ADDIS ABABA UNIVERSITY

ETHIOPIAN INSTITUTE OF WATER RESOURCES

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Determinants of malaria transmission and bed net utilization among households around Lake Tana, northwest Ethiopia

ASMAMAW MALEDE TAREKEGN

DISSERTATION FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (PhD) IN WATER AND PUBLIC HEALTH, ETHIOPIAN INSTITUTE OF WATER RESOURCES, ADDIS ABABA UNIVERSITY

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ASMAMAW MALEDE TAREKEGN

SUPERVISORS

DR. KASSAHUN ALEMU (MPH, PhD, ASSOCIATE PROFESSOR)

DR. MULUGETA AEMERO (MSc, PhD, ASSOCIATE PROFESSOR)

DR. SIRAK ROBELE (MSc, PhD, ASSISTANT PROFESSOR)

DR. HELMUT KLOOS (PhD, ASSOCIATE PROFESSOR AND RESEARCH ASSOCIATE)

FEBRUARY 2020

Date: 14/02/2020

Name of Candidate: Asmamaw Malede Tarekegn

After consideration of the dissertation of Mr. Asmamaw Malede Tarekegn entitled "Determinants of malaria transmission and bed net utilization among households around Lake Tana, northwest Ethiopia", members of the doctoral advisory committee approved by their signatures below the dissertation is ready for defence subject to the following criteria.

Criteria	**Acceptable**	**Unacceptable**
Contribution of the project to knowledge within the field	√	
Demonstration of knowledge of the content area and awareness of relevant research of others.	√	
Appropriateness of the methodology to answer the research Questions	√	
Demonstration of adequate understanding of the methodology	√	
Clarity and organization of writing	√	

Overall Recommendation

Approve as presented: √

Revise and resubmit:

Signature of Advisor 1: Dr. Kassahun Alemu	Date: 11/10/2019	Signature
Advisor 2: Dr. Mulugeta Aemero	Date: 26/09/2019	Signature *Mulugeta*
Advisor 3: Dr. Sirak Robele	Date: 02/10/2019	Signature
Advisor 4: Dr. Helmut Kloos	Date: 20/09/2019	Signature

ORIGINAL ARTICLES

This dissertation is based on the following original articles, which will be referred in the text by their Roman numerals.

I. Malede A, Alemu K, Aemero M, Robele S, Kloos H. Travel to farms in the lowlands and inadequate malaria information significantly predict malaria in villages around Lake Tana, northwest Ethiopia: a matched case-control study. Malaria Journal. 2018; 17(1):290. doi: 10.1186/s12936-018-2434-y.

II. Malede A, Alemu K, Aemero M, Robele S, Jemberie W, Kloos H. Older under-five children were at risk of local malaria in northwest Ethiopia where *Anopheles gambiae* complex and *Anopheles pharoensis* dominate (under review)

III. Malede A, Aemero M, Gari SR, Kloos H, Alemu K. Barriers of persistent long-lasting insecticidal nets utilization in villages around Lake Tana, Northwest Ethiopia: a qualitative study. BMC Public Health. 2019; 19(1):1303. doi: 10.1186/s12889-019-7692-2.

ACRONYMS AND ABBREVIATIONS

ACT	Artemisinin-based combination therapy
COR	crude odds ratio
DALYs	disability-adjusted life years lost
DHS	Demographic and Health Survey
FMOH	Ethiopian Federal Ministry of Health
GPS	geographical positioning system
HEWs	health extension workers
HH	Household
IQR	interquartile range
IRS	indoor residual spraying
ITNs	insecticide treated nets
LLINs	long-lasting insecticidal nets
Masl	meters above sea level
MIS	malaria indicator survey
mOR	matched odds ratio
PCA	principal component analysis
PCD	passive case detection
$Pf\mathrm{PR}_{2\text{-}10}$	age corrected *Plasmodium falciparum* parasite rate in children aged 2-10 years
RDTs	rapid diagnostic tests
SES	socioeconomic status
SSA	sub-Saharan Africa
UTM	Universal Transverse Mercator
WGS	World Geodetic System
WHO	World Health Organization
YLD	years lived with disability
YLL	years of life lost

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ABSTRACT

Background: Malaria still attacks millions of people predominantly in sub Saharan Africa, including Ethiopia. The contribution of house proximity to water bodies, the role of migration, malaria information and child age on malaria transmission dynamics have not yet been examined in detail in northwest Ethiopia. Identification of malaria vectors in meso-endemic settings with a high potential of introduced malaria has not also been done in the study setting. The ownership and use of LLINs is one of the primary prevention strategies for malaria transmission control and elimination. In Ethiopia, evidences showed the presence of major gaps between LLIN ownership and compliance. However, the reasons that influenced consistent utilization of LLINs have not yet explored qualitatively in Amhara region, particularly in the study area. Identifying factors for imported and locally acquired malaria, malaria vectors, and exploring barriers of consistent utilization of LLINs are useful to facilitating the effort for malaria elimination.

Objectives: This study aimed at investigating the contribution of house proximity to a water body, individual and household-level drivers of imported and locally acquired malaria, malaria vector species and barriers of consistent LLINs utilization in meso-endemic villages around Lake Tana, northwest Ethiopia.

Methods: A combination of approaches, including matched case-control study designs, entomological survey and phenomenological qualitative method were undertaken in 12 *kebeles* around Lake Tana, northwestern Ethiopia. Health facility-based matched case-control studies involving 303 and 81 matched pairs among all age groups and under-five children were conducted from October 10, 2016, to June 30, 2017, respectively. *Anopheles* mosquito larvae sampling was done from April 30, 2017, to June 24, 2017, from 7 potential breeding sites in the study area using the standard dipping method. A phenomenological qualitative approach comprising 23 community interviewees and 38 key informants was conducted from April to June 2017. Households for cases and controls, household proximate water bodies, health centers and larvae survey sites were geo-referenced. A semi-structured questionnaire was used to collect data from households. Collected larvae were reared to adulthood at an insectary. Each adult was individually identified at the species and species complex levels using standard adult mosquito morphological identification keys. In-depth interviews were carried out to explore the local contexts and reasons that influenced consistent use of LLINs. Quantitative data were entered and cleaned in EpiData Version 3.1 software. Qualitative data were managed and analyzed using NVivo Version 10 software. Principal component analysis was performed to estimate household wealth. Stratified analyses were used to confirm confounding and effect modification. Multivariable conditional logistic regression models were fitted to identify independent predictors of malaria occurrence. Thematic analysis was used for the interview data to code and identify themes. Statistical analyses were performed using Excel®, SPSS statistical software version 22 and STATA version 14.0. The maps were plotted using ArcGIS 10.5.

Results: Of 303 malaria cases, 59 (19.5%) were imported malaria whereas 244 (80.5%) were locally acquired. Travel to malarious lowlands in the preceding month (adjusted mOR = 7.23; 95% CI: 2.38-22.00), household member's travel to malarious lowlands (adjusted mOR = 3.04; 95% CI: 1.14-8.08), and inadequate malaria information (adjusted mOR = 1.56; 95% CI: 1.02-2.37) were observed as independent predictors of malaria occurrence in the study area. Stratified analyses confirmed that travel to malarious lowlands had a confounding effect on malaria occurrence in the study area.

Children aged 36-59 months (adjusted mOR = 3.88; 95% CI: 1.55-9.74) were at increased risk of locally acquired malaria among under-five children. Presence of water body within a 500m radius from a house was not a statistically significant predictor of local malaria. The malaria vectors, *Anopheles gambiae* complex, *An. pharoensis* and *An. funestus* group were identified in malaria meso-endemic villages around Lake Tana.

The qualitative investigation explored wrong perceptions about LLINs, malaria and mosquitoes; bedbug infestation; structural inconvenience; unintended uses; weather conditions; problem in distribution of nets; and socio-cultural and economic factors as critical barriers for consistent utilization of LLINs. Killing ability of nets against arthropods other than mosquitoes reportedly made use of LLINs a favored malaria prevention method despite their ineffectiveness after 3 months. Circular-shaped nets were preferred due to their compatibility with varied sleeping structures. Unintended uses were often associated with local needs and seldom linked with social issues and deficiencies in information about malaria and LLINs. Collateral benefits were considered equally important, principally in terms of short-term disinfestations of bedbugs.

Conclusions: In this study, travel to malarious lowlands and inadequate malaria information determined the occurrence of malaria infection in villages around Lake Tana. Children aged 36-

59 months old continued to be at increased risk of local malaria in these villages where *An. gambiae* complex is present. Non-consistent bed net use in villages around Lake Tana was associated with inconvenient bed net design and early damage; non-potency of the insecticide against other arthropods; facilitation of bedbug infestation; unintended uses; wrong perceptions about malaria, mosquitoes, and LLINs; and inadequate follow-up regarding LLINs utilization.

Recommendations: National malaria control & elimination programmers and health authorities should design improved effective and integrated interventions that consider imported malaria cases. Malaria information that involves IEC and SBCC should be given to optimize coverage and adequacy of information by considering the educational status of the community. Increment of long-acting insecticide spraying coverage and frequency, use of repellents until sleep under nets and equal management of both child age groups while applying LLINs utilization should be considered to reduce local malaria in children aged 36-59 months. Vector control interventions should be designed in accordance with malaria vector species present in a locality. The provision of nets that are structurally compatible with sleeping spaces and the delivery of adequate information about malaria and its vectors, and the properties and proper uses of LLINs to the community indicate substantial accumulation of knowledge that may guide effective LLIN programs in the study area.

Keywords: Locally acquired malaria, Malaria information, Travel, Matched analysis, Under-five children, Malaria vectors, LLINs, Consistent use, Circular nets, Bedbug infestation, Ethiopia

1. INTRODUCTION

1.1. Background

Malaria is a life-threatening disease transmitted through the bite of female *Anopheles* mosquitoes and poses a high health risk to under-five children in malaria-prone areas such as sub-Saharan Africa (SSA) (1, 2). It still attacks millions of people, predominantly in SSA. Substantial case incidence increment were recorded between 2015 & 2017 (1). Globally, 219 million cases of malaria were observed in 2017 compared with 239 million cases in 2010 and 217 million cases in 2016. The WHO African Region accounted for 92% of cases in 2017 (1). Of the 91 countries reporting indigenous malaria cases in 2016, 15 countries all in SSA except India carried 80% of the global malaria burden (3). Five countries, including Nigeria, Democratic Republic of the Congo, Mozambique, India and Uganda accounted for nearly half of all malaria cases worldwide (1). In 2017, there were 435, 000 malaria deaths globally and 61% of the deaths were occurred in under-five children. Likewise, the WHO African Region bears the largest burden (93%) of deaths in 2017 and mortality rates were stalled in the WHO regions of South-East Asia, the Western Pacific and Africa between 2015 and 2017 (1).

SSA had an estimated prevalence of 13% in 2015 (4). Malaria was the fourth highest cause of death which accounting for 10% of child deaths in SSA. Globally, in 2000, malaria accounted for 7% of deaths in under-five children, and 17% of these deaths were in SSA, where it was the leading cause of death. However, in 2015, it accounted for just 5% of under-five children deaths, and the deaths declined to 10% in SSA, where it was the fourth highest cause of death. The vast majority of deaths, 99% were due to *Plasmodium falciparum* malaria (4).

Globally, more countries are moving towards elimination. In 2017, 46 countries reported fewer than 10, 000 malaria cases, up from 37 countries in 2010 (1). Between 2000 and 2017, 19 countries attained zero indigenous cases for 3 consecutive years or more. United Arab Emirates (UAE), Morocco, Turkmenistan, Armenia, Kyrgyzstan, Sri Lanka, and Paraguay have been certified by WHO as malaria free in this period (1).

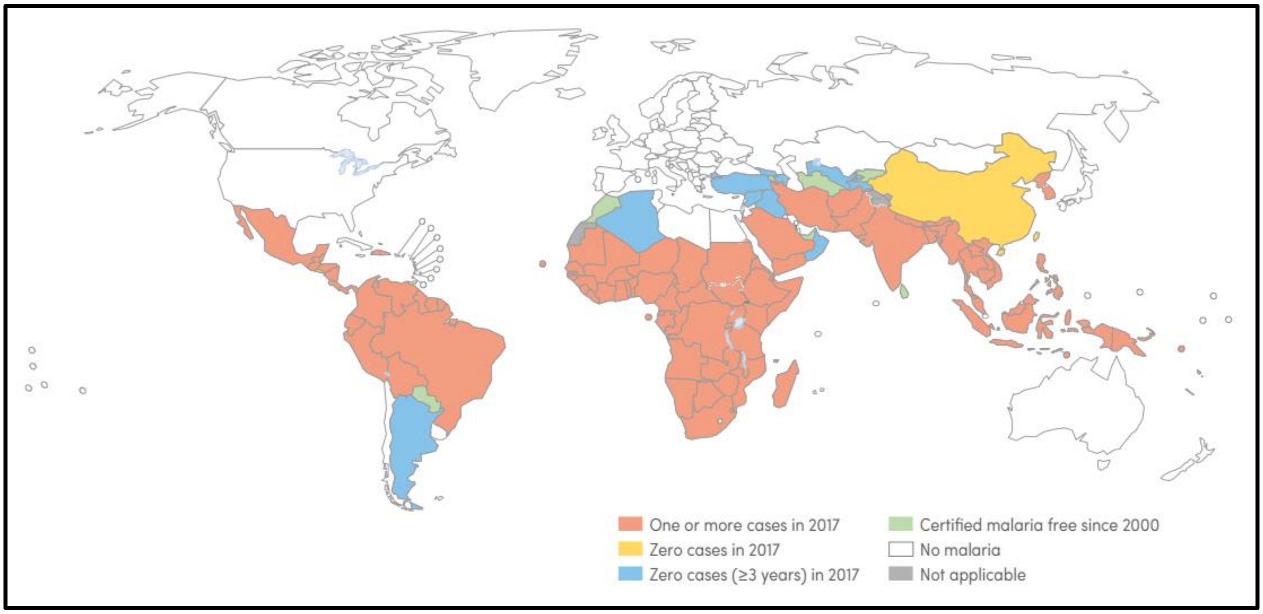

Figure 1: Map of World malaria epidemiology (number of indigenous cases in 2017) (1)

In Ethiopia, malaria is still a significant public health concern. It was among the top ten causes of morbidity and mortality, with falciparum malaria occupying the second and non-falciparum malaria the sixth positions in causing morbidity in 2012/2013. Also falciparum malaria was the sixth as cause of mortality (5, 6). A 2015 national malaria indicator survey (MIS) reported 0.5% and 0.6% of malaria prevalence in malarious areas among all ages and under-five children using microscopy, respectively. Its prevalence was 1.8% among children aged 36-59 months, which was lower, compared with among children below 36 months (2%) (7). In 2017, there were 2, 666, 954 malaria cases and 5, 369 deaths. Around 9% of estimated vivax malaria cases in 2017 occurred in Ethiopia (1). According to Ethiopian Federal Ministry of Health (FMOH), 15% of the reported outpatient visits and nearly 15% of the admissions were attributed to malaria (8).

Ethiopia has shown a declining malaria trend in the past two decades (1, 7, 9, 10). Ethiopia has noted estimated reductions in malaria burden, with 240, 000 fewer cases in 2017 than in 2016 (1). A review article on burden of malaria indicated that age-standardized mortality and incidence rates declined by 96% (30,323 to 1,561) and 89% (2.8 million to 621,345), respectively, between 1990 and 2015 (10). Another review analysis also showed that age-standardized disability-adjusted life years lost (DALYs) attributed to malaria also fell drastically between 1990 and 2015 with 95% (11). A 0.5% prevalence among all age groups in 2015 MIS was lower than a 0.9% in 2007 and a 1.3% in 2011 (7). Another scoping review reported the decline of incidence rate from 43.1 cases/1000 population annually between 2001 and 2010 to 29 cases/1000 population annually between 2011 and 2016. Malaria deaths also decreased from 2.1 deaths/100,000 people annually between 2001 and 2010 to 1.1 deaths/100,000 people annually between 2011 to 2016 (12). Amhara National Regional State accounted for 31% of the national malaria burden (6). In 2014/2015, 7% of outpatient visits, 2% of hospital admissions, and 1% of health facility deaths were caused by malaria (13). A 2015 MIS reported a prevalence of 0.8% among all ages and 1.1% among under-five children in the region (7).

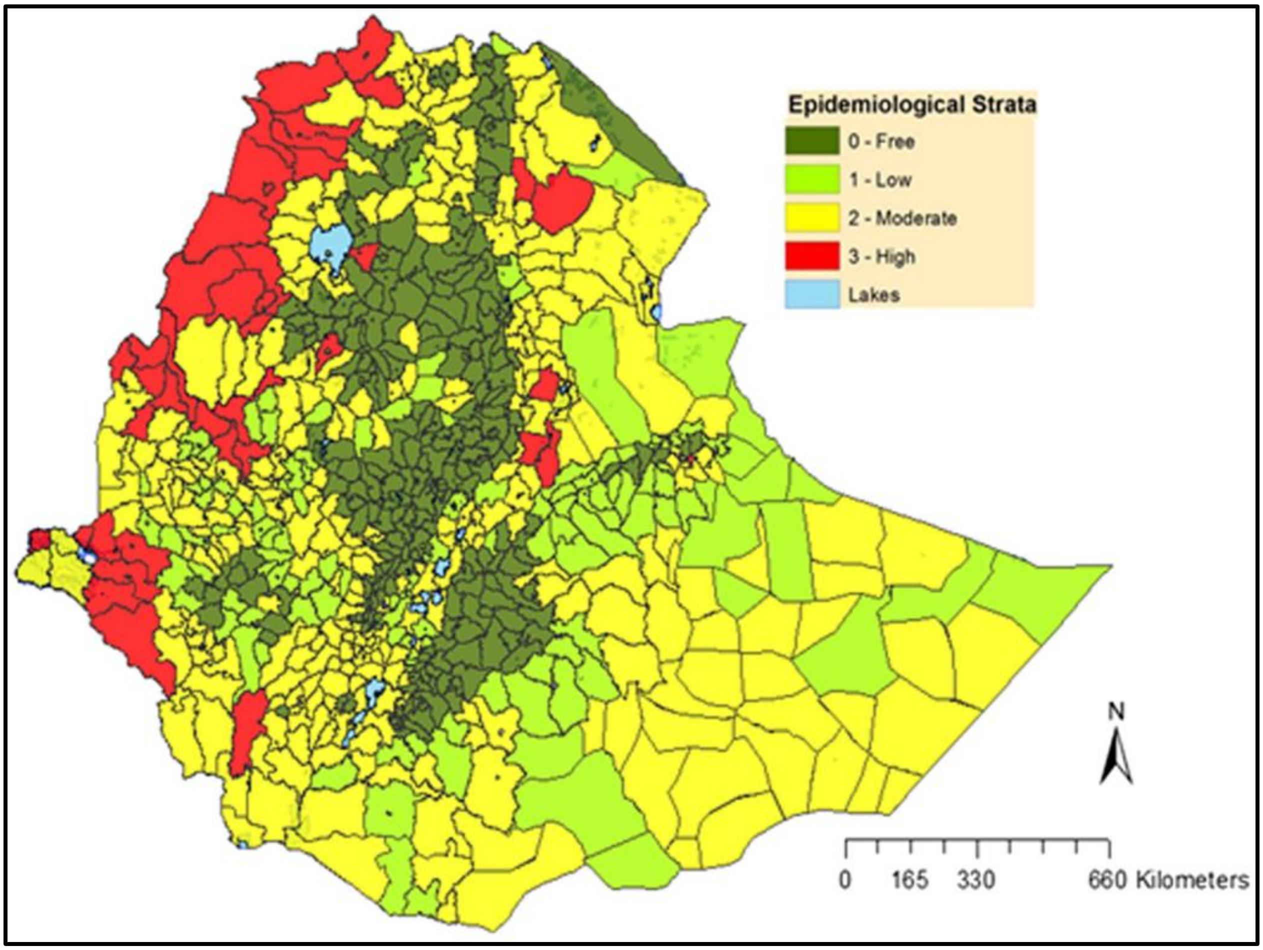

Figure 2: Map of malaria strata by districts in Ethiopia (14)

Given the topography and human settlement patterns, Ethiopia is characterized as a predominantly low, stable hypo-endemic ($Pf\mathrm{PR}_{2\text{-}10}$ <10%) with pockets of higher meso-endemic transmission ($Pf\mathrm{PR}_{2\text{-}10}$ =10-49%) and large areas of unstable transmission prone to epidemics (15, 16). *Anopheles* species, including *Anopheles arabiensis*, *An. pharoensis*, *An. funestus*, and *An. nili* are the malaria vectors in the country (15, 17, 18). *An. arabiensis* is the primary vector of malaria whereas *An. pharoensis*, *An. funestus* and *An. nili* are secondary vectors (19-21).

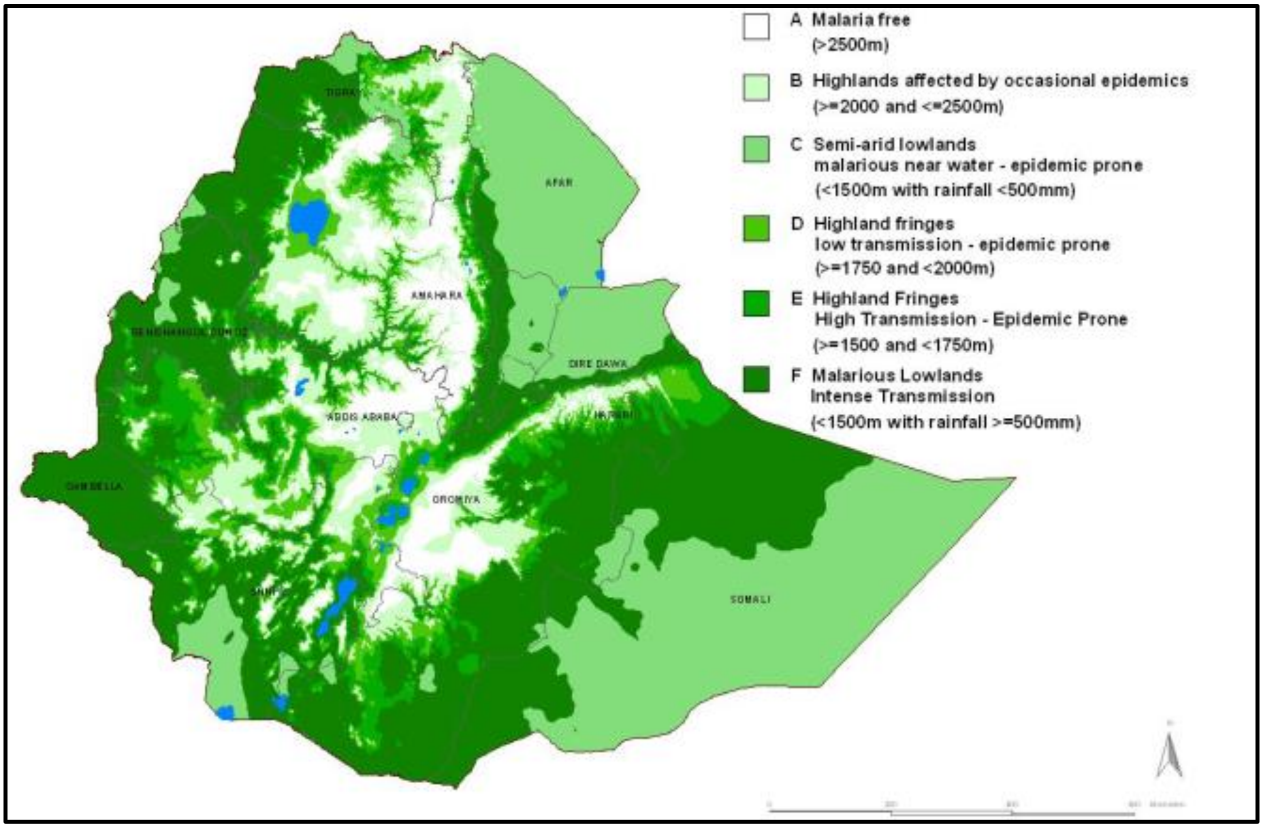

Figure 3: Malaria risk stratification of Ethiopia (7)

The WHO has set a goal for malaria in post-2015 era with a motto "end the epidemic of malaria" by 2030 (22). The use of long-lasting insecticidal nets (LLINs) is a widely accepted (23), and commonly available intervention for preventing the disease in Africa (24). It is a primary prevention and control strategy in Ethiopia and promoted as an effective approach to minimize risk of malaria transmission (7, 25). According to the 2015 National MIS, only 64% of households (HHs) owned at least one LLIN and only 40% of the population slept under LLINs the night before the survey, below the goals of 100% ownership and 80% utilization (7). The proportion of HHs having at least one LLIN for every two people was 31.7% nationally and 38% in Amhara Region in 2015 (7). In Amhara Region, 72.9% of HHs owned one LLIN and 43.4% of the population slept under the LLINs the night before the interview (7). In the region, the use of existing LLINs was 56%, the lowest in the country (7). However, small-scale surveys reported variable LLINs coverage and utilization (26-29).

An array of various factors contributes to the occurrence of malaria. Epidemiological evidences show that malaria was attributed to environmental, behavioral, socio-demographic, economic, and housing factors, and application of malaria intervention measures. Malaria interventions such as delivery of malaria information, LLINs ownership and utilization, and indoor residual spraying (IRS) were documented as critical determinants of malaria occurrence (30-35). In turn, evidences show that socio-demographic and socio-cultural characteristics, behavioral reaons and misconceptions, weather conditions, and livelihood and economic reasons influence consistent utilization of LLINs (25, 36-39). In systematic reviewed articles, environmental, housing, behavioral, socio-demographic and economic factors, mainly travel history, housing structure, and house proximity to a water body were the most frequently reported determinants of malaria (40-43).

Based on the aforementioned literature of community-based research and facility-based reports, we can conclude that malaria continues to be an important cause of morbidity and deaths in SSA, including in Amhara Region, Ethiopia.

1.2. Statement of the problem

WHO targeted to eliminate malaria from at least 35 countries in which malaria was transmitted in 2015 and prevent re-establishment of malaria in all countries that are malaria free by 2030 through locally tailored interventions (22).

Malaria remains one of the most common infectious diseases in Ethiopia (5-8, 10, 12) as well as in Amhara region (7, 13). Malaria incidence varies across WHO regions and countries as well as in different areas of a country. These variations can be attributed to environmental, socio-demographic, socio-economic, housing, behavioral and malaria intervention factors (30, 44-48).

Population movement is an important determinant of malaria transmission. Migrant workers often travel to malarious lowlands of Ethiopia to work on construction projects and large plantations growing sugarcane, sesame, or other crops and may import it to their home areas (46). A 2015 MIS using microscopy reported 0.4% malaria prevalence among people of all ages who travelled away from their home in the month preceding the survey and 0.5% among those who did not travel (7). Though there have been increased efforts to tackle malaria transmission in Amhara Region, travelers that are difficult to track, might be at greater risk of malaria infection and may extend its elimination from certain areas, or may even introduce malaria in areas where it had been eliminated (49). The understanding of travel risk for malaria (50) and identification of malaria vectors (51) in meso-endemic settings with a high potential of introduced malaria is necessary for the control and elimination of malaria.

The contribution of house proximity to a water body on malaria infection is not known in villages around Lake Tana. Literatures showed that most unmatched and matched case-control studies that identified risk factors, particularly contribution of house proximity to a water body on malaria occurrence used a case definition based on rapid diagnostic test (RDT) positivity. However, this study applied a case definition based on microscopic examination, which is a gold standard method to diagnose malaria (52, 53).

Although several statistical analysis techniques have been employed previously to detect the independent predictors of malaria, particularly the contribution of house proximity to a directly observed water body on malaria occurrence (30, 45, 46, 54, 55), stratified analysis and matched analysis have not been used in combination yet to detect the independent predictors. Cochran Mantel–Haenszel stratified analyses (56, 57) by travel to malarious lowlands and HH elevation were employed in this study since they are widely suggested to eliminate confounding and describe effect modification on the relationship between house proximity to a water body and malaria occurrence. Besides, conditional logistic regression model, which is the standard tool for the analysis of matched case-control studies or data with small stratum-specific sample sizes (58, 59), was used for two reasons. The first is that conditional logistic regression has high power or decreased type one error compared with an unconditional logistic regression model. Secondly, the matched analysis gives unbiased estimate or good estimate by comparing the groups internally (60, 61). Moreover, age, which was used for frequency matching, was also included in the matched analysis to control the residual confounding that may come due to the use of broad age bands.

Malaria elimination may be facilitated with the help of finer geographic scale studies. Evidences revealed that house proximity to a water body has an inconsistent association with malaria transmission (45, 55, 62, 63). Thus, this study investigated its association by taking into account the average flight range (from the breeding site to the household) of the main vector in Africa, *An. gambiae,* which is around 500 meters (64-66). Association of house proximity to a water body with malaria occurrence can be well measured in under-five children population who do not normally travel for temporary work in areas where malaria is transmitted. This method of measurement can exclude imported cases. This helped to identify the determinants of locally acquired malaria among under-five children.

Besides, the contribution of house proximity to a directly observed water body on malaria occurrence based on the flight range of *An. gambiae* using Euclidean/straight line distance has not yet investigated (67, 68). In Ethiopia, several studies have explored the association of house proximity to a dam, water hole, natural pond or an irrigation farm with malaria occurrence (54, 55, 69, 70). However, this study investigated association of house proximity to various types of water bodies with malaria occurrence. Moreover, malaria vectors responsible for local malaria transmission were identified in the study area to supplement the information on contribution of house proximity to a water body. Understanding more about the relationship between house proximity to water bodies and malaria occurrence may help to identify risk groups and contribute to improving malaria elimination efforts by optimizing the delivery of limited resources to higher-risk populations (71, 72).

Several studies reported that increased child age associated with high malaria infection among under-five children (48, 73-77). In Ethiopia, a 2015 MIS also reported a higher malaria prevalence and slightly higher LLIN use in children below 36 months than children aged 36-59 months (7). However, there is no information about the odds of differential malaria risk between older and younger under-five children using matched case-control study in Ethiopia, particularly in the study area. In Ethiopia, there is no matched case-control study that explored the determinants of malaria among all age groups and under-five children.

Studies in Ethiopia showed that *An. arabiensis* predominantly rests indoors. *An. pharoensis* rests mainly indoors in lowlands but not in midlands and highlands. However, *An. funestus* complex is predominantly exophilic (18). *An. gambiae* complex has longevity of 3.4 to 12.5 days and peak biting activity between 1800 and 2100 hours (21, 78). Early evening period is also a peak biting time for *An. pharoensis* (78). *An. arabiensis* and *An. pharoensis* are mainly outdoor biters in this period (78). A study conducted by Balkew et al in 2010 reported that all of *An. gambiae* complex samples were identified as *An. arabiensis* by polymerase chain reaction (79). Another study by Kibret et al in 2017 identified *An. arabiensis* followed by *An. pharoensis* as the predominant species by using morphological characteristics (18). A study in south-central Ethiopia also identified the dominant *Anopheles* species on the basis of larval morphology under a microscope

(19). Similar other studies also identified the dominant *Anopheles* species using adult morphological standard keys (21, 44, 55).

Reasons that influence consistent utilization of LLINs are not known in HHs around Lake Tana. The ownership and use of LLINs is the primary prevention strategy for malaria transmission control in Ethiopia. A scoping review article in 2018 indicated that countrywide LLIN coverage was low, with 64% coverage in 2016 (12). A 2015 MIS reported low utilization of LLINs with only 45% of under-five children used in the night before the survey in malarious areas. In Amhara region, 54% of under-five children slept under an LLIN (7). Small-scale studies also showed low utilization of LLINs (26, 80, 81). A recent national study also reported the presence of major gaps between LLIN ownership and compliance in malarious areas (12). However, the reasons that influenced consistent utilization of LLINs have not yet explored qualitatively in Amhara region, particularly in the study area. Thus, this study explored the reasons that influenced consistent utilization of LLINs using phenomenological qualitative approach. Phenomenology is a best approach and method of inquiry which helps to exhaustively describe and qualify a phenomenon in everyday lived human experiences (82, 83). This method was chosen to explore the behavioral, demographic, socio-cultural, economic, livelihood, housing and net delivery related experiences of the community while using LLINs in the study area. Textual and structural analyses were carried out to get comprehensive meanings of the lived experiences of the interviewees on LLINs utilization (84). Besides, interpretive phenomenological analysis was used to understand lived experience of the community about non-consistent utilization of LLINs and how participants themselves make sense of their experiences (85). Understanding the reasons that influenced consistent LLINs utilization in detail has helped malaria control officials to increase net utilization and reducing malaria transmission (86, 87). In the absence of such credible evidence, it is difficult to eliminate malaria and to inform ongoing effective social and behavior change strategies to improve consistent use, as well as the design of appropriate follow-up LLIN supply strategies.

This study aimed to investigate the contribution of house proximity to water bodies, identify socio-demographic, socio-economic, housing characteristics, behavioral and malaria intervention factors on imported and locally acquired malaria, identify malaria vectors and explore barriers of consistent LLINs utilization in meso-endemic villages around Lake Tana, northwest Ethiopia.

1.3. Significance of the study

The world is trying to eradicate malaria through various strategies, including accessing Artemisinin-based combination therapy (ACTs) even to remote communities, improving laboratory diagnostic techniques up to molecular techniques that deploy in the field, delivering, encouraging, promoting and supervising LLINs utilization and application of IRS.

Identifying a hotspot is beneficial because there is an intense mosquito exposure and high levels of asymptomatic parasite carriage in the human population, which require maximum effort to deliver interventions for communities and the vector to control malaria (88).

In areas with low malaria incidence, passive case detection (PCD) may lead to the identification of HHs with more infections than others that can be a source of new infections. Malaria transmission model is complex that involves numerous factors, including human host, arthropod vector, *Plasmodium* parasite, environment and intervention factors (30, 88-90). For this reason, malaria prevention and control measures should be designed and delivered in line with the transmission model.

Determining the distance between HHs and the proximate water bodies where symptomatic malaria cases originate may help to define hotspots of malaria and contribute to improving malaria elimination efforts by optimizing the delivery of limited resources to higher-risk populations (71, 72). Similarly, investigating the role of socio-demographic characteristics, travel history, HH wealth, housing structure, and malaria intervention measures on malaria heterogeneity helps to deliver interventions wisely and economically. Thus, this study provides information on the determinants of malaria which helps national malaria control and elimination programmers in re-designing programs for malaria elimination in Ethiopia.

Moreover, identifying malaria vectors in a meso-endemic setting is important. Thus, this study provides useful information on vectors which supports the local malaria officers to deliver interventions according to the local distribution. This study was also designed to provide useful information on the effect of house proximity to water bodies on malaria among under-five children and the contribution of other underlying factors. On one hand, exploring the behavioral, socio-cultural, and socioeconomic contexts explaining why the community did not use LLINs consistently is valuable to facilitate malaria elimination and this study provides useful information on the reasons from the locals' perspectives. Hence, this information helps the local malaria officers to increase proper and consistent utilization coverage of LLINs in the local communities.

Thus, to deliver effective and efficient interventions and control strategies for malaria elimination, malaria control and elimination programmers require knowledge on all the underlying determinants of malaria such as travel history, sufficiency of malaria information for the community, and vulnerable age groups among under-five children, malaria vectors for local malaria transmission, and the reasons that influence consistent utilization of LLINs in local communities.

2. LITERATURE REVIEW

2.1. Malaria burden

Malaria is a disease caused by the five *Plasmodium* parasites; *P. falciparum*, *P. vivax*, *P. ovale*, *P. malariae* and *P. knowlesi* (4, 91).

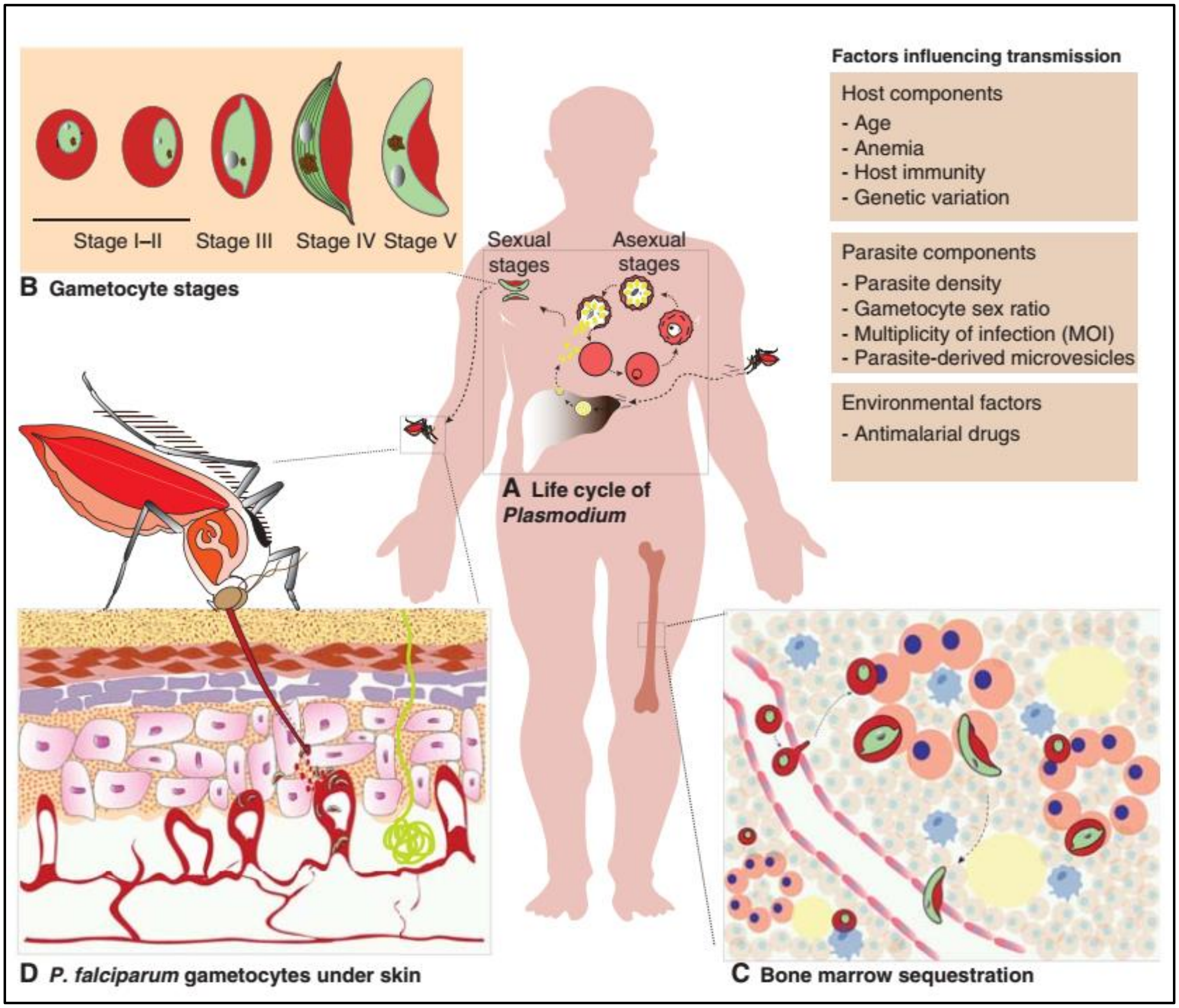

Figure 4: The *Plasmodium falciparum* life cycle in the human host (92)

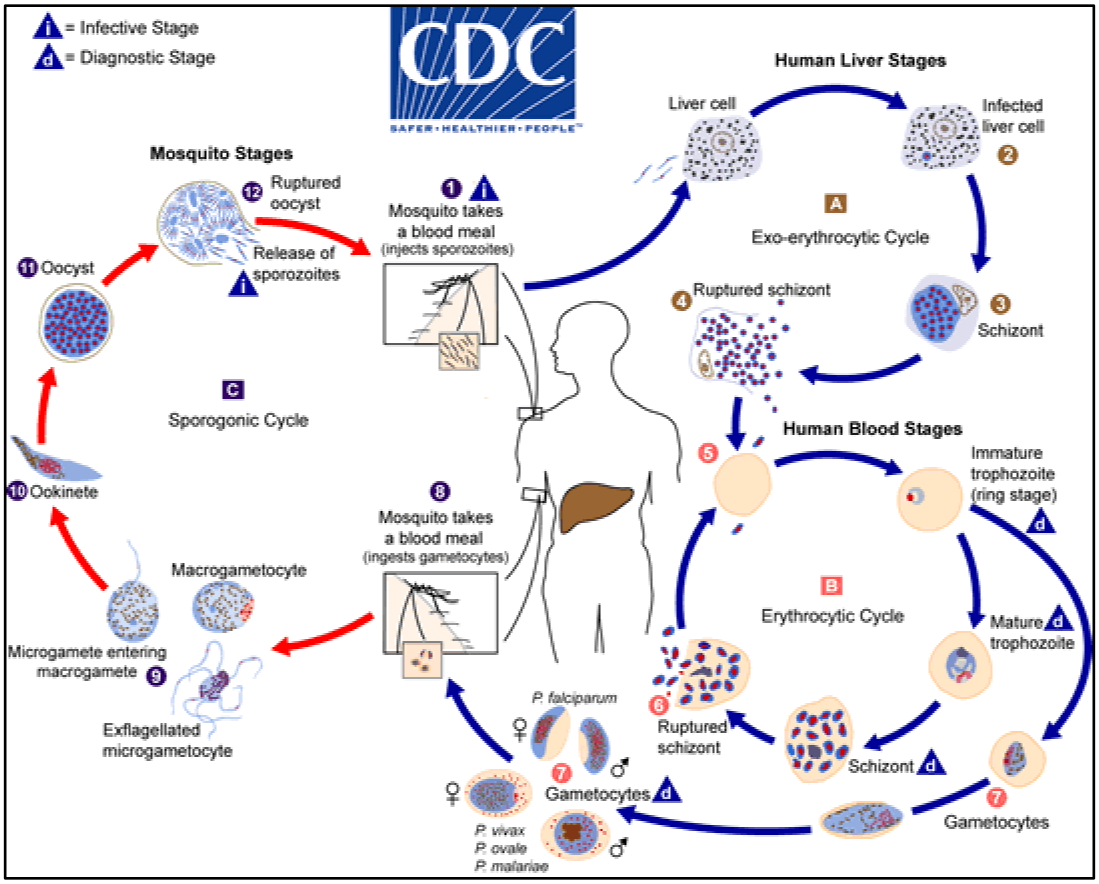

Figure 5: Malaria parasite life cycle (93)

Malaria is still a significant public health concern worldwide (3). A systematic analysis on global malaria trend showed that malaria deaths increased from 995, 000 in 1980 to 1.8 million in 2004, and declined to 1.2 million (42% in individuals ≥5 years) in 2010 (94). Another systematic review and analysis described that malaria was the third leading infectious cause next to pneumonia and diarrhea; with 7.3% (0.5 million) of deaths among children aged 1–59 months in 2013 (95). Between 2000 and 2013, mortality rate from malaria in children aged 1–59 months reduced by 4.5% per year globally. In 2030, under-five children mortality rate due to malaria is expected to be reduced to 1% compared with the 3.3% in 2013 (95). A systematic analysis for the Global Burden of Disease (GBD) Study reported that malaria mortality raised by 19.9% since 1990 (0.98 million) to 1.17 million deaths in 2010 and malaria was one of the leading causes of years of life lost due to premature mortality (YLLs) in 2010, similar to what was estimated for 1990. Similarly, 11.8% of post-neonatal and 20.8% (the most significant cause) of child (1-4 years) deaths due to malaria were estimated in 2010 globally. Besides, between 1990 and 2010, malaria had lowered in rank from ninth to eleventh among the top 25 causes of death globally (96).

An updated systematic analysis on causes of under-five mortality reported that malaria accounted for 5.2% of under-five deaths and 0.31 million deaths were estimated among children aged 1–59 months in 2015. Mortality rate due to malaria was reduced by more than 30% among children aged 0–59 months between 2000 and 2015 (97). Another systematic analysis on malaria incidence and mortality showed that malaria cases and deaths grew rapidly from 1990 reaching a peak of 232 million cases in 2003 and 1.2 million deaths in 2004, and declined to 165 million cases and 855, 000 deaths in 2013 (98).

A recent systematic analysis for the GBD Study indicated that malaria ranked 21^{st} from the leading 30 causes of global incidence in 2016 with 18% average change in age-standardized incidence rate from 2006–16 (99). A recent systematic analysis for the GBD Study 2017 reported that malaria caused 619,800 deaths with 31% reduction and 43.5 million YLLs with 35% reduction between 2007 and 2017. In 2017, there were 354,000 under-five deaths with 40% reduction between 2007 and 2017. Malaria was the 10^{th}, 7^{th} and down ranked again the 10^{th} leading cause of global YLLs for 1990, 2007, and 2017, respectively (100).

In Africa, a systematic analysis showed that malaria deaths increased from 493, 000 in 1980 to 1.6 million in 2004, declined by about 30% to 1.1 million in 2010. Malaria deaths in under-five children increased by about 3 times from 377, 000 in 1980 to a peak of 1.1 million in 2004 and reduced to 699, 000 in 2010 (94). Another systematic review and analysis described that 62% (1.9 million) deaths in under-five children were due to infectious causes in 2013, including nearly all global child deaths due to malaria (97%) in SSA. In 2000–13, significant reductions in under-five deaths had been observed in SSA, which was mainly attributed to malaria (21.7%) (95). A systematic analysis for the GBD Study reported that malaria remained one of the dominant causes of YLLs in SSA between 1990 and 2010. In Eastern SSA, malaria was the second leading cause of YLLs in 2010 (96).

Another systematic analysis on malaria mortality showed child deaths had decreased by 31.5% since 2004 in SSA (98). Another study also showed *P. falciparum* infection prevalence in endemic Africa halved and its incidence dropped by 40% between 2000 and 2015 (2). A recent systematic analysis for the GBD Study indicated that malaria ranked in the top ten for years lived with disability (YLDs) in 14 SSA countries. In eastern SSA, including Ethiopia, malaria was out of the leading ten causes of YLDs in 2016 (99).

Ethiopia had achieved a 50% reduction target of malaria of the millennium development goals (10). A time series analysis at hospitals indicated that malaria cases and deaths in Ethiopian hospitals decreased considerably during 2006–2011 in line with scale-up of malaria interventions (9). A systematic review indicated that malaria deaths of 22, 485 in 1980, 87, 163 in 2000 and 47, 507 in 2010 were estimated among individuals of all ages in Ethiopia (94). Similarly, in under-five-children, 15, 268 in 1980, 46, 918 in 2000 and 22, 165 malaria deaths in 2010 were observed in the country (94). Another trend analysis using GBD 2013 data showed that under-five mortality rate due to malaria had declined by 75% from 435 deaths/100,000 persons to 108 deaths/100,000 persons between 1990 and 2013 (5). Likewise, under-five mortality rate due to malaria ranked fourth in 1990 and sixth in 2013 (5).

A recent trend analysis showed that malaria was the ninth cause of age-standardized DALYs in 1990 but the fifty-ninth cause in 2015 (11). Similarly, premature mortality and disability rates from malaria dropped from 1764 age-standardized DALYs per 100,000 in 1990 to 154 in 2015 (11). A recent systematic review in 2017 reported that the number of DALYs due to malaria decreased from 2.2 million in 1990 to 0.18 million in 2015, with a total reduction of 91.7% and age-standardized DALY rate declined by 94.8% during this period (10).

A recent study explained that there was shrinkage in the malaria transmission map and high transmission was limited mainly to the western international border area between 2000 and 2016 (12). A 17-year trend analysis in northwest Ethiopia showed that a remarkable reduction of malaria during the last 17 years (101).

2.2. Determinants of malaria

2.2.1. Socio-demographic, economic and housing characteristics

Socio-demographic and socioeconomic factors have been reported in scientific literatures to making a population vulnerable to infection and contribute to the formation of residual reservoirs (43, 75, 102, 103). Socio-demographic variables such as age, occupational status, educational status and HH wealth were the most commonly reported determinants of malaria by numerous findings (46, 62, 102, 104, 105). A study carried out in high altitude villages in Ethiopia investigated that individuals aged above 15 years had statistically significant effect on the detection of malaria clusters (105). Another unmatched case-control study done in a neighboring district in northwest Ethiopia reported that individuals aged 15 years and above were at greater risk of malaria (106). A study that used a 2007 MIS conducted in Amhara, Oromiya and Southern Nation Nationalities and People regions of Ethiopia reported a unit increase in age implied a reduction of the odds of malaria by 3% (107).

A number of studies have associated increased age with high malaria prevalence among under-five children (7, 30, 47, 48, 75, 77). Studies in different countries showed that children aged 36-59 months were the most affected groups compared to below 36 months (48, 75, 76). A national MISs done in Malawi in 2012 and 2014 reported that the odds of testing positive for malaria parasites were higher among children who were 48 months of age or older than children below 48 months (77). A study conducted in highland Rwanda showed that malaria prevalence increased by 3% when the age of the under-five child increased by one unit (73). A 2014 MIS in Uganda revealed that malaria prevalence was significantly rose from under 6 months by 1.62 times among the age group of 7–12 months and to four times among those who were aged 49-59 months (74).

A matched case-control study in The Gambia among children found that children having a trader mother had 82% lower odds of malaria risk than those having a housewife mother and those having a farmer, trader, civil servant and handyman father had lower odds of malaria risk than children having a seasonal worker father (104). Maternal/caregiver schooling has been reported as a significant predictor of malaria infection in children (75, 76). A 2014 MIS in Uganda pointed out that malaria parasitaemia was lower among children that have educated mothers than children having mothers without any educational attainment (74). A study conducted in Burkina Faso among under-five children also evidenced children whose mother had higher education were at a lower risk of infection (47). A study that used a 2007 MIS involving Amhara, Oromiya and Southern Nation Nationalities and People regions of Ethiopia revealed that a unit increase in family size resulted in 5.1% increment in the number of persons infected by malaria in the HH (107). An unmatched case-control study in high altitude villages in Ethiopia revealed that those individuals leading their life in agriculture had 41% additional odds of risk compared with those employed in other occupations (46).

Several studies have reported that socio-economic factors significantly determine the risk of malaria infection (31, 62, 76). HH wealth index has been identified as a strong determinant of odds of malaria infection in under-five children (47, 75). A 2014 MIS in Uganda showed that malaria parasitaemia was higher among children having a family of poor HH wealth than the wealthier HHs (74). A national MISs done in Malawi in 2012 and 2014 reported that children coming from the poorest families were more likely to be infected (77). A study done in highland Rwanda indicated that having no such HH assets (cupboard, bicycle and radio) increased being infected with malaria compared with those owned these assets (73). A survey in Uganda reported that HHs that had electricity had lower odds of malaria infection among under-five children (76). Another Demographic and Health Survey (DHS) based study in Burkina Faso among under-five children also documented children from poorer HHs were more likely to be parasitaemic than children from wealthier HHs (47). Community based cross-sectional surveys conducted in Tanzania during the two main malaria transmission periods reported that low socioeconomic status (SES) and HH poverty were significantly associated with malaria prevalence (31).

Residential housing structure is reported to be a determinant for malaria infection (104, 107, 108). The 2014 MIS in Uganda identified that children lived in earth/sand or sand and dung made floor, and in finished walls or mud and poles/stone had higher odds of malaria infection than those lived in finished surface floor and unburnt bricks made walls (76). Several studies have also reported that individuals who lived in houses with mud walls (108), thatched and stick/mud roofs (107), earth/local dung plastered floors (107), and boarded windows (104) had higher risk of malaria. However, several studies evidenced that the nature of housing structure did not determine malaria transmission (30, 104). A study done by Woyessa et al in 2013 using multilevel analysis found that houses with holes had increased malaria infection (109).

2.2.2. Travel history

Human movement introduces malaria infections to areas targeted for elimination (49). Population movement has contributed to the spread of the disease, with the incidence of imported malaria increasing worldwide in conjunction with the greater ease of long-distance travel (110). Literatures showed that certain countries, such as those in West Africa and central Asia were much more strongly connected by relatively high levels of population and infection movement than others. In contrary, countries such as Ethiopia and Myanmar display significantly greater isolation in terms of likely infection movements in and out (111).

Travel away from home is the most independent predictor of malaria transmission (50, 112-115). A study that employed mathematical modeling and simulation quantified that even at low levels of receptivity, case management alone cannot reliably prevent re-establishment of *P. falciparum* malaria transmission in the face of medium to high importation rates (116). A retrospective study from 2002 to 2016, which used data through web-based reporting system, described that 93.2% were indigenous cases and 6.8% were imported cases (117). Another study done in Shandong Province, China using data of malaria cases during 2012-2014 reported no indigenous case for the first time since 2012 in the Province, a situation continued through 2014 and 95.2% of cases were imported from Africa (118). A study in Sri Lanka ascertained that the two clusters of imported malaria among a group of Pakistani asylum-seekers and local fishermen who returned from Sierra Leone had the potential impact on the risk of reintroducing the disease since importation is the only source of malaria in the country at present (51). A study done in Dubai, UAE free of endemic malaria identified 567 (90.1%) cases imported either from India or from Pakistan and 7% from SSA (119).

A study conducted in Singapore described a large cluster of 16 cases of imported *P. falciparum* malaria in visiting Nigerian students (120). Another study conducted in Singapore described that of the reported cases, 91.4% to 98.3% were imported, with about 90% originating from Southeast Asia and the Indian sub-continent and individuals needing work permit/employment pass holders had higher imported cases compared with local residents (121). A study done in Réunion Island from 2013 to 2016 reported that 95 imported malaria cases had been detected and affinity tourism in Madagascar and Comoros was the cause of 65% of imported malaria cases (122).

A time series analysis of data from 2001 to 2016 in Germany reported newly arriving refugees averaged 10 cases/year (1.5%) in 2001–13 and 292.5 cases/year (28.3%) in 2014–15 and total numbers of malaria notifications among native Germans and residents with migration background increased since 2007 (123). A study done at Academic Medical Center in Amsterdam, The Netherlands reported imported malaria in non-immune and semi-immune travelers acquired from SSA, Southeast Asia and Latin America (124).

A study done in Zanzibar investigated that residents traveling to malaria endemic regions were estimated to contribute 1–15 times more imported cases than infected visitors and the importation rate was estimated to be 1.6 incoming infections per 1,000 inhabitants per year (125). A prospective cohort study in Uganda revealed that among individuals who traveled, the incidence of malaria was higher in the first 60 days after traveling compared with individuals having periods without recent travel (1.15 vs. 0.33 episodes per person-year) (126). A cross sectional study in Zambia reported that out of 260 cases, 94.2% were classified as imported cases based on participants' travel history, and duration of stay in a highly endemic region and frequency of travel were significant determinants of malaria transmission and importation (127). A health facility based case–control study in highland, and highland fringe areas showed that in the highland site, patients who had travelled to areas of higher transmission intensity than their home areas recently were nearly seven times more likely to have malaria than those who had not and in the fringe site, there was also a statistically significant association between travel and malaria (128). A facility based matched case-control study in the western Kenyan highlands also found that travelling out of the study area was associated with increased risk (89).

A facility based cross-sectional study in Ethiopia also showed that history of travel to malaria endemic area was significantly associated with malaria positivity (129). Another unmatched case-control study conducted in a low transmission setting in Ethiopia identified that travel away from the home village in the prior month was a significant risk factor for infection with *P. falciparum* (130). An unmatched case-control study in high altitude villages in Ethiopia revealed that individuals who traveled away from their home in the previous month were 2 times more likely to be infected with malaria than who did not travel (46).

2.2.3. Interventional factors

The WHO recommends universal coverage for at risk populations with LLINs and targeted IRS for the control of malaria (4, 131). Both LLINs and IRS have been shown to be effective in reducing malaria transmission when applied alone (132). A study in Africa reported that malaria interventions had averted 663 million clinical cases between 2000 and 2015 and insecticide treated nets (ITNs) had averted 68% of cases (2).

2.2.3.1. Indoor residual spraying

Several IRS products have recently become available, including Actellic®300CS (Syngenta), and SumiShield®50WG (Sumitomo Chemical) (133). Besides, DDT, malathion, fenitrothion, bendiocarb and propoxur are the non-pyrethroid WHO-recommended insecticides for IRS against malaria vectors. Effectiveness of IRS product is relied on factors, including influence on vector populations (e.g., an ability to destroy mosquitoes from entering a sprayed structure); residual impact; place and timing of spraying (vector species and human behavior); and spray quality and coverage (134).

A study conducted in Mali indicated that two different non-pyrethroid insecticides: bendiocarb and pirimiphos-methyl rapidly reduced malaria incidence mainly in the first 2 months after spraying (135). An experimental trial on the efficacy of insecticides on various wall surfaces showed that pirimifos- methyl capsule suspension demonstrated a residual bioefficacy of over a period of 6 months on painted wood, unpainted wood, plastered cement, and unplastered cement surfaces. But, the pyrethroids (deltamethrin water-dispersible granules, alphacypermethrin suspension concentrate, etofenprox wettable powder [WP], and lambda-cyhalothrin WP, and the carbamate-bendiocarb WP showed a low residual bioefficacy (136). An experimental hut trial in Benin demonstrated that pirimiphos methyl CS (Actellic 300 CS) applied at 1 g/m^2 provided prolonged control of pyrethroid-resistant *An. gambiae*. However, pirimiphos methyl emulsifiable concentrate failed to kill *An. gambiae* two months after spraying. Lambdacyhalothrin also failed to control pyrethroid-resistant *An. gambiae* which entered the huts (137). Another study conducted in southwest Ethiopia identified that painted mud wall surface and standard spray showed better residual efficacy of propoxur than smooth and rough surfaces, and routine spray, respectively (138). An experimental hut trial in Ethiopia also showed that mixing bendiocarb in alkaline water did not reduce its residual bio-efficacy. However, it was effective much better on painted surfaces than on permeable dung or mud surfaces. Propoxur was less influenced by wall type than bendiocarb did (139).

A 2014 MIS in Uganda showed malaria parasitaemia was lower among children in which their houses were applied with IRS than children their houses were not sprayed (74). The 2014 Ghana DHS reported that the odds of malaria infection among children who slept in sprayed houses was significantly lower compared to those who are not protected (48). The 2014 MIS in Uganda showed that children whose houses got IRS in last 6 months had reduced odds of malaria risk when compared with those their houses were not sprayed (76). However, other studies evidenced that there was no significant association between IRS and malaria transmission (62).

In Ethiopia, a 2007 national MIS identified that not spraying of interior walls of houses with insecticide in the past 12 months increased malaria prevalence by six-folds (107). Another longitudinal study in south Ethiopia also explored that the time-span of the spatio-temporal clustering of malaria cases ended after IRS with Deltamethrin (32).

2.2.3.2. Long lasting insecticide treated nets

Various brands of LLINs have different characteristics such as durability, texture, mesh size, net size, shape and color, and insecticide effectiveness. Olyset® LLINs are stiff in texture, wrinkle after washing and have a large mesh size contrasting to PermaNet® LLINs. But, DuraNet® LLINs are durable and having small mesh size that avoided the unfavorable characteristics associated with Olyset® and PermaNet® LLINs (140). A mixed methods study conducted in Peruvian Amazon indicated that Olyset® LLINs' large mesh size, consequent transparency and perceived ineffectiveness, resulting in 63.3% of HHs not using any of the distributed LLINs (141). A study conducted in rural Kenya reported that 81.4% of Olyset® LLINs had an average of 34.2 holes and 15.2% of them were in good condition; 46.1% were moderately worn out and 38.7% were seriously torn after five years of utilization (142).

Sleeping under an LLIN the previous night was associated with reduction in odds of malaria risk (75). A 2012 national MIS in Malawi explored that children who did not sleep under LLIN last night had 1.4 times higher odds of parasitaemia than children who used LLINs (77). Another case-control study conducted in rural Malawi among under-five children found that bed net ownership lowered the occurrence of malaria infection (30). However, a matched case-control study in The Gambia among under-five children investigated that LLIN availability in the sleeping room or sleeping under it in the previous night did not predict malaria occurrence (104). Besides, a study conducted in Burkina Faso also marked that an ITN campaign was not associated with a decrease in all-cause mortality in under-five children (143). Several other studies also reported absence of statistical association between LLIN ownership or use and occurrence of malaria infection (48, 62). On the one hand, a study conducted in Tanzania during the two malaria transmission seasons showed contrasting findings on the effect of high community ITN ownership (31).

In Ethiopia, a 2007 national MIS showed HHs who were using mosquito nets were found to be at lower risk of malaria compared to the HHs who were not using mosquito nets (107). However, a longitudinal study in south Ethiopia evidenced that spatio-temporal clustering of malaria was not influenced by free mass distribution of ITNs (32). Studies also indicated absence of statistically significant association between LLIN ownership or use and malaria infection (46).

2.2.4. House proximity to water bodies

House proximity to a water body has an inconsistent contribution on malaria transmission (18, 50, 55, 62, 63). Several studies have concluded that closeness to a water body increased malaria risk. A spatial study in Huang-Huai plain, China estimated that 74% of malaria cases were located within the extent of 60m proximity to the water bodies and the risk rate of presenting with malaria was significantly higher than those distant from water bodies (144). A population based case-control study done in northwestern Peruvian coast identified that proximity to a water drain (<200 meters) was significantly associated with case-HHs (71). Another cross sectional study done in Burkina Faso among under-five children reported that children living beside a water gathering pond had higher odds of malaria infection (145).

Another spatio-temporal analysis of malaria in Mali pointed out two "hot spots" of malaria transmission, notably along a river, characterized by higher than expected numbers of malaria cases, and high numbers of clinical episodes per child (146). A cohort study among children in Kampala, Uganda also ascertained that children living in the swamp had around 4 times greater risk of malaria than did children living 200 meters away and 2 statistically significant clusters of high malaria risk was occurred within the swamp (147). A facility based matched case-control study in Kenyan highlands investigated association of higher malaria risk with living <250m of a swamp (89). Several other studies also revealed HHs far from water bodies had lower infectious bites and getting lower risk of malaria (148-150).

In Ethiopia, a population-based cohort study in Adama, Ethiopia also supported the evidence with the presence of one temporally stable spatial malaria cluster within 350m of a major *Anopheles* breeding site and compounds within 350m of the site were estimated to have higher malaria incidence compared with compounds >350m from the site (151). Another longitudinal study evidenced that spatial clusters were formed in HHs closer to a vector breeding site and individuals who lived closer to the vector breeding site were at increased risk of malaria infection (32).

Another study conducted in central Ethiopia revealed that monthly malaria incidence, sporozoite rate and annual entomological inoculation rate were significantly higher in the irrigated villages than the non-irrigated villages (44). A study done by Kibret et al at different eco-epidemiological settings in Ethiopia found that mean monthly malaria incidence and anopheline larval density was generally higher in the dam villages than in the non-dam villages in all the three altitude-stratified dam settings (18). A study done by Nissen et al using Cox regression modeling also showed strong evidence of association between proximity to breeding site and *P. vivax* infection resulted in higher rate of infection among the group closest to the breeding site (<2100m) compared with the group furthest away (>2700m) (45). An unmatched case-control study done in a neighboring district in northwest Ethiopia indicated that proximity to stagnant water determined malaria transmission dynamics in a meso-endemic setting (106).

On the contrary, other studies have documented that HHs have lower malaria risk near surface water. A study done around the Gilgel Gibe hydroelectric dam in southwest Ethiopia reported that incidence of *P. falciparium* and *P. vivax* exhibited increment with distance from the dam up to five kilometers (152).

Some studies have reported that malaria risk is independent of house proximity to water bodies. A Bayesian geostatistical modeling of MIS data of Tanzania showed the non-significant association of distance to nearest water body with the risk of parasitaemia (62). Another Bayesian geostatistical modeling using national malaria survey data found that distance to water body had no significant association with *P. falciparum* prevalence (153). A longitudinal cohort study in Gilgel Gibe hydroelectric dam in southwest Ethiopia with frailty models evidenced *P. falciparum* malaria incidence showed no statistically significant association with distance from the dam reservoir (55).

On the other hand, studies have indicated a greater dependence of HHs malaria risk on local topographic wetness indices than land uses and land covers (63).

2.3. Malaria vectors

Water bodies, which are the mandatory places for malaria vector breeding, play a central role for malaria transmission through increasing mosquito abundance. Mosquitoes need water for reproduction whereas turbulent water can wash away larvae population. Optimum temperature range for the development of *Anopheles* mosquito and *Plasmodium* parasite is approximately between 20°C and 30°C, with thermal death occurring at temperatures either below 16°C or above 40°C (154).

Anopheles mosquitoes breed at the river and stream edges, in temporary rain pools, in ponds, dams, drainage ditches, burrow pits, rice fields, swamp margins and roadside puddles, and in tree holes close to human dwellings (155-157). *An. arabiensis* commonly breeds in small, temporary, sunlit, clear, and shallow fresh water pools, although it also breeds in a variety of other habitats, including slow flowing, partially shaded streams, large and small natural and man-made habitats, turbid waters, and brackish habitats. Its density is seasonal across Ethiopia, increasing during the wet months (15, 21). *An. pharoensis* mostly inhabits lakes and reservoirs. It breeds in large, vegetated swamps, lakeshores, floating plants, rice fields, streams, ditches and overgrown wells (15, 20, 158). *An. funestus* breeds in a large, permanent or semi-permanent fresh water with emergent vegetation, such as swamps, large ponds, and lake edges (15, 158). Both *An. arabiensis* and *An. pharoensis* have been found breeding in regions up to 3000 meters above sea level (masl) (19, 159).

A review literature and other relevant resources resulted in the collation of information for seven dominant species in Africa, including *An. arabiensis*, *An. funestus*, *An. gambiae*, *An. melas*, *An. merus*, *An. moucheti* and *An. nili* (17). A study conducted by Coetzee and colleagues identified two new members of the *An. gambiae* complex, *An. coluzzii* and *An. amharicus* based on chromosomal, cross-mating and molecular evidence (160). A study done in rural western Kenya identified *An. gambiae* complex as the main vector species accounting for 86% followed by *An. funestus* (148).

An. arabiensis is the only malaria vector from the *An. gambiae* complex involved in malaria transmission in Ethiopia (18, 19, 79). *An. pharoensis* has a sympatric distribution with *An. arabiensis* and *An. funestus*, whereas *An. nili* has a much more restricted ecological niche (15).

A study conducted in irrigated and non-irrigated villages in the Ziway area, Central Ethiopia found that *An. arabiensis* was the predominant species followed by *An. pharoensis* and *An. coustani* (44). An altitude stratified study in Ethiopia also characterized that *An. arabiensis*, *An. pharoensis*, and *An. funestus* complex were the most common species, largely collected from lowland and midland dam villages (18). A study done in Gilgel Gibe hydroelectric dam in southwest Ethiopia identified *An. arabiensis* as more abundant in villages nearer to the dam reservoir (55).

A study conducted by Animut et al in a highland area in south-central Ethiopia described *An. cinereus* (32.5%), *An. arabiensis* (31.4%), *An. chrysti* (23%), *An. demeilloni* (12.2%), *An. pretoriensis* (0.6%), *An. azaniae* (0.1%), *An. rufipes* (0.1%), *An. sergentii* (0.06%), *An. garnhami* (0.06%) and *An. pharoensis* (0.03%), and the density of *An. arabiensis* decreased with elevation (19). Another study done by Balkew et al in central, northern and southwest Ethiopian villages characterized that all *An. gambiae* complex specimens were identified as *An. arabiensis* using polymerase chain reaction assay (79). Another study conducted in Gorgora, northern Ethiopia where near this study was carried out characterized *An. pharoensis* Theobald (20).

2.4. Barriers of consistent utilization of LLINs

The use of LLINs is a widely accepted method (23), and the most universally available intervention to prevent the disease in Africa (24), which is also a primary prevention and control strategy in Ethiopia (7, 25), and promoted as an effective approach to minimize risk of malaria transmission. Worldwide, studies have revealed major benefits from LLINs ownership and use (161-163). A recent systematic review and network meta-analysis characterized that use of ITNs is most effective for the prevention of malaria incidence (164). In Ethiopia, the most vulnerable groups, who are under-five children and pregnant women, have been prioritized to use LLINs (7). A 2015 national MIS reported that LLIN use varied among under-five children, with younger children using them slightly more often than older children (7).

Socio-demographic, socio-cultural, behavioral, economic, livelihood, housing and net delivery related reasons, misconceptions and weather conditions were documented in many findings as determinants of consistent utilization of LLINs (25, 36, 39, 165, 166). A systematic reviewed article by Pulford et al in 2011 summarized that discomfort primarily due to heat and perceiving low mosquito density (most common), sleeping elsewhere, or not sleeping at all, finding it inconvenient to hang, and the temporary unavailability of a normally available mosquito net primarily due to someone else using it as self-reported reasons for not using a mosquito net regularly among net 'owning' individuals (39).

A qualitative study in the Peruvian Amazon explored that embedding malaria within their culture, perceiving a shift in mosquito biting times to early evening, a consensus that malaria prevention was the government's responsibility, confusion on the purpose of space-spraying and persistence of misconceptions on cause of malaria and best practices for prevention were the determinants of net utilization (167). A qualitative study using in-depth interviews in Papua New Guinea explained that indifference resulted from lack of fear of malaria infection cultivated through lived experience was emerged as the most influential impediment towards regular net use (168).

A multi-country analysis of reasons for LLIN attrition described that of nets that left the HHs, they were discarded with low repurposed use and given to or taken by relatives and non-relatives (169). Positive experience prior to distribution, appreciation of a range of benefits, social support from within the community, and rectangular nets incompatibility with sleeping spaces and house type were identified as important reasons in determining continued use of LLINs in a study done by Strachan et al (165). This study also identified more consistent net use amongst settled urban and rural communities compared with fishing, pastoralist, refugee and immigrant communities (165).

An in-depth interview with female and male caretakers of under-five children revealed that stuffiness and low mosquito density were the main barriers that interrupted consistent bed net use. Nevertheless, caretakers perceived that LLINs had high self-efficacy and did not influence their sustained use and IRS was not identified as an alternative for bed nets (166). A qualitative study in Zanzibar among primary health care providers and local residents reasoned out that insufficiency of distributed LLINs and inadequate malaria education with an expression of desire for more education by residents as barriers for continued use of bed nets (170). A focus group discussion (FGD) study among individuals aged ≥18 years cited that feeling uncomfortable or trapped, perceived difficulty in breathing, or itching/rashes were the frequently mentioned reasons not to use a net consistently (171).

A qualitative study in four Ugandan districts during away from home also mentioned the contextual reasons for not using nets consistently. These were social barriers such as fear of appearing proud and social disapproval, logistical barriers such as not having a place to hang a net and time to grab net, crowding and congestion, and resource limitations such as not having an additional net to use during travel (172). Another qualitative study in Senegal documented that respondents reported the age of net, the number and size of holes and the presence of mosquitoes in the net at night were used to assess useful net life. This study also showed many respondents preferred getting a new net rather than using a very torn net consistently and participants reported observing alternative uses of nets, primarily for nets that were considered expired (173). A qualitative study conducted in eastern Rwanda also detailed the reasons for not using LLINs consistently. These comprised of increment of bedbugs (and the associated irritability), uncomfortable warmness particularly during the dry season and widespread use of LLINs in constructing chicken pens or as fences around vegetable gardens (174).

LLINs have a short lifespan, developing tears and holes and losing insecticide over time. Field studies showed that the useful life of a net might be varied between 18 months and 7 years, with a mean expected life span of 3 years (175, 176). A study conducted in Rwanda showed 58% of the LLINs needed replacement after two years and net serviceable life was actually closer to two rather than three years (177).

Perception of malaria vectors cannot harm, malaria is no longer a problem, dirtiness, aging and deterioration of LLINs and perception of losing their insecticidal activity after washing, and bedbug and flea infestations were mentioned as critical determinants of consistent utilization of LLINs (165, 171, 174). Insufficient information about LLINs, malaria transmission, and malaria vectors resulted in wrong perceptions, ignorance and negligence that led to non-persistence LLIN utilization (38, 177, 178). Studies also evidenced the preference of conical shaped nets by communities and suggestions to develop portable and user friendly nets to increase consistent utilization of LLINs (39, 174, 179).

Another study done in Southeast Nigeria found that LLIN use was significantly lower in individuals who did not get social support and exposure to a malaria-related social behavior change home visit, had increased education level, increased malaria knowledge level and reporting any disadvantage of bed nets (37). A study conducted in two differential malaria transmission sites in western Kenya explained that accessibility, preference of purchasing nets, perception of bed net use only in the rainy season, difficulty of utilization, attitudes that taking malaria drugs is easier than using a bed net and that use of a bed net will not prevent malaria were the leading barriers to LLINs use (178).

In Ethiopia, a qualitative study pointed out that rectangular shaped nets due to incompatibility with sleeping arrangements and house style, sleeping arrangements except beds, low risk perception, fear of chemical in LLINs, saving nets for future use, using for unintended purposes, lack of awareness and negligence, perception of low efficacy of the LLINs, insufficiency and mal-distribution of LLINs which contributed to failures to use LLINs regularly (25). A study done by Doda and colleagues also elaborated absence of collateral benefits, misuses and repurposed uses of LLINs as reasons for not using LLINs consistently (36). A longitudinal study done in south Ethiopia evaluated that before mass net distribution, having worn out bed nets whereas after mass ITN distribution, lack of convenient space to hang more than one ITN were the most frequent reasons for not using ITNs, and males and younger age groups (mainly 15–24 years) were less likely to use ITN (180).

A cohort study in south-central Ethiopia explored that LLINs were discarded, given away, worn out and used for other purposes before serving for the expected life span. Only 4% of 1532 distributed LLINs met the criteria for functional survival by the 24^{th} month, with a median functional survival time of 12 months (181). Another study conducted in southern Ethiopia indicated that inadequacy of nets per family size, dirtiness, lower education, oldness, having holes and lack of awareness on installation and its importance were the barriers for net utilization (182).

Moreover, a HH survey during malaria season in Amhara and Oromia Regional States of Ethiopia found that HHs residing in a house not getting IRS, having aged ITNs (>12 months), and having rectangular shaped nets were less likely to use nets consistently. Likewise, qualitatively, presence of few mosquitoes around or malaria is not a serious problem; perception of the ITN is no longer effective; poor condition of the ITN; saving of ITN and unintended uses were also stated as reasons for not using nets consistently (183). Another study conducted in Ethiopia reported that knowledge of malaria, and school attendances were significantly associated with increased ITN use (184).

2.5. Conceptual framework

The conceptual framework of this study was developed based on extensive review of the literature relevant to the research problem, to summarize all objectives of the study. As illustrated in the diagram below, the conceptual framework depicts the relationship between determinant factors (socio-demographic and economic variables, housing characteristics, behavioral and environmental factors, malaria interventional factors and reasons influencing consistent utilization of LLINs) for malaria infection occurrence (**Figure 6**).

Reasons (behavioral, demographic, socio-cultural, economic, livelihood, housing, LLINs distribution related) that influence consistent utilization of LLINs were explored using in-depth interviews which indirectly affect occurrence of malaria. The malaria vectors were identified, which play a critical role on the occurrence of locally acquired malaria.

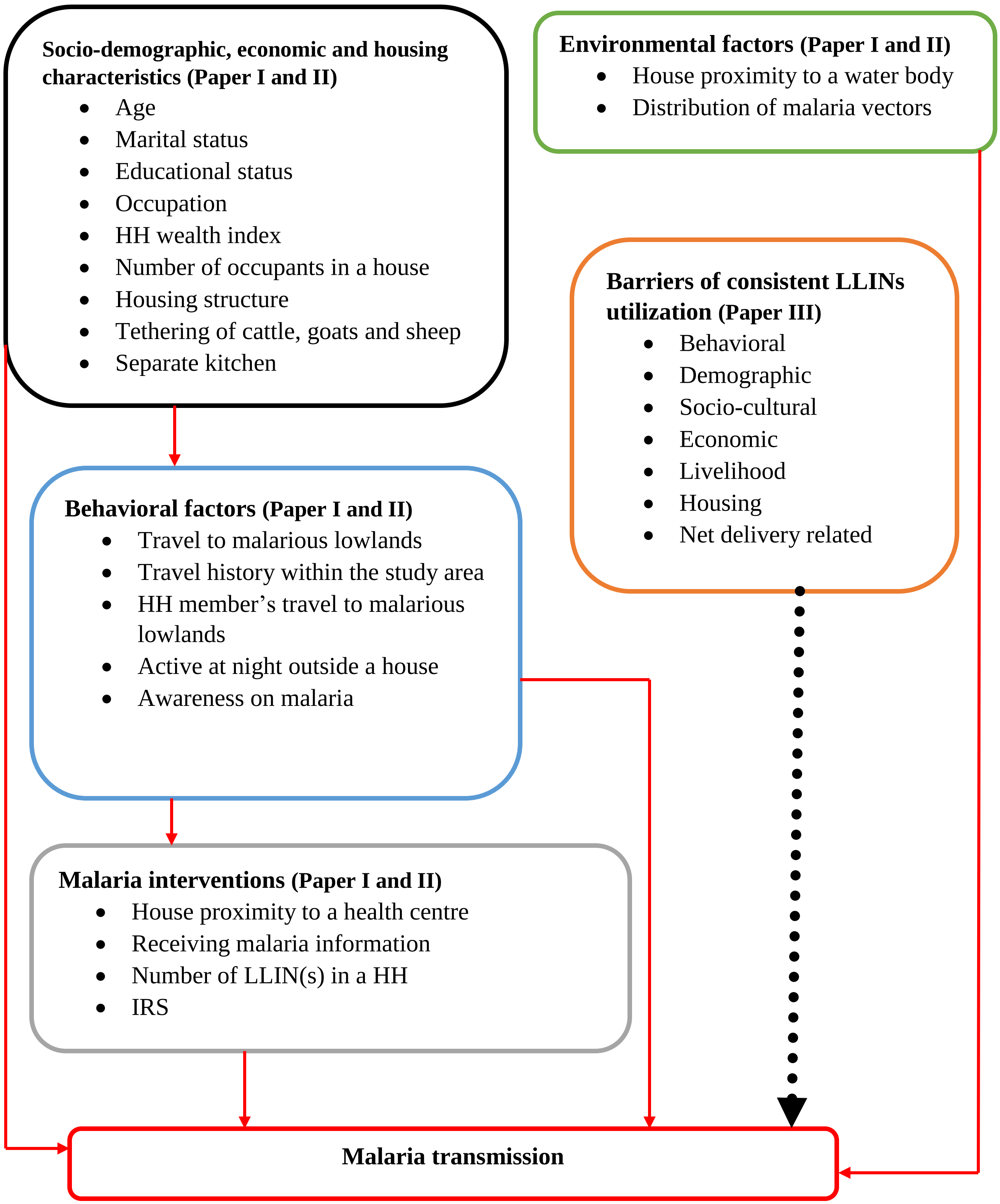

Figure 6: Conceptual framework for the determinants of malaria in its transmission model (185), and reasons influencing consistent utilization of LLINs

3. OBJECTIVES OF THE STUDY

3.1. General objective

The main objective of this dissertation was to investigate determinants of malaria transmission, malaria vectors and reasons affecting consistent utilization of LLINs in meso-endemic villages around Lake Tana, northwest Ethiopia

3.2. Specific objectives

- ✓ To investigate the contribution of house proximity to a water body and other underlying drivers on malaria occurrence
- ✓ To identify determinants of malaria among under-five children and malaria vectors
    - To identify the determinants of local malaria among under-five children
    - To identify malaria vectors in villages around Lake Tana
- ✓ To explore barriers of consistent utilization of LLINs

4. METHODS AND MATERIALS

4.1. Study area

The study was undertaken in 11 *kebeles* (the lowest administrative units in Ethiopia) of Gondar *Zuriya* District and 1 *kebele* of *Dembia* District, northwest Ethiopia (**Figure 7**). Out of 37 *kebeles* in Gondar *Zuriya* District, eight are not endemic for malaria. In 2016/2017, Gondar *Zuriya* and *Dembia* districts had a projected population of 222, 700 and 315, 390, respectively. The area of Gondar *Zuriya* District is 1108.5 km^2, with a population density of 188.4 persons/km^2 (186). Gondar *Zuriya* District is composed of hilly and plain landscapes, and the altitude ranges from 1750 to 2600 masl over three highland fringe zones. Subsistence agriculture is the main occupation of the inhabitants. The main crops in the study area are wheat, sorghum, *teff* and chickpea. Fertilizers, pesticides, and anti-weed chemicals are commonly used for agricultural purposes. Eucalyptus vegetation is common along the streams and the highly available wood for house construction. The study area has two malaria transmission seasons: the major transmission season follows the June–September rains, September to December, and the minor transmission season occurs between April and May, following the February–March rains. In 2016, total rainfall, mean maximum temperature, mean minimum temperature and relative humidity in the study area were 1047.6mm, 27.4^0C, 14.7^0C, and 45%, respectively (187). Gondar *Zuriya* District has seven health centers and 38 health posts that provide healthcare services for the population in the district.

Since 2004, guidelines on malaria case management in the country have recommended treatment based on parasitological diagnosis with microscopy and/or RDTs. Artemether-lumefantrine has been the first-line drug in Ethiopia since 2004. Since 2013, primaquine has been recommended in line with elimination plans to target gametocytes for *P. falciparum* transmission reduction (15). Chloroquine is recommended to treat vivax malaria and primaquine for radical cure. Seasonally, large numbers of malaria cases are occurred from September to December in northwest Ethiopia, mostly *P. falciparum* infections, following the June to September rain (188). In Gondar *Zuriya* District, large numbers of individuals travel to malarious lowlands for temporary work at commercial agricultural farms, mainly during the rainy and spring seasons (49). Males aged ≥15 years are the main travelers to the lowlands (49). A trend analysis (2002–2011) conducted in a neighboring district reported 23,473 malaria cases (75% *P. falciparum* and

25% *P. vivax*) with a fluctuating trend. From 2010 to 2011, *P. falciparum* prevalence decreased while *P. vivax* prevalence was increasing, indicating a trend shift. Males and those aged 15–44 years had been highly affected (188). Another study conducted in three districts reported 61.3% malaria prevalence (72.3% *P. falciparum* vs. 27.7% *P. vivax*) microscopically (189). A recent spatio-temporal analysis in northwest Ethiopian districts revealed a purely temporal high malaria cluster from July 1, 2015 to December 31, 2016 and significant spatio-temporal malaria cluster were identified in Dembia District from January 1, 2014 to December 31, 2017 (190). There is annual IRS application and distribution of LLINs, with replacement being done every three years. IRS has started since 2005. Recently, Bendiocarb or Propoxur has been used for spraying interior walls of houses alternatively and LLINs have been distributed since September 2005. Besides, filling with earth and drainage of larval breeding sites, removal of temporary water containment materials and cutting grasses have been practiced for larval control in the study area.

The study area has altitudes of 1750-2500 masl (191). The climate of Lake Tana basin is of the temperate tropical highland type (192). Most rain falls between June and September (192). The water of Lake Tana is turbid and the lake's shores are becoming covered with water hyacinth. Gumara Stream flows from east to west and into Lake Tana, irrigating extensive commercial garlic farms along its course. The irrigation water is pumped using generators, causing a substantial decrease in river flow during the dry season (October to February). The reduction in river flow creates stagnant areas, potential breeding habitats for mosquitoes.

4.2. Study designs and study periods

Mixed methods (quantitative and qualitative) were employed. A health facility-based paired-matched case-control study was undertaken from October 10, 2016, to June 30, 2017 to investigate the contribution of house proximity to water bodies and other underlying drivers on malaria occurrence (**For objective I**). Cases and controls were individually matched by sex. However, groups of malaria cases were matched with groups of controls based on the respected age categories (<15 years, 15-49 years and >49 years), which is called frequency matching by age. These three age categories of control selection criteria were somewhat consistent with previous studies (46, 89, 105).

Another health facility-based paired sex-matched case-control study was carried out from October 10, 2016, to June 30, 2017 to find out the association between child age and house proximity to a water body with locally acquired malaria occurrence among under-five children (**For objective II**). Correspondingly, *Anopheles* mosquito larvae survey was conducted from April 30, 2017 to June 24, 2017 to identify malaria vectors in the study area. The immature mosquitoes were collected during the autumn season (southern hemisphere) from various types of water bodies (**For objective II**).

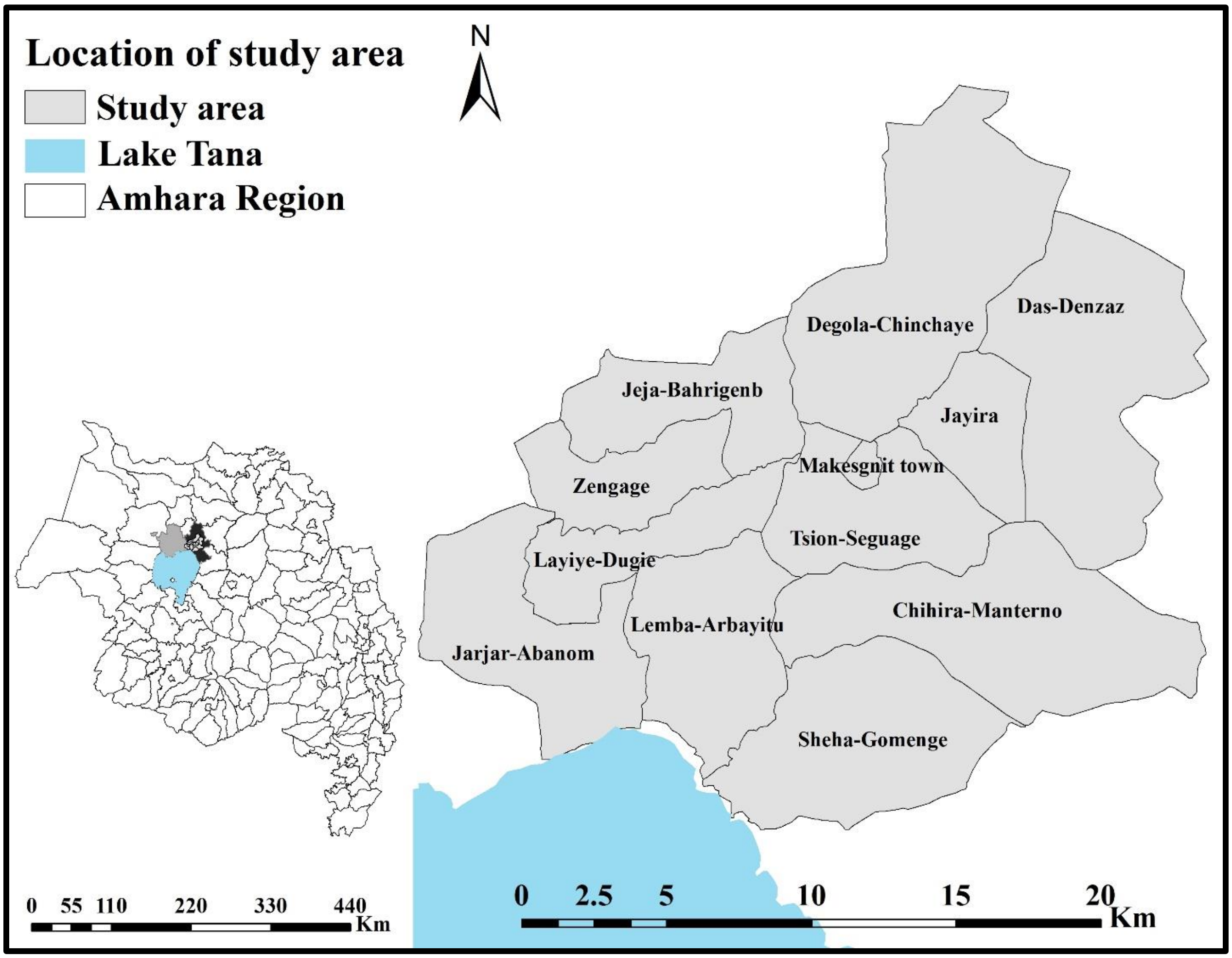

Figure 7: Geographic location of study area around Lake Tana, northwest Ethiopia

A phenomenological qualitative approach was undertaken from April to June 2017 to explore the local contexts, perspectives and reasons that influenced consistent use of LLINs. Phenomenology is a best approach and method of inquiry which helps to exhaustively describe, interpret, illuminate and qualify a phenomenon in everyday human life experiences (82). This method was chosen to explore the behavioral, demographic, socio-cultural, economic, livelihood, and housing situation, as well as net delivery related experiences of the community. Since LLINs utilization reveals lived experience of the communities, interpretive phenomenological approach was used (**For objective III**).

4.3. Sample size determination and study population

Sample size was computed using matched case-control study design sample size calculation methods (**For objective I)** (193-195). The sample size was computed with an assumption of 95% level of confidence, 80% power to detect exposure difference between cases and controls, odds ratio (OR) of 1.61, one control per case pairing, and assuming that 25% of the control-HHs were located within a 250m radius of water bodies (71).

Using the following formula (193), the required number of malaria cases were computed as follows:

$$n= \frac{(M+1)\,[Z_{\alpha/2}(1+OR)+2Z_{\beta}\sqrt{OR}]^2}{[2M(OR^2-1)\ s(f,OR)]}$$

Where $s(f, OR) = \frac{(OR-1)\,f(1-f)}{[(1-f)+f(OR)]}$, and f is the prevalence of the exposure factor in the population and is approximately equal to $P_{c'}$ (prevalence of the exposure factor among control groups).

Based on these assumptions, a total of 666 (333 cases and 333 controls) study participants could be included in the study.

All patients 5 months of age or older who visited *Lemba* and *Makesegnit* health centers and permanent residents in the study *kebeles* were considered. The patients (malaria cases and controls) were included into the study based on the clinical signs and symptoms of malaria and blood slides results. When patients came to the health centers for treatment, clinical diagnosis was performed for malaria. Then, the presence of *Plasmodium* parasites in the blood samples was confirmed using malaria microscopy. When a malaria case was found, the matched control was obtained from the patients by confirming through clinical diagnosis and slide results within three days after the case was diagnosed. Individuals who had no *Plasmodium*-positive blood film or symptoms of malaria during the preceding month confirmed using patient interview or health centre register were enrolled in the control group. Individuals with new episodes of malaria or people with recrudescent cases that presented after one month or more of the initial infection, and those who had taken malaria treatment in the previous 30 days were excluded from the study.

Sample size was computed using matched case-control study design sample size calculation methods (193) with an assumption of 95% confidence level, 80% power to detect exposure differences, OR of 2.37, one control per case, and assuming that 30% of the control-HHs were located within a 500m radius of water bodies (**For objective II)** (71). A total of 180 (90 case-control matched pairs) under-five children could be included in the study. The power for the actual sample size (81 matched pairs) was found to be 77%, which is almost similar with the commencement of the study.

Under-five children (5-59 months old) who visited *Lemba* and *Makesegnit* health centers were enrolled as cases and controls. Cases were patients who had signs and symptoms of malaria or reported fever during the previous 48 hours and were positive for single- or mixed-*Plasmodium* species in a blood sample examined microscopically. Controls were individuals presenting at the health centers whose thick blood smear tests were negative for malaria. When a malaria case was found, a matched control was obtained by confirming the clinical diagnosis and slide results within 3 days the case was diagnosed. Besides, the procedures for eligibility of under-five children into the study were similar with Objective I. Regarding entomological survey, *Anopheles* mosquito larvae collection was performed at seven representative potential breeding sites with three rounds across the study *kebeles*. The larvae survey sites were *Sara Wonez* and *Ferkit*, *Adiga*, *Woyenareb*, *Barengua* and *Kanuye*, *Ferenji Wuha*, *Derchit*, and *Embileba*.

Seven *kebeles* (*Lemba-Arebaytu*, *Layeye-Dugie*, *Zengage*, *Jeja-Bahriegeneb*, *Tsion-Seguage*, *Sheha-Gomenege* and *Makesegnit Town*) were purposefully selected by the researcher **(For objective III)**. Informants in the study *kebeles* were included based on ranges of criteria such as permanent residence and having LLINs user experience. The sample consisted of two groups: 23 community residents and 38 key informants. The sample size was estimated on the basis of richness, detailed nature and volume of data collected; relevant published literature; scope of study; and the amount of useful information obtained from each participant (196). Saturation, the most widely used principle for qualitative sample size determination, was achieved with this large sample due to the heterogeneity of the participants and the broad scope of the study. Proportional numbers of HHs were included from the seven *kebeles.* Then, community residents comprised of HH heads from a range of backgrounds and ages and both genders and lactating women were included. The key informants were people with knowledge of malaria control; distribution of LLINs in the study communities; and residents' living conditions, beliefs, and behaviors. They were 5 health professionals responsible for the prevention and control of malaria at *Makesegnit* and *Lemba* health centers and Gondar *Zuriya* District Health Office, 8 health extension workers (HEWs) who worked in the seven selected *kebeles*, 19 district/*kebele*/village leaders appointed by the local government, and 6 students. Village leaders were enlisted to recruit participants with support from a researcher to ensure a representative sample.

4.4. Data collection and quality assurance

Microscopic examination was used to confirm the presence of *Plasmodium* species in the clinically diagnosed patients (197) (**For objective I & II)**. Microscopy is the gold standard method of diagnosing malaria (52). Confirmation of malaria positivity or negativity of slide results was assured using standard operating procedures of Giemsa malaria microscopy at the health centers (**Annex 1**). Thick blood film was used to search for malaria parasites while thin film was used to confirm the malaria parasite species when this could not be done in the thick film. Patients were selected and classified as cases or controls based on the eligibility criteria. Cases were patients who had signs and symptoms of malaria or reported fever during the previous 48 hours and were positive for single or mixed *Plasmodium* species in a blood sample diagnosed by microscopy (197). Controls were individuals presenting at the health centers whose thick blood smear tests were negative for malaria. Experienced microscopists who were certified by the Ethiopian FMOH double checked all the slides at the health centers.

All tested slides (negative and positive) were stored at the health centers and three quarters of the slides were collected randomly for quality control. Blind examination of the slides was independently performed by a senior technician at the University of Gondar Specialized Hospital Laboratory. The quality control results showed 98.5% inter-rater agreement and kappa coefficient of 0.97 with the results at the health centers (p <0.0001). Discordant results were reread by a third senior technician and this result was taken as the final result.

A pre-tested, semi-structured intensive literature review-based questionnaire was used to collect individual and HH level data. The questionnaire consisted of questions/variables on socio-demographic characteristics, ownership of HH assets, housing characteristics (roofing, floor type, wall type, window type, presence of separate kitchen), ownership, utilization and condition of LLINs, status of IRS, travel to malarious lowlands and travel away home within the study area in the prior one month, and awareness of caregivers/guardians regarding malaria (transmission and prevention methods) (**Annex 2**). Males who completed grade 12 collected the individual and HH data through HH visits. The data were collected through face to face interviewing of HH heads or caregivers/guardians or the study participants themselves and direct observation for selected variables. Data collectors and supervisors were adequately trained on how to collect house to house data for cases and controls for three days. Study subjects were quitted from the study because they could not be contacted using the addresses they gave to the data collectors at the health centers during diagnosis; due to inability of getting matched controls for cases within three days, and because of refusal to be included in the study.

Geo-referencing (latitude, longitude and altitude) of case-HHs, control-HHs, the two health centers, small water bodies, a part of the shore of Lake Tana, and larval sampling habitats was recorded through a handheld GPS device (Garmin's GPSMAP 60CSx, Garmin International Inc., USA) with an accuracy goal of 5m. Geographic coordinates and altitudes were also recorded in notebooks and checklists. Field data collectors were blinded to the malaria status of the study subjects. Practical training was given for field data collectors on how to operate a GPS device. The questionnaire and checklist were prepared in English, translated into the Amharic language, and open responses from the study participants were translated to English.

Regarding entomological survey, *Anopheles* mosquito larvae were collected from the breeding sites in the study *kebeles* (**Figure 8** and **Table 1**) (**For objective II)**. The four *Anopheles* mosquito stages/instars: I, II, III, IV were collected from natural and man-made breeding sites (**Figure 9** and **Table 1**). The immature stages were collected using kitchen strainer and transferred to wide-mouthed 1L capacity plastic container that its 3/4th filled with water. The sampling was done using the standard dipping method according to WHO procedures (198) and an improvised dipper (199) which is suitable for small breeding sites such as, animal hoof prints. Scooping methods involving shallow skim, partial submersion, complete submersion, flow-in-method, scraping, simple scoop and salt marsh method were also applied for larvae collection. Ten to 13 dips were taken depending on the surface area of the larval habitat, at intervals. Samplings were done by the same individual in the morning (1100-1400 h) for about 30 minutes at each larval habitat. The larvae were immediately preserved in plastic jugs and taken to a laboratory for rearing (198).

In the entomological laboratory/insectary, homogenous larvae were separated and allowed to acclimatize in deionised water half-filled in a tray (25 cm X 12 cm X 12cm). In the laboratory, larvae were provided with finely powdered Tetramin® fish food (Fish Keeping, Melle, Germany) at 3:1 ratio as a source of food.

Once the larva reached the pupa stage, they were collected separately and kept in an adult emergence cage. The rearing of anophelines was maintained at 27±1°C, 65–70% relative humidity, and a photoperiod of 12-hour light and 12-hour dark in the laboratory. The adults that emerged within 1-4 days were killed by dehydration using silica gel desiccant inside beakers and stored at room temperature for identification. *Anopheles* larvae rearing and adult species identification were done in the General Entomology Laboratory, Department of Biology, University of Gondar. Each adult *Anopheles* mosquito was individually identified to species and species complex level using morphological characters within 24 hours of hatching (200).

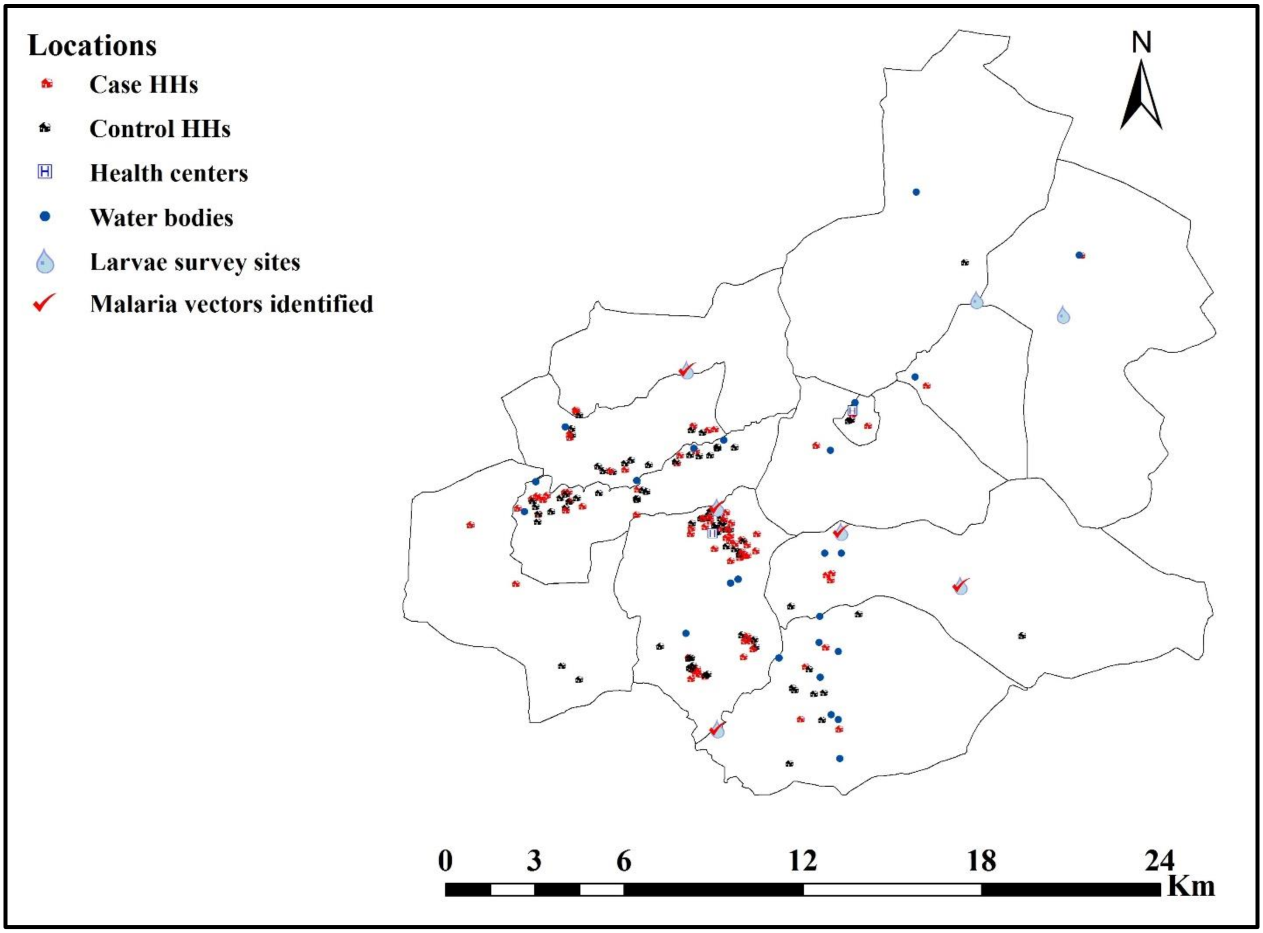

Figure 8: Location of HHs, health centers, water bodies and sites where malaria vectors were identified

Adult specimens were placed individually on microscopic slides and identified under a dissecting microscope with a 10x objective using standard adult mosquito morphological identification keys developed for the Anophelinae of Africa south of the Sahara (200). The standard operating procedures for *Anopheles* mosquito larvae collection, rearing and identification is attached as **Annex 3**.

Individual in-depth interviews and key informant interviews were conducted to obtain the perspectives on consistent LLIN utilization (**For objective III)**. This study wished to obtain a wide range of views and therefore sampled from different villages in communities around Lake Tana. In-depth interviews were undertaken with HH heads, lactating women, HEWs, local leaders, students, and health professionals. In-depth interviews were conducted in the local language, Amharic, and lasted up to one hour each.

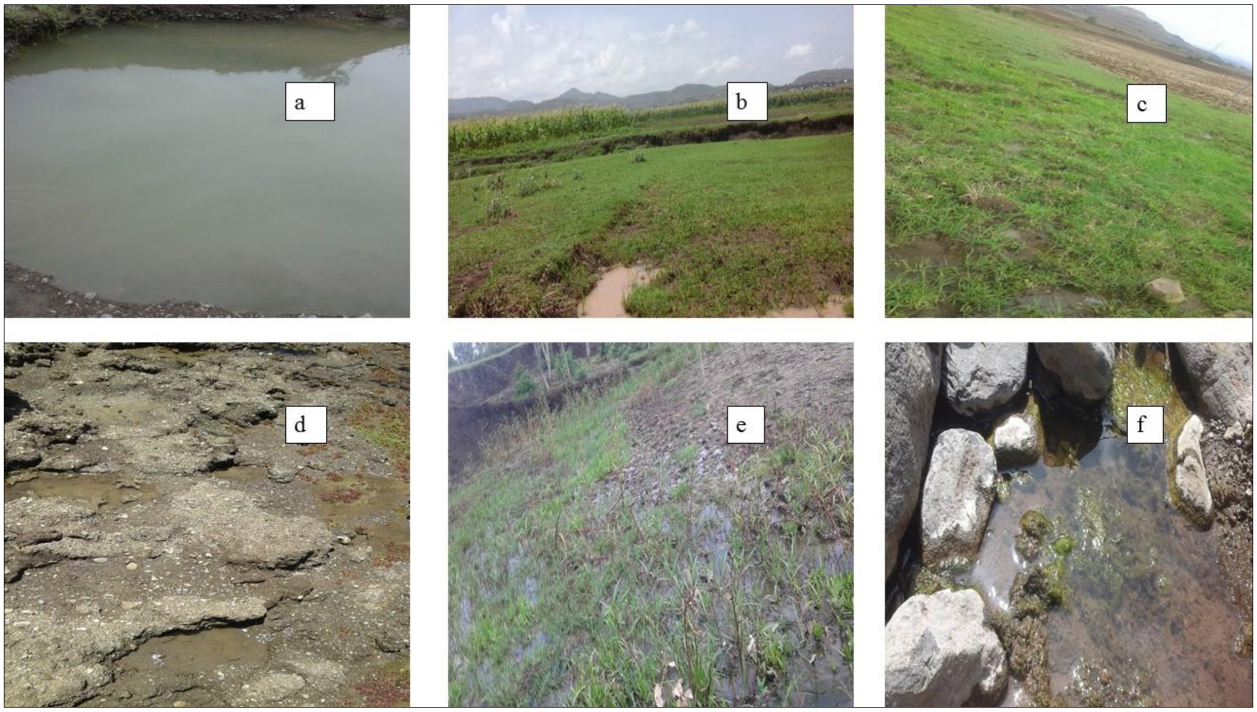

Figure 9: Larvae survey sites: a) Deep stagnant water in dry season; b) Puddles in stream overflow; c) Artificially created reservoir gradually changed into swamp; d) Hoof prints in the stream edge; e) Natural swamp and f) Streambed

The interview guide focused on reasons that affect consistent utilization of LLINs, HH members that get priority for use, types of sleeping spaces inside the house, outside and away from home, sleeping time under a LLIN, perceived strengths and weaknesses of LLINs, and suggestions that enhance proper utilization of LLINs (**Annex 2**). The interviewers (the researcher and local translators) were adequately prepared in the use of the interview guide with open questions and probing for more detail. Several probing questions and techniques were used to get more elaboration and investigating the phenomenon completely. Questions were followed in a consistent way for each interview. All individual in-depth interviews and key informant interviews were done using a digital voice recorder.

Table 1: Physical characteristics of larval sampling sites in villages around Lake Tana, Ethiopia, April-June 2017

Survey site	Geographic coordinates*	Round	Date (dd/mm/yy)	Characteristics
Sara Wonez & Ferkit	1836 12.35561 37.51133	First	30/04/17	Permanent, small muddy streams flowing very slowly; black soil; sampled from the edges of the streams where animal hoof prints were created; algae present in the stagnant waters; sediment with clay soil coming from the mountainous areas; water source for domestic animals; plain topography with some hills
		Second	31/05/17	Turbid and shallow water body having run-off transported sediments; the soil erodes easily; the animal hoof prints created during the dry season were filled by the sediments; the newly run-off created stagnant waters in gorges had larvae
		Third	23/06/17	Collected two weeks after the heavy run-off from all water body types, including deep stagnant large water bodies; larvae formed a bunch on clear large stagnant waters
Adiga	1874 12.348273 37.548854	First	03/05/17	A small perennial stagnant pool in the gorge; completely covered with green algae; having bushes along the slope of the gorge; plain topography
		Second	29/05/17	Run-off puddles; turbid muddy stagnant waters; collected from shallow stagnant waters and absent in deep stagnant waters; extensive erosion of cultivated lands
		Third	24/06/17	Run-off made small and large stagnant waters; collected two weeks after heavy run-off at small and large stagnant waters; clay-muddy water
Woyenareb	1783 12.28862 37.51152	First	08/05/17	A small stream having stagnant water during the dry season; located near Lake Tana; creates muddy swampy areas and has animal hoof prints; sandy seepage holes created for community water source; collected from the water holes and hoof prints; presence of irrigation farms (collections twice a year) starting from the source downstream to Lake Tana to produce garlic, onions, maize and *teff*; plain topography
		Second	02/06/17	Hoof prints and water holes filled by run-off sediments; collected from shallow stagnant waters from runoff; irrigated maize planation by the stream & Lake Tana
		Third	21/06/17	Run-off created large and small muddy water bodies; originate from mountains; run-off overflow created stagnant waters on the cultivated lands where the larvae were collected; fast run-off water

Barengua & Kanuye	1848 12.397069 37.502195	First	11/05/17	Stagnant waters and swampy areas covered with algae (larvae were denser); black, muddy soil; irrigation farms (twice a year): garlic, onions, and peppers are produced; no potable water supply for the communities; plain topography; collected from cattle hoof prints in the swamps
		Second	30/05/17	Not having a mountainous source; larvae found in the edges of swampy areas where hoof prints created
		Third	19/06/17	No run-off in the three successive sampling times; sampled from animal hoof prints in sandy soil
Ferenji Wuha	1960 12.33197 37.58500	First	12/05/17	Manmade water reservoir for irrigation but currently not functional; having no exposure to run-off; forms muddy swampy area downwards; having short and long grasses, and algae, used for grazing during the dry season; presence of animal hoof prints; hilly topography
		Second	29/05/17	After the heavy rains, the grasses grown tall since cattle get alternative grazing land; not easy to get mosquito larvae; the swampy area changed into grass land
		Third	24/06/17	Having long grasses, sampled after rain
Derchit	2038 12.41381 37.61596	First	14/05/17	Small stream flowing slowly year-round; small sandy & gravel enriched stagnant waters on the edges covered with green algae; presence of trees & bushes; presence of irrigation farms (potatoes, garlic, & onions); clay soil; hilly topography; collected on the edges of the slowly flowing stream
		Second	28/05/17	Collected from small stagnant waters created by run-off
		Third	19/06/17	Unable to find *Anopheles* mosquito larvae because of the heavy run-off
Embileba	1994 12.41827 37.58977	First	14/05/17	A small, slow flowing, perennial stream; presence of sandy & muddy stagnant waters on the edges; covered mainly with green algae; presence of bushes; presence of animal hoof prints; garlic cultivation through irrigation downstream, plain topography with steep valleys
		Second	28/05/17	The stream edges and hoof prints, which had green algae, were filled with run-off water sediments
		Third	19/06/17	Stagnant waters created by run-off

*altitude (masl), latitude and longitude (in degree decimals) of the larvae sampling site, respectively; dd/mm/yy: day/month/year

Variable measurements: Presence of a water body within a 250m radius from a house was the primary exposure variable, the remaining variables were covariates **(For objective I)**. The outcome variable was malaria status of a study participant, which is dichotomous/binary variable; malaria positive or negative (malaria case or control). Imported malaria cases were defined as cases which acquired the infection outside the area in which it is diagnosed. Locally acquired malaria cases were defined as cases who acquired the infection locally by mosquito-borne transmission and which can be indigenous or introduced (201). Two nearby water bodies (rivers, streams, marshes, swamps, stagnant water, natural pools, springs and water holes) to each case-HH and control-HH presented during the environmental survey were geo-referenced (**Figure 10**). The water bodies were either permanent or temporal and randomly labeled as water body 1 and water body 2.

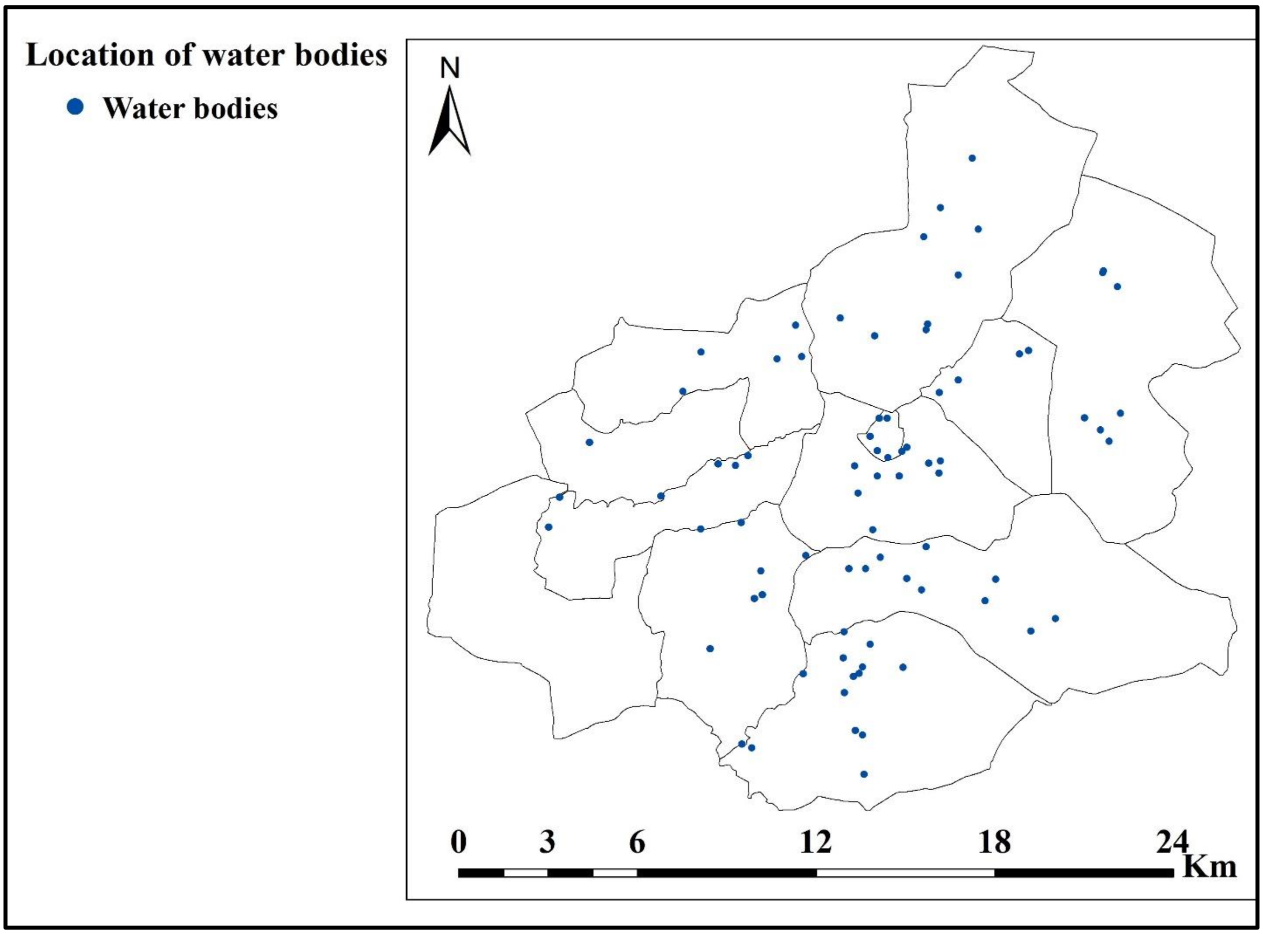

Figure 10: Location of proximate water bodies to case HHs and control HHs

For distance computation from the HH to the water bodies and health centers, decimal degrees were changed into Universal Transverse Mercator (UTM) using World Geodetic System (WGS) _84 Datum in the standardized MS Excel function. For the purpose of analysis, house proximity to water bodies (house proximity to water body 1, house proximity to water body 2 and house proximity to a water body) and health centers was computed as Euclidean (straight line) distance using GPS coordinates (67, 68). The average flight range of the main vector, *An. gambiae* is approximately 500 meters (64) and used as a base to create a dummy variable for distance. For this study, house proximity to a water body was categorized into three distance bands (<250m, 250-500m and >500m) (65). The Euclidean distance of each HH to the health centre was categorized as a dichotomous explanatory variable (≤5km and >5km) (202).

HH wealth reflects a composite of several dichotomous and polychotomous variables that used to indicate the SES of the HH. Variables that used for HH wealth index construction were developed on the basis of literature review (203, 204) and the Ethiopian DHS (205). Ownership of longer-run and shorter-run HH assets, type of housing structure, water supply source, ownership and type of sanitation facility, ownership and amount of agricultural land, ownership of domestic animals, and having a savings account (25 variables) were used to construct the wealth index. The values of the indicator variables were weighted ranging from 0 to 1 indicating the lowest and the highest values, respectively.

Variable measurements: Presence of a water body within a 500m radius from a house was the primary exposure variable, others were covariates **(For objective II)**. Two nearby water bodies (rivers, streams, marshes, swamps, stagnant water, natural pools, springs and water holes) to each case HH and control HH presented during the entomological survey were geo-referenced (**Figure 8**). The water bodies were either permanent or temporal and randomly labeled as water body 1 and water body 2.

For distance computation between the HH and the water bodies, decimal degrees were changed into UTM using WGS_84 Datum in the standardized MS Excel function. For the purpose of analysis, house proximity to water bodies was computed as Euclidean or straight line distance using GPS coordinates (67, 68). For this study, house proximity to water bodies was categorized into two distance categories (≤ 500m and >500m) (65). To determine the contribution of house proximity to a water body on locally acquired malaria, a third variable, presence of a water body within a 500m radius was derived from the two geo-referenced water bodies.

HH wealth index is a composite of several variables that can indicate the SES of the HH. Variables for the construction of the index were included based on the established scientific literature (203) and the Ethiopian DHS (205). HH head's educational status, longer-run and shorter-run HH assets, type of housing structure, water supply source, ownership and type of sanitation facility, ownership and amount of farmland, ownership of domestic animals, and having a savings account were used to construct the index. The values of the variables were weighted ranging from 0 to 1 indicating the lowest and the highest values, respectively.

4.5. Data management and analysis

Data were double entered, validated, coded, cleaned, and verified using EpiData Version 3.1 software (EpiData Association, Odense, Denmark). Data analyses were carried out using SPSS statistical software version 22 (IBM Corp. IBM SPSS Statistics for Windows, Armonk, NY, USA) and STATA version 14.0 (StataCorp. Statistical Software: College Station, TX 77845, USA). The maps of case-HHs, control-HHs, health centers, proximate water bodies and larvae survey sites were plotted using ArcGIS 10.5 (206). Microsoft Excel 2016 (Microsoft Corp., Redmond, WA, USA) was used to compute distance from the HHs to water bodies and health centers by developing a distance function, and a relative difference between the crude and adjusted ORs.

Descriptive statistics; *n* (%) and *n*, (% [95% confidence interval (CI)]) were computed for categorical variables. Median and interquartile range (IQR) were also calculated for continuous variables across malaria status. Categorical variables were cross-tabulated across malaria status through chi-squared or Fisher's exact tests to detect significant differences in proportions between cases and controls. Fisher's exact test was also used to test distributional differences of *Anopheles* mosquitoes across the larvae survey sites. All reported *p*-values were two-tailed and considered statistically significant if $p < 0.05$.

Principal component analysis (PCA) was used to estimate HH wealth (203). PCA is a multivariate analysis used to reduce the number of variables in a data set into a smaller number of dimensions. From an initial set of *n* correlated variables, PCA creates uncorrelated indices or components, where each component is a linear weighted combination of the initial variables. From a set of variables X_1 to X_n,

$PC_1 = a_{11}X_1 + a_{12}X_2 + \ldots\ldots + a_{1n}X_n$

$PC_m = a_{m1}X_1 + a_{m2}X_2 + \ldots. + a_{mn}X_n$, where a_{mn} represents the weight for the *m*th principal component and the *n*th variable (203).

The weights for each principal component were given by the eigenvectors of the co-variance matrix. The variance for each principal component is given by the eigenvalue of the corresponding eigenvector. The components are ordered so that PC_1 explains the largest possible amount of variation in the original data, subject to the constraint that the sum of the squared weights ($a^2_{11} + a^2_{12} + \ldots\ldots + a^2_{1n}$) is equal to 1. As the sum of the eigenvalues equals the number of variables in the initial data set, the proportion of the total variation in the original data set accounted by each principal component is given by $(\frac{Variance}{n})$. The higher the degree of correlation among the original variables in the data, the fewer components required to capture common information (203).

Principal component 1 was used to rank the HHs into three groups. Cutoff values/rank categories were set for the three groups. The original variables were transformed into scores having a mean equal to zero and standard deviation equal to one (standardization). The value of each standardized variable was multiplied by principal component 1 and a third variable created from the product for each variable. Finally, a HH wealth score was computed from the sum of the third variables. Based on the cutoff values of principal component 1 ranks, a final three-category HH wealth index variable was developed. The composite score was classified into tertiles, with the higher tertile reflecting higher wealth **(For objectives I and II)**.

The Cochran Mantel Haenszel (CMH) stratified analyses were employed to eliminate co-factors, and to discover and describe effect modifiers. CMH test is widely used to measure the strength of the association between an exposure and disease or response, after stratifying on the observed covariates and observed confounders are accounted for in the analysis. The data are stratified into multiple 2×2 tables by known confounders, where in each stratum the distributions of the confounders in both groups are similar (207).

Mantel Haenszel test of equality of stratum-specific ORs was used to identify effect modifiers. First, the equality of stratum-specific ORs were checked to confirm significant differences, which indicate the presence of effect modification between the exposure and other factors. If not different, the presence of confounding was then assessed. The Mantel–Haenszel test produced a single weighed estimate of the predictor by adjusting the effects of the third variable and the crude estimate. Then, presence of confounding was ascertained through degree of difference between the crude OR and adjusted OR. Magnitude of confounding is popularly evaluated by examining the relative change in estimated effect size before and after adjusting for the possible confounder. The difference in effect size is divided by the adjusted effect estimate, providing the magnitude of the difference, relative to the unadjusted effect size. For confirmation of confounding presence, a relative difference in the effect estimate with a cutoff of ≥10% was used (208, 209). The following formula was used for computation of the relative difference between the crude OR and adjusted OR.

Relative difference = $\frac{(|\,AOR - COR|)}{AOR} X100\%$

Where, AOR and COR stand for adjusted odds ratio and crude odds ratio, respectively (209). HH elevation and travel to malarious lowlands were considered as a stratifying variable to confirm whether they were effect modifiers, or confounders, or not **(For objective I)**.

Conditional logistic regression models were fitted to identify independent predictors of malaria among all age groups, and locally acquired malaria among under-five children **(For objectives I and II)**. The conditional logistic regression model is the standard tool for the analysis of matched case-control studies. It allows for the analysis of data with stratified samples. Matched case-control study is the commonly used stratified study design. Like other regression models, it allows for multiple variables, continuous exposures, confounding, and effect-modifying variables to be handled appropriately (58). It is designed for the analysis of data with small stratum-specific sample sizes (59). Since this study was employed pair matching (1: 1), the conditional likelihood for the kth stratum is given by

$$l_k(\beta) = \frac{e^{X_{1K}\beta}}{e^{X_{1K}\beta} + e^{X_{0K}\beta}},$$

Where, β is the coefficient, X_{1k} is the data vector for the case and X_{0k} is the data vector for the control (59).

Since frequency matching for age was applied during data collection, age would have been included in the matched multivariable model to eliminate the residual confounding effect that may come from broad age categories (**Objective I**). Through a matching variable for cases and controls, a matched analysis was employed to explore factors associated with malaria infection. The statistical modeling strategy estimated unadjusted matched odds ratio (mOR) and adjusted mOR of the studied variables with malaria infection at 95% CI. A bivariable matched analysis was executed for each variable; those variables having $p < 0.2$ along with variables having biological plausibility were included in the multivariable matched model (210). mORs with 95% CI and *p*-values were estimated for the multivariable matched analysis and variables at $p < 0.05$ were considered as statistically significant and independently associated with malaria infection. Goodness of fit of conditional logistic regression model was checked by clfit test through a package added from internet by a command findit clfit. Multicollinearity diagnostics were done by adding a package collin to exclude variables from the multivariable matched analysis.

Digital recordings of in-depth interviews were transcribed through verbatim and translated from Amharic to English by the researcher and the local translators. Qualitative data management and analysis were done using NVivo Version 10 (QSR International, Melbourne, Australia). Thematic analysis was used (211, 212) (**For objective III)**. The data were content-coded for thematic analysis. Initial coding was done based on preset categories on the basis of literature (36, 165) and emerging themes were derived from the data. The coded data were analyzed by querying to determine the frequency of occurring concepts, themes and relationships. Themes summarize the responses, and the words of the interviewees were presented in Word Clouds to illustrate key findings; quotes were taken from the interviews to illustrate the contextual quality of the findings. Textual and structural analyses were carried out to get comprehensive meanings of the lived experiences of the interviewees on LLINs utilization (84). Textual analysis refers to the description of what is expressed by the interviewees while structural analysis stands for the interpretation of how it is expressed by the interviewees. Interpretive phenomenological analysis, which was used to understand lived experience of the interviewees about non-consistent utilization of LLINs and with how participants themselves make sense of their experiences, was employed (85).

4.6. Ethical considerations

The study protocol was approved by the Ethiopian Institute of Water Resources, Addis Ababa University Institutional Review Board, and the Ethical Review Committee of Wollo University. The committee provided ethical approval after reviewing the informed consent forms submitted with all components of the research protocol. A support letter from this institution was given to the Amhara National Regional State Health Bureau, which in turn issued a support letter to District Health Offices and requested cooperation to run research activities effectively. Written consents from each District Health Office and study *Kebele* were also obtained before starting data collection for the current study. The informed consent or assent was included on the front page of the questionnaire below the briefing statements (**Annex 2**).

5. RESULTS

5.1. Role of house proximity to water bodies and other drivers on malaria

5.1.1. Socio-demographic and housing characteristics

Six-hundred six patients (cases and controls) participated in the study, giving a response rate of 90.9% and their HH geo-location was mapped (**Figure 11**). Half of the malaria infections, 152 (50.3% [44.5-55.8]), were *P. vivax* mono-infections while the other half (48.8%) were *P. falciparum* mono-infections, with only few mixed infections. Of the 303 malaria cases, 199 (65.7% [61.8-69.4]) were males and their median (IQR) age was 18 (4.42-30) years. The majority of malaria cases had houses with corrugated iron roof, 287 (94.7% [91.5-96.7]); mud-made wall, 296 (97.7% [95.2-98.9]) and dung plastered floor, 294 (97.0% [(94.4-98.5]) (**Table 2**).

5.1.2. Travel to commercial agricultural farms and other behaviors

Of the 303 malaria cases, 59 (19.5% [15.4-24.3]) were imported malaria whereas 244 (80.5% [75.7-84.6]) were locally acquired. Eighty three (13.7% [11.2-16.7]) travelled to malarious lowlands (Metema, Shehedi, Abderafi, Abrahajira, Humera, Maikadera, Dansha, Belessa and Fogera) in the preceding month. From those who travelled to malarious lowlands, 55 (66.3% [55.2-75.8]) were engaged in agriculture. The main reason for travel, cited by 75 patients (90.4% [81.7-95.2]), was to seek temporary jobs. Most of the travelers, (82, 98.8% [91.6-99.8]), were males; 58 (69.9% [59.0-78.9]) were 15-29 years of age; 39 (66.1% [52.8-77.3]) had *falciparum* malaria; and 42 (50.6% [39.8-61.4]) lived at elevations between 1901 and 2100 masl. Almost all the study patients, 603 (99.5% [98.5-99.8]) had been active at night (6pm to 12pm/1700 – 2300 h) outside the home in the preceding month. Seventy (11.6% [9.2-14.4]) took anti-malarial drugs presumptively (**Table 3**).

5.1.3. Intervention measures of malaria

The median (IQR) distance from house to health centre of the patients was 3.6 (0.9-5.3) km. Fewer than one-third of the patients, 185 (30.5% [27.0-34.3]) owned at least one LLIN per HH. Of those patients who had LLINs, 123 (66.5% [59.3-73.0]) reported having slept under a LLIN the night prior to the interviews. Overall, 451 (74.4% [70.8-77.8]) reported that their houses had been sprayed with IRS in the preceding year (**Table 4**).

5.1.4. Proximity of HHs to water bodies

Two hundred twenty-four (73.9% [(68.7-78.6]) of the case-HHs were located at an altitude between 1701 and 1900 masl. Only 18 (5.9% [3.8-9.3]) of case-HHs were located within 2 km of Lake Tana. Likewise, 28 (9.3% [6.4-9.13.1]) case-HHs had a water body within a 250m radius (**Table 5**).

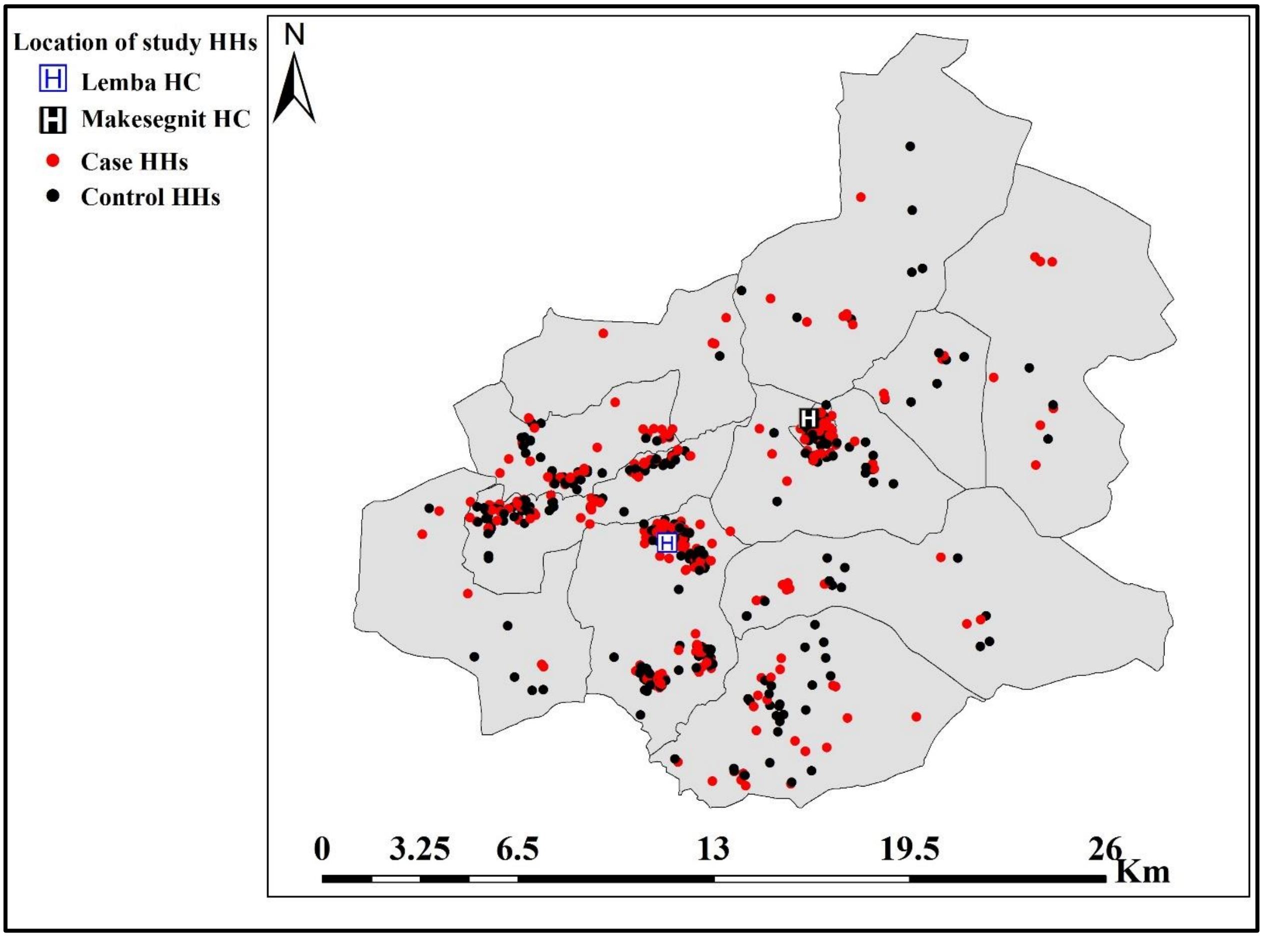

Figure 11: Location of case-HHs, control-HHs and health centers

Table 2: Socio-demographic and housing characteristics of cases and controls in villages around Lake Tana, Ethiopia, October 2016-June 2017.

Characteristic	Cases (n=303) n, %(95% CI)	Controls (n=303) n, %(95% CI)	Total n, %(95% CI)	Pearson's X^2/ Fisher's exact test**
Age (years) [‼]	18(4.42-30)	20(3-33)	19(4-30)	
<15	119, 39.3(33.9-44.9)	119, 39.3(33.9-44.9)	238, 39.3(35.5-43.2)	0.188
15-29	108, 35.6(30.4-41.2)	90, 29.7(24.8-35.1)	198, 32.6(29.0-36.5)	
30-44	42, 13.8(10.4-18.3)	62, 20.5(16.3-25.4)	104, 17.2(14.4-20.4)	
45–64	30, 9.9(7.0-13.8)	30, 9.9(7.0-13.8)	60, 9.9(7.8-12.6)	
≥ 65	4, 1.3(0.5-3.5)	2, 0.6(0.2-2.6)	6, 1.0(0.4-2.2)	
Religion*				
Orthodox Christian	299, 98.7(96.5-99.5)	293, 96.7(94.0-98.2)	592, 97.7(96.1-98.6)	0.105
Muslim	4, 1.3(0.5-3.5)	10, 3.3(1.8-6.0)	14, 2.3(1.4-3.9)	
Marital status*				
Married	235, 77.6(72.5-81.9)	257, 84.8(80.3-88.5)	492, 81.2(77.9-84.1)	0.068
Single	48, 15.8(12.1-20.4)	34, 11.2(8.1-15.3)	82, 13.5(11.0-16.5)	
Divorced/widowed	20, 6.6(4.3-10.0)	12, 4.0(2.3-6.9)	32, 5.3(3.8-7.4)	
Educational status*				
Illiterate[¶]	140, 46.2(40.6-51.9)	162, 53.5(47.8-59.0)	302, 49.8(45.9-53.8)	0.175
Able to read and write (informal)	63, 20.8(16.6-25.8)	55, 18.2(14.2-22.9)	118, 19.5(16.5-22.8)	
Grade 1 to 12 completed	93, 30.7(25.7-36.1)	75, 24.7(20.2-29.9)	168, 27.7(24.3-31.4)	
>12	7, 2.3(1.1-4.8)	11, 3.6(2.0-6.5)	18, 3.0(1.9-4.7)	
Occupation*				
Government employee	6, 2.0(0.9-4.4)	10, 3.3(1.8-6.0)	16, 2.6(1.6-4.3)	0.435
Merchant/trader	10, 3.3(1.8-6.0)	9, 3.0(1.5-5.6)	19, 3.1(2.0-4.9)	
Farmer/peasant	251, 82.8(78.1-86.7)	258, 85.2(80.7-88.7)	509, 84.0(80.8-86.7)	
Daily laborer	7, 2.3(1.1-4.8)	8, 2.6(1.3-5.2)	15, 2.5(1.5-4.1)	
Others [Ω]	29, 9.6(6.7-13.5)	18, 5.9(3.8-9.2)	47, 7.8(5.9-10.2)	
HH wealth index				
Poor	89, 29.4(24.5-34.8)	106, 35.0(29.8-40.6)	195, 32.2(28.6-36.0)	0.275
Medium	20, 6.6(4.3-10.0)	15, 5.0(3.0-8.1)	35, 5.8(4.2-7.9)	

Rich	194, 64.0(58.4-69.3)	182, 60.0(54.4-65.5)	376, 62.0(58.1-65.8)	
Number of occupants in a house‼	6(4-7)	6(4-7)	6(4-7)	
≤5 individuals	133, 43.9(38.4-49.6)	140, 46.2(40.6-51.9)	273, 45.0(41.1-49.0)	0.568
>5 individuals	170, 56.1(50.4-61.6)	163, 53.8(48.1-59.4)	333, 55.0(51.0-58.9)	
Roofing materials of the house				
Corrugated iron	287, 94.7(91.5-96.7)	278, 91.8(88.1-94.4)	565, 93.2(90.9-95.0)	0.145
Thatch	16, 5.3(3.3-8.5)	25, 8.2(5.6-11.9)	41, 6.8(5.0-9.1)	
Open eaves in the roof				
Yes	37, 12.2(8.9-16.4)	42, 13.9(10.4-18.3)	79, 13.0(10.6-15.9)	0.546
No	266, 87.8(83.6-91.0)	261, 86.1(81.7-89.6)	527, 87.0(84.0-89.4)	
Wall building materials				
Cement	5, 1.6(0.7-3.9)	3, 1.0(0.3-3.0)	8, 1.3(0.7-2.6)	0.896
Mud	296, 97.7(95.2-98.9)	298, 98.3(96.1-99.3)	594, 98.0(96.5-98.9)	
Others§	2, 0.7(0.2-2.6)	2, 0.7(0.2-2.6)	4, 0.7(0.2-1.7)	
Flooring materials of the house				
Cement and ceramic tiles	9, 3.0(1.5-5.6)	4, 1.3(0.5-3.5)	13, 2.2(1.2-3.7)	0.262
Dung plastered	294, 97.0(94.4-98.5)	299, 98.7(96.5-99.5)	593, 97.8(96.3-98.8)	
Window type of the house				
Corrugated iron	55, 18.2(14.2-23.0)	52, 17.2(13.3-21.9)	107, 17.7(14.8-20.9)	0.464
No windows	182, 60.1(54.4-65.5)	197, 65.0(59.4-70.2)	379, 62.5(58.6-66.3)	
Open windows/open wall	58, 19.1(15.1-24.0)	50, 16.5(12.7-21.1)	108, 17.8(.15.0-21.1)	
Others $^{\pi}$	8, 2.6(1.3-5.2)	4, 1.3(0.5-3.5)	12, 2.0(1.1-3.5)	
Number of rooms in the house‼	3(2-3)	3(2-3)	3(2-3)	
≤2 rooms	100, 33.0(27.9-38.5)	107, 35.3(30.1-40.9)	207, 34.2(30.5-38.0)	0.549
>2 rooms	203, 67(.61.5-72.1)	196, 64.7(59.1-69.9)	399, 65.8(.62.0-69.5)	
Tethering of cattle, goats and sheep©				
Yes	73, 24.1(19.6-29.3)	69, 22.8(18.4-27.9)	142, 23.4(20.2-27.0)	0.701
No	230, 75.9(70.7-80.4)	234, 77.2(72.1-81.6)	464, 76.6(73.0-79.8)	
Separate kitchen				
Yes	116, 38.3(32.9-43.9)	110, 36.3(31.1-41.9)	226, 37.3(33.5-41.2)	0.614
No	187, 61.7(56.1-67.1)	193, 63.7(58.1-68.9)	380, 62.7(58.8-66.5)	

*For cases and controls <18 years; religion, marital status, educational status & occupation of the HH head was taken. [Ω] Student, job seeker, street dweller, weaver, local musician, sewer, carter. [§]Cement & sand-made bricks, ink painted, ordered stones. [π] Wooden, glass sealed. [©]Tethering indoors at night in the month prior to visiting the health facility. [¶]Unable to read and write based on self-reporting**.** [‼]Continuous variables; summarized through median and IQR as median (IQR). CI: Confidence interval. ***p*< 0.05 was considered statistically significant.

Table 3: Travel history and other behaviors among cases and controls in villages around Lake Tana, Ethiopia, October 2016-June 2017.

Characteristic	**Cases (n=303)** n, %(95% CI)	**Controls (n=303)** n, %(95% CI)	**Total** n, %(95% CI)	**Pearson's X^2/ Fisher's exact test****
Travel to malarious lowlands [λ]				
Yes	59, 19.5(15.4-24.3)	24, 7.9(5.4-11.6)	83, 13.7(11.2-16.7)	**< 0.0001**
No	244, 80.5(75.7-84.6)	279, 92.1(88.4-94.6)	523, 86.3(83.3-88.8)	
Frequency of travel to malarious lowlands (n=83)				
One time	53, 89.8(78.7-95.5)	21, 87.5(65.5-96.3)	74, 89.2(80.2-94.3)	0.714
Two or three times	6, 10.2(4.5-21.3)	3, 12.5(3.7-34.5)	9, 10.8(5.7-19.8)	
Regular LLIN use during travels (n=83)				
Yes	3, 5.1(1.6-15.1)	1, 4.2(0.5-27.3)	4, 4.8(1.8-12.4)	1.000
No	56, 94.9(84.9-98.4)	23, 95.8(72.7-99.5)	79, 95.2(87.6-98.2)	
Reason for travel (n=83)				
To work temporarily/job seeking	53, 89.8(78.7-95.5)	22, 91.7(69.8-98.1)	75, 90.4(81.7-95.2)	1.000
Others [β]	6, 10.2(4.5-21.3)	2, 8.3(1.9-30.2)	8, 9.6(4.8-18.3)	
Travel history within the study area [λ]				
Yes	95, 31.4(26.4-36.8)	72, 23.8(19.3-28.9)	167, 27.6(24.1-31.3)	**0.037**
No	208, 68.6(63.2-73.6)	231,76.2(71.1-80.7)	439, 72.4(68.7-75.9)	
Regular LLIN use during travels (n=167)				
Yes	9, 9.5(4.9-17.4)	4, 5.6(2.1-14.2)	13, 7.8(4.5-13.0)	0.398
No	86, 90.5(82.6-95.1)	68, 94.4(85.8-97.9)	154, 92.2(87.0-95.5)	
HH member travel to malarious lowlands [λ]				
Yes	29, 9.6(6.7-13.5)	9, 3.0(1.5-5.6)	38, 6.3(4.6-8.5)	**0.001**

No	274, 90.4(86.5-93.3)	294, 97.0(94.4-98.5)	568, 93.7(91.5-95.4)	
Reason for travel (n=38)				0.574
To work temporarily/job seeking	26, 89.7(70.9-96.9)	7, 77.8(33.0-96.1)	33, 86.8(71.1-94.6)	
Others [β]	3, 10.3(3.1-29.1)	2, 22.2(3.9-67.0)	5, 13.2(5.4-28.9)	

[λ] In the month prior to visiting the health center . [β] For holy water, spiritual festivity, spiritual education, commercial issues, visiting friends and relatives, labor (playing music in resource rich areas of low lands). $^{**}p < 0.05$ was considered statistically significant.

Table 4: Malaria intervention measures among cases and controls in villages around Lake Tana, Ethiopia, October 2016-June 2017.

Characteristic	**Cases (n=303)** n, %(95% CI)	**Controls (n=303)** n, %(95% CI)	**Total** n, %(95% CI)	**Pearson's X^2/ Fisher's exact test****
House proximity to health centre"	3.5(0.7-4.9)	3.8 (1.2-5.5)	3.6(0.9-5.3)	0.065
≤5 km	233, 76.9(71.8-81.3)	213, 70.3(64.9-75.2)	446, 73.6(69.9-77.0)	
>5 km	70, 23.1(18.7-28.2)	90, 29.7(24.8-35.1)	160, 26.4(23.0-30.1)	
Received malaria information				**0.011**
Yes	123, 40.6(35.2-46.3)	93, 30.7(25.7-36.1)	216, 35.6(31.9-39.6)	
No	180, 59.4(53.7-64.8)	210, 69.3(63.9-74.3)	390, 64.4(60.4-68.1)	
Number of LLIN(s) in a HH				0.186
None	203, 67.0(61.5-72.1)	218, 71.9(66.6-76.7)	421, 69.5(65.7-73.0)	
1 LLIN/HH	52, 17.2(13.3-21.9)	56, 18.5(14.5-23.3)	108, 17.8(15.0-21.1)	
≥2 LLINs/HH	48, 15.8(12.1-20.4)	29, (9.6(6.7-13.5)	77, 12.7(10.3-15.6)	
Slept under LLIN regularly in last 1 month (n=185) [#]				0.085
Yes	38, 38.0(28.9-48.0)	43, 50.6(39.9-61.2)	81, 43.8(36.7-51.1)	
No	62, 62.0(52.0-71.1)	42, 49.4(38.8-60.1)	104, 56.2(48.9-63.3)	
LLIN(s) had holes/tear(s) (n=185)				0.603
Yes	39, 39.0(29.8-49.0)	30, 35.3(25.7-46.2)	69, 37.3(30.6-44.6)	
No	61, 61.0(51.0-70.2)	55, 64.7(53.8-74.3)	116, 62.7(55.4-69.4)	
Period since the HH obtained LLIN(s)(n=185)				0.723
<1 year	11, 11.0(6.1-18.9)	8, 9.4(4.7-17.9)	19, 10.3(6.6-15.6)	
≥1year	89, 89.0(81.1-93.9)	77, 90.6(82.1-95.3)	166, 89.7(84.4-93.4)	

Proper hanging of LLIN(s) (n=185)				
Yes	72, 72.0(62.3-80.0)	63, 74.1(63.6-82.5)	135, 73.0(66.1-78.9)	0.747
No	28, 28.0(20.0-37.7)	22, 25.9(17.5-36.4)	50, 27.0(21.1-33.9)	
Good condition of LLIN(s) (n=185)≈				
Yes	49, 49.0(39.2-58.9)	46, 54.1(43.3-64.6)	95, 51.4(44.1-58.5)	0.488
No	51, 51.0(41.1-60.8)	39, 45.9(35.4-56.7)	90, 48.6(41.5-55.9)	
IRS				
Yes	225, 74.3(69.0-78.9)	226, 74.6(69.4-79.2)	451, 74.4(70.8-77.8)	0.926
No	78, 25.7(21.1-31.0)	77, 25.4(20.8-30.6)	155, 25.6(22.3-29.2)	
Plastering/painting after IRS (n=451)				
Yes	27, 12.0(8.3-17.0)	21, 9.3(6.1-13.9)	48, 10.6(8.1-13.9)	0.351
No	198, 88.0(83.0-91.7)	205, 90.7(86.1-93.9)	403, 89.4(86.1-91.9)	

≈ Measured by service years of LLIN (aged if >3 years), presence of tears/holes and proper hanging. ‼Continuous variables; summarized through median and IQR as median (IQR). ***p*<0.05 was considered statistically significant.

Table 5: HH elevation and proximity to water bodies in villages around Lake Tana, Ethiopia, October 2016-June 2017.

Variables	**Cases (n=303)** n, %(95% CI)	**Controls (n=303)** n, %(95% CI)	**Total** n, %(95% CI)	**Pearson's X^2/ Fisher's exact test****
HH elevation (m) ‼	1854(1821-1907)	1846(1818-1893)	1851(1820-1904)	
1701-1900	224, 73.9(68.7-78.6)	230, 75.9(70.7-80.4)	454, 74.9(71.3-78.2)	0.426
1901-2100	72, 23.8(19.3-28.9)	70, 23.1(18.7-28.2)	142, 23.4(20.2-27.0)	
>2100	7, 2.3(1.1-4.8)	3, 1.0(0.3-3.0)	10, 1.7(0.9-3.0)	
House proximity to Lake Tana (km) ‼	6.5(5.4-9.5)	6.9(5.3-8.8)	6.8(5.3-8.9)	
<2	18, 5.9(3.8-9.3)	23, 7.6(5.1-11.2)	41, 6.8(5.0-9.1)	0.720
2-4	22, 7.3(4.8-10.8)	22, 7.3(4.8-10.8)	44, 7.2(5.4-9.6)	
>4	263, 86.8(82.5-90.2)	258, 85.1(80.7-88.7)	521, 86.0(.83.0-88.5)	
House proximity to a water body (m) ‼	711(473-1099)	742(461-1257)	723(468-1180)	
<250	28, 9.3(6.4-13.1)	25, 8.3(5.6-11.9)	53, 8.7(6.7-11.3)	0.459
250-500	54, 17.8(13.9-22.6)	66, 21.8(17.5-26.8)	120, 19.8(16.8-23.2)	
>500	221, 72.9(67.6-77.7)	212, 69.9(64.5-74.9)	433, 71.5(67.7-74.9)	

‼ Continuous variables; summarized through median and IQR as median (IQR). ***p* <0.05 was considered statistically significant.

5.1.5. Confounding factors and effect modifiers

The stratified analysis confirmed that there was no significant variation between stratum-specific ORs, indicating no effect modification between the explaining variables and the stratifying variables; HH elevation and travel to malarious lowlands. Stratified analysis also revealed no disparity between the pooled and adjusted ORs, indicating that HH elevation was not a confounder for the effect of predictors on malaria (**Table 6**). Nonetheless, travel to malarious lowlands was identified as a significant confounder for the effects of age, marital status, occupation, educational status, number of rooms, travel history within the study area, HH member's travel to malarious lowlands, IRS, and HH elevation on malaria infection occurrence (**Table 7**).

Table 6: Stratified analysis by HH elevation for predictors of malaria in villages around Lake Tana, Ethiopia, October 2016-June 2017.

Variables	COR	[1750m-2000m)	[2000m-2500m]	Adjusted (Mantel-Haenszel)			
		OR	OR	OR_{MH}	95% CI	X^2_{MH}	*p*-value
Age	1	0.97	2.5	1.01	0.73-1.40	0.97	0.3237
Marital status	1.62	1.69	1.5	1.68	1.10-2.56	0.02	0.8792
Occupation	1.19	1.22	0.79	1.19	0.77-1.84	0.17	0.6762
Educational status	1.34	1.31	5.45	1.36	0.98-1.88	1.5	0.2205
Number of occupants in a house	1.1	1.08	1.75	1.1	0.80-1.52	0.35	0.5523
HH wealth index	1.29	1.29	1.24	1.29	0.91-1.82	0	0.9629
Roofing materials	0.62	0.6	1.25	0.62	0.32-1.19	0.24	0.6233
Open eaves in the roof	0.86	0.79	3.11	0.87	0.54-1.40	1.96	0.1615
Number of rooms	1.11	1.17	0.3	1.09	0.78-1.52	2.65	0.1035
Separate kitchen	1.09	1.13	0.7	1.1	0.79-1.53	0.36	0.5464
Tethering of cattle, goats and sheep	1.08	1.09	0.98	1.08	0.74-1.58	0.02	0.8995
Travel history to malarious lowlands	2.81	3.3	0.98	2.91	1.73-4.90	2.14	0.1436
Travel history within the study area	1.47	1.52	1.17	1.49	1.04-2.15	0.11	0.737
Received health education on malaria	1.54	1.55	1.43	1.55	1.10-2.17	0.01	0.9153
Number of LLIN(s) in a HH	1.26	1.28	0.9	1.26	0.89-1.78	0.15	0.6984
IRS	0.98	0.95	0	0.94	0.63-1.39	0.77	0.3805

House proximity to health centre	0.71	0.7	1.11	0.71	0.49-1.04	0.26	0.6089
House proximity to a water body	1.05	1.09	0.67	1.04	0.81-1.34	1.17	0.2788

OR_{MH}: adjusted odds ratio using Mantel-Haenszel method, COR: crude odds ratio, X^2_{MH}: Mantel-Haenszel chi-square value.

Table 7: Stratified analysis by travel to malarious lowlands for predictors of malaria in villages around Lake Tana, Ethiopia, October 2016-June 2017.

Variables	**COR**	**Travel to malarious lowlands**		**Adjusted (Mantel-Haenszel)**			
		Yes (OR)	**No (OR)**	OR_{MH}	**95% CI**	X^2_{MH}	***p*-value**
Age	1	0	0.82	0.8	0.57-1.13	1.02	0.3123
Marital status	1.62	0.93	1.45	1.32	0.86-2.04	0.66	0.4182
Occupation	1.19	1.34	0.92	0.99	0.63-1.57	0.41	0.5242
Educational status	1.34	1.24	1.21	1.21	0.88-1.68	0	0.9725
Number of occupants in a house	1.1	0.99	1.18	1.16	0.84-1.60	0.11	0.7423
HH wealth index	1.29	1.21	1.26	1.26	0.89-1.78	0.01	0.9375
Roofing materials	0.62	0.38	0.66	0.61	0.32-1.17	0.36	0.547
Open eaves in the roof	0.86	1.02	0.79	0.82	0.50-1.33	0.13	0.7152
Wall building materials	0.71	0	1.09	0.77	0.22-2.73	1.23	0.2669
Flooring materials	0.44	0	0.58	0.45	0.13-1.60	0.71	0.401
Number of rooms	1.11	1.14	1.26	1.25	0.88-1.76	0.04	0.8482
Separate kitchen	1.09	0.9	1.04	1.02	0.73-1.43	0.08	0.7838
Tethering of cattle, goats and sheep	1.08	0.74	1.09	1.03	0.71-1.51	0.45	0.5
Travel history within the study area	1.47	0.29	1.18	1.03	0.68-1.56	3.08	0.0792
HH member travel to malarious lowlands	3.46	2.6	2.56	2.58	1.16-5.74	0	0.9841
Received health education on malaria	1.54	2.43	1.31	1.42	1.00-1.99	1.32	0.2508
Number of LLIN(s) in a HH	1.26	1.07	1.16	1.15	0.80-1.64	0.02	0.8749
IRS	0.98	2.19	1	1.13	0.78-1.65	2.12	0.1453
HH elevation	0.8	0.28	0.93	0.67	0.32-1.40	2.05	0.1526
House proximity to health centre	0.71	0.56	0.75	0.73	0.50-1.05	0.25	0.6138
House proximity to Lake Tana	1.3	1.54	1.37	1.4	0.73-2.69	0.02	0.8918
House proximity to a water body	1.05	1.58	1.04	1.11	0.86-1.43	1.40	0.2374

OR_{MH}: adjusted odds ratio using Mantel-Haenszel method, COR: crude odds ratio, X^2_{MH}: Mantel-Haenszel chi-square value.

5.1.6. Determinants of malaria

Matched multivariable analysis showed that travel to malarious lowlands in the preceding month (adjusted mOR = 7.23; 95% CI: 2.38-22.00), HH member's travel to malarious lowlands (adjusted mOR = 3.04; 95% CI: 1.14-8.08), and delivery of inadequate malaria information (adjusted mOR = 1.56; 95% CI: 1.02-2.37) were statistically significant and independent predictors of malaria infection occurrence in a meso-endemic setting (**Table 8**).

Table 8: Determinants of malaria transmission dynamics in villages around Lake Tana, Ethiopia, October 2016-June 2017.

Variables	Unadjusted mOR$^{\neq}$	*p*-value	Adjusted mOR (95% CI)‡	*p*-value
Age (years)	0.98	0.125	0.98(0.95-1.01)	0.196
Marital status				
Married	1		1	
Single	1.68	**0.057**	1.36(0.65-2.85)	0.413
Divorced/widowed	1.97	0.101	1.88(0.71-5.00)	0.203
Occupation				
Farmer	1		1	
Non-farmer	1.23	0.400	0.79(0.39-1.59)	0.508
Educational status				
Illiterate	1		1	
Able to read and write	1.38	0.163	1.49(0.89-2.50)	0.127
Grade 1 to 12 completed	1.54	**0.042**	1.05(0.63-1.76)	0.839
>12	0.72	0.535	0.58(0.15-2.24)	0.426
HH wealth index				
Poor	1		1	
Medium	1.62	0.197	1.43(0.62-3.27)	0.399
Rich	1.29	0.162	1.24(0.82-1.88)	0.316
Roofing materials				
Corrugated iron	1		1	
Thatch	0.57	0.122	0.71(0.31-1.62)	0.418

Flooring materials				
Cement and others	1		1	
Dung plastered	0.44	0.177	0.47(0.12-1.88)	0.284
Travel to malarious lowlands				
No	1		1	
Yes	9.75	**< 0.0001**	7.23(2.38-22.00)	< 0.0001
Travel history within the study area				
No	1		1	
Yes	1.56	**0.026**	1.02(0.62-1.65)	0.952
HH member travel to malarious lowlands				
No	1		1	
Yes	3.86	**0.001**	3.04(1.14-8.08)	0.026
Received health information on malaria				
No	1		1	
Yes	1.59	**0.010**	1.56(1.02-2.37)	0.038
Number of LLIN(s) in a HH				
None	1		1	
1 LLIN/HH	1.07	0.674	1.10(0.65-1.87)	0.721
≥2 LLINs/HH	1.87	**0.021**	1.74(0.92-3.29)	0.090
HH elevation				
1701-1900	1		1	
1901-2100	1.40	0.355	0.89(0.35-2.26)	0.810
>2100	3.06	0.137	2.22(0.36-13.88)	0.394
House proximity to health centre				
≤5	1		1	
>5	0.71	0.069	0.77(0.50-1.18)	0.229
House proximity to a water body				
<250	1		1	
250-500	0.75	0.393	0.99(0.44-2.24)	0.987
>500	0.94	0.842	1.25(0.58-2.69)	0.575

House proximity to Lake Tana				
<2	1		1	
2-4	1.32	0.552	1.40(0.49-4.03)	0.528
>4	1.33	0.399	1.52(0.70-3.33)	0.292

Unadjusted mOR, Unadjusted matched odds ratio; adjusted mOR, adjusted matched odds ratio; 1, Reference category
≠ Unadjusted mOR using 95% CI in bivariate conditional logistic regression analysis from matched case-control pairs.
ǂ Adjusted mOR using 95% CI in multivariable conditional logistic regression analysis from matched case-control pairs. *p* <0.05 was considered statistically significant.

5.2. Relationship of locally acquired malaria and house proximity to a water body among under-five children

5.2.1. Socio-demographic and residential housing characteristics

One-hundred sixty-two under-five children were enrolled in the study, giving a response rate of 88% and their HH geo-coordinates were plotted in the study area (**Figure 8**). Nearly three-quarters of the malaria infections, 60 (74.1% [63.2-82.6]) were *P. vivax* mono-infections and the remaining, 21 (25.9% [17.4-36.8]) were *P. falciparum* mono-infections. Of the total malaria cases, 19 (23.5% [15.3-34.1]) were found between October 10, 2016, and December 15, 2016; 27 (33.3% [23.8-44.5]) were found between December 16, 2016, and March 15, 2017; and 35 (43.2% [32.7-54.4]), were found between March 16, 2017, and June 30, 2017. Of the 81 *Plasmodium* positive under-five children, 50 (61.7% [50.5-71.8]) were males. The median (IQR) age of the *Plasmodium*-positive under-five children was 27 (20-48) months. The majority of malaria positive under-five children lived in houses with corrugated iron roof, 76 (93.8% [85.8-97.5]); mud-made wall, 80 (98.8% [91.4-99.8]) and dung plastered floor, 80 (98.8% [91.4-99.8]) (**Table 9**).

Table 9: Socio-demographic and housing characteristics of under-five children in villages around Lake Tana, Ethiopia, October 2016-June 2017

Characteristic	**Cases (n=81)** n, % (95% CI)	**Controls (n=81)** n, % (95% CI)	**Total** n, % (95% CI)	**Pearson's X^2/ Fisher's exact test****
Age of child (months) ‼	27 (20-48)	23 (12-30)	24 (17-36)	
5-35	45, 55.6 (44.4-66.2)	62, 76.5 (65.9-84.7)	107, 66.1 (58.3-73.0)	*0.005*
36-59	36, 44.4 (33.8-55.6)	19, 23.5 (15.3-34.1)	55, 33.9 (27.0-41.7)	

Marital status*				
Married	78, 96.3 (88.9-98.8)	78, 96.3 (88.9-98.8)	156, 96.3 (91.9-98.3)	1.000
Divorced	3, 3.7 (1.2-11.1)	3, 3.7 (1.2-11.1)	6, 3.7 (1.7-8.1)	
Educational status*				
Illiterate¶	39, 48.1 (37.3-59.2)	45, 55.6 (44.4-66.2)	84, 51.9 (44.1-59.5)	0.622
Able to read and write (informal)	22, 27.2 (18.4-38.1)	21, 25.9 (17.4-36.8)	43, 26.5 (20.3-34.0)	
Grade 1 to 6 completed	12, 14.8 (8.5-24.5)	7, 8.6 (4.1-17.3)	19, 11.7 (7.6-17.7)	
≥7	8, 9.9 (4.9-18.8)	8, 9.9 (4.9-18.8)	16, 9.9 (6.1-15.6)	
Maternal education				
Illiterate¶	64, 79.0 (68.6-86.7)	63, 77.9 (67.2 -85.7)	127, 78.4 (71.3-84.1)	0.726
Able to read and write (informal)	6, 7.4 (3.3-15.8)	4, 4.9 (1.8-12.7)	10, 6.2 (3.3-11.2)	
Grade 1 to 6 completed	6, 7.4 (3.3-15.8)	10, 12.3 (6.7-21.7)	16, 9.9 (6.1-15.6)	
≥7	5, 6.2 (2.5-14.2)	4, 4.9 (1.8-12.7)	9, 5.5 (2.9-10.4)	
Occupation*				
Farmer	75, 92.6 (84.2-96.7)	73, 90.1 (81.2-95.1)	148, 91.4 (85.9-94.8)	0.576
Non-farmer Ω	6, 7.4 (3.3-15.8)	8, 9.9 (4.9-18.8)	14, 8.64 (5.2-14.1)	
HH wealth index				
Poor	17, 21.0 (13.3-31.4)	25, 30.9 (21.6-42.0)	42, 25.9 (19.7-33.3)	0.252
Medium	6, 7.4 (3.3-15.8)	8, 9.9 (5.0-18.8)	14, 8.6 (5.2-14.1)	
Wealthy	58, 71.6 (60.6-80.5)	48, 59.2 (48.1-69.6)	106, 65.4 (57.7-72.4)	
Number of occupants in a house‼	6 (4-7)	6 (4-7)	6 (4-7)	
≤5 individuals	36, 44.4 (33.8-55.6)	39, 48.1 (37.3-59.2)	75, 46.3 (38.7-54.1)	0.636
>5 individuals	45, 55.6 (44.4-66.2)	42, 51.9 (40.8-62.7)	87, 53.7 (45.9-61.3)	
Roofing materials				
Corrugated iron	76, 93.8 (85.8-97.5)	71, 87.7 (78.3-93.3)	147, 90.7 (85.1-94.4)	0.175
Thatch	5, 6.2 (2.5-14.2)	10, 12.3 (6.7-21.7)	15, 9.3 (5.6-14.9)	
Wall building materials				
Cement	1, 1.2 (0.2-8.6)	3, 3.7 (1.2-11.1)	4, 2.5 (0.9 -6.5)	0.620
Mud and sticks	80, 98.8 (91.4-99.8)	78, 96.3 (88.9-98.8)	158, 97.5 (93.5-99.1)	
Flooring materials				
Cement plastered or ceramic tiles	1, 1.2 (0.2-8.6)	2, 2.5 (0.6-9.6)	3, 1.8 (0.6-5.6)	1.000
Dung plastered	80, 98.8 (91.4-99.8)	79, 97.5 (90.4-99.4)	159, 98.2 (94.4-99.4)	

Number of rooms in the house ‼	3 (2-3)	3 (2-3)	3 (2-3)	
≤ 2 rooms	18, 22.2 (14.3-32.8)	25, 30.9 (21.6-42.0)	43, 26.5 (20.3-34.0)	0.213
> 2 rooms	63, 77.8 (67.2-85.7)	56, 69.1 (58.0-78.4)	119, 73.5 (66.0-79.7)	
Tethering of cattle, goats, sheep ©				
Yes	24, 29.6 (20.6-40.7)	20, 24.7 (16.4-35.5)	44, 27.2 (20.8-34.6)	0.480
No	57, 70.4 (59.3-79.4)	61, 75.3 (64.5-83.6)	118, 72.8 (65.4-79.2)	
Presence of separate kitchen				
Yes	20, 24.7 (16.4-35.5)	24, 29.6 (20.6-40.7)	44, 27.2 (20.8-34.6)	0.480
No	61, 75.3 (64.5-83.6)	57, 70.4 (59.3-79.4)	118, 72.8 (65.4-79.2)	

*The HH head status was taken. Ω Government employee, merchant/trader, daily laborer, street dweller, carter. ©Tethering indoors at night in the month prior to visiting the health facility. ¶ Unable to read and write based on self-reporting**.** ‼ Continuous variables; summarized through median and IQR as median (IQR). CI: Confidence interval. ** $p< 0.05$ was considered statistically significant. The italics indicate statistically significant *p*-values

5.2.2. Awareness regarding malaria, malaria-related behaviors and intervention measures

Of all the 162 HH heads, 149 (92.0% [86.6-95.3]) had information on malaria transmissibility through a mosquito bite. One-hundred sixty (98.8% [95.1-99.7]) under-five children had been active (1700-2300 h) in the preceding month (**Table 10**).

Less than one-third of under-five children, 50 (30.9% [24.2-38.5]) resided in HHs that owned at least one LLIN. Of those under-five children who had LLINs, 32 (64.0% [49.4-76.4]) reportedly slept under an LLIN regularly two weeks prior to the diagnosis. More than half, 26, (52.0 % [37.9-65.8]) of HHs had LLINs that were in good condition. One hundred forty-three, (88.3% [82.3-92.4]) reported that their houses had been sprayed with IRS during the preceding year (**Table 11**).

Table 10: Awareness of malaria among HH heads and malaria-related behaviors in villages around Lake Tana, Ethiopia, October 2016-June 2017

Characteristic	Cases (n = 81) n, % (95% CI)	Controls (n = 81) n, % (95% CI)	Total n, % (95% CI)	Pearson's X^2/ Fisher's exact test**
Anopheles mosquito transmits malaria				
Yes	74, 91.4 (82.7-95.9)	75, 92.6 (84.2-96.7)	149, 92.0 (86.6-95.3)	0.772
No	7, 8.6 (4.1-17.3)	6, 7.4 (3.3-15.8)	13, 8.0 (4.7-13.4)	
LLIN use prevents malaria				
Yes	74, 91.4 (82.7-95.9)	74, 91.4 (82.7-95.9)	148, 91.4(85.9-94.8)	1.000
No	7, 8.6 (4.1-17.3)	7, 8.6 (4.1-17.3)	14, 8.6 (5.2-14.1)	
Travel history within study villages $^{\lambda}$				
Yes	16, 19.8 (12.3-30.1)	12, 14.8 (8.5-24.5)	28, 17.3 (12.2-24.0)	0.406
No	65, 80.2 (69.9-87.7)	69, 85.2 (75.5-91.5	134, 82.7 (76.0-87.8)	
Regular LLIN use during travels (n=28)				
Yes	4, 25 (8.6-54.3)	1, 8.3 (0.8-50.1)	5, 17.9 (7.2-37.9)	0.355
No	12, 75.0 (45.7-91.4)	11, 91.7 (49.9-99.2)	23, 82.1 (62.1-92.8)	
HH member travel to lowlands $^{\lambda}$				
Yes	3, 3.7 (1.2-11.1)	1, 1.2 (0.2-8.6)	4, 2.5 (0.9-6.5)	0.620
No	78, 96.3 (88.9-98.8)	80, 98.8 (91.4-99.8)	158, 97.5 (93.5-99.1)	

$^{\lambda}$ In the month prior to visiting the health center. **Test *p*-values.

Table 11: Malaria intervention measures among under-five children in villages around Lake Tana, Ethiopia, October 2016-June 2017

Characteristic	Cases (n = 81) n, % (95% CI)	Controls (n = 81) n, % (95% CI)	Total n, % (95% CI)	Pearson's X^2/ Fisher's exact test**
Received malaria information*				
Yes	32, 39.5 (29.3-50.7)	23, 28.4 (19.5-39.4)	55, 34.0 (27.0-41.7)	0.135
No	49, 60.5 (49.3-70.7)	58, 71.6 (60.6-80.5)	107, 66.0 (58.3-73.0)	
Number of LLIN(s) in a HH				
None	55, 67.9 (56.8-77.3)	57, 70.4 (59.3-79.4)	112, 69.1 (61.5-75.8)	0.941

1 LLIN/HH	16, 19.8 (12.3-30.1)	15, 18.5 (11.4-28.7)	31, 19.2 (13.7-26.0)	
≥2 LLINs/HH	10, 12.3 (6.7-21.7)	9, 11.1 (5.8-20.2)	19, 11.7 (7.6-17.7)	
Regular LLIN use in last 2 weeks (n = 50)				
Yes	16, 61.5 (40.7-78.9)	16, 66.7 (44.5-83.3)	32, 64.0 (49.4-76.4)	0.706
No	10, 38.5 (21.1-59.3)	8, 33.3 (16.7-55.5)	18, 36.0 (23.6-50.6)	
Regular LLIN use in last 1 month (n = 50)				
Yes	12, 46.2 (27.3-66.2)	14, 58.3 (36.9-77.1)	26, 52.0 (37.9-65.8)	0.389
No	14, 53.8 (33.8-72.7)	10, 41.7 (22.9-63.1)	24, 48.0 (34.2-62.1)	
Having holes/tear(s) in LLIN(s) (n = 50)				
Yes	10, 38.5 (21.1-59.3)	9, 37.5 (19.8-59.4)	19, 38.0 (25.3-52.5)	0.944
No	16, 61.5 (40.7-78.9)	15, 62.5 (40.6-80.2)	31, 62.0 (47.5-74.7)	
Period since delivered LLIN(s)(n = 50)				
<1 year	10, 38.5 (21.1-59.3)	11, 45.8 (26.3-66.8)	21, 42.0 (28.8-56.4)	0.598
≥1year	16, 61.5 (40.7-78.9)	13, 54.2 (33.2-73.7)	29, 58.0 (43.6-71.2)	
Proper mounting of LLIN(s) (n = 50)				
Yes	20, 76.9 (55.6-89.9)	16, 66.7 (44.5-83.3)	36, 72.0 (57.6-83.0)	0.420
No	6, 23.1 (10.1-44.4)	8, 33.3 (16.7-55.5)	14, 28.0 (17.0-42.4)	
Washing frequency (n = 50)				
< 4 times	22, 84.6 (63.7-94.5)	21, 87.5 (65.5-96.3)	43, 86.0 (72.9-93.4)	1.000
≥ 4 times	4, 15.4 (5.5-36.3)	3, 12.5 (3.7-34.5)	7, 14.0 (6.6-27.1)	
Good condition of LLIN(s) (n = 50) ≈				
Yes	13, 50.0 (30.5-69.5)	13, 54.2 (33.2-73.7)	26, 52.0 (37.9-65.8)	0.768
No	13, 50.0 (30.5-69.5)	11, 45.8 (26.3-66.8)	24, 48.0 (34.2-62.1)	
IRS				
Yes	71, 87.7 (78.3-93.3)	72, 88.9 (79.8-94.2)	143, 88.3 (82.3-92.4)	0.807
No	10, 12.3 (6.7-21.7)	9, 11.1 (5.8-20.2)	19, 11.7 (7.6-17.7)	
Plastering/painting after IRS (n = 143)				
Yes	4, 5.6 (2.1-14.4)	3, 4.2 (1.3-12.4)	7, 4.9 (2.3-10.0)	0.719
No	67, 94.4 (85.6-97.9)	69, 95.8 (87.6 -98.7)	136, 95.1 (90.0-97.7)	
Use other mosquito protections £				
Yes	7, 8.6 (4.1-17.3)	4, 95.1 (87.3-98.2)	11, 6.8 (3.8-11.9)	0.534
No	74, 91.4 (82.7-95.9)	77, 4.9 (1.8-12.7)	151, 93.2 (88.1-96.2)	

*Getting information on malaria signs and symptoms, transmission methods, preventive and control measures, and early treatment seeking behavior by HEWs. ≈ measured by service years of LLIN (aged if >3 years), absence of tears/holes, proper hanging and frequent washing. £Mosquito coils, homemade insecticides, grass or wood fumes. **Test *p*-values.

5.2.3. Proximity of HHs to water bodies

Eighty (98.8% [91.4-99.8]) of the case-HHs were located below 2000 masl. Only 13 (16.0% [9.4-26.0]) of case-HHs were located within 4 km of Lake Tana. Similarly, 19, (23.5% [15.3-34.1]) case-HHs had a water body within a 500m radius (**Table 12**).

Table 12: HH elevation and proximity to water bodies in villages around Lake Tana, Ethiopia, October 2016-June 2017

Variables	**Cases (n = 81)** n, % (95% CI)	**Controls (n = 81)** n, % (95% CI)	**Total** n, % (95% CI)	**Pearson's X^2/ Fisher's exact test****
HH elevation (m) ‼	1844 (1816-1859)	1833 (1816-1856)	1841 (1816-1859)	
< 2000	80, 98.8 (91.4-99.8)	79, 97.5 (90.4-99.4)	159, 98.1 (94.4-99.4)	1.000
≥ 2000	1, 1.2 (0.2-8.6)	2, 2.5 (0.6-9.6)	3, 1.9 (0.6-5.6)	
House proximity to Lake Tana (km) ‼	5.8 (5.1-7.4)	6.0 (5.0-7.5)	5.9 (5.1-7.5)	
≤ 4	13, 16.0 (9.4-26.0)	14, 17.3 (10.4 -27.3)	27, 16.7 (11.6-23.3)	0.833
> 4	68, 84.0 (74.0-90.6)	67, 82.7 (72.7-89.6)	135, 83.3 (76.7-88.4)	
Water body presence within 500m ‼	769 (522-1155)	825 (522-1279)	812.5 (522-1211)	
Yes	19, 23.5 (15.3-34.1)	20, 24.7 (16.4-35.5)	39, 24.1 (18.1-31.3)	0.854
No	62, 76.5 (65.9-84.7)	61, 75.3 (64.5-83.6)	123, 75.9 (68.7-81.9)	

!! Continuous variables; summarized through median and IQR as median (IQR). ***p* < 0.05 was considered statistically significant.

5.2.4. Determinants of locally acquired malaria among under-five children

Adjusted matched analysis verified that children 36-59 months of age (adjusted mOR = 3.88; 95% CI: 1.55-9.74) had higher odds to be infected with malaria than children under 36 months in villages around Lake Tana (**Table 13**).

Table 13: Determinants of malaria among under-five children in villages around Lake Tana, Ethiopia, October 2016-June 2017

Variables	**Unadjusted mOR≠**	***p*-value**	**Adjusted mOR (95% CI)ǂ**	***p*-value**

Age				
5-35	1		1	
36-59	3.13	*0.005*	3.88 (1.55-9.74)	*0.004*
Maternal education				
Illiterate	1		1	
Literate	0.91	0.827	0.87 (0.28-2.63)	0.799
HH wealth index				
Poor	1		1	
Medium	1.28	0.694	0.69 (0.16-3.02)	0.619
Wealthy	1.99	0.100	1.50 (0.58-3.86)	0.399
Roofing materials				
Corrugated iron	1		1	
Thatch	0.38	0.147	0.40 (0.07-2.19)	0.290
Number of rooms in the house				
≤ 2 rooms	1		1	
> 2 rooms	1.70	0.183	2.29 (0.80-6.54)	0.123
Presence of separate kitchen				
No	1		1	
Yes	0.67	0.374	0.73 (0.31-1.72)	0.475
Tethering of cattle, goats and sheep				
No	1		1	
Yes	1.31	0.467	1.14 (0.46-2.79)	0.777
Travel history within the study villages				
No	1		1	0.399
Yes	1.36	0.435	1.56 (0.56-4.36)	
Received malaria information				
No	1		1	
Yes	2.13	0.079	2.55 (0.89-7.29)	0.082
Water body presence within 500m				

Yes	1			
No	1.08	0.847	1.46 (0.54-3.93)	0.452
House proximity to Lake Tana				
≤ 4	1		1	
> 4	1.08	0.842	1.23 (0.43-3.50)	0.694

P < 0.05 was considered statistically significant. Unadjusted mOR, unadjusted matched odds ratio; adjusted mOR, adjusted matched odds ratio; 1, Reference category. ≠ Unadjusted mOR using 95% CI in bivariable matched analysis. ǂAdjusted mOR using 95% CI in multivariable matched analysis.

5.2.5. Malaria vectors in the study setting

A total of 1,509 adult specimens of *Anopheles* mosquitoes were considered for identification using morphological characters. However, 312 mosquitoes were excluded from microscopic examination due to incomplete anatomical morphologies. The male/female ratio of identified *Anopheles* adults was 0.84:1. Out of 1,197 adults, *An. pretoriensis* was the most common and predominant species (*n* = 327, 27.3%), followed by the *An. gambiae* complex (*n* = 308, 25.7%) (**Table 14** & **Table 15**, and **Figure 8**). There were statistically significant differences in *Anopheles* species distribution (*p* < 0.001) among the study sites. *An. pretoriensis* was collected in all the larval habitats, including natural breeding sites in riverbeds with sandy substrates (**Table 1**).

Table 14: Number of *Anopheles* mosquito species identified by sex in villages around Lake Tana, Ethiopia, April-June 2017

***Anopheles* mosquito species**	**Number of *Anopheles* species**		
	Females n(%)	**Males n(%)**	**Total n(%)**
An. gambiae complex	185 (60.1)	123 (39.9)	308 (25.7)
An. pharoensis	56 (62.2)	34 (37.8)	90 (7.5)
An. pretoriensis	165 (50.5)	162 (49.5)	327 (27.3)
An. dancalicus	13 (41.9)	18 (58.1)	31 (2.6)
An. cinereus	39 (48.8)	41 (51.2)	80 (6.7)
An. garnhami	22 (26.5)	61(73.5)	83 (6.9)
An. christyi	95 (64.6)	52 (35.4)	147 (12.3)
An. funestus group	42 (73.7)	15 (26.3)	57 (4.8)
An. erepens	11 (57.9)	8 (42.1)	19 (1.6)

An. coustani	7 (26.9)	19 (73.1)	26 (2.2)
An. domicolus	14 (48.3)	15 (51.7)	29 (2.4)
Total	649	548	1,197

Table 15: *Anopheles* mosquito species distribution by survey site in villages around Lake Tana, Ethiopia, April-June 2017

***Anopheles* mosquito species**	**Survey sites**							
	Sara Wonez and Ferkit n (%)	Adiga n (%)	Woyenareb n (%)	Barengua n (%)	Ferenji Wuha n (%)	Derchit* n (%)	Embileba n (%)	Total n (%)
An. gambiae complex	120 (38.3)	45 (26.9)$^{\infty}$	92 (61.3)	51 (31.3)	-	-	-	308 (25.7)
An. pharoensis	68 (21.7)$^{\beta}$	-	-	-	22 (13.8)$^{\infty}$	-	-	90 (7.5)
An. pretoriensis	75 (24.0)	54 (32.3)	58 (38.7)	41 (25.2)	34 (21.4)	38 (32.2)	27 (21.3)	327 (27.3)
An. dancalicus	31 (9.9)$^{\Omega}$	-	-	-	-	-	-	31 (2.6)
An. cinereus	-	-	-	47 (28.8)	25 (15.7)$^{\mu}$	-	8 (6.3)$^{\mu}$	80 (6.7)
An. garnhami	-	42 (25.1)$^{\infty}$	-	24 (14.7)$^{\mu}$	-	-	17 (13.4)$^{\mu}$	83 (6.9)
An. christyi	-	-	-	-	49 (30.9)	34 (28.8)	64 (50.4)$^{\infty}$	147 (12.3)
An. funestus group	-	-	-	-	-	46 (39.0)	11 (8.6)$^{\infty}$	57 (4.8)
An. erepens	19 (6.1)$^{\beta}$	-	-	-	-	-	-	19 (1.6)
An. coustani	-	26 (15.7)$^{\infty}$	-	-	-	-	-	26 (2.2)
An. domicolus	-	-	-	-	29 (18.2)$^{\infty}$	-	-	29 (2.4)
Total	313	167	150	163	159	118	127	1,197

*Unable to get *Anopheles* larvae in the third round due to run-off; $^{\infty}$ Not found in the first two rounds; $^{\beta}$ Not found in the first and third rounds; $^{\Omega}$ Not found in the last two rounds; $^{\mu}$ Not found in the third round.

5.3. Barriers of consistent LLINs utilization

5.3.1. Socio-demographic characteristics and sleeping time under LLINs

The majority of the 61 interviewees were adult males, without formal education, and local community members (**Table 16**). It was reported that most informants usually went to sleep between 9PM and 10PM (2100-2200 h) that depends on various reasons. A saying from an adult man elaborated this *"I have taken drugs at 2100 h and slept on a sofa until 2300 h or more"*. Another man mentioned that *"After all the domestic animals (sheep, goat, cattle, etc.) get in their corrals, around 2100 h"*. As reported, some individuals thought that mosquitoes do not bite in early evening (1800 h).

Table 16: Demographic characteristics of interviewees in villages around Lake Tana, April to June 2017

Characteristic		**Frequency** n (%)
Sex	Male	33 (54.1)
	Female	28 (45.9)
Age (in years)	15-25	9(14.8)
	26-45	35(57.4)
	>45	17(27.8)
Education level	No formal education/unable to read and write	24(39.3)
	Primary	17(27.9)
	Secondary	6(9.8)
	College/university	14(23.0)
Occupation	Local leaders	19(31.2)
	Students	6(9.8)
	Health professionals*	5(8.2)
	HEWs	8(13.1)
	Local community members**	23(37.7)

*Malaria focal persons, Environmental Health Officer and District Malaria Officers; **Farmers and town residents

5.3.2. Perceived benefits and shortcomings of LLINs

Favorable and unfavorable characteristics of currently distributed LLINs were mentioned and viewed from various perspectives. Conventionally treated nets/ITNs were frequently acknowledged relative to the current LLINs that were highly attributed to the secondary benefits of bed nets. Informants' perceptions of the benefits and weaknesses of LLINs varied considerably. Firstly, they evaluated them by their killing ability of other arthropods such as house flies, fleas, bedbugs, cockroaches and spiders. Most informants commented that the currently distributed LLINs had not killed these arthropods although almost all acknowledged they had done so when new and up to 3 months old. Many informants attributed the decrease in killing ability of LLINs after several months to inadequate impregnation. Loss of killing ability was one of the reasons residents considered them ineffective and discontinued their use.

"Nets distributed previously had adequate insecticide. The current nets are inadequately impregnated. I think that they cannot serve for 3 years. They do not serve even for 2 years." (Female, 38 years old, HEW in Sheha-Gomenege *Kebele).*

"The insecticide content of the current net is not a killer. It did not kill any arthropods. The current nets did not kill even mosquitoes that caused nuisance." (Male, 42 years old, local leader in Sheha-Gomenge *Kebele).*

Secondly, informants rated LLINs based on their physical integrity. They reported that the nets quickly became dirty and faded; they were worn out due to repeated washing and broke after 6 months of use. Loss of physical integrity, especially breakage, appeared to be due to the impoverished living conditions in rural houses. A saying from one informant heavily supported this.

"The strength of LLIN is also not as such strong compared with the previous ones. It did not serve even for 2 years and they easily tear off in most HHs." (Female, 35 years old, HEW in Tsion-Seguaj *Kebele*)

On the other hand, some informants reported that LLINs are very strong, adequate in size, and can serve throughout the stated lifetime if handled with care. They described the current LLINs as relatively smooth in texture and comfortable to the skin. However, a larger number of informants questioned the stated service length and the adequacy of the nets' size; they considered them serviceable for 2 years at most if handled with care. Some stated that the large mesh size allowed mosquitoes to go through and complained that the nets were too small for large beds. Additionally, new nets were said to cause skin irritations when in contact with skin.

Regarding the mounting and shape of LLINs, many informants reported that they or others in their HHs who used them preferred the circular shaped nets because they were compatible with any sleeping space. Circular nets mounted at one point in the ceiling were simple to install and operate and easy to roll up during daytime and suspend at night. For instance, an environmental health officer and ex-malaria worker noted, "Circular *shaped nets are durable and fit for thatched roof houses*". Rectangular shaped nets, by contrast, were viewed unfavorably due to the difficulty of installing them and the large space they required. Thus, informants revealed that only HHs with beds in *chiqqa bet* (mud-stick houses) could comfortably hang and use the rectangular nets. However, rectangular shaped nets were not preferred because their installation made holes and cracks in the mud walls.

"Even though the rectangular type [of nets] is suitable to use on beds, circular types (too long) are very comfortable to use on mats on the floor or on raised earthen platforms/plinths." (Female, 35 years old, HEW in Layeye-Dugie *Kebele*)

"We have seen nets which are circular in shape in towns and this type is very good for rural residents too. It is tied only on one rope and easy to suspend and roll. It is very good." (Male, 50 years old, main administrator of Sheha-Gomenge *Kebele*)

5.3.3. Barriers to the consistent utilization of LLINs, and accessibility and availability

During almost all interviews, bedbug infestation was mentioned and observed as a major deterrent for consistent use of LLINs (**Figure 12**). The hanging corners of LLINs and the top inside of the nets harbored bedbugs. Additionally, bedbug urine and feces were associated with soiling and pigmentation of LLINs. Bedbugs reportedly infested almost all houses in the study communities. Some individuals detached nets or slept on the floor where rectangular nets could not be hanged. Some also asked if LLINs cannot protect against bedbugs and fleas and questioned the reason for hanging nets during the hot season. However, there were informants that used LLINs despite their beds being infested with bedbugs. Informants noted that they themselves and the community tried to destroy bedbugs and fleas with various insecticides, but that was impossible.

"LLINs killed bedbugs when they were new. When the net stopped killing bedbugs, we suspected that it also did not kill mosquitoes." (Female, 55 years old, local leader in Makesegnit Town)

Community residents also indicated problems in receiving the nets as constraints for LLIN utilization. They cited insufficient supply of LLINs delivered to the HH, inequitable and late delivery, and irregular replacement of old nets. However, HEWs and some other informants argued that HHs received LLINs based on their family size per national guidelines. Informants also reported that not all the HH members slept under an LLIN because HH members did not follow the recommended guideline of sleeping in groups. Some HHs were denied LLINs because they did not meet the requirement of constructing a latrine.

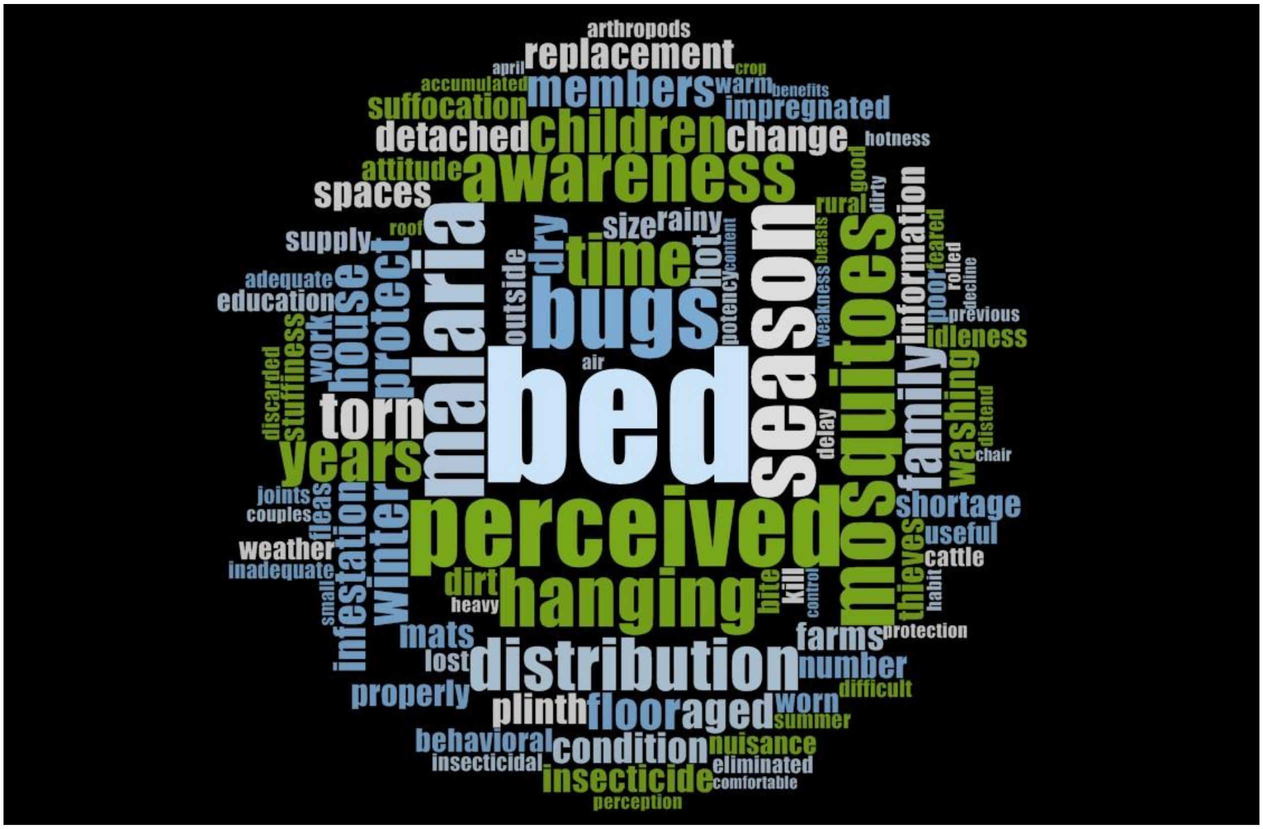

Figure 12: Word Cloud: 100 most occurring words, showing the word "bedbugs" as the most frequent one (NVivo Version 10)

As observed and reported, HHs with infants and pregnant women were most likely to use LLINs consistently. Wearing out of nets after using for several months left people exposed to malaria. For instance, three of the members of one HH who were not using LLINs had malaria and then they burnt plant leaves smoke to repel out mosquitoes. The damage was mainly associated with frequent washing, mice and poor housing conditions.

> *"We have no nets right now. We used them for one and a half year and when they became black and dirt due to soot, we stopped using it."* (Female, 32 years old, community member in Sheha Village, Sheha-Gomenge *Kebele)*

Another barrier to consistent utilization of LLINs was the lack of adequate information about their proper use. Many residents reported having been informed that LLINs had to be impregnated every 6 months like ITNs. Others thought that simply hanging a net without adjusting it or using it as a bed sheet would protect from mosquito bites. Some others perceived that mosquitoes are absent during the dry season. Some residents did not use the nets after washing them due to the perception that they had lost their insecticidal ability during laundering.

> *"After using for 6 or 7 months, I was not committed to reuse the net following washing. The nets did not serve for the recommended design periods."* (Male, 40 years old, resident of Dugie Village, Layeye-Dugie *Kebele)*

Some community residents believed that LLINs are not useful while some others did not know or ignored their importance as a physical barrier. Some community residents referred that only beds are used to suspend LLINs. Some others perceived malaria not to harm them by comparing with the recent increasing public health concern of non-communicable diseases, which are difficult to prevent, severe and untreatable. District malaria officers, malaria focal persons and HEWs said that in spite of high efforts to facilitate consistent utilization of LLINs, no significant behavioral change could be attained. The overall observation was also revealed that information scarcity exists.

> *"She (HEW) has taught properly, but the community did not internalize the information and adhere to utilize nets consistently."* (Male, 39 years old, community member in Lemba Village, Lemba-Arebayetu *Kebele)*

In some houses, bed structure was a critical barrier to net utilization. Sleeping spaces such as mud-made floors and sleeping platforms/plinths, chairs, verandas, and straw beds were unfit for rectangular nets. Children above five years commonly slept on such sleeping places in the study villages. However, children below three years were said to usually sleep with their parents or just the mother and sometimes with the grandmother, mostly on regular beds. Rectangular net mounting was reported and observed to be impossible in short and narrow thatched-roof houses that are common in the study area.

A number of other barriers were also identified. Residents disliked the nets; they were stuffy in dry season, had an odor, caused allergic reactions, and made sleeping spaces dark. Elderly residents often forgot to suspend them and busy farmers felt they could not take time from their work to hang them. LLINs were inconvenient for residents who traveled and those who were forced to sleep outside to protect and graze their cattle and protect other resources at night. A HEW reported that *"travel to lowlands for temporary work, travel to visit relatives or for holidays or mourning, irrigation at night time, elimination of mosquitoes with IRS and perception of sufficiency of one LLIN hanged on a bed as reasons for not using nets* *consistently."* Low educational status, negligence and idleness were also mentioned as barriers to consistent utilization.

> *"We farmers are not active to properly implement such activities. Since we have no education, we do not take things seriously. We focus on our day to day activities. Since managing our children is tiresome and having heavy work, we did not focus on net use."* *(*Female, 50 years old, community member in Lemba Village, Lemba-Arebaytu *Kebele)*

> *"During the rainy season, since there is runoff, thieves cannot come to loot our cattle and I sleep in my bed. But, they may steal in the dry season and forced to sleep outside."* (Male, 39 years old, community member in Lemba Village, Lemba-Arebayetu *Kebele)*

Regarding perceptions on the recent decline of malaria, some informants certainly believed or reported individuals' views that malaria and mosquito nuisance have been reduced or eliminated, and they associated this belief with a decline in the use of LLINs. For instance, one informant stated, *"since malaria is becoming to be history, LLINs utilization is currently forgotten."* Some others expected that malaria will not reoccur. Informants also reported that their communities no longer consider malaria as a major public health problem and a disease of the past.

5.3.4. Unintended and perceived collateral uses of LLINs

Unintended use, either misuse or repurposed use of LLINs was observed and reported by informants. Collateral use is an additional insect control benefit of LLINs beyond protection from mosquito bites and malaria. In general, informants admitted that using LLINs for unintended purposes was an inescapable truth. Most informants reported LLINs were used for unintended purposes when old, dirt, torn out, or had otherwise lost their physical integrity and after washing. Unsafe use and poor management practices were reportedly the major reasons for short run service damage, leading to repurposed uses.

Repurposed uses of LLINs included covering of pumpkin and pepper seedlings, drying of cereals, protecting and assembling straw and cereal harvest residues, bagging garlic for transport to markets with donkey carts, fencing, and use as a rope for binding or tethering purposes. For instance, a HEW reported that there was one individual who made a rope from torn nets for the community.

The key informants as well as community residents reported misusing of LLINs. Residents used new LLINs for certain domestic needs, such as for protecting and bagging straw and cereal harvest residues; for protecting pepper and eucalyptus seedlings; and drying cereals, buckthorn *(gesho*), malts (*bekel)* and pepper fruits. Residents placed LLINs under mattresses to protect them from bedbugs and as bed sheets and used them to cover latrine walls and make ropes (**Figure 13** and **Figure 14**). In rare cases, the nets were used as head scarves, curtains for windows and doors. Informants also reported that some residents used one net for mosquito protection and the remaining ones for unintended purposes. Misuse of nets also included giving them to friends or relatives as gifts, placing them in boiling water to kill bedbugs, or putting them as packed in plastic bags (**Figure 14**). Some informants reasoned that because malaria had been eliminated, using nets for other purposes made sense. However, several informants did not use new LLINs for unintended purposes and advised residents to also use them for their proper purpose.

> *"They used the net as a bed sheet. They did not use all the nets they obtained; instead they used certain nets for unintended purposes. They did not use the new net even for one month after they took it. For instance, I saw a new net at one kebele which they used for protecting pepper seedlings from herbivores*." (Female, 39 years old, HEW in Zengage *Kebele*)

> *"There was an individual who was sick in my neighborhood. My neighborhood got a net the same time I did. When he planted pumpkins, he used it for the protection of pumpkin seedlings from donkeys. When I asked him why he used the net for this purpose, he replied that pumpkins are used as food but not the net. I advised him not use it and he picked it up but he used it to make a rope."*(Male, 38 years old, local leader in Tsion-Seguaj *Kebele)*

Regarding perceived collateral uses of LLINs, informants acknowledged that LLINs can effectively destroy insects and other arthropods when new. There was a perception that LLINs must protect primarily against bedbugs and fleas, and additionally from other arthropods as insecticide which appeared to derive consistent use and reduced unintended use. Residents with infants reportedly used the nets day and night for protection against house flies, crawlers, debris, and dust. Cessation of insecticidal activity of LLINs against bedbugs after 2 or 3 months was the most frequent and serious complaint from community informants. Control of bedbugs was the commonly perceived primary collateral use of LLINs.

Figure 13: Word Cloud: 50 most occurring words showing terms like "rope", "seedlings" and "straw" (NVivo Version 10)

Figure 14: Misuse of new LLINs: a) Used for protection of *teff* (*Eragrostis teff*) straw from herbivore domestic animals; b) Put as packed in its plastic bag and c) Used as sleeping foam by filling it with straw

> *"Instead of hanging the net, they used it under the mattress since they believed the insecticide on the net killed bedbugs. They primarily used to protect from bedbugs despite they knew it protects from mosquitoes."* (Malaria focal person in Lemba HC)

5.3.5. Informants' suggestions to increase LLIN use

Informants and the wider community had different color preferences for bed nets. For instance, residents in Makesegnit Town reportedly preferred white colored nets. In addition, participants indicated a strong preference for circular nets over rectangular ones as the circular nets are easier to install and use (**Figure 15**). Circular types were frequently suggested for rural residents because their sleeping spaces are not uniform or comfortable, primarily because of their low socio-economic status, social and cultural issues, and seasonal changes. Due to high need, some residents switched from rectangular nets to circular nets on their own, and others tried to buy circular nets from shops. Some informants proposed a portable net that can be used in any space, similar to a sleeping bag, because individuals may sleep outside or away from home.

> *"The circular type is very good because it is easy to manage which is hanged at one point of the ceiling. The rectangular type is not comfortable to roll, suspend and move. The circular type is very comfortable for rural residents. I prefer the rectangular type to be replaced by circular one. Since the farmers' houses have not comfortable sleeping spaces, the circular one is good to use in any space."* (Male, 46 years old, local leader in Lemba-Arbaytu *Kebele)*

Furthermore, informants recommended that in-depth information on LLINs and malaria be provided to residents during distribution campaigns. In-depth information about the intended use of LLINs, how they work, and how long the insecticide lasts, as well as instructions on their care, should be made available to all HHs. Informants suggested that creation of awareness should be complemented with demonstrations at residences of role models, dialogue, discussion panels, and advising. Other recommendations for raising consistent use included strict supervision, presentations at conferences and churches, home visits, use of mass media, and sharing of experiences. Informants suggested renewing the frequent delivery of information that occurred in recent years, issuing frequent alerts, and mobilizing residents to install LLINs. Informants proposed delivery of the information through influential community members and senior health professionals as a way to avoid community fatigue and disrespect of community health workers. Providing residents with in-depth information in these ways can change their current mindset of carelessness in LLINs use, effect behavioral change, and foster a positive mental attitude toward LLIN use.

Informants recommended improving the effectiveness of LLINs by replacing them every year or 2 years, re-impregnated them every 6 months, or increasing the amount of the insecticide used. Prolonging the ability of LLINs to kill fleas and bedbugs would increase consistent use

> *"Since the net was not used for the recommended design period (aged, torn out and worn out), it is better to replace it in every two or three years*." (Male, 44 years old, local leader in Layeye-Dugie *Kebele)*

Some informants proposed reinforcing consistent use by establishing rules for LLIN use and imposing punishment or awarding incentives for following the rules. Other informants argued that the introduction of punishment would create a social crisis for HEWs and decrease net use. Inter-sectoral networking was suggested as a tool for applying positive punishment, which is generally expected by the population.

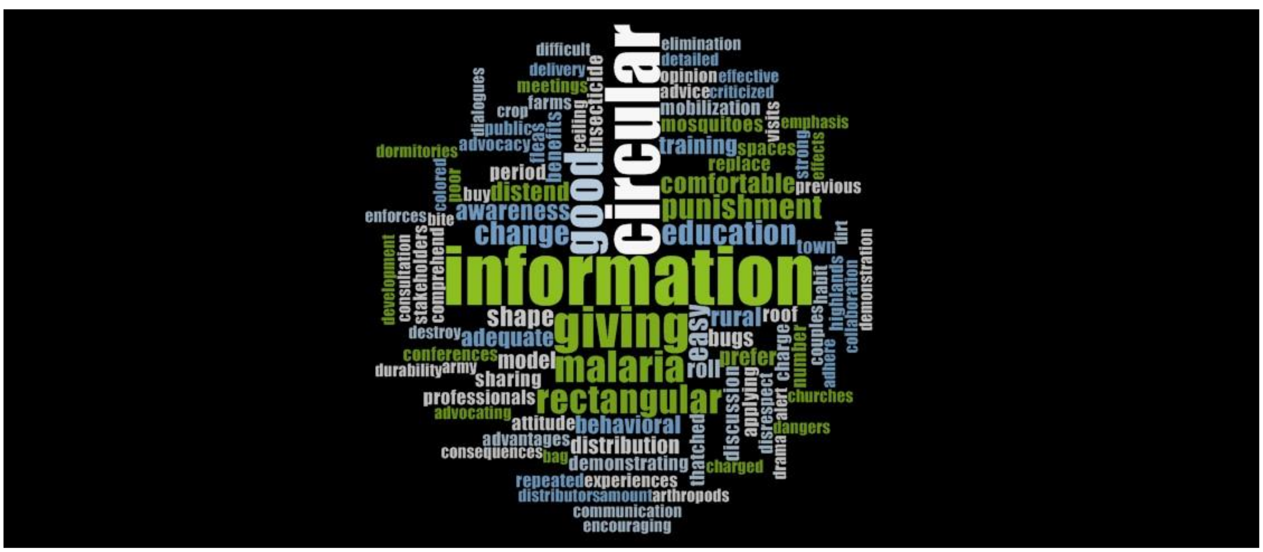

Figure 15: Word Cloud: 100 most occurring words showing the term "circular" as more frequent than "rectangular" (NVivo Version 10)

5.3.6. Follow-up, supervision and evaluation of LLINs utilization

Strict follow-up, supervision and evaluation of the use and efficacy of LLINs have reportedly not been carried out in the study area and represent a critical gap in malaria control efforts. This situation was mainly attributed to recent reduction in malaria occurrence.

> *"HEWs simply alerted us to take the nets. They simply told us to use them properly. There is no regular follow-up and supervision on how the community utilizes the net."* (Male, 40 years old, community member in Dugie village, Layeye-Dugie *Kebele)*

Community residents reported that implementing interventions have been beyond the capacity of HEWs since they were ignored by local officials. Nevertheless, some community informants acknowledged the effort of HEWs to attain consistent utilization despite no behavioral change in the community. On one occasion, the Malaria Prevention and Control District Office temporarily enforced punishment for HHs that did not use nets or utilized them for unintended purposes. Newly married couples, those who lost their assets due to disaster, and immigrants were mentioned to be considered in the meantime of the next replacement period. HEWs reported that some HHs were forced to purchase nets from shops or boutiques.

Another reason for lack of follow up was poor community acceptance of local mobilizers delivering information about net utilization. Inadequate HEW personnel was reported as a reason for the weakness of malaria interventions in the community.

Some informants preferred bi-annual IRS over using LLINs. They reasoned that IRS was better for people with asthma, elderly people, and those unable to hang nets; IRS had benefits in homes with faulty plastering and in newly constructed houses. Some informants preferred combining IRS and LLINs.

6. DISCUSSION

6.1. Role of house proximity to water bodies and other drivers on malaria

In this meso-endemic study setting, this study revealed that those individuals who travelled to malarious lowland areas had higher odds of malaria infection than those who did not travel. This finding is similar with that of other studies in Ethiopia (46, 129, 130) and elsewhere in the world (51, 89, 114, 115, 118, 119, 121, 123, 125-128) which identified travel history as a significant and independent predictor of malaria. Studies indicate that human migration and short-term travel are risk factors for malaria transmission in Amhara Region as well as other regions of Ethiopia (49). This may be due to the susceptibility of travelers from the midlands to malaria that progresses to severe symptomatic malaria, especially among those travelers who slept without personal protective measures (126, 213). Infection-naïve individuals are highly susceptible to malaria if exposed to an infectious anopheles mosquito, particularly in hyper-endemic areas (214, 215). The travels mainly take place during high malaria transmission periods among people seeking temporal job and engaging in social activities. Several studies indicated that lack of malaria chemoprophylaxis or poor adherence and low or irregular LLIN use were observed among travelers (46, 122). Studies also reported high proportion of local residents with imported malaria who did not take personal chemoprophylaxis when they travelled overseas and larger local outbreaks traced to foreign workers with imported relapsing vivax malaria while low malaria vector density was observed (121). Use of prophylactic drugs and ITNs are the first two effective measures for the prevention of malaria incidence relative to not using interventions (164). In the hot lowlands, many laborers sleep outdoors and in open spaces without protection from mosquitoes, and work at night, resulting in high malaria exposure risk (49, 213). Migrant laborers that do not use LLINs had higher risk of malaria infection (213). Northwestern Ethiopian lowland districts, including Metema, Gendawuha town administration, Tach Armachiho, West Armachiho, and Quara are hotspot areas of malaria (49, 190). In these areas, malaria prevalence among apparently healthy migrant laborers was significantly high (49, 213). Large numbers of imported malaria cases have been found in the northwestern Ethiopian highlands (46). Thus, imported malaria is a health risk besides locally acquired malaria in midland villages around Lake Tana. In most places, local transmission has contributed less to sustain transmission (125). This duality of malaria origins is also indicated by the fact that three-quarters of the malaria cases could not be traced to the lowlands. This epidemiological situation points to a critical obstacle to eliminating malaria through targeted interventions.

The finding of this study pointed out that individuals who did not know about malaria etiology, transmission, and prevention methods had higher odds of malaria infection than those who had awareness. The possible explanation could be the low educational status of the study population, delivery of malaria information independent of educational status, which prevents them from understanding and analyzing the information provided to them by HEWs, or poor acceptance or community fatigue for local promoters that leads to avoidance of the information. In addition, absence of follow up and supervision of HHs or effective information, education and communication (IEC) and social behavior change communication (SBCC) intervention strategies may be the possible reasons (216). This finding is consistent with other studies (217, 218). However, in Ethiopia, health extension program has played a tremendous role in the prevention and control of malaria. Under the program, the health service package includes promotion and preventive interventions to combat malaria at the community level through HEWs (219).

In this study, marital status was marginally significantly associated with malaria infection in unadjusted matched analysis. Unmarried individuals had 68% additional odds of malaria infection than married individuals. This may be because mostly young males travel to the hot spot malarious lowlands for temporal work in agricultural investment corridors (49). Unmarried people are generally in poorer health and have a higher mortality risk than married people (102). This finding agrees with other studies (220, 221).

This study revealed that individuals who completed grade 1 to 12 had higher odds of malaria without adjusting the potential confounders. The most likely reason may be due to the movement of male-young students in the period of July to October for seeking seasonal job (49, 105, 106). However, a study conducted among asymptomatic migrant travelers in northwest Ethiopia showed illiterate individuals had higher odds of malaria (213). Besides, other studies showed that the odds of getting malaria infection increased among those having no education (43). After multivariable adjustment, educational status was not a significant predictor of malaria infection, which is evidenced by other studies (70, 104). This may be most likely due to the homogeneity of the study population that involved majority of uneducated farmers.

In villages around Lake Tana, northwest Ethiopia, spatial malaria heterogeneity was not determined by fine-scale environmental factors, particularly water bodies close to HHs. This finding is in agreement with findings of previous studies that stated malaria infection was not associated with house proximity to a water body (55, 62, 153). However, other several studies contradicted this finding concluding that closeness to a water body increased malaria risk (18, 32, 44, 45, 71, 89, 106, 144-147). Other studies also reported lower odds of malaria infection in HHs closer to reservoirs than those at greater distances (152). On the other hand, studies have indicated a greater dependence of HHs malaria risk on local topographic wetness indices than land uses and land covers (63). The contradiction in findings might be attributed to differences in the use of LLINs or IRS, socioeconomic and environmental factors in study populations, vulnerabilities or transmission dynamics, differential health services accessibility, imported malaria cases, or variability of water bodies. In northwest Ethiopia, high number of seasonal migrant workers from mid-lands and highlands travel to malarious lowlands due to the presence of agricultural investments and high number of malaria cases were attributed to travel history (46, 222). Thus, this may avoid the association of house proximity to a water body with malaria infection occurrence. Individual exposures such as outdoor activities at night are common in the study communities that may most likely influence the association (106).

In the multivariable matched adjustment, socio-demographic factors, HH wealth, housing structure, travel history within the study area, and HH elevation were not associated with malaria. This might be explained by similarity of socio-demographic status, housing structure, HH wealth, elevation of HHs, and delivery of inadequate information on treatment-seeking, bed net use, and other preventive measures by Gondar *Zuriya* District Health Office.

This study also evidenced that number of LLIN(s) in a HH and IRS did not associate significantly with the occurrence of malaria infection. This finding is similar to that of studies revealing that LLINs ownership and use as well as indoor wall spraying did not show statistically significant association with occurrence of malaria (32, 46, 62, 104, 143). However, other studies reported a protective effect of LLINs utilization and IRS on malaria occurrence (30-32, 48, 74-77, 107). The difference may be attributed to failure to use LLINs properly and consistently, insufficient number or poor condition of LLINs, or failure to use them during travel away from home. As a result, the protective effect of LLINs could have been negated (191). Additionally, imported malaria, human activities at night outside the home, emergence of insecticide-resistant vectors, misuse and improper mixing of insecticides, coagulation of Propoxur at pumps while spraying, absence of on-time IRS application, faulty re-plastering/painting and spraying by untrained individuals may have reduced the protective effect of IRS**.**

6.2. Relationship of locally acquired malaria and house proximity to water bodies among under-five children

The findings of this study revealed that children aged 36-59 months had approximately four times higher odds of malaria infection risk than children below 36 months. This finding is corroborated by other studies (7, 30, 47, 48, 73-77). The possible reason children aged 36-59 months are at greater risk could be their frequency of/long exposure when playing with while youths looking after cattle, sheep, and goats, and other outdoor activities in the early evening (21, 78). The risk from these evening activities is compounded by the infrequent bathing and laundering of the clothes of this age group because poor hygiene increases the presence of mosquitoes (223). Studies revealed that early evening period (1800-2100 h) is the highest peak biting activity time of *An. arabiensis* (the most widely distributed *An. gambiae* complex species in Ethiopia) and *An. pharoensis* in the country (21, 54, 78) and having even higher outdoor biting than indoor biting in this period (78). Another important reason for the higher odds of infection for this age group may be the fact that they may not sleep with their mothers under one LLIN and therefore may not receive adequate protection from the net. Normally, the pattern of child care in Ethiopia is that younger children principally infants are given more priority and sleep with their parents, whereas older children do not sleep under a net and can be bitten by mosquitoes (7). Studies showed that children who shared a bed with their mothers were 21 times more likely to be covered by bed nets compared to those who did not (224). Moreover, only 24% and 25% of children aged 36-59 months' HHs owned LLINs and used them regularly at night for the 2 weeks prior to the survey compared with children below 36 months (76% and 75%), respectively, in this study.

In this study, by restricting the age group to under-five children, house proximity to a water body had not differential odds of local malaria infection. This finding is consistent with other studies (55, 62, 153). However, other studies also reported higher odds of malaria, or lower infection risk in HHs located near water bodies, or dependent on local topographic wetness indices instead of proximate land uses and land covers (18, 45, 63, 152). These inconsistent conclusions could result from differences in a number of factors: variations in proper and consistent use of LLINs, IRS coverage, habitat suitability for vector breeding, disappearance of environmental hotspots due to decrease in malaria transmission, engagement in outdoor activities at night, imported malaria leading to onward transmission, climatic conditions, study design, and endemicity. Immediately after the main wet season, many houses are surrounded by stagnant water in villages around Lake Tana. Concurrently, there is a mass return of young adults from agricultural farms in the malarious lowlands (46, 49, 213). The co-existence of these two factors may facilitate transmission through the imported cases in meso-endemic areas of northwest Ethiopia.

However, given how malaria spreads, it is biologically possible that people in HHs located near to mosquito habitats have increased risk of infection (41). As the female leaves the breeding site to find a human host, it is reasonable to assume that nearby individuals have high probabilities of being targeted. Nevertheless, it is not necessarily house proximity to a water body per se that matters; rather, house proximity might be considered a strong positive correlate of the likelihood of being infected. For instance, evidence shows that malaria infection risk for individuals in a given HH at a given distance to the breeding site was reduced if there were many other nearby HHs close to the breeding site (32). Lastly, given that malaria transmission depends on several area-specific characteristics, it might well be that a given variable is a significant risk factor in one area though less important in another setting.

In the multivariable matched analysis, the socio-demographic factors; HH wealth; residential housing structure; tethering of domestic animals at night; travel history within the study villages; HH member's travel to malarious lowlands; IRS; malaria information; and water body presence within a 500m radius were not independent predictors of local malaria. This is most likely due to the similarity of these factors as well as malaria-related behaviors and the provision of insufficient malaria information on treatment-seeking, LLIN, and other preventive measures by Gondar *Zuriya* District Health Office. For instance, around 98% of the houses had walls made of mud, which is not sufficient to keep mosquitoes from entry.

This study showed that significant association was not observed between number of LLIN(s) in a HH and local malaria occurrence. This finding is in line with previous studies, which did not predict protection offered by LLINs (48). Studies also recognized that increasing LLIN coverage did not lower malaria parasitaemia (77, 143). Nonetheless, other studies ascertained that LLIN use reduced malaria among under-five children (32, 77). Studies identified main attributes that may undermine the efficiency of LLINs: resistance of mosquitoes to pyrethroids, poor condition of nets (79, 225), primary caregivers' beliefs about causation and vulnerability, and obstacles in translating knowledge into behavior (39, 226). Additional reasons in this study setting may be use of LLINs for unintended purposes, heavy workload in rural communities, or low maternal education. In the study setting, malaria cases were found in newly constructed houses that were unsprayed due to marriage and resettlement and/or having no LLINs (227).

In Gondar *Zuriya* District, *An. gambiae* complex is dominant species, which includes the main malaria vector in Ethiopia, *An. arabiensis,* followed by *An. pharoensis*. The *An. gambiae* complex, presumably *An. arabiensis*, and *An. pharoensis* were reported as the predominant species from villages around Lake Tana, northwest Ethiopia (20, 79), Butajira, a highland area in south-central Ethiopia (19), Ziway area, central Ethiopia (44) and Gilgel Gibe hydroelectric dam, southwest Ethiopia in the country (55). An altitude-based study in Ethiopia also identified *An. arabiensis*, *An. pharoensis*, and *An. funestus* group as the most common species (18). A systematic review on dominant malaria vectors in Africa indicated that *An. arabiensis* and *An. funestus* are included among the seven dominant species in the region (17). In this study, *An. gambiae* complex and *An. pharoensis* were found in villages <2000 masl, indicating high distribution of local malaria among under-five children in these villages. Currently, malaria is not a primary public health concern in the study villages due to the integrated interventions against the identified vectors. The presence of the primary vectors may indicate the potential for the occurrence of malaria outbreaks if IRS, the most exercised intervention measure in the study villages, fails and due to the susceptibility of the communities. In addition, global warming, which aids in the expansion of malaria vectors, may cause the neighboring highland population, which is also susceptible, to be at greater risk of malaria (19).

This study revealed that anopheline breeding sockets were shallow stream edges and beds, small water bodies and holes, puddles in hoof prints exposed to sunlight, slow flowing or stagnant water with or without debris, and surface algae. These breeding types were reported from other parts of Ethiopia (19, 228), eastern Sudan (229), and Eritrea (230). *An. gambiae* complex has adapted to diverse habitats (18, 19). Absence of larvae at one site alongside streams in June could have resulted from heavy run-off, which swept them away. Heavy rainfall could also destroy larvae directly (231).

6.3. Barriers of consistent LLINs utilization

In this study, the findings are organized into four themes: (1) perceived benefits and shortcomings of LLINs, (2) unintended and perceived collateral uses of LLINs, (3) reasons that influence consistent utilization of LLINs, and (4) informants' suggestions to increase LLIN use.

The findings of this study show that community members gave high marks not for malarial protection benefits of bed nets, but for their collateral benefit of protecting against arthropods such as houseflies, crawlers, fleas, bedbugs, cockroaches, and spiders in the first 3 months of use. Similar information was reported from elsewhere in Ethiopia (36) and Uganda (165). Loss of insecticidal effectiveness of LLINs after several months was mentioned as critical limitation of LLINs in this study. Such perceived limitation of LLINs was reported elsewhere in Ethiopia (25, 36) and Kenya (178), where users were not aware of the chemical impregnation of nets and reported them ineffective as physical barriers. However, a study conducted in Zanzibar, Tanzania among caretakers of under-five children indicated LLINs had high self-efficacy (166). Capitalizing the information about the currently distributed LLINs might be used to overcome this misconception. Another important finding of this study was that informants noted LLINs became quickly dirty, faded, wore out due to repeated washing, degraded because of poor conditions of rural houses and mice infestation, and were no longer functional after 6 months. Doda and colleagues (36) also reported non-functionality of LLINs after 6 months as mentioned by informants and preferred to use for other purposes. A follow-up study by Solomon et al. (181) reported that LLINs had a 12-month median functional survival time and that successive laundering significantly increased feeding success and survival rates of *An. gambiae* complex (232). However, WHO indicates the serviceable life span of LLINs to be 3 years (175, 176). This study also showed that users reported that exposure to the chemicals caused skin irritation was also reported in several other studies (25, 171).

In this study, regardless of the study population characteristics, some key informants and most community residents questioned the strength and size, including the mesh size of the current LLINs. This might be explained by comparison of the current LLINs with ITNs. Other studies also reported small net size, weak physical integrity, and big mesh size as shortcomings of

LLINs (39, 140, 166). However, LLINs were highly credited for their strong texture, wide square shape and large mesh size in other studies (140, 166).

The findings of this study evidenced that circular shaped nets were acknowledged preferably by key informants and resident interviewees due to the compatibility to use at any sleeping space, and easiness for rolling during day time and suspension at night, also reported by other studies (36). Rectangular shaped nets were not favored due to the complexity of the installation procedure, the need for a wide area and compatibility only with beds in mud houses. Additionally, it was not credited even in mud-made wall houses since it makes the house unaesthetic by damaging the walls during installation. These challenges and shortcomings of rectangular nets were also reported by other studies (25, 36, 165).

The results of this study verified that the most common types of repurposed uses of nets were connected to the prevailing local livelihood and socio-economic conditions. These uses peaked during the harvest season in the study communities due to the service of the nets for various activities. Other studies documented similar repurposed uses of nets (36, 172, 173). This study explored that locals used LLINs for other purposes when they determined the nets had ceased to serve their intended purposes due to old age, or loss of mosquito-killing capacity, as reported by other studies (36, 169). It was reported and observed that repurposing of LLINs is an increasing phenomenon in the study communities. Similar studies elsewhere in Ethiopia and other parts of Africa reported that local users engage in using nets for various repurposed uses (25, 26, 36, 169, 174, 178). Poverty might be the reason for locals to use LLINs for unintended purposes. Doda et al. (36) and Short et al. (233) forwarded similar observations that underlying critical poverty was a factor to use LLINs for other uses.

In this study, both key informants and community interviewees mentioned misuse of nets. Informants were openly regretful for their community while misusing nets, especially when new. New LLINs were used for a wide range of purposes, similarly practiced among other communities in Ethiopia and elsewhere in Africa (25, 36, 234). Perceiving malaria as having been controlled and unable to hang nets in all sleeping spaces were cited as reasons for the misuse of nets. Similar risk perceptions that led to misuse of nets were reported by other studies (36).

In this study, informants reported that the main collateral uses of LLINs were for killing and warding off of arthropods, protection from hens, and protection from dust and debris, primarily for infants. Such uses, particularly fighting bedbug infestation, motivated residents to use nets consistently for the first few months. Similarly, Birhanu et al. (25), Strachan et al. (165) and Doda et al. (36) reported that community residents obtained diverse collateral benefits from LLINs beyond the prevention of malaria and the nuisance of mosquitoes. In this context, promoting consistent LLINs use can be most effective if accompanied by interventions that can eliminate bedbug infestation. WHO reported that bedbugs contribute indirectly to the ineffectiveness of malaria interventions and recommended the use of insecticides such as pyrethroids, diazinon, bendiocarb, and dichlorvos (235). However, bedbugs have already developed resistance to these insecticides and studies recommended to consider other disinfestation mechanisms (236). Capitalizing on equalizing this set of collateral benefits of LLINs may contribute to increase their consistent utilization.

This study identified that inadequacy of nets in a HH, inequitable distribution, and absence of on-time replacement were the first-line barriers of LLINs utilization. Such delivery and supply-related constraints were reported by similar studies in Ethiopia (25) and Zanzibar (170). Infants and pregnant women were reported category of population groups most likely to use LLINs consistently, was also observed in other studies (25, 36, 180). The benefits derived from consistent use; especially by HHs with under-five children and pregnant women has paramount importance. Nevertheless, LLINs were not distributed solely to these and other vulnerable sections of the population.

Consistent utilization of LLINs by villagers around Lake Tana was to a great extent determined by socio-demographic and socio-cultural characteristics, behavioral reasons and misconceptions, weather conditions, health-related reasons, and livelihood and economic reasons directly or indirectly. Equivalent characteristics and reasons were documented in other communities (25, 36-39, 165, 172, 237-240). The perceptions that malaria vectors cannot harm and malaria is no longer a problem contributed to non-consistent net use, also mentioned by other studies (25, 36, 171). This study also scanned that quick dirtiness, aging, and damage of LLINs were stated to led to stoppage of using LLINs, which is in line with findings of previous studies (25, 36). In addition, failure of the current LLINs to protect against bedbug and flea infestations after a few months was a predominant barrier of consistent use of bed nets in the study communities. This was also a serious problem cited by other studies elsewhere in Ethiopia (36), Uganda (165) and Rwanda (174).

Another significant fining of this study was that residents' insufficient information about LLINs, malaria transmission, and malaria vectors resulted in misperceptions and negligence, which in turn led to non-adherence to regular net use. Similar other studies also confirmed this analytical associations (36, 38, 177, 182, 184). Berhanu et al. (25) and Doda et al. (36) similarly reported a behavioral shift away from LLIN use due to perception of low malaria risk, saving of nets for future use; lack of awareness and negligence accounted for non-consistent use of LLINs. Moreover, lack of clear information about the recommended 3 service years of LLINs was a sound reason that constrained bed net use, which is consistent with other studies (25, 36, 178, 241). Finally, the perception that LLINs lose their insecticidal activity after repeated washing was mentioned that hinder consistent use. These misconceptions were reported from other communities in Ethiopia (25, 36), Ghana (242) and Kenya (178). A bio-efficacy study done in south-central Ethiopia showed that LLINs were effective up to 24 months (181).

In the studied local communities, sleeping spaces without beds and incompatible bed structures were associated with the failure to use nets consistently. Additionally, even small, thatched-roof houses were observed and reported to be incompatible with use of rectangular-shaped nets. Similar sleeping arrangement and housing structure problems were identified in various communities by other studies (25, 165, 172). These sleeping arrangements are an indication of poor socio-economic status of communities.

Informants in this study suggested promisingly consistent utilization of LLINs may be achieved through universal coverage of targeted communities by conical nets instead of rectangular nets. Distribution of conical nets was also suggested by other studies elsewhere in Ethiopia (183) and Uganda (174). Besides, some key informants even proposed provision of portable nets that can be used at any space like sleeping bags while sleeping outside the house or away from home. Such self–supporting and sealed pop up nets could be employed both indoors and outdoors and may possibly strategic and easier for older children and women to assemble and may also prevent, for example, soldier ants and reptile infestation. Other studies also recommended the development of portable and user friendly nets that do not need external supporting structures (39, 179). Another way to increase consistent use of mosquito nets, resolving technical difficulties related to mounting and using a net may best be addressed at the manufacturer level.

6.4. Validity and Generalizability

Internal validity refers the extent to which the information collected accurately answers the research question while external validity or generalizability refers the extent to which the inferences drawn from a study can be generalized to a broader population beyond the study population. The extent to which the findings are accurate and the degree to which the conclusions derived can be generalized depend on the quality of data at all stages of the study, the relevance of the study design and the proper selection of data analysis techniques (193).

Internal validity

Several various actions and mechanisms were employed to minimize information bias that may result from systematic disparities in the process of measuring the study variables. Use of a pre-tested, semi-structured questionnaire before data collection to evaluate the face validity and to ensure whether the study participants understood what the data collectors were asking, involving of direct observation measurement for variables that required, selection of controls within three days, use of local language for clarity to collect data and use of well-trained data collectors were the major actions taken to reduce information bias during measurement. Blinding of data collectors about the malaria status of study participants were considered to overcome interviewer bias.

Use of well-trained data collectors, use of holidays dates or non-working dates to trace malaria diagnosis status or its symptoms in the prior one month of study participants, travel history to malarious lowlands and travel away home within the study area in the prior one month, LLIN utilization history in the prior two weeks and one month were the actions taken to reduce recall bias during measurement. Regarding the entomological survey, larvae sampling, rearing, and adult *Anopheles* mosquito species identification were also carried out using standard operating procedures to overcome measurement errors.

Involving of proportional community interviewees from all *kebeles*, HH heads of both genders and age categories, lactating women, local leaders, students, and health professionals, and use of probing questions and techniques were the major actions to get detail information on consistent LLIN utilization.

External validity

The research protocols were strictly followed during this research project. An adequate sample size estimated to detect exposure difference between cases and controls, and all malaria suspected patients were included in the study. Both of these approaches may increase the study's generalizability to the source population.

Individual matching and frequency matching was used to eliminate the confounding effects of sex and age. Stratified analyses were used to control confounding and report effect modification. Besides, multivariable conditional logistic regression models were used to adjust confounding effect. Therefore, the findings of this study are transferable to the local population.

6.5. Strengths and Limitations

Strengths

Matched case-control studies have minimal bias relative to cross-sectional and unmatched case-control designs because they compare groups internally (58). The water bodies proximate to the HHs were geo-referenced through direct ecological surveys to increase measurement accuracy despite accessible satellite imagery. To avoid information bias, data collectors were blinded to the malaria status of patients during field data collection at the HH level. All other measurements of exposure variables were performed at home through interviews and direct observations.

Stratified analyses, multivariable matched analyses and malaria vectors identification allowed exploring effect of house proximity to water bodies on local malaria, which has rarely been considered in such studies. The non-significant association was validated by comparing groups internally and after eliminating possible confounders.

Data was collected after validation of data collection tools. Matched case-control study design sample size calculation methods were employed to take the required adequate sample size. The questionnaire was pre-tested to evaluate the face validity and modified based on the local context before data collection. Data collectors and supervisors were diploma holders and adequate training on data collection and interview techniques was given before data collection.

Phenomenological qualitative methodology, which is a best approach and method of inquiry which helps to exhaustively describe, interpret, illuminate and qualify a phenomenon in everyday human life experiences, was employed to explore the reasons that influence consistent utilization of LLINs. Besides, sufficient number of community interviewees from various backgrounds and population groups, and key informants from concerned institutions were included. All the reasons that led to non-consistent utilization of LLINs, including accessibility and delivery issues were addressed in detail. Textual, structural, and interpretive phenomenological analyses were used to understand lived experience of the informants about non-consistent utilization of LLINs.

Limitations

This study has some limitations. It is difficult to establish temporal relationships between exposures and occurrence of malaria infection. Employing PCD to measure the effect of house proximity to a water body on malaria occurrence was not efficient due to the presence of asymptomatic and submicroscopic parasite carriers and the treatment of malaria by drug vendors, private clinics, and health posts (243), which were not studied. Misclassification bias among cases and controls due to microscopy can be introduced. The submicroscopic parasite carriage influences negatively the risk factor analysis if the reservoirs occur in controls. Case and control selection from health facilities can be prone to bias since patients usually do not represent the general population. Recall bias could have been introduced during travel history measurement. Residual confounders or unmeasured variables (e.g. vegetation, moist places near the HHs, water pools in plastic or clay material, etc.) were not controlled but the effect on the finding is small. Despite principal component 1 is the most commonly used for wealth index construction, it is a limitation. Furthermore, due to the presence of political instability in the study area, this study did not include the month of September, at the end of the main rainy season, when more imported and locally acquired malaria cases occur in northwestern Ethiopia (105). Even though this is a low transmission setting, travel history associated with malaria does not necessarily identify imported cases.

The small sample size was the limitation while determining the effect of house proximity to a water body on locally acquired malaria occurrence. Differences in care seeking and variation in breeding suitability of the water bodies would influence the effect of house proximity to water bodies on local malaria. The flight capacity of mosquitoes which is influenced by topography, settlement pattern, and environmental factors should be taken into account while interpreting the results. The decision to exclude children who reportedly experienced malaria infection more than once might also be a limitation. However, since repeat infections might be relapse episodes of hypnozoites of *P. vivax* (244), exclusion was believed to be the best approach. On the other hand, the larvae survey did not include all months of a year. For instance, the exclusion of September, when various types of water bodies are created, may have reduced the number of malaria vectors. Data were not obtained on pH, temperature, turbidity, and conductivity of water where the larvae were collected and the vectorial capacity. FGDs and visual documentation through obtrusive observation were not conducted to explore the reasons for non-consistent utilization of LLINs, which may increase the richness and quality of the data.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1. Conclusions

In this study, travel to malarious lowlands and inadequate malaria information determined the occurrence of malaria infection in villages around Lake Tana. In addition, marital status and educational status, apparently related to the predominance of unmarried young male students travelling to the lowlands, are risk factors of malaria infection regardless of the potential confounders. However, house proximity to a water body was not a predictor of malaria infection occurrence in the study setting.

This study also identified that children aged 36-59 months were at increased odds of local malaria infection in meso-endemic villages around Lake Tana. Nonetheless, water body presence within 500m radius of a HH did not have differential odds of local malaria risk. On the other hand, the malaria vectors, *An. gambiae* complex*, An. pharoensis* and *An. funestus* group were identified in the study area.

The qualitative exploration found that wrongly perceived weaknesses of LLINs were common; rectangular LLINs were rated inferior to conical nets; unintended uses were widespread; collateral benefits of nets were considered equivalently important; and net delivery-related, socio-demographic, socio-cultural, behavioral, weather conditions, health-related, livelihood and economic reasons, and misconceptions generally impeded consistent use of LLINs.

7.2. Recommendations

Malaria elimination programmers, malaria officers, and communities

Regarding travel to malarious Ethiopian lowlands, it must be highly recommended that travelers should use both personal protective measures and chemoprophylaxis. Standby malaria self-treatment can be an alternative intervention for travelers. Carefully selected and geographically specific antimalarial drugs should be given to non-immune people travelling to high-risk areas. Besides, SBCC reminding residents in these areas on the risk of malaria infection through travel should be undertaken. Health authorities should improve diagnosis in health facilities in highland areas by adding travel history to malaria case definitions. Hence, national malaria control and elimination programmers and health authorities should design effective and integrated interventions that consider imported malaria cases. Besides, it is highly recommended to design effective and integrated approaches, including IEC and SBCC to give adequate and universal coverage in information by considering the educational status of the community.

The reduction of locally acquired malaria among under-five children requires increment of long-acting insecticide spraying coverage and frequency mainly due to low use of LLINs among children aged 36-59 months and reinforces the need to use repellents to keep children safe until they sleep under bed nets. Malaria information should also be provided for primary caregivers to equally manage children below 36 months and children aged 36-59 months while applying LLINs utilization. Vector control interventions should be designed in accordance with malaria vectors present in a locality.

Suggestions made by informants for increasing consistent LLIN use, including the provision of nets that are structurally compatible with sleeping spaces and the delivery of adequate information about malaria vectors and the properties and proper uses of LLINs to the community indicate substantial accumulation of knowledge that may guide effective LLIN programs in the study area.

Researchers

Community based prospective cohort study using Loop-mediated isothermal amplification is needed to identify determinants of imported malaria and locally acquired malaria independently in the meso-endemic villages of northwestern Ethiopia. In addition, further study is required on the onward transmission dynamics of imported malaria in the midlands of northwest Ethiopia. Forthcoming studies should use advanced molecular techniques for malaria diagnosis and buffer zone for water body exposure to investigate the association of house proximity to a water body with locally acquired malaria occurrence.

Identification of locally acquired malaria cases is a baseline for further studies, which should answer prevalence of introduced and indigenous malaria among under-five children in meso-endemic areas of Ethiopia. In the study area, advanced molecular techniques, including polymerase chain reaction for identification of sibling anophelines also need to be conducted in future studies. Malaria transmission potential through other anopheline mosquitoes identified in the study areas should be subjects of further investigation.

Moreover, the results of the qualitative study may provide baseline information for researchers to consider FGDs, visual data, and published literature and other document reviews to explore the reasons and challenges of consistent utilization of LLINs in detail.

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10. ANNEXES

Annex 1: Laboratory reagents, equipment and procedures for microscopic examination of malaria (standard operating procedure)

Blood film preparation

1) Reagents and equipment:

Cleaned and wrapped slides, sterile lancets, vacutainer/5 or 10ml syringes, tourniquet, sharps container, alcohol and water, absorbent cotton wool, slide box, micro-pore tape, lint free clean cotton cloth, pencil

2) Preparation of blood films with finger-prick blood

1. With the patient's hand, palm upwards, select the third or middle finger (the big toe can be used for infants). The thumb should not be used. With a pledge of cotton wool lightly soaked in alcohol, clean the finger, using firm strokes to remove dirt and grease from the ball of the finger. With the clean cotton towel dry the finger, using firm strokes to stimulate blood circulation.
2. With a sterile lancet puncture the ball of the finger using a quick rolling action. By applying gentle pressure to the finger express the first drop of blood and wipe it away with a dry piece of cotton wool. Dispose of the dirty lancet and cotton wool in a sharps container. Make sure no strands of cotton remain on the finger to contaminate blood.
3. Working quickly and holding a clean slide by the edges, collect the blood as follows: apply gentle pressure to the finger and collect a single small drop of blood (about 2 mm in diameter) on to the middle of the slide. This is for the thin film. Apply further pressure to express more blood and collect two or three large drops, about 2 mm in diameter, on to the slide about 1 cm from the drop intended for the thick film. Wipe the remaining blood away from the finger with a piece of cotton wool. Dispose the dirty cotton wool in a sharps container.
4. **Thick film**: When making a thick film always handle the slides by the edges or by a corner. Using the corner of the spreader, quickly join the drops of blood and spread them to make an even, thick film. The blood should not be excessively

stirred but can be spread in a circular or rectangular form with 3 to 6 movements. The circular film should be about 1.2 cm in diameter.

5. **Thin film**: Using another clean slide as a "spreader", touch the small drop with the spreader and allow the blood to run along its edge. Firmly push the spreader along the slide, keeping at an angle of 45 degrees. Make sure that the spreader is in even contact with the surface of the slide at all times the blood is being prepared.
6. Label the dry thin film with the soft lead pencil by writing across the thicker portion of the film the patient number and date (dd/mm/yy). Do not use ball pen for labeling the slide. Allow the thick film to dry in a flat, level position protected from flies, dust and extreme heat.
7. Transport and store slides in appropriate boxes, avoiding direct contact between slides. For long-term storage (several months), store in a dry area or in tight-closed bags/boxes with desiccant.

3) Preparation of reagents for Giemsa staining

Preparation of Giemsa stain

Stain formula: Giemsa Powder (3.8g), Methanol (250ml), Glycerol (250ml), Glass beads (50), large dark bottle

a. Preparation

1. An amber bottle is preferred but if one is not available use a chemically dry, clear, hard glass or polyethylene bottle of suitable size. You will need about 50 solid glass beads of about 5 mm in diameter.
2. Put the glass beads in the bottle, pour in the measured amount of methanol and add the stain powder.
3. Tightly stopper the bottle. Allow the stain powder to sink slowly through the methanol until it settles to the bottom. Shake the bottle with a circular motion for 2-3 minutes.
4. Add the measured amount of glycerol and repeat the shaking process. Continue to shake for 2-3 minutes at half-hourly intervals at least six times.

5. Leave the bottle unused for 2-3 days; shaking it 3-4 times each day until the stain is thoroughly mixed. Keep a small amount of this stock solution in a small bottle for routine use to avoid contamination of stock solution.
6. Each newly prepared batch of stain should be properly labeled, including date of preparation, and should be tested for optimal dilution and staining time. Always keep the bottle tightly stoppered, in a cool place, away from direct sunlight. Clear glass stock bottles can be covered with a thick dark paper jacket to keep out the light.

b. Giemsa staining reagents:

Giemsa stain, Methanol, Absorbent cotton wool, Test tubes (capacity 5ml), Buffered water (pH 7.2), Pasteur pipette, Curved plastic staining tray or plate, Slide-draining rack, Timing clock, Rapid Method (suitable for individual slides)

1. Allow the thick film to dry thoroughly; if really rapid results are required, drying may be hastened by fanning or briefly exposing the slides to gentle heat such as from the microscope lamp or hot air from a hair dryer. Care should be taken to avoid overheating; otherwise the thick film will be heat-fixed.
2. Fix the thin film by dipping it a container of methanol for a few seconds. To permit dehemoglobinization, the thick film should not be fixed; therefore avoid methanol or methanol vapor touching the film.
3. Prepare 10% Giemsa solution in buffered water (pH 7.2); if a small quantity is being used, 3 drops of stain to each milliliter or buffered water will give the correct concentration of Giemsa solution. One slide requires about 3 mL of made-up stain.
4. Gently pour the stain on the slide; a pipette can be used for this purpose. Alternatively, slides can be placed face down on a concave staining plate and the stain introduced underneath the slide.
5. Stain for 5-10 minutes.
6. Gently flush the stain off the slide by adding drops of clean water. DO NOT tip off the stain and wash, as this will leave a deposit of scum over the smear.
7. Place the slide in the rack, film side downwards, to drain and dry, making sure that the film does not touch the slide rack.

c. Blood film reading

Equipment: Microscope with x100 oil immersion objective, Tally counter, Immersion Oil

Thin film examination

Routine examination of thin film is not used as it gives a different parasite density to quantify on the thick film

Thick film examination for *Plasmodium* species identification

Routine examination of a thick film is based on examination of 100 good fields. That is, a slide can be pronounced negative only after no parasites have been found in 100 fields of the blood film. If parasites are found, a further 100 fields should be examined before a final identification of species is made. This ensures that there is little possibility of a mixed infection (more than one species present in the blood film) being overlooked.

The technique for thick film examination is as follows:

1. Using the x40 objective, scan the film for any microfilariae that may be present. At the same time, select a part of the film that is well stained, free of staining debris, and well populated with white blood cells. If the film is well made or even thickness, this should present no problems; poorer quality films may need to be quite extensively searched.
2. Place the immersion oil on the thick film.
3. Swivel the x100 oil immersion objective over the selected portion of the blood film
4. Confirm that the portion of the film selected is acceptable and continue to examine the slide for 100 immersion fields. Move the blood film by one oil immersion field each time, following the pattern described for the thin film.
5. Use a tally counter to count the fields as they are examined.

Thick film examination for parasite counts

ROUTINE malaria parasite counts are performed and are expressed as parasites seen per microliter of blood (n/µL). For the preparation of quality control samples, accurate malaria counts are crucial as the initial malaria parasite count of the blood is used to calculate and prepare the blood dilutions.

Parasite count per 500 white cells

1. The number of parasites relative to the 500 first white cells is counted.
2. If more than 150 parasites are counted for the first 200 white cells, and then calculate parasite count by 200 white cells instead.

3. Count all the species present and record separately the gametocytes of *P.falciparum* and the asexual parasites.
4. White cell counts (number of leukocytes per µL of blood) will be determined by a hematology analyzer and used in the parasite density calculation below:
5. (Number of counted parasites, divided by number of counted leukocytes) x (number of leukocytes per µL of blood, determined by hematology analysis) = number of parasites per µL of blood
6. Malaria smears will be read by two microscopists who are both blinded to the other reader's result; any discrepancies will also be resolved by a third microscopist. Ten percent of all samples will be re-examined by a senior technician and discrepant (positive versus negative) slides will be reread by a third technician until a consensus is reached.
7. The discrepancy between the two parasite counts will be calculated as follows:
8. ("Difference between the two counts", divided by "mean of the two counts") x 100.
9. If there is a discrepancy of 20% or less, then the mean of the two parasite counts will be used for calculation and preparation of blood dilutions.
10. If the discrepancy is greater than 20%, then the blood films should be read again by the two microscopists who should still be blinded.
11. If the discrepancy between the two repeated parasite counts is 20% or less, then the mean of the two repeated parasite counts is used for calculation and preparation of blood dilutions.
12. If the discrepancy between the two repeated parasite counts is again greater than 20%, then the sample will NOT be used to prepare dilutions.

4) Results reporting

Results are always expressed as the stage/s of malaria parasite seen, the species seen, and the number seen per microliter of blood.

Asexual (rings, trophozoites and schizonts) and sexual (gametocytes) are reported separately. Example: Mixed infection (*P. falciparum* and *P. vivax*)

Asexual (rings) of *P. falciparum*, count= 10000/ µL

Sexual (gametocytes) of *P. falciparum* seen, count=1000/ µL

Asexual (rings, trophozoites and schizonts) of *P. vivax*, count=2000/ µL

Sexual (gametocytes) of *P. vivax* seen, count=1000/ µL

Annex 2: English and Amharic version questionnaires

English version of the questionnaire

ADDIS ABABA UNIVERSITY

ETHIOPIAN INSTITUTE OF WATER RESOURCES

WATER AND PUBLIC HEALTH PROGRAM

Informed assent and consent forms

a) Consent/assent form

Ways of approaching and interviewing the caregiver/guardian or study participant in the data collection process

1. Selecting individuals who had malaria signs and symptoms from those visiting the health center for treatment.
2. Then, after explaining the overall nature of the study, objectives, benefits and having no risks, getting permission to take blood sample.
3. Then, confirming the individual as malaria positive with microscopy.
4. Then after, searching individuals who had no malaria parasites from those visiting the health center for treatment.
5. Finally, the data collectors collected the respected data from case-HHs and control-HHs. First of all, the data collectors should get permission to enter the compound (accidental entry is strictly prohibited).
6. Ask whether the HH head is present or not.
7. After introducing yourself, explain the reasons why you go there and the required data regarding the study participant. Elaborating all ideas is mandatory.
8. If the HH head is willing, please ask the study participant to put his/her signature on consent/assent form before interviewing.
9. After completing the interview, say thanks and end it.

Good morning/afternoon

I would like to thank you for investing your precious time to make interview with me (for individual in-depth interview and key informant interview).

My name is_______________. I am coming here for research and investigation for (PhD) data collection on behalf of Ethiopian Institute of Water Resources (EIWR), Addis Ababa University (AAU).

Title of the research: “Determinants of malaria transmission and bed net utilization among households around Lake Tana, northwest Ethiopia’’

Principal Investigator**:** Asmamaw Malede Tarekegn

Supervisor: __________________________

Coordinating office: EIWR, AAU

Introduction: Malaria is still threatening the life of millions of people in the globe, predominantly in SSA even though integrated intervention efforts have delivered. Evidence showed that presence of water bodies in close proximity to houses, non-consistent use of bed nets and other related drivers have hindered the efforts to eliminate malaria.

Purpose: The aim of this study is to investigate the contribution of house proximity to water bodies, identify individual and household-level environmental and socio-demographic drivers of imported and locally acquired malaria, identify malaria vectors and explore barriers for consistent LLINs utilization in meso-endemic villages around Lake Tana, northwest Ethiopia.This research is undertaken for partial fulfillment of Doctoral degree (PhD) in water and public health.

Procedure and Participation: Individuals (≥ 5months) who will visit the selected health centers for treatment and having signs and symptoms suggestive of malaria will be invited to participate in this study. Similarly, the corresponding potential controls (having no malaria) will be invited to enroll in the study. If the study participant/caregiver is agreed to take part in the study, a teaspoonful of blood sample will be drawn from the study participant (≥5 months) for malaria diagnosis using a finger prick method. After getting the malaria cases and controls, data on the risk factors will be collected at their HHs. The time spent for the interview and/or direct observation will no longer than 45 minutes. Moreover, data collection on proximate water bodies/other LULCs will be carried out without involving the household head.

You (study participant or caregiver/guardian) do not have to be in this research if you do not want to be. It is up to you. If you decide not to be in the research, it is okay and nothing changes. Even if you say "yes" now, you can change your mind later and it is still okay. You will be invited to participate in this study since the trustful information that you will provide is important for the understanding of the proposed research.

You (study participant or caregiver/guardian) will be asked to give your information related to malaria (demographic, socioeconomic, human behavioral/belief, health system &intervention data). Data collectors will also identify water bodies/LULCs within 500m radius of the house, and record the respected geographic coordinates and altitudes using GPS device. In addition, *Anopheles* mosquito larval surveying will be done at the selected potential breeding sites and reared in the laboratory for species identification. Moreover, individual in-depth interviews (local community members) and key informant interviews (students, local leaders, health professionals, HEWs and District malaria prevention and control officers) will be carried out to explore the reasons for non-consistent utilization of LLINs. The in-depth interview may last up to 60 minutes. Each in-depth interview will be audio recorded to capture all the ideas of the interviewee. Interviewees will be informed to talk louder to increase the quality of audio records.

Confidentiality/Is everybody going to know about this? Any information about you (study participant or caregiver/guardian) will have a numeric code on it instead of your name. Information about you that will be collected for the research will be put away and no-one but the researcher and supervisors will be able to see it. The original data will be locked up with a lock and key till the data analysis carried out. The use of data for any purpose other than that to which participants consented is unethical. The data you will provide will not be disclosed in the way that proving your personal characteristics and privacy. After the PhD dissertation defense and approval by the EIWR Academic Commission as well as AAU Senate, original data will be incinerated in secure manner. Before any larval sampling, verbal consent to access sampling sites will be obtained from both *kebele* officials and local residents during local village meetings. Audio records of in-depth interviews will not be available for third party.

Benefit/Is there anything good that happens?: This study does not give temporary financial, health care and capacity building advantages for the study participants individually or in groups. However, malaria cases/patients will be treated according to the national guideline and health education was given to seek healthcare services early for the control of malaria, and on mode of transmission and how to prevent future reoccurrence. For those patients who need extra treatment, referral will be advised and the conditions will be fulfilled to get adequate treatment.

During in-depth interviewing, malaria suspects were referred to health centers and treated accordingly if applicable.

In the long run, the findings of this study may help the community to reduce *Anopheles* mosquito bite, malaria and its clinical consequences. This may be accomplished through the incorporation of recommendations by the national health system structure (from the FMOH to the closest health structure to the community, health extension program). Moreover, civic organizations, stakeholders, NGOs and UN agencies that are working on malaria prevention, control and elimination in Ethiopia particularly in northwest Ethiopia will also take into account the findings to redesign, direct, formulate and planned their strategy and approach. Most importantly, the findings will be too vital in the era of malaria elimination to consider imported malaria/travel history equally with locally acquired malaria and keeping on track in delivering malaria information for communities.

Risk/Is this bad or dangerous? This study will not lead the study participant to any inhuman treatment such as physical (physical discomfort, pain, injury, illness or disease), psychological (anxiety, depression, guilt, shock and loss of self-esteem and altered behavior), social/economic (embarrassment, loss of respect of others, labeling a subject in a way that will have negative consequences, or in some way diminish those opportunities and powers a person has by virtue of relationships with others) risks. Blood sample collectors will be medical laboratory professionals who are highly qualified and experts in malaria diagnosis, including blood sample drawing. If you face any physical discomfort, pain, injury, illness or disease at the time of finger pricking (blood sample drawing) or later, however, I need to know and you should feel free you to call us anytime with your concerns or questions.

Money, coercion, undue inducement and compensation: This study will not be engaged in giving incentives, compulsion, and undue influence and result in any risks that require compensation.

Communication of findings: This study is undoubtedly planned to circulate the findings to policy-makers, health planners, stakeholders and participating communities. Specifically, the findings will be delivered to Gondar *Zuriya* District Health Office, Central Gondar Zone health department and Amhara National Regional State Health *Bureau* and Ethiopian Federal Ministry of Health. Moreover, the findings will be distributed to various NGOs, UN agencies and civic organizations working on malaria. Totally, three research articles will also be published from this study in scientific reputable journals.

Right to refuse or withdraw: The following information should be read to each study participant/caregiver or guardian. Participation in this study is voluntary**.** If you do not want to be in this research, no one will be angry or disappointed with you. It's your choice. You can think about it and tell us later if you change your mind. On the other hand, you can say "yes" now and decline later on without any negative consequences to you.

Who to contact: You can ask me questions now or later. I have written a cell phone number and address where you can reach us or, if you are nearby; you can come and see us. If you want to talk to someone else that you know like your doctor or family friend, etc., that is okay too.). As information, this study had got ethical approval by EIWR, Ethical Review Approval Committee of AAU and the Ethical Review Committee of Wollo University. If you want any information about this study, you can call or visit the following entities:

1. Institute:
    a. Name: Ethiopian Institute of Water Resources, Addis Ababa University, Akaki Campus
    b. E-mail: *water.resources@aau.edu.et* | *wateresources.edu@gmail.com*
    c. Website: *http://www.eiwr.org*
    d. Tel:- +251-114-341698
    e. Fax: +251-114-349417
    f. P.O. Box: 150461, Addis Ababa, Ethiopia
2. Principal investigator:
    a. Name: Asmamaw Malede Tarekegn (PhD fellow in water and public health)
    b. Mob: +251 (0) 912689264
    c. E-mail:coolmaldinni@gmail.com, asmamawmalede12@gmail.com
    d. Skype: asmamaw.malede2
3. Supervisor:
    a. Name: ________________________
    b. Mob:__________________________
    c. E-mail:________________________

d. Skype:________________________

4. Data collector
    a. Name: ________________________
    b. Mob:__________________________
    c. E-mail:________________________
    d. Skype:_________________________

Certificate of assent (for children ≤18 years)

I understand the research is about contribution of house proximity to water bodies and other underlying drivers for malaria heterogeneity, malaria vectors and barriers of consistent bed net utilization in meso-endemic villages around Lake Tana, northwest Ethiopia. I understand that I will be inquired to give blood sample with a finger prick from a child. In addition, I will be inquired to provide data on malaria related to the child.

All the information related to this study has been given in the language I understand. I have been informed that all the information I shall provide to the interviewer will be kept confidential. I also know that I have the right to withhold information, skip questions to answer or to withdraw from the study any time I have acquainted nobody will impose me to explain the reason of withdrawal. It is also enlighten there would have no effect at all in my health benefit or other administrative effect that I get from all sectors. I have assured the right to ask information that is not clear about the study before and/or during the study by contacting.

1. Institute:
    a. Name: Ethiopian Institute of Water Resources, Addis Ababa University, Akaki Campus
    b. E-mail: *water.resources@aau.edu.et* | *wateresources.edu@gmail.com*
    c. Website: *http://www.eiwr.org*
    d. Tel:- +251-114-341698
    e. Fax: +251-114-349417
    f. P.O.Box: 150461, Addis Ababa, Ethiopia

2. Principal investigator:
    a. Name: Asmamaw Malede Tarekegn (PhD Fellow in water and public health)
    b. Mob: +251 (0) 912689264
    c. E-mail: coolmaldinni@gmail.com, asmamawmalede12@gmail.com

d. Skype: asmamaw.malede2

3. Supervisor:

a. Name: ________________________

b. Mob:__________________________

c. E-mail:________________________

d. Skype:________________________

4. Data collector

a. Name: ________________________

b. Mob:__________________________

c. E-mail:________________________

d. Skype:_________________________

I have read this information (or had the information read to me). I have had my questions answered and know that I can ask questions later if I have them.

I agree to take part in the research. *OR*

I do not wish to take part in the research and I have not signed the assent below.

___________ (initialed by child/minor)

Only if child assents:

Print name of child: ___________________

Signature of child: ____________________

Date (day/month/year): ________________

If unable to read and write:

A literate witness will sign (if possible, this person should be selected by the participant, not be a parent, and should have no connection to the research team). Participants who are unable to read and write should include their thumb print as well.

I have witnessed the accurate reading of the assent form to the child, and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

*Print name of witness (not a parent):*_________________ *AND Thumb print of participant*

Signature of witness: ______________________

Date (day/month/year): ________________________

I have accurately read or witnessed the accurate reading of the assent form to the potential participant, and the individual has had the opportunity to ask questions. I confirm that the individual has given assent freely.

Print name of data collector: ________________

Signature of data collector: __________________

Date (day/month/year): _________________

Statement by the data collector

I have accurately read out the information sheet to the potential participant, and to the best of my ability.

I confirm that the child was given an opportunity to ask questions about the study, and all the questions asked by him/her have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

A copy of this assent form has been provided to the participant.

Print name of data collector: _______________________

Signature of data collector: _________________________

Date (day/month/year): __________________________

Copy provided to the participant ________ (initialed by data collector/supervisor)

Parent/Guardian has signed an informed consent

i) Yes___________

ii) No___________(initialed by data collector/supervisor)

A. Questionnaire and checklist for objective I

a) <u>Malaria diagnosis results of study participant (all age groups)</u>

1. Malaria status of study participant (by considering/using signs and symptoms of malaria): 1. Having signs and symptoms 2. Having no signs and symptoms
2. Malaria status of study participant(by laboratory): 1. Microscopically positive (**go to Q3**) 2.Mircoscopically negative
3. If the individual has malaria, which one is the *Plasmodium* parasite? **1.** *Plasmodium falciparum* **2**. *Plasmodium vivax* **3.** Mixed infection (both of the two)
4. Date of malaria diagnosis (day/month/year):________________________
5. Health center name:______________________

6. Sex of study participant: 1. Male   2. Female
7. Age of study participant:____________________
8. Matching code (case/control number with OPD name):__________________
9. *Kebele*/village name:___________________,__________________
10. Name and signature of data collector:_______________,_________________

b) **<u>Semi-structured interview questions/direct observations and geographic data about malaria (all age groups)</u>**

1. Matching code (case/control number with OPD name):__________________
2. *Kebele*/village name:___________________,__________________
3. Health center name:______________________
4. Date of data collection (day/month/year):________________________
5. Name and signature of data collector:_______________,_________________
6. Name and signature of supervisor:_______________,_________________

<u>N.B</u>: For study participants <18 years old, the interview will be undertaken with the HH head/caregiver.
***For study participants <18 years old, marital status, religion, occupation and educational status of the caregiver/guardian/head of the HH will be taken.*

Part I: Demographic and social characteristics				
Q. No	Questions	Responses/units	Coding/values	Remark
101	What is your marital status? (study participant *OR* caregiver/head of the HH)**	Married	0	
		Single	1	
		Widowed	2	
		Divorced	3	
102	What is your religion? (study participant *OR* caregiver/head of the HH)**	Christian	0	
		Muslim	1	
		Others/specify_____________	99	
103	What is your occupation? (study participant *OR* caregiver/head of the HH)**	Farmer	0	
		Merchant	1	
		Government	2	
		Daily laborer	3	
		Other/specify______________	99	
104	What is your educational status? (study participant *OR* caregiver/head of the HH)**	Unable to read and write	0	**If the participant is ≥18 years old, skip to Q106**
		Able to read and write-non formal	1	
		Grade 1-6 completed	2	
		Grade 7-12 completed	3	
		More than grade 12 completed	4	
105	What is the schooling status of the child? (*For study participants <18 years old*)	Too young	0	
		Age to go but doesn't	1	
		Schooling	2	
106	How many occupants live in the household?	Number	______________	

Part II: Socioeconomic status indicators /wealth indicators					
201	Household assets	**Does your household has: (*More than one response is possible*)**	Yes	No	Remark
		Electricity?	1	0	
		A watch/clock?	1	0	
		A radio?	1	0	
		A cell phone/telephone?	1	0	
		A table?	1	0	
		A chair?	1	0	
		Sponge bed?	1	0	
		Spring bed?	1	0	
		Kerosene lamp/pressure lamp?	1	0	
		Solar?	1	0	
		Does any member of this household own:	Yes	No	
		Bicycle?	1	0	
		Animal-drawn cart?	1	0	
		Motorcycle?	1	0	
		Car/lorry?	1	0	
		Bajaj?	1	0	
		Does any member of this household own any agricultural land? Yes…1 No…0			
		How many (local units) of agricultural land do members of this HH own?	________		
		How many number of sleeping rooms in the house?	__________		
		How many of the following animals do this household own? **IF NO '0'. IF MORE THAN ONE '95' IF DO NOT KNOW, '98'**	Write the answer		
			Cows/bulls/oxen		
			Horses/donkeys/mule		
			Sheep		
			Goats		
			Beehives		
			Chickens		
		Does any member of this HH own a bank/micro-finance account?	Yes…1 No….0		
		What is the source of water for the HH? ***More than one response is possible***	Public standpipe	0	
			Protected well/spring	1	
			Unprotected well/spring	2	
			Others: pond, river, lake, dam, rain water	3	

		Which type of toilet does the household has? ***Direct observation***	Pit latrine with cover slab	0	
			Pit latrine without cover slab	1	
			VIP latrine	2	
			No latrine facility/bush or field	99	
		What is the type of flooring material? ***Direct observation***	Earth or sand	0	
			Dung	1	
			Cement	2	
			Other/specify____________	99	

Part III: Mass media exposure				
301	Do you read newspapers at least once a week?	Yes	1	
		No	0	
302	Do you listen radio at least once a week?	Yes	1	
		No	0	

For study participants <18 years old, mass media exposure of the HH head will be taken.

Part IV: Housing characteristics				
401	Does the study participant have a house?	Yes	1	**If no, skip to Part V.**
		No	0	
402	How many room(s) your house has/have? ***Direct observation***	Number	_______	
403	What are the building materials for roofing? ***Direct observation***	Thatch	0	
		Corrugated iron	1	
		Others/specify_______________	99	
404	What are the building materials for walls? ***Direct observation***	Mud/*Chiqqa*	0	
		Cement	1	
		Others/specify______________	99	
405	What are the building materials for floor? ***Direct observation***	Earth or sand	0	
		Local dung plastered	1	
		Cement	2	
		Others/specify_______________	99	
406	Is there a separate kitchen for food preparation? ***Direct observation***	Yes	1	
		No	0	

407	What is the nature of windows? ***Direct observation***	No windows	0	
		Open windows	1	
		Corrugated iron windows	2	
		Screened windows (mosquito screen)	3	
		Others/specify_______________	99	
408	Are there open eaves (in the roof)? ***Direct observation***	Yes	1	
		No	0	
409	Did livestock (goats, cow, oxen, sheep, donkey, horse, mule & chicken) stay sometimes/always at night inside the house in the last one month?	Yes	1	
		No	0	
410	How many houses were found within 50m radius of the house?	Number	_________	

	Part V: Travel history			
501	Did you travel away from home (outside the study area) in the prior one-month (**study participant**)? Such as sesame, cotton and sorghum farms Metema, Shehedi, Abderaf, Abrahajira, Humera, Maikadera	Yes	1	**If no, skip to Q507**
		No	0	
502	If yes for **Q501**, how many times you travelled?	Number	______	
503	If yes for **Q501**, did you use LLINs regularly during your away home time?	Yes	1	
		No	0	
504	If yes for **Q501**, did you take malaria prophylaxis during your away home time?	Yes	1	
		No	0	
505	If yes for **Q501**, where did you travel? ***District name?***	_______________		
506	If yes for **Q501**, why you travelled? (Reason)? ***More than one response is possible***	To earn temporary job	0	
		For social issues (Visiting friends, relatives, etc.)	1	
		Having farms there	2	
		Others/specify_______________	99	
507	Did you travel away from home (inside the study area) in the prior one-month (**study participant**)?	Yes	1	**If no, skip toQ509**
		No	0	
508	If yes for **Q507,** did you use a LLIN regularly during your away home time?	Yes	1	
		No	0	
509	Is there any other HH member who travelled to malaria endemic areas (outside the study area)? (Metemma, Humera, Dansha, Sanja, Quara, Abederafi, Abrahajira)	Yes	1	**If no, skip to Part VI**
		No	0	

510	If yes for **Q509,** why travelled? (Reason)? ***More than one response is possible***	To earn temporary job	0	
		For social issues (Visiting friends, relatives, etc.)	1	
		Having farms there	2	
		Others/specify______________	99	

Part VI: Human behavior, beliefs and malaria information				
601	Did you (**study participant**) active outside the home (playing, working, journey, etc.) at 6PM-12PM in the last one month?	Yes	1	
		No	0	
602	Did you (**study participant**) go to a health facility the last time you encountered malaria signs and symptoms?**(For malaria cases, excluding the current presentation)**	Yes	1	**If no, skip toQ604**
		No	0	
603	If yes for **Q602** and got malaria, did you complete the full dosage based on the prescription?	Yes	1	
		No	0	
604	Do you (**study participant**) have the habit of visiting traditional healers (spiritual, herbal remedy, etc.) for malaria treatment?	Yes	1	
		No	0	
605	Do you (**study participant**) often practice home management of malaria (HMM) or self-treatment? (use of anti-malarial drugs bought from local market or pharmacy or herbal remedies)	Yes	1	
		No	0	
606	Do HEWs provide overall information about malaria for the study subject/caregiver? ***Through home to home or campaigns***	Yes	1	
		No	0	

Part VII: LLINs ownership and use, and indoor residual spraying				
701	Do you have an LLIN (s) in the house? ***Observational verification***	Yes	1	**If no, skip to717**
		No	0	
702	If yes for **Q701,** do you have only one LLIN in the house? ***Observational verification***	Yes	1	
		No	0	
703	If no for **Q702,** do you have two or more LLINs in the house? ***Observational verification***	Yes	1	
		No	0	
704	If yes for **Q701,** How many LLINs do you have in the house? ***Observational verification***	Number		
705	If yes for **Q701,** did you sleep under a LLIN last night?(**study participant**) *hanged or not*	Yes	1	
		No	0	
706	If yes for **Q701,** did you sleep under a LLIN at night regularly for the last one month? (**study participant**)	Yes	1	
		No	0	

707	If yes for **Q701,** did you sleep alone under a LLIN last night?	Yes	1	
		No	0	
708	If no for **Q707,** did you sleep in two per a LLIN last night?	Yes	1	
		No	0	
709	If no for **Q707**, how many individuals slept per LLIN last night?	Number	_____	
710	Did all family members sleep under LLIN last night?	Yes	1	
		No	0	
711	Who in the HH did not sleep under LLIN last night? ***More than one response is possible***	Pregnant women (optional)	0	
		Women of reproductive age (15-49)	1	
		Children <5 years	2	
		Children (5-14 years)	3	
		Men ages (15–49) and adults >49	4	
712	Who in the HH sleeps sometimes without LLIN? ***More than one response is possible***	Pregnant women (optional)	0	
		Women of reproductive age (15-49)	1	
		Children <5 years	2	
		Children (5-14 years)	3	
		Men ages (15–49) and adults >49	4	
713	If yes for **Q701,** Does/Do the ITN/LLIN(s) has/have hole/tear(s)? Condition of bed nets? *Direct observation*	Yes	1	
		No	0	
714	How long ago did your household obtain the mosquito net?	In months	______	
715	Does/Do the LLIN(s) properly hanged up?	Yes	1	
		No	0	
716	Is/are LLIN(s) in good condition? ***Direct observation*** (no holes/tears, not aged (in the active life span), and properly hanged up)	Yes	1	
		No	0	
717	At any time in the past 12 months, has anyone sprayed the interior walls of your dwelling against mosquitoes?	Yes	1	
		No	0	
718	At any time in the past 12 months, have the walls in your dwelling been plastered or painted after IRS?	Yes	1	
		No	0	

Part VIII: Environmental survey of water bodies, land uses/land covers presented within 500m radius of the house

***N.B*:** Record the following measurements if water bodies present within 500m of the house. If land uses/land covers present, put this symbol [√] on the space provided and if not, put this one [X] (water bodies/LULC classes will be recorded for each HH)

Codes	Measurements		
	Latitude(dd) (Northing)	Longitude(dd) (Easting)	Elevation (m)
HH___________			
801. River/lake**			
802. Stagnant water/reservoir**			
803. Irrigation channels**			
804. Barren land			
Codes	Space for marking [X] or [√]		
805. Vegetation/forest			
806. Brick making			
807. Trees			
808. Bushes			
809. Temporary water containers/roads			

Keys:
****River/lake** = presence of river or lake
****Stagnant water/reservoir**= stagnant water for irrigation, natural pond, dam, artificially developed reservoir, swamps
****Irrigation, trees, bushes**
Barren land = non-cultivating land, grazing land, land left to retain its fertility, rocks
Vegetation = natural forest or closed forest
Brick making = large mud pits, house construction
Temporary water containers= plastic bottles, tires, cisterns, pots, broken clays, barrels, discarded tins
Roads = Asphalt, small roads used for animals and people, road under construction, etc.

B. Questionnaire for objective II

a) <u>Malaria diagnosis results of a child (under-five children)</u>

1. Malaria status of a child (by considering/using signs and symptoms of malaria): 1. Having signs and symptoms 2. Having no signs and symptoms
2. Malaria status of a child (by laboratory): 1. Microscopically positive (**go to Q3**) 2. Microscopically negative
3. If a child has malaria, which one is the *Plasmodium* parasite? **1.** *Plasmodium falciparum* **2**. *Plasmodium vivax* **3.** Mixed infection (both of the two)
4. Date of malaria diagnosis (day/month/year):________________________
5. Health center name:______________________
6. Sex of a child: 1. Boy 2. Girl
7. Age of a child:____________________
8. Matching code (case/control number):__________________
9. *Kebele*/village name:___________________,__________________
10. Name and signature of data collector:_______________,_________________

b) <u>Semi-structured interview questions/direct observations (under-five children)</u>

Matching code (case/control number):__________________

Kebele/village name: ___________________, __________________

Health center name: ______________________

Date of data collection (day/month/year):________________________

Name and signature of data collector: _______________, ________________

Name and signature of supervisor: _______________, _________________

N.B: The interview will be undertaken with the HH head/caregiver.

Part I: Demographic and social characteristics				
Q. No	Questions	Responses/units	Coding/values	Remark
101	What is your marital status? (caregiver/head of the HH)	Married	0	
		Single	1	
		Widowed	2	
		Divorced	3	
102	What is your religion? (caregiver/head of the HH)	Christian	0	
		Muslim	1	
		Others/specify_____________	99	
103	What is your occupation? (caregiver/head of the HH)	Farmer	0	
		Merchant	1	
		Government	2	
		Daily laborer	3	
		Other/specify______________	99	
104	What is your educational status? (caregiver/head of the HH)	Unable to read and write	0	
		Able to read and write-non formal	1	
		Grade 1-6 completed	2	
		Grade 7-12 completed	3	
		More than grade 12 completed	4	
105	What is the educational status of the mother?	_________________________		
106	How many occupants live in the household?	Number	___________	
107	How many under 18 children live in the household?	Number	____________	

Part II: Socioeconomic status indicators /wealth indicators					
201	Household assets	**Does your household has: (*More than one response is possible*)**	Yes	No	Remark
		Electricity?	1	0	
		A watch/clock?	1	0	
		A radio?	1	0	
		A cell phone/telephone?	1	0	
		A table?	1	0	
		A chair?	1	0	
		Sponge bed?	1	0	
		Spring bed?	1	0	
		Kerosene lamp/pressure lamp?	1	0	
		Solar?	1	0	
		Does any member of this household own:	Yes	No	
		Bicycle?	1	0	
		Animal-drawn cart?	1	0	
		Motorcycle?	1	0	
		Car/lorry?	1	0	
		Bajaj?	1	0	
		Does any member of this household own any agricultural land?	Yes…1	No…0	
		How many (local units) of agricultural land do members of this HH own?		__________	
		How many number of sleeping rooms in the house?	___________		
		How many of the following animals do this household own? **IF NO ‘0’. IF MORE THAN ONE ‘95’ IF DO NOT KNOW, ‘98’**	Write the answer		
			Cows/bulls/oxen		
			Horses/donkeys/mule		
			Sheep		
			Goats		
			Beehives		
			Chickens		
		Does any member of this HH own a bank/micro-finance account?	Yes…1	No….0	
		What is the source of water for the HH? ***More than one response is possible***	Public standpipe	0	
			Protected well/spring	1	
			Unprotected well/spring	2	
			Others: pond, river, lake, dam, rain water	3	

		Which type of toilet does the household has? ***Direct observation***	Pit latrine with cover slab	0	
			Pit latrine without cover slab	1	
			VIP latrine	2	
			No latrine facility/bush or field	99	
		What is the type of flooring material? ***Direct observation***	Earth or sand	0	
			Dung	1	
			Cement	2	
			Other/specify____________	99	

Part III: Mass media exposure				
301	Do you read newspapers at least once a week?	Yes	1	
		No	0	
302	Do you listen radio at least once a week?	Yes	1	
		No	0	

Mass media exposure of the HH head should be taken

Part IV: Housing characteristics				
401	Does the family have a house?	Yes	1	**If no, skip to Part V.**
		No	0	
402	How many room(s) your house has/have? ***Direct observation***	Number	_______	
403	What are the building materials for roofing? ***Direct observation***	Thatch	0	
		Corrugated iron	1	
		Others/specify_______________	99	
404	What are the building materials for walls? ***Direct observation***	Mud/*Chiqqa*	0	
		Cement	1	
		Others/specify______________	99	
405	What are the building materials for floor? ***Direct observation***	Earth or sand	0	
		Local dung plastered	1	
		Cement	2	
		Others/specify_______________	99	
406	Is there a separate kitchen for food preparation? ***Direct observation***	Yes	1	
		No	0	

407	What is the nature of windows? ***Direct observation***	No windows	0	
		Open windows	1	
		Corrugated iron windows	2	
		Screened windows (mosquito screen)	3	
		Others/specify_______________	99	
408	Are there open eaves (in the roof)? ***Direct observation***	Yes	1	
		No	0	
409	Did livestock (goats, cow, oxen, sheep, donkey, horse, mule & chicken) stay sometimes/always at night inside the house in the last one month?	Yes	1	
		No	0	
410	How many houses were found within 50m radius of the house?	Number	_________	

Part V: Travel history in the locality				
501	Did the child travel away from home (local travel) in the prior one month?	Yes	1	**If no, skip to Q503**
		No	0	
502	If yes for **Q501,** did the child sleep a LLIN regularly during your away home time?	Yes	1	
		No	0	
503	Is there any other HH member who travelled to malaria endemic areas (outside the study area)? (Metemma, Humera, Dansha, Sanja, Quara, Abederafi, Abrahajira)	Yes	1	**If no, skip to Part VI**
		No	0	
504	If yes for **Q503,** why travelled? (Reason)? ***More than one response is possible***	To earn temporary job	0	
		For social issues (Visiting friends, relatives, etc.)	1	
		Having farms there	2	
		Others/specify______________	99	

Part VI: Human behavior, beliefs and malaria information				
601	Did the child active outside the home (playing, working, journey, etc.) at 6PM-12PM in the last one month?	Yes	1	
		No	0	
602	Did the child go to a health facility the last time you encountered malaria signs and symptoms? **(For malaria cases, excluding the current presentation)**	Yes	1	**If no, skip to Q604**
		No	0	
603	If yes for **Q602** and got malaria, did the child complete the full dosage based on the prescription?	Yes	1	
		No	0	
604	Do you (**caregiver**) have the habit of visiting traditional healers (spiritual, herbal remedy, etc.) for malaria treatment?	Yes	1	
		No	0	

605	Do you (**caregiver**) often practice home management of malaria (HMM) or self-treatment? (use of anti-malarial drugs bought from local market or pharmacy or herbal remedies)	Yes	1	
		No	0	
606	Do HEWs provide overall information about malaria for the study subject/caregiver? ***Through home to home or campaigns***	Yes	1	
		No	0	

Part VII: Parents'/caregivers' awareness level about malaria				
701	*Does Anopheles* mosquito transmit malaria?	Yes	1	
		No	0	
702	Does LLIN utilization prevent malaria?	Yes	1	
		No	0	

Part VIII: Prevention and control measures of malaria vectors				
801	Do you have an LLIN (s) in the house? ***Observational verification***	Yes	1	**If no, skip to Q815**
		No	0	
802	If yes for **Q801,** do you have only one LLIN in the house? ***Observational verification***	Yes	1	**If yes, skip to Q805**
		No	0	
803	If no for **Q802,** do you have two or more LLINs in the house? ***Observational verification***	Yes	1	
		No	0	
804	If yes for **Q801,** How many LLINs do you have in the house? ***Observational verification***	Number	_____	
805	If yes for **Q801,** did the child sleep under a LLIN last night? *Is it properly hanged or not***?**	Yes	1	
		No	0	
806	If yes for **Q801,** did the child regularly sleep under LLIN in the last two weeks?	Yes	1	
		No	0	
807	If yes for **Q801,** did the child sleep alone under a LLIN last night?	Yes	1	
		No	0	
808	If no for **Q807,** did the child sleep in two per a LLIN last night?	Yes	1	
		No	0	
809	If no for **Q807,** how many of you slept per LLIN last night?	Number		
810	If yes for **Q801,** Does/Do the LLIN(s) has/have hole/tear(s)? Condition of bed nets? *Direct observation*	Yes	1	
		No	0	
811	How long ago did your household obtain the mosquito net?	In months		
812	Does/Do the LLIN(s) properly hanged up?	Yes	1	

		No		0	
813	How many times you washed the LLIN(s) since you obtained?	Number			
814	Is/are LLIN(s) in good condition? ***Direct observation*** (no holes/tears, not aged (in the active life span), properly hanged up and frequently washed)	Yes		1	
		No		0	
815	At any time in the past 12 months, has anyone sprayed the interior walls of your dwelling against mosquitoes?	Yes	1	**If no, skip to Q817**	
		No	0		
816	At any time in the past 12 months, have the walls in your dwelling been plastered or painted after IRS?	Yes		1	
		No		0	
817	Does the household use other mosquito protections (mosquito coils, homemade insecticides, grass or wood fumes)	Yes		1	
		No		0	
818	Did the child take drugs that are believed to be effective against malaria (pant remedies, paracetamol, etc.) in the last two weeks?	Yes		1	
		No		0	

C. Interview guide for objective III

a) Interview guide for consistent utilization of LLINs (Individual in-depth interviews): local community members

1. What are the conditions/obstacles for not using LLINs? Probe it
2. Where is/are the LLINs you have taken?
3. What are the reasons for non-consistent utilization of LLINs? Probe it
4. Which household members do not use LLINs consistent?
    i. Pregnant women, **what are the reasons?**
    ii. Under-five children, **what are the reasons?**
    iii. Child bearing age (15-49 years), **what are the reasons?**
    iv. Children 5-14 years old, **what are the reasons?**
    v. Males, 15-49 years and above, **what are the reasons?**
5. Where the household members sleep (sleeping spaces)?
6. When is the sleeping time for the household members (under a LLIN)?

7. What you suggest to increase proper and consistent utilization of LLINs? Probe it
8. What are the favorable characteristics of LLINs (strengths)?
9. What are the unfavorable characteristics of LLINs (limitations/shortcomings)?
10. At the end, you can add points/ideas that have not been addressed yet.

b) Interview guide for consistent utilization of LLINs (key informant interviews): students, local leaders, health professionals, HEWs and District malaria prevention and control officers

1. What are the conditions/obstacles that made the local community not to use LLINs? Probe it
2. What reasons made the local community not to use LLINs consistently? Probe it
3. What are the unintended uses of LLINs by the local community? Probe it
4. What you suggest to increase proper and consistent utilization of LLINs in the local community? Probe it
5. What are the favorable characteristics of LLINs (strengths) with respect to manufacturing and compatibility?
6. What are the unfavorable characteristics of LLINs (limitations/shortcomings) with respect to manufacturing and compatibility?
7. At the end, you can add points/ideas that have not been addressed yet?

AMHARIC VERSION OF THE QUESTIONNAIRE

አዲስ አበባ ዩኒቨርሲቲ

የኢትዮጵያ ውሃ ሃብት ኢንስቲትዩት

ዉሃና ሕብረተሰብ ጤና ስፔሻሊቲ

ሀ. <u>ለጥናቱ ተሳታፊዎች የሚሰጥ መረጃ</u>

- ✓ ***መረጃ ሰብሳቢው ሊተገብራቸው የሚገቡ የአካሄድ ስልቶች***

10. ለህክምና ወደ ጤና ጣቢያ የመጡ እና የወባ በሽታ ምልክቶች ያሉት/ሏትን ሰዎች መምረጥ።
11. ከዚያም ስለጥናቱ ዓላማ፣ጥቅሞች እና ምንም ዓይነት ተያያዥ ችግሮች እንደማያመጣ ካስረዳህ በኃላ፤የእነሱን ሙሉ ፈቃድ ማግኘት፡
12. ቀጥሎም በማይክሮስኮፕ ወባ በሽታ መሆኑን ማረጋገጥ
13. ከዚያም ወደ ጤና ጣቢያ ለህክምና ከመጡ ሰዎች ከወባ ነጻ የሆነ/ነች ሰው መፈለግ።
14. በመጨረሻም መረጃ ሰብሳቢው የወባ በሽታ ከተገኘበ/ባት ሆነ ካልተገኘበ/ባት የጥናት ተሳተፊ ቤት በመሔድ መረጃ ይሰበስባል። መጀመሪያ ወደ ግቢው ለመግባት ፈቃድ ማገኘት አለበት (ዘሎ መግባት አይፈቀድም) ።
15. የቤቱ አባወራ/እማወራ መኖሩን/መኖሩዋን ጠይቅ
16. እራስህን/ሽን ለቤቱአባወራ/እማወራ ካስተዋወክ በኃላ ለምን እንደመጣህና ምን መረጃ እንደምትፈልግ ለጥናቱ ተሳታፊ የሚሰጠውን መረጃ በደንብ አስረዳ።ሁሉንም ሃሳቦች ማስረዳት ግዴታ ነው።
17. የቤቱ አባወራ/እማወራ ፍቃደኛ ከሆኑ ቃለመጠየቁን ከማካኄድህ በፊት የስምምነት መረጃውን አስፈርም።
18. ቃለ መጠየቁን ስትጨርስ እንደጨረስክ በመናገር በጣም አመስግነህ ተለያይ።

<u>እንደምን አረፈዳችሁ/ዋላችሁ</u>፡-

ጊዜ ሰጥተህ/ሽ ከእኔ ጋር ዛሬ ለመገናኘት በመወሰንህ/ሽ ላመሰግንህ/ሽእወዳለሁ።(**ለጥልቅ-መጠይቅ መጠይቆች**)

ስሜ_______________________________________ ይባላል።የመጣሁት ከአዲስ አበባ ዩኒቨርሲቲ የኢትዮጵያ ውሃ ሃብት ኢንስቲትዩት በዉሃና ሕብረተሰብ ጤና የሶስተኛ ድግሪ ተማሪ የሆነዉን አቶ አስማማው ማለደን ወክዬ ነዉ።

የጥናቱርዕስ፡ በስሜን ጣና ሐይቅ በሚገኙ የተወሰኑ ቀበሌዎች ለአካባቢያዊ የወባ በሽታ ስርጭት የውሃማ አካላት፣የአካባቢያዊ፣ግለሰባዊ እና ቤተሰባዊ ምክኒያቶች ያላቸውን ተፅዕኖ ለማጥናትና ለመለየት፣ በአካባቢው በስፋት ተሰራጭተው የሚገኙትን የወባ ትንኝ ብቾኛ ዝርያዎች ለመለየት፣ እናም ማህበረሰቡ የአልጋ አጎበርን ዘወትር እንዳይጠቀም የሚያደርጉትን ምክንያቶችለመለየት ነው።

- ✓ የጥናቱ ተመራማሪ ሙሉ ስም፡- አቶ አስማማው ማለደ ታረቀኝ
- ✓ አስተባባሪ ቢሮ፡- የኢትዮጵያ ውሃ ሃብት ኢንስቲትዩት፤አዲስ አበባ ዩኒቨርሲቲ

መግቢያ፡ የወባ በሽታን ለማጥፋት ብዙ የተቀናጁ መከላከያ መንገዶች ቢሰጡም፤በሽታው አሁንም በተለይም በሰሃራ በርሃ በሚገኙ ሃገራት የብዙ ሰዎችን ህይወት አደጋ ላይ እየጣለው ይገኛል። የውሃማ አካላት ከህብረተሰቦች መኖሪያ በቅርብ ርቀት መገኘት፣የአልጋ አጎበርን ዘወትር አለመጠቀም እና ሌሎች ተያያዥ ምክኒያቶች በሽታውን ለማጥፋት በሚደረገው ትግበራ ዋነኛ መሰናክል መሆናቸውን ጥናቶች ያመለክታሉ።

የጥናቱዓላማ፡ በስሜን ጣና ሐይቅ በሚገኙ የተወሰኑ ቀበሌዎች ለአካባቢያዊ የወባ በሽታ ስርጭት የውሃማ አካላት ፣የአካባቢያዊ፣ ግለሰባዊ እና ቤተሰባዊ ምክኒያቶች ያላቸውን ተፅዕኖ ለመለየት ነው።በተጨማሪም በአካባቢው በስፋት ተሰራጭተው የሚገኙትን የወባ ትንኝ ብቾኛ ዝርያዎች ለመለየት እና ማህበረሰቡ የአልጋ አጎበርን ዘወትር እንዳይጠቀም የሚያደርጉትን ምክንያቶች ለመለየት ነው። ጥናቱ የሚካሄደው ለ3ኛ ድግሪ (ዶክትሬት) በውሃና በህብረተሰብ ጤና ለመመረቂያ ጹሁፍ ጥናት ማሟያ ነው።

የጥናቱ አካሄድ እና ተሳትፎ፡ ጥናቱ የሚካሄደው ከጥቅምት እስከ ሰኔ ሲሆን ዕድሚያቸው አምስት ወራትና ከዚያ በላይ የሆናቸው ሰዎች በጥናቱ ይካተታሉ።ወባ በሽታ ያለባቸውና የሌለባቸው ሰዎች ከቃለመጠይቁ በፊት የነበራቸው የተጋላጭነት ደረጃ ይነፃፀራል። የህፃኑ ቤተሰብ/ግለሰቡ በጥናቱ ለመሳተፍ ፈቃደኛ ከሆነ፣አንድ የሻይ ማንኪያ የሚሆን ደም ይወሰዳል። ከዚያም መረጃ ሰባሳቢው በቤትዎ ከራስዎ/ከቤተሰቡ ጋር ለሚደረገው ቃለመጠይቅ/ቀጥታ ምልከታ ከ45 ደቂቃ የበለጠ አይወስድም። ለጥናቱ የእርስዎ ተሳትፎ የሚያስፈልገው የሚሰጡት መረጃ ታማኝነት ስላላውና ጥናቱን ሰርቶ ለማጠናቀቅ በጣም አስፈላጊ ስለሆነ ነው። የምጠይቅዎትም ስለዲሞግራፊያዊ ፣ማህበራዊ፣ ኢኮኖሚያዊ፣ ለብዙሃንመገናኛ ያለውን ቅርበት፣ ከቤት ውጭ የተደረገን ጉዞ፣ የሰውን ባህሪ እና እምነት፣ ለጤና ተቋም ያለውን ቅርበት፣የወባ ትንኝ መከላከያ አጎበር እና ፀረ-ትንኝ መድሐኒት ርጭትን የተመለከቱ ናቸው። ቀጥታ ምልከታም ጎን ለጎን አብሮ ይካሄዳል። ከቤቱ በ500 ሜትር ርቀት የሚገኙ አጠቃላይ አካባቢያዊ

ሁኔታዎችም ይመዘገባሉ። በተጨማሪም በአካባቢው በሚገኙ በተመረጡ ውሃማ አካላት የወባ ትንኝ እጮች ተወስደው በላቦራቶሪ ያድጋሉ። የአልጋ አጎበርን ዘወትር ላለመጠቀም ምክንያቶችን ለመለየት ደግሞ የተወሰኑ ግለሰቦችን ከአካባቢው ማህበረሰብ፣ ከወባ በሽታ መከላከልና ቁጥጥር ሃላፊዎች፣ከጤና ጣቢያ የጤና ባለሙያዎች፣ከጤና ኤክስቴንሽን ባለሙያዎች፣ከቀበሌ/ከጎጥ አመራሮች እና ከተማሪዎች ጋር የጥልቅ-መጠይቅ መጠይቆች ይካሔል። ቃለ-መጠይቁ እስከ 60 ደቂቃ ሊወስድ ይችላል። የጥልቅ-መጠይቅ እያንዳንዷ ሃሳብ ስለምታስፈልግ ቀረጻ ይካሔል። ሁሉንም መልሶች በወረቀት ለማስፈር ስለሚከብድ ለቀረጻው ጥራት ጮክ ብለው እንዲናገሩ ይደረጋል።

ሚስጥራዊነት፡የሚሰጡኝ መረጃበ ደንብ የሚያዝ ሲሆን ለማንም ሰውተላልፎ አይሰጥም። ከዚህ በተጨማሪም ከመረጃው ጋር የእርስዎ ስም አይያያዝም። ስለዚህም መረጃ ሰብሳቢው የሚጠቀመው ኮድ ነው።የሰጡት መረጃም ተቆልፎ በመረጃ መያዣነው የሚቀመጠው። ስለሆነም ከጥናቱ ተመራማሪና ከመረጃ ሰብሳቢዎች ተቆጣጣሪ ውጭ ማንም አያገኘውም፡ ፡የጥናቱ ተመራማሪም መረጃውን ከሚፈልገው አላማ ውጭ አይጠቀምበትም። ጥናቱ ካለቀ በኃላና ተመራማሪውም ከተመረቀ በኃላ መረጃ የተሞላበት መጠይቅ በጥንቃቄ ይቃጠላል። የጥልቅ-መጠይቅ መጠይቆች መቅረጸ ድምጽም ከተመራማሪው ውጭ ለሌላ አካል ተላልፈው አይሰጡም ።

ጥቅም፡ ጥናቱ ለአጭር ጊዜ የሚሆን የገንዘብ፣ የጤና እና የአቅም ግንባታ ድጋፍ አያደርግም። ወባ በሽታ ለተገኘባቸው የወባ መድሃኒት በአገር አቀፉ የመድሀኒት አሰጣጥ መሰረት ይታከማሉ። ህመሙ ለጠነከረባቸው የተሻለ ህክምና እንዲያገኙ ሁኔታዎች ይመቻቻሉ፤ ለሪፈርም አስፈላጊው ሁኔታ ይመቻቻል። ጥናቱ ካለቀ በኃላ ግን የጥናቱ ውጤት ለሚመለከታቸው መስሪያ ቤቶች፣ለጤና ፖሊሲ አርቃቂዎች፣ለጤና እቅድ አውጭዎች፣ ለባለደርሻ አካላት፣ ለሲቪክ ማህበራት እና ለተለያዩ አለማቀፋዊ እና መንግስታዊ ላልሆኑ ድርጀቶች ስለሚያገለገል ወባን ለመከላከል እና ለማጥፋት ጉልህ የሆነ አስተዋጾ አለው።

ጉዳት፡ጥናቱ ምንም አይነት አካላዊ፣ ስነልቦናዊ፣ማህበራዊ እና ኢኮኖሚያዊ ጉዳት አያስከተልም። የሆነ ችግር ካጋጠመዎ በማንኛውም ሰአት መረጃ ሰብሳቢውን ማነጋገር ይቻላል።

ጥቅማ ጥቅምና ማካካሻ፡ ጥናቱ ምንም አይነት ጉዳት ስለማያስከትል እና ለአደጋ ስለማያጋልጥ ማንኛውንም አይነት ጥቅማ ጥቅም እና ማካካሻ አይኖረውም።

<u>የጥናቱ ውጤት ስርጭት</u>፡ የጥናቱ ተመራማሪ የጥናቱን ውጤት የማሰራጨት እና ዶክመንቱንም ለጎንደር ዙሪያ ወረዳ ጤና ጽ/ቤት፣ለስሜን ጎንደር ዞን ጤና መምሪያ ጽ/ቤት፣ ለአማራ ክልል ጤና ቢሮ፣ ለጤና ፖሊሲ አርቃቂዎች እና በጤና ላይ ለሚሰሩ መንግስታዊ ላልሆኑ ድርጀቶች የመስጠት ሃላፊነት አለበት። በተጨማሪም የጥናቱ ውጤቶች ዕውቅና ባላቸው ሳይንሳዊ መፅሄቶች ይታተማሉ።

<u>ጥናቱን የማቋረጥ ነጻነት</u>፡መረጃ ሰጭዎች ቃለመጠይቁ በሚካሔድበት ጊዜ ደስተኛ ካልሆኑ መረጃ መስጠቱን በማንኛውም ጊዜ ማቋረጥ ይችላሉ። ሲያቋርጥም ምንም ዓይነት ተፅዕኖ አይደርስበትም።

<u>መረጃ ማግኘትን በተመለከተ</u>፡ መረጃ ሰጭው ተጨማሪ መረጃ ማግኘት ከፈለገ በማንኛውም ጊዜ መጠየቅ ይችላል። ለዚህም የጥናቱ ተመራማሪ ወይም የመረጃ ሰብሳቢዎች ተቆጣጣሪዎችን ማነጋገር ይችላሉ። ከዘህ በተጨማሪም ጥናቱን የሚያከናውነው አዲስ አበባ ዩኒቨርሲቲ የኢትዮጵያ ውሃ ሃብት ኢንስትቲዩት በሰጠው ፈቃድ ስለሆነም መጠየቅ ይችላሉ።

- ✓ አዲስ አበባ ዩኒቨርሲቲ የኢትዮጵያ ውሃ ሃብት ኢንስትቲዩት፡ 01114341698
- ✓ የጥናቱ ተመራማሪ ሙሉ ስምና አድራሻ፡አቶ አስማማው ማለደ፡ 0912689264
- ✓ የመረጃ ሰብሳቢዎች ተቆጣጣሪ ሙሉ ስምና አድራሻ፡______________________________

ለ.<u>የስምምነት መግለጫ ቅፅ</u>

<u>የጥናቱ ርዕስ</u>፡- በስሜን ጣና ሐይቅ በሚገኙ የተወሰኑ ቀበሌዎች ለአካባቢያዊ የወባ በሽታ ስርጭት የውሃ ማአካላት ፣ የአካባቢያዊ፣ ግለሰባዊ እና ቤተሰባዊ ምክኒያቶች ያላቸውን ተፅዕኖ ለማጥናትና ለመለየት፣ በአካባቢው በስፋት ተሰራጭተው የሚገኙትን የወባ ትንኝ ብቸኛ ዝርያዎች ለመለየት፣ እናም ማህበረሰቡ የአልጋ አጎበርን ዘወትር እንዳይጠቀም የሚያደርጉትን ምክንያቶች ለመለየት ነው።

እኔ ጥናቱ ለ3ኛ ዲግሪ (ዶክትሬት) ማሟያ እንደሆነና በአዲስ አበባ ዩኒቨርሲቲ በኢትዮጵያ ውሃ ሃብት ኢንስትቲዩት የገንዘብ ድጋፍ ተደርጎለት የሚካሄድ እና አቶ አስማማው ማለደ የጥናቱ ተመራማሪ እንደሆነ አውቃለሁ፡ ፡የጥናቱ አላማ በሚገባኝ ቋንቋ የተገለፀልኝ ሲሆን አላማውም በስሜን ጣና ሐይቅ በሚገኙ የተወሰኑ ቀበሌዎች ለአካባቢያዊ የወባ በሽታ ስርጭት የውሃማ አካላት ፣የአካባቢያዊ፣ ግለሰባዊ እና ቤተሰባዊ ምክኒያቶች ያላቸውን ተፅዕኖ ለመለየት ነው። በተጨማሪም በአካባቢው በስፋት ተሰራጭተው የሚገኙትን የወባ ትንኝ ብቸኛ ዝርያዎች ለመለየት እና ማህበረሰቡ የአልጋ አጎበርን ዘወትር እንዳይጠቀም የሚያደርጉትን ምክንያቶች ለመለየት ነው። እኔ የምሰጠው ሃሳብም በጥንቃቄ እንደሚያዝና ለሌላ ሰው ተላልፎ እንደማይሰጥ ተነግሮኛል። ጥናቱም ምንም አይነት ጉዳት እንደማያደርስና ምንም የአጭር ጊዜ

ጥቅምም ሆነ ማካካሻ እንደማይሰጠኝ አውቄለሁ። ከዚህ በተረፈም የምሰጠው መረጃም በወረዳዬ የማገኘውን ጥቅም እንደማይቀንስብኝ ተነግሮኛል። ስለጥናቱ ያልገባኝን ነገር መረጃው ከመሰብሰቡ በፊትም ሆነ በሌላ ጊዜ ከዘህ በታች የተጠቀሱትን አድራሻ በመጠቀም መጠየቅ እንደምችል ተነግሮኛል።

1. አዲስ አበባ ዩኒቨርሲቲ የኢትዮጵያ ውሃ ሃብት ኢንስትቲዩት፡ +251 1114341698
2. የጥናቱ ተመራማሪ ሙሉ ስምና አድራሻ፡ አስማማው ማለደ፡ +251 912689264
3. የመረጃ ሰብሳቢዎች ተቆጣጣሪ ስም፡__________________

   ስልክ ቁጥርና አድራሻ፡_________________________

ከዚህ በላይ ያለውን ቅፅ አንብቤዋለሁ ወይም በሚገባኝ ቋንቋ ተነቦልኝ የምጠየቀውን ጥያቄ ለመመለስ ፍቃደኛ ሆኜ ተስማምቻለሁ። መስማማቴንም በፊርማዬ አረጋግጣለሁ።

ፍቃደኛ ነኝ_________________________

ፍቃደኛ አይደለሁም____________________

ፊርማ_____________________________

የታዛቢው ስም_______________________ (መረጃ ሰብሳቢ፣መረጃ ተቆጣጣሪ፣ሌላ 3ኛ ሰው)

ፊርማ___________________________

ቀን_____________________________

1. <u>የጥናት አላማ አንድን በተመለከተ የተዘጋጀ መጠይቅ</u>

ሀ. <u>የጥናቱ ተሳታፊ (ሁሉንም የዕድሜ ክልል) የወባ በሽታ ምርመራ ውጤቶች</u>

1. የጥናቱ ተሳታፊ የወባ በሽታ ሁኔታ (የወባ በሽታ ምልክቶችን ግምት ውስጥ በማስገባት/በመጠቀም)፡1. የወባ በሽታ ምልክቶች አሉት 2. የወባ በሽታ ምልክቶች የሉትም
2. የጥናቱ ተሳታፊ የወባ በሽታ ሁኔታ (በላቦራቶሪ)፡1.በማይክሮስኮፕ ፖዘቲቭ ነው**(ወደ ቁጥር 3 ይሂዱ)**2. በማይክሮስኮፕ ነጌቲቭ ነው
3. የወባ በሽታ ካለበት፣የትኛው ፕላዝሞዲየም ፓራሳይት ነው? 1. *Plasmodium falciparum* 2. *Plasmodium vivax* 3. Mixed infection (both of the two)
4. የወባ በሽታ የተመረመረበት/ችበት ጊዜ (ቀን/ወር/ዓ.ም): _________________________
5. የጤና ጣቢያው ስም፡ ____
6. የጥናቱ ተሳታፊፆታ፡ 1. ወንድ 2. ሴት

7. የጥናቱ ተሳታፊ ዕድሜ፡_________________________________

8. የማጣመሪያ መለያ (የኬዝ/ኮንትሮል ቁጥር እና OPDው)፡___________________________

9. የቀበሌው/የጎጡ ስም: ______________________፣_______________________________

10. የጠያቂው/መረጃ ሰብሳቢዉ ስም እና ፊርማ:________________፣____________________

ለ. <u>የጥናቱ ተሳታፊ (ሁሉንም የዕድሜ ክልል) ስለወባ በሽታ የመጠየቅ ጥያቄዎች እና ጂኦግራፊያዊ መረጃዎች</u>

የማጣመሪያ መለያ (የኬዝ/ኮንትሮል ቁጥር እና OPDው)፡__________________________

የቀበሌው/የጎጡ ስም: ______________________፣____________________________

የጤናጣቢያው ስም፡ ____

መረጃው የተሰበሰበበት ቀን (ቀን/ወር/ዓ.ም): ____________________________________

የጠያቂው/መረጃ ሰብሳቢዉ ስም እና ፊርማ:__________________፣_____________________

የመረጃ ሰብሳቢዎች ተቆጣጣሪ ስም እና ፊርማ፡________________________፣_______________

<u>ማስታወሻ</u>፡ እድሜአቸው ከ18 አመት በታች ለሆኑ የጥናቱ ተሳታፊዎች፤ ቃለ-መጠይቁ የሚካሄደው ከቤተሰቡሃላፊ/ከአሳዳጊው ጋር ነው።

***እድሜአቸው ከ18 አመት በታች ለሆኑ የጥናቱ ተሳታፊዎች የጋብቻ ሁኔታ፣ የሀይማኖት ሁኔታ፣ የሥራ ሁኔታ እና የትምህርት ሁኔታ የቤተሰብ ሃላፊው/የአሳዳጊው መረጃ ይወሰዳል።*

ክፍል አንድ፡ዲሞግራፊና ማህበራዊ ሁኔታዎች

ጥያቄ ቁጥር	ጥያቄዎች	የመልስ ምርጫዎች/መለኪያዎች	የአማራጭ ምልክቶች/ልኬቶች	የሚዘለል
101	የጋብቻ ሁኔታ? (የጥናቱ ተሳታፊ ወይም የቤተሰቡ ሃላፊ)**	ያገባ/ች	0	
		ያላገባ/ች	1	
		ባል/ሚስት በሞት የተለያት/ችው	2	
		የፈታ/ች	3	
102	የሀይማኖት ሁኔታ? (የጥናቱ ተሳታፊ ወይም የቤተሰቡ ሃላፊ)**	ክርሥቲያን	0	
		ሙሥሊም	1	
		ሌላ (ይገለፅ)፡	99	
103	የሥራ ሁኔታ? (የጥናቱ ተሳታፊ ወይም የቤተሰቡ ሃላፊ)**	ግብርና	0	
		ንግድ	1	
		የመንግሰት ስራ	2	
		የጉልበት ሥራ	3	
		ሌላ (ይገለፅ)፡	99	
104	የትምህርት ሁኔታ? (የጥናቱ ተሳታፊ ወይም የቤተሰቡ ሃላፊ)**	ማንበብና መጻፍ የማይችል/ትችል	0	**የጥናቱ ተሳታፊ 18 አመት እና ከዛ በላይ ከሆነ ወደ ጥያቄ 106 ሂድ**
		ማንበብና መጻፍ የሚ/ምትችል-መደበኛያልሆነ	1	
		ከ1-6 ክፍል ያጠናቀቀ/ች	2	
		ከ7-12 ክፍል ያጠናቀቀ/ች	3	
		ከ12 ክፍል በላይ ያጠናቀቀ/ች	4	
105	የህጻናት/የልጆች የትምህርት ደረጃ? ***(ከ18 አመት በታች ለሆኑ የጥናቱ ተሳታፊዎች)***	ለትምህርት ያልደረሰ/ች	0	
		ዕድሜው/ዋየ ደረሰ/ሰች ግን የማይማር/ትማር	1	
		የሚማር/የምትማር	2	
106	የቤተሠቡ ብዛት ሥንት ነው?	በቁጥር	______________	

		ክፍል ሁለት፡ኢኮኖሚያዊ ሁኔታዎች			
201	የቤተሰቡ ንብረቶች	ከሚከተሉት ውስጥ ቤተሰቡ የትኞቹ አሉት? ***ከአንድ በላይ ማክበብ ይቻላል***	አለ	የለም	የሚዘለል
		ኤሌክትሪክ?	1	0	
		ሰዓት?	1	0	
		ሬድዮ?	1	0	
		ሞባይል?	1	0	
		ጠረጴዛ?	1	0	
		ወንበር?	1	0	
		ስፖንጅ አልጋ?	1	0	
		ስፕሪንግ አልጋ?	1	0	
		ኩራዝ/ፋኑስ?	1	0	
		ሶላር/በፀሐይ ብርሀን የሚሠራ የኤሌክትሪክ መብራት/የእጅ ባተሪ?	1	0	
		የሚከተሉትን የቤተሰቡ አባላት አሏቸው?	አለ	የለም	
		ባይስክል?	1	0	
		ጋሪ?	1	0	
		ሞተር ሳይክል?	1	0	
		መኪና/የጭነት መኪና?	1	0	
		ባጃጅ	1	0	
		ከቤተስቡ አባላት ውስጥ የእርሻ መሬት ያለው አለ? አዎ…….1 የለም……0			
		ቤተሰቡ ሰንት ቃዳ/ሄክታር መሬት አለው?	________________________		
		ቤቱ ስንት የመኝታ ክፍሎች አሉት?	________________________		
		ቤተሰቡ ከሚከተሉት እንስሳቶች ውስጥ የትኞቹ አሉት? **ከሌለ "0"ን ይጻፉ** **ከአንድ በላይ ከሆነ "95"ን ይጻፉ** **ካላወቁት, "98"ን ይጻፉ**	መልሱን ይጻፉ		
			የወተት ላሞች/ኮርማዎች/በሬዎች		
			ፈረሶች/አህያዎች/በቅሎዎች		
			በጐች		
			ፍየሎች		
			የንብቀፎዎች		
			ዶሮዎች		

		ከቤተሰቡ አባላት ውስጥ የባንክ/አነስተኛ የገንዘብ አካውንት ያለው አለ?	አዎ…1 የለም…0	
		ቤተሰቡ ውሃ የሚያገኘው ከየት ነው? ***ከአንድ በላይ ማክበብ ይቻላል***	ከህዝብ ቧንቧ	0
			ከተጠበቀ ጉድጓድ/ምንጭ	1
			ካልተጠበቀ ጉድጓድ/ምንጭ	2
			ሌሎች/ኩሬ, ወንዝ, ሔይቅ, ግድብ, ዝናብ	3
		ቤተስቡ የትኛውን ሽንት ቤት ነው የሚጠቀመው? ***በቀጥታ በመመልከት***	መክደኛ ያለው ጉድጓድ መፀዳጃ ቤት	0
			መክደኛ የሌለዉ ጉድጓድ መፀዳጃ ቤት	1
			የአየር መዉጫ የተገጠመለት መፀዳጃ ቤት	2
			ሽንት ቤት የለንም/ክፍት ቦታ፣ሜዳ	99
		የቤቱ ወለል የተሠራው ከምንድን ነው? ***በቀጥታ በመመልከት***	አሸዋ ወይም አፈር	0
			በእበት የተለቀለቀ	1
			ከሲሚንቶ ሊሾ	2
			ሌላ ይገለፅ፡	99

ክፍል ሦስት፡ለብዙሃን መገናኛ ያለውን ቅርበት በተመለከተ				
301	ጋዜጦችን ቢያንስ በሳምንት አንድ ጊዜ ታነባለህ/ቢያለሽ?	አዎ	1	
		አላነብም	0	
302	ሬዲዮ ቢያንስ በሳምንት አንድ ጊዜ ታዳምጣለህ/ጫለሽ?	አዎ	1	
		አላዳምጥም	0	

እድሜአቸው ከ18 ኣመት በታች ለሆኑ የጥናቱ ተሳታፊዎች፤ የቤተሰቡ ሃላፊ የመረጃ ቅርበት ይወሰዳል።

ክፍል አራት፡የቤቱ አጠቃላይ መገለጫዎች				
401	መኖሪያ ቤት አልዎት?	አዎ	1	**ቤት ከሌለው ወደ ክፍል አምሰትይሂዱ**
		የለኝም	0	
402	ቤትዎ ሰንት ክፍል/ሎች አሉት? ***በቀጥታ በመመልከት***	በቁጥር	_______	
403	የቤቱ ጣሪያ የተሠራው ከምንድን ነው? ***በቀጥታ በመመልከት***	የሳር ክዳን	0	
		ቆርቆሮ	1	
		ሌላ ይገለጽ:	99	

404	የቤቱ ግድግዳ የተሠራው ከምንድን ነው? ***በቀጥታ በመመልከት***	ከጭቃ	0	
		ከሲሚንቶ/ግርፍ	1	
		ሌላይ ገለጽ:	99	
405	የቤቱ ወለል የተሠራው ከምንድን ነው? ***በቀጥታ በመመልከት***	አሸዋ ወይም አፈር	0	
		በእበት የተለቀለቀ	1	
		ከሲሚን ቶሊሾ	2	
		ሌላ ይገለጽ፡	99	
406	ቤቱ ለምግብ ማብሰያ የሚሆን የተለ የቤት አለው? ***በቀጥታ በመመልከት***	አለው	1	
		የለም	0	
407	የቤቱ መስኮት ምን አይነት ነው? ***በቀጥታ በመመልከት***	መስኮት የለውም	0	
		ክፍት መስኮት	1	
		የቆርቆሮ	2	
		በተጠላላፈ ሽቦ የተዘጋ (ለወባ ትንኝ መከላከያ የሚሆን)	3	
		ሌላ ይገለጽ፡	99	
408	የቤቱ ጣሪያ ቀዳዳዎች አሉት? ***በቀጥታ በመመልከት***	አዎ	1	
		የለውም	0	
409	ባለፈው አንድ ወር ውስጥ የቤት እንስሳት ቤት ውስጥ ዘወትር/አልፎ አልፎ ያድሩ ነበር?	አዎ	1	
		አላደሩም	0	
410	ከቤቱ በአምሳ ሜትር ርቀት ውስጥ ስንት ቤቶች አሉ? ***በቀጥታ በመመልከት***	በቁጥር	_________	

ክፍል አምሰት፡ከቤት ውጭ የተደረገን ጉዞ በተመለከተ				
501	ባለፈው አንድ ወር ውስጥ ከጥናቱ ቦታ ውጭ ተጉዘሀ/ሽ ነበር? ለምሳሌ ወደ ሰሊጥ፣ ጥጥ፣ ማሽላ እርሻዎች (መተማ፣ ሁመራ፣ ዳንሻ፣ ቋራ፣ አብራጅራ)	አዎ	1	**ምላሹ አዎ ካልሆነ፣ወደ ጥያቄ 507 ይሂዱ**
		አልተጓዝኩም	0	
502	**ለጥያቄ 501 መልስዎ አዎ ከሆነ**,ስንት ጊዜ ተጉዘሀ/ሽ ነበር?	በቁጥር	______	
503	**ለጥያቄ 501 መልስዎ አዎ ከሆነ**, የወባ ትንኝ መከላከያ አጎበር ዘወትር ትጠቀም/ሚ ነበር?	አዎ	1	
		አልተጠቀምኩም	0	
504	**ለጥያቄ 501 መልስዎ አዎ ከሆነ**,የወባ መከላከያ መድሃኒት ወስደሀ/ሽ ነበር?	አዎ	1	
		አልወሰድኩም	0	

505	**ለጥያቄ 501 መልስዎ አዎ ከሆነ**, የትነው ተጉዘህ/ሽየ ነበረው? ***የወረዳው ስም?***			
506	**ለጥያቄ 501 መልስዎ አዎ ከሆነ**, ለምን ነበር የተጓዝከው/ሽው (በምን ምክኒያት)? ***ከአንድ በላይ ማክበብ ይቻላል***	ስራ ፍለጋ	0	
		ለማህበራዊ ጉዳይ (ጓደኛ፣ዘመድ፣ወዘተ. ለመጠየቅ)	1	
		የእርሻ ማሳ ስላለኝ	2	
		ሌላ ይገለጽ፡	99	
507	ባለፈው አንድ ወር ውስጥ ከቤት ውጭ በጉዞ ምክኒያት አድረህ/ሽ ነበር?	አዎ	1	**ምላሹ አዎ ካልሆነ፣ወደ ጥያቄ 509 ይሂዱ**
		አልተጓዝኩም	0	
508	**ለጥያቄ 507 መልስዎ አዎ ከሆነ**, የወባ ትንኝ መከላከያ አጎበር ዘወትር ትጠቀም/ሚ ነበር?	አዎ	1	
		አልተጠቀምኩም	0	
509	ከቤተሰቡ አባላት ውስጥ ወደ ወባማ ቦታዎች የተጓዘ ሰው ነበር? (**ከጥናቱ ቦታ ውጭ**) *መተማ፣ሁመራ፣ዳንሻ፣ሰንጃ፣ቋራ፣አብደራፊ፣አብራጅራ*	አዎ	1	**ምላሹ አዎ ካልሆነ፣ወደ ክፍል ስድስት ይሂዱ**
		የለም	0	
510	**ለጥያቄ 509 መልስዎ አዎ ከሆነ**, ለምን ነበር የተጓዘው/ችው (በምን ምክኒያት)? ***ከአንድ በላይ ማክበብ ይቻላል***	ስራ ፍለጋ	0	
		ለማህበራዊ ጉዳይ (ጓደኛ፣ዘመድ፣ወዘተ. ለመጠየቅ)	1	
		የእርሻ ማሳ ስላለው/ላት	2	
		ሌላ ይገለጽ፡	99	

ክፍል ስድስት፡የሰውን ባህሪ፣እምነት እና ስለወባ በሽታ የሚሰጥን ትምህርት በተመለከተ				
601	ባለፈው አንድ ወ ርውሰጥ ከምሽቱ 12:00 እስከ ምሽቱ 6:00 ባለው ጊዜ ከቤት ውጭ ታመሽ/ሺ ነበር? (**በጨዋታ፣በሥራ፣በጉዞ ወዘተ…**)	አዎ	1	
		አላመሽም	0	
602	ለመጨረሻ ጊዜ የወባ በሽታ ምልክቶችን ባየህ/ሽ ጊዜ ወደ ጤና ተቋም ሄደህ/ሽ ነበር? (**ለበሽተኞችያሁኑን ሳይጨምር**)	አዎ	1	**ምላሹ አዎ ካልሆነ፣ወደጥ ያቄ 604 ይሂዱ**
		አልሄድኩም	0	
603	**ለጥያቄ 602 መልስዎ አዎ ከሆነ** እና ወባ በተገኘብህ/ሽ ጊዜ, ሁሉንም የወባ መድሀኒቶች በሀኪሙ ትዕዛዝ መሰረት ጨርሰህ/ሽ ነበር?	አዎ	1	
		አልጨረስኩም	0	
604	የወባ በሽታን ምልክቶቸ ባየህ/ሽ ጊዜ ለመታከም የባህል ሀኪም/ጸበል ጋር የመሔድ ልምድአለህ/ሽ? (**ጠንቋይ፣ጸበል፣እፅዋት ወዘተ…**)	አዎ	1	
		የለኝም	0	
605	ከወባ በሽታ ለመፈወስ መድሐኒቱን (ምልክቶችን በመጠራጠር) ያለሀኪም ትዕዛዝ ይወስዳሉ? (ከሱቅ፣ከባህል ሀኪም)	አዎ	1	
		አልወስድም	0	
606	ጤና ኤክስቴንሽን ሰራተኞች ስለወባ በሽታ አጠቃላይ የጤናትምህርት ይሰጣሉ?	አዎ	1	

	(ለምሳሌ መተላለፊያ እና መከላከያ መንገዶች) ***ቤት ለቤት ወይም በዘመቻ***	አይሰጡም	0	

ክፍል ሰባት፡የወባ ትንኝ መከላከያ አጎበር እና ፀረ-ትንኝ መድሐኒት ርጭትን በተመለከተ				
701	የወባ ትንኝ መከላከያ አጎበር አለህ/ሽ? ***በቀጥታ በመመልከት***	አዎ	1	**ምላሹ አዎ ካልሆነ፣ወደ ጥያቄ 817 ይሂዱ**
		የለኝም	0	
702	**ለጥያቄ 701 መልስዎ አዎ ከሆነ** ከቤታችሁ አንድ አጎበር ብቻ ነው ያለው? ***በቀጥታ በመመልከት***	አዎ	1	
		አይደለም	0	
703	**ለጥያቄ 702 መልስዎ አይደለም ከሆነ** ሁለት እና ከዚያ በላይ አጎበር አላችሁ? ***በቀጥታ በመመልከት***	አዎ	1	
		የለንም	0	
704	**ለጥያቄ 701 መልስዎ አዎ ከሆነ** በቤታችሁ ውሰጥ ስንት አጎበር አለ? ***በቀጥታ በመመልከት***	በቁጥር	______	
705	**ለጥያቄ 701 መልስዎ አዎ ከሆነ** ትናንት ማታ በአጎበር ውስጥ ነው የተኛህው/ሽው? ***በትክክል መሰቀሉን/መወጠሩን ኣረጋግጥ***	አዎ	1	
		አይደለም	0	
706	**ለጥያቄ 701 መልስዎ አዎ ከሆነ** ባለፈው አንድ ወር አጎበር ሁሌም ማታ ማታ ተጠቅማሃል/ሻል?	አዎ	1	
		አልተጠቀምኩም	0	
707	**ለጥያቄ 701 መልስዎ አዎ ከሆነ** ትናንት ማታ በአጎበር ውስጥ ብቻህን/ሽን ነው የተኛህው/ሽው?	አዎ	1	
		አይደለም	0	
708	**ለጥያቄ 707 መልስዎ አይደለም ከሆነ**, በአንድ አጎበር ውስጥ ሁለት ሁናችሁ ነው የተኛችሁት?	አዎ	1	
		አይደለም	0	
709	**ለጥያቄ 707 መልስዎ አይደለም ከሆነ**, በአጎበሩ ውስጥ ስንት ሁናችሁ ተኛችሁ?	በቁጥር	_____	
710	ትናንት ማታ ሁሉም የቤተሰቡ አባላት በአጎበሩ ውስጥ ነው የተኙት/ተጠቅመዋል?	አዎ	1	
		አይደለም	0	
711	ከቤተሰቡ አባላት ውስጥ ትናንት ማታ በአጎበር ውስጥ ያልተኛው ማን ነው? ***ከአንድ በላይ ማክበብ ይቻላል***	ነፍሰጡር እናት	0	
		መውለድ የሚችሉ እናቶች (15-49)	1	
		እድሜአቸው ከ5 አመት በታች የሆኑ ህፃናት	2	
		እድሜአቸው ከ5-14 አመት የሆኑ ህፃናት	3	
		ወንዶች ከ15–49 እና ጎልማሶች ከ49 በላይ	4	
712	ከቤተሰቡ አባላት ውስጥ አልፎ አልፎ ያለአጎበር የሚተኛው ማን ነው?	ነፍሰጡር እናት	0	
		መውለድየሚችሉእናቶች (15-49)	1	

	ከአንድ በላይ ማክበብ ይቻላል	እድሜአቸውከ5 አመትበታችየሆኑህፃናት	2	
		እድሜአቸውከ5-14 አመትየሆኑህፃናት	3	
		ወንዶችከ15–49 እናጎልማሶችከ49 በላይ	4	
713	**ለጥያቄ 701 መልስዎ አዎከ ሆነ**አጎበሩ ቀዳደ አለው? ***በቀጥታ በመመልከት***	አዎ	1	
		የለውም	0	
714	አጎበሩን ከተቀበሉ ምን ያህል ጊዜ ሆነው?	በወራት	______	
715	አጎበሩ በጥሩ ሁኔታ/በትክከል ተሰቅሏል? ***በቀጥታ በመመልከት***	አዎ	1	
		አልተሰቀለም	0	
716	አጎበሩ በጥሩ ሁኔታ ላይ ነው ያለው? ***በቀጥታ በመመልከት*** (ቀዳዳ የለለው፣የአገልግሎት ጊዜውን ያልጨረሰ እና በትክክል የተሰቀለ)	አዎ	1	
		አይደለም	0	
717	ባለፉት 12 ወራት ውስጥ, የቤቱ ግድግዳዎች በፀረ-ትንኝ መድሐኒት ተረጭተው ነበር?	አዎ	1	
		አልተረጨም	0	
718	ባለፉት 12 ወራት ውስጥ, ቤቱ ከተረጨ በኃላ ግድግዳዎች ቀልም ተቀብተው ወይም ተለስነው ነበር?	አዎ	1	
		አልተቀቡም	0	

ክፍል ስምንት፡በ500 ሜትር ርቀት ውስጥ የሚገኙ ውሃማ አካላትን፣የመሬት አጠቃቀምን እና የመሬት ሽፈንን በተመለከተ

<u>ማስታወሻ</u>፡ ከቤቱ በ500 ሜትር ርቀት ውስጥ የሚከተሉት ውሃማ አካላት ካሉ የሚከተሉትን ልኬቶች ይመዝግቡ? የመሬት አጠቃቀም እና የመሬት ሽፋኖች ካሉ ደግሞ ፊትለፊት ባለው ባዶ ቦታ የ[√] ምልክት ያድርጉ ከሌሉ የ[X] ምልክት ያስቀምጡ (ውሃማ አካላት፣ የመሬት አጠቃቀም፣ የመሬት ሽፋኖች የሚመዘገቡት ለእያንዳንዱ ቤት ነው) ፡፡

መለያዎች	ልኬቶች		
	ኬክሮስ(Northing)	ኬንትሮስ(Easting)	ከፍታ/Elevation (m)
ቤት___________			
810. ወንዝ/ሐይቅ**፡			
811. የቆመ ውሃ**፡			
812. መስኖ**፡			
813. ባዶ መሬት፡			
መለያዎች	የ [√] ወይም የ [X] ምልክት ማድረጊያ		

814. ደን:	
815. ብሎኬት ስራ፡	
816. ዛፎች፡	
817. ቁጥቋጦዎች፡	
818. ጊዚያዊ ውሃ/መንገድ:	

<u>ቁልፎች</u>:

ወንዝ/ሐይቅ = ወንዝ ወይም ሐይቅ መኖር

የቆመ ውሃ = ለመስኖ የሚውል የቆመ ውሃ፣ተፈጥሯዊ ኩሬ፣ግድብ፣ምንጭ ማጎልበት፣ረገረጋማ በታዎች

መስኖ፣ዛፎች፤ቁጥቋጦዎች

ባዶ መሬት = የማይታረስ ምድረበዳ በታ፣ለግጦሽ የሚያገለግል፣ለምነቱ እንዲመለስ በጊዜው የማይታረስ፣አለት

ደን = የተፈጥሮ ወይም/ጥብቅ ደን፣

ብሎከት ስራ = ትልልቅ የጭቃ ጉድጓዶች፣ቤት ግንባታ),

ጊዚያዊ ውሃ የሚያጠራቅሙ ዕቃዎች = የፕላስቲክ ጠርሙሶች፣የመኪና ጎማዎች፣ሲሊንደሮች፣ የውሃ ማጠራቀሚያ ታንከር፣የተሰባበሩ ሸክላዎች፣የወዳደቁ ማርማርቴዎች፣**መንገዶች** = አስፓልት፣ጠጠር፣ትንንሽ ለሰው እና ለእንስሳት የሚሆኑ፣በመገንባት ላይ ያለመንገድ፣ወዘተ

2. <u>የጥናት አላማ ሁለትን በተመለከተ የተዘጋጀ መጠይቅ</u>

ሀ.<u>የጥናቱ ተሳታፊ (እድሜአቸው ከ5 አመት በታች የሆኑ) የወባ በሽታ ምርመራ ውጤቶች</u>

1. የጥናቱ ተሳታፊ የወባ በሽታ ሁኔታ (የወባ በሽታ ምልክቶችን ግምት ውስጥ በማስገባት /በመጠቀም) ፡**1**. የወባ በሽታ ምልክቶች አሉት **2**. የወባ በሽታ ምልክቶች የሉትም
2. የጥናቱ ተሳታፊ የወባ በሽታ ሁኔታ (በላቦራቶሪ) ፡**1**. በማይክሮስኮፕ ፖዘቲቭ ነው **(ወደ ቁጥር 3 ይሂዱ)** **2**. በማይክሮስኮፕ ነጌቲቭ ነው
3. የወባ በሽታ ካለበት፣የትኛውፕላዝሞዲየም ፓራሳይት ነው? **1.** *Plasmodium falciparum* **2**. *Plasmodium vivax* **3.** Mixed infection (both of the two)
4. የወባ በሽታ የተመረመረበት/ችበት ጊዜ (ቀን/ወር/ዓ.ም): ________________________
5. የጤና ጣቢያው ስም፡ _______________________________________
6. የህፃኑ ፆታ: 1. ወንድ 2. ሴት

7. የህፃኑ ዕድሜ:______________________________

8. የጥናቱ ተሳታፊ ቁጥር (የኬዝ/ኮንትሮል)፡____________________________

9. የቀበሌው/የጎጡ ስም: _______________________፣ ___________________________

10. የጠያቂው/መረጃ ሰብሳቢዉ ስም እና ፊርማ:_________________፣_____________________

ለ.<u>የጥናቱ ተሳታፊ (እድሜአቸው ከ5 አመት በታች የሆኑ) የወባ በሽታ የመጠየቅ ጥያቄዎች</u>

የጥናቱ ተሳታፊ ቁጥር (የኬዝ/ኮንትሮል)፡_________________________________

የቀበሌው/የጎጡ ስም: ____________________________፣ __________________

የጤና ጣቢያው ስም፡ ____

መረጃው የተሰበሰበበት ቀን (ቀን/ወር/ዓ.ም): ____

የጠያቂው/መረጃ ሰብሳቢዉ ስም እና ፊርማ:_____________________፣_______________________

የመረጃ ሰብሳቢዎች ተቆጣጣሪ ስም እና ፊርማ፡___________________፣______________________

<u>ማስታወሻ</u>፡ ቃለ-መጠይቁ የሚካሄደው ከቤተሰቡ ሃላፊ/ከአሳዳጊው ጋር ነው፡

ክፍል አንድ፡ዲሞግራፊና ማህበራዊ ሁኔታዎች				
ጥያቄ ቁጥር	ጥያቄዎች	የመልስ ምርጫዎች/መለኪያዎች	የአማራጭ ምልክቶች/ልኬቶች	የሚዘለል
101	የቤተሰቡ ሃላፊ/ያሳዳጊው የጋብቻ ሁኔታ?	ያገባ/ች	0	
		ያላገባ/ች	1	
		ባል/ሚስት በሞት የተለያት/ችው	2	
		የፈታ/ች	3	
102	የቤተሰቡ ሃላፊ/ያሳዳጊው የሀይማኖት ሁኔታ?	ክርሥቲያን	0	
		ሙሥሊም	1	
		ሌላ (ይገለፅ)፡	99	
103	የቤተሰቡ ሃላፊ/ያሳዳጊውየሥራ ሁኔታ?	ግብርና	0	

		ንግድ	1	
		የመንግሰት ስራ	2	
		የጉልበት ሥራ	3	
		ሌላ (ይገለፅ)፡	99	
104	የቤተሰቡ ሃላፊ/ያሳዳጊው የትምህርት ሁኔታ?	ማንበብና መጻፍ የማይችል/ትችል	0	
		ማንበብና መጻፍ የሚ/ምትችል-መደበኛ ያልሆነ	1	
		ከ1-6 ክፍል ያጠናቀቀ/ች	2	
		ከ7-12 ክፍል ያጠናቀቀ/ች	3	
		ከ12 ክፍል በላይ ያጠናቀቀ/ች	4	
105	የህፃኑ/ኗ እናት የትምህርት ሁኔታ?	______________________		
106	የቤተሠቡ ብዛት ሥንት ነው?	በቁጥር	__________	
107	ቤት ውስጥ ከ18 ዓመት በታች የሆኑ ስንት ህፃናት አሉ? በቁጥር		___________	

ክፍል ሁለት፡ኢኮኖሚያዊ ሁኔታዎች					
201	የቤተሰቡ ንብረቶች	ከሚከተሉት ውሰጥ ቤተሰቡ የትኞቹ አሉት? ***ከአንድ በላይ ማክበብ ይቻላል***	አለ	የለም	የሚዘለል
		ኤሌክትሪክ?	1	0	
		ሰዓት?	1	0	
		ሬድዮ?	1	0	
		ሞባይል?	1	0	
		ጠረጴዛ?	1	0	
		ወንበር?	1	0	
		ስፖንጅ አልጋ?	1	0	
		ስፕሪንግ አልጋ?	1	0	
		ኩራዝ/ፋኑስ?	1	0	
		ሶላር/በፀሐይ ብርሀን የሚሠራ የኤሌክትሪክ መብራት/የእጅ ባትሪ?	1	0	
		የሚከተሉትን የቤተሰቡ አባላት አሏቸው?	አለ	የለም	
		ባይስክል?	1	0	
		ጋሬ?	1	0	
		ሞተር ሳይክል?	1	0	
		መኪና/የጭነት መኪና?	1	0	
		ባጃጅ	1	0	
		ከቤተስቡ አባላት ውስጥ የእርሻ መሬት ያለው አለ? አዎ…….1 የለም……0			
		ቤተሰቡ ሰንት ቃዳ/ሄክታር መሬት አለው?	በቁጥር	__________	
		ቤቱ ስንት የመኝታ ክፍሎች አሉት?	በቁጥር	___________	
		ቤተሰቡ ከሚከተሉት እንስሳቶች ውስጥ የትኞቹ አሉት? **ከሌለ '0'ን ይጻፉ** **ከአንድ በላይ ከሆነ '95'ን ይጻፉ** **ካላወቁት, '98'ን ይጻፉ**	መልሱን ይጻፉ		
			የወተት ላሞች/ኮርማዎች/በሬዎች		
			ፈረሶች/አህያዎች/በቅሎዎች		
			በጎች		
			ፍየሎች		
			የንብ ቀፎዎች		
			ዶሮዎች		

		ከቤተሰቡ አባላት ውሰጥ የባንክ/አነስተኛ የገንዘብ አካውንት ያለው አለ?	አዎ…….1 የለም……0	
		ቤተሰቡ ውሃ የሚያገኘው ከየት ነው? ***ከአንድ በላይ ማክበብ ይቻላል***	ከህዝብ ቧንቧ	0	
			ከተጠበቀ ጉድጓድ/ምንጭ	1	
			ካልተጠበቀ ጉድጓድ/ምንጭ	2	
			ሌሎች/ኩሬ, ወንዝ, ሔይቅ, ግድብ, ዝናብ	3	
		ቤተስቡ የትኛውን ሽንት ቤት ነው የሚጠቀመው? ***በቀጥታ በመመልከት***	መክደኛ ያለው ጉድጓድ መፀዳጃ ቤት	0	
			መክደኛ የሌለዉ ጉድጓድ መፀዳጃ ቤት	1	
			የአየር መዉጫ የተገጠመለት መፀዳጃ ቤት	2	
			ሽንት ቤት የለንም/ክፍት ቦታ፣ሜዳ	3	
		የቤቱ ወለል የተሠራው ከምንድን ነው? ***በቀጥታ በመመልከት***	አሸዋ ወይም አፈር	0	
			በእበት የተለቀለቀ	1	
			ከሲሚንቶ ሊሾ	2	
			ሌላ ይገለፅ፡	99	

ክፍልሦስት፡ለብዙሃንመገናኛያለውንቅርበትበተመለከተ**				
301	ጋዜጦችንቢያንስበሳምንትአንድጊዜታነባለህ/ቢያለሽ?	አዎ	1	
		አላነብም	0	
302	ሬዲዮቢያንስበሳምንትአንድጊዜታዳምጣለህ/ጫለሽ?	አዎ	1	
		አላዳምጥም	0	

*** የቤተሰብ ሃላፊውን/ያሳዳጊውን የመረጃ ቅርበትይውሰዱ!!!*

ክፍል አራት፡የቤቱ አጠቃላይ መገለጫዎች				
401	መኖሪያ ቤት አልዎት?	አዎ	1	**ቤት ከሌለው ወደ ክፍል አምሰትይሂዱ**
		የለኝም	0	
402	ቤትዎ ሰንት ክፍል/ሎች አሉት? ***በቀጥታ በመመልከት***	በቁጥር	________	
403	የቤቱ ጣሪያ የተሠራውከምንድን ነው? ***በቀጥታ በመመልከት***	የሳር ክዳን	0	
		ቆርቆሮ	1	
		ሌላ ይገለጽ:	99	

404	የቤቱ ግድግዳ የተሠራው ከምንድን ነው? ***በቀጥታ በመመልከት***	ከጭቃ	0	
		ከሲሚንቶ/ግርፍ	1	
		ሌላ ይገለጽ:	99	
405	የቤቱ ወለል የተሠራው ከምንድን ነው? ***በቀጥታ በመመልከት***	አሸዋ ወይም አፈር	0	
		በእበት የተለቀለቀ	1	
		ከሲሚንቶ ሊሾ	2	
		ሌላ ይገለጽ፡	99	
406	ቤቱ ለምግብ ማብሰያ የሚሆን የተለየ ቤት አለው? ***በቀጥታ በመመልከት***	አለው	1	
		የለም	0	
407	የቤቱ መስኮት ምን አይነት ነው? ***በቀጥታ በመመልከት***	መስኮት የለውም	0	
		ክፍት መስኮት	1	
		የቆርቆሮ	2	
		በተጠላለፈ ሽቦ የተዘጋ (ለወባ ትንኝ መከላከያ የሚሆን)	3	
		ሌላ ይገለጽ፡	99	
408	የቤቱ ጣሪያ ቀዳዳዎች አሉት? ***በቀጥታ በመመልከት***	አዎ	1	
		የለውም	0	
409	ባለፈው አንድ ወር ውስጥ የቤት እንስሳት ቤት ውስጥ ዘወትር/አልፎ አልፎ ያድሩ ነበር?	አዎ	1	
		አላደሩም	0	
410	ከቤቱ በአምሳ ሜትር ርቀት ውስጥ ስንት ቤቶች አሉ?	በቁጥር		

	ክፍል አምስት፡ከቤት ውጭ የተደረገን ጉዞ በተመለከተ			
501	ባለፈው አንድ ወር ውስጥ ከቤት ውጭ በጉዞ ምክኒያት ህጻኑ/ኗ አድሮ/ራ ነበር?	አዎ	1	**ምላሹ አዎ ካልሆነ፣ወደ ጥያቄ 503 ይሂዱ**
		አልተጓዝኩም	0	
502	**ለጥያቄ 501 መልስዎ አዎ ከሆነ**, ህጻኑ/ኗ የወባ ትንኝ መከላከያ አጎበር ዘወትር ይጠቀም/ትጠቀም ነበር?	አዎ	1	
		አልተጠቀምኩም	0	
503	ከቤተሰቡ አባላት ውስጥ ወደ ወባማ ቦታዎች የተጓዘ ሰው ነበር? **(ከጥናቱ ቦታ ውጭ)** *መተማ፣ሁመራ፣ዳንሻ፣ሳንጃ፣ቋራ፣አብራጅራ*	አዎ	1	**ምላሹ አዎ ካልሆነ፣ ወደ ክፍል ስድስት ይሂዱ**
		የለም	0	

504	***ለጥያቄ 503 መልስዎ አዎ ከሆነ***, ለምን ነበር የተጓዘው/ችው (በምን ምክኒያት)? ***ከአንድ በላይ ማክበብ ይቻላል***	ስራ ፍለጋ	0	
		ለማህበራዊ ጉዳይ (ጓደኛ፣ዘመድ፣ወዘተ. ለመጠየቅ)	1	
		የእርሻ ማሳ ስላለው/ላት	2	
		ሌላ ይገለጽ፡	99	

ክፍል ስድስት፡የሰውን ባህሪ፣እምነት እና ስለወባ በሽታ የሚሰጥን ትምህርት በተመለከተ					
601	ባለፈው አንድ ወር ውሰጥ ከምሽቱ 12:00 እስከ ምሽቱ 6:00 ባለው ጊዜ ከቤት ውጭ ህጻኑ/ኗ ያመሽ/ታመሽ ነበር? **(በጭዋታ፣በሥራ፣በጉዞ ወዘተ…)**	አዎ		1	
		አላመሽም		0	
602	ለመጨረሻ ጊዜ የወባ በሽታ ምልክቶች ህጻኑ/ኗ ላይ በታዬ ጊዜ ወደ ጤና ተቋም ሄዳ/ዶ ነበር? **(ለበሽተኞች ያሁኑን ሳይጨምር)**	አዎ	1	**ምላሹ አዎ ካልሆነ፣ወደጥያቄ 604 ይሂዱ**	
		አልሄድኩም	0		
603	**ለጥያቄ 602 መልስዎ አዎ ከሆነ** እና ወባ በተገኘ ጊዜ, ሁሉንም የወባ መድሀኒቶች በሀኪሙ ትዕዛዝ መሰረት ጨርሷል/ሳለች?	አዎ		1	
		አልጨረስኩም		0	
604	የወባ በሽታ ምልክቶች ህጻኑ/ኗ ላይ በታዩ ጊዜ ለመታከም የባህል ሀኪም/ጸበል ጋር የመውሰድ ልምድ አለዎት? **(ጠንቋይ፣ጸበል፣እፅዋት ወዘተ…)**	አዎ		1	
		የለኝም		0	
605	ከወባ በሽታ ለመፈወስ መድሐኒቱን (ምልክቶች የወባ ናቸው በማለት) ያለሀኪም ትዕዛዝ ይወስዳሉ? (ከሱቅ፣ከባህል ሀኪም)	አዎ		1	
		አልወስድም		0	
606	ጤና ኤክስቴንሽን ሰራተኞች ስለወባ በሽታ አጠቃላይ የጤና ትምህርት ይሰጣሉ? (ለምሳሌ መተላለፊያ እና መከላከያ መንገዶች) ***ቤት ለቤት ወይም በዘመቻ***	አዎ		1	
		አይሰጡም		0	

ክፍል ሰባት፡የወላጆችን/የአሳዳጊዎችን ስለወባ በሽታ ያላቸውን እውቀት በተመለከተ				
701	የወባ በሽታ በወባ ትንኝ ንክሻ ይተላለፋል?	አዎ	1	
		አይተላለፍም	0	
702	የወባ በሽታን በአጎበር መከላከል ይቻላል?	አዎ	1	
		አይቻልም	0	

ክፍል ስምንት፡የወባ ትንኝ መከላከያ እና መቆጣጠሪያ ዘዴዎችን በተመለከተ				
801	ቤት ውስጥ የወባ ትንኝ መከላከያ አጎበርአለ? ***በቀጥታ በመመልከት***	አዎ	1	**ምላሹ አዎ ካልሆነ፣ወደ ጥያቄ 815**

		የለኝም	0	**ይሂዱ**
802	**ለጥያቄ 801 መልስዎ አዎ ከሆነ** ከቤታችሁ አንድ አጎበር ብቻ ነው ያለው? ***በቀጥታ በመመልከት***	አዎ	1	
		አይደለም	0	
803	**ለጥያቄ 802 መልስዎ አይደለም ከሆነ** ሁለት እና ከዚያ በላይ አጎበር አላችሁ? ***በቀጥታ በመመልከት***	አዎ	1	
		የለንም	0	
804	**ለጥያቄ 801 መልስዎ አዎ ከሆነ** በቤታችሁ ውስጥ ስንት አጎበር አለ? ***በቀጥታ በመመልከት***	በቁጥር	_____	
805	**ለጥያቄ 801 መልስዎ አዎ ከሆነ** ትናንት ማታ ህፃኑ/ኗ በአጎበር ውስጥ ነው የተኛው/ችው? ***በትክክል መሰቀሉን/መወጠሩን ኣረጋግጥ***	አዎ	1	
		አይደለም	0	
806	**ለጥያቄ 801 መልስዎ አዎ ከሆነ** ባለፈው ሁለት ሳምንት ህፃኑ/ኗ ሁሌም ማታ ማታ አጎበር ተጠቅሟል/ማለች?	አዎ	1	
		አልተጠቀመም	0	
807	**ለጥያቄ 801 መልስዎ አዎ ከሆነ** ትናንት ማታ በአጎበር ውስጥ ህፃኑ/ኗብቻውን/ዋን ነው የተኛው/ችው?	አዎ	1	
		አይደለም	0	
808	**ለጥያቄ 807 መልስዎ አይደለም ከሆነ**, በአንድ አጎበር ውስጥ ከህፃኑ/ኗ ሌላ አንድ ሰው አብሮ ተኝቷል?	አዎ	1	
		አይደለም	0	
809	**ለጥያቄ 807 መልስዎ አይደለም ከሆነ**, በአጎበሩ ውስጥ ስንት ሁነው ተኙ?	በቁጥር		
810	**ለጥያቄ 801 መልስዎ አዎ ከሆነ** አጎበሩ ቀዳደ አለው? ***በቀጥታ በመመልከት***	አዎ	1	
		የለውም	0	
811	አጎበሩን ከተቀበሉ ምን ያህል ጊዜ ሆነው?	በወራት		
812	አጎበሩ በጥሩ ሁኔታ/በትክክል ተሰቅሏል? ***በቀጥታ በመመልከት***	አዎ	1	
		አልተሰቀለም	0	
813	አጎበሩ ከተሰጣችሁ በኃላ ስንት ጊዜ ታጥቧል?	በቁጥር		
814	አጎበሩ በጥሩ ሁኔታ ላይ ነው ያለው? ***በቀጥታ በመመልከት*** (ቀዳዳ የለለው፣የአገልግሎት ጊዜውን ያልጨረሰ፣ ቶሎ ቶሎ የሚታጠብ እና በትክክል የተሰቀለ)	አዎ	1	
		አይደለም	0	
815	ባለፉት 12 ወራት ውስጥ, የቤቱ ግድግዳዎች በፀረ-ትንኝ መድሐኒት ተረጭተው ነበር?	አዎ	1	**ምላሹ አዎ ካልሆነ፣ወደ ጥያቄ 817ይሂዱ**
		አልተረጩም	0	
816	ባለፉት 12 ወራትውስጥ, ቤቱ ከተረጨ በኃላ ግድግዳዎች ቀለም ተቀብተው ወይም ተለስነው ነበር?	አዎ	1	
		አልተቀቡም	0	

817	ከአጎበር ውጭ ሌሎች የወባ ትንኝ መከላከያ ዘዴዎችን ትጠቀማላቸሁ **(የወባ ትንኝ መከላከያ ሽቦ፣ቤት ውስጥ የሚዘጋጅ ፀረ-ትንኝ ኬሚካል፣የሳር ጭስ)?**	አዎ	1	
		አንጠቀምም	0	
818	የወባ በሽታን ይከላከላሉ ተብለው የሚታመኑ መድሃኒቶችን (የዕጽዋት ሻይ፣ፓራሲታሞል፣ክሎሮኪል) ባለፈው ሁለት ሳምንት ህፃኑ/ኗ ወስዷል/ወስዳለች?	አዎ	1	
		አልወሰደም/ችም	0	

ቃለ-መጠይቁ የሚካሄደው ከህፃኑ/ኗወላጅ/አሳዳጊ ጋር ነው!!!

3. <u>የጥናት አላማ ሶስትን በተመለከተ የተዘጋጀ የመጠይቅ መመዘኛ</u>

ሀ.<u>የወባ በሽታ መከላከያ አጎበርን አጠቃቀም የተመለከተ የጥልቅ-መጠይቅ መጠይቆች (ለጥናቱ ተሳታፊ ለሆኑ የአካባቢው ማህበረሰብ)</u>

1. የወባ በሽታ መከላከያ አጎበር/ዛንዚራ/ሙስያ እንዳትጠቀም/ሙያደረጉህ/ዓችሁን ሁኔተዎች እስኪ ዘርዘር አድርገህ/ሽ ግለጽልኝ/ጪልኝ?
2. አጎበሩ የት እንዳለ እስኪ አሳዩኝ?
3. የወባ በሽታ መከላከያ አጎበር/ዛንዚራ/ሙስያ ሁልጊዜ ማታ ማታ እንዳትጠቀሙ የሚያደርጉ ነገሮችን ዘርዝርልኝ እስኪ?
4. ከቤተሰቡ አባላት ውስጥ ሁልጊዜ ማታ ማታ አጎበር የማይጠቀሙት እነማን ናቸው?

   ሀ) ነፍሰጡር እናቶች/እርጉዝ ሴቶች **ምክኒያቶቹ ምንድን ናቸው?**

   ለ) እድሜአቸው ከ5 አመት በታች የሆኑ ህፃናት **ምክኒያቶቹ ምንድን ናቸው?**

   ሐ) መውለድ የሚችሉ እናቶች (15-49) **ምክኒያቶቹ ምንድን ናቸው?**

   መ) እድሜአቸው ከ5-14 አመት የሆኑ ህፃናት **ምክኒያቶቹ ምንድን ናቸው?**

   ሠ) ወንዶችከ 15–49 እና ጎልማሰች ከ49 በላይ **ምክኒያቶቹ ምንድን ናቸው?**
5. የቤተሰቡ አባላት የሚተኙት የት የት ላይ ነው? (የመኝታ በታዎች)
6. አጎበሩ ውስጥ ለመተኛት ስንት ሰዓት ላይ ነው የምትገቡት?
7. አጎበርን በአግባቡ የመጠቀም ልማዶችን ይጨምራሉ የምትላ/ሏቸውን አስተያየቶችህን እስኪ ግለጽል/ሉኝ?

8. የወባ በሽታ መከላከያ አጎበሩ ምን ምን አይነት ጥሩ ባህሪያት አሉት/ጠንካራ ጎኖች?
9. የወባ በሽታ መከላከያ አጎበሩ ጉድለቶች/ደካማ ጎኖች የምትላቸውን እስኪዘርዝርልኝ?
10. በመጨረሻም ፣በእኔ በኩል ያልተነሱ ሌሎች ሃሳቦች/ነጥቦች ካሉ መጨመር ትችላለህ/ሽ?

ለ. <u>የወባ በሽታ መከላከያ አጎበርን አጠቃቀም የተመለከተ የቁልፍ መረጃ ሰጪ መጠይቆች (ለወባ በሽታ መከላከልና ቁጥጥር ሃላፊዎች፣ለጤና ጣቢያ የጤና ባለሙያዎች፣ለጤና ኤክስቴንሽን ባለሙያዎች፣ለቀበሌ/ለጎጥ አመራሮች እና ለተማሪዎች)</u>

1. የአካባቢውን ህዘብ የወባ በሽታ መከላከያ አጎበር እንዳይጠቀም ያደረጉትን ምክኒያቶች እስኪ ዘርዘር አድርገህ/ሽ ግለጽልኝ/ጪልኝ?
2. የአካባቢውን ህዘብ የወባ በሽታ መከላከያ አጎበር ሁልጊዜ ማታ ማታ እንዳይጠቀም የሚያደርጉ መሰናክሎችን/ምክኒያቶችን ዘርዝርል/ሊኝ እስኪ?
3. የዚህ አካባቢ ህብረተሰብ/ማህበረሰብ የወባ በሽታ መከላከያ አጎበሩን ከተፈቀደለት አገልግሎት ውጭ ለምን ለምን ተግባራት/አገልግሎቶች እንደሚያውለው እስኪ ካስተዋሉት ይንገሩኝ?
4. አጎበርን በአግባቡ የመጠቀም ልማዶችን ይጨምራሉ የምትላ/ሏቸውን አስተያየቶችህን እስኪ ግለጽል/ሉኝ?
5. የወባ በሽታ መከላከያ አጎበሩ ከስሪቱ(በፋብሪካ ሲመረት) እና አጠቃቀም አንፃር ምን ምን አይነት ጥሩ ባህሪያት አሉት/ጠንካራ ጎኖች?
6. የወባ በሽታ መከላከያ አጎበሩ ከስሪቱ(በፋብሪካ ሲመረት) እና አጠቃቀም አንፃር ጉድለቶች/ደካማ ጎኖች የምትላቸውን እስኪ ዘርዝርልኝ?
7. በመጨረሻም፣በእኔ በኩል ያልተነሱ ሌሎች ሃሳቦች/ነጥቦች ካሉ መጨመር ትችላለህ/ሽ?

Annex 3: *Anopheles* mosquito larvae collection, rearing and morphological identification

Sampling equipments and materials for Anopheles mosquito larvae and pupae collection

Ladle/spoon/dipper; covered containers (for holding samples)/plastic bottles having holes in the cover for aeration (used for transportation of the sample to the insectary); trays/wide-mouthed plastic containers (plastic tree) for the pouring of the sample from the dipper; recording forms; a GPS device

LARVAL SURVEY DATA COLLECTION FORM

1. Collection site identification: Region/district:________Locality:___________
   Geographic coordinates: Latitude: _______________Longitude_____________
2. Characterization of the breeding site: Type: 1. Permanent 2. Semi-permanent 3. Temporary
   Origin of the water (*e.g.* rain, river, lagoon, man-made):___________________
   Nature of the water collection (*e.g.* puddle, rice field, ditch):_________________
   Characteristics of the water (*e.g.* clear, turbid, polluted, dark):________________
   Exposure to sunlight: 1. Shaded 2. Partially 3. Shaded Sunlit
3. Sampling description: Sampling time (min) ___________Number of dips_____________
   Presence of larvae: 1. Anopheline 2. Culicine 3. Negative
4. Notes____
   Date___________Hour of the collection________ Name of the collector_________

Transportation of live larvae

All specimens collected from a particular breeding place were kept in one bottle and labeled in pencil. The label included identifiers such as date, location, initials of the collector, sample number. This was reflected on the data form. In addition, the side of the bottle was also labeled with a permanent ink marker. During transporting larvae for long distances, there is about 1- 2cm space in the bottle cover to allow air for larvae and pupae to breathe.

Rearing of *Anopheles* mosquito larvae into adults in the insectary

Laboratory equipment, materials and reagents for Anopheles larvae growth (larvae to adult) at the rearing room

Plastic tree; pure water (changed daily); yeast (food for larvae); dropper (for taking larvae from the plastic tree to another, since the old one having yeast has to be changed); sticker/plaster (used for labeling of the habitat type; date of sampling, name of the site and data collector); room suitable for larvae (naturally conditioned); beaker (for putting pupae); cage (a meshed one used for resting of adult mosquitoes); aspirator (used for collecting the adults from the cage); beaker (used to put the adults); silica gel (used to dehydrate and kill the adults at the beaker); cotton (used to cover the beaker); rope (used to tight the cover with the beaker)

Larvae

Temperature is the most important external factor that affects the growth rate of larvae. A constant water temperature of about 27°C is critical for larval development. The larva room should have a wide glass window to let in daylight or an artificial lighting system that allows for alternation of 12-hour light/dark cycles, another critical environmental factor for larval development. Larvae should be fed twice daily, usually with ground fish food. Both the quality and quantity of the diet are important to the longevity and fecundity of the adult stage. Larval mortality can be high if they are overfed. Underfeeding will produce smaller adults. The first feeding should be 24 hrs after hatching. The first instar larvae require more food than the fourth instar. Check for algae inside the larval trays as these can lead to high mortality. It is important to change the rearing water every 1-2 days and remove all dead larvae in the trays. Larvae should be handled gently, especially during transfer from tray to tray. Larva trays should not be overcrowded, as this will affect the larval development due to competition for food and cannibalism.

Pupae

This is a non-feeding stage. The larval trays should be checked daily for pupae. Pupae are removed and placed into adult cages where the adults will emerge. Separation of pupae from larvae can be done simply by the use of a pipette or a fine-net spatula; pupae are placed into a cup for transfer into an insect cage. For larger numbers, the tendency for larvae to swim down when disturbed, whereas pupae are tends to stay up can be used to facilitate this procedure. A cup containing larvae and pupa can be whirled and this causes the larvae move to the middle bottom of the cup but the pupa will stay up on the side. They can be separated then by use of a pipette. Chilled water can also be used to reduce pupal and larval activity to facilitate separation (but needs to be done quickly to avoid harm to developing stages) which then enables the pupae to be poured out into a sieve and transferred to water at room temperature.

Adults

Adults can be kept in net covered cups, which are inexpensive and can hold about 10-15 adults. Usually a hole is made in the net to introduce the adults and plugged with cotton wool. Adult cages can be used to hold larger numbers. Adults should be handled with care, using mouth aspirators from transfers between cages whenever necessary.

Species identification using morphological characteristics

Morphological structures were used to distinguish between anopheline species/species complexes. This was accomplished by the observation of species-specific characteristics at the adult stage. Mosquitoes were preserved in very good condition. Adults were kept dry inside entomological boxes with cotton wool and filter paper to avoid loss of scales during transportation. The identification method involved mounting specimens in slide and cover-slip (adult body parts) for observation under a microscope. The identification involved the use of taxonomic keys.

Essential materials and equipment

Optical dissecting microscope, entomological forceps, slides, cover slips, cotton wool, plastic tubes, miscellaneous laboratory glassware, permanent ink markers, pencils, adhesive tape, note book, silica gel, mounting medium for slide preparations

Annex 4: (Paper I-III)

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RESEARCH

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Travel to farms in the lowlands and inadequate malaria information significantly predict malaria in villages around Lake Tana, northwest Ethiopia: a matched case–control study

Asmamaw Malede[1*], Kassahun Alemu[2], Mulugeta Aemero[3], Sirak Robele[1] and Helmut Kloos[4]

Abstract

Background: In Ethiopia, malaria has declined in the last decade; only a small number of cases have been reported, primarily from hotspots. The contribution of house proximity to water bodies and the role of migration in malaria transmission has not yet been examined in detail in northwest Ethiopia. Individual and household-level environmental and socio-demographic drivers of malaria heterogeneity were explored contextually in meso-endemic villages around Lake Tana, northwest Ethiopia.

Methods: A health facility-based paired age-sex matched case–control study involving 303 matched pairs was undertaken from 10 October 2016, to 30 June 2017. Geo-referencing of case households, control households, proximate water bodies, and health centres was carried out. A pretested and structured questionnaire was used to collect data on socio-demography, household assets, housing, travel history, and malaria intervention measures. Medians (interquartile range) were computed for continuous variables. Pearson's Chi square/Fisher's exact test was used to detect significant differences in proportions. Principal component analysis was performed to estimate household wealth. Stratified analysis was used to confirm confounding and interaction. A multivariable conditional logistic regression model was used to detect risk factors for malaria.

Results: Of 303 malaria cases, 59 (19.5% [15.4–24.3]) were imported malaria cases whereas 244 (80.5% [75.7–84.6]) were locally acquired malaria cases. In bivariate analysis, marital status, educational status, and bed net ownership were significantly associated with malaria cases. In multivariable adjustment, travel to malarious lowlands in the preceding month (adjusted mOR = 7.32; 95% CI 2.40–22.34), household member's travel to malarious lowlands (adjusted mOR = 2.75; 95% CI 1.02–7.44), and inadequate health information on malaria (adjusted mOR = 1.57; 95% CI 1.03–2.41) were predictors of malaria. Stratified analysis confirmed that elevation of households and travel to malarious lowlands were not effect modifiers. Travel to malarious lowlands had a confounding effect on malaria but elevation of households did not.

Conclusions: In this study, travel to farms in the lowlands and inadequate health information on malaria were risk factors for malaria in villages around Lake Tana. This evidence is critical for the design of improved strategic interventions that consider imported malaria cases and approaches for accessing health information on malaria control in northwest Ethiopia.

Keywords: Locally acquired malaria, Malaria information, Travel, Matched case–control study

*Correspondence: coolmaldinni@gmail.com
[1] Ethiopian Institute of Water Resources, Addis Ababa University, Addis Ababa, Ethiopia
Full list of author information is available at the end of the article

Background

Malaria still threatens the lives of millions of people, predominantly in sub-Saharan Africa; incidence increased between 2014 and 2016 in the WHO African region [1]. WHO targeted to eliminate malaria from at least 35 countries in which malaria was transmitted in 2015 and prevent re-establishment of malaria in all countries that are malaria free by 2030 through locally tailored interventions [2]. Wide use of effective interventions, including long-lasting insecticidal nets (LLINs), indoor residual spraying (IRS), treatment based on microscopy/rapid diagnostic tests (RDTs), and artemisinin-based combination therapy (ACT) has led to a considerable reduction in global malaria burden [3]. However, delivering interventions that deny the exceptional role of hot spots will extend the time needed for malaria elimination [4].

Over three-quarters of the Ethiopian landmass is malarious and 68% of the population is at risk for contracting malaria, depending largely on altitude and season [5]. This signifies a critical public health concern in a severely resource-limited country. Malaria has declined in the last decade, with a small number of cases reported, particularly from hotspots [1]. A 2015 malaria indicator survey using microscopy reported 0.4% malaria prevalence among people of all ages who travelled away from their home in the month preceding the survey and 0.5% among those who did not travel [5]. To end malaria, Ethiopia has employed three crucial interventions: distribution of bed nets, IRS in epidemic-prone areas, and enhanced diagnostic testing through RDT and microscopy along with deployment of ACT. As a result of intensive and integrated intervention measures, malaria incidence declined by 50–75% between 2000 and 2015 in the country [6]. This included implementing a program to eliminate locally acquired malaria transmission in 50 districts by 2020. Despite the gains made to date, sizeable residual transmission remains. This localized transmission is determined by demographic, socioeconomic, and environmental factors [7].

Malaria heterogeneity is multifactorial [7–9]. For instance, different environmental exposures increase malaria heterogeneity, particularly in rural settings; these include land cover, altitude, topography, human and vector population densities, and construction of residential houses [10]. Previous studies showed socio-demography [7, 11], household (HH) wealth [12], housing structure [13], travel history [7, 14] and intervention measures [8, 15] to be major factors in malaria transmission. Agricultural labourers often travel to malarious lowlands to work on commercial farms [7]. The resultant acquisition of locally acquired and imported malaria in meso-endemic areas hinders effective interventions in midland and highland areas bordering hyper-endemic areas [16, 17]. In addition, house proximity to water bodies has an inconsistent effect on malaria transmission. Some studies concluded that closeness to water bodies increases malaria risk [18, 19] while others reported lower risk near surface water [20, 21]. Some studies asserted the independence of malaria risk and house proximity to water bodies [22].

The average flight range of the main vector, *Anopheles gambiae*, is reported to be approximately 500 m [23]. Over the last 15 years, malaria prevalence has been decreasing in most endemic settings, due to the aforementioned integrated control intervention strategy, and in some settings the disease has been confined to hot spots with specific vector ecology conditions [4]. For malaria elimination and eradication, vector ecology is important. However, there are several ecological obstacles to vector control with existing interventions, including variations in mosquito behaviour, insecticide resistance, avoidance behaviour, vector biodiversity, competitive and food web interactions, dispersal and mating behaviour, and environmental change [24].

Comprehending heterogeneity in malaria exposure produces opportunities for spatially oriented malaria control [25]. Targeted malaria interventions have direct benefits both for targeted populations and for the whole community. Targeted control efforts are vital tools in malaria elimination when malaria transmission is sustained in hot spots [1].

Malaria elimination may be facilitated by finer-scale spatial studies. In areas with low malaria incidence, passive case detection (PCD) may lead to the identification of households (HHs) with more infections than others that can be a source of new infections. Determining the distance between HHs and the proximate water bodies where symptomatic malaria cases originate may help to define hotspots of malaria and contribute to improving malaria elimination efforts by optimizing the delivery of limited resources to higher-risk populations [26, 27]. The role of GPS-based house proximity to water bodies on malaria has not yet been documented in northwest Ethiopia, and no studies have traced the potential role of imported malaria in maintaining transmission foci in the country. This study aimed to determine the effect of house proximity to water bodies and other underlying factors on malaria heterogeneity in villages around Lake Tana. Specifically, this study explored the role of socio-demographic characteristics, travel history, HH wealth, housing structure, and malaria intervention measures on malaria heterogeneity. The findings of this study may guide national malaria control and elimination programmes in re-designing programmes for malaria elimination in Ethiopia.

Methods

Study area and settings

The study was undertaken in 11 *kebeles* (the lowest administrative units in Ethiopia) of Gondar *Zuriya* District and 1 *kebele* of *Dembia* District, northwest Ethiopia, from 10 October 2016, to 30 June 2017 (Fig. 1). Out of 37 *kebeles* in Gondar *Zuriya* District, eight are not endemic for malaria. In 2016/2017, Gondar *Zuriya* and *Dembia* districts had a projected population of 222, 700 and 315, 390, respectively. The area of Gondar *Zuriya* District is 1108.53 km^2, with a population density of 188.4 persons/km^2 [28]. Gondar Zuriya District is composed of hilly and plain landscapes, and the altitude ranges from 1750 to 2600 m above sea level over three highland fringe zones. Subsistence agriculture is the main occupation of the inhabitants. In 2016, total rainfall, mean maximum temperature, mean minimum temperature and relative humidity in the study area were 1047.6 mm, 27.4 °C, 14.7 °C, and 45%, respectively [29]. Gondar Zuriya District has seven health centres and 38 health posts that provide health services for the people in the district.

Since 2004, guidelines on malaria case management in the country have recommended treatment based on parasitological diagnosis with microscopy/RDTs. Artemether–lumefantrine is the first-line drug in Ethiopia. Seasonally, large numbers of malaria cases are reported from September to December in northwest Ethiopia, mostly *Plasmodium falciparum* infections [30]. In Gondar *Zuriya* District, large number of individuals travel to malarious lowlands to temporarily work on commercial agricultural farms, mainly during the rainy and spring seasons. Males aged 15 years and above are the main travellers to the lowlands. Malaria is a common seasonal disease in the district. A 10-year (2002–2011) trend analysis conducted in a neighboring district's health centre reported 23,473 microscopically confirmed malaria cases (75% *P. falciparum* and 25% *Plasmodium vivax*) with a fluctuating trend and mean malaria cases of 2, 347. From 2010 to 2011, *P. falciparum* prevalence decreased while *P. vivax* prevalence was increasing, indicating a trend shift from *P. falciparum* to *P. vivax*. Males and those in the age group of 15–44 years were

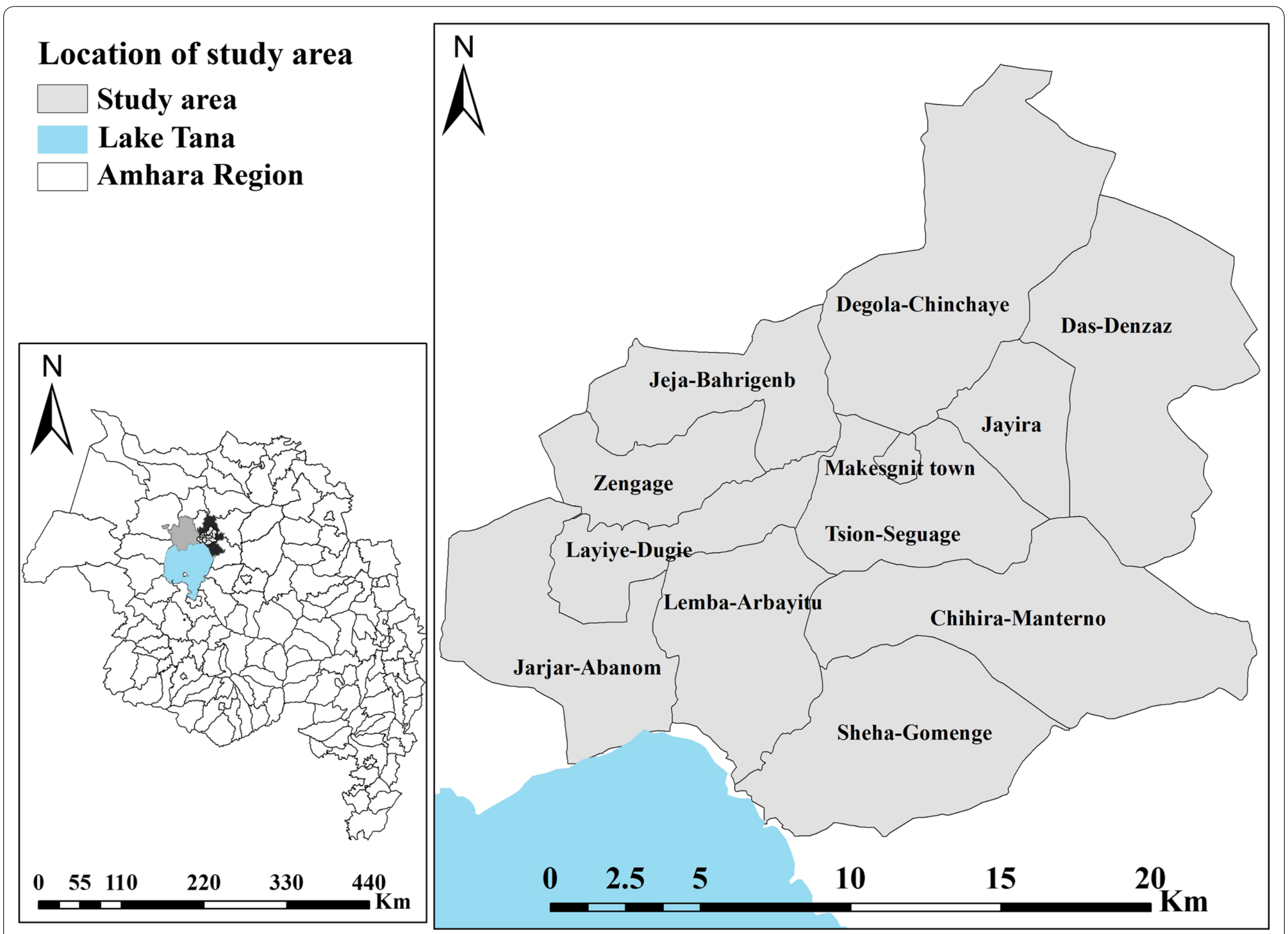

Fig. 1 Geographic location of study area around Lake Tana, northwest Ethiopia

highly affected [30]. Another study conducted at selected health institutions in three districts reported 61.3% prevalence of malaria (72.3% *P. falciparum* and 27.7% *P. vivax*) microscopically [31]. There is an annual IRS programme and distribution of LLINs, with replacement being done every 3 years. Bendiocarb and Propoxur has been used for spraying interior walls of houses and LLINs (DuraNet®) have been distributed since September 2005. One study recognized *Anopheles arabiensis* as a primary vector of malaria around Lake Tana [32].

The study area has altitudes of 1750–2500 m above sea level [33]. The climate of Lake Tana basin is of the temperate tropical highland type [34]. Most rain falls between June and September [34]. The water of Lake Tana is turbid and the lake's shores are becoming covered with water hyacinth. Gumara Stream flows from east to west and into Lake Tana, irrigating extensive commercial garlic farms along its course. The irrigation water is pumped using generators, causing a substantial decrease in river flow during the dry season (October to February). The reduction in river flow creates stagnant areas, potential breeding habitats for mosquitoes.

Study design and eligibility criteria

A health facility-based paired-matched case–control study was used. Cases and controls were individually matched by sex. However, frequency matching was done by age (< 15, 15–49, and > 49 years). All patients ≥ 5 months of age who visited *Lemba* and *Makesegnit* health centres and permanent residents in the study *kebeles* were included. Individuals who had no *Plasmodium*-positive blood film or symptoms of malaria during the preceding month confirmed using patient interview or health centre register were enrolled in the control group. Individuals with new episodes of malaria or people with recrudescent cases that presented after 1 month or more of the initial infection, and those who had taken malaria treatment in the previous 30 days were excluded from the study.

Study population

The patients (malaria cases and controls) were included into the study based on the clinical signs and symptoms of malaria and blood slides results. When patients came to the health centres for treatment, clinical diagnosis was performed for malaria. Then, the presence of *Plasmodium* parasites in the blood samples was confirmed using malaria microscopy. When a malaria case was found, the matched control was obtained from the patients by confirming through clinical diagnosis and slide results within 3 days after the case was diagnosed.

Sample size computation

Sample size was determined using matched case–control study design sample size calculation methods [35] with an assumption of 95% level of confidence, 80% power to detect exposure difference, odds ratio (OR) of 1.61, one control per case, and assuming that 25% of the control HHs were located within a 250 m radius of water bodies [26]. Based on these assumptions, 333 case–control matched pairs could be included in the study.

Data collection and quality assurance

Microscopy was used to confirm the presence of *Plasmodium* species in the clinically diagnosed patients [36]. Microscopy is the gold standard method of diagnosing malaria [37]. Confirmation of positivity or negativity of slide results was assured using standard operating procedures of Giemsa malaria microscopy at the health centres. Thick blood film was used to search for malaria parasites while thin film was used to confirm the malaria parasite species when this could not be done in the thick film. Malaria diagnoses were performed at the two health centres and patients were selected and classified as cases or controls based on the eligibility criteria. Cases were patients who had signs and symptoms of malaria or reported fever during the previous 48 h and were positive for single or mixed *Plasmodium* species in a blood sample diagnosed by microscopy [36]. Controls were individuals presenting at the health centres whose thick blood smear tests were negative for malaria. Experienced microscopists who were certified by the Ethiopian Federal Ministry of Health double checked all the slides at the health centres.

All tested slides (negative and positive) were stored at the health centres and three quarters of the sample were collected randomly for quality control. Blind examination of the slides was independently performed by a senior technician at the University of Gondar Specialized Hospital Laboratory.

A pre-tested, semi-structured questionnaire was used to collect individual and HH information. The questionnaire consisted of questions on socio-demography, HH assets, housing structure, LLINs, IRS, travel history, visits to traditional healers, and inappropriate home-based management of malaria (HMM). Males who completed grade 12 collected the individual and HH data through HH visits. Data collectors were trained in field data collection for 3 days by the lead researcher. If any case or control was absent at the first visit, the HH was revisited within 2 days. After the second visit, 15 HHs were excluded and 15 subjects refused to be interviewed.

Geo-referencing of case HHs, control HHs, small water bodies, a part of the shore of Lake Tana, and the two health centres was recorded through a handheld

GPS device (Garmin's GPSMAP 60CSx, Garmin International Inc., USA) with an accuracy goal of ~5 m. Geolocations were also recorded in notebooks and checklists. An additional image file shows the characteristics of study villages in more detail (see Additional file 1). Field data collectors were blinded to the malaria status of the enrolled individuals. The questionnaire was prepared in English, translated into the Amharic language, and the responses from the study participants were translated to English by independent language experts.

Variables and measurements

House proximity to water bodies within a 250 m radius was the primary exposure variable. The remaining variables were covariates. The outcome variable was malaria status (dichotomous). Through an ecological survey, two nearby water bodies (rivers, streams, marshes, swamps, stagnant water, natural pools, springs, water holes) were georeferenced for each case HH and control HH (Fig. 2). Then, by observational estimation, water bodies within a 500 m radius of HHs were grouped in Category 1 (water body 1) and those farther away from the HHs were grouped in Category 2 (water body 2).

For analysis, house proximity to water bodies and health centres was computed as Euclidean distance using GPS coordinates [38, 39]. The average flight range of the main vector *An. gambiae* is reported to be approximately 500 m [23]. For this study, house proximity to water bodies was categorized into three distance bands (<250 m, 250–500 m and >500 m) [40]. The Euclidean distance of each HH to the health centre was categorized as a dichotomous explanatory variable (≤5 km and >5 km) [41].

HH wealth reflects a composite of several dichotomous and polychotomous variables used to indicate the socioeconomic status of the HH. Variables that used for HH wealth index construction were developed on the basis of literature [42, 43] and the Ethiopian Demographic and Health Survey [44]. Longer-run HH assets, housing structure, water supply source, sanitation facility, agricultural land size, having domestic animals, and having a

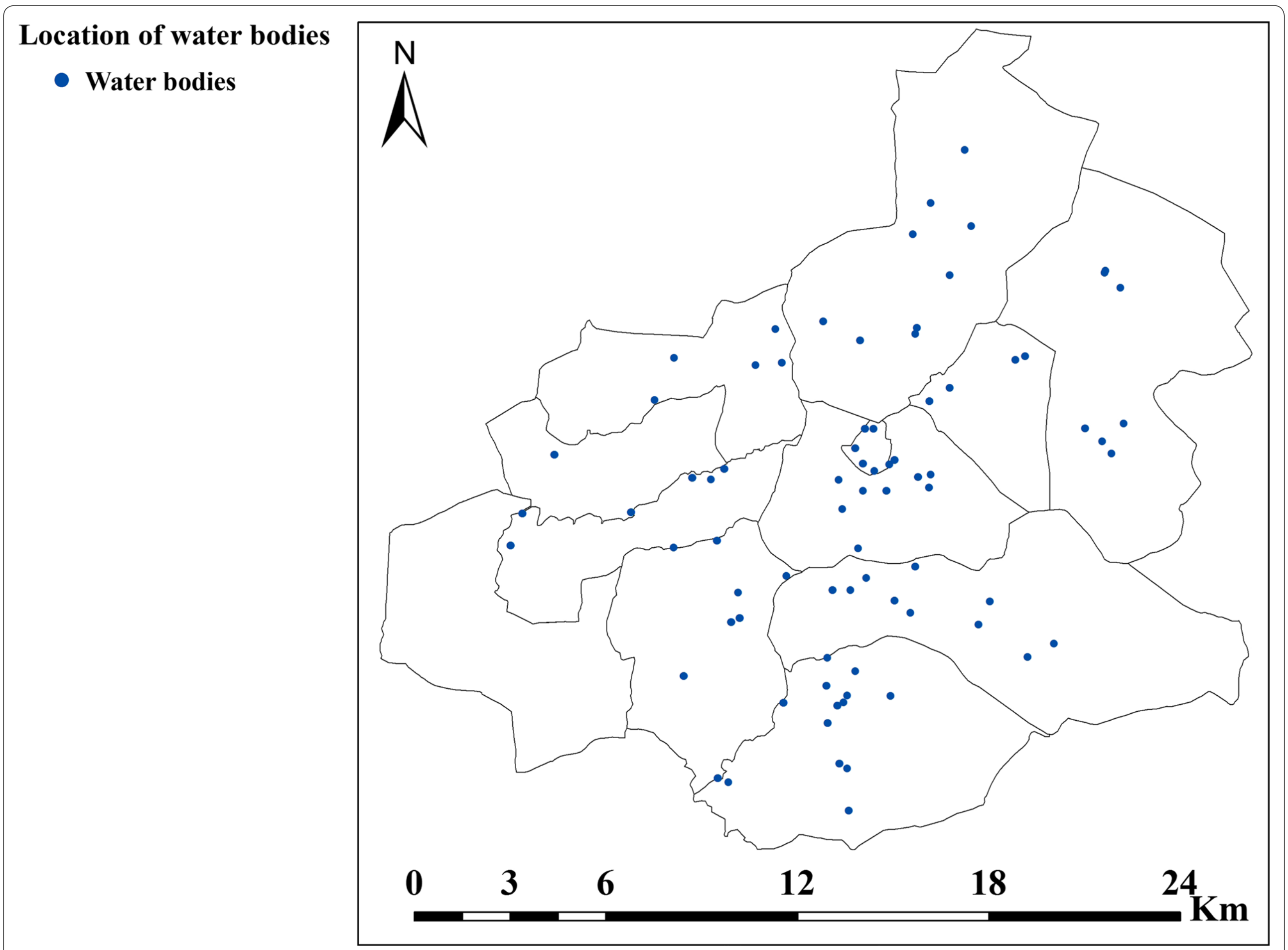

Fig. 2 Location of proximate water bodies to case HHs and control HHs

savings account were used to construct the wealth index. The values of the variables were weighted from 0 to 1, indicating the lowest and the highest values, respectively.

Statistical analysis

Data were double entered, coded, cleaned, and verified using *EpiData Version 3.1* software (EpiData Association, Odense, Denmark). Data analysis was carried out using SPSS statistical software version 22 (IBM Corp. IBM SPSS Statistics for Windows, Armonk, NY, USA) and STATA version 14.0 (StataCorp. Statistical Software: College Station, TX 77845, USA). Descriptive statistics [*n* (%)], including median IQR (interquartile range), were calculated for continuous variables. For categorical variables, Chi squared or Fisher's exact test were employed to detect significant differences in proportions. All reported *p*-values were two-tailed and considered statistically significant if $p < 0.05$.

Principal component analysis (PCA) was used to estimate HH wealth [42]. Principal component 1 was used to rank the HHs into three groups. Cutoff values/rank categories were set for the three groups. The original variables were transformed into scores having a mean equal to zero and standard deviation equal to one (standardization). The value of each standardized variable was multiplied by principal component 1 and a third variable created from the product for each variable. Finally, a HH wealth score was computed from the sum of the third variables. Based on the cutoff values of principal component 1 ranks, a final three-category HH wealth index variable was developed. The composite score was classified into tertiles, with the higher tertile reflecting higher wealth.

Cochran Mantel–Haenszel stratified analyses were employed to eliminate co-factors, and to discover and describe effect modifiers. Mantel–Haenszel test of equality of stratum-specific ORs was used to identify effect modifiers. First, the equality of stratum-specific ORs were checked to confirm significant differences, which indicate the presence of effect modification between the exposure and other factors. If not different, the presence of confounding was then assessed. The Mantel–Haenszel test produced a single weighed estimate of the predictor by adjusting the effects of the third variable and the crude estimate. Then, confounding presence was ascertained through degree of difference between the crude and adjusted ORs. For confirmation, a relative difference in the effect estimate with a cutoff of $\geq 10\%$ was used for evidence of confounding [45].

The conditional logistic regression model is the standard tool for the analysis of matched case–control studies. It allows for the analysis of data with stratified samples. Like other regression models, it allows for multiple variables, continuous exposures, confounding, and effect-modifying variables to be handled appropriately [46]. Although age was a matching variable, it was included in the model to eliminate the residual confounding effect that may come from broad age categories. Through a matching variable for cases and controls, a matched analysis was employed to explore factors associated with malaria infection. The modelling strategy involved estimating unadjusted matched odds ratio (mOR) and adjusted mOR of the studied variables with malaria infection at 95% CI. A bivariate analysis was executed for each variable; those variables having $p < 0.2$ along with variables having biological plausibility were included in the multivariable model. β-coefficients, ORs with 95% confidence intervals (CI) and p-values were estimated for the multivariable matched analysis and variables at $p < 0.05$ were considered as statistically significant and independently associated with malaria infection.

Results

Socio-demographic and household physical characteristics of cases and controls

A total of 606 patients (303 case–control matched pairs) participated in the study, and their HH geo-location was mapped (Fig. 3). Thirty matched pairs were ineligible for the study because they could not be contacted using the addresses they gave to the health centre during diagnosis, finding matched controls for cases within 3 days, and refusal to enroll, giving a response rate of 90.9%. Eight patients refused to participate in the study. The quality control results showed 98.5% inter-rater agreement and kappa coefficient of 0.97 with the results at the health centres ($p < 0.0001$). Discordant results were reread by a third senior technician and this result was taken as the final result.

The age distribution of cases and controls for matching was as follows: 238 (39.3% [35.5–43.2]) for subjects <15 years of age, 328 (54.1% [50.1–58.1]), for subjects 15–49 years of age, and 40 (6.6% [4.9–8.9]), for subjects >49 years of age. Half of the malaria infections, 152 (50.3% [44.5–55.8]), were *P. vivax* mono-infections while the other half (48.8%) were *P. falciparum* mono-infections, with only few mixed infections. Of the total malaria cases, 108 (35.6% [30.4–41.2]) occurred between September 15, 2016, and December 15, 2016; 71 (23.4% [19.0–28.6]) occurred between December 16, 2016, and March 15, 2017; and 124 (40.9% [35.5–46.6]), occurred between March 16, 2017, and June 30, 2017. The median (IQR) age of the malaria cases was 18 (4.42–30) years. Of the 303 malaria cases, 199 (65.7% [61.8–69.4]) were males (Table 1).

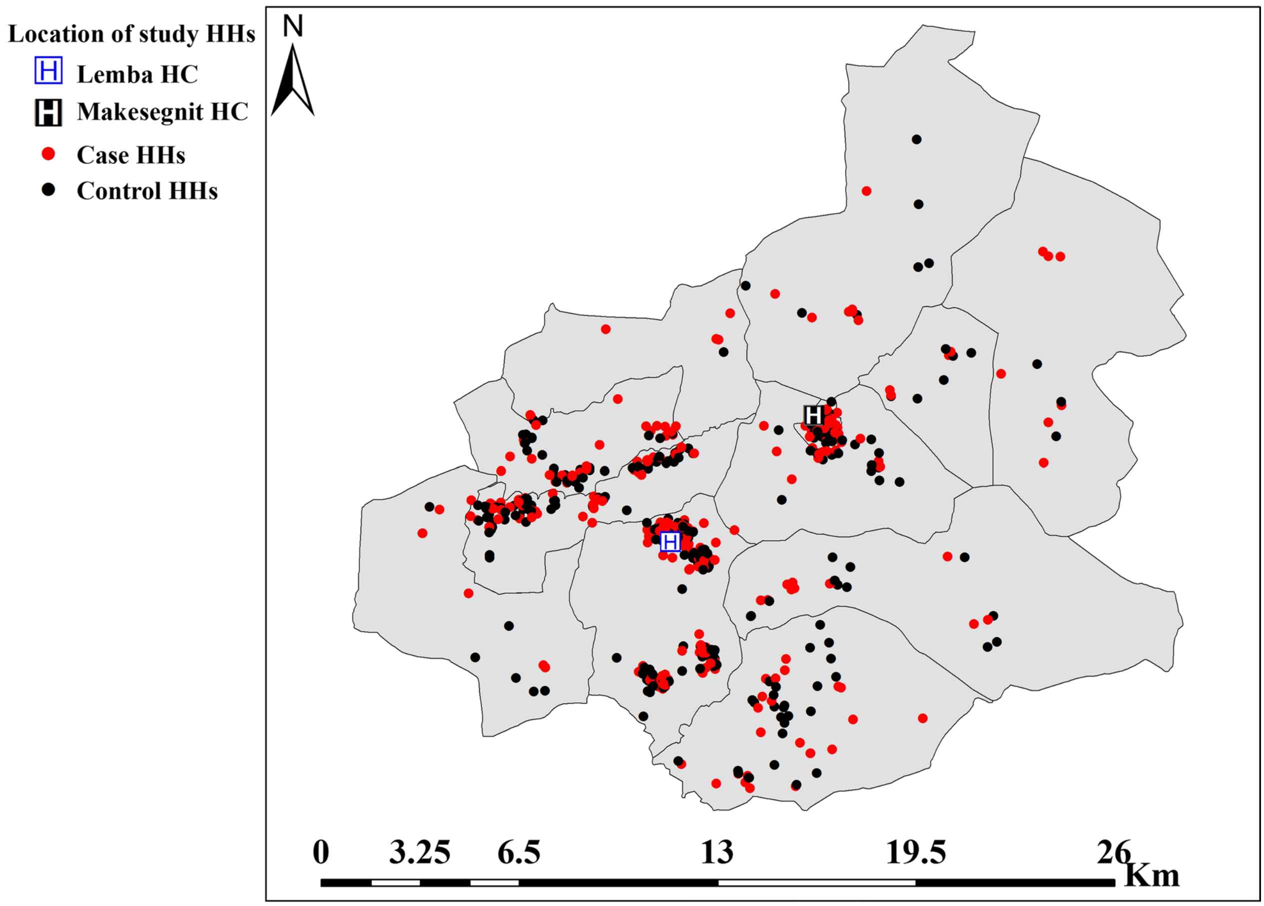

Fig. 3 Location of case HHs, control HHs and health centers

Travel to commercial agricultural farms and other behaviours among cases and controls

Almost all the study patients, 603 (99.5% [98.5–99.8]), had been active at night (6 pm to 12 pm) outside the home in the preceding month. Seventy (11.6% [9.2–14.4]) took anti-malarial drugs presumptively. In addition, 83 (13.7% [11.2–16.7]) travelled to malarious lowlands (Metema, Shehedi, Abderafi, Abrahajira, Humera, Maikadera, Dansha, Belessa and Fogera) in the preceding month. From those who travelled to malarious lowlands, 55 (66.3% [55.2–75.8]) were engaged in agriculture. The main reason for travel, cited by 75 patients (90.4% [81.7–95.2]), was to seek temporary jobs. Most of the travellers, (82, 98.8% [91.6–99.8]), were males; 58 (69.9% [59.0–78.9]) were 15–29 years of age; 39 (66.1% [52.8–77.3]) had *falciparum* malaria; and 42 (50.6% [39.8–61.4]) lived at elevations between 1901 and 2100 m above sea level. Of the 303 malaria cases, 59 (19.5% [15.4–24.3]) had imported malaria whereas 244 (80.5% [75.7–84.6]) had locally acquired malaria (Table 2).

Intervention measures of malaria among cases and controls

The median (IQR) distance from house to health centre of the patients was 3.6 (0.9–5.3) km. Fewer than one-third of the patients, 185 (30.5% [27.0–34.3]) owned at least one LLIN per HH. Of those patients who had LLINs, 123 (66.5% [59.3–73.0]) reported having slept under a LLIN the night prior to the interviews. Only 95 (51.4% [44.1–58.5]) of HHs had LLINs that were in good condition. Overall, 451 (74.4% [70.8–77.8]) reported that their houses had been sprayed with IRS in the preceding year (Table 3).

Proximity of case HHs and control HHs to water bodies

Two hundred twenty-four (73.9% [68.7–78.6]) of the case HHs were located at an altitude between 1701 and 1900 m above sea level. Only 18 (5.9% [3.8–9.3]) of case HHs were located within 2 km of Lake Tana. Likewise, 18 (5.9% [3.8–9.3]) case HHs had a water body 1 within a 250 m radius (Table 4).

Table 1 Socio-demographic and housing characteristics of cases and controls in villages around Lake Tana, Ethiopia, October 2016–June 2017

Characteristic	Malaria cases (n = 303) n, % (95% CI)	Controls (n = 303) n, % (95% CI)	Total n, % (95% CI)	Pearson's X^2/ Fisher's exact test**
Age (years)[g]	18 (4.42–30)	20 (3–33)	19 (4–30)	0.188
< 15	119, 39.3 (33.9–44.9)	119, 39.3 (33.9–44.9)	238, 39.3 (35.5–43.2)	
15–29	108, 35.6 (30.4–41.2)	90, 29.7 (24.8–35.1)	198, 32.6 (29.0–36.5)	
30–44	42, 13.8 (10.4–18.3)	62, 20.5 (16.3–25.4)	104, 17.2 (14.4–20.4)	
45–64	30, 9.9 (7.0–13.8)	30, 9.9 (7.0–13.8)	60, 9.9 (7.8–12.6)	
≥ 65	4, 1.3 (0.5–3.5)	2, 0.6 (0.2–2.6)	6, 1.0 (0.4–2.2)	
Religion[a]				0.105
Orthodox Christian	299, 98.7 (96.5–99.5)	293, 96.7 (94.0–98.2)	592, 97.7 (96.1–98.6)	
Muslim	4, 1.3 (0.5–3.5)	10, 3.3 (1.8–6.0)	14, 2.3 (1.4–3.9)	
Marital status[a]				0.068
Married	235, 77.6 (72.5–81.9)	257, 84.8 (80.3–88.5)	492, 81.2 (77.9–84.1)	
Single	48, 15.8 (12.1–20.4)	34, 11.2 (8.1–15.3)	82, 13.5 (11.0–16.5)	
Divorced/widowed	20, 6.6 (4.3–10.0)	12, 4.0 (2.3–6.9)	32, 5.3 (3.8–7.4)	
Educational status[a]				0.175
Illiterate[f]	140, 46.2 (40.6–51.9)	162, 53.5 (47.8–59.0)	302, 49.8 (45.9–53.8)	
Able to read and write (informal)	63, 20.8 (16.6–25.8)	55, 18.2 (14.2–22.9)	118, 19.5 (16.5–22.8)	
Grade 1–12 completed	93, 30.7 (25.7–36.1)	75, 24.7 (20.2–29.9)	168, 27.7 (24.3–31.4)	
> 12	7, 2.3 (1.1–4.8)	11, 3.6 (2.0–6.5)	18, 3.0 (1.9–4.7)	
Occupation[a]				0.435
Government employee	6, 2.0 (0.9–4.4)	10, 3.3 (1.8–6.0)	16, 2.6 (1.6–4.3)	
Merchant/trader	10, 3.3 (1.8–6.0)	9, 3.0 (1.5–5.6)	19, 3.1 (2.0–4.9)	
Farmer/peasant	251, 82.8 (78.1–86.7)	258, 85.2 (80.7–88.7)	509, 84.0 (80.8–86.7)	
Daily labourer	7, 2.3 (1.1–4.8)	8, 2.6 (1.3–5.2)	15, 2.5 (1.5–4.1)	
Others[b]	29, 9.6 (6.7–13.5)	18, 5.9 (3.8–9.2)	47, 7.8 (5.9–10.2)	
HH wealth index				0.275
Poor	89, 29.4 (24.5–34.8)	106, 35.0 (29.8–40.6)	195, 32.2 (28.6–36.0)	
Medium	20, 6.6 (4.3–10.0)	15, 5.0 (3.0–8.1)	35, 5.8 (4.2–7.9)	
Rich	194, 64.0 (58.4–69.3)	182, 60.0 (54.4–65.5)	376, 62.0 (58.1–65.8)	
HH size[g]	6 (4–7)	6 (4–7)	6 (4–7)	0.568
≤ 5 individuals	133, 43.9 (38.4–49.6)	140, 46.2 (40.6–51.9)	273, 45.0 (41.1–49.0)	
> 5 individuals	170, 56.1 (50.4–61.6)	163, 53.8 (48.1–59.4)	333, 55.0 (51.0–58.9)	
Roofing materials				0.145
Corrugated iron	287, 94.7 (91.5–96.7)	278, 91.8 (88.1–94.4)	565, 93.2 (90.9–95.0)	
Thatch	16, 5.3 (3.3–8.5)	25, 8.2 (5.6–11.9)	41, 6.8 (5.0–9.1)	
Open eaves in the roof				0.546
Yes	37, 12.2 (8.9–16.4)	42, 13.9 (10.4–18.3)	79, 13.0 (10.6–15.9)	
No	266, 87.8 (83.6–91.0)	261, 86.1 (81.7–89.6)	527, 87.0 (84.0–89.4)	
Wall building materials				0.896
Cement	5, 1.6 (0.7–3.9)	3, 1.0 (0.3–3.0)	8, 1.3 (0.7–2.6)	
Mud	296, 97.7 (95.2–98.9)	298, 98.3 (96.1–99.3)	594, 98.0 (96.5–98.9)	
Others[c]	2, 0.7 (0.2–2.6)	2, 0.7 (0.2–2.6)	4, 0.7 (0.2–1.7)	
Flooring materials				0.262
Cement and ceramics	9, 3.0 (1.5–5.6)	4, 1.3 (0.5–3.5)	13, 2.2 (1.2–3.7)	
Dung plastered	294, 97.0 (94.4–98.5)	299, 98.7 (96.5–99.5)	593, 97.8 (96.3–98.8)	

Table 1 (continued)

Characteristic	Malaria cases (n = 303) n, % (95% CI)	Controls (n = 303) n, % (95% CI)	Total n, % (95% CI)	Pearson's X^2/ Fisher's exact test**
Windows of the house				0.464
Corrugated iron	55, 18.2 (14.2–23.0)	52, 17.2 (13.3–21.9)	107, 17.7 (14.8–20.9)	
No windows	182, 60.1 (54.4–65.5)	197, 65.0 (59.4–70.2)	379, 62.5 (58.6–66.3)	
Open windows/open wall	58, 19.1 (15.1–24.0)	50, 16.5 (12.7–21.1)	108, 17.8 (15.0–21.1)	
Others[d]	8, 2.6 (1.3–5.2)	4, 1.3 (0.5–3.5)	12, 2.0 (1.1–3.5)	
Number of rooms in the house[g]	3 (2–3)	3 (2–3)	3 (2–3)	0.549
≤ 2 rooms	100, 33.0 (27.9–38.5)	107, 35.3 (30.1–40.9)	207, 34.2 (30.5–38.0)	
> 2 rooms	203, 67.0 (61.5–72.1)	196, 64.7 (59.1–69.9)	399, 65.8 (62.0–69.5)	
Tethering of cattle, goats and sheep[e]				0.701
Yes	73, 24.1 (19.6–29.3)	69, 22.8 (18.4–27.9)	142, 23.4 (20.2–27.0)	
No	230, 75.9 (70.7–80.4)	234, 77.2 (72.1–81.6)	464, 76.6 (73.0–79.8)	
Separate kitchen				0.614
Yes	116, 38.3 (32.9–43.9)	110, 36.3 (31.1–41.9)	226, 37.3 (33.5–41.2)	
No	187, 61.7 (56.1–67.1)	193, 63.7 (58.1–68.9)	380, 62.7 (58.8–66.5)	

CI confidence interval

** $p < 0.05$ was considered statistically significant

[a] For cases and controls < 18 years; religion, marital status, educational status and occupation of the household head was taken

[b] Student, job seeker, street dweller, weaver, local musician, sewer, carter

[c] Cement and sand-made bricks, ink painted, ordered stones

[d] Wooden, glass sealed

[e] Tethering indoors at night in the month prior to visiting the health facility

[f] Unable to read and write based on self-reporting

[g] Continuous variables; summarized through median and IQR

Mantel–Haenszel analysis for proving co-factors and interaction

The stratified analysis confirmed that there was no significant variation between stratum-specific ORs, indicating no interaction between the predictors and HH elevation or travel to malarious lowlands. Stratified analysis also revealed no disparity between the pooled and adjusted ORs, indicating that HH elevation was not a co-factor for the effect of predictors on malaria. Nonetheless, travel to malarious lowlands was a co-factor for the effects of age, marital status, occupation, educational status, number of rooms, travel history within the study area, HH member's travel to malarious lowlands, inappropriate HMM, IRS, and HH elevation on malaria (Tables 5 and 6). Additional table files show the determinants of malaria by HH elevation and travel to malarious lowlands (see Additional files 2 and 3).

Multivariable modelling through conditional logistic regression

Multivariable adjustment established that travel to malarious lowlands in the preceding month (adjusted mOR = 7.32; 95% CI 2.40–22.34), HH member travel to malarious lowlands (adjusted mOR = 2.75; 95% CI 1.02–7.44), and delivery of health information on malaria (adjusted mOR = 1.57; 95% CI 1.03–2.41) were independently associated with malaria heterogeneity (Table 7).

Age of patients; marital status, occupation, and educational status of the patient/HH head; HH size; HH wealth index; flooring, roofing, and wall building materials; number of rooms; separate kitchen; window types; open eaves in the roof; tethering of cattle, goats, and sheep at night; travel history within the study area; visits to traditional healers; inappropriate HMM; LLIN ownership; IRS; HH elevation; house proximity to health centre; house proximity to water body 1; house proximity to water body 2; and house proximity to Lake Tana were not significantly associated with malaria infection ($p > 0.05$). In other words, there were no significant differences between cases and controls with respect to these characteristics (Table 7).

Table 2 Travel history and other behaviours among cases and controls in villages around Lake Tana, Ethiopia, October 2016–June 2017

Characteristic	Malaria cases (n = 303) n, % (95% CI)	Controls (n = 303) n, % (95% CI)	Total n, % (95% CI)	Pearson's X^2/ Fisher's exact test**
Travel to malarious lowlands[a]				*< 0.0001*
Yes	59, 19.5 (15.4–24.3)	24, 7.9 (5.4–11.6)	83, 13.7 (11.2–16.7)	
No	244, 80.5 (75.7–84.6)	279, 92.1 (88.4–94.6)	523, 86.3 (83.3–88.8)	
Frequency of travel to malarious lowlands (n = 83)				0.714
One time	53, 89.8 (78.7–95.5)	21, 87.5 (65.5–96.3)	74, 89.2 (80.2–94.3)	
Two or three times	6, 10.2 (4.5–21.3)	3, 12.5 (3.7–34.5)	9, 10.8 (5.7–19.8)	
Regular LLIN use during travels (n = 83)				1.000
Yes	3, 5.1 (1.6–15.1)	1, 4.2 (0.5–27.3)	4, 4.8 (1.8–12.4)	
No	56, 94.9 (84.9–98.4)	23, 95.8 (72.7–99.5)	79, 95.2 (87.6–98.2)	
Reason for travel (n = 83)				1.000
To work temporarily/job seeking	53, 89.8 (78.7–95.5)	22, 91.7 (69.8–98.1)	75, 90.4 (81.7–95.2)	
Others[b]	6, 10.2 (4.5–21.3)	2, 8.3 (1.9–30.2)	8, 9.6 (4.8–18.3)	
Travel history within the study area[a]				*0.037*
Yes	95, 31.4 (26.4–36.8)	72, 23.8 (19.3–28.9)	167, 27.6 (24.1–31.3)	
No	208, 68.6 (63.2–73.6)	231,76.2 (71.1–80.7)	439, 72.4 (68.7–75.9)	
Regular LLIN use during travels (n = 167)				0.398
Yes	9, 9.5 (4.9–17.4)	4, 5.6 (2.1–14.2)	13, 7.8 (4.5–13.0)	
No	86, 90.5 (82.6–95.1)	68, 94.4 (85.8–97.9)	154, 92.2 (87.0–95.5)	
HH member travel to malarious lowlands[a]				*0.001*
Yes	29, 9.6 (6.7–13.5)	9, 3.0 (1.5–5.6)	38, 6.3 (4.6–8.5)	
No	274, 90.4 (86.5–93.3)	294, 97.0 (94.4–98.5)	568, 93.7 (91.5–95.4)	
Reason for travel (n = 38)				0.574
To work temporarily/job seeking	26, 89.7 (70.9–96.9)	7, 77.8 (33.0–96.1)	33, 86.8 (71.1–94.6)	
Others[b]	3, 10.3 (3.1–29.1)	2, 22.2 (3.9–67.0)	5, 13.2 (5.4–28.9)	
Visiting traditional healers[c]				0.412
Yes	55, 18.2 (14.2–22.9)	63, 20.8 (16.6–25.8)	118, 19.5 (16.5–22.8)	
No	248, 81.8 (77.1–85.8)	240, 79.2 (74.2–83.4)	488, 80.5 (77.2–83.5)	

** $p < 0.05$ was considered statistically significant. The italics indicate statistically significant *p*-values

[a] In the month prior to visiting the health centre

[b] For holy water, spiritual festivity, spiritual education, commercial issues, visiting friends and relatives, labour (playing music in resource rich areas of low lands)

[c] Spiritual healing, herbal remedy

Discussion

In this study, travel history to malarious lowlands in the preceding month, having a HH member who travelled to malarious lowlands in the preceding month, and delivery of health information on malaria were statistically significant and independent predictors of malaria in villages near Lake Tana, northwest Ethiopia.

Individuals who travelled to malarious areas had higher odds of malaria infection than those who did not travel. This finding agrees with that of other studies in Ethiopia [7, 14] and in Zanzibar [47]. This may be due to the susceptibility of travellers from the midlands to malaria that progresses to severe symptomatic malaria, especially among those travellers who slept without personal protective measures. Infection-naïve individuals are highly susceptible to malaria if exposed to an infectious anopheles mosquito, particularly in hyper-endemic areas [48]. The travels mainly take place during high malaria transmission periods among people seeking temporal job and engaging in social activities. This and other studies showed low chemoprophylaxis and LLIN use during travels [7]. In the hot lowlands, many labourers sleep outdoors and in open spaces without protection from mosquitoes, resulting in high malaria exposure risk. Large numbers of imported malaria cases have been found in the northwestern Ethiopian highlands [7]. Thus, imported malaria is a health risk besides locally acquired malaria in midland villages around Lake Tana. This

Table 3 Malaria intervention measures among cases and controls in villages around Lake Tana, Ethiopia, October 2016–June 2017

Characteristic	Malaria cases (n = 303) n, % (95% CI)	Controls (n = 303) n, % (95% CI)	Total n, % (95% CI)	Pearson's X^2/Fisher's exact test**
House proximity to health centre (km)[b]	3.5 (0.7–4.9)	3.8 (1.2–5.5)	3.6 (0.9–5.3)	0.065
≤ 5	233, 76.9 (71.8–81.3)	213, 70.3 (64.9–75.2)	446, 73.6 (69.9–77.0)	
> 5	70, 23.1 (18.7–28.2)	90, 29.7 (24.8–35.1)	160, 26.4 (23.0–30.1)	
Received health information on malaria				*0.011*
Yes	123, 40.6 (35.2–46.3)	93, 30.7 (25.7–36.1)	216, 35.6 (31.9–39.6)	
No	180, 59.4 (53.7–64.8)	210, 69.3 (63.9–74.3)	390, 64.4 (60.4–68.1)	
LLIN ownership				0.186
None	203, 67.0 (61.5–72.1)	218, 71.9 (66.6–76.7)	421, 69.5 (65.7–73.0)	
1 LLIN/household	52, 17.2 (13.3–21.9)	56, 18.5 (14.5–23.3)	108, 17.8 (15.0–21.1)	
≥2 LLINs/household	48, 15.8 (12.1–20.4)	29, 9.6 (6.7–13.5)	77, 12.7 (10.3–15.6)	
Slept under LLIN regularly in last 1 month (n = 185)[#]				0.085
Yes	38, 38.0 (28.9–48.0)	43, 50.6 (39.9–61.2)	81, 43.8 (36.7–51.1)	
No	62, 62.0 (52.0–71.1)	42, 49.4 (38.8–60.1)	104, 56.2 (48.9–63.3)	
LLIN(s) had holes/tear(s) (n = 185)				0.603
Yes	39, 39.0 (29.8–49.0)	30, 35.3 (25.7–46.2)	69, 37.3 (30.6–44.6)	
No	61, 61.0 (51.0–70.2)	55, 64.7 (53.8–74.3)	116, 62.7 (55.4–69.4)	
Period since the HH obtained LLIN(s) (n = 185) (year)				0.723
< 1	11, 11.0 (6.1–18.9)	8, 9.4 (4.7–17.9)	19, 10.3 (6.6–15.6)	
≥ 1	89, 89.0 (81.1–93.9)	77, 90.6 (82.1–95.3)	166, 89.7 (84.4–93.4)	
Proper hanging of LLIN(s) (n = 185)				0.747
Yes	72, 72.0 (62.3–80.0)	63, 74.1 (63.6–82.5)	135, 73.0 (66.1–78.9)	
No	28, 28.0 (20.0–37.7)	22, 25.9 (17.5–36.4)	50, 27.0 (21.1–33.9)	
Is/are the LLIN(s) in good condition? (n = 185)[a]				0.488
Yes	49, 49.0 (39.2–58.9)	46, 54.1 (43.3–64.6)	95, 51.4 (44.1–58.5)	
No	51, 51.0 (41.1–60.8)	39, 45.9 (35.4–56.7)	90, 48.6 (41.5–55.9)	
IRS				0.926
Yes	225, 74.3 (69.0–78.9)	226, 74.6 (69.4–79.2)	451, 74.4 (70.8–77.8)	
No	78, 25.7 (21.1–31.0)	77, 25.4 (20.8–30.6)	155, 25.6 (22.3–29.2)	
Plastering/painting after IRS (n = 451)				0.351
Yes	27, 12.0 (8.3–17.0)	21, 9.3 (6.1–13.9)	48, 10.6 (8.1–13.9)	
No	198, 88.0 (83.0–91.7)	205, 90.7 (86.1–93.9)	403, 89.4 (86.1–91.9)	

**$p < 0.05$ was considered statistically significant. The italics indicate statistically significant *p*-values

[a] Measured by service years of LLIN (aged if > 3 years), presence of tears/holes and proper hanging

[b] Continuous variables; summarized through median and IQR

duality of malaria origins is also indicated by the fact that three-quarters of the malaria cases could not be traced to the lowlands. This epidemiological situation points to a critical obstacle to eliminating malaria through targeted interventions.

Individuals who did not know malaria aetiology, transmission, and prevention methods had an increased odds of risk for malaria infection. The possible explanation for this finding may be the low educational status of the study population or delivery of malaria information independent of educational status, which prevents them from understanding and analysing the information provided to them by community health workers.

In the multivariable adjustment, sociodemographic factors, HH wealth, housing structure, travel history within the study area, visits to traditional healers, inappropriate HMM, LLIN ownership, IRS, HH elevation, and house proximity to water bodies were not associated with malaria. This might be due to low heterogeneity of housing structure, socio-demographic status, HH wealth,

Table 4 Household elevation and proximity to water bodies in villages around Lake Tana, Ethiopia, October 2016–June 2017

Variables	Malaria cases (n = 303) n, % (95% CI)	Controls (n = 303) n, % (95% CI)	Total n, % (95% CI)	Pearson's X^2/ Fisher's exact test**
HH elevation (m)[a]	1854 (1821–1907)	1846 (1818–1893)	1851 (1820–1904)	0.426
1701–1900	224, 73.9 (68.7–78.6)	230, 75.9 (70.7–80.4)	454, 74.9 (71.3–78.2)	
1901–2100	72, 23.8 (19.3–28.9)	70, 23.1 (18.7–28.2)	142, 23.4 (20.2–27.0)	
> 2100	7, 2.3 (1.1–4.8)	3, 1.0 (0.3–3.0)	10, 1.7 (0.9–3.0)	
House proximity to Lake Tana (km)[a]	6.5 (5.4–9.5)	6.9 (5.3–8.8)	6.8 (5.3–8.9)	0.720
< 2	18, 5.9 (3.8–9.3)	23, 7.6 (5.1–11.2)	41, 6.8 (5.0–9.1)	
2–4	22, 7.3 (4.8–10.8)	22, 7.3 (4.8–10.8)	44, 7.2 (5.4–9.6)	
> 4	263, 86.8 (82.5–90.2)	258, 85.1 (80.7–88.7)	521, 86.0 (83.0–88.5)	
House proximity to water body 1 (m)[a]	823 (548–1372)	918 (530–1482)	858.5 (545–1417)	0.345
< 250	18, 5.9 (3.8–9.3)	13, 4.3 (2.5–7.3)	31, 5.1 (3.6–7.2)	
250–500	43, 14.2 (10.7–18.6)	54, 17.8 (13.9–22.6)	97, 16.0 (13.3–19.2)	
> 500	242, 79.9 (74.9–84.0)	236, 77.9 (72.8–82.2)	478, 78.9 (75.4–82.0)	
House proximity to water body 2 (m)[a]	1770 (909–2343)	1783 (967–2432)	1776.5 (932–2383)	0.634
< 250	10, 3.3 (1.8–6.0)	12, 4.0 (2.3–6.9)	22, 3.6 (2.4–5.5)	
250–500	20, 6.6 (4.3–10.0)	15, 5.0 (3.0–8.1)	35, 5.8 (4.2–7.9)	
> 500	273, 90.1 (86.2–93.0)	276, 91.0 (87.3–93.8)	549, 90.6 (88.0–92.7)	

**$p < 0.05$ was considered statistically significant

[a] Continuous variables; summarized through median and IQR

Table 5 Stratified analysis by HH elevation for predictors of malaria in villages around Lake Tana, Ethiopia, October 2016–June 2017

Variables	COR	[1750–2000 m]	[2000–2500 m]	Adjusted (Mantel–Haenszel)			
		OR	OR	OR_{MH}	95% CI	X^2_{MH}	*p* value
Age	1	0.97	2.5	1.01	0.73–1.40	0.97	0.3237
Marital status	1.62	1.69	1.5	1.68	1.10–2.56	0.02	0.8792
Occupation	1.19	1.22	0.79	1.19	0.77–1.84	0.17	0.6762
Educational status	1.34	1.31	5.45	1.36	0.98–1.88	1.5	0.2205
HH size	1.1	1.08	1.75	1.1	0.80–1.52	0.35	0.5523
HH wealth index	1.29	1.29	1.24	1.29	0.91–1.82	0	0.9629
Roofing materials	0.62	0.6	1.25	0.62	0.32–1.19	0.24	0.6233
Open eaves in the roof	0.86	0.79	3.11	0.87	0.54–1.40	1.96	0.1615
Number of rooms	1.11	1.17	0.3	1.09	0.78–1.52	2.65	0.1035
Separate kitchen	1.09	1.13	0.7	1.1	0.79–1.53	0.36	0.5464
Tethering of cattle, goats and sheep	1.08	1.09	0.98	1.08	0.74–1.58	0.02	0.8995
Travel history to malarious lowlands	2.81	3.3	0.98	2.91	1.73–4.90	2.14	0.1436
Travel history within the study area	1.47	1.52	1.17	1.49	1.04–2.15	0.11	0.737
Visiting traditional healers	0.84	0.88	0.57	0.85	0.57–1.28	0.27	0.6019
HMM	1.14	1.15	1.38	1.17	0.70–1.94	0.05	0.8304
Received health education on malaria	1.54	1.55	1.43	1.55	1.10–2.17	0.01	0.9153
LLIN ownership	1.26	1.28	0.9	1.26	0.89–1.78	0.15	0.6984
IRS	0.98	0.95	0	0.94	0.63–1.39	0.77	0.3805
House proximity to health centre	0.71	0.7	1.11	0.71	0.49–1.04	0.26	0.6089
House proximity to water body 1	0.71	0.79	0.32	0.68	0.33–1.43	0.7	0.4024
House proximity to water body 2	1.21	1.13	1.71	1.19	0.50–2.81	0.09	0.7623

OR_{MH} adjusted odds ratio using Mantel–Haenszel method, *COR* crude odds ratio, *X^2_{MH}* Mantel–Haenszel Chi square value

Table 6 Stratified analysis by travel to malarious lowlands for predictors of malaria in villages around Lake Tana, Ethiopia, October 2016–June 2017

Variables	COR	Travel to malarious lowlands		Adjusted (Mantel–Haenszel)			
		Travel history (OR)	No travel history (OR)	OR_{MH}	95% CI	X^2_{MH}	*p* value
Age	1	0	0.82	0.8	0.57–1.13	1.02	0.3123
Marital status	1.62	0.93	1.45	1.32	0.86–2.04	0.66	0.4182
Occupation	1.19	1.34	0.92	0.99	0.63–1.57	0.41	0.5242
Educational status	1.34	1.24	1.21	1.21	0.88–1.68	0	0.9725
HH size	1.1	0.99	1.18	1.16	0.84–1.60	0.11	0.7423
HH wealth index	1.29	1.21	1.26	1.26	0.89–1.78	0.01	0.9375
Roofing materials	0.62	0.38	0.66	0.61	0.32–1.17	0.36	0.547
Open eaves in the roof	0.86	1.02	0.79	0.82	0.50–1.33	0.13	0.7152
Wall building materials	0.71	0	1.09	0.77	0.22–2.73	1.23	0.2669
Flooring materials	0.44	0	0.58	0.45	0.13–1.60	0.71	0.401
Number of rooms	1.11	1.14	1.26	1.25	0.88–1.76	0.04	0.8482
Separate kitchen	1.09	0.9	1.04	1.02	0.73–1.43	0.08	0.7838
Tethering of cattle, goats and sheep	1.08	0.74	1.09	1.03	0.71–1.51	0.45	0.5
Travel history within the study area	1.47	0.29	1.18	1.03	0.68–1.56	3.08	0.0792
HH member travel to malarious lowlands	3.46	2.6	2.56	2.58	1.16–5.74	0	0.9841
Visiting traditional healers	0.84	0.93	0.79	0.8	0.53–1.22	0.08	0.7788
HMM	1.14	0.9	0.92	0.91	0.54–1.54	0	0.9821
Received health education on malaria	1.54	2.43	1.31	1.42	1.00–1.99	1.32	0.2508
LLIN ownership	1.26	1.07	1.16	1.15	0.80–1.64	0.02	0.8749
IRS	0.98	2.19	1	1.13	0.78–1.65	2.12	0.1453
HH elevation	0.8	0.28	0.93	0.67	0.32–1.40	2.05	0.1526
House proximity to health centre	0.71	0.56	0.75	0.73	0.50–1.05	0.25	0.6138
House proximity to Lake Tana	1.3	1.54	1.37	1.4	0.73–2.69	0.02	0.8918
House proximity to water body 1	0.71	0.98	0.73	0.77	0.37–1.62	0.09	0.7599
House proximity to water body 2	1.21	1.7	1.26	1.34	0.56–3.19	0.08	0.7812

OR_{MH} adjusted odds ratio using Mantel–Haenszel method, *COR* crude odds ratio, X^2_{MH} Mantel–Haenszel Chi square value

proximity to water bodies, elevation of HHs, and delivery of inadequate information on treatment-seeking, bed net use, and other preventive measures by Gondar Zuriya District Health Office. Demographically, educational status did not vary significantly between cases and controls. This corroborates the findings of other studies in Ethiopia [49] and in Gambia [9], although advancement in education confers significant protection from malaria [50]. Occupation was not a significant predictor of malaria infection. This may have been due to the small number of non-agricultural workers in the study. However, another study in the Ethiopian highlands showed that agricultural workers were at elevated risk of malaria [7]. The difference in findings may be due to sample size. Interestingly, marital status was marginally significantly associated with malaria infection in bivariate analysis. This may be because mostly unmarried males travel to the malarious lowlands for work. In addition, unmarried people are generally in poorer health and have a higher mortality risk than married people [11].

In this study, HH size played no significant role in the odds of contracting malaria. This finding is consistent with that of other studies in Ethiopia [51] and Malawi [8]. Several studies associated larger HH size with malaria [52]. HH wealth facilitates the management of illness, and several studies reported better access to health care by wealthier groups [12, 51]. Nonetheless, HH wealth had no significant impact on malaria in this study.

Housing structure had no significant statistical association with malaria transmission, a finding also reported in previous studies [8, 9]. However, researchers have reported that individuals living in houses with mud walls [13], thatched roofs [53], dung plastered floors [53], and boarded windows had higher risk of malaria [9]. Surprisingly, spatial malaria heterogeneity was not determined by fine-scale environmental factors, particularly water bodies close to HHs. This study is in agreement

Table 7 Determinants of malaria transmission dynamics in villages around Lake Tana, Ethiopia, October 2016–June 2017

Variables	β	Unadjusted mOR[a]	p-value	β	Adjusted mOR (95% CI)[b]	p-value
Age (years)	− 0.02	0.98	0.125	− 0.02	0.98 (0.95–1.01)	0.183
Marital status						
Married		1			1	
Single	0.52	1.68	*0.057*	0.31	1.37 (0.65–2.87)	0.410
Divorced/widowed	0.68	1.97	0.101	0.64	1.89 (0.71–5.02)	0.200
Occupation						
Farmer		1			1	
Non-farmer	− 0.20	1.23	0.400	− 0.23	0.79 (0.39–1.60)	0.513
Educational status						
Illiterate		1			1	
Able to read and write (informal)	0.32	1.38	0.163	0.38	1.46 (0.87–2.44)	0.151
Grade 1 to 12 completed	0.43	1.54	*0.042*	0.04	1.04 (0.62–1.73)	0.885
>12	− 0.33	0.72	0.535	− 0.53	0.59 (0.15–2.30)	0.447
HH wealth index						
Poor		1			1	
Medium	0.48	1.62	0.197	0.36	1.43 (0.62–3.27)	0.400
Rich	0.26	1.29	0.162	0.21	1.24 (0.82–1.88)	0.316
Roofing materials						
Corrugated iron		1			1	
Thatch	− 0.56	0.57	0.122	− 0.31	0.73 (0.32–1.68)	0.459
Flooring materials						
Cement and others		1			1	
Dung plastered	− 0.81	0.44	0.177	− 0.83	0.42 (0.11–1.78)	0.248
Travel to malarious lowlands						
No		1			1	
Yes	2.28	9.75	*< 0.0001*	1.99	7.32 (2.40–22.34)	< 0.0001
Travel history within the study area						
No		1			1	
Yes	0.45	1.56	*0.026*	− 0.03	0.97 (0.59–1.58)	0.900
HH member travel to malarious lowlands						
No		1			1	
Yes	1.35	3.86	*0.001*	1.01	2.75 (1.02–7.44)	0.046
Received health information on malaria						
No		1			1	
Yes	0.46	1.59	*0.010*	0.45	1.57 (1.03–2.41)	0.037
LLIN(s) ownership						
None		1			1	
1 LLIN/household	0.07	1.07	0.674	0.11	1.12 (0.66–1.90)	0.684
≥ 2 LLINs/household	0.63	1.87	*0.021*	0.59	1.81 (0.95–3.46)	0.071
HH elevation (m)						
1701–1900		1			1	
1901–2100	0.34	1.40	0.355	− 0.09	0.91 (0.36–2.31)	0.844
> 2100	1.12	3.06	0.137	0.66	1.94 (0.30–12.49)	0.484
House proximity to health centre (km)						
≤ 5		1			1	
> 5	− 0.34	0.71	0.069	− 0.27	0.76 (0.49–1.18)	0.226
House proximity to water body 1 (m)						
< 250		1			1	
250–500	− 0.52	0.59	0.204	− 0.18	0.84 (0.30–2.32)	0.734

Table 7 (continued)

Variables	*β*	Unadjusted mOR[a]	*p*-value	*β*	Adjusted mOR (95% CI)[b]	*p*-value
> 500	− 0.28	0.75	0.459	− 0.03	0.97 (0.38–2.47)	0.950
House proximity to water body 2 (m)						
< 250		1			1	
250–500	0.44	1.55	0.409	0.59	1.81 (0.50–6.57)	0.365
> 500	0.14	1.15	0.740	0.39	1.48 (0.51–4.32)	0.475
House proximity to Lake Tana (km)						
< 2		1			1	
2–4	0.28	1.32	0.552	0.28	1.33 (0.46–3.81)	0.596
> 4	0.29	1.33	0.399	0.37	1.45 (0.66–3.16)	0.353

β: beta coefficients/regression coefficients. $p < 0.05$ was considered statistically significant. The italics indicate statistically significant *p*-values

Unadjusted mOR: Unadjusted matched odds ratio; adjusted mOR: adjusted matched odds ratio; 1: Reference category

[a] Denotes unadjusted mOR using 95% CI in bivariate conditional logistic regression analysis from matched case–control pairs

[b] Denotes adjusted mOR using 95% CI in multivariable conditional logistic regression analysis from matched case–control pairs

with a study that stated malaria incidence was not associated with distance to an Ethiopian dam reservoir [22]. Two other studies in Ethiopia reported that the odds of malaria infection were lower in HHs closer to reservoirs than those at greater distances [20, 21]. On the other hand, numerous studies have found large numbers of malaria cases in HHs near various types of water bodies [16, 18, 19]. Possible reasons for these contradictory findings may be differences in the use of LLINs or IRS, socioeconomic and environmental factors in populations, vulnerabilities or transmission dynamics, differential health services accessibility, or imported malaria cases.

In this study, LLIN ownership and IRS had no significant effect on malaria prevalence. This finding is similar to that of studies revealing that LLIN ownership and use as well as indoor wall spraying did not protect against malaria [7, 9, 20, 25]. However, other studies reported a protective effect of bed nets and IRS on malaria [8, 15, 25, 53]. The difference may be due to failure to use LLINs properly and consistently, inadequacy or poor condition of LLINs, or failure to use them during travel. As a result, the protective effect of LLINs could have been negated [33]. Besides, imported malaria, human activities at night outside the home, the spread of insecticide-resistant vectors, and spraying by untrained individuals and substandard insecticides may have reduced the protective effect of IRS.

A matched case–control study was used to eliminate the confounding effects of sex and age, which solidified the conclusions and recommendations. Matched case–control studies have minimal bias relative to cross-sectional and unmatched case–control designs because they compare groups internally. The water bodies proximate to the HHs were georeferenced through direct ecological surveys to increase measurement accuracy despite accessible satellite imagery. To avoid information bias, data collectors were blinded to the malaria status of patients during onsite data collection at the HH level. All other measurements of exposure variables were performed at home through interviews and direct observations. Stratified analyses and multivariable conditional logistic regression were used to control confounding and report interaction effects.

This study has several limitations. It is difficult to establish temporal relationships between exposures and malaria. Employing PCD to measure the effect of house proximity to water bodies on spatial malaria heterogeneity was not efficient due to the presence of asymptomatic and submicroscopic parasite carriers and the treatment of malaria by drug vendors, private clinics, and health posts [50], which were not studied. The asymptomatic parasite carriage may influence the risk factor analysis, especially if the reservoirs occur more often in controls than in cases. This study failed to obtain information on the size and nature of water bodies. Case and control selection from health institutions can be prone to bias since patients usually do not represent the general population. Recall bias could have been introduced during travel history measurement. The unmeasured residuals were not controlled but the effect on the finding is marginal. Moreover, due to unrest in the study area, the study did not include the month of September, at the end of the main rainy season, when more imported and locally acquired malaria cases occur in northwestern Ethiopia [54]. Even though this is a low transmission setting, travel history associated with malaria does not necessarily identify imported cases.

These study findings emphasize the fact that comprehending the sociodemographic characteristics of individuals who travel to malarious lowlands, travel patterns in individual villages, adequacy of health information on malaria, and taking into account the potential vector breeding sites in mid-altitude villages are central to facilitating malaria elimination strategies.

Conclusions

Seasonal and other short-term migration to commercial agricultural farms in the malarious Ethiopian lowlands is a significant independent risk factor for malaria infection in villages around Lake Tana. In addition, inadequate health information on malaria and marital status, apparently related to the predominance of unmarried young males migrating to the lowlands, are risk factors for malaria infection. There is a need for studies to explore risk factors of imported malaria and locally acquired malaria independently in the midlands of northwestern Ethiopia. In addition, information is needed on the transmission dynamics of imported malaria in the midlands. This information is critical for designing effective and integrated interventions that consider imported malaria cases and approaches to accessing health information on malaria control in northwest Ethiopia and other highland/lowland transitional areas.

Additional files

Additional file 1. Study *kebeles* characteristics. a) A section of the study area bordering Lake Tana. b) A stagnant water potential for *Anopheles* mosquitoes breeding. c) Use of LLINs for protection of straw. d) An LLIN they showed packed in its plastic bag.

Additional file 2. Characteristics of determinants of malaria by HH elevation in villages around Lake Tana, Ethiopia, October 2016-June 2017.

Additional file 3. Characteristics of determinants of malaria by travel to lowlands in villages around Lake Tana, Ethiopia, October 2016-June 2017.

Abbreviations

ACT: artemisinin-based combination therapy; AOR: adjusted odds ratio; COR: crude odds ratio; HH: household; HMM: home based management malaria; IQR: interquartile range; IRS: indoor residual spraying; LLINs: long-lasting insecticidal nets; MDG: Millennium Development Goals; mOR: matched odds ratio; PCA: principal component analysis; PCD: passive case detection; RDTs: rapid diagnostic tests; WHO: World Health Organization.

Authors' contributions

AM, KA, MA and HK conceived and designed the study; AM conducted the data collection; AM and KA conducted data management and data analysis; AM, KA, MA, SR and HK wrote and edited the manuscript. All authors read and approved the final manuscript.

Author details

[1] Ethiopian Institute of Water Resources, Addis Ababa University, Addis Ababa, Ethiopia. [2] Department of Epidemiology and Biostatistics, Institute of Public Health, University of Gondar, Gondar, Ethiopia. [3] Department of Medical Parasitology, School of Biomedical & Laboratory Sciences, University of Gondar, Gondar, Ethiopia. [4] Department of Epidemiology and Biostatistics, University of California, San Francisco, USA.

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Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

Data and all the materials will be available from the corresponding author upon request.

Consent for publication

Not applicable.

Ethics approval and consent to participate

The study protocol was approved by the Ethiopian Institute of Water Resources, Addis Ababa University Institutional Review Board, and the Ethical Review Committee of Wollo University. Informed assent was secured from the caregivers/guardians of study subjects < 18 years of age. Study participants aged ≥ 18 years gave their informed consent after having the nature of the study explained to them. For illiterate caregivers/guardians and participants, thumb-printed consent was obtained in the presence of an independent literate witness. Participation in the study was voluntary and confidentiality of the information was assured during as well as after data collection. Malaria cases were treated according to national guidelines.

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Older under-five children were at risk of local malaria infections in northwest Ethiopia where *Anopheles gambiae* complex and *Anopheles pharoensis* dominate

Asmamaw Malede[1]*, Kassahun Alemu[2], Mulugeta Aemero[3], Sirak Robele Gari[1], Wondmeneh Jemberie[4], Helmut Kloos[5]

[1]Asmamaw Malede; Ethiopian Institute of Water Resources, Addis Ababa University, Addis Ababa, Ethiopia. Email: coolmaldinni@gmail.com

[2]Kassahun Alemu; Department of Epidemiology and Biostatistics, Institute of Public Health, University of Gondar, Gondar, Ethiopia. Email: kassalemu@gmail.com

[3]Mulugeta Aemero; Department of Medical Parasitology, School of Biomedical & Laboratory Sciences, University of Gondar, Gondar, Ethiopia. Email: bmeskel@gmail.com

[1]Sirak Robele; Ethiopian Institute of Water Resources, Addis Ababa University, Addis Ababa, Ethiopia. Email: sirakr@gmail.com

[4]Wondmeneh Jemberie; Department of Biology, College of Natural & Computational Sciences, University of Gondar, Gondar, Ethiopia. Email: wondmeneh12@gmail.com

[5]Helmut Kloos; Department of Epidemiology and Biostatistics, University of California, San Francisco, USA. Email: helmutk@comcast.net

*corresponding author

Abstract

Background: Malaria causes 10% of the deaths among under-five children in sub-Saharan Africa. In northwest Ethiopia, dominant vector species, effect of age and house proximity to water bodies on local malaria among under-five children needs further study. This study aimed to find the association between local malaria and house proximity to water bodies and other selected potential predictors among under-five children and identify malaria vectors in meso-endemic villages around Lake Tana, northwest Ethiopia.

Methods: A health institution-based matched case-control study was conducted from October 10, 2016, to June 30, 2017. A total of 162 (81 case-control pairs) were included in the study. Households for cases and controls, proximate water bodies, and larvae survey sites were geo-referenced. A pre-tested and semi-structured questionnaire was used to collect data. *Anopheles* mosquito larvae sampling was done from April 30, 2017, to June 24, 2017, from seven potential breeding sites using the standard dipping method. Collected larvae were reared to adulthood at an insectary. Each adult was individually identified at the species and species complex levels using standard adult mosquito morphological identification keys. Multivariable conditional logistic regression was employed to identify predictors.

Results: About 60 (74.1% [63.2-82.6]) malaria infections were *Plasmodium vivax* mono-infections, followed by 21 (25.9% [17.4-36.8]) *P. falciparum* mono-infections. Children aged 36-59 months (adjusted mOR = 3.88; 95% CI: 1.55-9.74) were at increased risk of malaria. Water body presence within a 500m radius was not a statistically significant predictor of local malaria. Of 1,197 adult anophelines, *Anopheles pretoriensis* was the predominant species (327, 27.3%) followed by *An. gambiae* complex (308, 25.7%) and *An. christyi* (147, 12.3%). *An. pharoensis* and *An. funestus* group were also identified.

Conclusions: Older under-five children were at risk of local malaria in meso-endemic villages around Lake Tana, where both the primary and secondary malaria vectors of Ethiopia, are distributed. This age group needs attention in protecting them from mosquito bites. Identification of malaria vectors needs to be the first step to design vector control interventions for malaria control and elimination in meso-endemic settings.

Keywords/phrases: Local malaria, older under-five children, malaria vectors, northwest Ethiopia

Background

Malaria is a life-threatening disease transmitted through the bite of female *Anopheles* mosquitoes and poses a high health risk to under-five children. Globally, 70% of the deaths occurred in under-five children in 2015. Malaria causes 10% of the deaths among under-five children in sub-Saharan Africa [1]. Since 2010, under-five deaths decreased by 29%, despite that, malaria still claims the life of a child every 2 minutes [1]. Malaria is an important health concern for Ethiopia. Ethiopia has made remarkable progress in reversing the burden of malaria during the last two decades. In 2015 malaria indicator survey (MIS) by microscopy, malaria prevalence was reported to be 0.6% in malarious areas among under-five children and 1.8% in children 36-59 months of age (older under-fives). Amhara National Regional State had 1% of all malaria cases among under-five children in the same year [2]. Malaria deaths and admissions dropped by 81% and 73% in under-five children, respectively after the scale-up of malaria interventions between 2006 and 2011 [3]. In 2015 MIS, 45% of under-five children used long-lasting insecticidal nets (LLINs) in the night before the survey in malarious areas while 54% of under-five children slept under a LLIN in Amhara National Regional State [2]. In 2015, the Ethiopian Federal Ministry of Health (FMOH) reaffirmed the plan to achieve malaria elimination by 2020 in low transmission areas of Ethiopia [4]. Despite the fact that malaria is no longer the number one cause of death in Ethiopia [5], it is still a major cause of morbidity, especially in under-five children.

House proximity to breeding sites is a factor in malaria transmission that needs to be considered on the design of intervention strategies in micro-planning activities for malaria elimination. Nonetheless, house proximity to water bodies has an inconsistent influence on malaria transmission. Some studies have concluded that closeness to water bodies increases malaria risk [6-9] while others have reported lower risk near surface water [10, 11]. Some researchers have asserted that malaria risk is independent of house proximity to water bodies [12]. On the other hand, some studies have indicated a greater dependence of households (HHs) malaria risk on local topographic wetness indices than land uses and land covers [13]. The average flight range of the main vector in Africa, *Anopheles gambiae*, is reported to be approximately 500m [14]. Thus, a 500m buffer around each HH location is applied, and the water bodies within this buffer zone are used to define exposure [14, 15]. In addition, a number of studies have associated increased age with high malaria prevalence among under-five children [16-21]. In high transmission areas, children develop age-related immunity due to continuous exposure to infective mosquito bites [22, 23]. On the other hand, LLIN use varies among under-five children, with younger children using them slightly more often than older children [2].

An. arabiensis, *An. pharoensis, An. funestus*, and *An. nili* have been the dominant vector species (DVS) in

Ethiopia [8, 24, 25]. *An. arabiensis* is the main vector of malaria whereas *An. pharoensis*, *An. funestus* and *An. nili* are secondary vectors [26-28]. *An. arabiensis* is the only malaria vector from the *An. gambiae* complex involved in malaria transmission in Ethiopia [8, 26, 29]. *An. pharoensis* has a sympatric distribution with *An. arabiensis* and *An. funestus*, whereas *An. nili* has a much more restricted ecological niche [24].

Anopheles mosquitoes breed at the river and stream edges, in temporary rain pools, in ponds, dams, drainage ditches, burrow pits, rice fields, swamp margins and roadside puddles, and in tree holes close to human dwellings [30-32]. *An. arabiensis* commonly breeds in small, temporary, sunlit, clear, and shallow fresh water pools, although it also breeds in a variety of other habitats including slow flowing, partially shaded streams, large and small natural and man-made habitats, turbid waters, and brackish habitats. Its density is seasonal across Ethiopia, increasing during the wet months [24, 28]. *An. pharoensis* mostly inhabits lakes and reservoirs. It breeds in large, vegetated swamps, lakeshores, floating plants, rice fields, streams, ditches and overgrown wells [24, 27, 33]. *An. funestus* breeds in a large, permanent or semi-permanent fresh water with emergent vegetation, such as swamps, large ponds, and lake edges [24, 33]. Both *An. arabiensis* and *An. pharaoensis* have been found breeding in regions up to 3000 meters above sea level (masl) [26, 34].

To date, the effect of house proximity to water bodies on local malaria based on the average flight range of anophelines with matched case-control study has not yet been assessed. The effect of house proximity to water bodies on malaria can be measured in under-five children who do not normally travel for temporary work in areas where malaria is transmitted. This method of measurement can identify imported cases [35]. Moreover, the effect of child age on local malaria has not been investigated using the above design among under-five children in the Ethiopian context. The DVS responsible for local malaria transmission have not been identified in Gondar Zuriya District. Prior to malaria case management for transmission control and elimination, understanding and managing the modifiable risk factors is key to reducing malaria incidence among under-five children [36]. Few studies have been carried out to identify modifiable risk factors for local malaria among under-five children in northwest Ethiopia. In particular, information on the effect of geographical positioning system (GPS)-based house proximity to water bodies and child age on local malaria is lacking. Exploring the effect of various types of water bodies close to HHs on local malaria at the community level may help to deliver more efficient interventions [37].

There is no matched case-control study in Ethiopia that explores the determinants of local malaria among under-five children and identifies the malaria vectors. Thus, this study aimed to determine the effect of house proximity to water bodies and other risk factors on local malaria among under-five children and identify malaria vectors in meso-endemic villages around Lake Tana, northwest Ethiopia. The results can be utilized by malaria elimination programs to target their efforts on eradicating local malaria in under-five children in Ethiopia.

Methods

Study area, design and population

Health institution-based 1:1 matched case-control study was carried out in 11 *kebeles* (the smallest administrative units in Ethiopia) of Gondar Zuriya District and 1 *kebele* of Dembia District, northwest Ethiopia, from October 10, 2016 to June 30, 2017. The major malaria transmission season follows the June–September rain, occurring between September and December, while the minor transmission season occurs between April and May, following the February–March rain. Filling with earth and drainage of larval breeding sites, removal of temporary water containment materials and cutting grasses are practiced for larval control in the study area. The characteristics of the study area and settings are described in detail elsewhere [35].

Individual matching by sex was carried out for cases and controls. Under-five children (5-59 months old) who were permanent residents of the study kebeles and who visited Lemba and Makesegnit health centers were enrolled as cases and controls. Cases were patients who had signs and symptoms of malaria or reported fever during the previous 48 hours and were positive for single- or mixed-*Plasmodium* species in a blood sample examined microscopically [38]. Controls were individuals presenting at the health centers whose thick blood smear tests were negative for malaria. When a malaria case was found, a matched control was obtained by confirming the clinical diagnosis and slide results within 3 days the case was diagnosed.

Sample size computation

Sample size was computed using matched case-control study design sample size calculation methods [39] with an assumption of 95% confidence level, 80% power to detect exposure differences, odds ratio (OR) of 2.37, one control per case, and assuming that 30% of the control HHs were located within a 500m radius of water bodies [9]. A total of 180 (90 case-control matched pairs) under-five children could be included in the study. The power for the actual sample size was found to be 77%, which is almost similar with the commencement of the study.

Data collection and quality assurance

Microscopy was used to confirm the presence of *Plasmodium* species for the febrile under five children [38]. Confirmation of positivity or negativity of slide results was assured using standard operating procedures of Giemsa stained malaria microscopy at the health centers. Thick blood film was used to diagnose malaria parasites and thin film to confirm the malaria parasite species when this could not be done in the thick film. Experienced microscopists certified by the FMOH double read all the slides at the health centers and a senior technician at the University of Gondar Specialized Hospital Laboratory blindly examined three-quarter of the slides for quality control. Discordant results were re-read by a third senior microscopist and this result was taken as the final result.

A pre-tested and semi-structured questionnaire was used to collect data on socio-demography, HH wealth indicators, housing, LLINs, indoor residual spraying (IRS), travel history, visits to traditional healers, inappropriate home-based management of malaria (HMM), and awareness regarding malaria. If any case or control was absent at the first visit, the HH was revisited within two days. After the second visit, seven HHs were excluded and six subjects refused to be interviewed. Besides, study subjects were excluded because they could not be contacted at the addresses they gave during diagnosis, the difficulty of getting matched controls for cases within 3 days, or refused to enroll.

Geographic coordinate readings (latitude, longitude) and altitude of case HHs, control HHs, water bodies, larval sampling habitats, and health centers were obtained with a handheld GPS device (Garmin's GPSMAP 60CSx, Garmin International Inc., USA) with an accuracy goal of 5m. Field data collectors were blinded to the malaria status of the enrolled under-five children.

Larval collection, rearing and morphological identification

Anopheles mosquito larvae were collected from April 30, 2017 to June 24, 2017 at Sara Wonez and Ferkit, Adiga, Woyenareb, Barengua and Kanuye, Ferenji Wuha, Derchit, and Embileba breeding sites with three rounds in the study area (Fig. 1 and Additional file 1). The four *Anopheles* mosquito stages/instars I, II, III, IV were collected from natural and man-made breeding sites (Fig. 2 and Additional file 1). The sampling was done using the standard dipping method according to World Health Organization WHO procedures [40]. Ten to 13 dips were taken depending on the surface area of the larval habitat, at intervals. Samplings were done by the same individual in the morning (800-1200 h) for about 30 minutes at each larval habitat. The larvae were immediately preserved in plastic jugs and taken to a laboratory for rearing [40].

In the laboratory, homogenous larvae were separated and allowed to acclimatize in deionised water. In the laboratory, larvae were provided with finely powdered Tetramin® fish food (fishkeeping, Melle, Germany) at 3:1 ratio as a source of food. The rearing of anophelines was maintained at 27±1°C, 65–70% relative humidity, and a photoperiod of 12-hour light and 12-hour dark in the laboratory. The adults that emerged within 1-4 days were killed by dehydration using silica gel desiccant inside beakers and stored at room temperature for identification.

Each adult was individually identified to species and species complex level using morphological characters within 24 hours of hatching [41]. Adult specimens were placed individually on microscopic slides and identified under a dissecting microscope with a 10x objective using standard adult mosquito morphological identification keys developed for the Anophelinae of Africa south of the Sahara [41].

Variable measurements

Presence of a water body within a 500m radius was the primary exposure variable, others were covariates. Two nearby water bodies (rivers, streams, marshes, swamps, stagnant water, natural pools, springs and water holes) to each case HH and control HH presented during the survey were geo-referenced (Fig. 1). The water bodies were either permanent or temporal and randomly labeled as water body 1 and water body 2.

Statistical analysis

For distance computation between the HH and the water bodies, decimal degrees were changed into Universal Transverse Mercator (UTM) using World Geodetic System (WGS) _84 Datum. For analysis, house proximity to water bodies was computed as Euclidean distance using GPS coordinates [42, 43]. For this study, house proximity to water bodies was categorized into two distance bands (≤ 500m and >500m) [44]. To determine effect of house proximity to a water body on under-five malaria, a third variable, presence of a water body within a 500m radius was derived from the two geo-referenced water bodies.

HH wealth index is a composite of several variables that can indicate the socioeconomic status of the HH. Variables for the construction of the index were included based on the established scientific literature [45] and the Ethiopian Demographic and Health Survey [46]. HH head's educational status, longer-run HH assets, housing structure, water supply source, sanitation facility, farmland size, owning domestic animals, and having a savings account were used to construct the index. The values of the variables were weighted from 0 to 1, indicating the lowest and the highest values, respectively.

Data were double entered, validated, coded, cleaned, and verified using EpiData Version 3.1 software (EpiData Association, Odense, Denmark). Data analyses were carried out using SPSS statistical software version 22 (IBM Corp. IBM SPSS Statistics for Windows, Armonk, NY, USA) and STATA version 14.0 (StataCorp. Statistical Software: College Station, TX 77845, USA). Descriptive statistics *n* (%) and *n*, (% [95% confidence interval (CI)]), including median and interquartile range (IQR), were calculated for continuous variables across the response variable. Categorical variables were cross-tabulated across the response variable through chi-squared or Fisher's exact tests to detect significant differences in proportions. Fisher's exact test was also used to test distributional differences of *Anopheles* mosquitoes across the study sites. All reported p-values were two-tailed and considered statistically significant if $p < 0.05$.

Principal component analysis (PCA) was applied to estimate HH wealth [45]. Initially, only Principal Component 1 was used to categorize the HHs' wealth into three groups. Cutoff values were set for the three groups. The original variables were transformed into standardized variables. The value of each standardized variable was multiplied by Principal Component 1 and a third variable created from the product for each variable. Finally, a HH wealth score was computed from the sum of the third variables. Based on the cutoff values of Principal Component 1 grades, a final HH wealth index variable having three categories was developed. Those HHs having a value of 3 were considered to be relatively wealthy.

A conditional logistic regression model was chosen for the matched case-control study. Through a matching variable for cases and controls, a matched analysis was employed to investigate the independent effect of house proximity to water bodies on malaria spatial heterogeneity. The modeling strategy involved estimating unadjusted matched odds ratio (mOR) and adjusted mOR of the studied variables with malaria heterogeneity at 95% confidence interval (CI). A bivariate matched analysis was executed for each variable; those variables having $p < 0.2$ and biological plausibility were modeled in the multivariable matched analysis. β-coefficients, mORs with 95% CI, and p-values were estimated for the multivariable model and variables at $p < 0.05$ were considered to be statistically significant.

Results

Socio-demographic and residential housing characteristics of under-five children

A total of 162 under-five children (81 malaria cases and 81 controls) were enrolled in the study, and their HH geo-coordinates were plotted in the study area (Fig. 1). Nine matched pairs were ineligible for the study giving a response rate of 88%. Five caregivers refused to include their children in the study. The quality control results indicated 97.5% inter-rater agreement and kappa coefficient of 0.95 with the results at the health centers ($p < 0.0001$).

Nearly three-quarters of the malaria infections, 60 (74.1% [63.2-82.6]) were *P. vivax* mono-infections and the remaining, 21 (25.9% [17.4-36.8]) were *P. falciparum* mono-infections. Of the total malaria cases, 19 (23.5% [15.3-34.1]) were found between October 10, 2016, and December 15, 2016; 27 (33.3% [23.8-44.5]) were found between December 16, 2016, and March 15, 2017; and 35 (43.2% [32.7-54.4]), were found between March 16, 2017, and June 30, 2017. The median (IQR) age of the *Plasmodium*-positive under-five children was 27 (20-48) months. Of the 81 *Plasmodium* positive under-five children, 50 (61.7% [50.5-71.8]) were males (Table 1).

Awareness regarding malaria, malaria-related behaviors and intervention measures

Of all the 162 HH heads, 149 (92.0% [86.6-95.3]) had information on malaria transmissibility through a mosquito bite. One hundred sixty (98.8% [95.1-99.7]) under-five children had been active (1700-2300 h) in the preceding month. Only six (3.7% [1.7-8.1]) HH heads reportedly practiced inappropriate HMM (Table 2).

Less than one-third of under-five children, 50 (30.9% [24.2-38.5]) resided in HHs that owned at least 1 LLIN. Of those under-five children who had LLINs, 32 (64.0% [49.4-76.4]) reportedly slept under an LLIN regularly two weeks prior to the diagnosis. More than half, 26, (52.0 % [37.9-65.8]) of HHs had LLINs that were in good condition. One hundred forty-three, (88.3% [82.3-92.4]) reported that their houses had been sprayed with IRS during the preceding year (Table 3).

Proximity of case HHs and control HHs to water bodies

Eighty (98.8% [91.4-99.8]) of the case HHs were located below 2000 masl. Only 13 (16.0% [9.4-26.0]) of case HHs were located within 4 km of Lake Tana. Similarly, 19, (23.5% [15.3-34.1]) case HHs had a water body within a 500m radius (Table 4).

Multivariable matched analysis for case-control pairs

Adjusted matched analysis verified that children 36-59 months of age (adjusted mOR = 3.88; 95% CI: 1.55-9.74) had higher odds to be infected with malaria than children under 36 months in villages around Lake Tana (Table 5).

Marital status, occupation, and educational status of HH head, maternal education; HH size; HH wealth index; flooring, roofing, and wall building materials; number of rooms; separate kitchen; tethering of cattle, goats, and sheep at night; travel history within the villages; HH member travel to malarious lowlands; visits to traditional healers; inappropriate HMM; LLIN ownership; IRS; malaria information; HH elevation; water body presence within 500m radius; and house proximity to Lake Tana were not significantly associated with malaria infection ($p > 0.05$) (Table 5).

Table 1 Socio-demographic and housing characteristics of under-five children in villages around Lake Tana, Ethiopia, October 2016-June 2017

Characteristic	Malaria cases (*n*=81) *n*, % (95% CI)	Controls (*n*=81) *n*, % (95% CI)	Total *n*, % (95% CI)	Pearson's X^2/ Fisher's exact test**
Age of child (months)[‼]	27 (20-48)	23 (12-30)	24 (17-36)	
5-35	45, 55.6 (44.4-66.2)	62, 76.5 (65.9-84.7)	107, 66.1 (58.3-73.0)	*0.005*
36-59	36, 44.4 (33.8-55.6)	19, 23.5 (15.3-34.1)	55, 33.9 (27.0-41.7)	
Marital status*				
Married	78, 96.3 (88.9-98.8)	78, 96.3 (88.9-98.8)	156, 96.3 (91.9-98.3)	1.000
Divorced	3, 3.7 (1.2-11.1)	3, 3.7 (1.2-11.1)	6, 3.7 (1.7-8.1)	
Educational status*				
Illiterate[¶]	39, 48.1 (37.3-59.2)	45, 55.6 (44.4-66.2)	84, 51.9 (44.1-59.5)	0.622
Able to read and write (informal)	22, 27.2 (18.4-38.1)	21, 25.9 (17.4-36.8)	43, 26.5 (20.3-34.0)	
Grade 1 to 6 completed	12, 14.8 (8.5-24.5)	7, 8.6 (4.1-17.3)	19, 11.7 (7.6-17.7)	
≥7	8, 9.9 (4.9-18.8)	8, 9.9 (4.9-18.8)	16, 9.9 (6.1-15.6)	
Maternal education				
Illiterate[¶]	64, 79.0 (68.6-86.7)	63, 77.9 (67.2 -85.7)	127, 78.4 (71.3-84.1)	0.726
Able to read and write (informal)	6, 7.4 (3.3-15.8)	4, 4.9 (1.8-12.7)	10, 6.2 (3.3-11.2)	
Grade 1 to 6 completed	6, 7.4 (3.3-15.8)	10, 12.3 (6.7-21.7)	16, 9.9 (6.1-15.6)	
≥7	5, 6.2 (2.5-14.2)	4, 4.9 (1.8-12.7)	9, 5.5 (2.9-10.4)	
Occupation*				
Farmer	75, 92.6 (84.2-96.7)	73, 90.1 (81.2-95.1)	148, 91.4 (85.9-94.8)	0.576
Non-farmer[Ω]	6, 7.4 (3.3-15.8)	8, 9.9 (4.9-18.8)	14, 8.64 (5.2-14.1)	
HH wealth index				
Poor	17, 21.0 (13.3-31.4)	25, 30.9 (21.6-42.0)	42, 25.9 (19.7-33.3)	0.252
Medium	6, 7.4 (3.3-15.8)	8, 9.9 (5.0-18.8)	14, 8.6 (5.2-14.1)	
Wealthy	58, 71.6 (60.6-80.5)	48, 59.2 (48.1-69.6)	106, 65.4 (57.7-72.4)	
HH size[‼]	6 (4-7)	6 (4-7)	6 (4-7)	
≤5 individuals	36, 44.4 (33.8-55.6)	39, 48.1 (37.3-59.2)	75, 46.3 (38.7-54.1)	0.636
>5 individuals	45, 55.6 (44.4-66.2)	42, 51.9 (40.8-62.7)	87, 53.7 (45.9-61.3)	
Roofing materials				
Corrugated iron	76, 93.8 (85.8-97.5)	71, 87.7 (78.3-93.3)	147, 90.7 (85.1-94.4)	0.175
Thatch	5, 6.2 (2.5-14.2)	10, 12.3 (6.7-21.7)	15, 9.3 (5.6-14.9)	
Wall building materials				
Cement	1, 1.2 (0.2-8.6)	3, 3.7 (1.2-11.1)	4, 2.5 (0.9 -6.5)	0.620
Mud and sticks	80, 98.8 (91.4-99.8)	78, 96.3 (88.9-98.8)	158, 97.5 (93.5-99.1)	

Flooring materials				
Cement plastered or ceramics	1, 1.2 (0.2-8.6)	2, 2.5 (0.6-9.6)	3, 1.8 (0.6-5.6)	1.000
Dung plastered	80, 98.8 (91.4-99.8)	79, 97.5 (90.4-99.4)	159, 98.2 (94.4-99.4)	
Number of rooms in the house‼	3 (2-3)	3 (2-3)	3 (2-3)	
≤ 2 rooms	18, 22.2 (14.3-32.8)	25, 30.9 (21.6-42.0)	43, 26.5 (20.3-34.0)	0.213
> 2 rooms	63, 77.8 (67.2-85.7)	56, 69.1 (58.0-78.4)	119, 73.5 (66.0-79.7)	
Tethering of cattle, goats, sheep ©				
Yes	24, 29.6 (20.6-40.7)	20, 24.7 (16.4-35.5)	44, 27.2 (20.8-34.6)	0.480
No	57, 70.4 (59.3-79.4)	61, 75.3 (64.5-83.6)	118, 72.8 (65.4-79.2)	
Separate kitchen				
Yes	20, 24.7 (16.4-35.5)	24, 29.6 (20.6-40.7)	44, 27.2 (20.8-34.6)	0.480
No	61, 75.3 (64.5-83.6)	57, 70.4 (59.3-79.4)	118, 72.8 (65.4-79.2)	

*the HH head status was taken. $^{\Omega}$ government employee, merchant/trader, daily laborer, street dweller, carter. © Tethering indoors at night in the month prior to visiting the health facility. ¶ Unable to read and write based on self-reporting**.** !! continuous variables; summarized through median and IQR. CI: confidence interval. ** $p < 0.05$ was considered statistically significant. The italics indicate statistically significant *p*-values

Table 2 Awareness of malaria among HH heads and malaria-related behaviors in villages around Lake Tana, Ethiopia, October 2016-June 2017

Characteristic	Malaria cases (*n* = 81) *n*, % (95% CI)	Controls (*n* = 81) *n*, % (95% CI)	Total *n*, % (95% CI)	Pearson's X^2/ Fisher's exact test**
***Anopheles* mosquito transmits malaria**				
Yes	74, 91.4 (82.7-95.9)	75, 92.6 (84.2-96.7)	149, 92.0 (86.6-95.3)	0.772
No	7, 8.6 (4.1-17.3)	6, 7.4 (3.3-15.8)	13, 8.0 (4.7-13.4)	
LLIN use prevents malaria				
Yes	74, 91.4 (82.7-95.9)	74, 91.4 (82.7-95.9)	148, 91.4(85.9-94.8)	1.000
No	7, 8.6 (4.1-17.3)	7, 8.6 (4.1-17.3)	14, 8.6 (5.2-14.1)	
Travel history within study villages $^{\lambda}$				
Yes	16, 19.8 (12.3-30.1)	12, 14.8 (8.5-24.5)	28, 17.3 (12.2-24.0)	0.406
No	65, 80.2 (69.9-87.7)	69, 85.2 (75.5-91.5	134, 82.7 (76.0-87.8	
Regular LLIN use during travels (n=28)				
Yes	4, 25 (8.6-54.3)	1, 8.3 (0.8-50.1)	5, 17.9 (7.2-37.9)	0.355
No	12, 75.0 (45.7-91.4)	11, 91.7 (49.9-99.2)	23, 82.1 (62.1-92.8)	
HH member travel to lowlands $^{\lambda}$				
Yes	3, 3.7 (1.2-11.1)	1, 1.2 (0.2-8.6)	4, 2.5 (0.9-6.5)	0.620
No	78, 96.3 (88.9-98.8)	80, 98.8 (91.4-99.8)	158, 97.5 (93.5-99.1)	
Visiting traditional healers†				

Yes	10, 12.3 (6.7-21.7)	14, 17.3 (10.4-27.3)	24, 14.8 (10.1-21.2)	0.376
No	71, 87.7 (78.3-93.3)	67, 82.7 (72.7-89.6)	138, 85.2 (78.8-89.9)	
Inappropriate HMM				
Yes	4, 4.9 (1.8-12.7)	2, 2.5 (0.6-9.6)	6, 3.7 (1.7-8.1)	0.682
No	77, 95.1 (87.3-98.2)	79, 97.5 (90.4-99.4)	156, 96.3 (91.9-98.3)	

$^{\lambda}$ in the month prior to visiting the health center. ┼Spiritual healing, herbal remedy. **Test *p*-values.

Table 3 Malaria intervention measures among under-five children in villages around Lake Tana, Ethiopia, October 2016-June 2017

Characteristic	**Malaria cases (*n* = 81)** *n*, % (95% CI)	**Controls (*n* = 81)** *n*, % (95% CI)	**Total** *n*, % (95% CI)	**Pearson's X^2/ Fisher's exact test****
Received malaria information*				
Yes	32, 39.5 (29.3-50.7)	23, 28.4 (19.5-39.4)	55, 34.0 (27.0-41.7)	0.135
No	49, 60.5 (49.3-70.7)	58, 71.6 (60.6-80.5)	107, 66.0 (58.3-73.0)	
LLIN ownership				
None	55, 67.9 (56.8-77.3)	57, 70.4 (59.3-79.4)	112, 69.1 (61.5-75.8)	0.941
1 LLIN/HH	16, 19.8 (12.3-30.1)	15, 18.5 (11.4-28.7)	31, 19.2 (13.7-26.0)	
≥2 LLINs/HH	10, 12.3 (6.7-21.7)	9, 11.1 (5.8-20.2)	19, 11.7 (7.6-17.7)	
Regular LLIN use in last 2 weeks (n = 50)				
Yes	16, 61.5 (40.7-78.9)	16, 66.7 (44.5-83.3)	32, 64.0 (49.4-76.4)	0.706
No	10, 38.5 (21.1-59.3)	8, 33.3 (16.7-55.5)	18, 36.0 (23.6-50.6)	
Regular LLIN use in last 1 month (n = 50)				
Yes	12, 46.2 (27.3-66.2)	14, 58.3 (36.9-77.1)	26, 52.0 (37.9-65.8)	0.389
No	14, 53.8 (33.8-72.7)	10, 41.7 (22.9-63.1)	24, 48.0 (34.2-62.1)	
Having holes/tear(s) in LLIN(s) (n = 50)				
Yes	10, 38.5 (21.1-59.3)	9, 37.5 (19.8-59.4)	19, 38.0 (25.3-52.5)	0.944
No	16, 61.5 (40.7-78.9)	15, 62.5 (40.6-80.2)	31, 62.0 (47.5-74.7)	
Period since delivered LLIN(s) (n = 50)				
<1 year	10, 38.5 (21.1-59.3)	11, 45.8 (26.3-66.8)	21, 42.0 (28.8-56.4)	0.598
≥1year	16, 61.5 (40.7-78.9)	13, 54.2 (33.2-73.7)	29, 58.0 (43.6-71.2)	
Proper mounting of LLIN(s) (n = 50)				
Yes	20, 76.9 (55.6-89.9)	16, 66.7 (44.5-83.3)	36, 72.0 (57.6-83.0)	0.420
No	6, 23.1 (10.1-44.4)	8, 33.3 (16.7-55.5)	14, 28.0 (17.0-42.4)	
Washing frequency (n = 50)				
< 4 times	22, 84.6 (63.7-94.5)	21, 87.5 (65.5-96.3)	43, 86.0 (72.9-93.4)	1.000
≥ 4 times	4, 15.4 (5.5-36.3)	3, 12.5 (3.7-34.5)	7, 14.0 (6.6-27.1)	

Good condition of LLIN(s) (n = 50) ≈				
Yes	13, 50.0 (30.5-69.5)	13, 54.2 (33.2-73.7)	26, 52.0 (37.9-65.8)	0.768
No	13, 50.0 (30.5-69.5)	11, 45.8 (26.3-66.8)	24, 48.0 (34.2-62.1)	
IRS				
Yes	71, 87.7 (78.3-93.3)	72, 88.9 (79.8-94.2)	143, 88.3 (82.3-92.4)	0.807
No	10, 12.3 (6.7-21.7)	9, 11.1 (5.8-20.2)	19, 11.7 (7.6-17.7)	
Plastering/painting after IRS (n = 143)				
Yes	4, 5.6 (2.1-14.4)	3, 4.2 (1.3-12.4)	7, 4.9 (2.3-10.0)	0.719
No	67, 94.4 (85.6-97.9)	69, 95.8 (87.6 -98.7)	136, 95.1 (90.0-97.7)	
Use other mosquito protections £				
Yes	7, 8.6 (4.1-17.3)	4, 95.1 (87.3-98.2)	11, 6.8 (3.8-11.9)	0.534
No	74, 91.4 (82.7-95.9)	77, 4.9 (1.8-12.7)	151, 93.2 (88.1-96.2)	

*getting information on malaria signs and symptoms, transmission methods, preventive and control measures, and early treatment seeking behavior by HEWs**.** ≈ measured by service years of LLIN (aged if >3 years), absence of tears/holes, proper hanging and frequently washed. £ Mosquito coils, homemade insecticides, grass or wood fumes**.** **Test *p*-values.

Table 4 HH elevation and proximity to water bodies in villages around Lake Tana, Ethiopia, October 2016-June 2017

Variables	**Malaria cases (*n* = 81)** *n*, % (95% CI)	**Controls (*n* = 81)** *n*, % (95% CI)	**Total** *n*, % (95% CI)	**Pearson's X^2/ Fisher's exact test****
HH elevation (m) ‼	1844 (1816-1859)	1833 (1816-1856)	1841 (1816-1859)	
< 2000	80, 98.8 (91.4-99.8)	79, 97.5 (90.4-99.4)	159, 98.1 (94.4-99.4)	1.000
≥ 2000	1, 1.2 (0.2-8.6)	2, 2.5 (0.6-9.6)	3, 1.9 (0.6-5.6)	
House proximity to Lake Tana (km) ‼	5.8 (5.1-7.4)	6.0 (5.0-7.5)	5.9 (5.1-7.5)	
≤ 4	13, 16.0 (9.4-26.0)	14, 17.3 (10.4 -27.3)	27, 16.7 (11.6-23.3)	0.833
> 4	68, 84.0 (74.0-90.6)	67, 82.7 (72.7-89.6)	135, 83.3 (76.7-88.4)	
Water body presence within 500m ‼	769 (522-1155)	825 (522-1279)	812.5 (522-1211)	
Yes	19, 23.5 (15.3-34.1)	20, 24.7 (16.4-35.5)	39, 24.1 (18.1-31.3)	0.854
No	62, 76.5 (65.9-84.7)	61, 75.3 (64.5-83.6)	123, 75.9 (68.7-81.9)	

‼ Continuous variables; summarized through median and IQR. ***p* < 0.05 was considered statistically significant.

Table 5 Determinants of malaria among under-five children in villages around Lake Tana, Ethiopia, October 2016-June 2017

Variables	***β***	**Unadjusted mOR≠**	***p*-value**	***β***	**Adjusted mOR (95% CI)ǂ**	***p*-value**
Age (months)						
5-35		1			1	

36-59	1.14	3.13	*0.005*	1.36	3.88 (1.55-9.74)	*0.004*
Maternal education						
Illiterate		1			1	
Literate	-0.10	0.91	0.827	-0.14	0.87 (0.28-2.63)	0.799
HH wealth index						
Poor		1			1	
Medium	0.25	1.28	0.694	-0.38	0.69 (0.16-3.02)	0.619
Wealthy	0.69	1.99	0.100	0.41	1.50 (0.58-3.86)	0.399
Roofing materials						
Corrugated iron		1			1	
Thatch	-0.98	0.38	0.147	-0.92	0.40 (0.07-2.19)	0.290
Number of rooms in the house						
≤ 2 rooms		1			1	
> 2 rooms	0.53	1.70	0.183	0.83	2.29 (0.80-6.54)	0.123
Separate kitchen						
No		1			1	
Yes	-0.41	0.67	0.374	-0.31	0.73 (0.31-1.72)	0.475
Tethering of cattle, goats and sheep						
No		1			1	
Yes	0.27	1.31	0.467	0.13	1.14 (0.46-2.79)	0.777
Travel history within the study villages						
No		1			1	
Yes	0.31	1.36	0.435	0.44	1.56 (0.56-4.36)	0.399
Received malaria information						
No		1			1	
Yes	0.75	2.13	0.079	0.93	2.55 (0.89-7.29)	0.082
Water body presence within 500m						
Yes		1				
No	0.07	1.08	0.847	0.38	1.46 (0.54-3.93)	0.452
House proximity to Lake Tana (km)						
≤ 4		1			1	
> 4	0.08	1.08	0.842	0.21	1.23 (0.43-3.50)	0.694

β: beta coefficients/regression coefficients. $p < 0.05$ was considered statistically significant. The italics indicate statistically significant p-values
Unadjusted mOR, unadjusted matched odds ratio; adjusted mOR, adjusted matched odds ratio; 1, Reference category
≠ Denotes unadjusted mOR using 95% CI in bivariate conditional logistic regression analysis from matched case-control pairs.
ǂ Denotes adjusted mOR using 95% CI in multivariable conditional logistic regression analysis from matched case-control pairs.

Anopheles mosquito species identification

A total of 1,509 specimens of the *Anopheles* mosquitoes, including 1,197 adults, were identified using morphological characters. However, 312 mosquitoes were excluded from microscopic examination due to incomplete anatomical morphologies. The male/female ratio of identified *Anopheles* adults was 0.84:1. Out of 1,197 adults, *An. pretoriensis* was the most common and predominant species (n = 327, 27.3%), followed by the *An. gambiae* complex (n = 308, 25.7%) and *An. christyi* (n = 147, 12.3%) (Tables 6 and 7). There were statistically significant differences in *Anopheles* species distribution ($p < 0.001$) among the study sites. *An. gambiae* complex and *An. pharoensis* are the major malaria vectors in villages around Lake Tana (Fig. 1). *An*. *pretoriensis* was collected in all the larval habitats, including natural breeding sites in riverbeds with sandy substrates. Permanent and clear water bodies in full sunlight with algae were preferred by *An*. *pretoriensis* (see Additional file 1).

Table 6 Number of *Anopheles* mosquito species identified by sex in villages around Lake Tana, Ethiopia, April-June 2017

***Anopheles* mosquito species**	**Number of *Anopheles* species**		
	Females	**Males**	**Total**
	***n* (%)**	***n* (%)**	***n* (%)**
An. gambiae complex	185 (60.1)	123 (39.9)	308 (25.7)
An. pharoensis	56 (62.2)	34 (37.8)	90 (7.5)
An. pretoriensis	165 (50.5)	162 (49.5)	327 (27.3)
An. dancalicus	13 (41.9)	18 (58.1)	31 (2.6)
An. cinereus	39 (48.8)	41 (51.2)	80 (6.7)
An. garnhami	22 (26.5)	61(73.5)	83 (6.9)
An. christyi	95 (64.6)	52 (35.4)	147 (12.3)
An. funestus group	42 (73.7)	15 (26.3)	57 (4.8)
An. erepens	11 (57.9)	8 (42.1)	19 (1.6)
An. coustani	7 (26.9)	19 (73.1)	26 (2.2)
An. domicolus	14 (48.3)	15 (51.7)	29 (2.4)
Total	649	548	1,197

Table 7 *Anopheles* mosquito species distribution by survey site in villages around Lake Tana, Ethiopia, April-June 2017

***Anopheles* mosquito species**	**Survey sites**							
	Sara Wonez and Ferkit *n* (%)	Adiga *n* (%)	Woyenareb *n* (%)	Barengua *n* (%)	Ferenji Wuha *n* (%)	Derchit* *n* (%)	Embileba *n* (%)	Total *n* (%)
An. gambiae complex	120 (38.3)	45 (26.9)[∞]	92 (61.3)	51 (31.3)	0	0	0	308 (25.7)
An. pharoensis	68 (21.7)[β]	0	0	0	22 (13.8)[∞]	0	0	90 (7.5)
An. pretoriensis	75 (24.0)	54 (32.3)	58 (38.7)	41 (25.2)	34 (21.4)	38 (32.2)	27 (21.3)	327 (27.3)
An. dancalicus	31 (9.9)[Ω]	0	0	0	0	0	0	31 (2.6)
An. cinereus	0	0	0	47 (28.8)	25 (15.7)[μ]	0	8 (6.3)[μ]	80 (6.7)
An. garnhami	0	42 (25.1)[∞]	0	24 (14.7)[μ]	0	0	17 (13.4)[μ]	83 (6.9)
An. christyi	0	0	0	0	49 (30.9)	34 (28.8)	64 (50.4)[∞]	147 (12.3)
An. funestus group	0	0	0	0	0	46 (39.0)	11 (8.6)[∞]	57 (4.8)
An. erepens	19 (6.1)[β]	0	0	0	0	0	0	19 (1.6)
An. coustani	0	26 (15.7)[∞]	0	0	0	0	0	26 (2.2)
An. domicolus	0	0	0	0	29 (18.2)[∞]	0	0	29 (2.4)
Total	313	167	150	163	159	118	127	1,197

*unable to get *Anopheles* larvae in the third round due to run-off.
[∞]not found in the first two rounds.
[β] not found in the first and third rounds.
[Ω] not found in the last two rounds.
[μ] not found in the third round.

Discussion

This study found that older under-five children had nearly four-fold odds of being infected with malaria compared to younger under-fives after adjusting for potential confounders. This finding is corroborated by other studies [2, 16-21]. The possible reason older under-fives are at greater risk could be their frequency of exposure when playing with while youths looking after cattle, sheep, and goats in the early evening [28, 47]. The risk from these evening activities is compounded by the infrequent bathing and laundering of the clothes of older under-fives because poor hygiene increases the presence of mosquitoes [48]. This period (1800-2100 h) is the peak biting period of the *An. gambiae* complex and *An. pharoensis* [28, 47, 49] and even higher outdoor biting [47]. Another reason for the higher risk of older under-fives may be the fact that they may not sleep with their mothers under one LLIN and therefore may not receive adequate protection from the net. Normally, the pattern of child care in Ethiopia is that younger children are given more priority and sleep with their parents, whereas older children do not sleep under a net and can be bitten by mosquitoes [2]. One study showed that children who shared a bed with their mothers were 21 times more likely to be covered by bed nets compared to those who did not [50]. Moreover, only 24% and 25% of older under-fives' HHs had LLINs and used them fully at night for the 2 weeks prior to the survey compared with youngsters (76% and 75%), respectively, in this study.

In the multivariable matched analysis, the socio-demographic factors HH wealth; residential housing structure; tethering of domestic animals at night; travel history within the study villages; HH member travel to malarious lowlands; visits to traditional healers; inappropriate HMM; LLIN ownership; IRS; malaria information; and water body presence within a 500m radius were not independent predictors of local malaria. This is likely due to the similarity of these factors as well as malaria-related behaviors and the provision of insufficient malaria information on treatment-seeking, LLIN, and other preventive measures by Gondar Zuriya District Health Office. For instance, around 98% of the houses had walls made of mud, which is not sufficient to keep mosquitoes from entry.

In this study, significant association was not observed between LLIN ownership and local malaria. This finding is in line with previous studies, which did not predict protection offered by LLINs [16, 35]. Studies also recognized that increasing LLIN coverage did not lower malaria parasitaemia [21, 51]. Nonetheless, other studies ascertained that LLIN use [21, 52] reduced malaria among under-five children. Studies identified main attributes that may undermine the efficiency of LLINs: resistance of mosquitoes to pyrethroids, poor condition of nets [29, 53], primary caregivers' beliefs about causation and vulnerability, and obstacles in translating knowledge into behavior [54, 55]. Additional reasons in this study setting may be low LLIN coverage, heavy workload in rural communities, or low maternal education. Malaria cases were found in newly constructed houses that were unsprayed due to marriage and resettlement and/or having no LLINs [35].

In this study, house proximity to a water body was not associated with odds of malaria infection. Some previous studies also showed proximity to a water body had no association with malaria risk [12, 35, 56]. Researchers have pointed out local topographic wetness indices as preferred determinants of HH malaria risk instead of land uses and land covers [13]. On one hand, some studies have reported low infection risk in HHs located near water reservoirs [10, 11]. On the other hand, several studies have reported that HHs near water bodies had higher malaria infection rates [6-9]. These inconsistent conclusions could result from differences in a number of factors: variations in proper and persistent use of bed nets, IRS coverage, habitat suitability for vector breeding, disappearance of environmental hotspots due to decrease in malaria transmission, engagement in outdoor activities at night, imported malaria leading to onward transmission, climatic conditions, study design, and endemicity. Immediately after the main wet season, many houses are surrounded by stagnant water in villages around Lake Tana. Concurrently, there is a mass return of young adults from agricultural farms in the malarious lowlands [35, 57]. The co-existence of these two factors may facilitate transmission through the imported cases in meso-endemic areas of northwest Ethiopia.

Given how malaria spreads, it is biologically possible that people in HHs located near to mosquito habitats have increased risk of infection [58]. As the female leaves the breeding site to find a human host, it is reasonable to assume that nearby individuals has a high probability of being targeted**.** Nevertheless, it is not necessarily house proximity to water bodies in itself that matters; rather, house proximity might be considered a strong positive correlate of the likelihood of being infected. For instance, evidence shows that malaria infection risk for individuals in a given HH at a given distance to the breeding site was reduced if there were many other nearby HHs close to the breeding site [52]. Lastly, given that malaria transmission depends on several area-specific characteristics, it might well be that a given variable is a significant risk factor in one area though less important in another setting.

In the study area, *An. gambiae* complex is the DVS, which includes the main malaria vector in Ethiopia, *An. arabiensis,* followed by *An. pharoensis*. The *An. gambiae* complex, presumably *An. arabiensis*, and *An. pharoensis* have been reported from villages around Lake Tana [27, 29] and Butajira area [26]. An altitude-based study in Ethiopia also identified *An. arabiensis*, *An. pharoensis*, and *An. funestus* group as the most common species [8]. *An. gambiae* complex and *An. pharoensis* were found in villages <2000 masl, indicating high distribution of malaria among under-five children in these villages. Currently, malaria is not a primary public health concern in the study villages due to the integrated interventions against the identified vectors. The presence of the primary vectors may indicate the potential for the occurrence of malaria outbreaks if IRS, the most exercised intervention measure in the study villages, fails and due to the susceptibility of the communities. In addition, global warming, which aids in the expansion of malaria vectors, may cause the neighboring highland population, which is also susceptible, to be at greater risk of malaria [26].

This study revealed that anopheline breeding sockets were shallow stream edges and beds, small water bodies and holes, puddles in hoof prints exposed to sunlight, slow flowing or stagnant water with or without debris, and surface algae. These breeding types were reported from other parts of Ethiopia [26, 59], eastern Sudan [60], and Eritrea [61]. *An. gambiae* complex has adapted to diverse habitats [8, 26]. Absence of larvae at one site alongside streams in June could have resulted from heavy run-off which swept them away. Heavy rainfall could also destroy larvae directly [62].

Although the study employed a matched case–control design, it has several strengths. Interviews using a semi-structured questionnaire, direct observation, and larvae survey were employed to examine multiple possible contributors to malaria risk. The water bodies close to HHs, hypothesized to constitute differential malaria risk, were geo-referenced to increase proximity measurement accuracy. Multivariable matched analysis and vector identification allowed exploring effect of house proximity to water bodies on local malaria, which has rarely been considered in such studies. The non-significant association was validated by comparing groups internally and after eliminating possible confounders.

Although this study has outlined some policy implications, its findings are limited by the small sample size and power. Misclassification among cases and controls due to microscopy and residual confounding cannot be excluded. Differences in care seeking and variation in breeding suitability of the water bodies would influence the effect of house proximity to water bodies on local malaria. Also it is possible that most transmission relates to mosquitoes breeding in small temporary water containments rather than the water bodies. The flight capacity of mosquitoes which is influenced by topography, settlement pattern, and environmental factors should be taken into account while interpreting the results. Malaria treatment at drug vendors, private clinics, and health posts may also have influenced the results [63]. Moreover, malaria cases in September, when more local malaria cases occur in northwestern Ethiopia [64], were not included due to political unrest in the study area. The decision to exclude children who reportedly experienced malaria infection more than once might also be a limitation. Nevertheless, since repeat infections might be relapse episodes of hypnozoites of *P. vivax* [65], exclusion was believed to be the best approach. On the other hand, the larvae survey did not include all months of a year. For instance, the exclusion of September, when various types of water bodies are created, may have reduced the number of malaria vectors. Data were not obtained on pH, temperature, turbidity, and conductivity of water where the larvae were collected and the vectorial capacity.

These study outcomes indicate that understanding the behaviors, activities, and caregiving that make older under-five children prone to local malaria, providing adequate malaria information and recognizing vectors distribution need to be considered in accelerating efforts to eliminate local malaria in meso-endemic areas around Lake Tana.

Conclusion

Older under-five children were at risk of local malaria in meso-endemic villages around Lake Tana, where both the primary and secondary malaria vectors of Ethiopia, are distributed. However, water body presence within 500m radius did not have differential malaria risk. Hence, it is recommended to increase long-acting insecticide spraying coverage and frequency due to low use of LLINs among older under-fives and reinforces the need to use repellents to keep children safe until they sleep under bed nets. Besides, malaria information should be provided for primary caregivers to equally manage younger and older under-fives while applying LLIN utilization. Identification of malaria vectors also needs to be the first step to design vector control interventions in meso-endemic settings. Critical information is urgently needed to identify introduced and indigenous malaria in meso-endemic areas of Ethiopia. Advanced molecular techniques for identification of sibling anophelines also need to be conducted in future studies.

Abbreviations

FMOH: Ethiopian Federal Ministry of Health; MIS: malaria indicator survey; LLINs: long-lasting insecticidal nets; IRS: indoor residual spraying; masl: meters above sea level; DVS: dominant vector species; HH: household; HMM: home-based management of malaria; UTM: Universal Transverse Mercator; WGS: World Geodetic System; GPS: geographical positioning system; IQR: interquartile range; PCA: principal component analysis; OR: odds ratio; mOR: matched odds ratio.

Authors' contributions

AM, KA, MA, WJ, and HK contributed to the conception and design of the study; AM and WJ conducted the field work and entomological laboratory analysis; AM and KA conducted data management and statistical analysis; AM, KA, MA, SR, WJ, and HK wrote and edited the draft manuscript. All authors critically revised the draft manuscript and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

Data and all the materials will be available from the corresponding author upon request.

Consent to publish

Not applicable.

Ethics, consent and permissions

The study protocol was approved by the Institutional Review Board of the Ethiopian Institute of Water Resources, Addis Ababa University and the Ethical Review Committee of Wollo University. Written assent was secured from the caregivers/guardians of the under-five children. For illiterate caregivers/guardians, thumb-printed consent was obtained in the presence of an independent literate witness. Participation in the study was voluntary and confidentiality of the information was assured during as well as after data collection. All malaria cases were treated following national guidelines. Before any larval sampling was initiated, verbal consent to access sampling sites was obtained from both *kebele* officials and local residents during local village meetings in all study communities.

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Barriers of persistent long-lasting insecticidal nets utilization in villages around Lake Tana, Northwest Ethiopia: a qualitative study

Asmamaw Malede[1*], Mulugeta Aemero[2], Sirak Robele Gari[1], Helmut Kloos[3] and Kassahun Alemu[4]

Abstract

Background: Malaria remains a major public health problem in Ethiopia. The use of LLINs is an effective approach to reducing transmission. Persistent use of LLINs is determined by numerous factors. Quantitative studies have assessed LLIN ownership and utilization, but the behavioral, socio-cultural, socioeconomic and net distribution contexts that impact their use have not been examined in depth. This study aimed to explore barriers of persistent LLIN use among communities around Lake Tana.

Methods: Twenty-three community residents who owned LLINs (15) or not (8) during the study period and 38 key informants were interviewed from April to June 2017. Phenomenological study was employed to explore the local contexts and factors that influence persistent use of LLINs. Individuals were purposefully selected to capture different views. Community residents were selected based on their permanent residence and LLIN use experience. Key informants were health extension workers, local leaders, students, and health professionals. The data were managed using QSR International NVivo Version 10 software and coded, and themes were identified.

Results: Killing ability of nets against arthropods other than mosquitoes reportedly made use of LLINs a favored malaria prevention method despite their ineffectiveness after 3 months. Conical nets were preferred due to their compatibility with varied sleeping structures. Numerous factors influenced persistent use, notably erroneous perceptions about LLINs, malaria and mosquitoes; bedbug infestation; inconvenience; unintended uses; distribution problem of nets; and socio-cultural and economic factors. Unintended uses were often associated with local needs and seldom linked with social issues and deficiencies in information about malaria and LLINs. Collateral benefits were considered important, principally in terms of disinfestation of bedbugs.

Conclusions: Non-persistent LLIN use was associated with inconvenient bed net design and early damage; non-potency of the insecticide against other arthropods; facilitation of bedbug infestation; unintended uses; wrong perceptions about malaria, mosquitoes, and LLINs; and inadequate follow-up regarding LLINs utilization. Distribution of conical nets and provision of adequate information on LLINs and malaria may promote persistent use. Using an insecticide that also kills arthropods other than mosquitoes may reduce unintended uses and increase persistent use.

Keywords: Malaria, Mosquitoes, LLINs, In-depth interviews, Conical nets, Bedbug infestation

* Correspondence: coolmaldinni@gmail.com
[1]Ethiopian Institute of Water Resources, Addis Ababa University, Addis Ababa, Ethiopia
Full list of author information is available at the end of the article

Background

Malaria is a major public health concern in Ethiopia [1]. The use of long-lasting insecticidal nets (LLINs) is a widely accepted [2] and commonly available intervention for preventing malaria in Africa [3]. It is a primary prevention and control strategy in Ethiopia [1, 4] and promoted as an effective approach to minimizing risk of malaria transmission. Worldwide, studies have revealed major benefits from LLINs ownership and use [5].

According to the 2015 National Malaria Indicator Survey, only 64% of Ethiopian households (HHs) owned at least one LLIN and only 40% of the population slept under LLINs the night before the survey, below the goals of 100% ownership and 80% utilization. The proportion of HHs having at least one LLIN for every two people was 31.7% nationally and 38% in Amhara Region in 2015. In Amhara Region, where this study was carried out, 72.9% of HHs owned one LLIN and 43.4% of the population slept under the LLINs the night before the interview. The use of existing LLINs in Amhara Region was 56%, the lowest nationwide [1]. Evidence from rural Ethiopia showed variable LLIN coverage and utilization [6]. A recent study reported that only 12% of HHs owned one or more LLINs [7].

Persistent utilization of LLINs is determined by an array of factors, including, first and foremost, insufficient access to LLIN within HHs and mal-distribution of LLINs, and availability or ownership of LLINs [1, 4, 8–10], followed by seasonality and overall mosquito abundance. Misconceptions about malaria risk, symptoms, and transmission; community norms and values; and gender or age priorities contribute to nonuse of LLINs. In Ethiopia, the groups most vulnerable to malaria and therefore prioritized for LLIN usage are children under 5 years of age and pregnant women. The age or physical condition of the nets, perceptions of net ineffectiveness, structural incompatibilities and practical issues, and use of nets for unintended purposes affect utilization [1, 4, 11–18]. The most frequently cited reasons for non-persistent use of nets are perceived low mosquito abundance and stuffiness, usually during hot weather [11]. Promotion of net use in Ethiopia and other countries has focused almost exclusively on malaria prevention. Therefore, use of nets may be considered unimportant in communities in which malaria is no longer seen as a serious health problem. Moreover, LLINs have a short lifespan, developing tears and holes and losing insecticide over time; field studies show that the useful life of a net may vary between 18 months and 7 years, with a mean expected life span of 3 years [19, 20]. However, a cohort study in south-central Ethiopia revealed only 4% of 1532 distributed LLINs met the criteria for functional survival by the 24th month, with a median functional survival time of 12 months [21].

Parallel matched case-control studies in villages around Lake Tana identified risk factors for malaria in a meso-endemic setting. The results showed that under-five age (36–59 months), travel to malarious lowlands, and inadequate malaria information were independent predictors. Ownership and use of LLINs were low; 69.5% of the participants had no nets [22, 23]. These studies provide information on determinants of malaria prevalence, but they did not explore the behavioral, sociocultural, and socioeconomic contexts explaining why communities did not use LLINs persistently. Thus, factors that influence persistent LLIN utilization in specific areas need to be investigated to facilitate malaria elimination. The aim of the present study was to explore context-based barriers to persistent LLINs use among residents in villages around Lake Tana. Findings of this study may have implications for malaria elimination strategies.

Methods

Study setting and population

The study was carried out in seven *kebeles* (the lowest administrative units in Ethiopia), including Lemba-Arebaytu, Layeye-Dugie, Zengage, Jeja-Bahriegeneb, Tsion-Seguage, Sheha-Gomenege and Makesegnit Town in Gondar *Zuriya* District, northwest Ethiopia, from April to June 2017. Gondar Zuriya District is composed of hilly and plain landscapes, and the altitude ranges from 1750 to 2600 m above sea level. The study area has two malaria transmission seasons, which are the major transmission season (September to December) and the minor transmission season (April to May). In the study area, numerous individuals travel to malarious lowlands for temporary work, mainly during the rainy and spring seasons. A trend analysis (2002–2011) conducted in a neighboring district reported 23,473 malaria cases (75% *Plasmodium falciparum* and 25% *P. vivax*) with a fluctuating trend. From 2010 to 2011, *P. falciparum* prevalence decreased while *P. vivax* prevalence was increasing, indicating a trend shift [24]. Another study conducted in three districts, including Gondar *Zuriya* District, reported 61.3% malaria prevalence microscopically [25]. A recent spatio-temporal analysis in northwest Ethiopian districts revealed a purely temporal high malaria cluster from July 1, 2015 to December 31, 2016 and significant spatio-temporal malaria cluster were identified in Dembia District from January 1, 2014 to December 31, 2017 [26].

The characteristics of the study area, settings, and residential housing are described in detail elsewhere [22]. All the *kebeles* are within 12 km of Lake Tana, the largest lake in Ethiopia, bordering them in the southwest direction. The lake is the source of the Blue Nile and geo-located in 10.95°-12.78°N latitude and 36.89°-38.25°E longitude. The climate of Lake Tana basin is warm-temperate dominated by the tropical highland monsoon. Most rainfall (70–90%) falls between June and September. The water of Lake Tana is decreasing in volume and becoming increasingly turbid, resulting in the spread of water hyacinth. Houses in the study villages are predominantly of the mud-stick type with corrugated iron roofs. Sleeping mats made of hides are used in most rural HHs. Culicine mosquitoes, houseflies, fleas, bedbugs, cockroaches, crawlers, and spiders are the most common nuisance causing arthropods in local houses. Many of the villagers are subsistence farmers. Women are involved mainly in agriculture and domestic work.

Study design

The present study employed a phenomenological qualitative methodology to explore the local contexts and factors that influence persistent use of LLINs. Phenomenology is a best approach and method of inquiry which helps to exhaustively describe, interpret, illuminate and qualify a phenomenon in everyday human life experiences [27, 28]. This methodology was chosen to explore the behavioral, demographic, socio-cultural, economic, livelihood, and housing situation, as well as net delivery related experiences of the community. Since LLINs utilization reveals lived experience of the communities, interpretive phenomenological approach was used. Descriptions of the participants' LLIN utilization experiences were summarized and analyzed thematically.

Sampling of study population

The study sites were purposefully selected to capture the views and practices of residents living in areas identified by the investigators facing challenges in LLINs utilization. The sample consisted of two groups: 23 community residents and 38 key informants. The sample size was estimated on the basis of richness, detailed nature and volume of data collected; relevant published literature; scope of study; and the amount of useful information obtained from each participant [29]. Saturation, the most widely used principle for qualitative sample size determination, was achieved with this large sample due to the heterogeneity of the participants and the broad scope of the study [30]. Proportional number of households were included from the 7 *kebeles.* Then, community residents comprised of household heads from a range of socioeconomic backgrounds and ages, and both genders and lactating women were sampled. They were interviewed about their LLINs utilization experiences and practices. Most of the study households (15 interviewees) owned LLINs and some others (8 interviewees) did not during the study period. The key informants were people with knowledge of malaria control and distribution of LLINs in the study communities and who knew the living conditions, beliefs, and behaviors. They were 5 health professionals responsible for the prevention and control of malaria at Makesegnit and Lemba health centers and Gondar Zuriya District Health Office, 8 health extension workers (HEWs) who worked in the 7 selected *kebeles*, 19 district/*kebele*/village leaders appointed by the local government, and 6 students. Village leaders were enlisted to recruit participants with support from a researcher to ensure a representative sample.

Data collection procedures

Interviews were conducted in the local language, Amharic, and lasted up to 1 h each. The interview guide focused on reasons for not using LLINs persistently, inequitable use of LLINs among family members, compatibility of nets with sleeping spaces, sleeping time under an LLIN, perceived benefits and inadequacies of LLINs, and proper utilization of LLINs. The interviewers were trained in the use of the guide, asking open-ended questions, and probing for more detail. Questions were asked consistently during all interviews. All interviews were recorded on a digital voice recorder.

Data analysis

Digital recordings of interviews were transcribed verbatim and translated from Amharic to English by the first author and local translators. Data management and analysis were done using NVivo Version 10 (QSR International, Melbourne, Australia). Thematic analysis is a flexible approach to identifying, analyzing, and reporting patterns of data and is compatible with both essentialist (realist) and constructionist paradigms [31]. The data were content-coded for thematic analysis. Initial coding was based on preset categories developed from the literature [13, 14] and emerging themes were derived from the data. The coded data were analyzed by querying to determine the frequency of occurring concepts, themes and relationships. Themes summarize the responses, and the words of the interviewees were presented in Word Clouds to illustrate key findings; quotes were taken from the interviews to illustrate the contextual quality of the findings. Textual and structural analyses were carried out to get comprehensive meanings of the lived experiences of the interviewees on LLINs utilization [32]. Textual analysis refers to the description of what is expressed by the interviewees while structural analysis stands for the interpretation of how it is expressed by the interviewees. Interpretive phenomenological analysis, which was used to understand lived experience of the interviewees about non-persistent utilization of LLINs and with how participants themselves make sense of their experiences, was employed [33].

Results

Socio-demographic description and sleeping time under LLINs

Of the 61 interviewees, the majority were males, adults, uneducated, and local community members (Table 1). Most informants reported usually going to sleep between 9 PM and 10 PM. One man said, *"After all the domestic*

Table 1 Demographic Characteristics of Interviewees

Characteristic	Frequency *n* (%)
Sex	
Male	33 (54.1)
Female	28 (45.9)
Age (years)	
15–25	9 (14.8)
26–45	35 (57.4)
> 45	17 (27.8)
Education level	
Uneducated (unable to read and write)	24 (39.3)
Primary	17 (27.9)
Secondary	6 (9.8)
College/university	14 (23.0)
Occupation	
Local leader	19 (31.2)
Student	6 (9.8)
Health professional[a]	5 (8.2)
HEW	8 (13.1)
Local community member[b]	23 (37.7)

[a]Malaria focal persons, Environmental Health Officer and District Malaria officers; [b]Farmers and town residents

animals get in their corrals, around 2100 h." Some individuals thought mosquitoes do not bite in the early evening.

Perceived benefits and shortcomings of LLINs reported by informants

Informants' perceptions of the benefits and weaknesses of LLINs varied considerably. First, they evaluated them by their ability to kill arthropods such as houseflies, fleas, bedbugs, cockroaches, and spiders. Most informants commented that the currently distributed LLINs had not killed these arthropods although almost all acknowledged they had done so when new and up to 3 months old. Many informants attributed the decrease in killing ability of LLINs after several months to inadequate impregnation. Loss of killing ability was one of the reasons residents considered them ineffective and discontinued their use.

> *Nets distributed previously had adequate insecticide. The current nets are inadequately impregnated. I think that they cannot serve for 3 years. They do not serve even for 2 years.* (Female, 38 years old, HEW in Sheha-Gomenege *Kebele*)

> *The insecticide content of the current net is not a killer. It did not kill any arthropods. The current nets did not kill even mosquitoes that caused nuisance.* (Male, 42 years old, local leader in Sheha-Gomenge *Kebele*).

Secondly, respondents rated LLINs based on their physical integrity. They reported that the nets quickly became dirty and faded; they were worn out due to repeated washing and broke after 6 months of use. Loss of physical integrity, especially breakage, appeared to be due to the impoverished living conditions in rural houses.

> *The strength of LLIN is also not as such strong compared with the previous ones. It did not serve even for 2 years and they easily tear off in most HHs.* (Female, 35 years old, HEW in Tsion-Seguaj *Kebele*)

On the other hand, some informants reported that LLINs are very strong, adequate in size, and can serve throughout the stated lifetime if handled with care. They described the current LLINs as relatively smooth in texture and comfortable to the skin. However, a larger number of informants questioned the stated service length and the adequacy of the nets' size; they considered them serviceable for 2 years at most if handled with care. Some stated that the large mesh size allowed mosquitoes to go through and complained that the nets were too small for large beds. Additionally, new nets were said to cause skin irritations when in contact with skin.

Regarding the mounting and shape of LLINs, many informants reported that they or others in their HHs who used them preferred the circular shaped nets because they were compatible with any sleeping space. Circular nets mounted at one point in the ceiling were simple to install and operate and easy to roll up during daytime and suspend at night. An environmental health officer and ex-malaria worker noted that "*circular shaped nets are durable and fit for thatched roof houses.*" Rectangular shaped nets, by contrast, were viewed unfavorably due to the difficulty of installing them and the large space they required. Thus, informants revealed that only HHs with beds in *chiqqa bet* (mud-stick houses) can comfortably hang and use the rectangular nets. However, rectangular nets were not preferred because their installation made holes and cracks in the mud walls.

> *Even though the rectangular type [of nets] is suitable to use on beds, circular types (too long) are very comfortable to use on mats on the floor or on raised earthen platforms.* (Female, 35 years old, HEW in Layeye-Dugie *Kebele*)

> *We have seen nets which are circular in shape in towns and this type is very good for rural residents too. It is tied only on one rope and easy to suspend*

and roll. It is very good. (Male, 50 years old, main administrator of Sheha-Gomenge *Kebele*)

Barriers to the persistent utilization of LLINs

During almost all interviews, bedbug infestation was mentioned and observed as a major deterrent for persistent use of LLINs (Fig. 1). The hanging corners of LLINs and the top inside of the nets harbored bedbugs. Additionally, bedbug urine and faeces were associated with soiling and pigmentation of LLINs. Bedbugs reportedly infested almost all houses in the study communities.

Perception of the ineffectiveness of LLINs in killing bedbugs and other arthropods was cited as a major barrier to persistent use of the nets. Some interviewees questioned the efficacy of LLINs that cannot protect against bedbugs and fleas beyond the first few months of use:

> *LLINs killed bedbugs when they were new. When the net stopped killing bedbugs, we suspected that it also did not kill mosquitoes.* (Female, 55 years old, local leader in Makesegnit Town)

Community residents also indicated problems in receiving the nets as constraints for LLIN utilization. They cited insufficient supply of LLINs delivered to the HH, inequitable and late delivery, and irregular replacement of old nets. However, HEWs and some other informants argued that HHs received LLINs based on their family size per national guidelines. Informants also reported that all the HH members did not sleep under an LLIN because HH members did not follow the recommended guideline of sleeping in groups. Some HHs were denied LLINs because they did not meet the requirement of constructing a latrine.

Another barrier to persistent utilization of LLINs was the lack of adequate information about their proper use. Many residents reported having been informed that LLINs had to be impregnated every 6 months like conventionally treated nets. Others thought that simply hanging a net without adjusting it or using it as a bed sheet would protect from mosquito bites. Some residents did not use the nets after washing them due to the perception that they had lost their insecticidal ability during laundering.

In some houses, bed structure was a critical barrier to net utilization. Structures such as mud-made floors and sleeping platforms, chairs, verandas, and straw beds were unfit for rectangular nets. Rectangular net mounting was reported and observed to be impossible in short and narrow thatched-roof houses that are common in the study area.

A number of other barriers were also identified. Residents disliked the nets; they were stuffy, had an odor, caused allergic reactions, and made sleeping spaces dark. Elderly residents often forgot to suspend them and busy farmers felt they could not take time from their work to hang them. LLINs were inconvenient for residents who traveled and those who were forced to sleep outside to protect their cattle and other resources at night.

Some informants reported that residents believed mosquitoes and the threat of malaria had been reduced or eliminated, and they associated this belief with a decline in the use of LLINs. The common perceptions that mosquitoes are absent during the dry season and

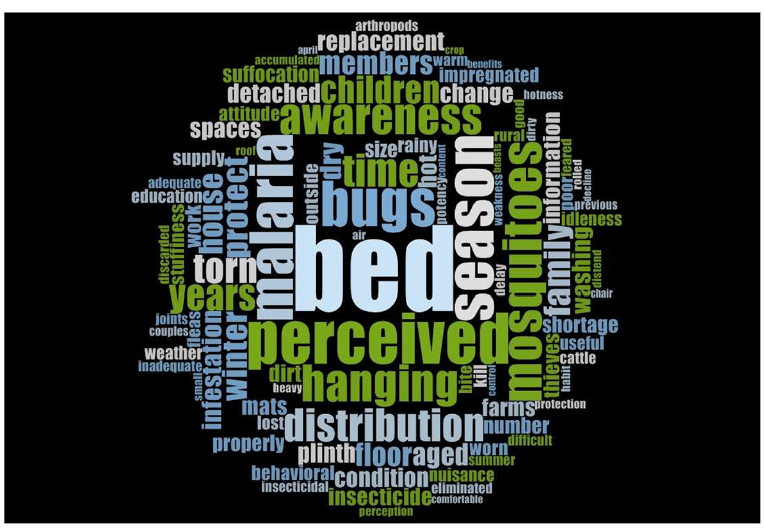

Fig. 1 Word Cloud: 100 most occurring words, showing the phrase "bed bugs" as the most frequent one (NVivo Version 10)

that malaria is a disease of the past impede LLIN use despite efforts of the key informants to facilitate persistent utilization of LLINs.

Unintended and perceived collateral uses of LLINs

Informants observed and reported unintended use of LLINs, either misuse or repurposed use. LLINs were used for unintended purposes when they were old, dirty, torn, or had otherwise lost their physical integrity and after washing. Unsafe use and poor management practices were reportedly the major reasons for widespread damage, leading to repurposed uses.

Repurposed uses of LLINs included covering of pumpkin and pepper seedlings, drying of cereals, protecting and assembling straw and cereal harvest residues, and bagging garlic for transport to markets on donkey carts. Torn nets were repurposed for fencing and made into ropes for binding and tethering purposes.

The key informants as well as community residents reported misusing LLINs. Residents used new LLINs for domestic needs, such as for protecting and bagging straw and cereal harvest residues; protecting pepper and eucalyptus seedlings; and drying cereals, buckthorn *(gesho)*, malts (*gebs)* and pepper fruits. Participants placed LLINs under mattresses and as bed sheets to protect them from bedbugs and used them to cover latrine walls and make ropes (Figs. 2 and 3). In rare cases, the nets were used as head scarves, curtains for windows, and doors. Some residents used one net for mosquito protection and the remaining ones for unintended purposes. Misuse of nets also included giving them to friends or relatives as gifts, placing them in boiling water to kill bedbugs, and storing them in plastic bags (Fig. 3). Some informants reasoned that because malaria had been eliminated, using nets for other purposes made sense. However, several informants did not use new LLINs for unintended purposes and advised residents to also use them for their proper purpose.

Both key informants and residents saw the insect control ability of LLINs as a collateral benefit beyond protection from mosquito bites and malaria. LLINs can effectively destroy insects and other arthropods when new. There was a perception that LLINs must protect primarily against bedbugs and fleas, and additionally against other arthropods. Residents with infants reportedly used the nets day and night for protection against house flies, crawlers, debris, and dust. Cessation of insecticidal activity of LLINs against bedbugs after 2 or 3 months was the most frequent and serious complaint of community informants. Control of bedbugs was the commonly perceived primary collateral use of LLINs:

> *Instead of hanging the net, they used it under the mattress since they believed the insecticide on the net killed bedbugs. They primarily used to protect from bedbugs despite they knew it protects from mosquitoes.* (Malaria focal person in Lemba HC)

Informants' suggestions to increase LLIN use

Informants and the wider community in the study villages had color preferences for bed nets. In addition, participants indicated a strong preference for circular nets over rectangular ones as the circular nets are easier to install and use (Fig. 4). Circular types were frequently suggested for rural residents because their sleeping spaces are not uniform or comfortable, primarily because of their low socio-economic status, social and cultural issues, and seasonal changes. Some informants proposed a portable net that can be used in any space, similar to a sleeping bag, because individuals may sleep outside or away from home.

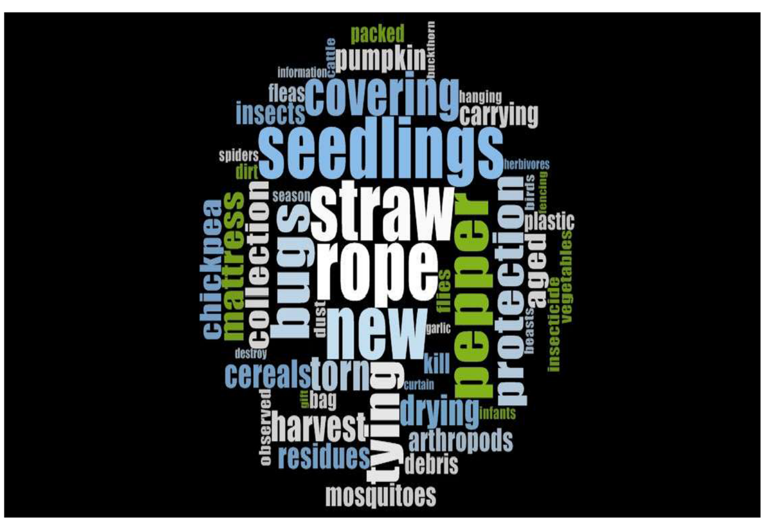

Fig. 2 Word Cloud: 50 most occurring words showing terms like "rope", "seedlings" and "straw" (NVivo Version 10)

Fig. 3 Misuse of new LLINs: **a**) Used for protection of tef (*Eragrostis tef*) straw from herbivore domestic animals. **b**) Put as packed in its plastic bag. **c**) Used as a sleeping foam by filling with straw

Suggestion by informants indicated that information, education and communication (IEC) and behavior change communication (BCC) interventions should always go along with distribution of LLINs and during the active life span of nets in communities' utilization. Informants recommended improving the effectiveness of LLINs by replacing them every year or 2 years, re-impregnating them every 6 months, or increasing the amount of insecticide used. Prolonging the ability of LLINs to kill fleas and bedbugs was said to increase persistent use.

Some informants proposed reinforcing persistent use by establishing rules for LLIN use and imposing punishment or awarding incentives for following the rules. Other informants argued that the introduction of punishment would create a social crisis for HEWs and decrease net use. Inter-sectoral networking was suggested as a tool for applying positive punishment.

Follow-up, supervision and evaluation of LLINs utilization

On one occasion, the Malaria Prevention and Control District Office temporarily enforced punishment for households that did not use nets or utilized them for unintended purposes. Generally, however, strict follow-up, supervision, and evaluation of the use and efficacy of LLINs have reportedly not been carried out in the study area:

> *HEWs simply alerted us to take the nets. They simply told us to use them properly. There is no regular follow-up and supervision on how the community utilizes the net."* (Male, 40 years old, community member of Dugie Village, Layeye-Dugie *Kebele*)

The lack of follow-up and supervision constitutes a critical gap in malaria control efforts. The absence of follow-up

Fig. 4 Word Cloud: 100 most occurring words showing the term "circular" as more frequent than "rectangular" (NVivo Version 10)

was attributed mainly to recent reduction in malaria occurrence. Another reason for lack of follow-up was poor community acceptance of local mobilizers delivering information about net utilization. Inadequate HEW personnel was reported as a reason for the weakness of malaria interventions in the community. Informants from the study community reported that implementing comprehensive interventions is beyond the capacity of HEWs because they are ignored by local officials. Nevertheless, some community residents praised the efforts of HEWs to obtain persistent utilization even in the absence of behavioral change.

Some informants preferred bi-annual indoor residual spraying (IRS) over using LLINs. They reasoned that IRS was better for people with asthma, elderly people, and those unable to hang nets; IRS had benefits in homes with faulty plastering and in newly constructed houses. Some informants preferred combining IRS and LLINs.

Discussion

The findings of this study are organized into four themes: (1) perceived benefits and shortcomings of LLINs, (2) unintended and perceived collateral uses of LLINs, (3) factors that influence persistent utilization of LLINs, and (4) informants' suggestions for increasing LLIN use.

Study participants gave high marks not for malarial protection benefits of bed nets, but for their collateral benefit of protecting against arthropods such as house flies, crawlers, fleas, bedbugs, cockroaches, and spiders in the first 3 months of use. Similar information was reported from elsewhere in Ethiopia [14] and Uganda [13]. Loss of insecticidal effectiveness of LLINs after several months, considered a critical limitation, was reported elsewhere in Ethiopia [4, 14] and Kenya [9], where users were not aware of the chemical impregnation of nets and reported them ineffective as physical barriers. In our study, informants noted that LLINs quickly became dirty, faded, worn out due to repeated washing, degraded under the conditions of rural houses and mice infestation, and were no longer functional after 6 months. Doda and colleagues [14] also reported LLINs non-functional and repurposed after 6 months. Solomon et al. [21] reported that LLINs had a 12-month median functional survival time and that successive laundering significantly increased feeding success and survival rates of *Anopheles gambiae* sensu lato [34]. However, WHO indicates the serviceable life span of LLINs to be 3 years [19, 20]. Our finding that users reported that exposure to the chemicals caused skin irritation was also reported in several others studies [4, 18]. Regardless of study population characteristics, some key informants and most community residents questioned the strength and size, including the mesh size of the current LLINs in this study. Other studies also reported small net size, weak physical integrity, and big mesh size as shortcomings of LLINs [11, 15, 35]. However, LLINs were highly credited for their strong texture, wide square shape and large mesh size in other studies [15, 35].

In this study, key informants and residents preferred circular-shaped nets due to their adaptability to any sleeping space and ease of operation; this preference was also reported by other studies [14]. The challenges and shortcomings of rectangular nets—the complexity of installation, the need for a wide area, and usefulness only with beds in mud houses (although their installation damages the mud walls)—were also reported by other studies [4, 13, 14].

Our findings verified that the most common repurposed uses of nets were connected to the prevailing local livelihood and socio-economic conditions. These uses peaked during the harvest season. Other studies documented similar repurposed uses of nets [14, 36, 37]. In our study, residents used LLINs for other purposes when they determined the nets had ceased to serve their intended purpose due to age or loss of mosquito-killing capacity; this was also reported in other studies [14, 38]. Repurposing LLINs is an increasing phenomenon in villages around Lake Tana. Similar studies elsewhere in Ethiopia and Africa reported that residents repurpose nets for various uses [4, 6, 9, 14, 38, 39].

We found misuse of nets, even when new, for a wide range of purposes. Similar misuse was practiced in other communities in Ethiopia and elsewhere in Africa [4, 14, 40]. The reasons cited for the misuse of LLINs in our study were the perception that malaria has been controlled and the inability to hang nets in all sleeping spaces. Similar perceptions that led to misuse of nets were reported in other studies [14].

In our study, the main collateral uses of LLINs were for killing and warding off of arthropods, protection from hens, and protection from dust and debris, primarily for infants. Such uses, particularly fighting bedbug infestation, motivated residents to use nets persistently for the first few months. Similarly, Birhanu et al. [4], Strachan et al. [13] and Doda et al. [14] reported that community residents obtained diverse collateral benefits from LLINs beyond the prevention of malaria and the nuisance of mosquitoes. In this context, promoting persistent LLIN use can be most effective if accompanied by interventions that can eliminate bedbug infestation. WHO reported that bedbugs contribute indirectly to the ineffectiveness of malaria interventions and recommended the use of insecticides such as pyrethroids, diazinon, bendiocarb, and dichlorvos [41]. However, bedbugs have already developed resistance to these insecticides and studies recommended consideration of other disinfestation mechanisms [42].

Our study found that inadequacy of nets in a HH, inequitable distribution, and absence of on-time replacement were first-line barriers to LLIN utilization. Such delivery-related constraints were reported by similar studies in Ethiopia [4] and Zanzibar [17]. The finding that infants and pregnant women were most likely to use LLINs persistently was also seen in other studies [4, 14, 43].

Persistent utilization of LLINs by villagers around Lake Tana was to a great extent determined by socio-demographic and socio-cultural characteristics, behavioral factors and misconceptions, weather conditions, and livelihood and economic factors. Equivalent factors were reported in other communities [4, 11, 13, 14, 36, 44–49]. The perception that malaria is no longer a problem contributed to non-persistent net use was also mentioned in other studies [4, 14, 18]. Our finding that dirtiness, aging, and deterioration of LLINs, together with the perception that LLINs lose their insecticidal activity after washing, corroborates findings of other studies [4, 14]. In addition, failure of the nets to protect against bedbug and flea infestations after a few months was a predominant barrier of persistent use of bed nets in the study communities. This was also cited as a serious problem in other studies elsewhere in Ethiopia [14], Uganda [13], and Rwanda [39].

Residents' limited information about LLINs, malaria transmission, and vectors resulted in misperceptions and negligence, which in turn led to non-adherence to net use. Other studies confirmed such analytical associations [14, 49–52]. Berhanu et al. [4] and Doda et al. [14] similarly reported a behavioral shift away from LLIN use due to perception of low malaria risk, saving of nets for future use; lack of awareness and negligence accounted for non-consistent use of LLINs. In addition, lack of clear information about the life span of LLINs constrained bed net use, corroborating the findings of other studies [4, 9, 14, 53]. Misperceptions about the effectiveness of insecticides after repeated washing were major barriers to persistent use. These misconceptions were reported from other communities in Ethiopia [4, 14], Ghana [54] and Kenya [9]. A study in south-central Ethiopia showed that LLINs were effective up to 24 months [21].

Sleeping spaces without beds and incompatible bed structures were associated with the failure to use nets persistently. Even small, thatched-roof houses were observed and reported to be incompatible with use of rectangular-shaped nets. Similar challenges were identified in other studies [4, 13, 36]. These sleeping arrangements are an indication of poverty.

Informants in our study suggested greater persistent utilization of LLINs may be achieved through wider distribution of circular or conical nets instead of rectangular nets, a suggestion also reported in studies elsewhere in Ethiopia [55] and Uganda [39]. Informants also proposed provision of a portable net, such as a self-supporting and sealed pop-up net, that can be used in any space indoors or outdoors. Such a net might be easier for older children and women to assemble and may also prevent, for example, soldier ants and reptile infestation. Other studies also recommended the development of portable, user friendly nets that do not need external supporting structures [11, 56]. Another way to increase persistent use of mosquito nets, resolving technical difficulties related to mounting and using a net, may best be addressed at the manufacturer level.

This analysis of 61 interviews with community residents and key informants offers new insights into perceived benefits and shortcomings of LLINs, unintended and collateral uses of LLINs, and reasons for non-persistent use, including bedbug infestation, wearing out of LLINs, and misconceptions about LLINs. These insights may help Gondar Zuriya District Health Office take measures to optimize persistent LLIN use to support malaria elimination efforts.

Conclusion

We conclude that wrongly perceived weaknesses of LLINs were common; rectangular LLINs were considered inferior to conical nets; unintended uses were widespread; collateral benefits of nets were considered important; and behavioral, socio-cultural, livelihood, housing, and net delivery-related factors generally impeded persistent use of LLINs. Suggestions made by informants for increasing persistent LLIN use, including the provision of nets that are structurally compatible with sleeping spaces and the delivery of adequate information about malaria vectors and the properties and proper uses of LLINs to the community indicate substantial accumulation of knowledge that may guide effective LLIN programs in the study area.

Abbreviations

BCC: Behavior change communication; HEWs: Health extension workers; HHs: Households; IEC: Information, education and communication; IRS: Indoor residual spraying; LLINs: Long-lasting insecticidal nets

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Authors' contributions

AM, KA, MA, and HK contributed to the conception and design of the study; AM conducted the interviews; AM and KA performed data management and thematic analysis; AM, KA, MA, SR, and HK wrote and edited the draft manuscript. All authors critically revised the draft manuscript and approved the final manuscript.

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Availability of data and materials

Data and all the materials will be available from the corresponding author upon request.

Ethics approval and consent to participate
The study protocol was approved by the Institutional Review Board of the Ethiopian Institute of Water Resources, Addis Ababa University and the Ethical Review Committee of Wollo University. Individual informed consent (written or witnessed thumb print) was obtained from all informants prior to the interviews following a verbal and written explanation of study aims and procedures. Informed assent was secured from the caregivers/guardians of study subjects under 18 years of age. Participation in the study was voluntary and confidentiality of the information was assured during as well as after data collection. Participants suspected of having malaria were referred to health centers for treatment.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Ethiopian Institute of Water Resources, Addis Ababa University, Addis Ababa, Ethiopia. [2]Department of Medical Parasitology, School of Biomedical & Laboratory Sciences, University of Gondar, Gondar, Ethiopia. [3]Department of Epidemiology and Biostatistics, University of California, San Francisco, USA. [4]Department of Epidemiology and Biostatistics, Institute of Public Health, University of Gondar, Gondar, Ethiopia.

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Declaration

I, the undersigned declare that this dissertation is my original work; it has not been presented in other universities, colleges or institutes for a degree or other purpose. All sources of the materials used have been duly acknowledged.

Name: Asmamaw Malede signature: date: 16/10/2019

This work has been done under my supervision.

Name: Dr. Kassahun Alemu	Signature-	Date: 11/10/2019
Dr. Mulugeta Aemero	Signature Mulugeta	Date: 26/09/2019
Dr. Sirak Robele	Signature	Date: 02/10/2019
Dr. Helmut Kloos	Signature Helmut Kloos	Date: 20/09/2019

ABABA UNIVERSITY

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ETHIOPIAN ONSTITUTE OF WATER RESOURCES

This is to certify that the thesis presented by **Asmamaw Malede Tarekegn entitled 'DETERMINANTS OF MALARIA INFECTION/TRANSMISSION, DOMINANT VECTOR SPECIES, AND BARRIERS OF BED NET UTILIZATION IN VILLAGES AROUND LAKE TANA, NORTHWEST ETHIOPIA'** is submitted in partial fulfillment of the requirements for **THE DEGREE OF DOCTOR OF PHILOSOPHY IN WATER AND HEALTH: SPECIALIZATION WATER AND PUBLIC HEALTH** complies with the regulations of the university and meets the accepted standards with respect to originality and quality.

Signed by the examining committee:

External Examiner: Prof. Argaw Ambelu Signature______ Date 13 Jan 2020

Internal Examiner: Dr. Bezatu Mengistie Signature______ Date 10/03/2020

Internal Examiner: Dr.Tadesse Awoke Signature______ Date 19-Feb-2020

Advisor: Dr. Kassahun Alemu Signature______ Date______

Dr. Mulugeta Aemero Signature______ Date 19 Feb 2020

Dr. Sirak Robele Signature______ Date 3/10/2020

Dr. Helmut Kloos Signature______ Date 11/03/2020

Chairman: Dr. Tekalign Ayele Signature______ Date 09 Mar 2020

Institute Director: Dr. Bayou Chane Signature______ Date 11/03/2020