EFFECTS OF BEDNET USE, TOPOGRAPHY AND TARGETED VECTOR CONTROL ON MALARIA TRANSMISSION IN THE HIGHLANDS OF VIHIGA AND KAKAMEGA COUNTIES, WESTERN KENYA

BY

ATIELI HARRYSONE ETEMESI (MPH)
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2012
DECLARATION

This thesis is my original work and has not been presented for a degree in any other university or any other award.

_________________________________________  ____________________________
Signature                                        Date

ATIELI HARRYSONE ETEMESI (MPH)

P97/15183/2008

We confirm that the work reported in this thesis was carried out by the candidate under our supervision

_________________________________________  ____________________________
Signature                                        Date

Dr. Isaac Mwanzo

Department of Community Health,

Kenyatta University

_________________________________________  ____________________________
Signature                                        Date

Dr. Andrew K. Githeko

Centre for Global Health Research,

Kenya Medical Research Institute

_________________________________________  ____________________________
Signature                                        Date

Prof. Guiyun Yan

Program in Public Health, College of Health Sciences,

University of California, Irvine, USA.
DEDICATION

I dedicate this thesis to: my mum Anjeline, dad Joshua; my wife Everlyne; my sons Rooney, Ramsey and daughter Natasha and my sister Roseline. They have always offered encouragement and support in my endeavours.
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LIST OF ACRONYMS

APS............................Asymptomatic Parasite Screening
CDC............................Centre for Disease Control
CM.............................Case Management
DALYs..........................Daily Adjusted Life Years
DEM............................Digital Elevation Model
DFID...........................Department for International Development
DOMC..........................Division of Malaria Control
f/h/n............................females/house/night
FGD.............................Focus Group Discussion
GDP..............................Gross Domestic Product
GIS.............................Geographic Information System
GPS.............................Geographic Positioning System
IEC..............................Information Education Communication
IMM.............................Intervention Malaria Management
IRS.............................Indoor Residual Spray
ITNS...........................Insecticide Treated Nets
IVC.............................Integrated Vector Control
KDHS...........................Kenya Demographic Health Survey
KEMRI..........................Kenya Medical Research Institute
KII.................................Key Informant Interview
KMIS...........................Kenya Malaria Indicator Survey
KNBS...........................Kenya National Bureau of Statistics
LLINs............................Long Lasting Insecticide Nets
MCP........................Malaria Control Program
PMCC........................Provincial Malaria Control Coordinator
PP..............................Personnal Protection
PSC............................Pyrethrum Spray Collection
RBM............................Roll Back Malaria
SSA............................Sub-Saharan Africa
WHO............................World Health Organization
ABSTRACT

Insecticide-treated bed nets (ITNs) are known to be highly effective in reducing malaria morbidity and mortality. However, there is scanty information on actual usage of owned nets which varies among households. Such variations may limit the potential effect of nets and cause spatial heterogeneity on malaria transmission. Likewise there is limited information and utilization of topographic parameters such as the shape of the underlying valley ecosystem in identification of high-risk malaria foci to help enhance surveillance and targeted vector control activities in regions where they are most needed. The objective of this study was to determine the effect of ITNs use, topography and targeted vector control on malaria transmission. The study was done in; Igulu, Mbale and Emutete in Vihiga and Kakamega counties, in malaria hypo-meso-endemic highlands of western Kenya. All houses in study sites were geo-referenced and mapped. Using a randomized-repeated cross-sectional study design, residents of 300 households randomly selected from each site in Igulu and Emutete were interviewed for ITNs ownership/usage, their houses sprayed for vector abundance and occupants screened of malaria during the dry and rainy seasons of 2009-2010. Association of topography and spatial distribution of malaria vectors and infections were determined between broad ‘U’-shaped versus narrow ‘V’-shaped valley ecosystems in the three sites. Baseline information from spatio-temporal data above was used to identify intense transmission areas for target vector control using Indoor Residual Spray (IRS) and Biological larviciding. Entomological and parasitological data were used for impact evaluation. Data was managed in excel spread sheets and analyzed by STATA software. Student t-test was done to determine differences in adult vectors and larval densities while Chi-square test was done to determine differences in occurrence of malaria infection prevalence. Univariate and multivariate analysis of Turkey HSD test was done to determine the most predictive independent variable for the occurrence of larvae, adult vectors and malaria cases. Despite ITN ownership reaching more than 71%, usage was low at 56.3%. The proportion of non-adherence to ITN use was significantly higher during the dry season than rainy season, 46.6% vs. 32.9% in Igulu ($\chi^2 = 12.42$, d.f. = 1, $P < 0.001$) and 53.4% vs. 41.8% in Emutete ($\chi^2 = 21.12$, d.f. = 1, $P < 0.0001$), respectively. Indoor resting female An. gambiae s.l. density was lower (43% t = 2.38, d.f. = 167, P = 0.02) in houses with functional ITNs. Infection prevalence for all age groups was significantly lower by 30% among net users compared to non-net users during the rainy season (OR 0.72, 95% CI 0.51-1.00, P < 0.05). Broad flat bottomed valleys had significantly high number of anopheles larvae per habitat (P=0.024 Tukey HSD test), indoor resting vector density (t=5.7, P<0.0001) and malaria infections (t=9.96, P<0.0001) than narrow valleys ecosystem during both seasons. Targeted vector control was associated with up to 61.3% reduction in indoor resting vector densities although the reduction/effect on malaria infection was not significant. The findings of this study highlight the wide gap between ITN ownership and usage and effect on malaria transmission. Likewise, it recognises the importance of topographic parameters on vector abundance and malaria transmission. Based on this study, there is need to sensitize households on sustained use of owned ITNs in order to optimize their role as a malaria control tool and the need to consider topographic parameters in identification of high-risk malaria foci and use of this in programmatic targeted vector control to fight malaria.
CHAPTER ONE: GENERAL INTRODUCTION

1.1 Background

Malaria is a vector-borne infectious disease caused by protozoan parasites of the genus *Plasmodium*. Malaria parasites are transmitted from person to person by the bite of an infected female Anopheles mosquito (Barry, 2005). Four *Plasmodium* species are responsible for human malaria: *Plasmodium falciparum*, *Plasmodium vivax*, *Plasmodium ovale* and *Plasmodium malariae*. Of the four species, *Plasmodium falciparum* is the most virulent parasite and is responsible for the majority of malaria related mortality. It is found in all malaria endemic regions of the world and is the most common human malaria parasite in Africa (WHO, 2005). Recent findings indicate that a fifth species, *Plasmodium knowlesi*, which causes malaria in macaques has been increasingly reported to infect humans in South East Asia (Vythilingam et al., 2008).

Malaria is a major public health problem in the tropics. Globally it is estimated that in the year 2010, there were 216 million cases of malaria and an estimated 655,000 deaths from malaria (WHO, 2011). Earlier estimates indicate that the burden of malaria exceeds 40 million disability adjusted life years (DALYs) (Lopez et al., 2006). In sub-Saharan Africa, 15% of all disability adjusted life-years are lost to malaria (Chima et al., 2003). According to 2006 estimates, globally 3.3 billion people were at risk of malaria. 41% of malaria endemic countries were found in the WHO African region. 247 million cases were reported worldwide; 86% of them in
Africa. 881,000 malaria deaths were estimated; 91% occurring in Africa (WHO, 2008b).

Malaria is one of the most important causes of morbidity and mortality in developing countries in the sub-Saharan Africa (SSA) (WHO, 2003). For instance, in Kenya, approximately 20 million people are exposed to stable malaria transmission every year, including 3.5 million children below the age of 5 years (KMIS, 2010). Case fatality is very high among children with an estimated death toll of 26,000 per year (WHO, 2011).

Historically malaria was a rare occurrence in the African highlands. Highland malaria in East Africa has a long recorded history dating back to the 1920s and 1950s when it was first reported (Garnham, 1948; Roberts, 1964; Githeko and Clive, 2005). The early highland malaria epidemics were not as severe or as frequent as they have been within the last two decades. For instance, from the 1960s to the early 1980s, there were virtually no recorded malaria epidemics in the East African highlands. In the recent past however, these areas have experienced frequent malaria outbreaks raising concerns that highland malaria may be on the increase (Lindblabe et al., 2000, Zhou et al., 2011). Fifteen percent of the African population lives in the highlands and is at high risk from the impacts of epidemic malaria particularly in the eastern and southern African regions (Worrel et al., 2004). Complications due to malaria such as severe anaemia (especially in children and pregnant women) and cerebral malaria are widespread posing a major health risk. Low birth weight caused by malaria is responsible for about 6 percent of infant mortality; for instance, in
Kenya, malaria accounts for 26,000 infant deaths annually. Malaria is also an economic burden, as it deprives Africa of U.S$ 12 billion every year in lost Gross Domestic Product (GDP) (Greenwood, 2004).

Several postulates have been advanced to explain increase in malaria epidemics in the highlands. Land use changes (Lindblade et al., 2000), climate change (Githeko et al., 2001; Zhou et al., 2004), changes in demographic patterns and cessation of mosquito and malaria control are among such efforts. These processes change the ecological balance and context within which disease vectors and parasites breed, develop, and transmit disease.

Malaria parasite transmission is often strongly associated with locality and Spatio-temporal distribution of vector species. This association has two main features: First, the disease is focused around specific mosquito breeding habitats and can be transmitted only within certain distances from them. Second, there is a marked clustering of persons with malaria parasites and clinical symptoms at particular sites usually households (Carter et al., 2000, Wanjala et al., 2011). Unlike those who live in endemic regions, the highland populations generally have low immunity (Ototo et al., 2011). This compounded with other factors such as environmental changes may enhance the likelihood of malaria epidemics among the highland population despite existing control efforts. This study investigated the effect of ITN ownership/use, topography and targeted vector control on malaria transmission and Spatio-temporal malaria vectors distribution during the dry and rain season in the highland areas of western Kenya.
1.2 Problem statement and justification

The regions of Africa situated in high altitudes (>1500 m) were free of malaria until the recent past (Hay et al., 2002). However, since the 1980s malaria has been increasing (Zhou et al., 2011). This resurgence has been reported widely.

In western Kenya highlands, malaria epidemics have spread from 3 to 15 districts during the last 13 years. The epidemics normally occur at the valley bottoms, which are poorly drained thus providing permanent mosquitoes breeding sites (Minakawa et al., 2004). In these highlands, it is noticed that the malaria epidemics are mainly located in the valley with declivity or depression in plateau where water collects and provides a suitable environment for mosquitoes to breed (Githeko et al., 2005). This situation has generated considerable public attention, because amongst the population living in these highland areas where there is little immunity, epidemic behaviour of malaria is always followed by high case fatality (Hay et al., 2002; Wanjala et al., 2011).

Though malaria epidemics have frequently occurred in western Kenya highlands, more efforts are still required to outline the epidemiology of malaria in the study areas of western Kenya Highlands. Since the year 2004, the government of Kenya and its partners through the ministry of health (MOH) has provided subsidized Bednets to populations in these affected areas. Likewise the government has targeted IRS in 3 endemic districts and those at endemic fringes in western Kenya. Since the scale-up of ITNs and introduction of IRS 5 years ago, there have been reports of
reduction in malaria cases mostly in endemic zones (KMIS, 2010). Despite these control efforts, limited success has been reported in the low transmission zones like the highlands regions of western Kenya where transmission was reported to increase (KMIS, 2010; Zhou et al., 2011). There have been limited studies to evaluate the actual utilization and effect of owned ITNs as an intervention tool on both malaria vectors and transmission in low to moderate malaria transmission highlands of western Kenya. Most ITNs evaluation studies have focused mainly endemic lowland areas. This study was therefore seeking to describe the entomological and parasitological patterns of malaria through; 1) Use of Insecticide treated bednets in the highlands which would be important in understanding the possible effects of ITN on malaria incidences and vectors distribution and abundance, 2) Determining the role of topography (shape of valley bottoms-“U” and “V” shaped valley ecosystems) as a characteristic feature of the highlands, on the occurrence/abundance of malaria vectors and transmission, and 3) Evaluating the effect of targeted vector control on entomologic and parasitological indicators of malaria transmission. The results of this study will contribute new knowledge in determining malaria high transmission spots, prediction, planning, programmatic implementation and measurement of the effectiveness of interventions to reduce malaria transmission in western Kenya highlands.
1.3 Research questions

1. What are the current ownership and utilization levels of ITNs in the highlands of western Kenya?

2. What is the effect of ITNs ownership and actual usage on the occurrence and distribution of malaria vectors in the highlands of western Kenya?

3. What is the effect of ITNs ownership and actual usage on malaria transmission in the highlands of western Kenya?

4. What is the role of topographic parameter ("U" and "V" shaped valley ecosystem) on the occurrence and spatio-temporal distribution of malaria vectors in the highlands of western Kenya?

5. What is the association between topographic parameter ("U" and "V" shaped valley ecosystem) and risk of malaria infection in the highlands of western Kenya?

6. What is the effect of targeted malaria vector control through IRS and larviciding on the occurrence and distribution of malaria vectors and malaria transmission in the highlands of western Kenya?
1.4 Objectives of the study

1.4.1 General objective

The main objective of this study was to determine the effect of ITN ownership/use, topography and targeted malaria vectors control on malaria transmission in selected areas of the western Kenya highlands.

1.4.2 Specific objectives

1. To determine the current ownership and utilization levels of ITNs in the highlands of western Kenya.
2. To determine the effect of ITNs ownership and actual usage on the occurrence and distribution of malaria vectors in the highlands of western Kenya.
3. To determine the effect of ITNs ownership and actual usage on malaria transmission in the highlands of western Kenya.
4. To determine the role of topographic parameter (“U” and “V” shaped valley ecosystem) on the occurrence and spatio-temporal distribution of malaria vectors in the highlands of western Kenya.
5. To determine the association of topographic parameter (“U” and “V” shaped valley ecosystem) and risk of malaria infection in the highlands of western Kenya.
6. To evaluate the effect of IRS and larviciding targeted malaria vector control on the occurrence and distribution of malaria vectors and malaria transmission in the highlands of western Kenya.
1.5 Hypotheses

a) $H_0$: There are no variations in the current ITNs ownership versus utilization levels in the highlands of western Kenya.

b) $H_0$: ITNs ownership and actual usage have no effect on the occurrence and distribution of malaria vectors in the highlands of western Kenya.

c) $H_0$: ITNs ownership and actual usage have no effect on malaria transmission in the highlands of western Kenya.

d) $H_0$: Topographic parameter (“U” and “V” shaped valley ecosystem) have no effect on the occurrence and spatio-temporal distribution of malaria vectors in the highlands of western Kenya.

e) $H_0$: There are no associations between topographic parameter (“U” and “V” shaped valley ecosystem) and risk of malaria infection in the highlands of western Kenya.

f) $H_0$: Targeted malaria vector control using IRS and larviciding has no effect on occurrence and distribution of malaria vectors and malaria transmission in the highlands of western Kenya.
1.6 Conceptual framework

The conceptual framework below shows the interplay between the independent and dependent variable in the study (Figures 1.1 and 1.2). Depending on the epidemiology of malaria, people are at risk of acquiring infection due to factors related to environment, climate, demographic and socio-economic status. Strong malaria control program (MCP) and health care system with adequate global and national support, prevention and control of malaria using early diagnosis & prompt treatment, and vector-control strategies have a significant effect on reducing malaria morbidity and mortality. Prevention methods inhibit the establishment of infection or suppress the progression of the parasite after infection. Access to early diagnosis and prompt treatment with effective antimalarial drug significantly reduce the severity of the illness, which will ultimately affect malaria mortality. A related factor is the perception of people about what causes malaria, their understanding of early treatment with appropriate antimalarials, the use/adherence of personal preventive methods and participation in disease prevention.
The above concept was used to develop the adopted conceptual framework below (Figure 1.2). The framework shows the interplay between the main variables that determine the heterogeneity in malaria burden within the highlands. The highlands region characterized by ragged terrain, hills and valleys topography plays a major role in rainfall based seasonal malaria transmission. Likewise, individual household characteristics such as, education levels, presence and utilization of personal vector protection tools, distance to breeding source/valley bottom and demography, determines the abundance of vectors and subsequent malaria transmission.
Figure 1.2 Adopted conceptual framework of malaria burden from Figure 1.1
(Source: Measure Evaluation, 2010)

1.7 Significance and Anticipated Output

The study was expected to determine actual utilization rates of current presumed high percentage of owned ITNs and the effects of this important malaria control tool in hypo-meso endemic malaria transmission highlands area. Likewise information on reasons for non-adherence to ITN use will be valuable for sensitization and scaling
up utilization. Data on topography and adult mosquitoes and malaria transmission Spatio-temporal distribution from objective 1 and 2, was used to identify high intensity diseases transmission areas (‘Hot spots’). Targeted vector control using IRS and larviciding was done in these identified areas during low and high transmission seasons. Targeted vector control approach is expected to maximize reduction in malaria vectors with subsequent reduced transmission with use of minimal resources and cost.

1.8 Study limitations

The study captured at least 300 randomly selected houses in a 4 x 4 Kilometre area in each selected region within Kakamega and Vihiga County. This was expected to be representative enough of the households’ malaria situation in the highland region. The most probable limitation was bias in participants report on bednet use behaviour. Some participants might not have reported genuinely whether they use or own any nets. This scenario was controlled by physical observation of nets presence or use by field staff to verify responses given by participants.
CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter starts by giving literature on the life cycle of the mosquito as the malaria vector and also that of malaria parasite. It highlights the general situation of malaria in the World, Africa and Kenya. Consequently, the chapter gives a detailed account of malaria in the Highlands of Western Kenya as the centre of the study interest. The chapter equally focuses on some of the major determinants (role of topography as a determinant in malaria spatial distribution), and intervention approaches aimed at controlling malaria. Literature on malaria determinants and interventions is to identify the study objectives with existing control efforts in the area of study. Some of the interventions discussed in this chapter are; IRS application for vector control and its effect on malaria transmission, ITNs as an intervention tool and finally targeted vector control as a cost effective approach in malaria intervention.

2.2 The Mosquito Life Cycle

Mosquito life cycle consists of four stages: egg, larva, pupa and adult (Figure 2.1). These stages are divided between two different habitats namely: aquatic and terrestrial. Egg, larva and pupa are always aquatic while adults are terrestrial as classified by Kreir (1980). Mosquitoes mate soon after pupal exclusion. Female mosquitoes of most species require a blood meal to obtain the necessary nutrients for ovarian development. Once the blood is digested the gonotrophic stage of the mated female adults changes from blood fed to half gravid and then to gravid. Gravid
female then oviposits their eggs in stagnant aquatic habitat. Egg hatching occurs in response to low oxygen tension, a condition that develops in standing water once micro-organisms begin to flourish in it as found by Harwood and James (1979). Eggs hatch into larva within 2 - 3 days in the tropics. Mosquitoes have special adaptations for moving, breathing, feeding in aquatic environment and pass through four instars which then develop into a pupa and eventually emerge into adult. A larva moults three times resulting into a pupa. According to Munga, (2006) and Kweka, (2011) larval development is species, temperature and food availability dependent. About 4 – 10 days depending on the temperature are required for the completion of larval development under optimum food conditions in the tropics. The pupa stage consists of single instar and is very short lasting about 2 – 3 days. The pupa is very active and sensitive to disturbances and emerges into adult mosquito which disperses thus perpetuating the life cycle.
2.3 The Life Cycle of the Malaria Parasite

Understanding the malaria lifecycle is useful for a full appreciation of the complexities of treatment, prevention and surveillance. For example life cycle biology identifies several points where the malaria parasite can be damaged or destroyed. For example, Artemisinin drugs have the ability to target parasites in the erythrocytic stages which prevents the growth and spread of *plasmodium* (Dundorp *et al.*, 2010).

Figure 2.1 Mosquito life cycle [Source: http://ocw.jhsph.edu/].
The malaria parasite has a complex life cycle involving both asexual and sexual stages with obligatory phases in both humans and female Anopheles mosquito (Figure 2.2).

Figure 2.2 Life cycle of the malaria parasite [Source: http://ocw.jhsph.edu/].
Malaria infects both humans and mosquitoes spending its lifecycle partly in the mosquito and partly in the human host. The mosquito acts as the ‘vector’ to carry infection from one person to another (Wirth et al., 2002). Human stage: When a female Anopheles mosquito takes a blood meal on a human, it injects parasites from its salivary glands into the human blood stream. The parasites injected into the human are in their sporozoite form. Sporozoites then enter the liver cells and reproduce. These liver cells eventually rupture and release merozoites into the blood. The human blood stage is when these merozoites invade the red blood cells, reproduce and rupture red blood cells. This is often the stage when clinical features such as fever and chills begin. It is also the stage that is targeted by many antimalarial drugs. Some of the merozoites differentiate into becoming male or female gametocytes (CDC, 2010). Mosquito stage: When another Anopheles mosquito takes a blood meal from an infected human it will then ingest these gametocytes; microgametocytes (male) and macrogametocytes (female). While in the mosquito gut, the fertilised gametes fuse into a zygote and become ookinetes. Ookinetes which traverses the mosquito gut wall develop into sporozoites-filled oocysts. These oocysts grow, rupture and release more sporozoites. The sporozoites travel up to the mosquito’s salivary glands and are injected into the human during another blood meal. Thus, the process begins again (CDC, 2010).

2.4 Malaria occurrence and distribution

Malaria, which is the world’s most common and debilitating disease is currently restricted to the tropics (mainly tropical Africa and Central America and Asia) and sub-tropics where its vector Anopheles species is widely distributed (Hay et al.,
2010). The disease is mainly found in sub-Saharan Africa, where it causes high case fatalities. In other parts of the world the disease occurs in Asia and Central America where it is transmitted by An. culifacies and An. oswaldoi, An. albimanus, and An. darling, respectively among other species.

Occurrence of anopheline species is often associated with the occurrence and distribution of malaria as earlier reported by Carter (2000). The distribution and the occurrence of the disease are limited by environmental and climatic factors (Hay et al., 2010). These factors govern the distribution of insects either by acting directly on their populations or by affecting the structure of the ecosystem they inhabit. Climatic factors influence the distribution of malaria by limiting the development of the causative agents Plasmodium species both in man and mosquitoes (Hay et al., 2002; Afrane et al., 2006). For example, higher temperatures may influence the survivorship and the development of the vector species (Afrane et al., 2006; Bayoh and Lindsay, 2004). Thus in areas where temperatures are low such as some highland regions even within the tropics, malaria have been a rare occurrence (Lindblade et al., 2000).

2.4.1 Malaria in the World

Malaria is world's most widespread infection. According to the World Malaria Report (WHO, 2010), malaria is prevalent in 106 countries of the tropical and semitropical world, with 35 countries in central Africa bearing the highest burden of cases and deaths (WHO, 2010). Compared to a century earlier, the area of malaria risk has reduced from 53% to 27% of the Earth’s land surface and the number of
countries exposed to some level of malaria risk has fallen from 140 to 106 (WHO, 2010; DFID, 2010). In 2007, 2.37 billion people were estimated as being at risk of \( P. falciparum \) malaria worldwide, with 26% located in the WHO AFRO region compared to 62% in the combined SEARO-WPRO regions (DFID, 2010). Of this total population at risk, about 42% or almost 1 billion people lived under extremely low malaria risk (DFID 2010).

There are five Plasmodia species that infect human beings (\( P. falciparum, P. vivax, P. malariae, P. ovale \) and \( P. knowlesi \)). Of the five species, \( P. falciparum \) and \( P. vivax \) cause the significant majority of malaria infections. \( P. falciparum \), which causes most of the severe cases and deaths, is generally found in tropical regions, such as sub-Saharan Africa and Southeast Asia, as well as in the Western Pacific and in countries sharing the Amazon rainforest. \( P. vivax \) is common in most of Asia (especially Southeast Asia) and the Eastern Mediterranean, and in most endemic countries of the Americas (Hay et al., 2010).

Estimates of the annual incidence of malaria vary widely. The World Malaria Report, 2010 estimated about 225 million cases of malaria in 2009 and about 90% being due to \( P. falciparum \) (WHO, 2010). However, Hay et al., (2010) estimated the number of clinical cases of \( P. falciparum \) malaria in 2007 at 451 million (95% credible interval 349-552) (Hay et al., 2010). About 60 and 87% of \( P. falciparum \) cases occur in Africa with nineteen countries in Africa – Rwanda, Angola, Zambia, Guinea, Chad, Mali, Malawi, Cameroon, Niger, Burkina Faso, Côte d'Ivoire, Ghana, Mozambique, Uganda, Kenya, United Republic of Tanzania, Ethiopia, Democratic Republic of the Congo and Nigeria – accounting for 90% of all WHO estimated cases in 2006.
(DFID, 2010). Hay et al. (2010) reported that more than half of all estimated *P. falciparum* clinical cases occurred in Nigeria, the DRC, Myanmar (Burma) and India.

*Plasmodium vivax* is transmitted in 95 countries in tropical, sub-tropical and temperate regions, (Guerra et al., 2010) except where there is a natural absence of anopheline mosquitoes (east of Vanuatu in the South Pacific) or among populations lacking the Duffy receptor on red cells (in much of Africa) (Baird et al., 2009). It is only *P. vivax* malaria that occurs in the temperate latitudes — up to the Korean peninsula and across the southern temperate latitudes of Asia to the Mediterranean Sea (Collins et al., 2007). Approximately 2.6 billion people are at risk of infection with *P. vivax* malaria, and the ten countries with the highest estimated population at risk, in descending order, are India, China, Indonesia, Pakistan, Viet Nam, Philippines, Brazil, Myanmar, Thailand and Ethiopia (Guerra et al., 2010; Baird et al., 2009). Estimates of annual infections range from 70 to 390 million, with about 80% occurring in South and Southeast Asia (Price et al., 2007, Baird et al., 2009). Approximately 10-20% of the world's cases of *P. vivax* infection occur in Africa, south of the Sahara (WHO, 2010). In eastern and southern Africa, 10% of malaria cases are due to *P. vivax*, whereas it accounts for <1% of cases in western and central Africa. Outside of Africa, *P. vivax* accounts for >50% of all malaria cases and about 80-90% of *P. vivax* outside of Africa occurs in the Middle East, Asia, and the Western Pacific and 10-15% in Central and South America.

*Plasmodium malariae* is wide spread throughout sub-Saharan Africa, much of southeast Asia, into Indonesia, and on many of the islands of the western Pacific. It is
also reported in areas of the Amazon Basin of South America (Collins et al., 2007). *P. ovale* is found in Africa and sporadically in Southeast Asia and the Western Pacific. *P. malariae* and *P. ovale* contribute to only a small number of malaria infections, but the incidence of *P. malariae* is probably underestimated. *P. knowlesi* is a primate malaria species that is being increasingly reported from remote areas of Southeast Asia from countries such as Malaysia, Thailand, Viet Nam, Myanmar and Philippines (Cyrus et al., 2009; Chaturong et al., 2009).

According to the World Malaria Report, 2010, the number of deaths annually due to malaria was estimated at 781,000 in 2009 (WHO, 2010). For the year 2010, the malaria mortality was estimated at 655,000 by the WHO (WHO, 2011). Of the 35 countries that accounted globally for ~98% of malaria deaths, 30 were located in sub-Saharan Africa, with four countries (Nigeria, Democratic Republic of Congo, Uganda and Ethiopia) alone accounting for ~50% of deaths on the continent (WHO, 2010). However, a recent systematic analysis by Murray (2012) has estimated that the global malaria deaths increased from 995 000 in 1980 to a peak of 1,817,000 in 2004, decreasing to 1,238,000 (929 000—1 685 000) in 2010 (almost double of the WHO estimate for the same year) (Murray et al., 2012). This study estimated more deaths in individuals aged 5 years or older than has been estimated in previous studies: 435,000 (307 000—658 000) deaths in Africa and 89,000 (33 000—177 000) deaths outside of Africa in 2010 (Murray et al., 2012).
2.4.2 Malaria in Africa

Malaria is generally endemic in the tropics, with extension into the sub-tropics. In Africa malaria is mainly extensive, prevalent and is on the increase even in the regions that were previously considered malaria free. In the sub-Saharan region of Africa malaria is mainly transmitted by members of the *Anopheles gambiae* complex as first reported by Gillies and De Meillon (Gillies and De Meillon, 1968). Earlier studies by Carter et al found that larvae and pupae of these vectors mainly develop in habitats that are close to human dwellings (Carter *et al.*, 2000). The major parasite which causes malaria in the SSA, is *Plasmodium falciparum* though mixed infections of *Plasmodium malaria* and *Plasmodium vivax* have been found in some countries in Sub-Sahara Africa (Genton *et al.*, 2008).

Malaria is still one of the most important causes of morbidity and mortality in developing countries in the SSA (WHO, 2010). In Africa stable malaria predominates throughout the continent, however epidemics occur at the fringes of the endemic areas, particularly among communities at the northernmost latitudes, across the arid regions of North Africa, and mostly among the highlands of East, Central and Horn of Africa (Hay *et al.*, 2010). Distribution of malaria varies greatly from country to country and is dependent on the flight range of the vector from breeding habitats (www.micro.msb.le.ac.uk/224/Bradley/History.html). The maximum flight range appears to be 2 – 3 km in Africa but may exceed 5 km in some areas such as in the Americas.
Most *falciparum* malaria cases and a high proportion of malaria deaths originate from the Africa region. In this region, malaria accounts for a third of all hospital admissions, and up to a quarter of all deaths under the age of five (Murray *et al*., 2012). However, there have been encouraging declines in the disease burden of malaria in some countries in SSA over the last five years (Prudhomme *et al*., 2011). In the Horn of Africa, country-wide surveillance in Ethiopia and Eritrea has shown a 70% reduction in malaria morbidity. Similar patterns have been reported in East Africa; for example paediatric malaria admissions in the coastal area of Kenya declined by as much as 75% between 2003 and 2007 (Okiro *et al*., 2007), although this varies across the country (Okiro *et al*., 2009).

In West Africa, surveillance from five healthcare facilities in Gambia showed a 50-85% decline in prevalence of slide confirmed malaria between 2003 and 2007 (Ceesay *et al*., 2008), a trend that has continued through to 2009 (Ceesay *et al*., 2010). Zanzibar, Tanzania, Zambia, South Africa, Mozambique, Ethiopia and Rwanda have also had reliable reports of malaria cases dropping, sometimes dramatically (Bhattarai *et al*., 2007; Mmbando *et al*., 2010; Barnes *et al*., 2009; Otten *et al*., 2009). Whilst evidence of a decline is strong, some caution should be used in interpreting its exact extent however, as many reports are based on health attendance data which have a number of obvious and less obvious flaws, including that there are changes in patterns of referral over time, that many cases do not reach formal healthcare, and that as diagnosis has improved so the number of non-malaria cases attributed to malaria has declined (Rowe *et al*., 2009). Nevertheless recent reports do provide solid evidence that, where effective anti-vector methods are combined with
Artemisinin-based antimalarials in countries that are developing economically, significant reductions in malaria can be achieved in previously high-burden African countries. In contrast, limited data from Central Africa shows little change in the malaria burden in Brazzaville-Congo and the DRC (Guerra et al., 2010; WHO, 2010). In central and western parts of SSA, where the greatest burden of disease falls, there is no evidence of any decline in malaria cases, although this is largely due to the absence of any evidence, rather than good evidence that a decline (or increase) has not occurred.

2.4.3 Malaria in Kenya

Malaria is the leading cause of morbidity and mortality in Kenya. More than 70% of the Kenya’s population reside in areas where malaria is transmitted. Malaria is responsible for approximately 30% of out-patient visits (requiring more than eight million out-patient treatments each year), and 19% of all hospital admissions. At least 14,000 children are hospitalized annually for malaria, and there are an estimated 34,000 deaths among children under-five each year. Annually, an estimated six thousand pregnant women suffer from malaria-associated anaemia, and four thousand babies are born with low birth weight as a result of maternal anaemia. Economically, it is estimated that 170 million working days are lost each year because of malaria illness (Kenya, 2009). In 2006, an estimated 11.3 million malaria cases occurred in Kenya, making it one of the five countries contributing over half of malaria cases reported in the WHO African region. Between 2001 and 2006, the number of reported cases in Kenya increased in four out of five years (WHO, 2008b).
Kenya has four malaria epidemiological zones (Figure 2.3); endemic areas along the shores of Lake Victoria and the south coast where malaria transmission is perennial but peaks from June to August and again in late November; 2) highly populated epidemic-prone areas in the highlands; 3) epidemic prone areas in the arid/semi-arid lowlands which are sparsely populated; and 4) very low risk or transmission-free areas in the highlands above 2,000 meters. Transmission in the epidemic-prone/seasonal areas is highest from April through June.
Increasing evidence shows that the epidemiology and risk of malaria in Kenya declined between 1999 and 2009 (KMIS, 2010). A comparison of previous malaria
maps and recently updated maps on malaria prevalence shows the shrinking of malaria endemic areas and expansion of low transmission zones (KMIS, 2010). It is estimated that 60–70 per cent of the Kenyan land mass has a parasite prevalence of less than 5 per cent where 78 per cent of the population of Kenya lives. On the other hand, there is also a decline in the level of endemicity in endemic areas characterized by a reversal in the age group with the highest prevalence between children less than five years old and those 5–15 years of age.

2.4.4 History of Highland malaria in Kenya

Highland malaria is classified as being unstable or epidemic occurring at altitudes above 1500 m (Hay et al., 2002, KMIS, 2010). Malaria epidemics are common only in areas of unstable ecosystems where any slight modification in any of the transmission factors may upset the equilibrium. In the western Kenya highlands, malaria did not exist until the second decade of the 20th century as first reported by Matson (Matson, 1957). The completion of the railway line from the Kenyan coast across the highlands and down to Lake Victoria in 1901 coupled with increased road transport appear to have facilitated the gradual spread of infective mosquitoes into the highlands from the low-lying hyper-endemic disease areas. The development of the tea estates and agriculture in the highlands, with the concomitant clearing of the forests, may have created suitable mosquito breeding grounds (Roberts, 1964). Earlier studies by Garnham reported that importation of malaria-infected labourers to work in extensive highland agriculture farms likely completed the conditions necessary for malaria transmission (Garnham, 1948). After the introduction of
malaria into Kenyan highlands, the disease continued to be a serious public health problem until the 1950’s when the extensive control program essentially eliminated the disease in the 1960s (Roberts, 1964). Thereafter, highlands were considered to be free of malaria through the 1960’s but since the 1980’s malaria epidemics reappeared and it has been on the increase since then (Zhou et al., 2011).

Malaria epidemics occur in areas of altitude of between 1500 - 2200 m above sea level with annual mean daily temperature ranging from 18 – 20 °C (Parham et al., 2010). Changes in climatic conditions especially temperature and rainfall in the highlands affect the development of mosquitoes and malaria parasites (Parham et al., 2010). Warmer temperatures accelerate mosquito larval development, frequency of blood feeding by adult females on human and reduce the time it takes for malaria parasite to mature in female mosquitoes (Afrane et al., 2006). On the other hand increase in rainfall amounts increase the availability of breeding habitats (Krefis et al., 2011).

2.4.5 Epidemiology of Malaria in the Highlands of Western Kenya

Malaria epidemics in western Kenya highlands are usually associated with high morbidity and mortality in all age groups, with prevalence of the disease rising from about 20% to about 60% (KMIS, 2010). Earlier studies by Some (1994) and Khan (1992) indicated the resurgence of malaria in the highlands. These studies reported that the cases of mortality in functional health facilities were estimated at about 7.5%.
According to Some, (1994) an increase of between 2.2 to 8.6 times in deaths was attributed to malaria during an epidemic in Uasin Gishu district in western Kenya. Malaria proportionate deaths peaked at 75% with case fatality rates not being different from those of the periods before and after the epidemic. Most malaria-related cases deaths (62.1%) occurred in Eldoret district hospital during that time. High mortality cases (92.3%) were reported from near Turbo rural demonstration health centre. There were 3.7 times increase in the number of patients with primary clinical diagnosis of malaria in the hospital at the peak of the epidemic than there were usually (Khan et al., 1992). These reports indicated a resurgence of malaria in the highlands of western Kenya hence raising an alarm for need to investigate and understand its epidemiology. Although studies have confirmed a fall in malaria cases in the country, most of these reductions are observed in the endemic zones. Despite intervention efforts by the Kenyan government together with its partners (Presidents Malaria Initiative-PMI, Rollback Malaria, Global fund) to control malaria, several studies have shown an increase in malaria within the epidemic prone and low transmission zones. A systematic study by Zhou et al (2011) has reported a fall and rise of malaria in the highlands of western Kenya. Likewise, the Kenya Malaria indicator survey (KMIS) reported decrease in malaria within endemic zones but with increase in low transmission zones like the highlands of western Kenya (KMIS, 2010). Given the current intervention scale-up efforts where the country has done more efforts to achieve universal LLINs coverage and with targeted IRS in endemic and regions at the fringe of endemic zones, malaria is expected to reduce significantly. Following this current unfortunate reports of continued occurrence and even raise in malaria cases in these regions, this study was carried out to find: 1)
Some of the possible reasons why the effect of existing intervention tools such as mosquito bed nets with their well known efficacy are not significantly realised, 2) If the topographic characteristic of the highlands play a role on malaria vectors and disease transmission distribution as a unique characteristic of the highlands compared to the endemic lowlands that are characterised by flat terrain, 3) The effect of targeting vector control efforts using IRS and larviciding in malaria high transmission spots found within epidemic prone and low transmission zones given the heterogeneity in malaria transmission in these regions as compared to the lowlands which exhibit homogeneity.

2.5 Topographic parameters and malaria transmission

Research indicates that the mechanisms leading to epidemic malaria in the highlands are complex and are probably due to the concerted effects of factors such as topography, hydrology, climate variability, land-use/land-cover change, and drug resistance. Effective disease control calls for a clear understanding of the interaction between these epidemiologic factors (Githeko and Clive, 2005).

The prevalence of malaria in the highlands of Eastern Africa varies spatially and temporally as a result of seasonal weather changes, climate variability and topography (Abeku et al., 2003; Balls et al., 2004). The topography of the highlands comprises hills, valleys and plateaus. Rivers and streams running along the valley bottoms in the valley ecosystem and swamps are a common feature. Unlike in lowland plains, where drainage is poor and mosquito breeding habitats have an extensive distribution, the majority of breeding habitats in the hilly highlands are
confined to the valley bottoms because the hillside gradients provide efficient drainage (Minakawa et al., 2004). The non-homogeneous distribution of larval breeding habitats is likely to affect adult vector spatial distribution and may, consequently, lead to focal malaria transmission and heterogeneous human exposure to malaria. It can thus be expected that the malaria immunity profile in the highlands is influenced not only by age, but also by distance from the foci of transmission. The pattern of malaria transmission in the highland plateau ecosystems may be less distinct due to the flat topography and the more diffuse hydrology resulting from numerous streams. Heterogeneity in transmission can lead to highly variable stability of malaria transmission in space with some areas having stable and others unstable transmission. This would lead to different sensitivities to epidemics within relatively short distances.

The topographic features of the highlands restrict the spatial distribution of vector breeding habitats. Earlier work in the same site has demonstrated that larval breeding habitats are confined to the valley bottom and hence a low intensity of exposure to malaria in hilltop residents resulting in a non-homogeneous parasite burden and probably the incidence of morbidity (Munga et al., 2006). This unique epidemiology has important implications in the development of malaria control strategies. Furthermore, it indicates that failure to take topographic effects on transmission into consideration can lead to biased data on the spatial distribution of malaria prevalence in the highlands.

Transmission of *Plasmodium falciparum* generally decreases with increasing elevation, in part because lower temperature slows the development of both parasites
and mosquitoes. However, other aspects of the terrain, such as the shape of the land, may affect habitat suitability for Anopheles breeding and thus risk of malaria transmission. This study would lead to understanding these local topographic effects in terms of valley shapes (“U” and “V” shapes) that may permit prediction of regions at high risk of malaria within the highlands at small spatial scales and thus employ appropriate control methods.

2.6 Malaria Control

The World Health Organization advocates the combined use of all the proven strategies and available malaria control tools as the most effective way to check the spread of malaria (Utzinger et al., 2002). These methods include the simultaneous application of a range of malaria control tools targeting malaria *Plasmodium* parasites in humans through case management (CM), the mosquito vector through integrated vector control (IVC) and personal protection (PP). Case management is the use of anti-malaria medicines (Winstanley et al., 2006) to remove malaria parasites from the human host to prevent transmission to the mosquito vector, thus preventing the spread of new malaria infections. Integrated Vector Control is the use of adult mosquito killing measures such as indoor adulticide sprays (Mabaso et al., 2004) and environmental management to remove the mosquito breeding sites, thus lowering the population densities of malaria vectors. Personal protection includes measures such as insecticide treated nets (Kitua et al., 2008), indoor residual sprays and window and door screens. The use of all these measures together is called Integrated Malaria Management (IMM). Its principle strength is that each individual intervention contributes to the overall reduction of the malaria burden in the
population when applied in a practical, economically sustainable manner in the community while protecting the environment. Although the use of ITNs alone has been shown to reduce morbidity and mortality due to malaria (Nahlen et al., 2003), there is an additive value when used together with effective antimalarial medicines, indoor residual sprays and environmental management. However, there is a dearth of information on the use of IMM that includes environmental management and its effect on malaria transmission parameters in Kenya and Africa as a whole. Figure 2.4 shows chronological major anti-malarial policy changes in Kenya since the year 2000 in the effort to scale-up intervention efforts.

Figure 2.4 Major anti-malarial policy changes in Kenya since 2000
2.6.1 Malaria parasite management

Antimalarial medicines can also be used to prevent malaria. This antimalarial suppresses the blood stage of malaria infections, thereby preventing malaria disease. There are several approaches of using antimalarials for malaria prevention. For instance, WHO recommends intermittent preventive treatment with sulfadoxine-pyrimethamine for pregnant women living in high transmission areas, during the second and third trimesters. Similarly, for infants living in high-transmission areas of Africa, 3 doses of intermittent preventive treatment with sulfadoxine-pyrimethamine is recommended delivered alongside routine vaccinations. For travellers, malaria can be prevented through chemoprophylaxis. In 2012, WHO recommended Seasonal Malaria Chemoprevention as an additional malaria control strategy for areas of the Sahel sub-Region of Africa. The strategy involves the administration of monthly courses of amodiaquine plus sulfadoxine-pyrimethamine to all children under 5 years of age during the high transmission season.

2.6.2 Mosquito larvae management

Larval control can be attained through environmental management, large space coverage, and community participation, and can be done through chemical or biological control. Larval control of mosquitoes either through source reduction, larviciding or a combination of these is a preferred method of reducing the abundance of adult mosquitoes in many parts of the world (Muller et al., 2001). Larvae tend to breed everywhere in a small amount of water on the surface of the
ground. This characteristic makes their control approach viable only under suitable mapping and characterization of breeding sites, and may work mainly in urban and peri-urban areas. Larviciding has been reported to successfully reduce habitat larvae densities by up to 36% and with prospects of reducing adult vectors and subsequently reduce malaria transmission by a study done in urban and peri-urban region at the Kenyan coast (Mwangangi et al., 2011). Larviciding has a major advantage in killing the vectors before they disperse and transmit disease (Killeen et al., 2002). Due to the inability of the larvae to move and avoid chemicals applied, larviciding therefore is an efficient method of controlling mosquitoes. At the same time application of larvicides does not need expensive equipment and, can be locally organised and is highly acceptable in the community (Kibe et al., 2006).

### 2.6.3 Adult mosquitoes control strategies

There are a few major vector control strategies that target the adult mosquitoes; Indoor spraying of insecticides, personal protection measures, and environmental control. Indoor spraying has been relied on as a vector control strategy in the past and showed clearly if it is properly implemented can yield significant reduction in malaria transmission. However it faces difficulties due to sustainability and cost effectiveness, but it can still be a good choice under certain circumstances, like in high-mortality endemic areas and in drug resistant areas. This raises the need of being quite selective, having a very good target and understanding where to apply the method. Personal protection measures are based on insecticide-impregnated materials such as bed nets and curtains mainly. Likewise this strategy faces implementation
and adherence problems. It has been demonstrated that if bed nets are properly applied they can provide a 30 to 60 percent reduction in malaria morbidity, and can be useful in terms of preventing drug resistance.

Environmental control is used to prevent breeding, resting, and feeding of vectors by source reduction and even through better housing, windows, doors, screening. Environmental changes from road, dam, or pipeline construction, deforestation, agriculture, and irrigation can generate larval breeding sites. Environmental control can mostly be used in urban and peri-urban areas, and mostly require community participation and inter-sectoral collaboration. Below are insights on the major vector control strategies.

2.6.3.1 Indoor Residual Spray (IRS)

The effectiveness of IRS is well established (WHO, 2006). The rationale for IRS is based on the behaviour of the principal vector species that are endophilic and endophagic; rest indoors on walls before and after a blood meal (Sindato et al., 2011). For a long time, IRS has been one of the most effective ways of controlling malaria by reducing vector population density, shortening vector life span, and human-vector contact. IRS programmes eradicated malaria from the USA and Europe, and were dramatically successful in many poor countries with endemic malaria, such as, India, Sri Lanka, (Roberts et al., 2004) and much of South Africa (Romi et al., 2002). Control programs during the post war years showed that, well coordinated and focussed IRS can reduce malaria burden. IRS remains a vital malaria control tool in many parts of Africa, Asia and Latin America. For instance, South Africa has successfully used IRS to keep malaria under control for more than 50
37

years. Also Swaziland, Namibia, Zimbabwe and Botswana have sustained a well-managed IRS programme. In Zanzibar, IRS suppressed malaria infections from holo-endemic levels to below 5% (Curtis et al., 2000). Likewise, initial baseline surveys of targeted vector control using IRS reduced malaria vectors population by 95% for five months in the highlands of western Kenya (Zhou et al., 2007). This study therefore shades more light by providing data to support this phenomenon through targeted vector control using IRS in different sites in the highlands of western Kenya.

2.6.3.2 Insecticide Treated Nets (ITNs)

Roll Back Malaria has adapted ITN use as a major tool for the achievement of its malaria control objective. ITNs were introduced during World War II when a half of American servicemen were stricken by malaria. A number of studies have demonstrated that use of insecticide treated nets (ITNs) is effective and cost friendly in reducing malaria related morbidity and mortality (Alonso et al., 1993; D’Alessandro et al., 1995; Nevill et al., 1996; Hawley et al., 2003). A remarkable decrease in vector numbers in intervention communities supplied with ITNs and positive effects have been reported for untreated houses close to intervention area in western Kenya (Gimnig et al., 2003). This demonstrated community wide protection effect of ITNs as an intervention tool.

Insecticide-treated bed nets (ITNs) as a new tool in malaria control have received considerable interest over the last two decades. A number of large-scale randomized controlled trials, in which children have partly been followed-up for extended periods of time, have consistently demonstrated a sustainable efficacy of ITNs in
reducing malaria morbidity and mortality over a broad range of malaria transmission intensities in SSA (Binka et al., 2002, Phillips-Howard et al., 2003; Diallo et al., 2004; Lindblade, 2004). Moreover, technical progress has now enabled the development of reliable long-lasting insecticide-treatment, both for the production of long lasting insecticidal nets (LLINs) (Lindblade et al., 2005; Gimnig et al., 2005; Dabin et al., 2006) and as impregnation or re-impregnation with an insecticide formulation (Yates et al., 2005). ITNs were already employed on a large-scale since the 1980s in a number of malaria endemic areas of Asia, where they have contributed to major successes in malaria control (Hung, 2002). Today, the need for a large scale utilization of ITNs in SSA is well accepted in the international scientific community (Curtis et al., 2003; Lines et al., 2003; Hawley et al., 2003). A high coverage with ITNs would also lead to a mass effect on the mosquito populations similar to what can be achieved through systematic insecticide spraying programs (Maxwell et al., 2002). However, due to major problems with infrastructure, public service organization, funds and leadership, progress in the implementation of ITN, programs in SSA remains slow (Victora et al., 2004; Kouyate et al., 2007).

Two approaches for scaling up ITN coverage in SSA have been discussed; one considered ITNs as a public good that should be provided free of charge (Curtis et al., 2003). The other is to strengthen commercial markets while providing subsidies for the groups most at risk, such as children and pregnant women (Lines et al., 2003). Those in favour of free ITN distribution support their argumentation by the evidence from a number of SSA projects and programs regarding the feasibility of such an approach, the proof of a significant community effect in most areas with high ITN
coverage, the reality of a high proportion of SSA populations being unable to pay for such an intervention, and the hope that rich countries would sustain their financial commitment for malaria control in SSA (Curtis et al., 2003). On the other side, those in favour of strengthening commercial markets support their argumentation by the success of a large ITN social marketing program in countries such as rural Tanzania (Hansen et al., 2003; Mushi et al., 2003). Although numerous studies have been done to determine the role of ITNs on malaria transmission, most of them are controlled-intervention studies focusing on endemic regions. This skewed approach has generated scanty information on the role of this important malaria control tool in regions of low to moderate transmission like the highlands of western Kenya. Similarly, there is little information on actual utilization of owned nets, reasons behind under utilization and possible effects on malaria transmission and Spatio-temporal distribution of malaria vectors in the highlands of western Kenya since the government’s introduction of subsidized ITN distribution to general population and antenatal care services. This study would therefore like to explore and provide information regarding the same.

2.6.3.3 Targeted Vector Control

Intensive anti-malaria campaigns targeting local mosquito populations with either Indoor Residual Spraying (IRS) or Long-lasting Insecticide Treated Nets (LLINs) in a number of endemic areas, particularly in Africa, have resulted in 10-50 fold reductions in the adult mosquito population and have been associated with similar declines in the prevalence of infection and incidence of disease in people living in these areas (Sharp et al., 2007; Bayoh et al., 2010). Understanding the determinants
of such declines is crucial in the context of malaria control and elimination. Consideration of adult mosquitoes alone (the tenet of simple malaria models) is insufficient to fully understand the resulting changes in mosquito density. Instead, the entire mosquito lifecycle, including larvae, pupae and adults, and mosquito behaviour while feeding, resting and ovipositing needs to be considered. Indeed, it has recently been argued that a comprehensive understanding of vector ecology is a prerequisite for malaria elimination (Ferguson et al., 2011).

The stable mosquito population exist in a fixed environment only if the population is regulated. In ecological models this is usually assumed to be via density-dependent regulation or by a limited environmental carrying capacity. Both mechanisms lead to a limitation in the number of mosquitoes that a particular environment can sustain. In aquatic stage mosquito ecology, carrying capacity describes how many mosquito larvae/pupae an environment can support, whereas density dependence describes the intra-specific competition between larvae for food and resources, resulting in increased mortality and extended developmental times for high larval densities (Munga et al., 2006). The net result of increasing density-dependent competition is equivalent to decreasing the carrying capacity; however when considering interventions directed at different stages of the mosquito lifecycle, care must be taken to differentiate between these two concepts. Environmental management, e.g. filling in breeding sites, will directly reduce the carrying capacity without involving inter- or intra-specific interactions, whereas IRS and LLINs directed against adult mosquitoes will cause a reduction in oviposition and hence reduce density-dependent competition between larvae in breeding sites resulting in decreased larval mortality.
This raises the need for multifaceted approach in intervention at both larval and adult mosquito stages.

Vector control interventions can be targeted at several stages of the mosquito’s lifecycle. Successful interventions will result in a dramatic drop in mosquito density, although interventions directed against adult mosquitoes will have the added benefit of reducing the probability that an infected mosquito survives sporogony to become infectious. Understanding mosquito population dynamics will aid in the selection of optimal packages of vector control interventions. The effect of vector control interventions on malaria transmission and adult mosquito dynamics has been widely investigated using mathematical models (Worrall et al., 2007; Chitnis et al., 2010). In addition a number of studies include models of the full mosquito life cycle including eggs, larvae and adults (Depinay et al., 2004). In contrast to these studies we focus on the interaction between vector control interventions and the adult, aquatic stages of the anopheline vector and some possible effect on malaria transmission. The ultimate goal is to understand the role of combined effect of larvae and adult mosquitos targeted interventions in malaria hypo-meso-endemic settings in the highlands of western Kenya in which An. gambiae s.l. is the prevailing species.
CHAPTER THREE: MATERIALS AND METHODS

3.1 Introduction

This chapter highlights the materials and methods involved in the execution of this study. It focuses on the study sites which are equivalent of provincial administrative divisions. The chapter explains in details sampling designs and data collection techniques for each objective. Subsequently, the chapter highlights how the study data was managed and analysed. Finally, the chapter clarifies on the ethical consideration of the study.

3.2 Study site

The study areas are situated at Iguhu, Mbale and Emutete in Kakamega and Vihiga counties respectively in the highlands of Western Kenya (Appendix I). Kakamega and Vihiga Counties are provincial administration boundaries well known as Districts. The study sites are located within a grid of $4 \times 4$ km$^2$ and at 0°17’ N, 34°74’ E, and densely populated with approximately 3000 inhabitants each. The study areas have an average population of 900 persons per square Kilometre and with a growth rate of 2.98% per annum (KNBS, 2010). These sites were selected based on altitude and previous malaria studies that have been done in the area during the 2002/2007 ecology of highland malaria as earlier highlighted in the problem statement and study justification (Zhou et al., 2007). Like many highland areas in Western Kenya, these sites have experienced tremendous land use changes and continued degradation due to increased human population growth and demand for more land. These changes
have subjected these sites to many malaria epidemics and focal malaria transmission
down the valley bottoms.

The study areas experience three peaks of rains with an average annual rainfall of
1800 mm. The first peak of rains occurs between March and July having an average
monthly rainfall of 150 – 260 mm. The other peak of rainy season occurs in August,
while short rains occur between September and October and has an average monthly
rainfall of at least 125 mm. The dry period occurs between December to February.
Temperature within the study areas ranges between annual maximum of 27.5°C and
minimum of 15.1°C with a daily average temperature of 20.0°C. The rainfall patterns
experienced in these areas determine greatly the transmission of malaria. The high
malaria transmission season peaks are experienced two weeks following the start of
rain season. This two weeks lag period is the duration through which the mosquito
aquatic life cycle and parasite development undergoes before transmission can be
initiated. These high transmission peaks are exasperated by increased indoor
mosquito vectors densities following availability of larval habitats created by rains.
The areas therefore experience malaria peaks during the months of June-July and
September-October. The other months of the year are characterised by low
transmission but with stable transmission experienced in areas along the valley
bottom where there are year round stable malaria vector breeding habitats.

3.2.1 Healthcare facilities in the Study areas

Malaria remains the main challenge in these study areas. Although overall coverage
and physical access to health care services seem quite good in Kenya where almost
80 percent of the population leave within 5 kilometres of a facility (KDHS, 2010), findings by (KSPA, 2004) indicated that facilities have the challenge of serving very large populations. The median population in a hospital catchment area is more than 100,000, while dispensaries, which have limited staff, serve a catchment population of around 8,000. The areas are well covered with health facilities with Emuhaya district having 29 facilities (1 level 4, 8 level 3 and 20 level 2). Kakamega South district where Iguhu site was selected has a total of 18 health facilities. Among these, 2 are level 4, 5 level 3 and 11 level 2. Vihiga has the least number (11) of health facilities but with a well equipped level 4 hospital, 3 level 3 and 6 level 2 health facilities. Seeking healthcare at health facilities has been reported to be more likely for children from households with higher socioeconomic status and with more symptoms of severe illness. Therefore, health facility and hospital-based surveillance would underestimate the burden of disease substantially in rural western Kenya where home based treatment is still high. Seeking health care at health facilities and hospitals varies by syndrome, severity of illness, and characteristics of the patient (Burton et al., 2011).

### 3.3 Research Design

The research design undertaken during this study was a randomized repeated cross-sectional survey. This survey was repeated during both the rainy and the dry seasons of the year 2009 and 2010. During these surveys, a subset of the population at household level was selected randomly from the study sites for participation in the study. To gather data on bednet use, vectors and malaria transmission, 300 households were selected randomly for this study. On the other hand, same design
was used on the selected valley ecosystems to collect data on the indoor resting malaria vectors and malaria transmission among the residents. A longitudinal study design was deemed not suitable for this study. Some of the reasons were because of the large sample size involved, the mobility of study participants during schools going and farming seasons. There was a likelihood of a major loss to follow-up if longitudinal survey was undertaken. Likewise the resources required for follow-up in longitudinal studies might have been enormous compared to the available resources for this study. Point by point execution of this research design is explained in details later in this document in sampling design section.

3.4 Study Variables

3.4.1 Dependent Variables

The dependent variables of interest in the study were; number of ITNs owned, those in use and not in use, malaria vectors both larval and adult mosquitoes and malaria cases. A record of the number of Bednet owned was collected using a household questionnaire during each visit in the house both in the dry and rainy season. The actual usage was recorded as having slept under the particular net the previous night. Owned but not used nets were equally recorded during the dry and rainy season. Malaria vectors larvae were collected in all aquatic habitats while adult mosquitoes collected indoors during the day in all study houses during the dry and rainy season. Malaria infection prevalence was determined by active case surveillance of randomly selected houses where indoor spraying was simultaneously done.
3.4.2 Independent Variables

The independent variables used in the study included; aquatic sites, both positive and negative aquatic habitats for larvae, house location in respect to the valley ecosystem, habitat stability, seasonality of both dry and rainy season, head of household education level, bednet use practices, household demography and the main socio-economic status of the households.

3.5 Targeted Population

This study targeted the residents of malaria epidemic prone regions of Western Kenya highlands. These areas are known to experience low to moderate malaria transmission with occasional severe epidemics commonly referred to as a meso-hypoendemic transmission zone. In these areas, the ITNs coverage is fairly high (78%) almost reaching the recommended global health standards of 80% coverage although transmission is still high (KMIS, 2010; Zhou et al., 2011). The population of these regions has no immunity against malaria because of the unstable transmission levels although some few cases of immunity are experienced among inhabitants living along the valleys bottoms ≤500 meters from the river line. The study therefore targeted all the age groups in the regions to ascertain the importance of ITNs as a malaria intervention tool, the role played on malaria transmission by topography as a main characteristic of the highlands and the effect of targeted vector control as a cost effective malaria intervention approach in a malaria heterogeneity region.
### 3.6 Sampling technique and sample size

The working hypothesis was that no difference will be seen between those who own and those who use nets and malaria prevalence among them and that infection would be randomly distributed. The binomial model was used to estimate the confidence interval (CI). Because the prevalence of malaria is unstable in this highland area, a 50% estimate, which gives the best sample size, was used for the peak-transmission season, and a 25% estimate used for the low-transmission season. The two sample sizes were calculated with a 95% CI and precision level of 5% using the formula below:

$$n = \frac{z^2 \cdot pq}{d^2}$$  

(Equation 3.1)

In this equation, $n$ is the sample size, $z$ is the critical value of the standard normal distribution at the 5% level (1.96), $p$ is the malaria prevalence estimate, $q = 1 - p$, and $d$ is the precision level. The population size was estimated to be 3,000. The sample size obtained was 341 persons for the peak-transmission season and 263 for the low-transmission season. Three hundred houses per site were therefore sampled for the study with the assumption that some houses had a single occupant.

### 3.7 Development and testing of research tools

Two standardised questionnaires (Appendix II and III) containing open ended and closed questions were designed. One questionnaire (Appendix II) was used to collect data on bednet ownership, usage, malaria infection episodes, demography, health
seeking behaviour and education level of the household head. The second questionnaire (Appendix III) was used to collect data on household demography and their main socio-economic factors. The questionnaires were translated into Swahili language. The services of two independent native Luhya speakers was sort to check the authenticity of the Swahili translation to make sure intended questions were not distorted and that the response would be consistent. The questionnaires were pre-tested during the training period of enumerators. Ten pre-tests were conducted with randomly selected residents of the study areas. Returned pre-test questionnaires checked and discussions held with the respective enumerators. Unclear questions were reformulated and tested in the successive pre-tests until the final clear versions of the research tools were arrived.

Six enumerators (three men and three women) were recruited to conduct the surveys. Three of the enumerators were college diploma graduates in the field of community health and development while the other three were experienced graduates in laboratory technology who equally served as laboratory technologists during the study. All the enumerator had been involved in various surveys in the area. The enumerators underwent a two weeks intensive training on scientific data collection methods which included interviewing, indoor spraying, larvae collection, blood sample collection, GPS data collection and spot checking. Enumerators were involved in simulated face to face interviews among themselves. The researcher evaluated the sessions and gave feedback to enable the trainees improve on the skills. Special practical training sessions on GPS coordinates collection, finger pricking, making thick and thin blood smears, slide reading, house spraying, larvae collection,
mosquito identification, sample transportation, processing and storage were conducted in the homesteads of some of the enumerators and in the laboratory at KEMRI in Kisumu. Assimilation of all the skills and techniques taught was evaluated during the pre-tests surveys conducted as part of the training. Training was enhanced throughout the study period by conducting brief interactive sessions every morning before departing to the field. Difficulties experienced in the field were discussed and solutions suggested by the group. Enumerators were instructed to telephone the researcher directly where there were doubts or situations which required immediate attention. Motivation was maintained through holding weekly lectures on topics of general interest. Additionally, an excursion, a seminar on job interviews and how to write curriculum vitae were organised for the enumerators. Quality of data collection was ensured through strict supervision by the researcher who accompanied the enumerators to the field and individually checked each completed questionnaire, blood slides and adult mosquitoes spot checks for clarity and completeness. Incomplete questionnaires and spot check forms or those containing mistakes were returned to the respective enumerator for completion or clarification. A sample of slide read by the enumerators/laboratory technologists were taken for proof reading at the centre of excellence laboratory in CDC for quality control.
3.8 Sampling Designs

3.8.1 Study houses sampling

All houses within the three sites were numbered, GPS (Geographic positioning system) taken and then mapped using a handheld GPS unit. Three hundred houses were selected randomly from the total houses for this study from each site. Owners of selected houses were requested to sign a freely administered informed consent form for participation in the study for both entomologic and parasitological surveys.

3.8.2 Administration of the questionnaire

Voluntary consent was sought from the household head of randomly selected house before questionnaire interview or any other proceeding study. The questionnaires were administered through face to face standardised interviews with the wife or household head in the Swahili language. In some rare occasions local Luhya language was used where the respondent was not familiar with Swahili language. In situations where none of them was available, information about their availability was sought from other members of the household and a revisit appointment made. Where a revisit was not feasible (for example deceased members or prolonged absence) then another adult member of the household was interviewed. When there was no other adult member available, a son or daughter (≥15 years) was interviewed. The duration of the interview was fixed to 20-25 minutes. Demographic factors were investigated by recording the names of all the permanent resident members of the household and their age. In addition to these demographic factors, data on educational level of the head of household (decision maker) was recorded. Health seeking behaviour was
investigated by carrying out a detailed event analysis of the sickness episode for the last two weeks. Any member(s) of the household who got sick with malaria in the two weeks preceding the survey plus the treatments they took were recorded.

Data on malaria preventive measures was collected by asking the respondents if members of their household owned any bednet. If the answer was in the affirmative, they were asked to say how many bednets they own and how many were in actual use the previous night. Bed net use was investigated by spot checks, asking and recording the names of all members of the household who slept under a net during the previous night.

Details of the households’ socio-economic characteristics were recorded based on family house type, ownership of selected household goods, assets and employment if any (Appendix 3). Given that the study population comprised of rural people, many of them without a regular income, this was considered a more feasible way of assessing the main socio-economic status. A detailed inventory of cash crops grown, domestic animals kept and durable goods owned by the household was filled in at the end of the face to face interview. The inventory was developed after discussions with key informants on what goods and assets best indicated the measure of socioeconomic status of a household in the area.

3.8.3 Entomological data collection

Mosquitoes were collected using PSC method (WHO, 1975) during dry (February) and rainy (May) seasons of the year 2010 from all the study houses (total 900). In
PSC, the insecticide is 5ml of pyrethrum extract with 6ml of butoxide mixed in 5liters of paraffin as a solvent in Hobra 5liter hand pump. The insecticide has the potential to knock down mosquitoes and has no residual effect. Samples were eventually taken to the laboratory for counting, morphological identification to species and gender. In the laboratory, these samples were classified according to their gonotrophic stages as empty, fully fed, half fed, half gravid and gravid and recorded in data forms (Appendix IV). Larval surveys were equally done during the same period where all aquatic habitats were sampled for presence of anopheline larvae. The sampled larvae were recorded in larval collection form (Appendix V) and samples taken to KEMRI for species identification.

3.8.4 Parasitological data collection

The whole study population from study houses where PSC was done was screened for malaria during the dry and rainy seasons. Participants with clinical malaria and fever were identified and screened. Clinical malaria definition: temperature of >37.5oC at time of visit or history of fever in preceding 24 hours and one other symptoms of malaria.

3.8.5 Development of digital elevation model

Digital files consisting of points of elevation, sampled systematically at equally spaced intervals were used in the generation of terrain profiles between selected points to display the shape of the valleys (Appendix VI). To determine how topography and terrain characteristics are associated with the availability and
stability of mosquito breeding habitats and malaria transmission, 3-D images of broad (Appendix VII) and narrow (Appendix VIII) shaped valleys were constructed using 30 meters and 1 meter horizontal and vertical resolutions. Elevation data was obtained from contour maps and satellite images of LANDSTAT and IKONOS 2007 of Western Kenya. Using these maps the contours were digitized and interpolated to create a digital elevation model (DEM). Details of the peaks and valleys in the terrain were represented with small grid spacing. Elevation recorded by a hand-held global positioning system (GPS) receiver (E Trex HC series, Garmin International, Inc) helped to fill in points that may not be present in the contour maps. Ground truthing was carried out using GPS units of a 2 × 2 kilometer cross-section of the valleys to ascertain the accuracy of topography maps. Where there was variance, the geographic information system (GIS) data was used as inputs in the model. The elevation differences between upstream and downstream drainage points were determined to indicate the efficiency of drainage thus the stability of the breeding habitats.

The surface area with no slope at the bottom of the valleys was determined. Valley shape is one of the terrain characteristic which is a key driver to malaria in the highlands (Cohen et al., 2010). The U-shaped valleys were defined as broad valleys with slow moving rivers or streams and have poor drainage. Their river flow slope change rate is 1% and with a flat surface from the river edge of >10 meters. On the other hand, the V-shaped valleys have a narrow bottom with a fast flowing river or stream and have good drainage. Their river flow slope change rate is 10% and with a flat surface of <10 meters from the river edge (Githeko et al., unpublished data).
These parameters were compared in a pair of villages within narrow V-shaped and another pair within flat-bottomed U-shaped valleys to determine whether there is consistency in the characteristics as explained above. The difference in topographic parameters between broad and narrow valley and their association with occurrence and stability of malaria risk was determined.

### 3.8.6 Randomized-Targeted intervention survey

Vector control interventions were targeted in two sites where malaria prevalence was presumed high as compared to the other transmission sites in the highlands of western Kenya. Iguhu and Emutete were therefore selected for larval and adult mosquitoes intervention. A randomized malaria intervention methods that included targeted indoor spraying (IRS) of lamda-cyhalothryn (brand name ICON) and larval control using larvicide *Bacillus thuringiensis israelensis* (Bti) was done during the dry season of February-March 2011 when mosquitoes densities are usually low. Six paired clusters were selected from two study sites; one cluster of each pair was randomly selected for intervention and the other was used as control (Appendix IX). Each cluster was divided into targeted and non-targeted sections. The size of each cluster was approximately 2x2 km. Clusters were paired up based on their similarity in ecological settings and entomological and parasitological survey results prior to intervention. The targeted IRS area in the intervention cluster was selected based on entomological surveys prior to the trial. During IRS intervention, ICON was applied only in the targeted section of the intervention clusters in March, 2011 prior to the long rainy season that triggers increase in density of malaria vectors and the beginning of the peak malaria transmission period in this highland area. All houses in
the intervention area were identified, marked and numbered using satellite images, and were sprayed with lambda-cyhalothrin (ICON), which is among the insecticides recommended by the World Health Organization and National Malaria Control Board of Kenya. The interior walls and roofs of the targeted houses were sprayed. The average number of houses sprayed was 463 (ranging from 447-483) households per site. The average size of the surveyed population was 1,896 individuals (ranging from 1,275-1,767) per site. Larvicide application of Bti (CG formulation, VectoMax, Valent BioSciences Corp, Illinois, USA) granules were applied in all potential breeding habitats in all intervention clusters. The first application was completed in February/March, 2011, and the second in March/April, 2011, four weeks after the first application.

3.8.6.1 Intervention evaluation

Vector population densities of indoor resting mosquitoes were collected from a total of 300 houses in each intervention/control cluster by pyrethrum spray collection method (PSC). Houses were selected randomly to ensure maximal spatial coverage. The number of female Anopheles mosquitoes was recorded for all intervention and control clusters. The indoor resting density was determined as the average number of Anopheles females collected per house per night (f/h/n). The timings of the mosquito surveys were selected to represent the vector population during the different seasons both before IRS (February, 2011) and after IRS (May and July, 2011). Anophelines were morphologically identified and classified as Anopheles gambiae and Anopheles funestus.
Asymptomatic parasite screening (APS) using a cross-sectional survey was conducted at each study cluster during February–March, 2011, before the IRS and Bti application, to obtain the baseline malaria parasite prevalence data. The same survey was repeated in May and July, 2011, to evaluate the effect of the intervention. Finger prick blood samples were taken from approximately 150 and 250 randomly selected individuals of different ages within each cluster for the detection of the *Plasmodium* parasite. A thin and a thick smear were prepared for parasite detection and species identification. Blood smears were read by a Kenya Medical Research Institute (KEMRI) laboratory technician. Quality was controlled by additional readings of randomly selected slides (Zhou et al., 2011). Individuals found to be positive for malaria infection and with malaria symptoms were referred to local health facilities for free anti-malarial treatment according to Kenyan guidelines. Information on bed net usage, for the previous night before the APS survey, for each participant was recorded. Parasite prevalence was calculated as the percentage of individuals in the surveyed population having positive slide readings during the survey. Prevalence was calculated for each survey occasion.

### 3.8.7 Community interviews

Focus group discussions were held among community members from the two study sites where targeted vector intervention was done. In each study site, participants in this qualitative study were organized into 2 focus groups categorized into men and women. Under the supervision of the researcher, research and field assistants were trained on the purpose of the group discussions. The assistants eventually contacted
and informed the occupants of the households that had participated in the quantitative research. This approach was more realistic as these participants had already consented to participate in the study. The assistants were asked to invite 8-12 members of the community to participate in each group sessions. The following inclusion criteria were used to recruit the participants for the group discussions:

1. The participant must be a resident of previous randomly chosen households that had consented and participated in the quantitative research
2. The participants should be a responsible parent (at least married and with children) or a guardian
3. The participant should be between the ages of 20 years to 40 years old.
4. For informed discussion, the participant should be able to understand and communicate freely and effectively in a group
5. The participants of the focus group discussions should represent the different areas serviced by the main health facilities.

Two sessions were planned for each focus group categorised into men and women groups. The sessions were categorised into gender so as to allow free and genuine discussion on the family health issues as some participants may not be comfortable to discuss such issues in the presence of their opposite gender. This may be due to perceived cultural issues/barriers that would only allow a particular family member (men) to participate or dominate a discussion while the other member (mostly women) playing a passive role. The discussions were held at either the village elder’s compound or at the district hospital compound. The researcher and the research assistant took written notes. The interview guide consisted of 8 questions (Appendix X).
3.8.8 Interviews with key informants

At the end of the field research, semi-structured interviews were conducted with key informants in the health facilities within the study areas and Provincial malaria control coordinator. The Kenya National Malaria Control Director was also interviewed during the first Kenya National Malaria Forum held on the October 10th – 11th 2011, in Nairobi where part of the results of this research was invited for oral presentation for policy evaluation. The interview consisted of 5 themes. At Iguhu and Emuhaya district hospitals, semi-structured interviews were conducted with the clinical officer in charge of the facility and a public health officer. They were asked of what they thought were the factors underlying the observed situation of malaria in the area and the best remedies. In addition, questions on malaria control, diagnosis and treatment were asked (Appendix XI).

3.9 Data management

Data was collected and recorded as filled questionnaires, check lists and record forms. Subsequently, data was entered into and managed in spreadsheets using excel software (Microsoft Corporation) and statistical analysis performed by the use of STATA SE 9 (StataCorp LP, 4905 Lake Way Drive, College Station, TX 77845 USA) and Epi Info (version 3.4.7).
3.10 Data Analysis

To determine ownership and use of Insecticide-Treated bednets and its effect on malaria transmission in Western Kenya Highlands; Chi square test was done to determine the risk of getting malaria infection for those without ITN. Likewise Odds Ratio was calculated to determine the odds of malaria infection risk for those who do not use ITN. The proportions of incidences and non incidences were determined to know the association between malaria and not using ITNs. A univariate analysis test was done based on site and age difference to know malaria risk groups.

To determine the association between topography ("U" and "V" shaped valleys) and exposure to malaria vectors and transmission; Study results were categorized into two, those closest (≤ 500m) to the main river line valley where the majority of breeding habitats occurred at the valley bottom (VB) while those above that distance of 500m were considered to be uphill (UH). A distance of 500 m was chosen having been used successfully elsewhere (Cohen et al., 2010), although published distance of risk gradients vary (Carter et al., 2000) and sharp declines in risk are generally reported at greater distances (Cohen et al., 2008). For comparison, density/house of indoor collected vectors, positive larval occurrence and abundance and the rate of malaria within the valley bottom and uphill between broad and narrow shaped valley villages were calculated.

During analysis, data from the two broad valley villages were grouped together, likewise those from the two narrow valley villages were grouped together after preliminary results confirmed that in addition to their topographic aspects similarity,
there were no intra-specific differences in both adult vectors and larval abundance and distribution characteristics. To determine whether there were differences in the abundance of adult vectors between the valley bottom and uphill in each particular village, i.e. broad and narrow shaped valley villages, density of vectors/house in houses located at the valley bottom were compared by t-test to those located uphill during both the rainy and the dry season. Similar comparisons using chi-square test were done to determine the difference in occurrence of positive larval habitats between areas located at the valley bottom and uphill during the dry and the rainy seasons in the broad and narrow shaped valley villages. Chi-square test was carried out to examine whether patterns of malaria surrounding households closer to the valley bottom locations might appear analogous to those uphill in broad and narrow shaped valley villages during both the rainy and dry seasons. Inter valley shape comparison between broad and narrow shaped villages were done comparing adults, larval and malaria occurrences. As for the abundance and distribution of adult vectors, a t-test was used, whilst a chi-square test was used for both positive larval habitats and malaria cases. Multivariate analysis- Tukey HSD test was done to determine the most predictive independent variable among valley shape, altitude and season for the occurrence of larvae, adult vectors and malaria cases as dependent variables.

To evaluate the entomological and parasitological effect of targeted malaria vector control, clusters were classified as intervention and control clusters; each cluster was further divided into two areas, targeted and non-targeted areas. The details can be found on Appendix IX. The targeted area within the intervention cluster was the
targeted IRS area, and the rest of the intervention cluster was the non-targeted area. The targeted area within the non-intervention cluster was the area corresponding to the targeted IRS area in the intervention cluster, and the rest of the non-intervention cluster was the non-targeted area. The buffer zones are areas where samples were excluded from final data analysis so as to avoid edge effect.

The rate ratio (RR) was defined as the ratio of the number of observed cases in the intervention cluster to the number of observed cases in its counterpart control cluster. The test of significance was based on a Poisson generalized likelihood ratio test, using 999 replications for a Monte Carlo inference. Changes in seasonal mean vector densities and monthly parasite prevalence before and after intervention were tested by the use of the planned comparison of GLM, using survey periods (before and after intervention) as independent variables and using the outcomes from the corresponding non-intervention area as contrast for the dependent variable. To assess changes in mosquito densities and *Plasmodium* parasite prevalence, associated with the implementation of IRS and Bti, the percentage reductions (PR) in parasite prevalence and mosquito densities in targeted intervention cluster were calculated using the following formula:

\[
PR = 100 \left( 1 - \frac{C_1T_2}{C_2T_1} \right)
\]

Where \( C_1 \) and \( C_2 \) (\( T_1 \) and \( T_2 \)) describe the average densities of mosquitoes or parasite prevalence in the control cluster (intervention cluster) during baseline (subscript 1) and intervention (subscript 2) periods. The reductions were adjusted for the background differences between intervention clusters and control clusters.
Data collected from key informants and community interviews were transcribed and ordered according to themes. Data were cleaned and categorical variables transformed into dummy variables. Indicator variables were created for questions with multiple answers. For the open ended questions, a detailed content analysis involving grouping of responses into categories of related answers was done. Dummy variables were then assigned to the categories formed.

It should be noted that, Entomological and Parasitological data from Mbale was not used during analysis whenever the outcome was extremely low not to generate statistically meaningful values for comparison.

3.11 Ethical consideration

House owners were administered with freely given consent form written in English and a copy in Swahili (Appendix XII and XIII respectively) and in the presence of an independent witness conversant with both Swahili and Luhya languages to consent for participation in the study. Explanation in the presence of a witness about the study was done to those unable to read in their own language. Nobody was convinced to participate if they were not interested participating and people were allowed to decide to drop out of the study at any time.

The study was approved by Graduate School Board of Kenyatta University dated 31st March 2011 (Appendix IX). Likewise, permission was granted by the National Council for Science and Technology No. NSCT/RRI/12/MED011/113 for the study to be done (Appendix XV). This study was part of a major study titled “Ecology of African Highland Malaria (II)” which had approval, SSC No. 1382 (N): cleared by KEMRI/ National Ethical Review Committee dated May 15th 2008 (Appendix XVI).
CHAPTER FOUR: RESULTS

4.1 Introduction

This chapter presents the results of main socio-demographic factors in the study community. The chapter gives detailed results of all the objectives in the study. It therefore presents results of; the current ownership and utilization levels of ITNs in the highlands of western Kenya, the effect of ITNs ownership and actual usage on the occurrence and distribution of malaria vectors in the highlands, the effect of ITNs ownership and actual usage on malaria transmission, the role of topographic parameter (“U” and “V” shaped valley ecosystem) on the occurrence and spatio-temporal distribution of malaria vectors, the association of topographic parameter (“U” and “V” shaped valley ecosystem) and risk of malaria, the effect of IRS and larviciding targeted malaria vector control on the occurrence and distribution of malaria vectors and malaria transmission. Finally, the chapter presents responses of the community on the intervention process and its outcome and the response of key informants on malaria situation in the region.

4.2 Demographic and Socio-economic characteristics of study households

The role of demographic and socio-economic factors as determinants in malaria transmission is well known. The study highlights general demographic and socio-economic factors of the targeted 300 households per site in the two study areas (Iguhu and Emutete). Table 4.1 on next page shows data from 586 households as 14 houses did not give complete response to qualify inclusion in the analysis. These two sites were focused following preliminary results that indicated high malaria
prevalence. This table provides a summary of some of the demographic and socio-economic characteristic of study households. Additional specific demographic and socio-economic factors are presented in subsequent sections to address specific objectives of the study. As shown in Table 4.1, the study found that 87% of the households lived below the poverty line. As an indicator of poor housing, 69% had their houses made of iron and mud-wall while only 9% had permanent houses. Sixty five percent of the 586 households had at least experienced a malaria episode in their family in the last 2 weeks before the survey. Most of the households (53%) had more than 4 people per house. Secondary and primary education levels were predominant among the households.
Table 4.1 Demographic and Socio-Economic characteristics of households in Iguhu and Emutete (N=586)

<table>
<thead>
<tr>
<th>Variables</th>
<th>N</th>
<th>%</th>
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<tbody>
<tr>
<td><strong>Socio-Economic factors</strong></td>
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<tr>
<td>Household incomes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Income less or equals to 1090</td>
<td>170</td>
<td>29%</td>
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<tr>
<td>Income between 1091 and 2000</td>
<td>188</td>
<td>32%</td>
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<td>Income between 2001 and 5300</td>
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<td>25%</td>
</tr>
<tr>
<td>Income greater than 5300</td>
<td>82</td>
<td>14%</td>
</tr>
<tr>
<td>High # of people/household (≥4)</td>
<td>310</td>
<td>53%</td>
</tr>
<tr>
<td>Poverty levels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Below poverty level</td>
<td>508</td>
<td>87%</td>
</tr>
<tr>
<td>Education level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very good (tertiary)</td>
<td>24</td>
<td>4%</td>
</tr>
<tr>
<td>Good (Secondary)</td>
<td>134</td>
<td>23%</td>
</tr>
<tr>
<td>Fair (Primary)</td>
<td>176</td>
<td>30%</td>
</tr>
<tr>
<td>Poor (None)</td>
<td>252</td>
<td>43%</td>
</tr>
<tr>
<td>House quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grass/Mud wall</td>
<td>126</td>
<td>22%</td>
</tr>
<tr>
<td>Iron/Mud wall</td>
<td>408</td>
<td>69%</td>
</tr>
<tr>
<td>Permanent</td>
<td>52</td>
<td>9%</td>
</tr>
<tr>
<td><strong>Demographic factors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>House Location</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hill top</td>
<td>34%</td>
<td></td>
</tr>
<tr>
<td>Mid hill</td>
<td>38%</td>
<td></td>
</tr>
<tr>
<td>Valley bottom</td>
<td>28%</td>
<td></td>
</tr>
</tbody>
</table>

NB. No sufficient data for the missing 14 households.
4.3 Bednet ownership, usage and malaria transmission

4.3.1 Characteristics of study participants

During the dry and the rainy seasons, a total of 600 houses per season (300 houses from each site) were surveyed. A total of 1,160 and 1,265 participants of all ages were surveyed in the dry and rainy seasons respectively (Table 4.2). Slightly less than 60% of the study participants, in both the dry and rainy seasons, were from Emutete, and the remainders were from Ighu (Table 4.2). As expected, age categories reflected a population with more persons aged below the age of 15 years old. The age categories used in the figure and in the other parts of the document are justified following the transmission patterns of malaria within the ages given in low transmission regions like in the highlands. Because immunity against clinical malaria increases slowly with age in areas of low-intensity transmission, the incidence rate among 5- to 14-year-olds and those (greater than or equal to) 15 years are considered to be the same as that in young children below 5 years and half that rate, respectively. As shown in Table 4.2, there were more female than male participants in both the dry and the rainy season and with age specific variations.
Table 4.2 Characteristics of the study participants by season

<table>
<thead>
<tr>
<th>Participants location</th>
<th>Dry season (n=1160)</th>
<th>Rainy season (n=1265)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emutete</td>
<td>669 (57.7%)</td>
<td>745 (58.9%)</td>
</tr>
<tr>
<td>Iguhu</td>
<td>491 (42.3%)</td>
<td>520 (41.1%)</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>522 (45.0%)</td>
<td>520 (41.1%)</td>
</tr>
<tr>
<td>Female</td>
<td>638 (55.0%)</td>
<td>745 (58.9%)</td>
</tr>
<tr>
<td><strong>Age groups</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤4</td>
<td>301 (26.0%)</td>
<td>326 (25.8%)</td>
</tr>
<tr>
<td>5-14</td>
<td>381 (32.8%)</td>
<td>437 (34.5%)</td>
</tr>
<tr>
<td>≥15</td>
<td>478 (41.2%)</td>
<td>502 (39.7%)</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ITN ownership</td>
<td>858 (74.0%)</td>
<td>909 (71.4%)</td>
</tr>
<tr>
<td>ITN use</td>
<td>426 (36.6%)</td>
<td>560 (44.3%)</td>
</tr>
<tr>
<td>Parasite infection rate</td>
<td>75 (6.5%)</td>
<td>189 (15.0%)</td>
</tr>
</tbody>
</table>

4.3.2 Household ITN ownership and usage

The study identified bednet ownership and actual usage among the residents in the study households. The study recorded a total of 858 and 909 nets in the two sites during the dry and rainy season respectively. Iguhu had 386 and 389 nets during the dry and wet season respectively, while Emutete had 472 and 520 nets during the same period. The study found that 96.3% and 94.3% of the nets in Iguhu and
Emutete respectively were in good condition, i.e., not torn and either LLINs or retreated ITNs. Reported and confirmed net ownership and usage among the study participants is summarized in Table 4.3. The overall percentage of participants who owned at least one ITN was 73.8% in the dry season and 71.4% in the rainy season. During this study, all the bednets recorded being in use were either ITNs or LLINs. This was due to the re-treatment and replacement of regular and old nets respectively, during a campaign that had been done by DOMC. Regular untreated nets observed during this study were not in use for malaria personal protection but were old nets used for other protections such as fencing against chicken. Studies have confirmed that presence of at least one functional net in a household is considered important and protective due to its mosquito repellent characteristics. Community large scale intervention studies have reported community wide protective effect of ITNs where high coverage and usage of above 90%, protected the neighbouring community that had no bednet. This means that households with at least functional LLINs/ITNs were well protected even if some used old untreated nets. There was an inter-site difference in ITN ownership (Table 4.3). The seasonal ITN usage during the dry season was significantly lower than that in the rainy season (49.5% vs. 61.8%, OR = 0.6, $\chi^2 = 37.8$, d.f. = 1, $P < 0.001$). In both regions, participants’ ITN usage was significantly higher in the rainy than the dry season (Table 4.3). The proportion of non-compliant individuals (those who owned ITNs but did not use them) was significantly higher during the dry season than rainy season, 46.6% vs. 32.9% in Iguhu ($\chi^2 = 12.42$, d.f. = 1, $P < 0.001$) and 53.4% vs. 41.8% in Emutete ($\chi^2 = 21.12$, d.f. = 1, $P < 0.001$), respectively.
Table 4.3 Seasonality in bednet ownership and usage rate in Iguhu and Emutete

<table>
<thead>
<tr>
<th>Season</th>
<th>Site</th>
<th>N (Number of nets)</th>
<th>Ownership (%)</th>
<th>Usage (%)</th>
<th>Non-compliance (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainy</td>
<td>Emutete</td>
<td>520</td>
<td>69.0</td>
<td>58.2</td>
<td>41.8*</td>
</tr>
<tr>
<td></td>
<td>Iguhu</td>
<td>389</td>
<td>74.8</td>
<td>67.1</td>
<td>32.8*</td>
</tr>
<tr>
<td>Dry</td>
<td>Emutete</td>
<td>472</td>
<td>70.3</td>
<td>46.6</td>
<td>53.4*</td>
</tr>
<tr>
<td></td>
<td>Iguhu</td>
<td>389</td>
<td>78.6</td>
<td>53.4</td>
<td>46.6*</td>
</tr>
</tbody>
</table>

*P<0.001 i.e. ownership significantly higher than usage

The study found that, bednet use was the main personal protection strategy against malaria mosquitoes’ bites in this study area. Being a highland area where malaria occurs in moderate to low transmission, there are fewer vectors and nuisance mosquito densities that would trigger efforts for other personal protection strategies as it is in the lowlands where there are high densities of mosquitoes. Figure 4.1 shows age specific net usage among those who owned ITNs during the dry and the rainy season. The age specific ITN usage across the age groups was 71.3%, with significantly higher usage for children under 5 years (percent usage of 78.4%) than both the 5-14 year age group (percent usage of 69.1%) and the 15 year and older age group (percent usage of 72.2%). There was a significant inter-site difference in ITN usage for different age groups (Figure 4.1). For example, for the ≥15 year age group, the ITN usage was 67.9% in Emutete whereas it was 78.5% in Iguhu ($\chi^2 = 13.28$, d.f. = 1, P < 0.001) (Figure 4.1).
A comparison between ownership and actual ITN use was considerably lower (<55%), regardless of seasonality and inter-site variation. There was a significant seasonal change in ITN usage in all age groups. For example, the ITN usage for ages ≥15 years was 56.4% during the rainy season compared to 43.8% during the dry season ($\chi^2 = 6.31$, d.f. = 1, $P = 0.01$). There was also a significant inter-site difference in ITN usage for different age groups (Figure 4.1). For example, the ITN usage for children under 5 years during the dry season was 62.3% in Iguhu but it was 49.2% in Emutete ($\chi^2 = 5.38$, d.f. = 1, $P = 0.02$). Determination of ITN coverage...
was a limiting factor as this would only be ascertained by doing spot checks very early in the morning to confirm participants who had their nets properly hung.

4.3.3 Malaria prevalence and ITN usage

The results indicated that, bednets had a protective efficacy against malaria infection across the age groups both during the rainy and dry seasons. Table 4.4 is a summary of the prevalence of malaria infection by non-use and use of ITNs during the rainy and dry seasons respectively in the two study areas. When age and site is controlled, the overall infection prevalence across the age groups was significantly lower among net users compared to non-net users (12.8% vs. 16.7%) during the rainy season (OR 0.73, 95% CI 0.52-1.00, P<0.05) (Table 4.4). The results indicated that, the odds of being positive with malaria was 0.73 less in net users than in non users during the rainy season. Similarly, during the dry season infection prevalence was lower among net users than non-net users (6.1% vs 6.9%) although they were not statistically different (Table 4.4). The odd of getting malaria infection was 0.82 lower in net users than in non-users during the dry season.

Table 4.4 ITN use and malaria parasite prevalence during the wet and dry season

<table>
<thead>
<tr>
<th>Season (N)</th>
<th>Net Use (N)</th>
<th>Malaria positive (N)</th>
<th>Prevalence (%)</th>
<th>Chi</th>
<th>OR</th>
<th>95% CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet (1260)</td>
<td>Yes (560)</td>
<td>71</td>
<td>12.8</td>
<td>3.7</td>
<td>0.73</td>
<td>0.52-1.00</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>No (705)</td>
<td>118</td>
<td>16.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry (1160)</td>
<td>Yes (424)</td>
<td>26</td>
<td>6.1</td>
<td>0.58</td>
<td>0.82</td>
<td>0.48-1.38</td>
<td>0.44</td>
</tr>
<tr>
<td></td>
<td>No (709)</td>
<td>49</td>
<td>6.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.3.4 Age-specific malaria prevalence and ITN use during the rainy season

The results indicated that, all age categories that were using ITNs were equally protected compared to non-users during the rainy season. This observation may be because of the low immunity among all age groups from low malaria transmission areas of the highlands. Figure 4.2 illustrates differences in age-specific malaria prevalence between ITN users and non-ITN users across age groups. In Emutete, the parasite infection rate was 9.0% in ITN users compared with 13.0% in the non-ITN user group (P = 0.09), whereas in Iguhu parasite prevalence was 16.9% in ITN users compared with 23.2% in the non-ITN user group (P = 0.07) (Figure 4.2).
Figure 4.2 Age-specific malaria parasite prevalence among ITN and non-ITN users during rainy season
4.3.5 Age-specific malaria prevalence and ITN use during the dry season

During the dry season, the overall infection prevalence was low compared with the rainy season. The transmission was similar between ITN users and non-users (6.1% vs. 6.7% in Ighuhu and 7.3% vs. 8.4% in Emutete) in the dry season. There were significant differences in parasite prevalence among different age groups, with the highest infection rate in the 5-14 year age group. This group also showed the highest reduction in parasite prevalence in ITN users relative to non-ITN users during infection peak than low season, i.e., the rainy season (Figure 4.3 and Figure 4.2).
Figure 4.3 Age-specific malaria parasite prevalence among ITN and non-ITN users during dry season
4.3.6 Malaria vectors density and ITN usage

The study found that households with at least a functional ITN had significantly fewer malaria vectors during the high transmission season than those without a net. Due to the very low *An. funestus* densities in the two highlands sites, this data was categorized into season for analysis. Unlike in the dry season where there was no difference in the number of indoor *An. funestus* collected in the houses with or without ITNs, there was significantly high number of *An. funestus* collected in houses without an ITN compared with those with one during the wet season ($\chi^2 = 3.86$, $P=0.04$). Table 4.5 shows *An. gambiae* s.l. density during the two study seasons. No significant differences were detected during the dry season in indoor resting female *An. gambiae* s.l. density between ITN owning houses and houses without ITNs (Table 4.5). Indoor resting *An. gambiae* s.l. density in Emutete was 0.58 females/house/night (f/h/n) in houses using ITNs compared with 0.80 f/h/n in houses not using ITNs ($t = 1.25$, d.f. = 282, $P = 0.21$). *An. gambiae* s.l. density in Iguhu was 0.10 females/house/night (f/h/n) in houses using ITNs compared with 0.09 f/h/n in houses not using ITNs ($t = 0.06$, d.f. = 262, $P = 0.95$). However, during the rainy season, indoor resting female *An. gambiae* s.l. density in houses with functional ITNs were significantly lower, 43% lower, compared to those not using ITNs in both Emutete and Iguhu (Table 4.5). Indoor resting female *An. gambiae* s.l. densities in Iguhu were 0.64 f/h/n and 1.10 f/h/n in houses using and not using ITNs, respectively ($t = 1.96$, d.f. = 212, $P = 0.05$), whereas those densities were 0.90 f/h/n and 1.56 f/h/n in Emutete ($t = 2.38$, d.f. = 167, $P = 0.02$).
Table 4.5. Household bed net coverage and *Anopheles gambiae* s.l density (female/house/night) during the dry and rainy seasons

<table>
<thead>
<tr>
<th>Season</th>
<th>Site</th>
<th><em>An. gambiae</em> density (95% CI)</th>
<th>Household without ITN</th>
<th>Household with ITN *</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry season</td>
<td>Emutete</td>
<td>0.80 [0.48, 1.13]</td>
<td>0.58 [0.37, 0.79]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Iguhu</td>
<td>0.09 [0.02, 0.17]</td>
<td>0.10 [0.00, 0.19]</td>
<td></td>
</tr>
<tr>
<td>Rainy season</td>
<td>Emutete</td>
<td>1.58 [1.04, 2.07]</td>
<td>0.90 [0.68, 1.12] *</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Iguhu</td>
<td>1.11 [0.72, 1.50]</td>
<td>0.64 [0.44, 0.84] *</td>
<td></td>
</tr>
</tbody>
</table>

* Household with ITN is defined as household that has at least one ITN being used at the time of survey.

* Significant difference at level of 0.05 in two sample t-test assuming unequal variances.

4.3.7 Factors affecting ITN use

4.3.7.1 Education level of Household head

Education level and knowledge about malaria transmission were some of the significant reasons affecting ownership and usage of ITNs. Education level of household head or family guardian was a significant determinant on the ownership and usage of bednets. When compared to household with no formal education, households with at least a member having primary or secondary education level had significant higher (P<0.05) percentage ITN ownership and usage. When asked about
malaria transmission knowledge, those houses with at least a member having primary or secondary level of education had knowledge about malaria and with significant high level (P<0.05) of ITN ownership and usage than those with no knowledge. Although there were variations between study sites, in general, houses with non-educated parents or guardians had significantly lower ITN ownership, fewer ITNs, lower ITN usage, and significantly less knowledge about malaria prevention using ITNs (Table 4.6).

Table 4.6. Education level of household heads or guardians and bed net usage

<table>
<thead>
<tr>
<th>Site</th>
<th>Education level **</th>
<th>None (111)</th>
<th>Primary (417)</th>
<th>≥Secondary (215)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Emutete</strong></td>
<td>ITN usage and other factors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Houses with ITNs (%)</td>
<td></td>
<td>43.18 a</td>
<td>69.92 b</td>
<td>68.69 b</td>
</tr>
<tr>
<td>Average number of ITNs per house</td>
<td></td>
<td>0.59 a</td>
<td>0.91 b</td>
<td>1.27 c</td>
</tr>
<tr>
<td>ITN usage in adults in houses owning ITN (%)</td>
<td></td>
<td>79.17 a</td>
<td>75.16 a</td>
<td>72.60 a</td>
</tr>
<tr>
<td>ITN usage in children in houses owning ITN (%)</td>
<td></td>
<td>43.06 a</td>
<td>47.83 a</td>
<td>51.70 a</td>
</tr>
<tr>
<td>ITN usage in adults: overall (%)</td>
<td></td>
<td>36.54 a</td>
<td>53.64 b</td>
<td>51.46 b</td>
</tr>
<tr>
<td>ITN usage in children: overall (%)</td>
<td></td>
<td>22.14 a</td>
<td>35.11 b</td>
<td>36.25 b</td>
</tr>
<tr>
<td>% of people knows that ITN prevents malaria</td>
<td></td>
<td>30.30 a</td>
<td>56.91 b</td>
<td>52.53 b</td>
</tr>
<tr>
<td><strong>Iguhu</strong></td>
<td>ITN usage and other factors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Houses with ITNs (%)</td>
<td></td>
<td>40.16 a</td>
<td>65.93 b</td>
<td>67.95 b</td>
</tr>
<tr>
<td>Average number of ITNs per house</td>
<td></td>
<td>0.46 a</td>
<td>0.87 b</td>
<td>1.05 b</td>
</tr>
<tr>
<td>ITN usage in adults in houses owning ITN (%)</td>
<td></td>
<td>87.32 a</td>
<td>94.41 a</td>
<td>91.76 a</td>
</tr>
<tr>
<td>ITN usage in children in houses owning ITN (%)</td>
<td></td>
<td>52.50 a</td>
<td>62.50 b</td>
<td>68.42 b</td>
</tr>
<tr>
<td>ITN usage in adults: overall (%)</td>
<td></td>
<td>40.79 a</td>
<td>68.53 b</td>
<td>73.58 b</td>
</tr>
<tr>
<td>ITN usage in children: overall (%)</td>
<td></td>
<td>24.71 a</td>
<td>46.12 b</td>
<td>57.02 b</td>
</tr>
<tr>
<td>% of people knows that ITN prevents malaria</td>
<td></td>
<td>38.58 a</td>
<td>65.93 b</td>
<td>67.95 b</td>
</tr>
</tbody>
</table>

* Same letter in the same row indicates no significant difference whereas different letters in the same row represent significant difference at p = 0.05 level.
4.3.7.2 Demographic and Socio-Economic risk factors

The study assessed some of the main demographic and socio-economic factors that may be associated with risk to malaria. These factors were assessed as they may be possible confounders during this study. As reported earlier in this study, 65% of the households reported having experienced a malaria episode in the last two weeks (Table 4.1). During this study, two factors were found to be significantly risk factor to occurrence of malaria episodes (Table 4.7). The middle income households earning below Ksh 2000 per month in this study site were associated with increased malaria episodes (OR 1.51, P=0.009). Likewise, households with more than 4 inhabitants had a significant higher risk of malaria infection (OR 1.58, P=0.02). Table 4.7 shows that poor households with income less than Ksh 1090 per month were more vulnerable (OR 1.3) to malaria infection compared to their richer counterparts. Households whose houses had screened eaves were less likely (OR 0.77) to have malaria episodes. Other factors analysed were considered important but had no statistical significance to the occurrence of reported malaria episodes during the study.
Table 4.7 Bivariate analysis of malaria associated Socio-Economic factors in Iguhu and Emutete

<table>
<thead>
<tr>
<th>Socio- Economic Variables</th>
<th>Prevalence N=586</th>
<th>p-value</th>
<th>Crude OR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Has cows</td>
<td>55%</td>
<td>0.5275</td>
<td>0.85 (0.53 - 1.39)</td>
</tr>
<tr>
<td>Screens exists</td>
<td>10%</td>
<td>0.2362</td>
<td>1.77 (0.68 - 4.58)</td>
</tr>
<tr>
<td>Eaves exist</td>
<td>87%</td>
<td>0.8426</td>
<td>0.93 (0.44 - 1.94)</td>
</tr>
<tr>
<td>High # of people/household (≥4)</td>
<td>48%</td>
<td>0.0266*</td>
<td>0.58 (0.35 - 0.94)</td>
</tr>
<tr>
<td><strong>Monthly Incomes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Income less or equals to 1090</td>
<td>31%</td>
<td>0.3327</td>
<td>1.31 (0.76 - 2.24)</td>
</tr>
<tr>
<td>Income between 1091 and 2000</td>
<td>27%</td>
<td>0.0094*</td>
<td>0.51 (0.31 - 0.85)</td>
</tr>
<tr>
<td>Income between 2001 and 5300</td>
<td>29%</td>
<td>0.0568</td>
<td>1.77 (0.98 - 3.18)</td>
</tr>
<tr>
<td>Income greater than 5300</td>
<td>13%</td>
<td>0.8788</td>
<td>0.95 (0.47 - 1.91)</td>
</tr>
<tr>
<td><strong>Education level</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very good</td>
<td>4%</td>
<td>0.7779</td>
<td>0.85 (0.27 - 2.66)</td>
</tr>
<tr>
<td>Good</td>
<td>26%</td>
<td>0.1206</td>
<td>1.61 (0.88 - 2.95)</td>
</tr>
<tr>
<td>Fair</td>
<td>28%</td>
<td>0.4672</td>
<td>0.82 (0.49 - 1.39)</td>
</tr>
<tr>
<td>Poor</td>
<td>42%</td>
<td>0.5973</td>
<td>0.88 (0.54 - 1.42)</td>
</tr>
<tr>
<td><strong>House quality</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grass/Mud wall</td>
<td>21%</td>
<td>0.7502</td>
<td>0.91 (0.51 - 1.63)</td>
</tr>
<tr>
<td>Iron/Mud wall</td>
<td>72%</td>
<td>0.7038</td>
<td>1.11 (0.65 - 1.88)</td>
</tr>
<tr>
<td>Permanent</td>
<td>7%</td>
<td>0.874</td>
<td>0.93 (0.38 - 2.29)</td>
</tr>
</tbody>
</table>

* Significant association of the variable with the occurrence of malaria at p<0.05 level.
4.4 Topographic parameter (Valley shape) and malaria transmission

4.4.1 Larvae distribution and valley shape ecosystem

The results indicated that, the broad U-shaped valleys had higher vector densities and malaria infections than the narrow/steep V-shaped valleys both during the dry and rainy seasons (Table 4.8). The broad valley ecosystems were associated with wider flat surface area that would hold water to create aquatic mosquito habitats whereas the narrow steep valley ecosystems were characterised by fast running gullies of water with less surface to hold aquatic larval habitats.

Table 4.8 Summary of vector densities and parasite prevalence by valley shape and season

<table>
<thead>
<tr>
<th>Valley shape</th>
<th>U-shaped valleys</th>
<th>V-shaped valleys</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rainy</td>
<td>Dry</td>
</tr>
<tr>
<td>Mean number Larvae/dip</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>An. gambiae s.l</em></td>
<td>1.66</td>
<td>1.89</td>
</tr>
<tr>
<td><em>An. funestus</em></td>
<td>2.19</td>
<td>4.39</td>
</tr>
<tr>
<td>Mean adults vectors/house</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>An. gambiae s.l</em></td>
<td>0.77</td>
<td>0.46</td>
</tr>
<tr>
<td><em>An. funestus</em></td>
<td>0.19</td>
<td>0.17</td>
</tr>
<tr>
<td>Parasite prevalence (%)</td>
<td>17.15</td>
<td>14.55</td>
</tr>
</tbody>
</table>
4.4.2 Mosquito larvae and Valley shape ecosystem

The density of both *An. gambiae* s.l and *An. funestus* larvae per dip found in aquatic habitats in broad U-shaped valleys were significantly higher than those found in the narrow V-shaped valleys in both the rainy and the dry seasons. During the rainy season survey, 655 aquatic habitats (total negative and positive) were identified in the study areas. Of these habitats, 376 (57.40%) were found in the broad U-shaped valley sites. During the dry season, a total of 1,338 habitats were found in the study sites and of these, 574 (42.90%) were in the broad U-shaped valley site. Of the 376 aquatic habitats found in the broad U-shaped valley area during the rainy season, 97 (25.80%) were positive for anopheline larvae while of the 574 habitats found during the dry season, 140 (24.39%) were positive for anopheline larvae. In the narrow V-shaped valley, of the 279 habitats found during the rainy season, 78 (27.95%) had anopheline larvae while during the dry season 108 (14.13%) habitats out of 764 habitats were positive of anophelines. Table 4.9 shows the percentage of habitats positive with anopheline larvae categorized by habitat location of valley bottom (≤500m from the valley river line) and uphill area (≥500m from the valley river line). During univariate analysis, anopheline larvae occurrence was associated with many topographic variables. Altitude was negatively associated with occurrence of anopheline larvae (t=-2.81, P<0.05). Habitats positive for anopheline larvae were evident in lower altitude areas along the main river bank, 500m distance both sides of the river, categorized as valley bottom (Figure 4.4).
Table 4.9 Percentage of habitats with malaria vector larvae within valley bottom and uphill locations in different valley shapes and different seasons

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Valley bottom</td>
<td>Uphill</td>
</tr>
<tr>
<td>U-shape</td>
<td>25.6</td>
<td>26.8</td>
</tr>
<tr>
<td>V-shape</td>
<td>28.7A</td>
<td>26.7A</td>
</tr>
</tbody>
</table>

Note: \( \chi^2 \)-test at significant level of 5%. Different capital means; seasonal difference at same location within valley shape. i.e. a difference at the valley bottom between rainy and dry season in V-shape valleys. Different small letters; means difference within location between valley shapes in each season. i.e. a difference between U and V-shape at both valley bottom and uphill during the dry season.
Figure 4.4 The distribution and abundance of seasonal malaria vector larvae positive habitats (Source, Atieli et al., 2011).

The study found that, valley shape, either U or V-shape (t=3.77, P<0.0001) and wet season (t=3.97, P<0.0001) were positively associated with anopheline occurrence with more anopheline positive habitats in broad than narrow valleys. Likewise, during rainy season, more positive habitants were identified than during the dry season. Multivariate analysis showed that, An. gambiae s.l larvae positive habitat occurrence was significantly dependent on the valley shape of either broad U-shaped or narrow V-shaped valley irrespective of the season. The broad U-shaped valley had a significantly higher probability of positive larval habitat occurrence than the narrow V-shaped valleys (P=0.024, Tukey HSD test) during both the rainy and the
dry season. In contrast, although there were more *An. funestus* positive habitats in the broad valley than the narrow valley, their occurrence was strongly season dependent (P=0.06, Tukey HSD test).

### 4.4.3 Adult malaria vectors and valley shape ecosystem

Majority of the total indoor resting adult mosquitoes collected, 54.75% and 90.64% were found in the houses located in the broad valley during the dry and rainy seasons respectively. Houses in the broad valley ecosystem had significantly higher densities (P<0.05) of vectors than houses in the narrow valley ecosystem during the dry and rainy season (Figure 4.5). During the dry season, of the total houses sampled in the broad valley, 38.33% were positive for at least one vector while during the rainy season 41.89% were positive. In the narrow valley, 16.25% of the houses were positive for malaria vectors during the dry season while 6.11% were positive in this valley during the rainy season. Adult vector densities were higher in houses in the broad rather than in the narrow valley ecosystem during both the dry (0.64 versus 0.33) and rainy (0.80 versus 0.08) seasons. When categorized by valley location, both the valley bottom and uphill location houses of the broad valley had significantly higher densities of vectors when compared to similar locations in the narrow valley (Table 4.10).

In univariate analysis, *An. gambiae s l.* densities were positively associated with valley shape (t=5.70, P<0.0001) with more vectors found in houses within the broader U-shaped valley (Figure 4.5). Altitude was negatively associated with indoor vector densities (t= -4.91, P<0.0001). There was no association of vector densities
Two models were generated during multivariate analysis, including valley and altitude variables. In the first model, where indoor vector densities and only valley shape was used as an independent variable, valley shape improved the prediction. Despite being negatively associated with indoor vector densities, addition of altitude in the second model did not improve the model prediction for presence of indoor vectors. The additional proportion variability accountable for by altitude was 0.9%, an evident lack of significance effect by addition of altitude in the prediction model.

Figure 4.5 The distribution and abundance of seasonal indoor malaria vectors in different valley shapes (Source, Atieli et al., 2011).
Table 4.10 Percentage of houses with malaria vectors within valley bottom and uphill in different valley shapes and seasons

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Valley bottom</td>
<td>Uphill</td>
</tr>
<tr>
<td>U-shape</td>
<td>43.9a</td>
<td>13.9Aa</td>
</tr>
<tr>
<td>V-shape</td>
<td>8.0Ab</td>
<td>2.9b</td>
</tr>
</tbody>
</table>

**Note:** $\chi^2$-test at significant level of 5%. Different capital means; seasonal difference at same location **within valley shape**. i.e. a difference at the valley bottom between rainy and dry season in V-shape valleys. Different small letters; means difference within location **between valley shapes** in each season. i.e. a difference between U and V-shape at both valley bottom and uphill during the dry season.
4.4.4 Malaria infection rates and valley shape ecosystem

The study found that, the risk of malaria infection differed across the valley shapes (Table 4.11). Malaria prevalence was significantly higher in participants residing within broad valley villages than those in narrow valley villages during the dry (14.55% vs. 7.48%) and rainy (17.15% vs. 1.20%) seasons (Figure 4.6). In univariate analysis, malaria infections were associated with topographic variables. Malaria infections were positively associated with valley shapes while season and altitude had a negative association. Broad valley shape was associated with high malaria infections (t=9.96, P<0.0001). Both season and altitude had a negative association with malaria infection occurrence, t=-2.49, P<0.013 and t= -5.83, P<0.0001 respectively. High rainy season was likely to reduce infections probably because of larval wash effect leading to low vector production. High altitude was likely to be associated with fewer malaria cases. Multivariate models using topographic independent variables of valley shape, altitude and season all predicted malaria infection cases. In every model repetition, adding valley shape and altitude improved prediction of malaria infection cases (P=0.06, Turkey HSD test). However, valley shape predicted malaria infection cases better than altitude in all the repetitions. Valley shape and altitude generated the best prediction model with the highest coefficient.
Table 4.11 Malaria parasite positive rates in participants within valley bottom and uphill in different valley shapes and different seasons

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>U-shape</td>
<td>20.6a</td>
<td>12.7a</td>
<td>15.2a</td>
<td>13.9</td>
</tr>
<tr>
<td>V-shape</td>
<td>1.6Ab</td>
<td>0.7Ab</td>
<td>7.8Bb</td>
<td>7.8B</td>
</tr>
</tbody>
</table>

Note: χ²-test at significant level of 5%. Different capital means; seasonal difference at same location within valley shape. i.e. a difference at the valley bottom between rainy and dry season in V-shape valleys. Different small letters; means difference within location between valley shapes in each season. i.e. a difference between U and V-shape at both valley bottom and uphill during the dry season.
Figure 4.6 Seasonal distribution of microscopy malaria positive participants in two different valley shapes (Source, Atieli et al., 2011).
4.5 Targeted vector intervention

4.5.1 Larval intervention survey

Targeted indoor spraying with ICON was conducted in 2,846 targeted houses in 2011. Table 4.12 and 4.13 shows An. gambiae s.l larvae weighted density/dip, adult indoor mosquito/house and parasite prevalence in Emutete and Iguhu respectively. Anopheles gambiae larvae density in the intervention clusters was low by 15% and 33% during the dry and wet season respectively when compared to density in control clusters in Emutete post intervention. In Iguhu, there was significant less (50%) larvae density in intervention clusters during the rainy season when compared to control clusters although no significant difference was recorded during the dry season between the control and intervention clusters. When seasonal change of larvae density within control and intervention clusters was considered, there was no significant difference in the change of density in both clusters. Although rainy season had high densities (2fold) of larvae compared to dry season, but low compared to non-intervention period where the change is always not less than 4fold. This indicated a community wide benefit of targeted intervention where the entire area both intervention and control experienced reduction in larval density following an intervention program targeting larvae and adult mosquitoes.
Table 4.12 Seasonal Larval, adult vectors and parasite prevalence in Emutete post target Intervention

<table>
<thead>
<tr>
<th>Cluster</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larval</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Weighted/20 dips)</td>
<td>3.4</td>
<td>2.7</td>
<td>1.2</td>
<td>1.3</td>
<td>6.9</td>
<td>3.4</td>
<td>5.6</td>
<td>5.0</td>
</tr>
<tr>
<td>Adult</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Mean An. gambiea/hse)</td>
<td>0.05</td>
<td>0.16</td>
<td>0.07</td>
<td>0.15</td>
<td>0.01</td>
<td>0.08</td>
<td>0.07</td>
<td>0.04</td>
</tr>
<tr>
<td>Parasite prevalence (%)</td>
<td>4.5</td>
<td>10.7</td>
<td>11.8</td>
<td>5.3</td>
<td>7.8</td>
<td>10.9</td>
<td>11.8</td>
<td>9.5</td>
</tr>
</tbody>
</table>

Table 4.13 Seasonal Larval, adult vectors and parasite prevalence in Iguhu post target Intervention

<table>
<thead>
<tr>
<th>Cluster</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larval</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Weighted/20 dips)</td>
<td>3.28</td>
<td>3.62</td>
<td>2.31</td>
<td>1.66</td>
<td>14.85</td>
<td>5.07</td>
<td>5.94</td>
<td>7.35</td>
</tr>
<tr>
<td>Adult</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Mean An. gambiea/hse)</td>
<td>0.43</td>
<td>0.48</td>
<td>0.23</td>
<td>0.22</td>
<td>0.59</td>
<td>0.39</td>
<td>0.36</td>
<td>0.31</td>
</tr>
<tr>
<td>Parasite prevalence (%)</td>
<td>6.7</td>
<td>11.4</td>
<td>6.9</td>
<td>5.1</td>
<td>7.3</td>
<td>10.4</td>
<td>6.2</td>
<td>7.1</td>
</tr>
</tbody>
</table>

Note: Green shaded clusters are intervention clusters
4.5.2 Adult mosquitoes intervention survey

Indoor resting densities of adult *An. gambiae s.l* per house were generally low with none of the clusters recording a mean of one vector per house (Table 4.12 and 4.13). Before larvae and IRS intervention program, these sites recorded indoor *An. gambiae s.l* average of between 1.8 and 2.4 female/house/night (f/h/n) (compared to the current 0.4f/h/n after the intervention, which was in general a 80.9% reduction. Although there was a general reduction in *An. gambiae* density, Emutete recorded a 61% reduction in intervention cluster during the rainy season (0.12 f/h/n) compared to the dry season (0.31 f/h/n) while in control cluster the reduction was at 33% between the rainy season (0.08 f/h/n) and dry season (0.12 f/h/n). The decrease in vector density in control clusters during the dry season may be attributed to the community wide effect of the targeted intervention. An increase in vector density was experienced in Iguhu during the rainy season although not compared to increase during pre-intervention period. There was an increase of 1.3fold in f/h/n in control clusters while intervention clusters recorded no change between the seasons. Lack of change in vector density between seasons gives the assumption that the population was kept stable at low dry season levels following the intervention program.

4.5.3 Parasitological survey

During pre and post intervention parasitological survey among parasites detected, *P. falciparum* accounted for over 96% of positive samples, while *Plasmodium malariae* and *Plasmodium ovale* comprised less than 4%. There were a few cases of mixed
infections of two parasite species in one participant. The longitudinal follow up study (Dry and rainy season 2011) shows that malaria parasite prevalence in both the intervention and non-intervention areas have decreased since the targeted intervention exercise was done compared to pre-intervention period. Parasite prevalence was at an average of 20.6% and 17.4% (Table 4.4) in Emutete and Iguhu respectively during pre-intervention period, but this dropped to an average of 9.0% and 7.6% (Table 4.12 and 4.13) in Emutete and Iguhu respectively. This represented a community wide relative reduction of 53.3% and 56.3% in parasite prevalence following the targeted intervention. Same trend of reduction in confirmed cases of malaria was also recorded in Iguhu and Emuhaya district hospitals which are main hospitals in the study areas of Iguhu and Emutete respectively (Figure 4.7). Due to logistic difficulties, data on mortality during the same period was not recorded by this study.

Figure 4.7 Malaria confirmed cases in the major hospitals in the study areas
4.6 **Community interviews feedback**

The community interviews revealed that not only the community appreciated the use of ITNs for malaria control, but also recognised the effect of IRS as a vector and malaria control strategy. They indicated that the spraying period was appropriate and that this should be done more often. Some members were excited that they felt this intervention demonstrated that the government was caring about their health to reduce malaria. The community advocated for this approach as they cited its multifaceted benefits of killing other nuisance insects in their houses such as cockroaches and houseflies. The respondents suggested that the most successful approach to reduce malaria in the region was by spraying IRS monthly, distribute more ITNs and provide free antimalarials to the sick. Table 4.14 summarizes the main responses from the community focus group discussions.
Table 4.14 Summary of community response on IRS for malaria vector control

<table>
<thead>
<tr>
<th>i) Response on the IRS approach for vector control</th>
</tr>
</thead>
<tbody>
<tr>
<td>I like it</td>
</tr>
<tr>
<td>It is selective leaving other areas uncovered</td>
</tr>
<tr>
<td>Felt the presence of government care</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ii) Timing of the intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Was timely and should continue</td>
</tr>
<tr>
<td>Should be done regularly</td>
</tr>
<tr>
<td>Was late as we have lost so many people</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>iii) Experience with the intervention exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comfortable with the exercise</td>
</tr>
<tr>
<td>Infringing people privacy upto the bedrooms</td>
</tr>
<tr>
<td>Eye irritating</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>iv) Associate low vectors and malaria with the intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Totally associate with reduction</td>
</tr>
<tr>
<td>Partially</td>
</tr>
<tr>
<td>Not sure because sometimes malaria is high or low</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>v) Would you advocate for this approach as compared to ITNs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, because kills other household nuisance insects too</td>
</tr>
<tr>
<td>Should complement each other</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>vi) Best way to control malaria in this area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spray monthly</td>
</tr>
<tr>
<td>Give us more nets</td>
</tr>
<tr>
<td>Give drugs for free</td>
</tr>
</tbody>
</table>
4.7 Key informants responses

The discussion with key informants revealed that malaria was still a threat in the study area (Table 4.15). The hospital personnel (clinical officer in-charge and public health officer) indicated that cases of malaria were on the rise in the last one year despite the scale-up of ITNs. Some of the reasons cited for the recorded rise in malaria cases were; accurate diagnosis of reported cases at the hospital following the introduction of microscopic test confirmation and RDTs, occasional free drugs supply, the introduction of free nets at the health facility for expectant mothers and under fives and the elevation of the hospital to a District level health facility. These factors presumably have increased hospital admissions. Interview with The Provincial Malaria Control Coordinator (PMCC), indicated that malaria situation was under control although with challenges. Challenges mentioned among others were, delays in drugs supply, community adherence to ITNs use and poor/delayed community health seeking behaviour. The coordinator mentioned that there were plans with other partners to scale-up door to door ITNs distribution and regular supply of drugs. The malaria control office had also concluded recruitment of community health workers (CHW) that were being trained for trials on door to door diagnosis and treatment of malaria cases. Provincial malaria control office also indicated that they were upbeat about the studies and control efforts done by other partners in the region. Plans are underway to simulate targeted vector control in this region as it is being done in other parts of the country that are prone to epidemics and high transmission. Communication with the Director of Division of Malaria Control in Nairobi during the first annual malaria forum where part of this study results were
presented to policy makers (Appendix XVIII), indicated that plans are underway to scale-up targeted vector control in other parts of the country prone to epidemics.

Table 4.15 Key informant response on malaria situation in the study area

i) Situation of malaria in study site
- Under control
- Under control although with challenges
- Dynamic, sometimes high sometimes low

ii) Factors underlying responses above
- High ITN coverage
- More partners including KEMRI doing lots of control
- Periodic malaria drugs availability

iii) Possible remedies
- More nets distribution and use demonstration to owners
- Regular drugs supply
- Continuous integrated control efforts from all partners
- Continuous surveillance efforts and door to door treatment

iv) Malaria diagnosis and treatment
- No enough drugs supply to sustain confirmed hospital cases
- More personnel
- Rapid diagnostic test should be sustained

v) Community response to malaria control
- Most community members can diagnose malaria by signs
- Community like buying own drugs from shops/self medication
- Free ITN are the main personal protection in the community
CHAPTER FIVE: DISCUSSION

5.1 Introduction

This chapter presents the discussion of mosquito bednet ownership versus actual usage and the effect of this variation among users and non-users on the abundance of indoor malaria vectors and malaria transmission during the dry and rainy seasons. Secondly, the chapter discusses the role of topography classified as broad ‘U’ shaped valley and steep/narrow ‘V’ shaped valley ecosystem on the occurrence, abundance and distribution of malaria vectors, both larvae and adult mosquitoes and malaria transmission. Lastly, the chapter discusses the effect of targeted vector control of identified transmission hot spots on the abundance of malaria vectors and malaria transmission.

5.2 Bednet ownership versus usage on malaria vectors and transmission

Most parts of Kenya have approached or met the RBM household ITN coverage target of at least 60% as reported by previous studies (CBS 2003). Similarly, after almost six years of Kenya Division of Malaria Control (DOMC) efforts towards distribution of nets on a national scale, this study has shown that despite current high net ownership (>60%) within the highlands, actual usage remains low, with only approximately 53% of the residents who own nets reporting net use. This scenario may be a set-back on the intended and expected role and effect of distributed ITNs. As observed, most of the unused nets were either new and kept safely from damage or hung but not used. Low education level of the head of the household is one of the reasons why such a high percentage of the population own but do not use nets.
Compared with heads of household with no education at all, the majority of heads of household with at least a primary level education know that mosquitoes transmit malaria and they eventually tend to acquire and use nets. Another reason mentioned by majority respondents was seasonality, with the onset of the colder/rainy season improving use of nets among those who own them, either because of the cold weather or because of noted presence of biting mosquitoes. This observation is consistent with previous studies conducted earlier in Ethiopia, where 35% of nets owned were not being used (Baume et al., 2009). In contrast, studies in Sierra Leone and Madagascar recorded very low percentages of owned but unused nets (5.1% and 5.6% respectively) (Vanden et al., 2010). There is therefore need for targeted sensitization of the less educated group on importance of ITN ownership and usage so as to scale-up utilization. Likewise, there is need to sensitize the community on the importance of ITN adherence throughout the seasons with emphasis that malaria transmission occurs year round thus need for protection regularly. One of the probable ways to approach this may be through routine household visit by trained community health workers.

Even though ITN ownership was similarly high across seasons, seasonality in use was remarkable during this survey in both sites of study. Net use was considerably higher in the rainy, cooler season of April-May than in the dry, hot season of January-February. During the rainy season, the non-compliance rate was lower compared with the dry season. Similar findings have also been reported in surveys in ITN intervention trials in the lowlands of western Kenya and northern Ghana (Alaii et al., 2003; Binka et al., 1997). As in this highland region, the rainy months are characterized by the highest incidence of mosquito biting and malaria transmission.
Unlike most parts of Africa where malaria is perennial and not limited to the rainy season (Craig et al., 1999), this area experiences seasonality in malaria transmission, but with “stable” transmission in areas along the valley bottoms (Githeko et al., 2000). Because of stable vector breeding habitats in the valley bottoms in the highlands (Lindsay et al., 1998), malaria transmission occurs year round, but with low intensity, and thus the need for continuous use of ITNs. Lower use of ITNs during the dry season with the assumption of no vectors and therefore no transmission can be detrimental as experienced in Ouagadougou in Burkina Faso, where most malaria occurs in the hotter months just after the rains (Procacci et al., 1991). Remarkable seasonality in net use reported in this area highlights the need for education to promote year-round use. For accurate monitoring and evaluation of ITN effect on malaria transmission, it would be preferable to conduct daily surveys on household ITN use year round to capture both low and high malaria transmission seasons. Unfortunately, this study could not accomplish this because of logistic difficulties. However, this study was able to undertake a two season survey in two similar geographic highland regions. This made it more appropriate to compare between surveys conducted in different seasons with less bias.

The proportion of households possessing mosquito net(s) and the proportion of children less than 5 years of age who slept under a net the preceding night are two of the key RBM bed net ownership indicators used to investigate the strengths and weaknesses of monitoring malaria control (RBM, 2005). In this study, the comparative difference in use by children and adults did not depend on any characteristic of the surveys, such as region or season. Usage of young children below age of 5 years with nets was often as high as or higher than for adults above
15 years old. Children between ages of 5-14 years had significantly lower usage during the dry and rainy seasons in both the regions. This phenomenon has also been found elsewhere in studies in Uganda (Kampala City Council, 2002), in Ghana and The Gambia, but in contrast with earlier findings from, Kenya, Rwanda, Zimbabwe and Burkina Faso, where the pattern was inverse (Korenromp et al., 2003), with adult ITN use being higher than that for children under 5 years of age. Another contrasting finding was observed in rural south central Somalia, where net use in younger children, older children, and adults was not different (Noor et al., 2009). It thus appears that young children are not at a disadvantage in the allocation of scarce nets and eventual use within households in either of the regions in any season.

The protective effect of nets on infection prevalence during the rainy season among sampled participants was consistent across age-groups except for ages under 5 years in Iguhu. Unlike in the rainy season, the nets’ protection role was not clearly observed in older children and adults in the dry season. Children under 5 years old in both regions had the largest protection margin with net use. Overall, during the dry season infection prevalence among net users was lower than in non-users by 56.7% in Emutete and by 26.2% in Iguhu among this age group. During this season, the odds of malaria infection among this age group were 2.3 fold and 1.4 fold higher among non-net users in Emutete and Iguhu respectively. While the approach of targeting interventions to protect at-risk individuals is based on solid scientific grounds (Smith et al., 2006, 2007; Woolhouse et al., 1997) and is widely accepted (Nafo-Traore et al., 2005), this strategy should not preclude efforts to maximize communal protection through less selective delivery mechanisms, more so in areas where all age groups are vulnerable. Targeting limited subsidies to maximize
personal protection of the most vulnerable should remain a priority, mostly in malaria endemic zones, but more equitable and effective suppression of risk for entire populations in hypo-meso endemic areas where all ages are more susceptible to malaria infections should be encouraged. Likewise, given the relatively higher prevalence of infection through older childhood and into adulthood, during high transmission seasons, it is important to recognize the need to provide ITNs to all members of a community, and not to focus only on young children in areas of low transmission. This resonates with recent calls for high coverage among all community members across the range of transmission settings (Killeen et al., 2007) where it is also recognized that individuals older than five years contribute to transmission.

The effects of ITNs very much depend on their excito-repellent and insecticidal properties (Lindsay et al., 2003). Furthermore, the interaction of these two properties, to yield maximum levels of personal and communal protection, is complex and has crucial implications for ITN programmes across Africa (Killeen et al., 2007; Roberts et al., 2000). Households with a functional net during high transmission season, when densities of malaria vectors are high had significantly fewer mosquitoes than those without a functional net. These household vector reduction outcomes concur with findings from earlier studies on the properties of ITNs where it has been clearly shown that ITNs reduce malaria risk among unprotected individuals by suppressing the density, survival (Magesa et al., 1991), and feeding frequency (Charlwood et al., 2001) of malaria vector populations. With both insecticidal and excito-repellent properties, ITNs can protect not only the individuals and households that use them, but also members of the surrounding
community (Hawley et al., 2003). This is because they kill adult mosquitoes directly or force them to undertake longer, more hazardous foraging expeditions in search of vertebrate blood and aquatic habits. They repel mosquitoes to reduce the frequency with which they successfully acquire blood, often diverting them to feed on other mammals that do not host the malaria parasite, resulting in greatly reduced prevalence of sporozoite infection (Killeen et al., 2007). These two major properties add to the effectiveness of ITNs for personal protection because they constitute the major motivating force behind ITN uptake and use at the individual and subsequently the community level.

5.3 Valley shape as a topographic parameter and malaria transmission

Malaria risk mapping requires inclusion of factors related to vector distribution, human-vector contact, human practices, and the environmental context in which they occur (Noor et al., 2009). Highland topographic features restrict the spatial distribution of vector breeding habitats confining them to the valley bottom (Minakawa et al., 2005; Munga et al., 2006). Furthermore, it restricts high intensity of exposure to malaria at the valley bottom resulting in a heterogeneous incidence of morbidity when compared to hilltop. Identification of area specific topographic features has important implication in classification of malaria epidemiology for specific micro-regions. Moreover, accurate prediction of malaria vector occurrence and *Plasmodium* transmission risk is essential in heterogeneous environments to permit focal cost effective intervention strategies and heightened surveillance in the regions that require them the most (Githeko et al., 2006). Results of this investigation concur with previous studies demonstrating associations between malaria vectors occurrence and malaria risk and topographic characteristics specifically the shape of
the valley in the highlands where malaria epidemics occurs (Balls et al., 2004). Importantly, however, it demonstrate that factors associated with malaria are not necessarily predictive of it, most likely because strong correlations between environmental factors can lead to confounded relationships.

In highland regions of East Africa, where unstable malaria transmission may result in part from the very low numbers of anopheine mosquito vectors (Bodker et al., 2003), the proximity of houses to locations with suitable topography for mosquito breeding may be an important determinant of malaria risk (Carter et al., 2000). During this study, spatial surveys of the availability of larval habitats and presence of larvae in this habitats showed that, the actual numbers of positive larvae habitats in broad valley region were more and stable in both the rainy and the dry seasons. In contrast, percentages of positive larval habitats were season depended in narrow V-shaped valley with significant high occurrence during the rainy than during the dry season. This can be explained by the fact that unlike the broad U-shaped valleys that are characterized by meandering slow moving rivers, poor drainage and with large surface to hold water at the valley bottom suitable for larval breeding, the narrow V-shaped valley systems are characterized by fast running rivers at the valley bottoms. They too have steep slopes that provide good drainage in the area and so there are few vector breeding habitats in these ecosystems. Similarly, during adult vectors survey, households within the broad U-shaped valley had higher densities of vectors per house during both the dry and rainy seasons compared with those within the narrow V-shaped valley. This result concurs with earlier studies in the highlands which indicated that anopheline larval habitats and malaria transmission were
generally clustered near the streams and rivers with poor drainage (Minakawa et al., 2005; Noor et al., 2009). Broad U-shaped valley regions were therefore suitable for larvae breeding and productivity of adult vectors than the steep narrow V-shaped valley regions.

High larval and adult vector abundance within broad than narrow valley further explains why spatial variation in malaria transmission in the highlands is well a function of the terrain characteristics (Cohen et al., 2008). This phenomenon also shades more light on the reason why there is heterogeneity in malaria transmission in the highlands (Ototo et al., 2011) and with variations in close proximity areas within the same region. Steep V-shaped valleys experience fast surface water and river flows during the rains. These events do not allow formation of habitats that would stay long enough to sustain survival of mosquito aquatic life cycle. These ecosystems therefore experience wash effect on potential larval habitats. Habitats with either eggs or new hatched larvae are often washed down-stream with running water. This fact was evident where vector densities in narrow valley shape exhibited significant seasonality in distribution while those in broad valley had similar distribution across the seasons (Table 4.8). Probably because of the wash effect, the narrow valley exhibited unusual vector densities during the rainy season. Unlike in the broad valley where there were fairly higher densities of vectors/house during the rainy season, narrow valley had significantly fewer vectors during the rainy than the dry season. Vector abundance and distribution were associated with valley shape, location and season. Similar studies on vector distribution in this region have shown that low-lying flat areas and reclaimed swamps are highly productive than steep terrains.
habitats (Githeko et al., 2006; Munga et al., 2006; Ototo et al., 2011; Lindblade et al., 2000). These findings using topographic parameters to identify area specific larvae and adult vectors spatial distribution can be utilized to characterize risk regions with close proximity for the purpose of targeted larval or adult vector control. Unlike blanket control, targeted approach would use limited resources with expected great outcome.

The magnitude of the differences in vector abundance (2-10-fold difference) and 2-14-fold difference in malaria incidences between the narrow and broad valley regions during the dry and the rainy season respectively was striking, suggesting that even within this small area, risk of malaria ranges from very low to quite high depending on the shape of the valley. The ecological factors independently associated with increased malaria risk in this study – abroad U- shape valley, lower altitude and rainy season – are all physical contributors to increased malaria risk in the highlands (Cohen et al., 2010; Githeko et al., 2006). Moreover, the associations of these risk factors with vector abundance and malaria incidence were strong, consistent, similar over the seasons, and highly significant. The results of this study indicate that as a topographic factor, the shape of the valley either broad U-shaped or narrow V-shaped and distance from the valley bottom predicted presence of both anopheline positive aquatic habitats and indoor malaria vectors and thus are highly predictive of malaria patterns in this small region. People living in areas within the broad valley shape appeared to be at significantly greater risk of fairly stable malaria infections than those living in areas of narrow valley shape. The non-homogeneous distribution of larval breeding habitats and adult vector spatial distribution between these two valley
shape ecosystems may, consequently, lead to focal malaria transmission and heterogeneous human exposure to malaria. It can thus be expected that the malaria transmission profile in the highlands is influenced not only by hydrological factors, but also by topographic factors and distance from the foci of transmission. This heterogeneity in transmission can lead to variable stability of malaria transmission in space with some areas having stable and others unstable transmission. This would lead to different sensitivities to epidemics within relatively short distances in the highlands. Future studies should assess the utility of valley shape as a topographic factor for malaria risk prediction across larger and more geographically diverse areas, especially at scales useful for National division of malaria control to target interventions. Such replication of this work will be required before conclusions can be drawn about the utility of these methods elsewhere.

5.4 Targeted vector control as a malaria intervention tool

Insecticide-treated bed nets (ITNs) and indoor residual spray (IRS) are among the principal malaria prevention and control measures in Africa. Targeted operational programs involving these two intervention and control tools can successfully reduce malaria vectors and concurrently malaria transmission (Zhou et al., 2010, Atieli et al., 2011). However, the high efficacy of indoor residual spraying in malaria control is usually offset by high costs in terms of logistics and the cost of insecticides. The western Kenya highlands provide an excellent opportunity for targeted malaria control because more than 90% of the vectors are confined to a narrow band almost <500 meters each side of the valley bottoms (Zhou et al., 2007, Atieli et al., 2011). Such intervention approach reduces vector densities and transmission intensity
within the high transmission spots and reservoirs and thus expected to have a mass effect in the unsprayed areas, i.e., the community-wide benefits (Killeen et al., 2004, Hawley et al., 2003), while reducing the costs involved in the spray programme. This targeted approach is applicable in many settings across Africa because much of the population of Africa lives in highland areas and even more of the population is aggregated around rivers, streams, lakes and swamps because land and fertile soil are limiting resources. Vector control measures vary considerably in the scope of their applicability. The result of this targeted intervention using IRS stabilizes malaria prevalence during the expected high transmission season to low levels comparable to that of low/dry transmission season. This effect is comparable to the average effectiveness of mass IRS and ITNs (Curtis et al., 2000). An important advantage of this targeted IRS programme is the reduction in cost. A blanket application of IRS in the intervention zone would have a costed four times the cost of targeted intervention. However, since only 25% of the houses were sprayed in our study, the cost of insecticide was reduced 4 fold. It is estimated that the same proportional cost saving (and equivalent time saving) was achieved on transport and personnel budgets. Hence, a lasting and substantial reduction in malaria prevalence that is comparable to previous mass spray studies resulted from our targeted approach representing considerable financial savings.
CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter explains the major conclusions of the study based on the objectives. Each objective’s findings have been explained in terms of the context of the study and its implication to the study site population and to the general population in similar malaria transmission and geographical zones. The chapter also gives recommendations based in the gaps realized during this study for further research.

6.2 Conclusions

This study demonstrates that in hypo-meso endemic highlands of western Kenya, despite high mosquito net ownership, actual usage is still remarkably low. To track progress and draw inferences about this principal malaria intervention tool, both ownership and actual use indicators must be taken into account. Based on these findings, ITN use in this region could be increased, if information, education and communication (IEC) messages on malaria transmission were strengthened either through community health workers or net provider programs to encourage participants to use nets they already possess. Since the analyses found that there were disparities in net use across age groups, the current distribution of free nets to the entire population may optimize coverage as well as help increase ITN use.

Given the cost of malaria intervention, accuracy of predicting and classifying high-risk foci in unstable malaria transmission regions is crucial. Despite being in the highlands, this study just like other similar studies confirms that, local areas within
low gradient topography characterized by broad valley bottoms have stable and significantly high malaria risk unlike those with steep gradient topography, which exhibit seasonal variations. Topographic parameters such as valley shape could therefore be considered in identification of high-risk malaria foci to help enhance surveillance or targeted control activities in regions where they are most needed.

Vector control remains the most generally effective measure to prevent malaria transmission. In addition to providing protection to individuals against the bites of malaria infected mosquitoes, vector control interventions can also have a substantial effect on mosquito population dynamics; large reductions in mosquito numbers are frequently seen following the introduction of insecticide-treated nets or indoor residual spraying. IRS has been proven as one of the most effective methods for controlling malaria transmission. Targeted IRS is most suitable for low endemic areas with focal malaria such as the highlands of western Kenya where it can greatly reduce programme cost with comparable effectiveness. Appropriate application or integration of IRS with other interventions, such as ITNs, elsewhere on the continent has to be based on sound scientific research which takes into account the ecological and epidemiological setting, organizational capacity, and social and financial considerations as these in turn effect on operational feasibility and sustainability. This study have demonstrated how this effective control tool might become more widely available as part of an integrated malaria management programme.
6.3 **Recommendations**

1. Division of Malaria Control at district level through community health workers should implement a regular, region-specific rapid assessments of household ITNs ownership, usage and respondent's knowledge to complement ongoing universal coverage/free net distribution, and findings should be incorporated into National malaria control programme policy.

2. National malaria control programs operating in ragged terrain and highland regions should consider topographic and local geographic variance to efficiently identify and derive risk maps of locations that are highly suitable for transmission and which may benefit from targeted interventions and enhanced vigilance.

3. The National Malaria Control Division should implement programmatic targeted IRS interventions on large scale as a complementary intervention tool to already existing ones so as to effectively evaluate and realize its effect on clinical malaria.
6.4 Suggestions for further research

1. The results of this study indicated that more than a half of people who own nets do not actually use them. There is need to carry out an operational case control research using education on need for regular use of owned nets as an intervention so as to evaluate the role of providing education on the level of bednets utilization.

2. The results from this study showed a significantly reduced effect even with combined intervention of ITN, IRS and Bti, which is rather different than predicted by mathematical models (Killeen et al., 2007) and by previous evidence (Bayoh et al., 2010, Mutuku et al., 2011). It is not clear whether Anophelines in these places have changed their biting behavior or not; further investigation is needed to monitor outdoor biting intensity and the possibilities of early evening biting.

3. In this study, although targeted intervention using topographic characteristic of the area did not elicit significant reduction in malaria incidences, there is need to carry out more operational research by targeting both malaria hot spots for vector control and mass drug treatment for all malaria cases (both symptomatic and asymptomatic) to clear both malaria vectors and parasites respectively and to evaluate if this approach would reduce transmission.
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APPENDICES

Appendix I: Map of Study site
Appendix II: Household bednet ownership/use questionnaire

ECOLOGY OF HIGHLAND MALARIA PROJECT
ITN USE AND MALARIA INCIDENCES STUDY

Study site __________________________ Date_______________________
House No.__________

1) How many people sleep in this house?     _________ Adults     _________ Children

2) What are the ages of each adult and child who sleeps in this house?

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<tr>
<th>Adults</th>
<th>DOB</th>
<th>Children</th>
<th>DOB</th>
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(If more, use back page)

3) Head of household education level?

4) Other household with higher education level than the household head? No/Yes.
   If yes, which education level? Primary--/Secondary--/Tertiary--

5) Do you have a bed net? (   ) Yes - proceed to question 4 (   ) No – skip to question 10

6) How many bed nets do you have? _________

7) Is (are) the bed net(s) treated? (   ) Yes - proceed to question 6 (   ) No – skip to question 7
   (   ) Some treated – proceed to question 6

8) When the bed net was treated? _________ month _________ year

9) Who sleeps under a bed net? Why?

10) Who does not sleep under a bed net? Why not?

11) Did you sleep under the bed net last night? (   ) Yes (   ) No

12) Is any member of family sick with malaria right now? (   ) Yes (   ) No – the questionnaire is now complete

13) Who is sick with malaria right now? ( ) Children ( ) Adult

14) Has anyone been sick of malaria in the last 2 weeks? (   ) Yes (   ) No
Appendix III: Socio-demography questionnaire

Bed Nets, Topography and Targeted Vector Control Study in Kakamega and Vihiga Counties

Household Demography

HOUSEHOLD LOCATION
Form Number________Date _______ Interviewer:__________________________

1. Study site 01) Iguhu  02) Emutete
2. House Number _____G.P.S.  Altitude _____ Latitude _____Longitude _____
3. Location of the house: 01) Hill top 02) Mid Hill 03) Valley bottom

DEMOGRAPHIC AND SOCIO-ECONOMIC CHARACTERISTICS

4. Name of head of household ____________________________________________

5. Head of household education level?
   i) None  ii) Primary  iii)Secondary  iv) Tertiary
6. Marital status: 01) married    02) single 03) separated/divorced  04) Widowed
7. How many people living with you are in the following age groups:
   (<1)_____ (1-4)____(5-9)____(10-14)__ (15-19)___(20-49)___(50+)_____
8. Has anyone in this house been sick of malaria in the last two weeks? 01)Yes 02) No

Property Ownership Status

9. Type of family house
   a) Materials (01) Grass roof/mud wall  (02) Iron roof/mud wall  (03) Permanent
   b) Presence of  a)Eaves 01)Yes 02) No  b) Screens? 01)Yes  02) No
10. Land owned in acres ____________________
11. Which food crops do you grow? ______________________________________
12. Do you own any livestock? 01) Yes  02) No.
13. If yes, which ones? 01) Local cows_________02) Pedigree__________
    03) Sheep_____/Goat__________
    04) Pigs_________ 05) Poultry__________
14. Do you own the following properties? 01) Radio 02) Television 03) Bicycle 04) Motor-cycle 05) Car

15. **Household main source of income**

<table>
<thead>
<tr>
<th>Sources of Income</th>
<th>Approx income/wk</th>
<th>Approx Income/month</th>
<th>Approx Income/year</th>
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Appendix IV: Adult mosquitoes collection form

ECOLOGY OF HIGHLAND MALARIA STUDY

ADULT MOSQUITOES COLLECTION FORM

<table>
<thead>
<tr>
<th>Area</th>
<th>Date</th>
<th>Treatment</th>
<th>House Number</th>
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Number of sleepers | Team Leader
-------------------|-------------

### Gonotrophic Stage

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<tr>
<th>Gonotrophic Stage</th>
<th>Species</th>
<th>Gambiae</th>
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Remarks
Appendix V: Larval collection form

LARVAL FIELD COLLECTION COLLECTION FORM

Area……………Date……………House……..Team Leader ……………………………

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<thead>
<tr>
<th>SITE #</th>
<th>LATITUDE</th>
<th>LONGITUDE</th>
<th>LAND USE</th>
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Appendix VI: Terrain profile for "U" (Ighu and Emutete) and "V" (Mbale) shaped valleys as generated from actual cross section elevation values.
Appendix VII: A 3D map of a broad “U”-shaped valley in Emutete
Appendix VIII: A 3D map of a narrow “V”-shaped valley in Mbole
Appendix IX: Targeted vector control study design

![Diagram showing targeted vector control study design]
Appendix X: Community focus group discussion questions

Targeted Vector Control in Kakamega and Vihiga Counties

Interview questions for Focus Group Discussion

1. As a member of this community, if you could rate did you like the approach of Indoor Spraying for malaria vector control that was done last year in March?
2. What would you comment about the timing of the intervention?
3. What was your experience with the exercise during the time of the intervention?
4. What would you comment about the situation of malaria vectors abundance/nuisance and disease episodes since the intervention?
5. Would you associate the vectors and malaria situation with the vector control exercise?
6. Would you advocate for this approach as compared to ITNs which is the main intervention here?
7. Do you think this intervention has complemented the existing intervention tools?
8. What would be the best way to control malaria in this area?
Appendix XI: Key Informant Interview questions

THEMES FOR KEY INFORMANT INTERVIEWS

Theme 1: Situation of malaria in the study area
Leading question
• How would you describe the situation of malaria in this area?

Theme 2: Factors underlying the situation in theme 1
Leading question
• What do you think are the factors underlying the situation you have just explained?

Theme 3: Possible remedies
Leading question
• What do you think could be done to improve the situations that contribute to malaria in this area?
  i. What are some of the major challenges on the control of malaria?
  ii. What is the government’s plan through the division of malaria control doing to control malaria as one of the components of Millennium Development Goals?
  iii. With your experience, what would be the best malaria control approach specific for this highland region?

Theme 4 Malaria diagnosis and treatment (For health care personnel)
Guiding questions
• How is malaria diagnosed at the health facility where you work?
• How is it treated?

Theme 5 Community response to malaria
Guiding questions
• Is the community you serve able to recognise malaria?

• What kind of treatment do the people normally use for malaria?

• Do people in this area protect themselves from malaria?

If so how do they protect themselves?
Appendix XII: English consent statement for the respondents

ECOLOGY OF HIGHLAND MALARIA PROJECT

Hello, my name is _______________________________. We are carrying out a survey on malaria that will involve asking you some general questions about the composition of your family, inspection of your houses for existing malaria intervention efforts, spraying your houses with mosquito insecticide and free screening of household members for malaria. The survey is part of a PhD dissertation conducted by Harrysone Atieli, a Kenyan student, studying at Kenyatta University, Kenya. The study has been approved by Graduate School Board of Kenyatta University, Likewise, permission was granted by the National Council for Science and Technology No. NSCT/RRI/12/MED011/113 for the study to be done. This study was part of a major study titled “Ecology of African Highland Malaria (II)” which had approval, SSC No. 1382 (N): reviewed and cleared by KEMRI/ National Ethical Review Committee dated May 15th 2008.

Your household has been selected to participate in this survey. We request that you participate in this survey voluntarily. Giving consent would not mean permanent participation in the study. You may withdraw from the study at will anytime if you are not comfortable by any reason to continue participation.

All the information you give to us shall be treated with optimum confidentiality and will be used solely for the purpose of analysis of data collected.

Do you have any questions?

We hope that you will accept to take part in the survey but if you decide not to, it is your right and we shall respect your decision.

ACCEPTANCE
I accept/do not accept to take part in the survey.
Name: ___________________________ Date: _____________________
Appendix XIII: Swahili consent form

UTAFITI WA EUNEZAJI WA MAGONJWA YA MALARIA KATIKA ENEO LA MABONDE

Habari,

Kwa majina mimi ni______________________________________. Tunafanya utafiti juu ya ugonjwa wa malaria. Utafiti huu utahusu kuuliza maswali ya kawaida kuhusu familia yako, kuchungulia nyumbani mwako kama kuna kinga unazotumia dhidi ya mmbu, kupuliza nyumba yako na dawa dhidi ya mmbu na kuwapima bure jamii nzima dhidi ya malaria. Utafiti huu ni harakati ya masomo yangu mimi Harrysone Atieli ya kiwango cha udaktari kijulikanayo kama PhD. Mimi ni mwanafunzi katika chuo kikuu cha Kenyatta huko Nairobi, hapa nchini Kenya.

Utafiti huu umekubalika na kupatiwa idhini na idara ya elimu ya juu chuoni Kenyatta, idara ya sayansi na teknologia ya Kenya nambari NSCT/RRI/12/MED011/113 na pia idara ya utafiti wa magonjwa ujulikanayo kama KEMRI numbari SSC No. 1382 (N).


Habari utakayo tupa wakati wa utafiti huu itakuwa siri yetu na wewe tu and utatumika kwa ajili ya utafiti huu pekee.

Baada ya maelezo haya, una swali lolote?

Tunatumai utakubali kushiriki kwa utafiti huu bali ukikana pia ni kwa haki yako na tutaieshimu.

NAKUBALI

Nakubali/ Sijakubali kushiriki kwa utafiti huu.

Jina: ______________________________ Sahihi: ________________________
Appendix XIV: Study approval by Graduate School

KENYATTA UNIVERSITY
GRADUATE SCHOOL

E-mail: kulasa@yahoo.com
dean-graduate@kcu.ac.ke
Website: www.ku.ac.ke

P.O. Box 43844, 00100
NAIROBI, KENYA
Tel. 810901 Ext. 57530

Internal Memo

FROM: Dean, Graduate School
TO: Harrysone Etemesi Atiei
    C/o Public Health Dept.

DATE: 31st March, 2011
REF: P97/15183/08

SUBJECT: APPROVAL OF RESEARCH PROPOSAL

This is to inform you that your P.H.D Research Proposal was approved by the Graduate School Board on 28th March, 2011.

Thank you.

JOHN M. ODONGI
FOR: DEAN, GRADUATE SCHOOL

cc. Chairman, Public Health Department
    Supervisors:

1. Dr. Isaac Mwanza
   Department of Public Health

2. Dr. Andrew Githeko
   Chief Research Officer, Centre for Global Health Research, Kenya Medical Research Institute

3. Prof. Guiyun Yan
   Program in Public Health, College of Health Sciences,
   University of California, Irvine, USA

JMD/bwk

Committed to Creativity, Excellence & Self-Reliance
Appendix XV: Study approval from higher education research council

NGST/L/2/1/MED011/113

Harysone Efemese Atieli
Kenyatta University
P.O BOX 43844
Nairobi

Dear Sir,

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on: “Impact of bednet use, topography and targeted vector control on malaria transmission in the highlands of Vihiga and Kakamega Counties, Western Kenya.” I am pleased to inform you that you have been authorized to undertake research in Vihiga and Kakamega Counties Kenya for a period ending 30th August 2012

You are advised to report to The District Commissioners, The District Education Officers and The District Medical Officers Of Health, Vihiga and Kakamega County before embarking on the research project.

On completion of your research project you are advised to submit one hard copies and one soft copy of your thesis/project to this office.

P.N NYAKUNDI
FOR: SECRETARY/CEO

Copy to:

The District Commissioners
Vihiga District
Kakamega District
Appendix XVI: Study approval from KEMRI

KENYA MEDICAL RESEARCH INSTITUTE

KEMRI/RES/7/3/1

MAY 15, 2009

FROM: SECRETARY, KEMRI/National Ethical Review Committee

THRO: Dr. J Vulule,
CENTRE DIRECTOR, CGHR,
KISUMU

TO: Dr. Andrew K. Githeko (Principal Investigator)

RE: SSC No. 1382 (N): Ecology of African highland malaria (II)

Dear Sir,

We acknowledge receipt of the revised protocol and ICD (bio-sketches) in your letter dated 2 May 2008. The compromise reached to add the suffix (II) at the end of the title of the study is acceptable in order to accommodate the position of the funding agency and this Committee.

We also note the changes to the ICD to standardize the font size throughout the ICD and the deletion of the section on ownership of DNA which has been overtaken by events.

Due consideration has been given to ethical issues and the study is granted approval from today the 15th May 2008 to 14th May 2009.

Please note that any changes to the research study must be reported to the Scientific Steering Committee and to the Ethical Review Committee prior to implementation. This includes changes to research design, equipment, personnel, funding or procedures that could introduce new or more than minimum risk to research participants.

Respectfully,

R. C. Kithinji,
For: Secretary,
KEMRI/NATIONAL ETHICAL REVIEW COMMITTEE
Appendix XVII: Publication on Bednet ownership and usage

Insecticide-treated net (ITN) ownership, usage, and malaria transmission in the highlands of western Kenya

Haryonse E Atieli1,2*, Guofa Zhou2, Yaw Afrane1, Ming-Chieh Lee1, Isaac Mwanza1, Andrew K Githeko1 and Guyun Yar2

Abstract
Background: Insecticide-treated bed nets (ITNs) are known to be highly effective in reducing malaria morbidity and mortality. However, usage varies among households, and such variations in actual usage may seriously limit the potential impact of nets and cause spatial heterogeneity on malaria transmission. This study examined ITN ownership and underlying factors for among-household variation in use, and malaria transmission in two highland regions of western Kenya.

Methods: Cross-sectional surveys were conducted on ITN ownership (possession), compliance (actual usage among those who own ITNs), and malaria infections in occupants of randomly sampled houses in the dry and the rainy seasons of 2009.

Results: Despite ITN ownership reaching more than 71%, compliance was low at 56.3%. The compliance rate was significantly higher during the rainy season compared with the dry season (62% vs. 49.6%). Both malaria parasite prevalence (11.8% vs. 5.1%) and vector densities (1.0 vs.04 female/house/nighth) were significantly higher during the rainy season than during the dry season. Other important factors affecting the use of ITNs include: a household education level of at least primary school level, significantly high numbers of nuisance mosquitoes, and low indoor temperatures. Malaria prevalence in the rainy season was about 30% lower in ITN users than in non-ITN users, but this percentage was not significantly different during the dry season.

Conclusion: In malaria hypo-mesoclimatic highland regions of western Kenya, the gap between ITN ownership and usage is generally high with greater usage recorded during the high transmission season. Because of the low compliance among those who own ITNs, there is a need to sensitize households on sustained use of ITNs in order to optimize their role as a malaria control tool.

Background
Insecticide-treated mosquito nets (ITNs) used for protection against mosquito bites have proven to be a practical, highly effective, and cost-effective intervention against malaria [1]. The evidence of the public health impact of ITNs, supporting their wide-scale use in Africa, is drawn from areas of stable malaria transmission where Plasmodium falciparum infection prevalence in the community is often over 40% [1,2]. Community-based randomized controlled trials (RCT) in these regions have documented average reductions of 28% in all causes of mortality in children under 5 years old within 2 years of increasing ITN use from 0 to 50-70% [3-8]. Scaling up ITN coverage and use by young children and pregnant women has been made a consensus target of the Millennium Development Goals (MDGs), the Roll Back Malaria Partnership (RBM), and the US President’s Malaria Initiative (PMI) [9-11]. Targeting individual protection to these vulnerable groups [12-14] is a well-founded and explicitly accepted priority of all three initiatives because these groups bear the highest risk of morbidity and mortality from malaria. However,
Appendix XVIII: Publication on Topography and malaria risk

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Research

Topography as a modifier of breeding habitats and concurrent vulnerability to malaria risk in the western Kenya highlands
Harryson E Atieli 1, 2, * , Geila Zhou 3, Ming-Chon Lee 3, Elieaguan J Kwaiko 3, Isaac Afilau 2, Isaac Panariti 2, Andrew H Gilthorpe 1 and Golyan Yoo 1

* Corresponding author: Harryson E Atieli (atieli@kmu.ac.ke)
1 College and Human Health Research Unit, Centre for Global Health Research, Kenya Medical Research Institute, P.O. Box 15709-01000, Nairobi, Kenya
2 Community Health Department, School of Public Health, Kenyatta University, P.O. Box 34-00401, Nairobi, Kenya
3 Department of Public Health, College of Health Sciences, University of California, Irvine, CA 92697, USA
4 Tropical Pesticide Research Institute, Division of Human and Disease Vectors Control, Mosquito Section, P.O. Box 38214, Arusha, Tanzania

For all author details, please see pp. 9-10.


The electronic version of this article is the complete one and can be found online at: http://www.parasitesandvectors.com/content/4/1/241

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Abstract

Background

Topographic parameters such as elevation, slope, aspect, and ruggedness play an important role in malaria transmission in the highland areas. They affect biological systems, such as larval habitats presence and productivity for malaria mosquitoes. This study investigated whether the distribution of local spatial malaria vectors and risk of infection with malaria parasites in the highlands is related to topography.

Methods

Four villages each measuring 9 km² lying between 1400-1700 m above sea level in the western Kenya highlands were categorized into a pair of broad and narrow valley shaped terrain sites. Larval, culde-sac resident adult malaria vectors and infection surveys were collected originating from the valley bottom and ending at the hilltop on both sides of the valley during the rainy and dry seasons. Data collected at a distance of 156 m from the main rivers/streams were categorized as valley bottom and those above as uphill. Larval surveys were categorized by habitat location while vectors and infections by house location.

Results

Overall, broad bottomed valleys had a significantly higher number of anophelinae larvae/callip in their habitats than in narrow valleys during both the dry (1.89 vs. 0.81 larvae/callip) and the rainy season (1.69 vs. 0.89 larvae/callip). Similarly, vector adult densities/house in broad valley villages were higher than those within narrow valley villages during both the dry (1.54 vs. 0.40) and the rainy season (3.95 vs. 1.05). Anomalous malaria prevalence was significantly higher in participants residing within broad than those in narrow valley villages during the dry (34.5% vs. 7.4%) and rains (17.3% vs. 1.2%) season. Malaria infections were wide spread in broad valley villages during both the dry and rainy seasons, whereas over 65% of infections were clustered at the valley bottom in narrow valley villages during both seasons.

Conclusion

Despite being in the highlands, local areas within low gradient topography characterized by broad valley bottoms have stable and significantly high malaria risk unlike those with steep gradient topography, which exhibit seasonal variations. Topographic parameters could therefore be considered in identification of high-risk malaria hotspots to help enhance surveillance or targeted control activities in regions where they are most needed.

Background

One fifth of the African population lives in malaria endemic zones across (plains, foothills and highlands) [1] where all age groups are at risk of chronic disease due to the limited acquired immunity. The prevention of malaria in these vulnerable populations is one of the priorities for the governments, African leaders and international agencies [2]. To curb this transmission of Plasmodium falciparum in the highlands has been a re-emerging problem in several regions in the last three decades [2]. The malaria situation has been getting worse partly due to resistance to anti-malarial drugs and lack of sufficient vector control measures [3, 4]. Furthermore, it has been demonstrated that malaria epidemics in the Western Kenya highlands are partly driven by climate variability [5, 6]. The impact of malaria epidemics on human morbidity and mortality may become more severe because climate variability is predicted to become more frequent and intense [7]. Understanding the epidemiology of malaria transmission and variations that occur within areas with close proximity in the highlands would support the improvement of an area specific national strategic plan for prevention and transmission control. It is therefore, necessary to explore possible factors that create changes in transmission so as to identify vulnerable valleys to allow interventions to be directed at these high-risk communities [8].

Topography has long been recognized to be one of the factors associated with malaria [9, 10] due to its association with river temperatures that close the development of anopheles vectors and the Plasmodium parasites they transmit [9, 11]. The topography of the highlands comprises hills, valleys and plateaux. Rivers and streams run along the valley bottoms in the valley ecosystem and swamps are a common feature. Unlike lowland plains, where drainage is poor and mosquitoes breeding habitats have an extensive distribution, the majority of breeding habitats in the highlands are confined to the valley bottoms because the tephra gradients provide efficient drainage [12]. Variation in the local shape of the land may also play an important role in determining regions of suitability for mosquito breeding at small spatial scales [12]. Depending on altitude in total valley shape, malaria risk may diminish within a few hundred meters from known breeding sites [12, 15], although a number of vector and environmental factors have been found to influence this range [16, 17].

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5/29/2012