and comparison with a polynomial model confirmed that a linear function was the best fit to the data. However, at lower access values the variation in use was high, then significantly decreased as access rates improved (test for heteroskedasticity p=0.008), indicating more consistent use of ITNs at higher access rates (Figure 6.4). For the four surveys where household ownership met Abuja targets (greater than 80%), the mean ratio of ITN use to access was 0.98.

Figure 6.3: Relationship of ITN use to ITN access. The figure illustrates the linear relationship of use to access. The red dots are proportion of the population that used an ITN the previous night from the survey datasets. The blue line represents the regression line (fitted values). The shaded area is the 95% confidence interval of the fitted values. The red dashed line represents the equity line, where use equals access. On average, 89% of those with access used a net the previous night. Coefficient 0.89, R^2=0.97, $p<0.001$.

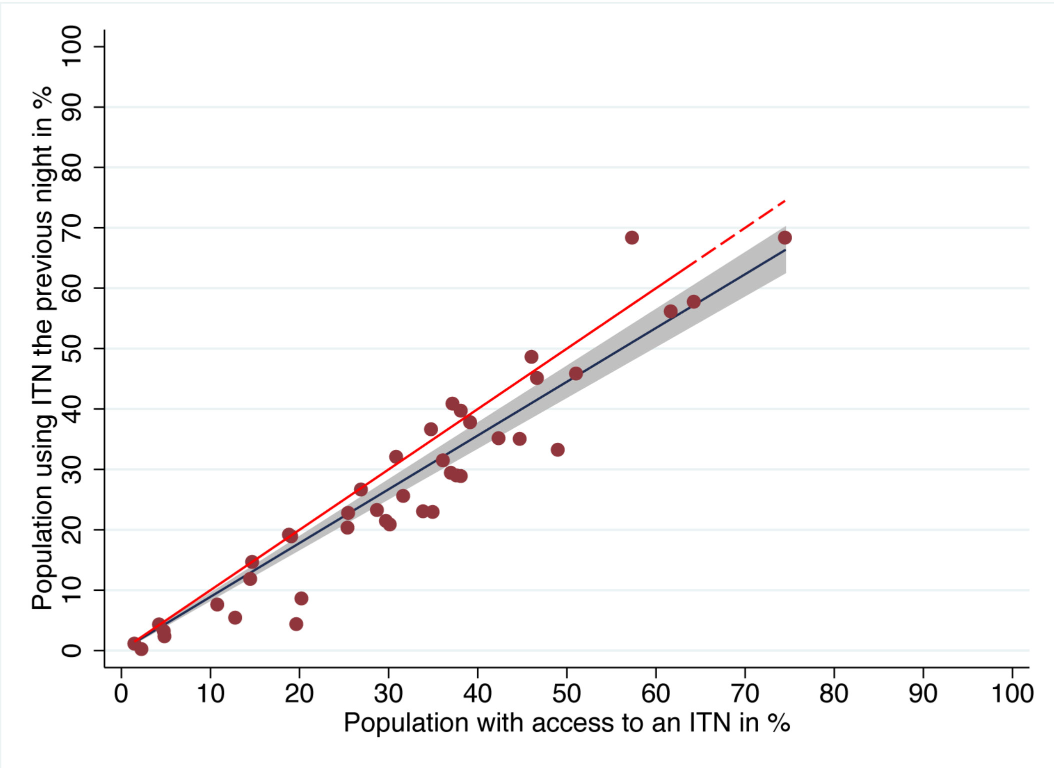
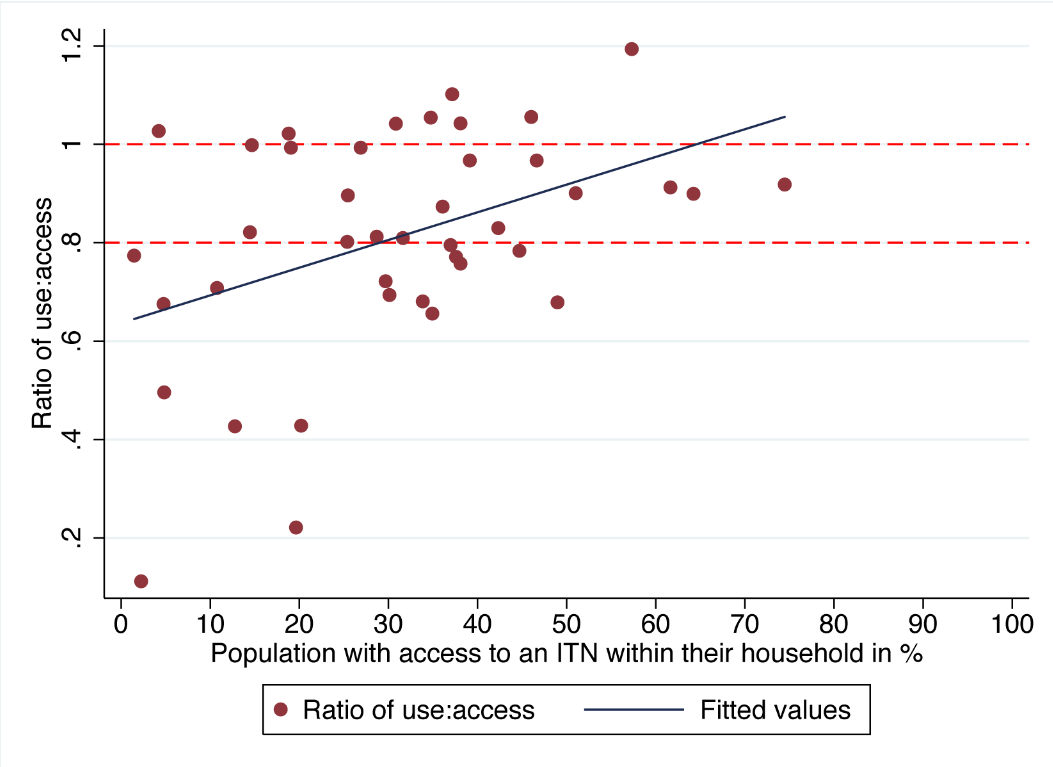


Figure 6.4: Ratio of use to access by access to an ITN within the household. The ratio of use to access is plotted in red dots, by access. The top red dashed line represents the threshold of 100% use among those with access; the lower dashed line represents a nominal minimum target of 80% use among those with access. The blue line is the fitted values indicating the positive linear relationship between the use to access ratio and access. As access (x-axis) increases, use also increases. Coefficient 0.56, R^2=0.18, p=0.005.



The relationship between the ratio of ITN use to access appeared initially to increase over time, but multivariate regression analysis indicated that the relationship was confounded by increasing access over time, due to the scale up through mass ITN distributions of the past few years.

6.5 Discussion

The newly recommended indicator of population access to an ITN within the household provides a much more appropriate comparison for ITN use than does the household ownership indicator. Previously, when comparing household ownership to population use, it was not possible to determine whether the gap between the two indicators was due to behavioural factors or due to not having enough nets for all the members of the household. Since the two indicators had different denominators, conclusions were difficult to draw. Comparing population ITN use against population ITN access provides a clearer picture of the size of the behavioural gap.

Below 50% access, the median use to access ratio was 80.5%, and above 50% access, the median use to access ratio increased to 91.2%, indicating that at high rates of population access, very few people are not using them. Even at lower levels of population access, use to access ratios above 80% indicate that there is – in general – perhaps only a small amount of room for improvement in net use behaviour.

As the population ITN access indicator is calculated by randomly assigning household members to nets, it is not possible to analyze the determinants of non-use for individuals who had access. It is not known whether the individual truly had access or not, due to the randomization process in the population access calculation. This prevents detailed analysis of the determinants of non-use among those with access which might inform BCC planning to improve targeting of messaging to these 'hold outs'. However, analysis of use rates by age in households with enough nets compared to households without enough nets indicates that those most likely not to be using a net when nets are scarce are adolescents and the elderly (Kilian *et al*. 2013b), as adults and young children tend to be prioritized for net use (Noor *et al*. 2009; Fernando *et al*. 2009; Tsuang *et al*. 2010; Iwashita *et al*. 2010; Ahmed *et al*. 2011; Graves *et al*. 2011; Koenker *et al*. 2012; Stevens *et al*. 2013; Garley *et al*. 2013). Reported reasons for not using nets when one is available are well documented (Baume *et al*. 2011; Pulford *et al*. 2011; Alaii *et al*. 2003; Beer *et al*. 2012; Galvin *et al*. 2011), and non-use is primarily due to lack of perceived mosquito density and hot nighttime temperatures (Pulford *et al*. 2011). Aside from these main subjective reasons, preferences for various design aspects (size, shape, color, texture, density of fabric) have been shown to limit use of nets in some households in Ghana, Ethiopia, and in the Peruvian Amazon (Baume *et al*. 2011; Baume *et al*. 2009; Grietens *et al*. 2013), although preferences have not been widely shown to significantly affect ITN use in sub-Saharan Africa. While comparative acceptability and preference studies are useful for determining stated preferences in a given area, they do not indicate whether households would use a non-preferred net just as often, in the absence of their preferred net. Other objective barriers also prevent net use such as its usual user being absent, particularly for funerals (Monroe *et al*. 2014), being too old or torn, or the net not yet being dry from washing or otherwise unavailable (Pulford *et al*. 2011; Koenker *et al*. 2013a; Kilian *et al*. 2015).

These results should be considered encouraging for both donors and malaria control program officials, as they show that the vast majority of those who have access to ITNs are using them, and that donor investments are not being wasted. Whether these high use rates are due to the extensive BCC efforts of the past decade, to an increasing familiarity with ITNs (Koenker *et al*. 2013a), or solely to improvements in access is not known. It is likely, despite a dearth of published literature specifically on malaria, that BCC has contributed significantly to the high rates of use, given evidence from Cameroon (Bowen 2013) and Zambia (Boulay *et al*. 2014) that ITN use is significantly associated with exposure to messages about malaria. What is apparent from these data, however, is that as population access increases, the ITN use to access ratio increases, which may indicate a growing social norm of ITN use as ITNs are increasingly available. Ratios of use to access above 100% indicate that more than two people are sharing a net, on average, which should not be surprising considering that multiple children may be sharing both a sleeping space and its ITN, particularly in conditions of ITN scarcity, or in homes where hanging multiple nets is made difficult due to the size or other characteristics of the dwelling or the sleeping rooms' alternative uses (Toé *et al*. 2009; Iwashita *et al*. 2010).The very low use to access ratios from Namibia, Swaziland, and Niger date from 2006, prior to any scale-up of ITNs; Swaziland benefited from robust IRS operations at the time, while in Niger use dropped dramatically during dry season, when fieldwork was conducted (Thwing *et al*. 2008).

These findings are in line with other national-level studies (Eisele *et al*. 2009) that demonstrate that access is the main driver of ITN use. A recent analysis from Nigeria (Kilian *et al*. 2013b) showing that use to access ratios vary considerably between northern and southern Nigeria (0.89 and 0.64, respectively) is already being utilized to focus BCC efforts more strategically in the southern part of the country (Nigeria Malaria Elimination Programme, personal communication). It will be important to look more closely at subnational trends in order to effectively identify and respond to variations in net use within countries. The population access indicator, while it does not allow for individual-level analyses, does allow for analyses at the household level, such as socio-economic status, geographic location, and others. While the use:access ratio provides a better quantification of the behavioural "use gap", this calculation still does not offer any insights into the reasons why individuals do not use the nets. Future studies will need to include questions that allow these reasons and determinants to be elucidated. The recent Malaria BCC Indicator Reference Guide was designed by RBM partners to help with this and other areas of malaria BCC evaluation (Roll Back Malaria Communication Community of Practice 2014).

Malaria program officials should continue to work towards closing the access gap by ensuring ways of providing enough nets to all households. Continuous distribution of ITNs through antenatal clinics, immunization programs, school distributions and community distributions, as well as through social marketing and retail sales, provide several options to ensure households can obtain nets between or instead of mass campaigns. At the same time, better understanding of the ITN use gap and the effects of BCC will be necessary to maintain the gains in use and to strengthen the culture of net use that is growing around the continent (Koenker *et al*. 2013a; Loll *et al*. 2013; Berthe *et al*. 2014).

6.6 Conclusion

The “net use gap” often referred to by program planners when looking at the standard indicators of household ownership of ITNs and then at population ITN use does not take into account whether there are enough ITNs in the household. On the whole, over 80% of those with access to an ITN within their household reported using an ITN the previous night. This has significant implications for planning behaviour change interventions to increase use. These results clearly show that previous interpretations of the net use gap as a failure of behavioural change communication interventions were not justified and that the gap was instead primarily driven by lack of intra-household access. They also demonstrate the usefulness of the newly recommended distinction between use and actual access to ITN.

6.7 Acknowledgments

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6.8 Author Contributions

Conceived and designed the experiments: HK AK. Performed the experiments: HK. Analyzed the data: HK AK. Contributed reagents/ materials/analysis tools: HK AK. Wrote the paper: HK AK.

7 What happens to lost nets: a multi-country analysis of reasons for ITN attrition using 14 household surveys in 4 countries

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7.1 Abstract

While significant focus has been given to net distribution, little is known about what is done with nets that leave a household, either to be used by others or when they are discarded. To better understand the magnitude of sharing LLIN between households and patterns of discarding LLIN, the present study pools data from 14 post-campaign surveys to draw larger conclusions about the fate of nets that leave households.

Data from 14 sub-national post-campaign surveys conducted in Ghana, Senegal, Nigeria (10 states), and Uganda between 2009 and 2012 were pooled. Survey design and data collection methods were similar across surveys. The timing of surveys ranged from 2-16 months following their respective mass LLIN distributions.

Among the 14 surveys a total of 14,196 households reported owning 25,447 nets of any kind, of which 23,955 (94%) were LLINs. In addition, a total of 4,102 nets were reported to have left the households in the sample: 63% were discarded, and 34% were given away. Only 255 of the discarded nets were reported used for other purposes, representing less than 1% of the total sample of nets. The majority (62.5%) of nets given away were given to or taken by relatives, while 31.1% were given to non-relatives. Campaign nets were almost six times (OR 5.95, 4.25-8.32, p<0.0001) more likely to be given away than non-campaign nets lost during the same period. Households were more likely to give away nets if they had more than one net for every household member (OR 1.88, 1.39-2.54, p<0.0001), and lived in urban areas (OR 1.79, 1.27-2.53, p=0.001). Nets were primarily given away within the first few months after distribution. The overall rate of net redistribution was 5% of all nets.

Intra-household re-allocation of nets does occur, but was sensitive to current household net ownership and the time elapsed since mass distribution. These factors can be addressed programmatically to further facilitate reallocation within a given community. Secondly, the overwhelming majority of nets were used for malaria prevention. Of the repurposed nets (<1% overall), the majority were already considered too torn, indicating they had already served out their useful life for malaria prevention. National programs and donor agencies should remain confident that overall, their investments in LLIN are being appropriately used.

7.2 Background

Long-lasting insecticidal nets (LLIN) are the main preventive tool against malaria, providing a reduction in malaria episodes of 50% (Lengeler 2004). WHO recommends implementing universal coverage of LLIN for all populations at risk (World Health Organization 2013b), and since 2004, over 800 million nets have been distributed in sub Saharan Africa (Milliner 2014), primarily through mass campaigns but also through antenatal care services, immunization clinics, and the retail sector. While significant focus has been given to net distribution, little is known about what is done with nets that leave a household, either to be used by others or when they are discarded.

The loss of nets from households, or net attrition, is important for two reasons. First, attrition is a significant component of calculating LLIN durability. Durability is calculated based on the direct observation of the number of nets given out originally that have survived to a certain time point, minus those that have been lost to follow-up and need to be accounted for in this denominator (World Health Organization 2013a). These lost nets are divided into two categories: a) those that are given away, sold, or stolen, and can be assumed to be still in use, but cannot be assessed and therefore are excluded from the denominator, and b) those that were thrown away, destroyed, or used for another purpose, which are included in the denominator. The decision to discard nets is therefore one of the principal drivers of calculating overall LLIN durability. Secondly, the percent of surviving nets is then measured using information on the number and proportionate hole index of existing LLIN, to obtain the median net lifespan for a given crop of nets, and the importance of correctly doing so is well-described in the WHO Guidelines on measuring net durability (World Health Organization 2011a). Despite this, many recent durability studies (Tsuzuki *et al*. 2011; Batisso *et al*. 2012; Wills *et al*. 2013; Mejia *et al*. 2013; Mutuku *et al*. 2013) fail to include this measurement when they are calculating lifespans of LLIN in a given sample.

Household decisions around end of net life are highly subjective. Decision-making about when a net is no longer useful has been discussed in one study in Senegal (Loll *et al*. 2013), where respondents were asked hypothetical questions about when they would discard nets in varying degrees of disrepair, and what they would do with it. Most respondents stated that they would prefer to get a new net when possible rather than attempt to repair their nets when damaged. Batisso et al (Batisso *et al*. 2012) found in Ethiopia that the primary reason for non-use was that nets were considered too old or torn, although the condition of these 'unusable nets' was similar to other nets in use in the community: nets were considered old when they only had a few holes. One third of nets were discarded when they were just under a year old, but the physical condition of these nets was not reported. Reports from qualitative research in Madagascar on decisions to give up nets for recycling also shed light on the reasons why households might prefer to discard or keep old nets. These depended on whether the family felt they had sufficient nets to protect all family members, whether they had paid for the net or received it free, whether they were currently using it for an alternative purpose, among other reasons (Nelson *et al*. 2011).

There is little information on the extent to which LLIN are shared between families and within communities, although recent unpublished data from a study on the effects of Hang Up activities in Uganda (Kilian *et al*. 2015) indicate that nets that were given away were primarily given to family members who reside elsewhere, particularly students away at school. An older study in Tanzania recorded that between 6% and 20% of nets used the previous night were obtained as gifts from relatives or friends (Khatib *et al*. 2008). Sharing of LLIN is an important question in the context of recent community distribution strategies that may not target every household, for example school distribution strategies (Koenker *et al*. 2013b) or other strategies that may rely in part on households sharing nets with others that were not reached.

Lastly, there is evidence that LLIN are used for other purposes in some instances or in certain communities. While the overall percentage of nets that are used for purposes other than sleeping has been shown to be small (Eisele *et al*. 2011), there are documented cases of nets being used for other purposes in coastal Kenya (Mutuku *et al*. 2013), for drying fish near Lake Victoria (Minakawa *et al*. 2008), for fishing in the Tamatave region of Madagascar (Andrea Brown & Mohamad Sy-Ar, personal communication), and for fishing in Lake Tanganyika (McLean *et al*. 2014). Other studies (Pulford *et al*. 2011; Lover *et al*. 2011; Honjo *et al*. 2013; Nyunt *et al*. 2014) note that alternative use of LLINs occurs without being able to quantify the extent or nature of the practice.

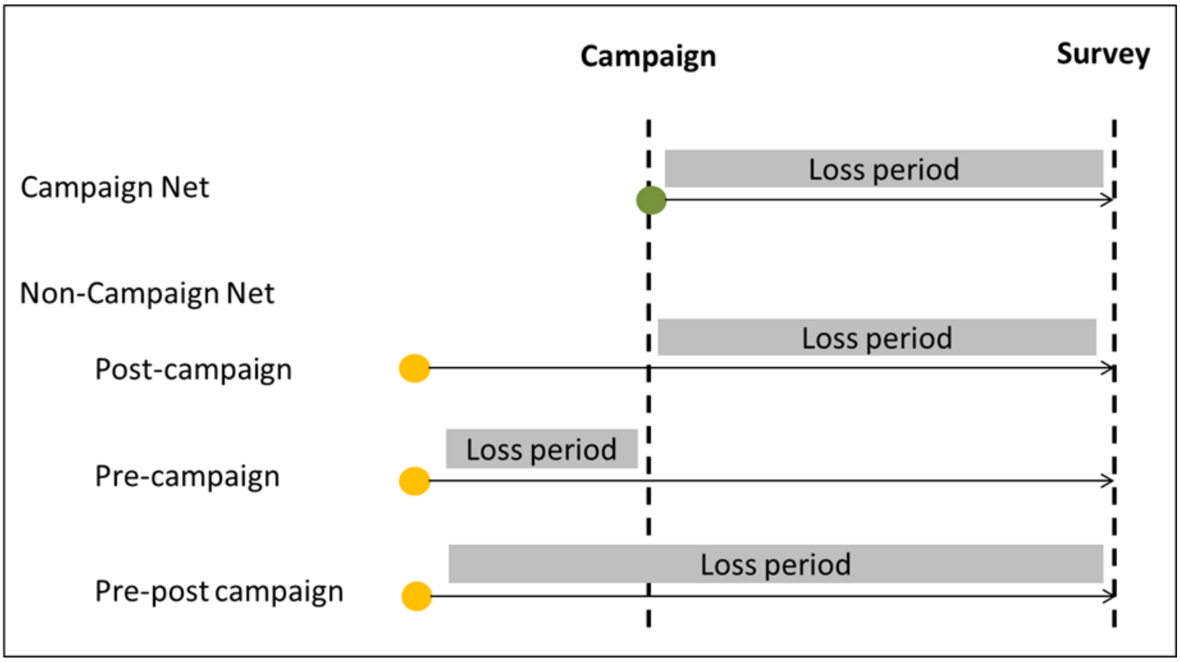
To better understand the magnitude of sharing LLIN between households and patterns of discarding LLIN, and because the number of nets ‘lost’ in any given post-campaign survey is insufficient for individual analysis, the present study pools data from 14 post-campaign surveys to draw larger conclusions about the fate of nets that leave households.

7.3 Methods

The post-campaign surveys were conducted to measure LLIN ownership and use following mass campaigns in four countries. The 14 subnational surveys were conducted in Ghana (Northern and Eastern regions), Senegal (single survey covering Kaffrine, Kaolack, Kolda, Sedhiou, Kedougou, and Tambacounda regions), Nigeria (Kano, Anambra, Sokoto, Niger, Ogun, Nasarawa, Katsina, Cross River, Enugu, and Lagos states), and Uganda (Western Uganda region) between 2009 and 2012. Survey design and data collection methods were similar across surveys, i.e. representative cross sectional household surveys with a two-stage cluster sampling design and a standard questionnaire. Analysis included 14,196 households and accounted for cluster survey design and sampling probabilities. The timing of surveys ranged from 2-16 months following their respective mass LLIN distributions.

The data collection tool consisted of the standard MIS questionnaire with the basic household module and a household member and net roster (MEASURE Evaluation *et al*. 2013). Modules on the process of obtaining nets from the campaign and ownership of previous nets were added. Previously owned nets were divided into two broad categories, namely nets obtained from the campaign and those from other sources obtained before the campaign. As shown in Figure 7.1, any loss between the campaign and the survey was considered as "post-campaign" while a net owned before the campaign and lost within the 12 months preceding the campaign, i.e. no longer present at the time of the campaign, were considered as "pre-campaign" losses. In the Ghana survey for the Northern Region, no distinction was made of the time when non-campaign nets were lost, and this category is referred to as "pre-post campaign".

Figure 7.1: Loss periods for campaign nets and non-campaign nets.



For each lost net the reported age at the time of loss was recorded. The fate of the net was inquired and noted in 10 categories (see Table 7.1 for details) which in turn were grouped into two main categories: i) nets given away for others to use (including those stolen) and ii) those discarded. These categories follow the recommendation on assessment of causes for attrition established by WHO (World Health Organization 2011a). Subsequently, the reasons for the loss were explored.

Data were merged from the surveys and descriptive statistics, median ages, and regression analyses were conducted with Stata 12 (Stata Corporation, College Station, Texas, USA). All statistical analyses were done taking into account the design effect from the cluster survey design. Univariate logistic regression was performed with potential explanatory variables to determine the selection of variables for the multivariate regression. To assess differences in the distribution of net age at the time of loss for the different types of nets and country settings, inverse cumulative distributions were created and plotted against net age.

The wealth index was computed at the household level for each survey and strata using principal component analysis (PCA) (Vyas *et al*. 2006). The variables for household amenities, assets, livestock, and other characteristics that are related to a household's socioeconomic status were used for the computation. All variables were dichotomized except those of animal ownership where the total number owned was used. The first component of the PCA was used as the wealth index.

Households were then classified according to their index value into quintiles, calculated separately for each survey. For analysis of individual nets the quintile allocation of the household was applied.

Ethical clearance for the original post-campaign survey in Senegal was obtained from the Johns Hopkins University Bloomberg School of Public Health Institutional Review Board in Baltimore, Maryland, USA and the *Comité National d'Ethique pour la Recherche en Santé* in Dakar, Senegal. For Ghana, clearance was obtained from the Ghana Health Service Ethical Review Committee (Northern and Eastern), and from the JHSPH IRB (Eastern Region), In Nigeria, clearance was obtained from National Health Research Ethics Committee of Nigeria, and in Uganda, ethical review was provided by the Uganda National Council of Science and Technology (UNCST) in Kampala, Uganda.

7.4 Results

7.4.1 Global Results

Among the 14 surveys a total of 14,196 households reported owning 25,447 nets of any kind (Table 7.1) on the day of the survey, of which 23,955 (94%) were ITNs. In addition, a total of 4,102 nets were reported to have left the households in the sample: of these, 2,580 were discarded (63%), and 1,383 were given away (34%). A small percentage (3.4%) of nets were reported lost but were missing fate (n=139) or age (n=16) (Table 7.2). These nets were excluded from the subsequent analysis, leaving 3,947 lost nets.

Table 7.1: Number of nets in the sample

	# of households	# of nets present on day of survey	# of nets that left the household	Total nets past and present
Uganda	549	1,646	397	**2,043**
Ghana	1,821	4,093	716	**4,809**
Senegal	1,540	7,029	1,818	**8,847**
Nigeria	10,286	12,679	1,171	**13,850**
Total	**14,196**	**25,447**	**4,102**	**29,549**
Lost nets with incomplete data			155	
Total lost nets for analysis			**3,947**	

Table 7.2 presents details of what happened to the lost nets. Of the nets reported discarded (2,465), 53% (1,298) were thrown away while 37% (921) were destroyed. Only 255 of discarded nets were

reported used for other purposes, representing 6% of the total sample of lost nets (n=3,947) and less than 1% of the total sample of nets owned by households (255/29,551).

Of the nets reported given away, the majority (845, or 62.5%) were given to or taken by relatives, while 31.1% (420) were given to non-relatives. Only 5.3% (71) were reported stolen, and 1.2% (16 nets out of the total sample) were reportedly sold.

Table 7.2: Fate of nets lost from household

Fate of net		N		Overall %	Within group %
Discarded	2,465		62.5%		
Thrown away		1,298		32.9%	52.7%
Destroyed		921		23.3%	37.4%
Used for other purpose		246		6.2%	10.0%
Given Away	1352		34.3%		
Given or taken by relatives		845		21.4%	62.5%
Given to others		420		10.6%	31.1%
Stolen		71		1.8%	5.3%
Sold		16		0.4%	1.2%
Unknown	130		3.3%		
Do not know		66		1.7%	50.8%
Other		64		1.6%	49.2%
Total	3,947		100		

7.4.2 Age of nets when 'lost'

The median age at which nets were reported lost was 0.96 years (Inter-Quartile Range [IQR] 0.25 – 3.00 years old). However, as shown in Figure 7.2, the age distribution differed significantly between nets given away to others and those discarded. Nets that were given away had a median age of 0.34 (IQR 0.08 – 1.00 years old), while nets that were discarded had a median age of 2.00 (IQR 0.42 – 3.00 years old). The difference between these groups was statistically significant (p=0.0001, Kruskal-Wallis test). Nets given to other people were on average older than nets given to family members, at median ages of 0.62 (IQR 0.17 – 2.00) years old and 0.19 (IQR 0.06 – 0.77) years old, respectively and this difference was also statistically significant (p=0.0001, Kruskal-Wallis test). No difference in age at loss was found for nets thrown away or destroyed versus those used for other purposes (p>0.05, Kruskal-Wallis test).

Distribution of age at time of loss also differed by country (Figure 7.3). In Senegal, more nets were lost within the first year compared to the other countries. In contrast, loss of nets occurred generally later in Ghana while the age distribution curves of lost nets were very similar in Nigeria and Uganda.

Figure 7.2: Distribution of net age at time of loss for nets given away (solid blue line) and those discarded (dashed red line

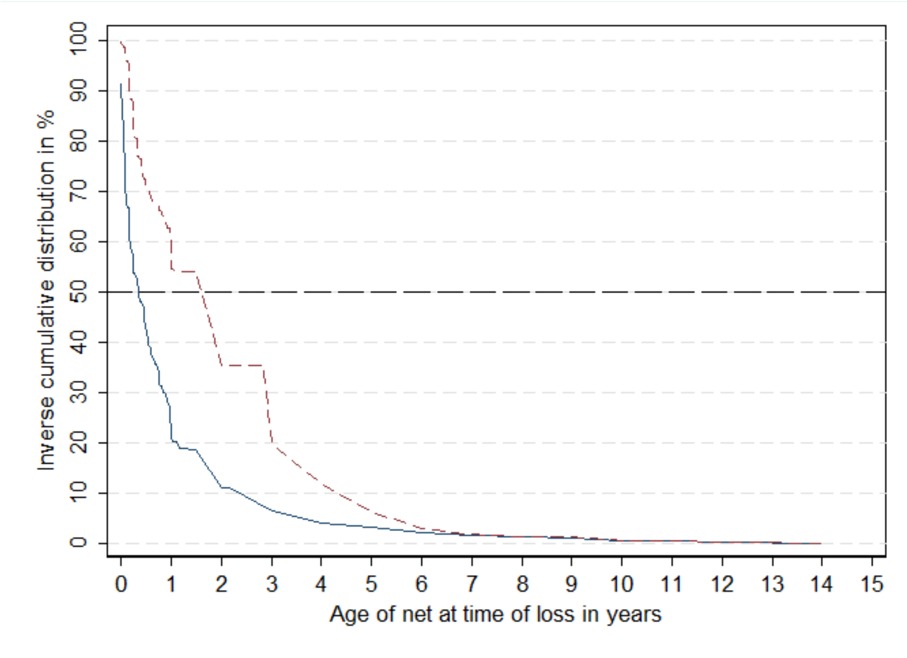
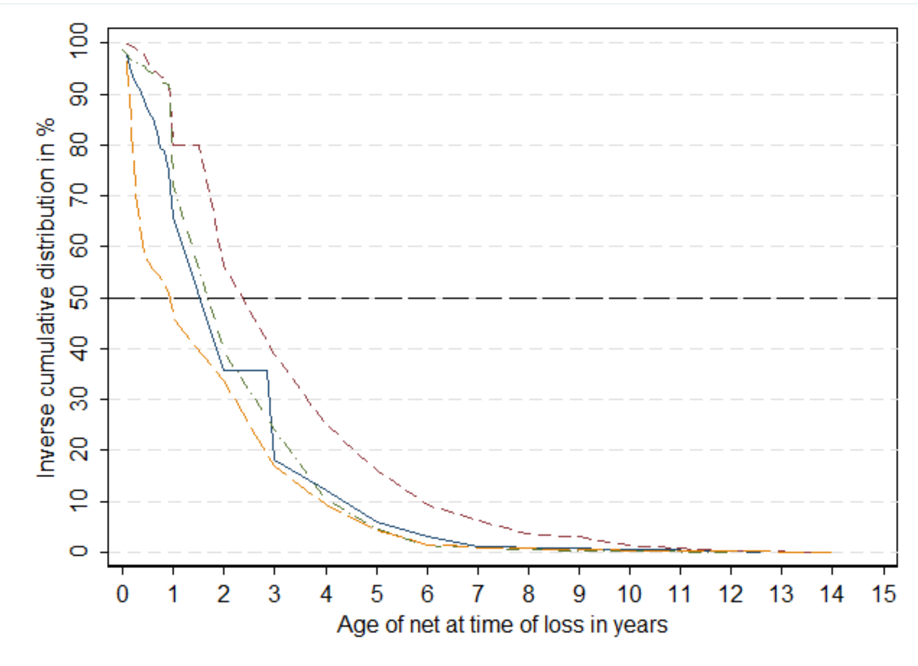


Figure 7.3: Distribution of net age at time of loss by country. Nigeria: solid blue line; Senegal: long-dash yellow line; Uganda: dash-dot green line; Ghana: dash red line.



7.4.3 Determinants of fate of 'lost' nets in univariate analysis

Households dealt differently with nets obtained from campaigns and nets obtained through other sources: campaign nets represented 73.0% of nets given away, compared to non-campaign nets (21.4%, p<0.0001). The other major determinant was the age of net at time of loss: 51.4% of nets less than 6 months old were given away, 44.1% of those between 6 months and one year, 24.2% aged 1-3 years and 13.9% of nets older than three years (p<0.0001). Table 7.3 combines these two determinants and shows that for campaign nets, most of the "giving away" occurred within the first months after distribution. Non-campaign nets also showed a declining trend but the proportion given away rather than discarded was much lower throughout.

Table 7.3: Proportion of previously owned nets given away by type of net and age at loss

Type of net	Reported age of net at time of loss in months							Total
	0-1	1-3	3-6	6-12	12-36*	36-60	>60	
Campaign								
N	379	200	155	200	51			985
% of nets given away (vs discarded)	87.6%	66.5%	62.6%	62.5%	62.8%	No data	No data	73.0%
95% CI	80.2 – 92.3	56.1 – 75.5	47.4 – 75.6	50.4 – 73.2	45.1 – 77.5			67.5 – 77.9
Non-campaign								
N		328	420	294	862	694	364	2962
% of nets given away (vs discarded)	No data	35.2%	20.0%	33.0%	21.9%	13.4%	14.8%	21.4%
95% CI		25.8 – 45.9	13.9 – 28.0	24.5 – 42.8	18.1 – 26.4	10.6 – 16.8	10.5 – 20.5	18.7 – 24.3

** for campaign nets only up to 16 months maximum*

A number of other factors were identified in the univariate analysis that showed a significant association with whether a net was given away for others to use rather than discarded. The proportion given away was higher in urban settings (38.7% vs. 30.3% rural, p=0.007), in smaller sized households (52.1% if 1-3 people, 38.4% for 4-6 people and 26.3% for 7 or more, p<0.0001), among households with more educated heads of household (29.9% if non-literate, 34.0% if primary education, 38.4% if secondary and 40.1% if tertiary, p=0.02), and among households that did not have any children under 5 (41.4% vs. 29.7% with children, p<0.0001). The proportion of lost nets given away also differed by country with Nigeria showing the highest rate (49.2%), followed by Uganda (39.6%), Ghana (29.4%) and Senegal (24.2%, p<0.0001).

Household socio-economic status (wealth quintiles) was not statistically associated with the fate of the lost nets in the univariate analysis, nor was there a difference between non-campaign nets lost before or after the campaign or between households that owned enough nets for all members (1 net for 2 people) and those that did not.

7.4.4 Multivariate logistic regression

Since a number of the variables found to be associated with giving nets away in the univariate analysis are inter-related, such as household size and presence of children under five, and others significantly differed between countries, such as educational status, a multivariate logistic regression was used to assess the determinants of a previously owned net being given away. Results are shown in Table 7.4 and confirm that campaign nets were almost six times (OR 5.95, 4.25-8.32, $p<0.0001$) more likely to be given away than non-campaign nets lost during the same period between campaign and survey. The regression model also revealed that non-campaign nets lost before the campaign were significantly less likely to be given away compared to non-campaign nets lost after the campaign (OR 0.57, 0.39-0.83, $p=0.004$). In contrast to the univariate analysis the model also suggests that households are more likely to give away nets if they have more nets than one for every two household members (OR 1.88, 1.37-2.54, $p<0.0001$). Other factors that were confirmed to be significantly associated with giving away the net were age of net at time of loss, urban residence and country.

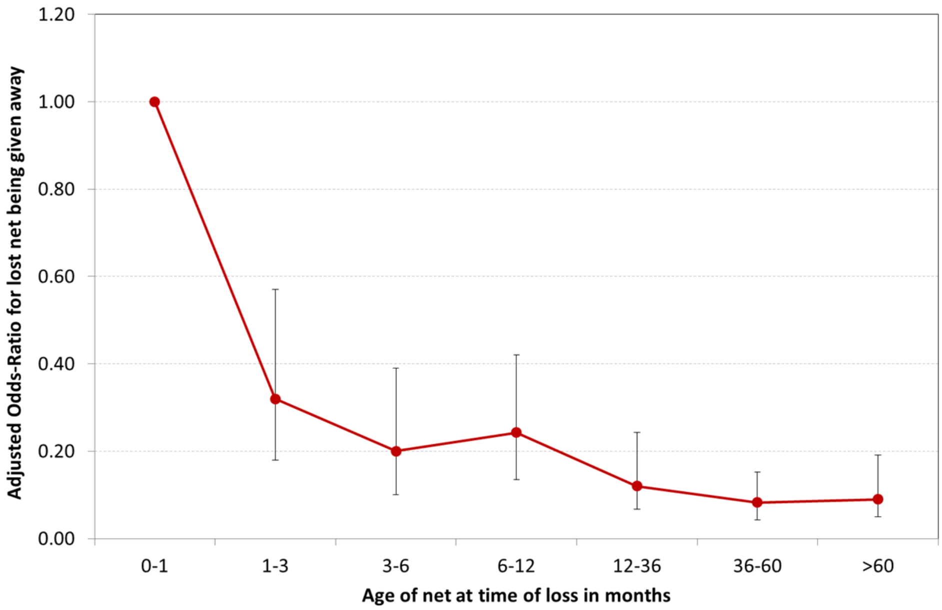
In contrast, educational status of the head of household or having children under five were no longer influential after controlling for other factors, and the association with household size was much weaker than in the univariate analysis, with only large households showing a statistically significant reduction in the probability of giving away a net compared to small families.

The adjusted odds ratios for all previously owned nets being given away by age at the time of loss are presented in Figure 7.4 using the covariates as shown in Table 7.4 but with a more detailed breakdown of age of net intervals. This demonstrates that the most likely period a net was given away to others was within a month of obtaining it. Even for nets one to three months old at time of loss the odds of giving it away were less than half compared to a new net and then continuously declined to reach about one tenth of the odds ratio after more than one year.

Table 7.4: Multi-variable logistic regression models of determinants of giving lost net away to others

Explanatory variables	Adjusted Odds Ratio	95% CI	p
Type of net and period of loss			
Non-campaign net lost post-campaign	1.00		
Campaign net lost after campaign	5.95	4.25 – 8.32	< 0.0001
Non-campaign net lost pre-campaign	0.57	0.39 – 0.83	0.004
Non-campaign net lost pre-post campaign	1.45	0.70 – 3.00	0.31
ITN owned by the household			
Less than 1 ITN / 2 people	1.00		
Exactly 1 ITN / 2 people	1.29	0.92 – 1.80	0.14
More than 1 ITN / 2 people	1.88	1.39 – 2.54	< 0.0001
Age of net at time of loss			
0-5 months	1.00		
6-11 months	0.75	0.52 – 1.09	0.13
12-35 month	0.47	0.32 – 0.69	< 0.0001
36+ months	0.32	0.22 – 0.47	< 0.0001
Country			
Nigeria	1.00		
Ghana	0.45	0.25 – 0.83	0.01
Uganda	0.79	0.45 – 1.40	0.42
Senegal	0.24	0.15 – 0.37	< 0.0001
Rural	1.00		
Urban	1.79	1.27 – 2.53	0.001
Number of household members			
1-3 people	1.00		
4-6 people	0.82	0.59 – 1.15	0.24
7 or more people	0.70	0.49 – 0.98	0.045
Wealth quintile			
Highest	1.00		
Fourth	0.91	0.63 – 1.31	0.60
Middle	0.95	0.61 – 1.47	0.81
Second	0.97	0.62 – 1.51	0.88
Poorest	0.62	0.38 – 1.02	0.06
Educational level of head of household			
Tertiary	1.00		
Secondary	1.03	0.62 – 1.71	0.90
Primary	1.01	0.62 – 1.64	0.99
Non-literate	1.36	0.83 – 2.22	0.22
Number of children under five			
None	1.00		
Any	0.97	0.74 – 1.27	0.85

Figure 7.4: Odds-Ratio of a net being given away as a function of time. Adjusted OR based on model presented in Table 7.3.



7.4.5 Nets used for other purposes

Overall 6.2% of previously owned nets were reported to have been used for purposes other than sleeping under, but rates significantly varied between countries (p<0.0001). Senegal had the highest rate, at 11.1% of lost nets (201 of 1,818 nets), followed by Uganda at 4.0% (16 of 397 nets), and Nigeria at 2.1% (25 of 1,171 nets) while Ghana had the lowest rate, at 1.8% (13 of 716 nets). Relating the nets used for other purposes to the overall total of all nets found in the surveyed households (see Table 7.1) gives an estimate of misuse of nets of only 0.9% (255 of 29,549 nets).

7.4.6 Reasons for loss of nets

Respondents were asked to provide the reason for the loss of the net. The vast majority of nets that were destroyed or thrown away were described as “too torn” (86% and 93% respectively). Of nets that were given to others, 71% of respondents said it was because the net was not needed. For the 19 nets that were sold, seven were sold because the household needed money, seven because they were not needed, and four were reportedly sold because they were too torn. Three quarters of the nets that were used for other purposes were described as too torn. Even for the few (148) nets that were relatively new (under a year old) and used for another purpose, 66% were used for other purposes because the net was reportedly too torn.

7.5 Discussion

Campaign nets and non-campaign nets were treated differently by households. Campaign nets were nearly six times more likely to be given away than non-campaign nets, and nets were far more likely to be given away in the first month following a campaign, suggesting that the bulk of redistribution among family and friends occurs in this period. Non-campaign nets, which were generally older and may not have been LLINs, were more likely to have been discarded, most likely being replaced by newer nets acquired through the mass campaign.

Discarding nets was primarily associated with the age and condition of the net – nets were discarded because they were too torn, and at a median age of two years. This does not however indicate that the median lifespan of nets is two years. Median lifespan cannot be calculated solely from observing remaining nets, or on the basis of the age of discarded nets. It is calculated by dividing the number of LLIN originally received, minus those given away, by the number of current LLIN present in the household that are in serviceable condition, as follows:

Figure 7.5: Calculation of % of nets surviving to time x

$$\text{\% surviving to time x} = \frac{\text{\# of LN present and "serviceable" at time x}}{\text{\# of LN originally received and not given away at time x}} \text{ X 100}$$

The criteria of being serviceable is based on the Proportionate Hole Index (World Health Organization 2011a) result for each net using a cut-off that is equivalent to a total estimate hole surface of the net of more than 0.1 square meters (World Health Organization 2013a).

The multivariate regression provides insights into determinants of the fate of nets, either given away or discarded. None of the findings are surprising; households that have more nets than they need are more likely to give away nets, as are urban households, who may be in closer proximity to relatives or friends in need of nets. It is worth emphasizing that level of education and wealth quintile did not significantly affect net fate. Differences by country are apparent but inscrutable: the relatively younger age of discarded nets in Senegal could potentially reflect harsher conditions, more consistent usage leading to net wear and tear, or socio-cultural factors. As an example of the latter, recent qualitative research in Nigeria, Senegal, and Uganda indicates that households appear to value the look of an intact net as a reflection on the cleanliness and housekeeping skills of the family {Hunter 2014; Loll 2014; Scandurra 2014). Qualitative research conducted in the Dadaab refugee camps in Kenya also revealed that having only a few holes in one's net was considered cause for discarding it (Hoibak 2010), and other studies found that net usage was the main contributor to holes in nets (Mutuku *et al*. 2013; Batisso *et al*. 2012). A combination of increased use and stress on the net with social norms making torn nets less desirable could contribute to discarding of nets at younger ages when they still have a limited number of holes. On the other end of the spectrum, nets that are retained for longer periods of time may be due to households saving nets without using them for some time prior to hanging them up, effectively postponing use of (and wear and tear on) the net, leading to an older crop of nets in better condition. That household decision-making on net end of life is highly subjective creates an opportunity for behaviour change communication activities to contribute to promoting keeping nets for longer periods of time, keeping them in better condition through preventive actions such as tying nets up during the day, and even repair behaviours, discussed further in two forthcoming studies.

This analysis shows that redistribution of LLINs does occur following mass campaigns, primarily to family members, but also to non-family members. The scale of this redistribution is small but important: recent continuous distribution pilots of school-based distribution to children in selected classes operate on an assumption that households that receive an excess of LLINs for their needs will give extra nets away to community members that did not benefit from the distribution, or who need additional nets (Koenker *et al*. 2013b). The overall rate of net redistribution in this sample was just under 5% of all nets (1,383 nets out of 29,549 nets owned by households).

Open-ended answer options in these datasets indicated that nets are given in a large number of cases to students in school (particularly boarding school) or given to or taken by family members residing in other areas. This is also the case in a separate study in Uganda (Helinski, personal communication). Further research is needed to assess under what circumstances households would preferentially hoard or give away nets, and to whom. Since it already occurs to a limited degree, LLIN redistribution may be a behaviour that can be encouraged as part of distribution channels that reach only a selected target population, such as school distributions that target selected classes on a yearly basis. These channels miss households that have no school-aged children, although these households do not make up a large proportion of the overall population (Koenker *et al*. 2013b). These data also suggest that the conditions under which net redistribution is more likely to occur are net-rich environments, where population access to LLIN is relatively high. Continuous distribution through schools may have an opportunity to build up LLIN access within households over time. Given that LLIN are more likely to be redistributed soon after a distribution, school distributions could promote this behaviour as part of their targeted messaging to parents and school-children, to capitalize on the brief window of opportunity within the first month or two post-distribution.

There are limited studies on the use of nets for purposes other than sleeping under (Eisele *et al*. 2011), and observational studies are generally limited to a particular study area (Minakawa *et al*. 2008; Lover *et al*. 2011; Mutuku *et al*. 2013). This analysis makes an important contribution to the quantification of this perceived problem, which tends to be exaggerated or exacerbated by newspaper reports of nets being used for protecting crops or as soccer goals. The evidence here clearly demonstrates that in general, across several geographic areas and time points, use of nets for other purposes is very rare, at less than 1% of nets, and that when it occurs, it happens primarily with older nets. National malaria programs, ministries of health, donors, and implementing agencies should therefore remain confident that their investments in malaria control are being used effectively. As Eisele et al have also shown, it is unlikely that the use of old or no-longer-needed nets for other purposes is impeding the use of nets for malaria prevention within households (Eisele *et al*. 2011), rather, households are reusing materials once they are deemed no longer useful for sleeping under, or because they are an extra net that is not needed. Echoing the present findings, in coastal Kenya, Mutuku et al found that between 60-80% of nets used for chicken shelter, window screening, fencing and other purposes were over two years old (Mutuku *et al*. 2013). Certainly, in specific areas, the economic benefits of using nets for fishing outweigh the perceived health benefits of using the nets for sleeping, and this phenomenon has even been described using econometric game theory models in Honjo et al (Honjo *et al*. 2013). Given that net misuse of this type is rational economic behaviour, this requires action not only to ensure that residents of that area are protected from malaria, but also to improve households' economic status, to diminish the marginal utility of misusing nets. From an environmental standpoint, it is important to prevent overfishing of fish fry, endangering the food supply, and to prevent pyrethroids from leaching into water systems, where they can be toxic to a large range of aquatic life (Hirsch *et al*. 2002; Ehiri *et al*. 2004; Thatheyus *et al*. 2013).

Taken together, these data indicate a relatively consistent pattern and distribution of nets given away vs. discarded (Figure 7.3). Studies that do not quantify the number of nets given away or discarded in their durability calculations could use data from the present study to adjust their estimates. In the absence of information regarding the rates at which nets are lost, and the reasons for their loss, these data could be used in retrospective durability studies to adjust for recall bias. Retrospective durability studies rely on the recall of household members on when they received their nets, from which source, and what happened to nets lost from the household.

7.5.1 Limitations

As the data in this analysis come from retrospective cross-sectional surveys, it is possible that details about the nets were affected by recall bias, particularly for the age of the nets acquired through channels other than a recent mass campaign. It is also possible that respondents may have underreported repurposing of nets to the enumerators; to reduce this response bias, the questionnaire was structured to ask the fate of each lost net as an unprompted question.

This analysis has shown that inter-household re-allocation of nets does occur, but was sensitive to current household net ownership and the time elapsed since mass distribution. These results have important implications for continuous LLIN distribution strategies, which have to date assumed that redistribution of excess nets between households occurs without any supporting or contradictory evidence. These factors can be addressed programmatically to further facilitate reallocation within a given community. Continuous distribution channels that rely in part on reallocation to achieve broad community coverage will need to focus on BCC and other activities to encourage this practice.

A second important finding was that the overwhelming majority of nets were used for malaria prevention. Of the repurposed nets (<1% overall), the majority were already considered too torn, indicating they had already served out their useful life for malaria prevention. National programs and donor agencies should remain confident that overall, their investments in LLIN are being appropriately used.

7.6 Author Contributions

HK designed the study, conducted analysis, and drafted the manuscript. AK designed the original post-campaign surveys, conducted analysis, and drafted portions of the manuscript. CZ, EO, RS, TA implemented the surveys and contributed to the manuscript. MF and ML contributed to the manuscript. All authors reviewed and approved the final manuscript.

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8 Impact of a behaviour change intervention on long-lasting insecticidal net care and repair behaviour and net condition in Nasarawa State, Nigeria

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8.1 Abstract

While some data on net durability have been accumulating in recent years, including formative qualitative research on attitudes towards net care and repair, no data are available on how the durability of a net is influenced by behaviour of net maintenance, care and repair, and whether behavioural change interventions (BCC) could substantially impact on the average useful life of the net.

The study used an intervention-control design with before-after assessment through repeated cross-sectional household surveys with two-stage cluster sampling following Nasarawa State's December 2010 mass campaign. All campaign nets were 100-denier polyester, long-lasting insecticidal nets (LLIN). Baseline, midline, and endline surveys occurred at one-year intervals, in March 2012, March 2013, and April 2014, respectively. Outcome measures were the proportion of confirmed campaign nets with observed repairs, and the proportion in serviceable condition, measured with proportionate hole index (pHI) and according to WHO guidelines.

For all respondents, exposure to BCC messages was strongly correlated with increased positive attitude towards care and repair, and increases in attitude were positively correlated with observed net repairs, and with the proportion of nets in serviceable condition. In a multivariate regression model, positive care and repair attitude (OR 6.17 p=0.001) and level of exposure (1 source: OR 4.00 p=0.000; 3 sources: OR 9.34 p=0.000) remained the most significant predictors of net condition, controlling for background and environmental factors. Nets that were tied up had 2.70 higher odds of being in serviceable condition (p=0.001), while repairs made to nets were not sufficient to improve their pHI category. Estimated median net lifespan was approximately one full year longer for nets in households with a positive compared to a negative attitude.

Exposure to multiple channels of a comprehensive BCC intervention was associated with improved attitude scores, and with improved net condition at endline. It is possible for BCC interventions to change both attitudes and behaviours, and to have an important effect on overall median net lifespan. Care and repair messages are easily incorporated into existing malaria BCC platforms, and will help contribute to improved net condition, providing, in principle, more protection from malaria.

8.2 Introduction

Malaria prevention with long-lasting insecticidal mosquito nets (LLINs) has seen an intensive scale-up in sub-Saharan Africa in recent years. As many countries have now achieved high ownership coverage with LLIN and are approaching the universal coverage target of one net for every two people of the population at risk as recommended by WHO, the question of how these successes can be sustained, i.e., high coverage levels be maintained, becomes the focus of discussion. In this context the importance of net durability and the 'average useful life' of a net is increasingly recognized as one of the critical factors that determines the frequency at which nets need to be replaced. This is reflected in recent WHO guidelines for the monitoring of LLINs in the field, which outlines the issues and suggests methods of net assessment (World Health Organization 2011a; World Health Organization 2013b).

While data on net durability has been accumulating in recent years (Atieli *et al*. 2010; Tsuzuki *et al*. 2011; Batisso *et al*. 2012; Mejia *et al*. 2013; Wills *et al*. 2013; Mutuku *et al*. 2013; Okumu *et al*. 2013), including formative qualitative research on attitudes towards net care and repair (Loll *et al*. 2013; Loll *et al*. 2014; Hunter *et al*. 2014), there is some indication that it may vary by environmental or climatic conditions. Allan *et al.* (Allan *et al*. 2012) found the physical condition of polyester nets in eastern Chad to be much poorer than would have been expected from similar nets seen in the more moderate climate of western Uganda (Kilian *et al*. 2008). While a 2006 case study describes a behavioural change communication (BCC) intervention and its effect on prevalence of repairs to nets (Panter-Brick *et al*. 2006), no data at all are available on how the durability of a net is influenced by behaviour of net maintenance, care and repair, and whether BCC could significantly impact on median net lifespan.

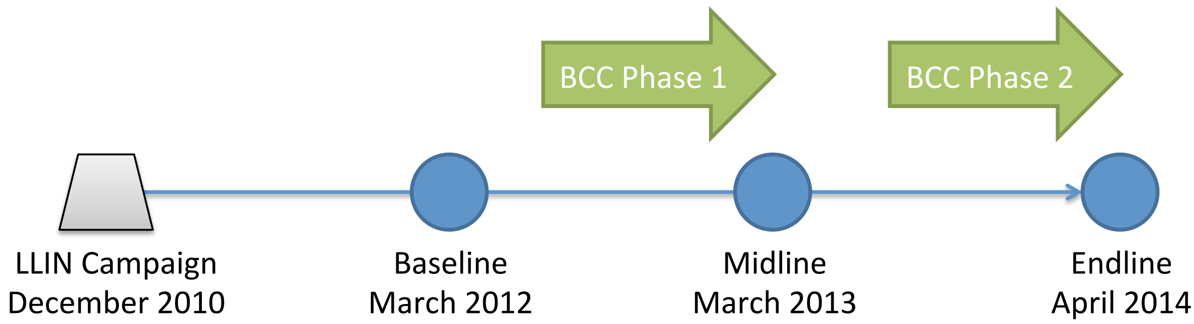
Improvements in knitting pattern or other aspects of textiles themselves have potential for extending net life (Skovmand *et al*. 2011), but have been difficult to implement due to lack of evidence for their impact on overall net life in field conditions, and procurement practices that maintain a focus on lowest price. Should improvements in net durability be possible via BCC interventions, the time period between net replacement could in theory be extended, leading to overall cost savings for program planners and donor agencies. At minimum, improved condition of nets would protect more people for longer periods of time between resupply.

8.3 Methods

8.3.1 Survey Design

The study used an intervention-control design with before-after assessment through repeated cross-sectional household surveys with two-stage cluster sampling following Nasarawa State's December 2010 mass campaign, which aimed to deliver two LLINs per household. All campaign nets were 100-denier polyester. Baseline, midline (whose results are not reported here) and endline surveys occurred at one-year intervals, in March 2012, March 2013, and April 2014, respectively (Figure 8.1). The study was nested within a larger LLIN durability study in three states in Nigeria. Kokona Local Government Area (LGA) was selected as the intervention arm, with BCC activities as described below. Toto LGA, similar in environment and cultural aspects but out of the reach of the Nasarawa Broadcasting Service, was selected as the control site. Durability data and exposure to BCC messaging were collected from households in both sites.

Figure 8.1: Study timeline



For baseline and midline, a sample of 20 clusters with 15 households each (300 households) per site and time point was selected, using probability proportionate to size (PPS). Based on the interim results for the care and repair component the sample was increased for the control group (Toto LGA) for the endline survey to 28 clusters with 15 households each (420 households) in order to compensate for anticipated contamination for radio messaging in the control group, due to a planned extension of radio signal by the Nasarawa Broadcasting Service. The additional eight clusters were selected using PPS, after excluding the existing 20 clusters from the sampling frame. The targeted sample for the third round was 770 households bringing the targeted sample for the entire study to 2,170.

Clusters were selected once and maintained for all survey rounds, with an exception in the midline when six wards in the intervention LGA had to be replaced due to communal violence. Residents of these wards had either fled the area at the time of the midline or violence was still ongoing. For the endline, the six replacement wards added at midline were maintained. Households were newly selected in each cluster at each survey to minimize the Hawthorne effect of repeatedly interviewing the same households about net care and repair practices.

Sample size was calculated using an alpha error of 95%, a beta error of 80%, a design effect of 1.75, an anticipated non-response rate of 5%, and the expectation that households would own an average of 1.8 campaign nets at baseline, 1.5 at midline, and 1.0 at endline. These estimates were based on previous post-campaign surveys in Nigeria and on an assumed three-year average net survival.

8.3.2 Study population

Respondents were adult members of the household, 18 years of age or older, usually the head of household or their spouse. Households had to have received at least one net from the December 2010 campaign to be eligible for interview.

8.3.3 Procedures

A team of 20 interviewers were trained during a one-week training prior to each survey. Interviewers were retained by and large through each survey to provide consistency in data collection. Interviewers practiced translating the English questionnaire into Hausa to ensure all interviewers used consistent terminology, and training also included role-play, net hole assessment practice in the classroom and in local volunteer households, and pilot interviews.

Local authorities were informed as soon as clusters were selected and assisted in preparing communities for the interviews and in planning logistics. Fieldwork teams enumerated all households in the community, except in those larger than 200 households, where an equal-size section approach was used to first subdivide the community into neighbourhoods, and then selecting one of the sections for enumeration using a random-number list (Brogan *et al*. 1994). Households were then selected for interview using a random-number sheet, and the head of household interviewed if the household was eligible for participation. Three attempts were made to reach respondents and if the third was unsuccessful the household was replaced.

A structured questionnaire was used to gather data on household characteristics, nets received from the December 2010 campaign and any nets lost, net care and repair behaviour and attitudes, exposure to care and repair messages, and assessment of existing campaign nets. A visual aid for identification of LLIN brands was used, along with visual aids and plasticized tally sheets for the assessment of holes (JHUCCP 2014) according to WHO Guidelines for Monitoring the Durability off LLINs under Operational Conditions (World Health Organization 2011a).

Holes were categorized as size one (0.5-2 cm in diameter), size two (2-10 cm), size three (10-25 cm) and size four (larger than 25cm) per WHO guidelines (World Health Organization 2011a; World Health Organization 2013b). The presence and number of repairs were also counted on each net.

Data entry was done using EpiData 3.1 software with double entry of all records. Both data sets were then compared and any discrepant records were verified from the original questionnaires. The data set was transferred to Stata 12 Statistical software package (StataCorp2011) for further consistency checks and preparation for analysis.

8.3.4 Ethical Consideration

Ethical approval was obtained from the Johns Hopkins School of Public Health Institutional Review Board (IRB #4108) and from the National Health Research Ethics Committee, Federal Ministry of Health in Nigeria (NHREC/01/01/2007). Respondents were informed about the purpose of the study in the local language (primarily Hausa) using a written script and the interview proceeded when verbal consent was given. This consent script contained information on the objectives of the survey, the risks, benefits and freedom of the participation, as well as information on confidentiality plus respondent rights.

8.3.5 Analysis

The proportionate hole index (pHI) for each net was calculated per WHO guidelines using the following formula: pHI= (# size 1 holes) + (# size 2 holes x 23) + (# size 3 holes x 196) + (# size 4 holes x 578). Based on their pHI, nets were then categorized into the following conditions (note that 'good' is also included in 'serviceable').

Good: total hole surface area $<0.01m^2$ or pHI<64

Serviceable: total hole surface area $<=0.1\ m^2$ or pHI<=642

Too Torn: total hole surface area$>0.1m^2$ or pHI>642

Care and repair attitude scores were based on responses to eight statements using a Likert scale, where 1 was 'strongly disagree' and 4 was 'strongly agree'. These were recoded during analysis to have -2 be 'strongly disagree' and +2 be 'strongly agree'. Two statements were negatively phrased, and therefore were inversely recoded to make a positive response +2. Attitude scores for each respondent were summed and divided by eight to calculate an overall attitude score. Scores were then categorized into three groups: equal or less than zero (negative attitude); 0.01-1 (positive attitude), and 1.01-2 (very positive attitude).

The wealth index was computed at the household level using principal component analysis (PCA). Variables for household amenities, assets, livestock, and other characteristics that are related to a household's socio-economic status were used for the computation. All variables were dichotomized except those of animal ownership where the total number owned was used. The first component of the PCA was used as the wealth index. Households were then classified according to their index value into quintiles.

Nets were assessed for brand labels, colour, and shape. Nets reported received from the campaign were counted as confirmed campaign nets, along with any other nets that matched the brand and colour distributed during the campaign. The main outcome indicators were the proportion of confirmed campaign nets with any observed repairs and the proportion of nets in serviceable condition at endline. Statistical analysis used logistic regression modelling techniques to assess potential associations between background characteristics, exposure to messages, attitude scores, and LLIN condition. All analysis accounted for sampling weights and adjusted standard errors for correlated data at the cluster level using the survey family commands in Stata. Pearson Chi-square tests were used to test for difference among categorical variables. The multivariate model was constructed using backwards elimination and Wald tests for significant parameters.

Estimates of the proportion of nets surviving at endline were calculated according to the WHO guidelines (World Health Organization 2011a; World Health Organization 2013b), taking into account the number of nets received from the campaign, the number lost due to wear and tear, and the number given away. Nets given away were excluded from analysis, as their ultimate fate was unknown. In addition, survival rates were adjusted for recall bias of number of nets received using the net/person ratio from the first post-campaign survey as an inflating factor (AK, personal communication). The proportion of nets surviving at endline was plotted against hypothetical decay curves (World Health Organization 2011a; World Health Organization 2013b) to determine the difference in estimated median survival between groups of nets.

8.3.6 Behaviour Change Communication Intervention

The BCC intervention followed the P-Process©, a five-step planning process for behaviour change programs developed by JHUCCP (Health Communication Capacity Collaborative 2013). The intervention used an evidence-based design, beginning with a conceptual model (Figure 8.2) used to design formative research and the overall intervention (Hunter *et al*. 2014), and informed by existing research (Panter-Brick *et al*. 2006). Through this process, the target audience, key behaviours, barriers, and motivators related to net care and repair were identified. These findings informed the BCC campaign strategy, which was developed by the Center for Communication Programs Nigeria, a Nigerian non-governmental organization. Materials and messages were designed at a participatory workshop with local malaria stakeholders, scriptwriters, and design experts. The target audience for the care and repair messaging were all adults who own and use mosquito nets, with a focus on women, as they were identified in the formative research as being primarily in charge of net care and repair duties (Hunter *et al*. 2014). The multi-channel BCC strategy consisted of advocacy, radio airings, interpersonal communication (IPC), and print materials. Radio spots, print materials, campaign logos, and key messages (Table 8.1) were pre-tested in focus groups in rural and urban communities and further refined before launch in the 20 focus communities of the intervention site.

Campaign activities were conducted in two phases, from November 2012 to March 2013, and from December 2013 to March 2014. Findings of the midline assessment in March 2013 led to refinements in the campaign activities for the second phase.

Figure 8.2: Conceptual model for care and repair behaviours and outcomes. Attitudes are shown on the left, leading to specific intentions and behaviours. Textile strength, knitting pattern, and environmental factors are outside the household's control, but contribute to overall net integrity. Likewise, overall impact is also affected by bioavailability of insecticide on the net, and presence and proportion of insecticide-resistant vectors (not measured in this study).

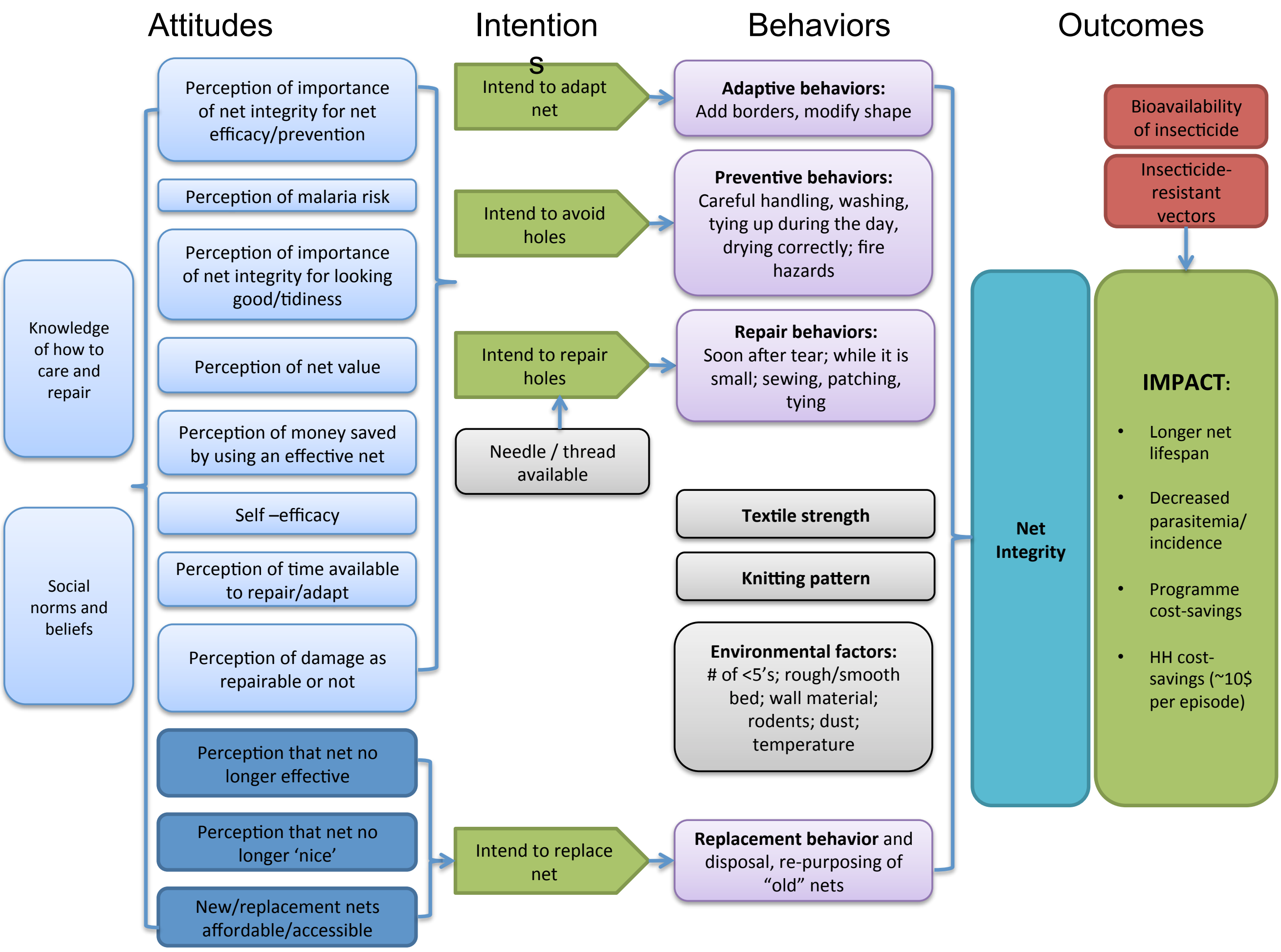


Table 8.1: BCC Messages

Issue to address identified in formative research	Key message for BCC
Specific sources of damage to nets	Fold or tie net away when not in use to keep out of reach of children, do not let children play with the net To avoid attracting rodents, do not soil a net with food, keep food away from nets Like a newborn baby, nets need to be handled with care
Lack of clarity on what are and how to carry out the concrete care and repair behaviours	You can tie, patch or stitch holes in nets Wash nets only when dirty and no more than once every three months, wash gently with mild soap
Making net care and repair a priority and incorporating into household routines	Nets are valuable and worth the time to care and repair A torn net can still be effective if repaired Repair small holes immediately When laying out the net for the evening, inspect it regularly for holes Holes in your net are like holes in your fence; if thieves (mosquitoes) can enter they may steal your health, money, sound sleep, and even your life

8.3.6.1 Radio

Radio content was broadcast exclusively on Nasarawa Broadcasting Service, (NBS), a local radio station selected because it reached the intervention site, but not the control site due to the strength of the station's signal. However, during phase two of this BCC campaign, NBS upgraded its broadcasting signal, enabling its programming to reach into the control site.

The radio component focused on providing cues to action and reminder messages to reinforce the IPC activities. Five 60-second radio spots were produced, which were gradually introduced on the air during phase one. During phase two, only the three most popular spots were aired. In total, spots were aired over 800 times during the two phases. The airtime plan was initially prepared in coordination with the radio station, and subsequently refined based on a midline radio listenership assessment on peak listening times to the campaign radio station among the target audience. In phase two, 14 episodes of a 15-minute radio magazine show were produced and aired to reinforce the main messages, comprised of radio personality interviews with community leaders, community members, and recordings from community activities.

8.3.6.2 Interpersonal communication (IPC)

For the IPC component, 40 community mobilizers were recruited and trained. Eligibility for recruitment consisted of the ability to read and write in English and living in or being very familiar with one of the 20 intervention communities. Community mobilizers attended a three-day training on malaria, care and repair behaviour, community mobilization skills, and on the conduct of campaign activities. A campaign manager or one of two campaign coordinators accompanied the mobilizers during most of their community activities for supportive supervision. Monthly meetings brought together all mobilizers and supervisors to review progress on the interpersonal activities, trouble-shoot challenges, ensure correct completion of field monitoring forms and reinforce concepts. Community mobilizers were paid a monthly stipend of 15,000 naira, which covered time and travel costs ($91).

IPC activities focused on modelling appropriate care and repair behaviours and consisted of house visits, community dialogues with street theatre, community outreach at weekly markets (‘market storms’), and road shows. During these events, community mobilizers shared the key messages, demonstrated net care and repair behaviour, and encouraged community members to stitch or patch demonstration nets. A song contest was organized in which all 20 communities composed and performed an original song about net care and repair in front of a live audience. A panel of judges selected the winning song, which was studio-recorded and broadcast over radio in phase two. The market storms and road shows were discontinued in phase two due to low effectiveness at reaching the target population during phase one, and IPC efforts (house visits and community dialogues) were intensified. In total, three community dialogues and an average of 87 house visits were conducted in each focus ward.

8.3.6.3 Local advocacy

In the advocacy component, the campaign obtained the support of respected leaders, one of which participated in the recording of a radio spot encouraging families to care for and repair their nets. The chiefs of each of the 20 communities were approached during advocacy meetings to explain the BCC campaign and obtain their buy-in prior to conducting any community-level activities.

8.3.6.4 Print

Finally, the print component consisted of five poster designs with photographs of community members modelling net care and repair behaviour, in particular demonstrating what a net looks like before, during and after repair. Other posters used photographs to demonstrate proper washing technique and ways to fold or tie a net out of harm's way when not in use. These visual explanations were helpful to reach the low-literacy target audience. Posters were placed in public spaces in communities, in the nearest health facilities, and were used during public events. A printed job aid for the community mobilizers was also created, which listed frequently asked questions and answers regarding net care and repair, and served as a discussion guide for mobilizers during their IPC activities.

All of the above-referenced campaign materials are publically available in an online toolkit (JHUCCP 2014).

8.4 Results

8.4.1 Household characteristics

At baseline and at endline the two LGAs were similar in household size, number of children under five years old, household head level of education, radio and TV ownership, and ownership and population access of LLINs (Table 8.2). While the two LGAs were similar at baseline in the proportion of polygamous households, at endline the intervention area had 64.7% of households identifying as polygamous, against 42% of households in the control area. It is possible that this reflects the impact of communal violence in Nasarawa State, which occurred in the intervention area and affected implementation of some of the BCC activities (in both phases) in specific wards. Since households were selected based on having received at least one net during the December 2010 campaign, overall net ownership was high, increasing from 90 and 85% (for any net and any ITN, respectively, at baseline) to 100 and 97.5%, respectively, at endline, likely reflecting health facility, community LLIN distributions, and retail sales that were ongoing during the period. Population access to an LLIN (the proportion of people with access to an LLIN within their household) had decreased only slightly from baseline to endline, from 44.9 to 41.3% in the control area and from 41.1 to 40.7% in the intervention area.

Table 8.2: Household characteristics for control and intervention sites at baseline and endline

	N	Baseline control (%)	Baseline intervention (%)	P*	n	Endline control (%)	Endline intervention (%)	P*
No. of children under five	432			0.219	539			0.737
1		30.4	41.4			34.8	34.6	
2		36.4	32.1			30.4	30.0	
3		15.7	14.4			19.9	17.1	
4+		17.5	12.1			14.9	18.4	
Household is polygamous	591	57.6	47.6	0.291	709	42.0	64.7	0.0002
Level of education of head of household	591			0.465	709			0.345
Non-literate		52.2	49.0			52.7	47.5	
Some primary		14.5	18.7			22.1	27.3	
Some secondary		21.2	24.8			20.6	17.5	
Some higher education		12.1	7.5			4.6	7.7	
Own radio	591	74.4	83.0	0.071	709	87.4	85.5	0.669
Own TV	591	36.7	33.7	0.686	709	23.1	29.0	0.329
Own at least 1 mosquito net	591	92.9	87.8	0.304	709	100	100	1.000
Own at least 1 LLIN	591	87.5	82.6	0.409	709	98.1	97.0	0.442
Population access to an LLIN within the household	591	44.9	41.3	0.076	709	39.0	40.7	0.839
HH ever had hole in nets	576	49.5	45.3	0.576	709	76.5	72.7	0.555
From tears	273	37.1	40	0.6387	531	57.1	50.9	0.4342
From corner ripping	273	20.3	14.6	0.3082	531	42.9	40.7	0.6917
From burns	273	2.1	6.2	0.1048	531	11.8	8.3	0.2527
From rats	273	17.5	27.7	0.1766	531	60.6	55.6	0.439

Households reported an increase in ever having experienced holes in their nets, from roughly half of households at baseline to three-quarters of households at endline, with no differences between control and intervention areas. The majority of holes were due to tears (baseline and endline), and more holes were attributed to rat damage at endline (58.6% of all households reported this type of damage) than at baseline. Burns were not a major source of damage in this area.

8.4.2 Intention to treat analysis

As shown in Table 8.3, the per cent of campaign nets with any observed repairs between control and intervention sites was statistically similar at endline (p=0.128). From baseline to endline, the per cent of nets with observed repairs increased in both areas, from 10.3 to 17.8% in the control area (p=0.11) and 10.5 to 27% at endline in the intervention area (p=0.003). However, proportions of nets in good, serviceable, and torn condition were statistically the same in the two LGAs at endline. As expected, an overall deterioration in net condition was observed at endline, with nets in serviceable condition falling from 90% at baseline to just over 50% at endline. Given the similarity of net condition between study areas, an analysis by exposure was conducted to assess differences by exposure to the campaign.

Table 8.3: Condition of confirmed 2010 campaign nets in 2012 baseline survey and 2014 endline survey

Net Characteristics	Baseline Control	Baseline Intervention	p	Endline Control	Endline Intervention	p
N	156	134		443	253	
Any observed repairs (among nets with holes)	10.3	10.5	0.961	17.8	26.5	0.128
N	425	376		522	327	
% of nets in good condition	79.1	82.7	0.443	30.7	33.3	0.684
% of nets in serviceable condition	92.5	92.0	0.862	51.5	55.7	0.514
% of nets too torn for use	7.5	8.0	0.862	48.5	44.3	0.514

P-values are for comparisons between control and intervention areas for each survey, using a Pearson chi-square test.

8.4.3 Analysis by Exposure

8.4.3.1 Evidence of contamination

The BCC intervention was targeted only in Kokona LGA, where there was significant recall of care and repair messages, with 72.7% of respondents reporting hearing any care and repair message in the last six months. However, exposure to messages was also relatively high in the control LGA (Toto), at 46.8% (Table 8.4). Figure 8.3 shows the sources of messages in each LGA. As expected, radio, community health worker (CHW), community event and health workers were the main sources of exposure in the intervention area. In the control area, radio (29.1%) and health workers (15.5%) were the primary sources of exposure, indicating that indeed the boost in signal strength of NBS resulted in care and repair messages reaching the control LGA. Health workers in the control LGA were not trained in care and repair messages, but may have advised patients on this spontaneously, or possibly because they had been exposed to the campaign themselves. Community leaders and faith leaders were the least cited sources of care and repair information, and family members were a small but equally prevalent source in both areas.

Table 8.4: Exposure to care and repair messages (endline)

	N	Baseline Control	Baseline Intervention	p	N	Endline Control	Endline Intervention	p
Heard/saw any messages about care and repair	591	0.3	1.4	0.176	709	46.8	72.7	0.0005
Dose (# of sources cited)	591				709			0.0001
0		99.7	98.6	0.176		53.2	27.3	
1						25.7	23.6	
2		--	--			12.6	28.0	
3+		--	--			8.5	21.2	

*Figure 8.3: Sources of messages on care and repair (endline only: * = p<0.05; *** = p<0.001).*

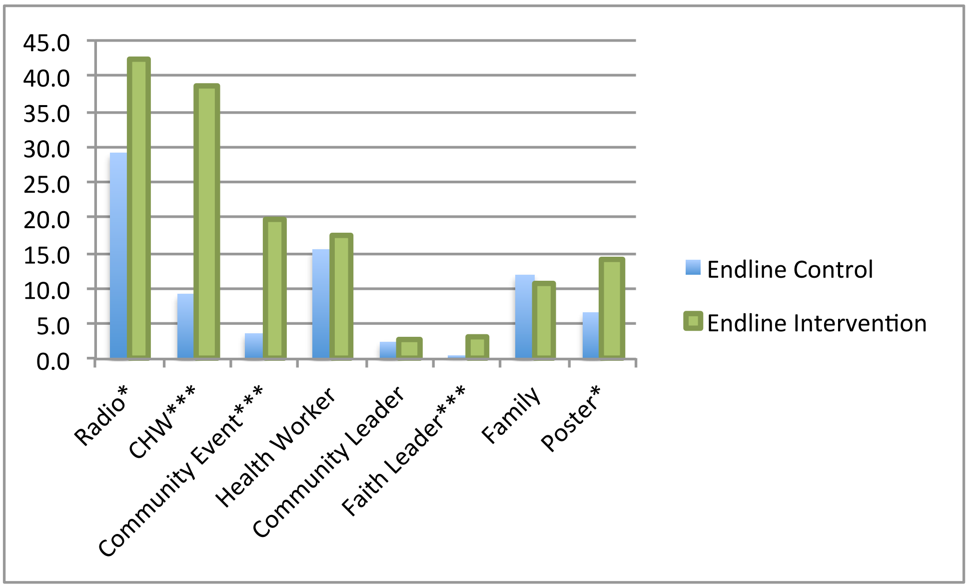
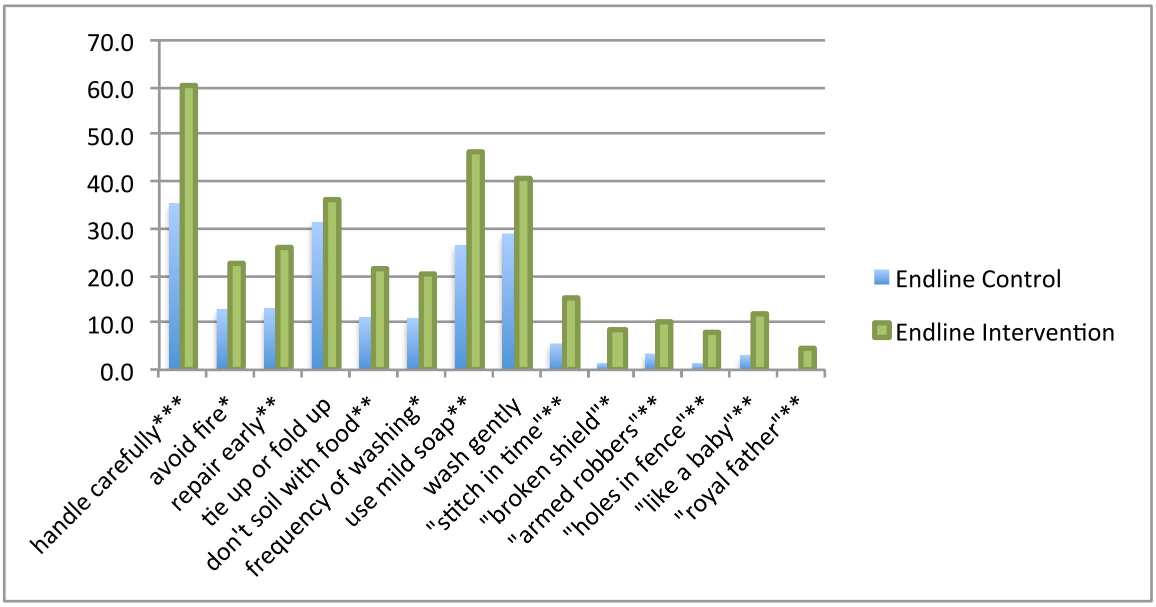


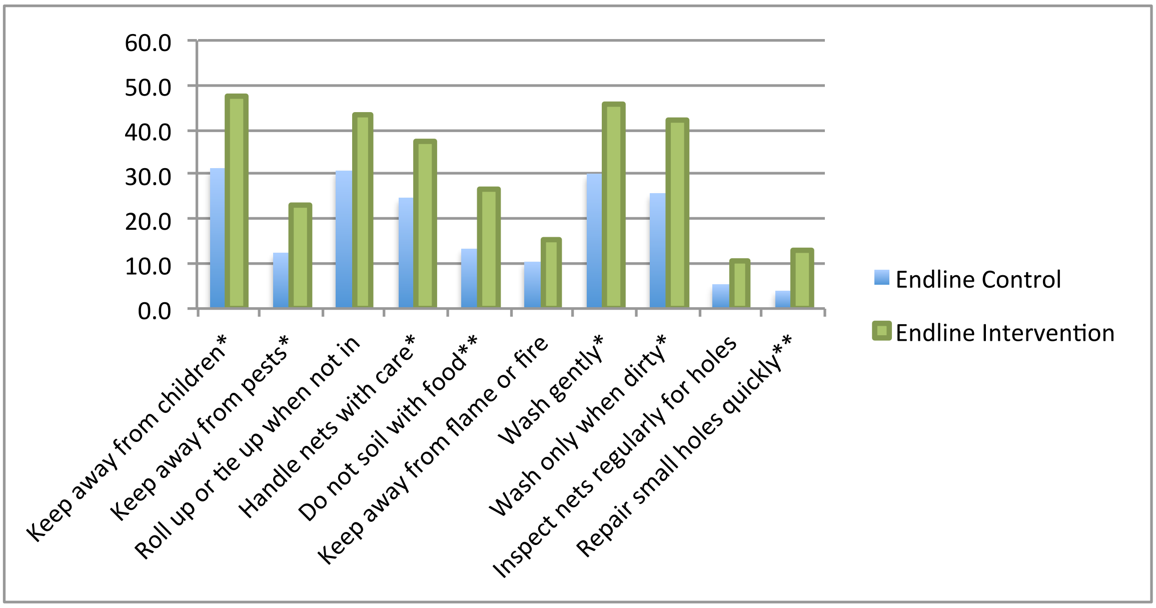
Figure 8.4 shows the percent of respondents who spontaneously recalled various messages used in the BCC intervention. Recall of messages was higher in the intervention than in the control area, but significant recall was observed in the control area, particularly for preventive messages including “handle carefully”, “tie up/fold up”, and messages on gentle washing. Patterns of recall were the same in both areas for specific messages. As is the norm in BCC campaigns, recall was lower for the specific radio spots and slogans than for the general key messages.

*Figure 8.4: Recall of messages on care and repair (endline only: * = p<0.05; ** = p<0.01; *** = p<0.001)*



Respondents were also asked what behaviours they do at home to take care of nets in the endline survey (Figure 8.5). The most common were ‘keep away from children’, ‘wash gently’, ‘roll up or tie up when not in use’, ‘wash only when dirty’, and ‘handle nets with care’. Significantly more respondents in the intervention area than the control area cited each behaviour. Likewise, significantly more respondents in the intervention area were able to list the recommended ways of washing a net, e.g. “gently” (p=0.001), “in a basin” (0.002), and “with mild soap” (p=0.005).

Figure 8.5: What if anything do you do at home to prevent nets from tearing or getting holes? (endline only)



8.4.3.2 Attitudes

A series of eight Likert-scale statements were presented to respondents, who then indicated whether they strongly disagreed, disagreed, agreed, or strongly agreed with the statement. The statements measured self-efficacy to repair holes and to do so immediately, confidence in repaired nets to remain effective, perceived social norms of net repair, and perception of nets as valuable. Attitude scores in the intervention area were significantly higher for confidence to repair holes immediately, to make the net last longer, and for perceived social norms. Overall attitude scores were relatively high in each area, with 61% and 56% of respondents with positive attitudes in control and intervention, respectively, and 27% and 36% with very positive attitudes (Table 8.5).

Table 8.5: Attitude scores by intervention area (endline only)

Grouped composite attitude scores	N	Control	Intervention	P=
Positive attitude group	**692**			**0.270**
-2 to 0 (negative)		12.1	8.7	
0.01 to 1 (positive)		61.1	55.6	
1.01 to 2 (very positive)		26.9	35.7	
Specific attitudes (range: -2 to 2)	**708**			
Nets are valuable*		1.87	1.81	0.038
There are actions I can take to make my net last long**		1.21	1.37	0.018
It is not possible to repair holes in nets★		-0.49	-0.44	0.595
A repaired net can still be effective against mosquitoes		0.93	1.09	0.055
Other people in this community fix holes in their mosquito nets***		-0.40	0.11	0.000
I do not have time to repair a hole in my net★		-0.07	0.00	0.465
I can help protect my family from malaria by taking care of my net		1.47	1.51	0.501
I am confident I can repair holes immediately***		-0.02	0.48	0.000

Italics indicate negatively-phrased question; inverted when calculating composite attitude score. Pearson chi-square. * p<0.05, ** p<0.01, *** p<0.001

8.4.3.3 Response Bias

We compared self-reported repair within the last 6 months to observed repairs on the nets themselves to check for response bias. At baseline, the rates of discontinuity were similar: around 4% of respondents reported repairs where none were observed, and 4% did not report repairs yet repairs were observed. At endline, rates of reported repair without observed repair rose to 11% overall, and were 14% in the intervention LGA vs 8% in the control LGA. Although it is possible that repairs were overlooked during observations, these results may indicate some response bias was present for self-reported repair, particularly in the intervention LGA. For this reason, only observed repairs and net condition (based on pHI) were included as outcome indicators, to be conservative.

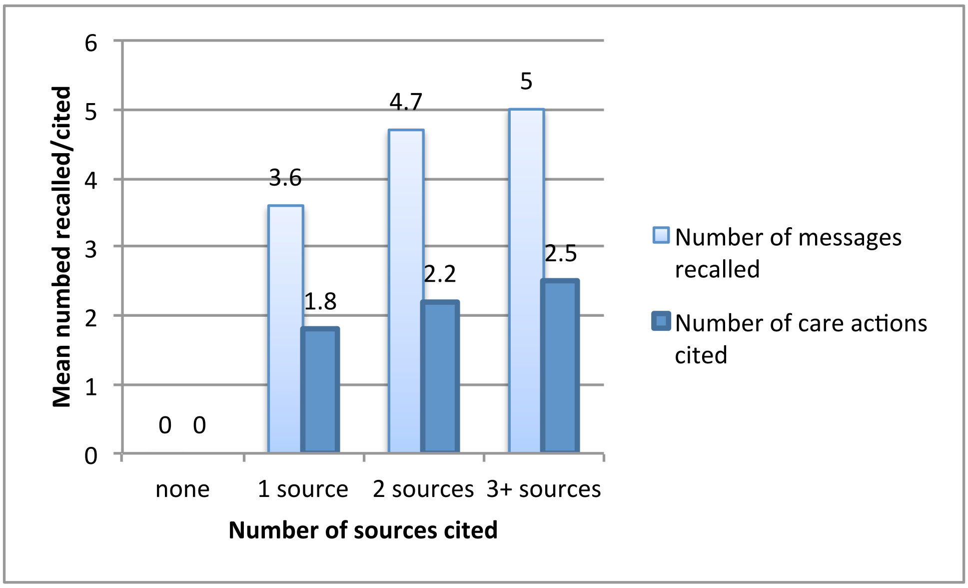
8.4.3.4 Analysis by exposure using the entire sample

Given the high levels of exposure in both intervention and control areas, outcome indicators were assessed by exposure to the campaign rather than by study area, to determine the overall effects of the BCC messages on attitudes and net condition.

8.4.3.5 Exposure is correlated with positive attitude

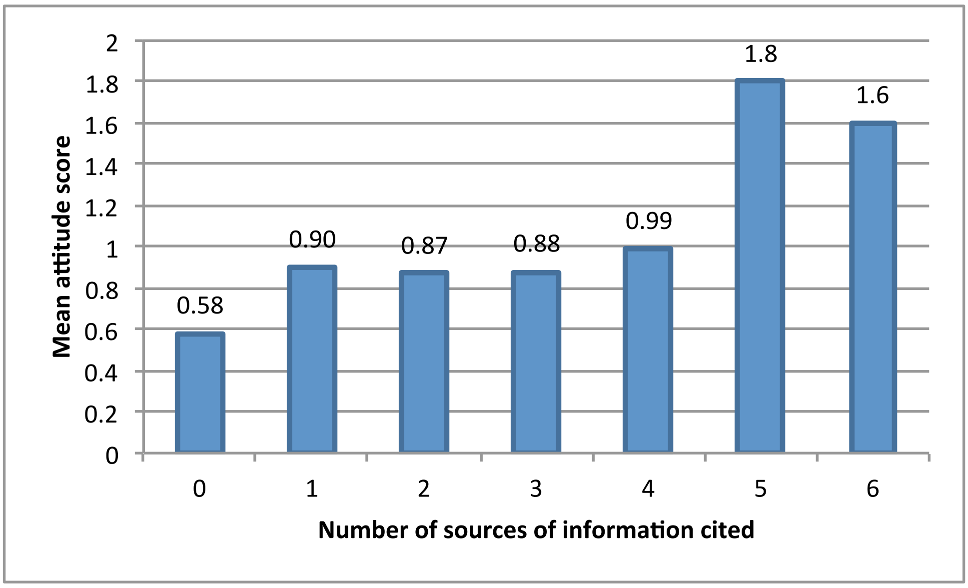
Dose-response relationships were assessed for exposure (number of sources cited) and for number of messages recalled, and with attitude groups. The number of sources cited was closely associated with the number of messages recalled (regression coefficient 1.67; p<0.000) and with the number of care actions the respondent cited (Figure 8.6).

Figure 8.6: Mean number of messages recalled and care actions cited, by number of sources mentioned



Attitude scores also increased with an increasing number of sources cited (Figure 8.7). These were linearly correlated with a regression coefficient of 0.13 (p<0.000).

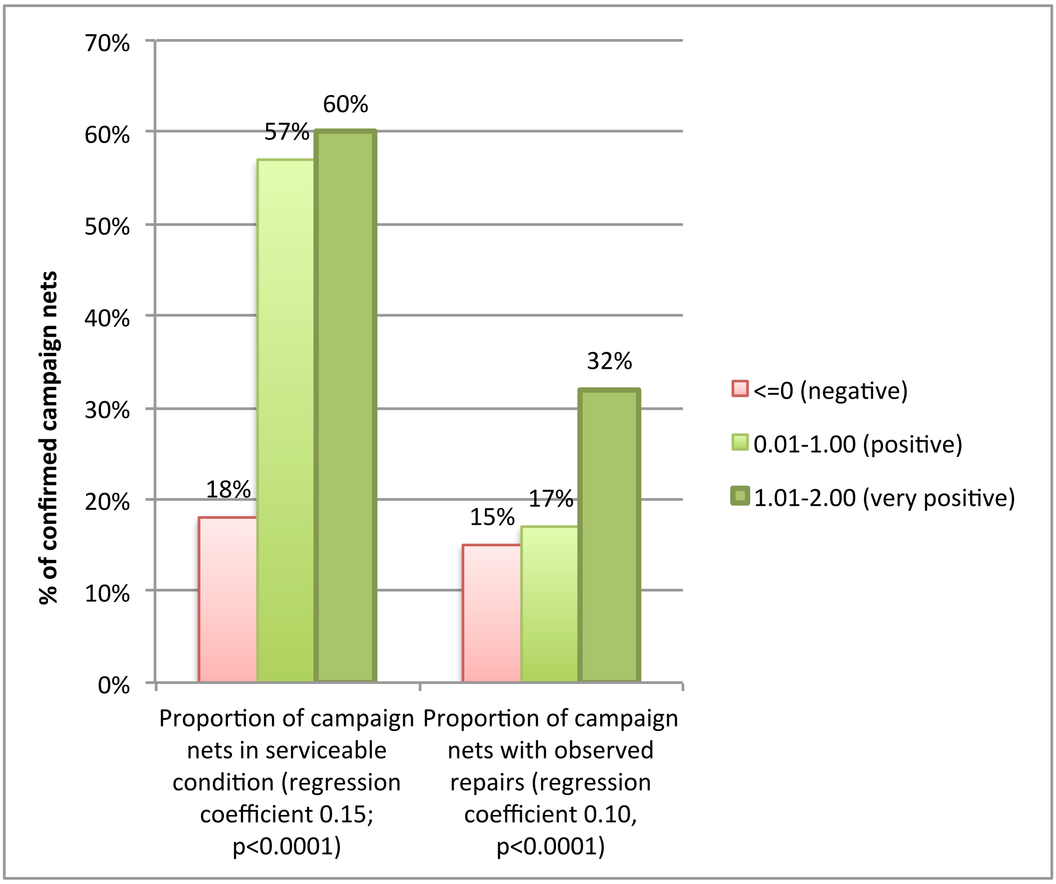
Figure 8.7: Mean attitude score, by number of sources cited (endline). Regression coefficient 0.13, p<0.0001.



8.4.3.6 Attitude is correlated with observed repair and net condition

Attitude scores were in turn correlated with increased observed repairs to campaign nets themselves, and with the proportion of campaign nets in serviceable condition. Only 18% of nets were in serviceable condition for those in the 'negative attitude' category, compared to 57% of nets for those with 'positive attitude', and 60% for 'very positive' attitude (Figure 8.8).

Figure 8.8: Positive relationship between attitude scores and condition of nets (left) and observed repairs (right)



8.4.4 Median estimated net lifespan

Three years after LLIN distribution, significantly higher proportions of nets survived among households with an attitude score greater than zero (45.3%) as compared to households with attitude scores of zero or less (15.4%), shown in Table 8.6). Similarly, when attitude scores were further broken down into categories, a trend towards dose-response was observed, although this was not statistically significant (Table 8.6 middle section). When dichotomized by recall of messages, 30.9% of nets in households with no exposure to the care and repair campaign survived to endline, compared to 50.1% of nets for exposed households. Net survival was then plotted against hypothetical survival curves of defined median and median net lifespan estimated in households with positive and negative attitude (Figure 8.9). This indicated an approximately 1.0 year difference in median net lifespan for nets in households with positive attitudes, giving a two-year estimated median lifespan for nets in households with negative attitude toward care and repair, and a three-year estimated lifespan for those in households with a positive attitude. The estimated median lifespan difference was slightly less but still statistically significant for exposed *vs* unexposed households, where a difference of approximately 0.7 years was observed (Figure 8.10). This translates into a 9-month longer estimated lifespan for nets in households exposed to the campaign.

Table 8.6: Estimated % of campaign nets in serviceable condition at endline, by attitude score and by level of exposure to BCC messages (both study sites)

Indicator	**Estimated % of campaign nets surviving 3.3 years after campaign**	**95% CI (adjusted for design effect)**
Attitude score C&R		
<=0	15.4%	8.1, 25.0
0.01-1.0	45.4%	39.6, 51.3
1.01-2.0	45.3%	39.7, 50.9
0.01-2.0	45.3%	40.1, 50.7
Attitude score C&R		
<=0	15.4%	8.1, 25.0
0.01-0.74	40.3%	33.5, 47.5
0.74-1.49	47.5%	41.0, 54.1
1.5-2.0	51.5%	37.3, 65.7
Messages recalled		
0	30.9%	23.1, 39.0
>= 1	50.1%	44.0, 56.1

Figure 8.9: Plot of proportion of campaign nets surviving at endline (3.3 years after distribution) by attitude score against standard decay curves. Decay curves are labelled according to where each curve hits the 50% line (dotted red line), e.g. the green curve crosses the median at 3 years since distribution, and is therefore the curve for a 3-year net.

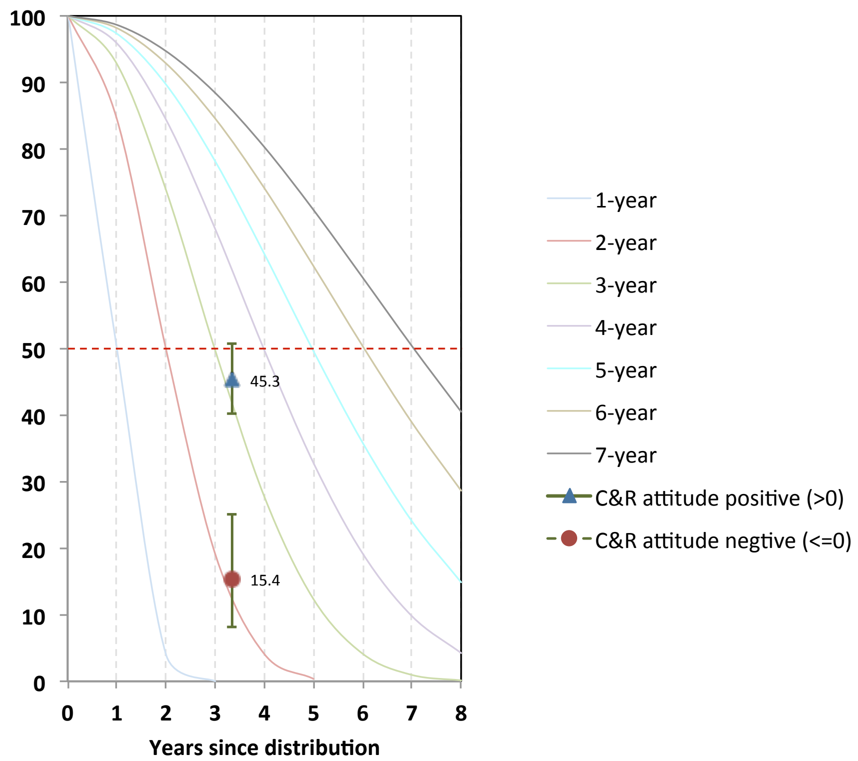
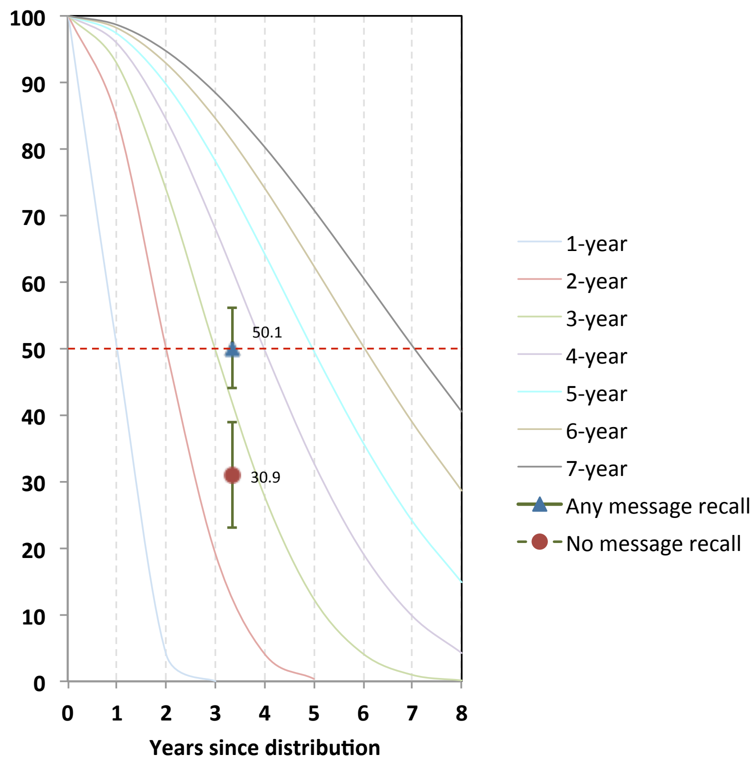


Figure 8.10: Plot of proportion of nets surviving at endline (3.3 years after distribution) by exposure to the BCC intervention against standard decay curves. Decay curves are labelled according to where each curve hits the 50% line (dotted red line), e.g. the green curve crosses the median at 3 years since distribution, and is therefore the curve for a 3-year net.



8.4.5 Multivariate regression

Multivariate logistic regression was performed with the confirmed campaign nets at endline to determine relative contributions of attitudes and exposure to messages, controlling for background variables and predictors selected by using the conceptual model in Figure 2. Univariate analysis was first performed for these predictors, which included positive attitude, evidence of repair, whether the net was observed tied up, frequency of washing, presence of rodents in the house, type of sleeping place, exposure to the BCC campaign, poorest wealth quintile, education level of the head of household, gender of the respondent, polygamous household, drying location, and intervention area. Backwards elimination using Wald tests to assess significant predictors resulted in the multivariate model shown in Table 8.7. Head of household education, household being polygamous, frequency of washing, drying location, presence of rodents, and type of sleeping place were not significantly associated with net condition and were not included in the multivariate model.

Table 8.7: Multivariate logistic regression for confirmed campaign nets in serviceable condition at endline in both study sites

Confirmed campaign net is in serviceable condition	**Odds Ratio**	**95% CI**	**p**
Positive attitude towards care and repair	6.17	2.19-17.36	0.001
Net has any observed repair	0.36	0.18-0.73	0.005
Net is tied up	2.70	1.50-4.86	0.001
Dose			
1 source	4.00	2.30-6.94	0.000
2 sources	2.67	1.35-5.31	0.006
3+ sources	9.34	3.75-23.29	0.000
# of children under five	0.82	0.69-0.97	0.022
Poorest Quintile	0.47	0.24-0.95	0.035
Respondent is the spouse	1.62	1.00-2.62	0.05
Intervention LGA	0.48	0.24-0.97	0.04

Attitudes and level of exposure to the campaign were the strongest predictors of net condition (Table 8.7). Nets in households with positive attitude were 6.17 times as likely as those in households with negative attitude to be in serviceable condition. The number of sources recalled remained significant at one and three+, with 4.00 greater odds of nets being in serviceable condition for households reporting one source compared to no exposure, and 9.34 times greater odds for nets in households reporting three or more sources of information. Wealth quintile was also significant, with nets in the poorest quintile having half the odds of being serviceable compared to nets in the upper wealth quintiles. Nets that were hanging tied up had 2.70 greater odds of being in serviceable condition, while nets with observed repairs were in poor condition, with an odds ratio of 0.36. The number of children under five in the household was associated with a 0.82 reduction in odds of the net being serviceable. The respondent being the spouse resulted in 1.62 greater odds of the net being in serviceable condition, reflecting gender influence potentially related to exposure and attitudes.

In the same model, specific attitudes were assessed as predictors of nets in serviceable or better condition, shown in Table 8.8. General self-efficacy to repair, and response efficacy (confidence in a repaired net to protect against malaria) were both significant predictors of serviceable condition of nets. Self-efficacy to repair nets immediately and perceived social norm of net repair were not predictive. The perception that nets were valuable negatively predicted net condition, although this attitude was extremely positive for nearly all respondents, and may reflect the overall condition of nets in the sample.

*Table 8.8: Specific attitudes predicting serviceable condition of campaign nets, using the same regression model as Table 7. Italics indicate negatively phrased questions; ** indicates p<0.001.*

Confirmed campaign net is in serviceable condition	Odds ratio	95% CI	p
**There are actions I can take to make nets last long	1.61	1.25-2.08	0.001
**A repaired net is still effective against mosquitoes	1.62	1.25-2.10	0.001
Others in this community repair holes in nets	0.85	0.64-1.13	0.255
I do not have time to repair holes in my net	0.92	0.78-1.09	0.314
I can help protect my family from malaria by taking care of my net	1.10	0.74-1.63	0.629
I am confident I can repair holes immediately	1.00	0.74-1.34	0.985
**Nets are valuable	0.38	0.21-0.69	0.002
It is not possible to repair nets	1.15	0.90-1.45	0.254

Italics indicate negatively-phrased question; inverted when calculating composite attitude score. Pearson chi-square. * p<0.05, ** p<0.01, *** p<0.001

Table 8.9: Types of exposure predicting serviceable condition of campaign nets, using same regression model as Table 7.

Confirmed campaign net is in serviceable condition	Odds Ratio	95% CI	p
Type of exposure (vs none)			
Radio only	2.77	1.34-5.74	0.007
IPC only	1.63	0.82-3.25	0.160
Radio and IPC	1.82	1.02-3.24	0.042
Other	1.80	0.77-4.16	0.168

Further regression by type of exposure showed that nets in households with only radio exposure had 2.77 times greater odds of being in serviceable condition (p=0.007), while only IPC exposure (either community health worker, community event, or health worker) was not significantly predictive (Table 8.9). The combination of radio and at least one IPC exposure was also significantly predictive, but with a lower odds ratio of 1.82 (p=0.042). This likely reflects the skewed application of radio in the control LGA with absence of other channels.

8.5 Discussion

For all respondents, exposure to the net care and repair BCC campaign was strongly correlated with increased positive attitude towards net care and repair, and increases in attitude were strongly correlated with self-reported actions taken to care for nets, with observed net repair, and with the proportion of nets in serviceable condition three years after net distribution. Estimated median net lifespan was approximately one full year longer for nets in households with a positive attitude compared to a negative attitude towards care and repair.

Intention to treat analysis indicated no difference between intervention and control areas in terms of observed repair or net condition. As other studies have found (Keating *et al*. 2012), it is often difficult to successfully implement experimental designs for BCC interventions due to leakage of messages into control areas. In this case, the boosting of the radio signal was factored into the design of the endline survey, and additional clusters were added to allow for the subsequent analysis by exposure.

At baseline, care and repair behaviours were quite rare, and the formative research also indicated that LLIN users in the study areas had not considered repair or care as a necessary activity (Hunter *et al*. 2014).

Analysis by exposure found that indeed radio exposure was common (47%) in the control area, and that health workers were also a small but significant source of information in that area, indicating that the radio station was reaching into Toto. It is unclear whether health workers received other training including care and repair messaging or also heard the radio messages, or whether they spontaneously were recommending similar key messages. It is plausible that health workers may have heard the radio spots and been inclined to pass messages along to those receiving nets at health clinics.

Regression analysis showed that the number of channels through which respondents were exposed to BCC messaging, and their attitudes about care and repair were predictive of nets being in serviceable condition at the endline survey. Attitudes and level of exposure were the strongest predictors in the multivariate model. Given that exposure to radio was a better predictor of serviceable condition than IPC, it is possible that radio alone would be sufficient to promote care and repair behaviour. Radio has been shown to be a cost-effective way of changing behaviour, as it reaches many more people than community activities (Do *et al*. 2006). Nonetheless, the data also support the central tenet of BCC strategy design that the reinforcing properties of using multiple channels are more effective than using a single channel (Plautz *et al*. 2007; Kiwanuka-Tondo *et al*. 2002).

Other significant predictors in the regression model were the number of children under five in the household, poorest wealth quintile, and tying up the net during the day, echoing findings from the durability study within which the present study was nested (Kilian *et al.*, in prep). Children under five are skilled at breaking all kinds of household items; preventing their access to the net by tying it up during the day is likely a key strategy for prevention of tears. The data also indicate that preventive behaviour is likely to be more effective than repair behaviour in overall contribution to net longevity. Indeed, nets with observed repairs were in worse condition, most likely indicating that repairs occur at a late stage, once a net is already quite torn, and are not done at a level sufficient to improve the pHI category of the net from 'torn' to 'serviceable'.

Frequency of washing and drying practices were not significant predictors of net condition, indicating that these behaviours may not be as damaging to nets as previously suspected, or that they are being conducted with care already. The type of sleeping place was significant in the univariate model but not in the final model, most likely because it is closely correlated with wealth quintile.

Care and repair behaviours are non-controversial and common sense, and therefore seem fairly easy to promote, particularly compared to other health behaviour such as condom use or uptake of family planning. The only other study on this topic found that a BCC intervention was able to increase the per cent of holes in nets that were repaired from 27% to 41% over six months in The Gambia, although repair did not have any effects on the numbers of mosquitoes caught at dawn under the nets (Panter-Brick *et al*. 2006). Similar to that study, the present BCC intervention encouraged small do-able actions, mainly tying the net up during the day to keep away from young children and rodents, and treating it carefully. It is plausible that given the relative simplicity of the actions needed, that only a small 'push' from the BCC intervention was needed to encourage these behaviours. This is borne out by the results of the regression of serviceable condition on the different types of attitudes. Where self-efficacy and perception that repair took only a little time were strong, nets were more likely to be in serviceable condition at endline.

While this BCC intervention was conducted as a stand-alone intervention, its key components, the radio spots, CHW job aids and key messages, and community events, are relatively easily incorporated into existing malaria BCC platforms. Particularly for malaria prevention programmes that already train and support CHWs, the production of simple job aids is inexpensive, and key messages can be added into their routine work. Given the impact of radio-only exposure on serviceable condition of nets, planners may want to consider developing two to three short spots and adding them into the rotation of net use messaging, even if other community platforms are not available.

Formative research conducted in Senegal, Mali, Nigeria, and Uganda shows that attitudes around net care and repair are largely similar across these settings prior to BCC interventions (Loll *et al*. 2013; Loll *et al*. 2014; Hunter *et al*. 2014; Leonard *et al*. 2014; Scandurra *et al*. 2014). Care and repair behaviours are not widespread and while respondents expressed anxiety about neighbours seeing their own torn or dirty nets, or view those with such nets as careless or lazy, there is also a clear lack of urgency to complete repairs. As attitudes, perceptions, and behaviours around net care and repair in these other settings were similar to Nigeria, it is reasonable that BCC interventions in other areas would potentially have similar impact, even where formative research reveals a lack of current care and repair practices.

While these results show that repairs made to nets did not improve their condition, this does not necessarily imply that BCC messages on repair should be dropped. Certainly the key message for program planners is that care and prevention help the most, but continuing to include some key messages on net repair is unlikely to hurt, and may contribute overall to a positive attitude towards care of the net, as evidenced by specific attitudes about repair remaining significantly predictive of net condition at endline.

Improved care practices are a ‘low-hanging fruit’ for LLIN longevity and malaria prevention. There are limited opportunities and technologies that allow LLINs to last longer in the field; apart from improvements in knitting pattern, procurement practices based primarily on lowest price per LLIN prevent manufacturers from investing in more expensive but more durable textiles. This study demonstrates that there are substantial gains to be made in median net lifespan simply by improving the way that nets are handled within households. While these results alone are unlikely to change current procurement timelines, improved net care can contribute to maintaining cohorts of nets in better overall condition within a given timeframe, leading to higher rates of net use between mass distributions, as one example, or prior to replacement via continuous distribution channels. Improved net condition should also provide better protection from malaria. Further research is urgently needed to assess the relationship between malaria parasitaemia, malaria cases, and the proportionate hole index of LLINs. This would help in being able to set more evidence-based thresholds for ‘good’, ‘serviceable’, and ‘too torn’ nets, and help relate net condition to public health impact.

8.6 Conclusion

Exposure to multiple channels of a comprehensive BCC intervention was associated with improved net care and repair attitude scores, and with improved net condition at endline. It is possible for BCC interventions to change both attitudes and behaviour, and to have a significant effect on overall median net lifespan. Care and repair messages are easily incorporated into existing malaria BCC platforms, and will help contribute to improved net condition, providing, in principle, more protection from malaria.

8.7 Authors Contributions

HK conducted the behavioural analyses and drafted the manuscript. AK conducted analysis on pHI and contributed to the manuscript. GH and AA drafted portions of the manuscript. EO and BF implemented the intervention and contributed to the manuscript. MF and ML contributed to study design and edited the manuscript. All authors read and approved the final manuscript.

8.8 Acknowledgements

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9 Discussion

The present thesis aims to examine different aspects of LLIN distribution, including options for continuous distribution, issues in measuring LLIN ownership, access, and use, and BCC programming to maintain use and to maintain LLINs in good condition. This work is the first to present detailed considerations regarding delivery of LLINs through school and community channels, to illuminate LLIN use behaviours appropriately in the context of population access to LLIN, and to evaluate whether a care and repair intervention can extend the useful life of nets. This section begins with a discussion of the main research findings, with implications for LLIN distribution, behaviour change communication programming, and recommendations for future research.

9.1 Implications for Continuous Distribution of LLIN

The work completed in Chapter 3 presents a theoretical modelling of LLIN coverage based on inputs of nets into Tanzania. As of this writing, Tanzania has now completed two rounds of school distribution in three regions, and is preparing for a mass campaign in the remainder of the country. More research is needed, and some is already on-going, to evaluate the extent to which school distribution in Tanzania and elsewhere can improve LLIN ownership, household and population access, and to what extent households are or are not sharing LLINs when they have an excess within their household. Likewise, Zanzibar is currently implementing community-based distribution using coupons distributed via shehas, and nets stocked at health clinics. Evaluations of community-based distributions in Madagascar, Nigeria, and South Sudan show that the success of this channel is highly dependent on effective implementation.

For both school and community distributions, as for any LLIN distribution, the timing of the subsequent distributions is crucial to maintain coverage at an appropriate level before it dips too low. As continuous distribution channels are primarily designed to maintain high levels of coverage rather than to scale up (particularly for community distribution), extended periods between a scale-up mass campaign and the implementation of a subsequent continuous distribution system will result in ‘failure’ of the continuous channels to reach the targeted coverage levels, particularly in the first year of implementation. To avoid this, continuous channels must begin delivering nets within one year of the mass campaign, or else provide additional nets beyond the maintenance levels during the first year of implementation in order to not fall behind.

The planning models used to design and select continuous distribution channels assume that nets are redistributed between households, perfectly matching household need with net supply. This is not the case in reality. Since school channels will definitely miss households that have no school-age children (either because they have no children or because their children are past school age, or because the children in the household do not attend school or have dropped out), more work is needed to measure how and to what extent sharing of nets to these specific types of households can be achieved through existing distribution channels. The rate of redistribution of nets is 5% overall, as noted in Chapter 7, but the majority of these are going to households that are related to the giving household. Continuous distribution evaluations must measure which households 'miss out' on the distribution channels, and whether these households eventually receive a net via sharing, or not. Finally, BCC interventions should be tested to ascertain whether they could influence behaviours such that untargeted households receive nets from families receiving excess nets through the system. If not, separate measures will need to be taken to ensure that these households are served. This might be through existing retail channels, a special subsidy for households without children, or some other type of targeting mechanism.

For community distribution, equity needs to be monitored throughout the sequence of steps required to get a coupon through redeeming the coupon for a net. Initial results from community pilots indicate that the perceived availability of nets influences coupon redemption behaviour, and that the poorest quintiles are less likely to receive coupons and then also to redeem them. The community channel brings with it the possibility for favouritism, either overt (coupon holder prioritizes their close friends or family) or geographic (coupon holder does not visit into the furthest corners of his/her area of responsibility to ensure all know about the program and can access a coupon, or serves their immediate neighbourhood first). To ensure equitable coverage community channel design will need to take these factors into account, measure them, and assess their impact on the overall success of the program.

An area of immediate need for further research is in costing of pilot continuous distributions. The costing methodology used in Chapter 3 was based on costs of mass campaigns, the TNVS, and other data available at the time. With the several pilots now underway or completed in other countries, a priority should be evaluating the financial and economic costs of these pilots. This will provide three important pieces of data: First, budget data that can be used to plan school, community, and health facility distributions going forward, including lists of budget lines. These are crucial for planning purposes and should be presented in such a way that other countries considering continuous distributions can use them to develop their own implementation guidelines and costed plans for delivering the nets within their available budgets. Secondly, programmers should be able to see whether school or community channels cost more per net delivered, and to what degree. Given that countries developing continuous distribution strategies are most often choosing either a large school channel or a large community channel, knowing whether one is more expensive to implement (or if they are roughly equivalent) is vital information, and can then be considered along with the operational and political buy-in issues raised above. Thirdly, cost per net delivered is a rather simplistic metric. As noted in Chapter 3, mass campaigns are nearly always cheaper per net delivered because the large procurements generally result in a significant savings, due to volume discounts from manufacturers. Until continuous distribution procurements can negotiate similar volumes (for multi-year periods), cost per person-year of protection should be evaluated for each type of channel, assuming a three-year lifespan for nets on average. With finer detail in the costing of different channels, cost per PYP becomes a useful metric for national programs when considering and budgeting out longer-term national strategies. As more and more pilots are completed and countries begin to scale up continuous distribution activities, additional data for revising these cost analyses should be made available and taken into consideration.

9.2 Implications of Care and Repair findings on LLIN BCC planning

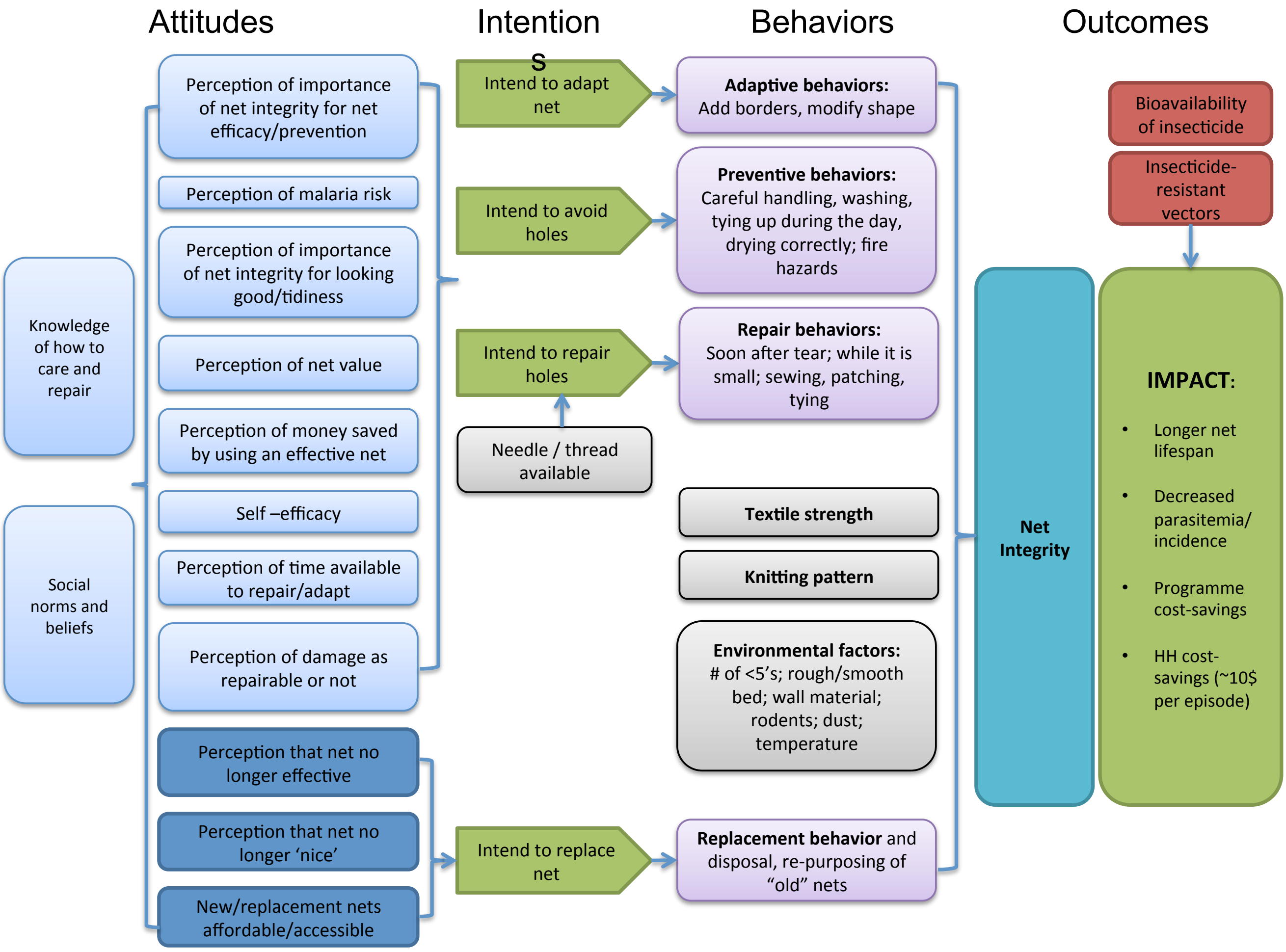
The care and repair study findings demonstrate that exposure to BCC can improve care and repair behaviours. The implications of this are significant. First, a nine-month longer median lifespan for nets in households exposed to the campaign means that those using the nets are protected even longer from malaria. This leads to cost savings at the household level in reduced expenditure on malaria treatment, but also for overall program costs. Even if procurement schedules do not change as a result of increased median net lifespan, in theory, more people will be protected for longer periods of time if their nets remain in good condition.

It is important to keep in mind that the preventive behaviours of tying nets up during the day appear to be the most predictive of nets ending up in serviceable condition; this makes sense especially when considering that the biggest dangers to nets are increasing numbers of children under five in the household, and rodents. Tying nets up during the day puts them out of the way of children playing and renders them much less accessible to rodents. It would be possible for the key message of “tie up the net during the day” to be integrated into existing BCC platforms with minimal cost to programs and potentially a large impact, even without the accompanying community events and stand-alone activities of this pilot. Updates of national malaria BCC strategies and frameworks should include care and repair messaging as a component of overall LLIN use messaging explicitly.

If BCC can lead to a 15% increase in the proportion of nets in serviceable condition, in a population of 1 million people and 500,000 LLINs, by the end of three years one could normally expect to see 250,000 of these nets too torn for use, based on the median lifespan of three years. An increase of 15% would mean that 75,000 additional nets would be in serviceable condition. It could also mean that for those 75,000 nets, replacement could be postponed, leading to further cost savings, if a continuous distribution channel is set up whereby nets can be replaced as needed (as opposed to a strategy where nets are replaced every three years, as with mass campaigns, or every year, as with school distributions).

In practice, postponing replacement is unlikely to occur, as national programs are continuously told by RBM working groups and WHO that nets are expected to last three years (World Health Organization 2011a; World Health Organization 2013a; World Health Organization 2014; Roll Back Malaria Harmonization Working Group 2011; Roll Back Malaria Harmonization Working Group 2013; Roll Back Malaria Harmonization Working Group 2014), and also being told that local durability study results should be taken into account (World Health Organization 2013a). Given that most of the current durability studies available do not correctly apply or measure the lost nets calculation into the denominator (Atieli *et al*. 2010; Tsuzuki *et al*. 2011; Batisso *et al*. 2012; Mejia *et al*. 2013; Wills *et al*. 2013; Mutuku *et al*. 2013; Okumu *et al*. 2013; Hakizimana *et al*. 2014), an increasing number of countries feel strongly that nets in their countries are only lasting two years (Hakizimana *et al*. 2014). This is exacerbated by anecdotal evidence and qualitative study results (neither of which are representative) in which net users express their observations that their nets do not last very long: 18 months or less (Hunter *et al*. 2014; Baume *et al*. 2009; Loll *et al*. 2013; Loll *et al*. 2014; Hoibak 2010).

Figure 9.1: Conceptual model for care and repair attitudes, intentions, behaviours, and outcomes



In Figure 9.1, the conceptual model for care and repair behaviours is presented. From the left, basic knowledge about how to care for and how to repair LLINs is a necessary but insufficient precursor. Social norms and beliefs also play an initial role in setting the stage for specific individual attitudes about care and repair. At the top of column are the perceptions related to perception of risk of malaria, response efficacy (an individual's confidence that an LLIN is protective against malaria, and that it works better when it is intact), self-efficacy to perform care and repair behaviours, including whether or not time is available to do so (and how time-consuming these behaviours are considered to be). At the bottom of the column in darker blue are the perceptions related to when a net should be discarded; if it is no longer perceived to be effective, or in such poor condition that it is aesthetically displeasing. Crucial here too is whether or not new or replacement nets are available, and if they are accessible. These last three elements contribute to individual intention to replace a net (or not), influencing replacement behaviour, disposal, and repurposing of old nets. The lighter elements previously mentioned are related to intentions and behaviours to adapt or modify nets, to avoid holes through preventive behaviours such as tying the net up during the day, and to repair holes once they appear. Along with these perceptions and behaviours are environmental or structural factors unrelated to the individual – the textile strength (denier) of the LLIN material, its knitting pattern (demonstrated to have a significant impact on how quickly small holes develop into large ones (Skovmand *et al*. 2011)), and household environmental factors – number of under-fives, presence of rodents, and whether the surfaces the net comes into contact with on a daily basis are abrasive or not. All these behaviours and structural factors then influence overall net integrity (as measured with pHI). The physical integrity of the LLIN is the strongest predictor of its longevity; however, overall durability also includes whether bioavailability of the insecticide is sufficient to meet WHOPES criteria. This is not easily measured in the field, but must be acknowledged in the conceptual model. At the same time, the degree to which the prevalent malaria vectors are resistant to the insecticide is also important when determining the overall outcomes of longer net lifespan, changes in parasitemia rates and malaria incidence, programme cost-savings, and household cost-savings.

9.3 Further applications of universal coverage indicators for LLIN BCC planning

Maintaining high rates of access to nets is a precursor for maintaining high rates of use; national programs need not only to ensure that access to LLINs is achieved and maintained, but that their use is maintained. The universal coverage indicators described here and developed and adopted by the RBM MERG provide a much more comprehensive picture of the state of LLIN use, and can therefore be used to guide allocation of resources for BCC appropriately.

It is vital that the new indicators be used regularly to inform LLIN programming, both for distribution and for BCC activities to improve and maintain high use rates. While the overall picture of net use among those with access is fairly rosy, as described in Chapter 6, these national averages hide regional variability and differences among particularly groups that remain to be further explored. Already the net use: access ratio has been used to inform BCC planning for national mass campaigns in Benin and Liberia, and to provide fuller pictures of net use behaviours in Madagascar.

Since the population access indicator can only be calculated at the household level, and not at the individual level, there are limitations on what types of analyses can be done to determine which factors influence individual non-use of nets when they are available. However, the household-level is largely sufficient to determine BCC strategy. One example is in Mozambique, where an analysis of

LLIN use:access ratios by region reveals that while overall Mozambique has reasonably high use of nets (at 0.75), the southern region of the country (Inhambane and Gaza, where malaria prevalence is slightly lower but still includes large areas of intermediate and high risk (Malaria Atlas Project 2010)) lags behind the other areas, despite having similar levels of population access.

Table 9.1: Regional rates of population use:population access in Mozambique DHS 2011

	Population ITN access	Population ITN use	Ratio of use:access
Niassa	34.0%	34.3%	1.01
Nampula	48.6%	44.0%	0.91
Zambezia	30.6%	28.6%	0.93
Tete	33.2%	24.6%	0.74
Manica	35.5%	30.7%	0.87
Sofala	38.9%	34.4%	0.88
Inhambane	44.3%	20.3%	0.46
Gaza	31.6%	7.5%	0.24
Mean	**37.1%**	**28.1%**	**0.75**

9.4 Limits of universal coverage indicators

While these new indicators are extremely useful for pinpointing geographic areas and other groups of households, the indicators continue to be limited to measurement of LLIN use the night before the survey. It is well-documented that LLIN use varies with seasons, according to perceived mosquito density, heat, and outdoor sleeping (Winch *et al*. 1994; Agyepong *et al*. 1999; Thwing *et al*. 2008; Fernando *et al*. 2009; Toé *et al*. 2009; Gunasekaran *et al*. 2009; Iwashita *et al*. 2010; Pulford *et al*. 2011; Lam *et al*. 2014). Without measuring in a more continuous manner the patterns of LLIN use throughout the year, and the barriers to consistent net use, BCC programs will not be able to develop appropriate responses to specific barriers. Further research is needed to investigate behaviours that may contribute to residual transmission – that is, transmission that occurs despite high coverage with LLINs or IRS (Killeen 2014).

Residual transmission scenarios include *A. arabiensis* or earlier biting behaviour of *A. funestus* or *A. gambiae* transmitting malaria during early evening or early morning hours while individuals are completing evening chores or passing time outside, unprotected, or during peak biting hours when people are unprotected, particularly at funerals, which has been documented in Uganda (Lam *et al*.

2014) and Ghana (Monroe *et al*. 2014). It also includes transmission related to night-time occupations including night-shift workers, night watchmen, night-time vendors (e.g. of food or alcohol), sex workers, etc. Illegal occupations such as rubber tapping in SE Asia, smuggling, etc. also present challenges in residual transmission.

While LLINs have the potential to be used in some of these residual transmission scenarios, such as setting up nets outdoors when people sleep outside, many more of these scenarios require a different vector control solution. The current universal coverage indicators do not measure the prevalence of outdoor sleeping, patterns of seasonal net use, prevalence of sleeping away from home, or work or other night-time activities that put individuals at risk. More work is needed to clarify the ways in which these activities can be documented and measured to develop models that will predict residual transmission and estimate its contribution to overall malaria transmission, even once universal coverage is achieved in a given area. The Health Belief Model (Figure 1.2) is likely to continue to be a useful framework with which to develop BCC interventions both for expanded use of LLINs outdoors and indoors, and for new vector control measures.

9.5 BCC in the context of malaria elimination

As new tools are developed to address residual transmission, and as patterns of net use are identified that can be influenced by BCC, BCC is required to support continued use of LLINs (e.g. outside) as well as to support interventions like spatial repellents, surveillance, active case detection, and others (Koenker *et al*. 2014).

As discussed in Chapter 4, Tanzania offers a strong example of how habits can maintain persistent net use even in the face of perceived decreases in malaria risk. It is crucial for continued high rates of LLIN use that nets are seen as not only a malaria prevention tool, but as providing other additional benefits. The data from Tanzania show that with time this perception has naturally occurred, but BCC can further strengthen these perceptions by emphasizing non-malaria benefits to nets, including getting a good night's sleep, feeling comfortable and protected from nuisance bites of any kind, and peace of mind. These can be added to existing BCC messaging to promote net use.

Much more work is needed on measuring the impact of BCC interventions on LLIN use behaviours. As net use increases this becomes more difficult, as high net use rates can make statistical differences between exposed and unexposed groups difficult to find without very large sample sizes. Recent work from Zambia (using propensity score matching to create matched exposed and unexposed groups) shows that exposure to BCC results in a 29-percentage-point increase in net use. However, application of this technique is not always feasible, particularly for smaller datasets, and it requires a large number of background variables on which to control. The impact of BCC depends highly on the quality and reach of its implementation, and on the existing net culture. A study of “Hang-Up” door-to-door visits in Uganda found that there was no difference in net use between control, 1-visit, and 2-visit areas over a 9 month time period; net use increased at the same rate in all three groups over the study period (Kilian *et al*. 2015). Studies in Senegal showed no association between exposure to the “Trois Toutes” campaign and LLIN use (Zegers de Beyl 2013), but the reasons behind all these results are unknown. More work is needed to identify in what contexts BCC is most likely to work effectively, and where intensive and costly BCC efforts, such as the Hang Up visits, are unlikely to have additional impact. As net culture continues to grow, and people get more and more used to and comfortable with their LLINs, we are likely to see the secular trend of net use increase. BCC can play a role in making sure that the trend continues in the right direction, and that nets are not abandoned when malaria burden goes down. Precise measurement of the contributions of BCC are vital, or programs risk cuts in funding for BCC due to lack of evidence of value for money.

10 Conclusion

In conclusion, this thesis demonstrates that high rates of use of LLIN are the norm rather than the exception, and that use is primarily driven by intra-household access – that is, households having enough nets for their family members. Reaching and maintaining high levels of access will require concerted efforts to determine the best continuous distribution strategy based on a given country’s (or region’s) operational capacity to deliver nets, and mass campaigns are by no means obsolete. Program planners must take into account the best options for continuous distribution of nets through optimal channels, as delivering the correct number of nets will eventually lead to cost savings over time, by minimizing the number of excess nets. In addition, replacement occurs when nets are needed, rather than at pre-determined intervals. Behaviour change communication has already contributed to high LLIN use rates, and has been demonstrated herein to significantly impact median net lifespan. National plans that optimize both distribution strategies and accompanying BCC strategies will be necessary to ensure continuing protection of all individuals at risk of malaria, and to maximize investments.

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12 Curriculum Vitae

HANNAH KOENKER

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EXPERIENCE

Johns Hopkins Bloomberg School of Public Health Center for Communication (JHU·CCP), Baltimore, MD, USA
2006-Present

Deputy Director, Malaria Vector Control Project (2014-present)
Senior Technical Advisor, NetWorks (2013-2014)
Provides technical oversight and assistance for the NetWorks/MVC project and its 13 country programs; responsible for oversight of all NetWorks research activities. Serves as Deputy Director and manages team of twelve in Baltimore; monitors and supervises subawardees; responsible for ensuring quality of technical assistance provided by subs and by all NetWorks staff.

Senior Program Officer (2010-Present)

- Provides technical assistance and oversight for the NetWorks project and CCP malaria programs in Senegal, Mali, Tanzania, Ghana, and Nigeria in the areas of behaviour change communication, global BCC policy, and monitoring and evaluation, as well as for LLIN campaigns, LLIN use, treatment, diagnosis, and IRS.
- Provides oversight for research activities for the NetWorks project, including net care and repair studies in Nigeria and Uganda, baseline and endline surveys evaluating continuous distribution in Ghana, process evaluations of LLIN distribution in Mali, Madagascar, and Ghana, and qualitative research activities in the Mekong Region and for the Culture of Net Use studies in Senegal and Uganda. Oversight includes ensuring IRB submissions, research plan, management of surveys and write up of results are on time and of high quality.
- Team Leader for PMI-funded design of continuous distribution for Zanzibar (March and October 2013).
- Team member for PMI-funded design of Ghana's continuous distribution strategy in November 2011.
- Team Leader for SDC-funded assessment of options for maintaining universal coverage in Tanzania in June-July 2011.
- Team Leader for PMI-funded process evaluation of Mali's first Universal Coverage campaign in Sikasso region in April-May 2011, producing a 35-page report in French and revising microplan and training manuals to improve subsequent distributions.
- Organized meeting to bring together major BCC partners to provide

guidance for Round 11 Global Fund applicants and Global Fund Technical Review Panel.

- Serves as chair of Roll Back Malaria's Alliance for Malaria Prevention BCC working group; organized and facilitated training on BCC for LLIN campaigns through AMP in Bamako (Sept 2010) and facilitated sessions for CCP's Leadership and Strategic Health Communication training in French (Dakar, Jan 2011).

Program Officer (2006-2010)

- Provided technical assistance for malaria advocacy and BCC programs in Mali, Ghana, Tanzania, and Nigeria for strategy and workplan development, budget development and monitoring, media and materials development, contracts, annual reports and success stories.
- Coordinated proposal-writing process on successful large malaria-focused RFAs and RFPs; wrote and edited sections of proposals.
- Led Communication/BCC sessions at the Nairobi LLIN Scale-Up Training organized by AMP, May 2009; chaired AMP BCC subgroup working on BCC M&E guidelines for LLIN use.
- Organized international meeting and commissioned literature review on increasing the use of LLINs in conjunction with the IFRC and RBM partners for the RBM Alliance for Malaria Prevention working group, October 2008.
- Designed quantitative study examining net use over a six-month period in rural Tanzania in conjunction with large-scale trachoma study
- Guided development of malaria and BCC training curricula for Red Cross volunteers from conception through pre-testing and finalization for the American Red Cross and International Federation of the Red Cross.

Population Services International & US Peace Corps, Bamako, Mali, 2003-2005

Health Volunteer (2003-2004) & Consultant (2004-2005)

Developed formative research protocol for social marketing of artemisinin-combination therapy. Coordinated production of HIV/AIDS-awareness television spots with 23 local and regional musicians. Managed partnership with cellular service company for monthly blast text messages on HIV/AIDS and malaria and recharge cards containing BCC messages.

US Peace Corps, Gabon, 2001-2003

Health Volunteer

Trained 20 Gabonese youth as peer educators in HIV/AIDS information, presentation techniques, and event planning; organized mural contest, painting 2 AIDS-awareness murals at the town's center and at the high school, involving 800 contestants and 20 peer educator painters. Expanded the availability of condoms in Gabon's two southern provinces by facilitating agreement between PMU-Gabon and PNLS to allow condoms to be sold through volunteers.

EDUCATION

PhD in Public Health & Epidemiology (2012-2015)
Swiss Tropical and Public Health Institute, Basel, Switzerland
Supervised by Prof. Christian Lengeler
MPH, Master of Public Health (2005-2006)
International Health / Social and Behavioural Sciences
Johns Hopkins University School of Hygiene and Public Health, Baltimore, Maryland, USA.
BA, Bachelor of Arts Degree (1996-2000)
English Literature, Minor in French Studies
Carleton College, Northfield, Minnesota, USA.

LANGUAGE SKILLS:

English: Native Speaker
French: Full Professional Fluency

Professional Memberships
American Society of Tropical Medicine and Hygiene

PUBLICATIONS & PRESENTATIONS

WORKING PAPERS

Zegers de Beyl, C, **Koenker** H, Obi E, Adegbe E, McCartney-Melstad A, Selby RA, Kilian A: Multi-country comparison of delivery strategies for mass campaigns to achieve universal coverage with insecticide treated nets: What works best? Malaria Journal, in review.

Kilian A, Balayo C, Feldman M, **Koenker** H, Lokko K, Ashton RA, Bruce J, Lynch M, Boulay M: The effect of single or repeated home visits on the hanging and use of insecticide-treated mosquito nets following a mass distribution campaign - a cluster randomized, controlled trial. PLoSOne, in press.

PUBLISHED ARTICLES

Ricotta E, Boulay M, Ainslie R, Babalola S, Fotheringham M, **Koenker** H, Lynch M: The use of mediation analysis to assess the effects of a behaviour change communication strategy on bed net ideation and intra-household net access in Tanzania. Malaria Journal 2015, 14:15.

Koenker H, Kilian A, Hunter G, Acosta A, Scandurra L, Fagbemi B, Onyefunafoa EO, Fotheringham M, Lynch M: Impact of a behaviour change intervention on long-lasting insecticidal net care and repair behaviour and net condition in Nasarawa State, Nigeria. Malaria Journal 2015, 14:18.

Koenker H, Kilian A, Zegers de Beyl C, Obi E, Selby R, Abeku T, Fotheringham M, Lynch M: What happens to lost nets? A multi-country analysis of reasons for ITN attrition using 14 household surveys in 4 countries. Malaria Journal 2014, 13:464.

Scandurra L, Acosta A, **Koenker** H, Musoke DK, Harvey S: "It's not really

about the time that has passed. It is about how the net looks": A qualitative study of perceptions and practices related to mosquito net care and repair in Uganda. Malaria Journal 2014, 13:504.

Leonard L, Diop S, Doumbia S, Sadou A, Mihigo J, **Koenker** H, Berthe S, Monroe A, Bertram K, Weber R: Net use, care and repair practices following a universal distribution campaign in Mali. Malaria Journal 2014, 13:435

Boulay M, Lynch M, **Koenker** H: Comparing two approaches for estimating the causal effect of behaviour-change communication messages promoting insecticide-treated bed nets: an analysis of the 2010 Zambia malaria indicator survey. Malaria Journal 2014, 13:342.

Berthe S, Loll D, Faye SL, Wone I, **Koenker** H, Arnold B, Weber R: "When I sleep under the net, nothing bothers me; I sleep well and I'm happy": Senegal's culture of net use and how inconveniences to net use do not translate to net abandonment. Malaria Journal 2014, 13:357.

Hunter GC, Scandurra L, Acosta A, **Koenker** H, Obi E, Weber R: "We are supposed to take care of it": a qualitative examination of care and repair behaviour of long-lasting, insecticide-treated nets in Nasarawa State, Nigeria. Malaria Journal 2014, 13:320.

Ricotta E, **Koenker** H, Kilian A, Lynch: Are pregnant women prioritized for bed nets? An assessment using survey data from 10 African countries. Global Health Science and Practice 2014, 2

Loll DK, Berthe S, Faye SL, Wone I, Arnold B, **Koenker** H, Schubert J, Lo Y, Thwing J, Faye O, Weber R 2014. "You need to take care of it like you take care of your soul": perceptions and behaviours related to mosquito net damage, care, and repair in Senegal, Malaria Journal, 13(1), p. 322

Koenker H, Kilian A. Recalculating the net use gap: a multi-country comparison of ITN use versus ITN access. PLOS One 2014, 9:e97496.

Koenker H, Keating J, Alilio M, Acosta A, Lynch M, Nafo-Traore F. Strategic roles for behaviour change communication in a changing malaria landscape. Malaria Journal 2013, 13:1

Loll DK, Berthe S, Faye SL, Wone I, **Koenker** H, Arnold B, Weber R. User-determined end of net life in Senegal: a qualitative assessment of decision-making related to the retirement of expired nets. Malaria Journal 2013, 12:337

Koenker H, Loll D, Rweyemamu D, Ali AS. A good night's sleep and the habit of net use: perceptions of risk and reasons for bed net use in Bukoba and Zanzibar. Malaria Journal 2013, 12:203

Kilian A, **Koenker** H, Paintain L. Estimating population access to insecticide-treated nets from administrative data: correction factor is needed. Malaria Journal 2013, 12:259

Koenker H, Yukich JO, Mkindi A, Mandike R, Brown N, Kilian A, Lengeler C. Analysing and recommending options for maintaining universal coverage with long-lasting insecticidal nets: the case of Tanzania in 2011. Malaria Journal 2013, 12:150

de Savigny D, Webster J, Agyepong IA, Mwita A, Bart-Plange C, Baffoe-Wilmot A, **Koenker** H, Kramer K, Brown N, Lengeler C. Introducing

vouchers for malaria prevention in Ghana and Tanzania: context and adoption of innovation in health systems. Health Policy & Planning 2012, 27:iv.

Kaufman M, Rweyemamu D, **Koenker** H, Macha J. "My children and I will no longer suffer from malaria": a qualitative study of the acceptance and rejection of indoor residual spraying to prevent malaria in Tanzania. Malaria Journal 2012, 11:220

Koenker H, Munoz B, Boulay M, Mkocha H, Levens J, West SK, Lynch M. Trends in weekly reported net use by children during and after rainy season in central Tanzania. Malaria Journal 2012, 11:218

Koenker, H. "Creating a 'net culture'. Public Health, No. 22, April 2011.

Kilian A, Boulay M, **Koenker** H, Lynch M: "How many mosquito nets are needed to achieve universal coverage? Recommendations for the quantification and allocation of long-lasting insecticidal nets for mass campaigns." Malaria Journal 2010, 9:330

CONFERENCE PRESENTATIONS

Koenker H. (November 4, 2014). Impact of a behaviour change intervention on care and repair behaviours for long-lasting insecticidal nets in Nasarawa State, Nigeria. Poster presentation for the American Society of Tropical Medicine and Hygiene Annual Meeting, New Orleans, LA.

Koenker H. (November 15, 2013). Recalculating the net use gap: a multi-country comparison of ITN use versus ITN access. Poster presentation for the American Society of Tropical Medicine and Hygiene Annual Meeting, Washington, DC.

Koenker H. (December 7, 2011). Continuous distribution strategy development – maintaining universal coverage after scale-up: recent examples from Tanzania and Ghana. Oral presentation as part of the symposium "Options for maintaining universal coverage in LLIN: continuous distribution systems". 2011 American Society of Tropical Medicine and Hygiene Annual Meeting, Philadelphia, PA.

Koenker H. (November 7th, 2010). Achieving and sustaining high levels of use of LLINs. Oral presentation as part of the symposium "Malaria Prevention in Africa - Beyond mass campaigns of long-lasting insecticidal nets (LLIN)". 2010 American Society of Tropical Medicine and Hygiene Annual Meeting, Atlanta, GA.

Koenker H. (November 4th, 2010). Tracking weekly LLIN use in Kongwa, Tanzania. Poster presentation for the American Society of Tropical Medicine and Hygiene Annual Meeting, Atlanta, GA.