

**Malaria Risk and the Role of Routine Outdoor Nocturnal Activities and
Livelihoods among Adults in Dar es Salaam, Tanzania**

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A thesis submitted in partial fulfilment of the requirements for the award of the degree of
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DECLARATION

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

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DEDICATION

This thesis is dedicated to my lovely wife Caroline, daughter Eddah and son Naboth, larger family and friends for the encouragement and support they gave me through difficult times.

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ACRONYMS AND ABBREVIATIONS

CDC	Centres for Disease Control and Prevention
EIR	Entomological inoculation rates
EPB	Enlarged Polystyrene Beads
GFFATM	Global Fund to Fight HIV/AIDS, Tuberculosis and Malaria
GMAP	Global Malaria Action Plan
IPT _c ,	Intermittent Presumptive Treatment for Children
IPT _i ,	Intermittent Presumptive Treatment for Infants
IPT _p	Intermittent Presumptive Treatment for Pregnant women
IRS	Indoor Residual Spraying
ITN	Insecticide-Treated Net
LLIN	Long Lasting Insecticidal Net
MoHSW	Ministry of Health and Social Welfare
NBS	National Bureau of Statistics
RNA	Ribonucleic Acid
TCU	Ten cell unit
ULV	Ultra Low Volume Applications
UMCP	Urban Malaria Control Program

ABSTRACT

Humans become infected with malaria upon receiving infectious bites from blood-feeding female anopheline mosquitoes. The human-mosquito contact is directly attributable to individual lifestyles and although predominantly domestic, it may also occur outside houses. Indoor malaria transmission has been largely subdued across large parts of Africa through wide scale coverage of insecticide treated nets (ITNs) and indoor residual spraying (IRS). Nonetheless, increasing evidence shows outdoor biting mosquitoes often dominate residual transmission systems and undermine efforts to achieve elimination of malaria transmission. Effective interventions which target outdoor malaria transmission are available but remain unproven in rigorous epidemiological terms.

This study assessed malaria risk among the residents of Dar es Salaam and established the impact upon malaria prevalence of routine outdoor nightly activities and common livelihoods among adults. A baseline cross-sectional daytime survey and evening follow-ups were conducted and data collected through one-on-one interviews based on structured questionnaires. Malaria risk was estimated as a function of the proportion of exposure that occurs indoors (π_i) and in bed (π_s). Predictive variables were analysed by binary logistic regression against blood test outcomes obtained through rapid diagnosis and microscopy.

Individuals spent more time indoors sleeping at night and higher risk of malaria occurred during these hours. There was estimated lower but significant outdoor exposure with both π_i and π_s strongly predictive of prevalence ($p < 0.001$). Spending 1 to 2 hours outdoors during evenings doubled the risk of malaria infection ($p < 0.001$, OR = 2.162 95% CI: 1.685-2.773). Resting outdoors during evenings was a routine activity among most adults and increased malaria risk. Most households used bednets as the key malaria protective measure. However, livelihoods were not associated with prevalence of malaria. Improved surveillance and control of outdoor exposure is requisite for malaria elimination in Dar es Salaam.

1.0 CHAPTER ONE: INTRODUCTION AND LITERATURE REVIEW

1.1 INTRODUCTION

The human-malaria vectors are known to be nocturnal, endophagic and endophilic (Gilles and DeMeillon, 1968). Therefore, humans are predisposed to a higher risk of infection while indoors sleeping (Seyoum *et al.*, 2012). This long established dependence of malaria vectors to feed indoors upon humans has necessitated drastic reductions in malaria transmission mainly by insecticide treated nets (ITNs) and indoor residual spraying (IRS) (Okumu and Moore, 2011). However, malaria vectors also feed outdoors during evening, night and early morning hours (Reddy *et al.*, 2011, Russell *et al.*, 2011) where they easily encounter humans without exposing themselves to the possible detriments of the control measures. Presently, only a few interventions can directly restrain outdoor malaria transmission and none has been proven to be effective in rigorous epidemiologic terms (Killeen and Moore, 2011).

Although outdoor malaria transmission is often less intense, it comprises an efficient self-sustaining residual transmission system that may greatly threaten malaria elimination. Outdoor malaria transmission is further aggravated by the complex and diverse nature of human behavioural risks particularly among urban communities. Risk behaviours are often deeply rooted in the wider aspects of lifestyles and livelihoods that influence exposure to malaria vectors (Stoddard *et al.*, 2009, Gonzalez *et al.*, 2008). The rapid growth of urban regions in sub-Saharan Africa poses an even greater challenge for malaria elimination (Keiser *et al.*, 2004) and the associated transformations of ecosystems and round-the-clock human activity bear significant implications for the ecology and epidemiology of malaria (Philips, 1993). Moreover, frequent and prolonged absence from houses particularly among adults, could impede exhaustive cross-sectional household data collection for purposes of research and public health action.

1.2 LITERATURE REVIEW

1.2.1 Human malaria transmission biology

Malaria is an infectious disease caused by a protozoan parasite of the genus *Plasmodium*. Five parasite species are known to cause human malaria, namely the anthroponotic species; *Plasmodium falciparum*, *P. malariae*, *P. vivax*, and *P. ovale* as well as the simian parasite *P. knowlesi* in specific areas of south east Asia (Cox-Singh and Singh, 2008, Luchavez *et al.*, 2008). *Plasmodium falciparum* is the most virulent (Gupta *et al.*, 1994) and causes the greatest number of deaths while *P. vivax* has the most widespread geographic distribution (Warrell and Gilles, 2002). Malaria is transmitted by the female *Anopheles* mosquito and can cause fatal consequences without prompt diagnosis and treatment (Chandler and Read, 1961). There are about 430 *Anopheles* species generally, but only 60 transmit malaria in nature and approximately 30-40 are of major importance (Gilles and DeMeillon, 1968), and perhaps the three African species: *Anopheles gambiae* Gillies, *An. arabiensis* Patton and *An. funestus* Gillies are the most efficient (Hocking and MacInnes, 1948). Malaria is among the world's notorious infectious killers and first priority tropical diseases of the World Health Organization (WHO, 2011).

Plasmodium is a very widespread parasite of lizards, birds and mammals but importantly humans, and exhibits a complex lifecycle progressing through a continuum of different morphological forms in both the vertebrate and arthropod hosts. When a mosquito bites an infected individual, and ingests blood alongside gametocytes (sexual forms of *Plasmodium*) normally ensheathed within red blood cell membranes, it can become infected. Within the mosquito gut, male gametocytes exit from the red blood cell membranes and become gametes. The male gametes are referred to as microgametes, and by use of locomotory flagella, they move to unite with female gametes (macrogametes), first through exflagellation and then

fertilization, thus generating zygotes and finally motile and elongated forms known as ookinetes.

The resulting ookinetes, sack-like, and full of pre-transcribed RNA for oocyst and sporozoite proteins, attach onto the peritrophic membrane enclosing the bloodmeal and gradually penetrate beneath to lie under the basal lamina of the midgut epithelium and grow to form oocysts. Oocysts contain numerous sporozoites resulting from proliferation of the precursor germ cells and grow steadily in the haemocoel attached between the mosquito gut wall and the basal lamina that supports it. Upon rupturing, oocysts release mature sporozoites that swim through the insect haemocoel and invade the salivary glands (Olsen, 1962, WHO, 1987). A mosquito with sporozoites in its salivary glands is infectious to humans. When this mosquito bites a person for a blood meal which she needs to nourish her eggs, she inoculates the sporozoites into the human bloodstream, thus transferring the infection to the human. Parasite propagation in the mosquito is known as the sporogonic phase and takes 10-12 days on average although it varies greatly with parasite species and ambient temperature (Beier, 1998, Olsen, 1962).

Although the general nature of the lifecycle of all species of *Plasmodium* is similar (Figure 1), there are some marked differences between them which have very important practical consequences. These differences are more clearly distinct during the schizogonic cycles within the human host. Generally, however; when sporozoites are injected by the vector mosquito, they infect liver cells in 30 minutes to 2 hours (Amino *et al.*, 2008) and mature into schizonts which rupture and release tens of thousands of merozoites in 6 and 8 days for *P. vivax* and *P. falciparum*, respectively. In *P. vivax*, and *P. ovale*, a dormant stage called a hypnozoite can persist in the liver and cause relapses by invading the bloodstream weeks, months or even years later (Hulden and Hulden, 2011, WHO, 1987). After this initial replication in the liver (exo-erythrocytic schizogony), the parasite undergoes repeated asexual

multiplication in the erythrocytes (erythrocytic schizogony). Merozoites infect red blood cells (RBCs) and develop into ring stage trophozoites that mature into schizonts in 48-72 hours, with the latter typically containing 14-20 (up to 24), 6-12 (up to 18), 8-10 (up to 12) and 16-24 (up to 36) newly formed merozoites for *P. vivax*, *P. ovale*, *P. malariae* and *P. falciparum*, respectively. The infected RBCs lyse and liberate merozoites which proceed to repeat the cycle by infecting more RBCs over a few seconds and then begin the next asexual cycle. Some merozoite forms of the parasite differentiate into sexual erythrocytic stages (gametocytes) infective to the vector mosquito. The classical signs of clinical malaria such as acute febrile episodes and rigor (sometimes with paroxysm) therefore tend to occur in waves every 48 to 72 hours, coinciding with the synchronized lysis of infected RBCs releasing merozoites (Woolhouse, 1998). Notably, it is the blood stage parasites that are responsible for the clinical manifestations of malaria and progression to severe disease or even death (Olsen, 1962, WHO, 1987, Warrell and Gilles, 2002, Chandler and Read, 1961).

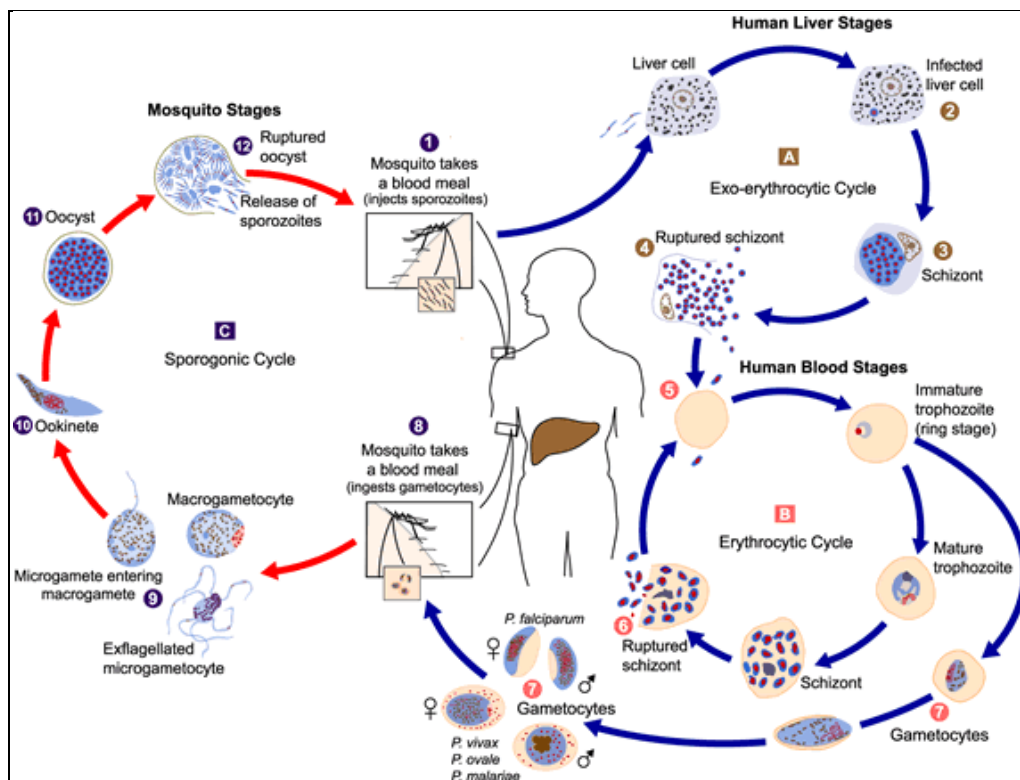


Figure 1: Lifecycle of the human malaria parasite *Plasmodium* spp. (Adapted from CDC).

Clinical signs and symptoms of malaria occur in three distinct phases (Chandler and Read, 1961). The first is called the cold phase and is characterised by shivering and feeling cold. The second phase is known as the hot stage, typically occasioned by fever, nausea, vomiting headache, general discomfort, body aches and convulsions, particularly among non-immunes, including young children from endemic areas. The third and final phase in this cycle is the sweating stage and is characterised by sweating even though the patient may feel cold (Bruce Chwatt, 1985, Warrell and Gilles, 2002). In *P. falciparum* cases, there may be mild jaundice and increased respiratory rate (Ndyomugenyi *et al.*, 2007, Trampuz *et al.*, 2003). When an infection develops and progresses in this way, but no further, it is termed as uncomplicated malaria. Complicated malaria results in blood and organ disorders, including pulmonary oedema, acidosis and loss of kidney function (Sherman, 1998).

Following repeated exposure to malaria over a period of time, one ordinarily acquires natural immunity (Cohen, 1979, Hogg, 1996, Long *et al.*, 1994). This protection is both location and species specific, thus adults in a stable malaria transmission zone often have immunity against the pathogen strain in that zone. However upon moving to a geographically separate place, the immunity against re-infection by the same parasite species may be ineffective (Borrmann and Matuschewski, 2011).

1.2.2 The treatment, prevention and control of malaria

The WHO emphasizes diagnostic tests to confirm prognosis of malaria disease before ensuing treatment except perhaps in children under the age of five years, (WHO, 2006, WHO, 2010a). Treatment is administered selectively based on careful examination and consideration of most importantly three specifications: the species of infecting parasite, the physical state of the patient, and the known drug sensitivity/resistance level of the parasite population in the place the person was infected (White, 2009). However, other ailments or contra-indications a person may have, including pregnancy, drug allergies and sensitivities are also considered (Bloland

and Ettlting, 1999, WHO, 2010b). The usual medications considered for malaria include chloroquine, sulfadoxine-pyrimethamine, mefloquine, atovaquone-proguanil, quinine, doxycycline, amodiaquin, clindamycin, naphroquine, piperazine, primaquine, pyronaridine, tetracycline and artemisin derivatives (WHO, 2010b, White, 2009, WHO, 2010a).

Malaria prevention is done primarily by chemoprophylactic therapy but most basically through avoiding mosquito bites. Anti-malaria drug prophylaxis is administered to non-immune individuals (Greenwood, 2004, McLarty *et al.*, 1984) and is recommended mostly for individuals visiting other than residing in endemic areas because of the risk of drug resistance and the temporary nature of its protective effect. However, the intermittent presumptive treatment for pregnant mothers, infants and children (IPT_p, IPT_i and IPT_c) in endemic populations is also a rational and essential preventive strategy for these risk groups (WHO, 2010a, Grobusch *et al.*, 2007). Together with vaccines, preventive therapy constitutes the most direct way to block establishment and progress of infection to levels of clinical significance. Although there exists no feasible malaria vaccines to date, their perceived potential of ending the transmission cycle of malaria beyond just protecting individual humans has stimulated immense effort to develop them (Loucq *et al.*, 2011, Carter, 2001).

Avoidance of mosquito bites is achievable through the effective use of bednets preferably insecticide treated nets (ITNs), indoor residual spraying (IRS), mosquito repellents, and proper screening of mosquito entry points into houses (Lindsay and Gibson, 1988, Gupta and Rutledge, 1994, Gillies and Smith, 1960). Insecticide treated nets double as protective measures barring mosquitoes off humans, and as control measures that kill mosquitoes thus confer both individual and communal level protection (Govella *et al.*, 2010).

1.2.3 The global burden of malaria

Malaria parasites infect 300-600 million people and kill over half a million others each year around the world (WHO, 2011) and perhaps there occurs even higher true infection incidence and mortality (Murray *et al.*, 2012). An estimated 3.3 billion people globally, approximately half of the world's population, are at risk (WHO, 2011) and a child dies every 30-45 seconds from malaria (WHO, 2005a). It is the leading cause of morbidity and mortality worldwide, accounting for a loss of 35.4 million years in disability adjusted life years (DALYs), (Snow *et al.*, 2003). The disease affects mostly children and pregnant women in Sub-Saharan Africa where at least 90% of cases and over 85% of deaths occur (Crawley *et al.*, 2010, WHO, 2011). Malaria causes direct annual losses amounting to US\$ 12 billion which obstructs Africa's GDP growth by an estimated 1.3% each year (Sachs and Malaney, 2002). The disease is geographically restricted (Figure 2) and remains entrenched within poor countries with climates optimal for transmission (Snow *et al.*, 2005).

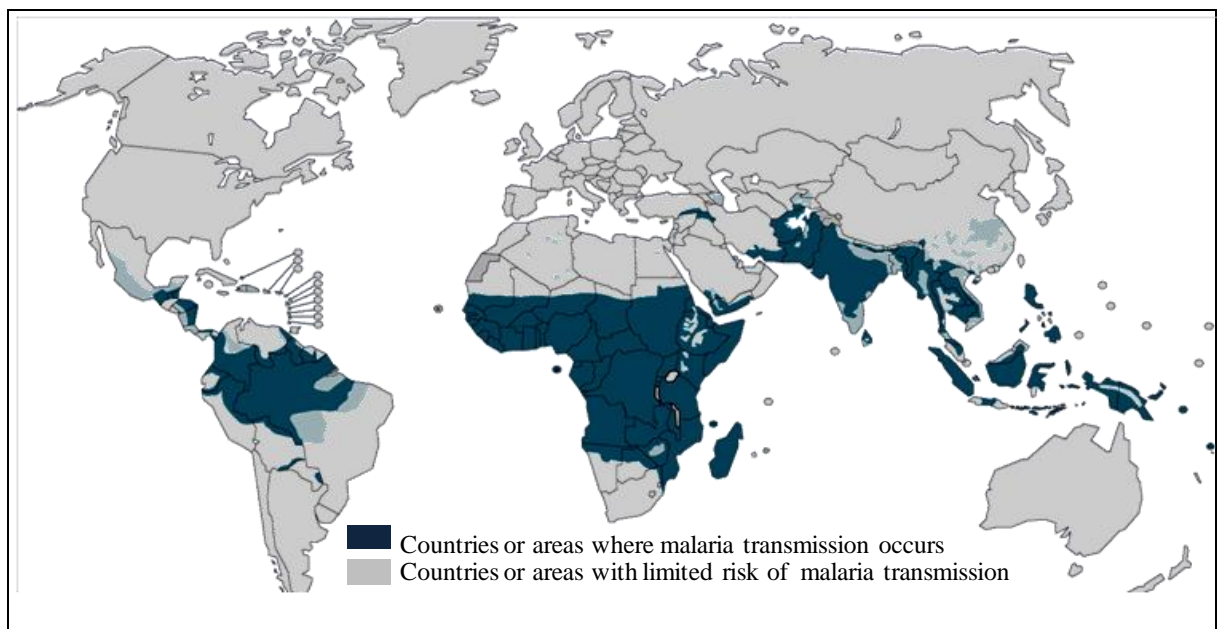


Figure 2: The global distribution of malaria risk in 2009 (Adapted from the WHO)

In Tanzania malaria transmission is perennial with two seasonal peaks occurring around the rainy seasons in most parts of the country (MoHSW, 2003a). Malaria accounts for 30% of the national disease burden (NIMR, 2006) and leads in the inpatient and outpatient hospital statistics (MoHSW, 2008). As recently as 2007-2008, prior to the national initiative for intensive malaria control particularly through the rapid scaling-up of coverage of long lasting insecticide treated nets (LLINs) (Bonner *et al.*, 2011, MoHSW, 2003b), malaria caused deaths of an estimated 100,000-125,000 people in Tanzania each year with 70,000-80,000 of these being children 0-4 years old (MoHSW, 2002, WHO, 2009). Over 95% of Tanzania's 37.4 million people are at risk, and over a third and one fifth of deaths in the under 5 year olds and pregnant women respectively, are attributed to malaria (MoHSW, 2006). Malaria control alone accounts for up to 39% of Tanzania's health expenditure and 1.1% of its GDP (Jowett and Miller, 2005, MoHSW, 2008).

1.2.4 Lifestyles, livelihoods and malaria in the urban African settings

Urban lifestyles may have beneficial aspects in the respect of basic public health. Access to improved infrastructural amenities including electricity and safe piped water supply for domestic use, fairly proper housing, availability of healthcare facilities, varieties of media for information, communication and education, etc, generally enhance better and healthy living (Castro, 2003). Moreover, the typical associated environmental pollution considerably transforms urban ecosystems affecting suitable malaria ecology (Chinery, 1993), and population density causing extensive human settlements and constructions reduce mosquito breeding habitats leading to high human-mosquito ratio that reduces malaria transmission intensity (Killeen *et al.*, 2000).

Nevertheless, certain urban socio-demographic features may reinforce malaria transmission. For instance, the occasion of individuals without malaria immunity can cause devastating epidemics in the typical stable, low transmission urban malaria systems (Robert *et al.*, 2003).

But as concerns individuals, one critical risk determining component of lifestyles is their livelihood activities. Livelihoods are health hazards when they influence the risk of getting a disease during specified intervals of time (Carstensen and Glumer, 2005). Urban agriculture, often based on irrigation farming has been identified as one such malaria occupational hazard. Increased malaria vector populations in urban environments have initially been largely linked to the presence of irrigated farmlands like rice paddies (Mwangangi *et al.*, 2010). In an urban area of the city of Kumasi in Ghana, more episodes of malaria and days lost due to illness were reported in the farming than in the non-farming regions (Afrane *et al.*, 2004).

In Dar es Salaam, Tanzania, it has been previously documented that larval anophelines dominate all larval mosquito populations in agricultural sites (Dongus *et al.*, 2007). Elsewhere, in a predominantly fishing and farming livelihood in a region of western Kenya, higher cases of malaria are observed among fishermen and fish-traders and also during the farming season (Weckenbrock, 2005). In this setting, increased cases among fishermen and fish-traders are attributed to high risks incurred while fishing at night, early morning or late evening on-shore fish processing and trading. However, as the farmers work late in their farms to keep pace with rains during the planting season, they become more vulnerable to mosquito bites (Weckenbrock, 2005).

1.2.5 Dar es Salaam's household population and housing characteristics

Dar es Salaam is located to the south-east coast of Tanzania. It is Tanzania's commercial and political capital and occupies an estimated 1400km². Dar es Salaam is administratively divided into three municipalities; Kinondoni, Temeke and Ilala (Figure 3) which are further sub-divided into wards, neighbourhoods and ten cell units (TCUs). A TCU in principle comprises a geographical cluster of ten houses and is the smallest sub-unit of local government with an elected representative known in Swahili as a *Mjumbe* (Dongus *et al.*, 2010).

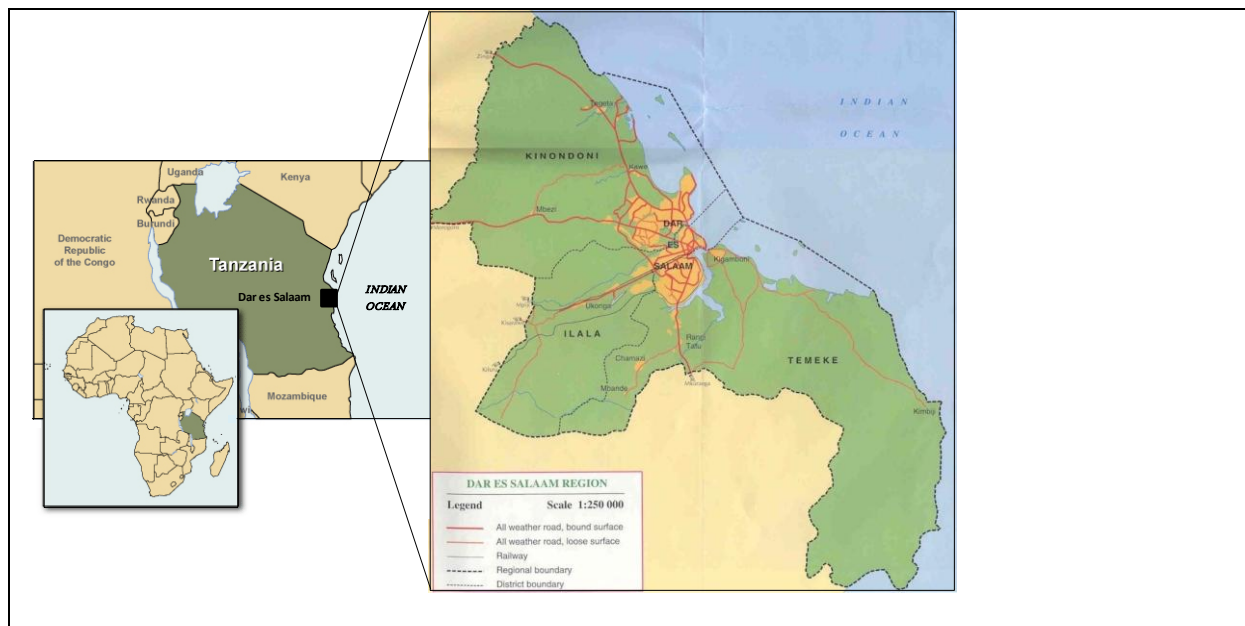


Figure 3: The geographical location of Dar es Salaam city, United Republic of Tanzania (adapted from openstreetmaps).

During the country's last population and housing census, an estimated 2.5 million individuals were recorded in over half a million households across Dar es Salaam (NBS, 2003). Even though the population of Tanzania is predominantly rural (NBS, 2011), Dar es Salaam's population has constantly grown rising from barely 348,000 in 1968, to 852,000 in 1978, 1.3 million in 1988, 2.5 million in 2002 and is likely to reach 5 million by 2020 (NBS, 2003, NBS, 2009, NBS, 2011). The 2010 Demographic and Health survey (2010 DHS) records an average household size of 4 to 5 individuals in Dar es Salaam, headed mostly by men, and most children stay with their biological parents (NBS, 2011). There is almost equal male and female population although slight proportional variations have occurred before (NBS, 2003). Surprisingly, due to prolonged absence from houses, males comprised only 20% of the total 2010 DHS survey respondents (NBS, 2011). Over 80% of Dar es Salaam's population is below the age of 45 years and only half of its residents are in the economically productive age range (15-64 years). Faced with unemployment and underemployment crises and the rising

costs of living, substantial household burden weighs upon these individuals to fend for the younger and older household members (NBS, 2011, Treichel, 2005).

Residents of Dar es Salaam are on average among the most educated in the country (NBS, 2011), with only 4% and 11% of males and females respectively, having not attended school at all (NBS, 2011). Over 80% of Dar es Salaam's children (18 years and below) attend primary school education. Dar es Salaam also records the highest proportion of individuals with beyond secondary school education in the country (NBS, 2003, NBS, 2008, NBS, 2009, NBS, 2011). Generally, the residents of Dar es Salaam are also among the wealthiest and are rated in the highest wealth quintile in the national household budget statistics (NBS, 2009). Most of Dar es Salaam's households have relatively good housing, built with concrete, stone, cement, metal and iron sheets, with structural fittings barring mosquito entry including window and door screens and ceiling boards (Sliuzas, 2001, Ogoma *et al.*, 2009, Geissbuhler *et al.*, 2007). In most of these households, electricity is the main power supply and piped water is available for domestic use. Dar es Salaam households also record the highest ownership of electrical and non-electrical goods, including, televisions, radios, computers, and mobile phones for information, communication and education (NBS, 2009, NBS, 2011).

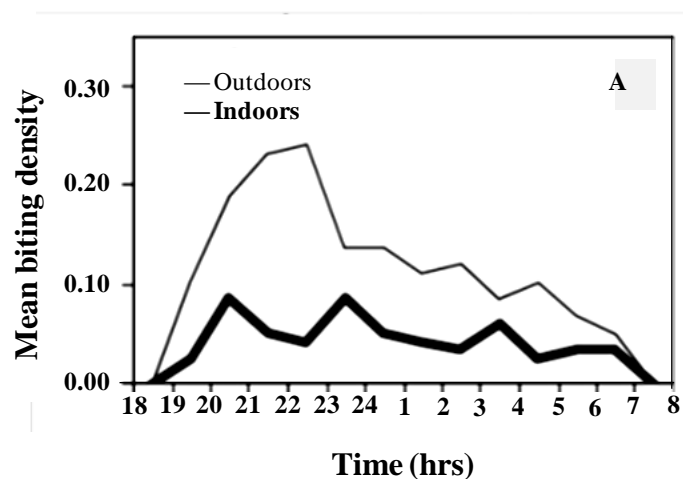
Dar es Salaam reportedly has 82% and 68% of its respective male and female population employed. However, more than half (51%) of its population is involved in unskilled manual work and the rest in professional (8%), clerical (3%), sales and services (10%), skilled manual (11%), domestic service (13%) and agricultural (4%) occupations (NBS, 2011).

Most Dar es Salaam households have sufficient awareness regarding the role of mosquitoes in malaria transmission (MoHSW, 2006). Consequently, a large number of them use protection measures against mosquito bites. Besides fitting houses with structures which obstruct mosquito entry, most households report use of various protection measures including bednets,

coils, chemical sprays and a few others use repellents (Geissbuhler *et al.*, 2007). Many households are also able to access basic healthcare services from both government and private facilities across the city including maternal and neonatal healthcare and timely diagnosis and treatment of malaria (Wyss *et al.*, 2000).

1.2.6 Human-mosquito behavioural and ecological interactions in Dar es Salaam

Dar es Salaam's main malaria vectors include members of the *Anopheles gambiae* complex and *An. funestus* that mainly bite humans indoors at night (Govella *et al.*, 2010). Generally, most individuals spend most of their nights indoors sleeping although a past study has revealed fine-scale nightly outdoor human activity (Geissbuhler *et al.*, 2007). As a result, evidence indicates that bednet usage in Dar es Salaam can prevent up to 90% of malaria risk (Govella *et al.*, 2010). *Anopheles arabiensis* Patton, a member subspecies of the *An. gambiae* complex has been frequently identified as a predominant component of residual malaria transmission systems in sub-Saharan Africa (Russell *et al.*, 2011). This vector subspecies experiences peak biting activity during the evenings and early parts of the night (Figure 4).



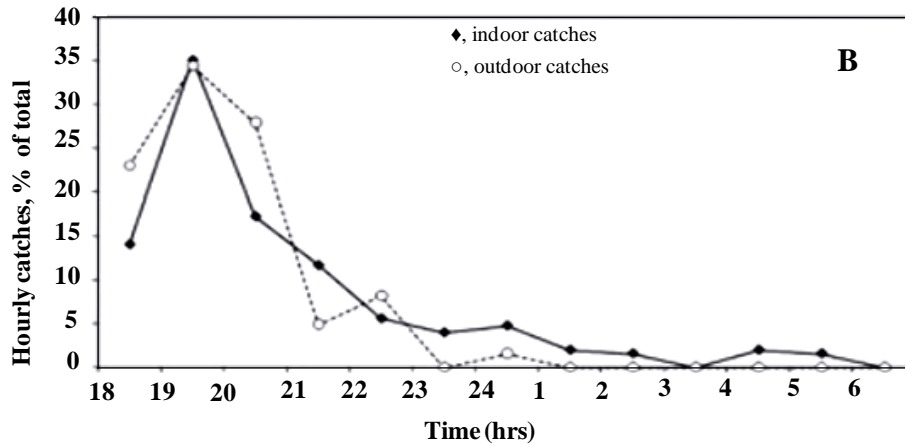


Figure 4: Biting behaviour of *Anopheles arabiensis* Patton in (A) Dar es Salaam, Tanzania and (B) Tigray in Ethiopia (Govella *et al.*, 2010, Yohannes and Boelee, 2012).

In Dar es Salaam, transitional human movements within settlements and outdoor resting or sleeping at night mainly because of heat and poor ventilation of houses exposes individuals to outdoor biting malaria vectors (Geissbuhler *et al.*, 2007). Although outdoor malaria transmission is typically less intense, few protective measures are available for use while outside the house and barely any has been rigorously proven to effectively confer protection (Killeen and Moore, 2011). Many Dar es Salaam houses have structural fittings that block mosquito entry (Ogoma *et al.*, 2009) and approximately three in every four of over 80% reported bednet owners among the general population, use them (NBS, 2008). Moreover, occasional use of insecticide sprays, repellents and mosquito coils makes houses more hostile to malaria vectors. As access to humans within houses becomes harder and riskier to the persistent blood seeking mosquitoes, they become more compelled to feed outdoors upon less protected humans (Russell *et al.*, 2011). Therefore, although nocturnal outdoor human activity in Dar es Salaam occurs on a relatively minimal scale, the potential impact to the epidemiology of malaria is significant since outdoor biting mosquitoes may sustain malaria transmission mainly as the major component of the residual transmission system.

Proximity to mosquito breeding habitats often puts local communities to higher risk of getting malaria infection. Dar es Salaam's larval habitats are widespread across its three municipalities (Chaki *et al.*, 2009, Dongus *et al.*, 2007) and are typically small-sized and highly organically polluted but with low water turbidity (Sattler *et al.*, 2005). Non-agricultural artificial habitats are not common larval anopheline habitats and range from drains, ditches, construction sites, building foundations, man-made holes to motor-vehicle tire tracks, however, they form the bulk of Dar es Salaam's larval habitats (Vanek *et al.*, 2006, Chaki *et al.*, 2009). Moreover, greater than 70% of larval habitats in Dar es Salaam are human made (Castro *et al.*, 2010).

1.2.7 The history, present and future of malaria control in Dar es Salaam

Malaria research and control efforts in Tanzania began in the late 1890s, (Clyde, 1961, Schneppen, 2000), but the focus on Dar es Salaam followed more than half a century later in the 1950s. At the beginning of this time, larval control was the predominant intervention (Castro *et al.*, 2004). In 1971, the Dar es Salaam City Council in an Urban Malaria Control Program (UMCP) co-initiated with the WHO's East Africa *Aedes* Research Unit experimented with integrated vector control (Bang *et al.*, 1975). The program mainly included environmental management particularly monolayer oiling and drainage of stagnate water as alternative methods to chemical spraying following the fear of environmental contamination and resistance (Bang *et al.*, 1973, Kouznetsov, 1977) and by 1973 malaria transmission rates reached historical low levels. But, the reductions in the local mosquito populations were also partly attributed to ecological changes following the expansion of the city (Bang *et al.*, 1977). However, Tanzania's economic crisis of the early 1970 grossly compromised its budgetary dedication to health (Briggs, 1979, Messkoub, 1996, Lugalla, 1995) leading to the closure of the National Malaria Control Program and subsequent deterioration of healthcare systems

leaving drug administration, exclusively chloroquine, by the pharmaceuticals, as the single anti-malarial intervention (Castro *et al.*, 2004).

Malaria parasite resistance to chloroquine was later reported along the coast of Tanzania and Kenya in the 1980s (Nuwaha, 2001, Sherman, 1998, Weniger *et al.*, 1982). By 1980, vector populations had increased almost 10-fold from the levels between 1967 and 1971 (Bang *et al.*, 1975, Yhdego and Majura, 1988). In 1983, the Ministry of Health in Tanzania spearheaded the revision of malaria control policies and emphasized a combination of three interventions including vector control, chemotherapy and monitoring of drug resistance (Yhdego and Majura, 1988). Later in 1988, Dar es Salaam again experienced a large-scale malaria control intervention, another UMCP was established through a bilateral agreement between the governments of Japan and Tanzania, specifically funded by the Japan International Corporation Agency (JICA). The program had a mandate lasting up to 1996, defined by two objectives: (1) to reduce urban malaria prevalence to the lowest possible level, and (2) to encourage the community to use personal protection measures and to improve their local environment. The objectives of the program expanded when the WHO presented the Global Malaria Control Strategy in 1992 to include: (1) increase people's perception of malaria; and (2) involve the community in routine activities to reduce the risks of malaria transmission (e.g. cleaning and rehabilitation of drains); and (3) implement an integrated urban malaria control program based on different types of interventions, but with particular emphasis on vector control (Castro *et al.*, 2004).

Chemical larviciding, indoor residual spraying (IRS), space spraying of insecticides at ultra low volume (ULV), ITNs and environmental management were used for vector control. The application of expanded polystyrene beads (EPB) was used to control *Culex* larvae in addition (Castro *et al.*, 2004). Following implementation of the JICA funded UMCP, there was recorded a drop in malaria prevalence rates among school children in the central, intermediate

and peripheral zones of Dar es Salaam, roughly from 6% to 3-10%, 28-41% to 10-25% and 68-74% to 21-46% respectively (Castro *et al.*, 2004). The launch of the Roll Back Malaria (RBM) partnership in 1998 (Dobson *et al.*, 2000, Nabarro, 1999) and later the Abuja declaration in 2000 (WHO, 2005b) both targeting reduction of malaria mortality by 50% by 2010 and elimination in some countries by 2015 (WHO, 2006, MoHSW, 2001) had considerable influence on malaria control in Dar es Salaam. In part, is the almost decade long predominance of four operational and two supportive strategies stipulated in the National Malaria Medium Term Strategic Plan 2002-2007 and the National Malaria Control Program. These include; case management, vector control particularly by use of ITNs (with subsidization of costs for children below the age of five and pregnant mothers), (Mushi *et al.*, 2003), intermittent treatment in pregnant mothers, epidemics prevention and control, and information, education and communication and operational research (MoHSW, 2003b). At present, malaria prevalence has reduced to 10% (Geissbuhler *et al.*, 2009), the transmission intensity has dropped significantly, the EIR is estimated at less than 1 infectious bites per year and the anopheline density now averages at 1% of Dar es Salaam's entire mosquito population (Fillinger *et al.*, 2008). The contemporary UMCP prioritizes vector control through the promotion of ITN usage (Magesa *et al.*, 2005) and the targeting of mosquitoes in their larval stages (Dongus *et al.*, 2011, Chaki *et al.*, 2009).

The future of malaria control in Dar es Salaam is greatly vested upon vector control through prioritization of universal coverage of ITNs (Magesa *et al.*, 2005) and larval control (Dongus *et al.*, 2011), promotion of efficient use of the recommended anti-malaria drugs (Tren *et al.*, 2011), the development of vaccines (Abdulla *et al.*, 2008) and the streamlining of monitoring and surveillance networks for proper case management and prevention of epidemics (MoHSW, 2003b).

1.3 JUSTIFICATION AND SIGNIFICANCE OF THE RESEARCH

Dar es Salaam's low malaria transmission intensity is prerequisite for its elimination (Dongus *et al.*, 2011). However, efforts to terminate malaria transmission and subsequently achieve elimination from this region have so far been fruitless (Mboera *et al.*, 2007). A significant amount of the risk of malaria infection occurs while individuals are sleeping indoors at night when the major Afro-tropical malaria vectors are predominantly known to feed (Gilles and DeMeillon, 1968). On the basis of this long established malaria vector dependence upon indoor feeding, ITNs, indoor residual spraying and other indoor targeted malaria control measures have been able to rapidly decrease malaria transmission in Dar es Salaam and many other parts of Africa (Russell *et al.*, 2010, Steketee and Campbell, 2010, Govella *et al.*, 2010). However, malaria vectors can and have been proven to feed outdoors sometimes (Russell *et al.*, 2011, Reddy *et al.*, 2011, Riehle *et al.*, 2011, Garrett-Jones, 1964) thus routine outdoor activities and occupations around evenings could expose individuals to outdoor feeding malaria vectors. Although outdoor malaria transmission is typically less intense than indoor transmission (Seyoum *et al.*, 2012), it is a challenge to elimination because few control measures other than bednets, have been documented to confer effective individual level protection, yet, scarcely any of these is appropriate for outdoor use (Killeen and Moore, 2011). The evaluation of malaria risk occurring both indoors and outdoors and the assessment of the impact of behavioural and occupational risks are imperative for the optimization of existing malaria control measures and the development of better ones.

The bulk of the human infectious reservoir consists of adults (Drakeley *et al.*, 2000, Ross *et al.*, 2006) yet most household cross-sectional surveys in Dar es Salaam continue to under-sample them, due largely to their prolonged absence from houses (NBS, 2011). Since the elimination of malaria entails the reduction of transmission in the general population to below

the levels of public health significance, it is rational that Dar es Salaam's adult population particularly those often missed by regular household surveys be targeted for research.

1.4 OBJECTIVES

1.4.1 General objective

To assess the risk of malaria parasite infection among residents of urban Dar es Salaam and evaluate the role of routine outdoor nocturnal activities and livelihoods among adults in determining the risk of malaria infection.

1.4.2 Specific objectives

1. To determine the impact upon malaria infection prevalence of the variations in the times individuals enter the house, go to bed, get out of bed and leave the house in the morning.
2. To identify routine outdoor behavioural activities around dusk and night and common livelihoods among adults that are associated with increased malaria risk.
3. To identify and characterise the demographic composition of individuals missing from routine daytime household surveys that are captured by supplementary follow-up surveys in the evenings and on the weekends.

1.5 HYPOTHESES

1. The variations in the times individuals enter the house in the evenings, go to sleep, get out of bed and leave the house in the morning, routine outdoor activities during dusk and night and common livelihoods among adults bear significant impact upon the prevalence of malaria parasite infection.
2. The demographic sections often missed by routine daytime household surveys consist of mainly working adults and mostly males.

2.0 CHAPTER TWO: METHODOLOGY

2.1 Study area and timeline

The study was conducted across 58 wards (Figure 5), initially mapped for malaria surveillance work by the Malaria Transmission Consortium (MTC); a collaboration of the City Council of Dar es Salaam, the Ifakara Health Institute (IHI) and affiliated overseas partner institutions. The UMCP larviciding exercise had taken place within a total of 15 wards among the 58 (Dongus *et al.*, 2011, Dongus *et al.*, 2007, Geissbuhler *et al.*, 2009). This study was done from March to December 2011, for a duration over both the long (March through May) and short (October through December) rainy seasons.

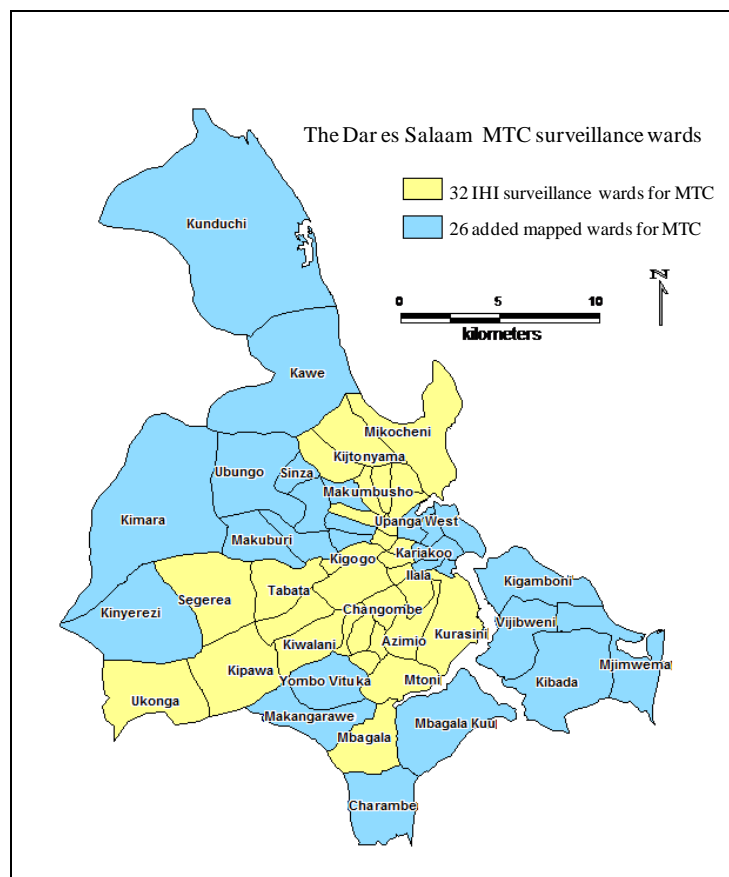


Figure 5: The 58 urban Dar es Salaam wards comprising the study area. Initially, MTC work covered a total 32 wards and later other 26 wards were added (Map courtesy of Dr. Dongus).

2.2 The sampling design for household surveys

Ten cell unit (TCU) housing clusters (*mashina*) were sampled with a probability proportional to the recorded number of households within each. The number of households in each TCU had been recorded through a participatory mapping and household enumeration exercise done by the MTC prior to this study. For each TCU sampled, 20 households were randomly selected and surveyed. In case a TCU had fewer than 20 households, additional households were randomly picked from one among its neighbouring TCUs also randomly selected at the neighbourhood (*mtaa*) level. Every eligible and willing participant was interviewed in each household visited.

2.3 Household interviews

Conventional household surveys were carried out during the daytime working hours between 10:00am and 4:00pm on all weekdays from Mondays through Fridays. All individuals residing in a household were eligible for participation. Eligible participants who were missing at the time of these conventional daytime surveys were followed up with return visits to the households outside regular working hours consisting weekday evenings, between 5pm and 8pm and during normal working hours on Saturdays.

One-on-one interviews were conducted for every eligible consenting or assenting householder using a structured questionnaire. The basic questionnaire (Appendixes) was pre-programmed in a global positioning system (GPS)-fitted personal digital assistant (PDA) and was used to record participant responses. Each questionnaire was initially addressed to the head of the household to collect answers to household level questions and circumstances. The rest of the household interviewees responded to questionnaire sections with questions concerning their personal behaviours. A supplementary hardcopy questionnaire was administered to adult household occupants asking additional questions about their livelihoods and regular nocturnal outdoor activities. The interview team consisted four members; two trained interviewers

accompanied by a qualified community-nurse (who carried out all blood collection, treatment, referral and incidental clinical care activities) and a nurse assistant. A household was defined as the biological parents or guardians and their immediate families i.e. the man and his wife, grandparents, uncle, aunt etc and the children under their care. People who were part of the family but did not sleep in the house were not considered.

2.4 Parasite detection and treatment

A rapid diagnostic test (RDT) was used to determine the *Plasmodium falciparum* infection status of each participant. The blood tests were done *in situ* by use of rapid test kits made by the South African based Ict diagnostics® Ltd industry. The kits detect circulating antigens by use of monoclonal antibodies specific to histidine-rich protein II antigens (HRPII). An antiseptic swab was applied at the tip of the left middle finger and 2-3 blood drops obtained by rapid finger prick. The drawn blood samples were then immediately loaded onto the test kit with a micropipette. For quality control, thick and thin blood films were prepared for microscopy from every patient to establish parasite infection status from a subsample of RDT positive and negative participants. Participants positive for rapid tests were offered immediate anti-malaria treatment in accordance with the national guidelines by the community health nurse in the survey team. Patients were offered Artemether/Lumefantrine combination therapy (Co-Artem® tabs manufactured by the Novartis industry). If the participants refused this treatment option, they were referred to a nearby health facility and offered every encouragement and logistical assistance to attend. Women of child bearing age found to be infected with malaria were offered treatment with Co-Artem®, unless they were known or suspected to be pregnant and in their first trimester. In the latter case, they were advised to seek clinic-based quinine therapy rather than Co-Artem®, as is the national policy.

2.5 Preliminary data processing and data analysis

2.5.1 Quality control, data entry, and archiving

The questionnaire and informed consent forms were checked by a supervisor in the field and inconsistencies verified with the respondents after each day of surveys. The completed informed consent forms were then arranged in box files and kept in locked cabinets. Responses to the supplementary, adult, questionnaire recorded on the hardcopy forms were entered into an Excel spreadsheet on password-protected computers. Memory cards were drawn from the personal digital assistants (PDAs) and data downloaded onto password protected computers every fortnight. The PDA databases on the same computers were then imported onto Access spreadsheets and carefully examined, cleaned and linked in readiness for analysis.

2.5.2 Data analysis

2.5.2.1 Computation of individual estimates of the proportion of exposure that occurs indoors (π_i) and the proportion of exposure that occurs in bed (π_s)

These two estimates of the distribution of malaria risk were calculated on the basis of a fundamental concept as outlined previously (Govella *et al.*, 2010, Seyoum *et al.*, 2012, Kiware *et al.*, 2012). The aggregate exposure to malaria vectors that individuals can incur while outdoors, indoors and out of bed or in bed were calculated based on the estimated vector biting rates in these respective compartments, and which of these compartments participants reported being in, at each hour of the night. The malaria vector biting rates estimated as the number of bites per person per hour indoors or outdoors throughout the period of malaria vector activity, were adopted as secondary data from the work of Geissbuhler and colleagues (Geissbuhler *et al.*, 2007). The respective overall indoor and outdoor exposure estimates were obtained by adding all the mean vector biting rates for the

indoors (B_i) and outdoors (B_o) for each of the hours that an individual was indoors (O_t) and outdoors (I_t), respectively. The total in bed exposure was obtained by adding all the mean indoor biting rates (B_i) for each of the hours that an individual was in bed (S_t). The proportion of exposure that occurred indoors (π_i) was thus computed by dividing the total indoor exposure by the sum of the total indoor and total outdoor exposure as shown in equation 1. In the same way, the proportion of exposure that occurs in bed was calculated by dividing the total exposure in bed over the sum of the total indoor exposure and total outdoor exposure as shown in equation 2.

$$\pi_i = \frac{\sum_{t=0}^{23} [B_{i,t} I_t]}{\sum_{t=0}^{23} [B_{i,t} I_t + B_{o,t} O_t]} \quad (\text{Equation 1})$$

$$\pi_s = \frac{\sum_{t=0}^{23} [B_{i,t} S_t]}{\sum_{t=0}^{23} [B_{i,t} I_t + B_{o,t} O_t]} \quad (\text{Equation 2})$$

Table 1: The definition of parameters used in the computation of π_i and π_s .

Parameter	Definition
π_i	proportion of exposure occurring indoors
π_s	proportion of exposure occurring while in bed/sleeping
$\sum_{t=0}^{23}$	the summation; from the onset of malaria vector activity at $t=0$ (1800 to 1900hrs) through $t=23$ (1700 to 1800hrs)
$B_{i,t}$	the indoor biting rate at the time t
$B_{o,t}$	the outdoor biting rate at the time t
I_t	equals 1 or 0 if an individual is indoors or outdoors respectively, at the time (t)
O_t	equals 1 or 0 if an individual is outdoors or indoors respectively, at the time (t)
S_t	equals 1 or 0 if an individual is in bed or awake respectively, at the time (t)

2.5.2.2 Statistical data analysis and presentation

Demographic data was descriptively explored by the Chi-square test to assess statistical significance in the associations of individual, household and community level test variables. Quantitative statistical analyses were done by Correlation and Binary Logistic Regression to characterise associations and evaluate effect of predictive variables upon prevalence using the Predictive Analytics SoftWare (PASW) package.

2.6 Informed consent, protection of human participants and ethical approval

Permission was granted by the head of the household before every household-level survey. In the presence of all eligible participants, the objectives of the study, the methods of data collection, benefits and possible risks; as well as their rights to refuse or withdraw from participation of the study were verbally explained in detail. Consenting eligible participants were then offered a written informed consent form with the study details for further reading, inquiry and clarification. Upon satisfaction regarding the decision to or not to participate, individuals were asked to sign the consent forms as a record of their willingness to participate, otherwise they were allowed to return them and withdraw from the surveys. Assent from individuals below 18 years of age was recorded in the consent form from a parent or guardian and was recognised in practice as either voluntary acceptance or mild refusal without fear. Participants who decided to withdraw at any stage of the interviews were unreservedly allowed to do so. This study was approved by the Ethical Review Board of the Ifakara Health Institute and the Medical Research Coordination Committee of the National Institute for Medical Research, approval reference NIMR/HQ/R.8a/Vol.IX/801.

3.0 CHAPTER THREE: RESULTS

3.1 The demographic characteristics of the study population

A total of 6,071 individuals (40.7% males and 59.3% females) were successfully interviewed from 1,484 households from a total of 84 sampling clusters. The regular time (daytime) survey yielded 71.2% (4325) of the total respondents whereas only 28.8% (1746) of the respondents were sampled by the supplementary follow-up surveys. A higher proportion of adults (>18yrs) was recorded than children out of the total respondents interviewed by both surveys (62.2% against 37.8% respectively) likely due to school attendance and subsequent evening remedial classes by the schooling children (5-18 years). The age distribution by the sex of individuals varied significantly across the study population ($p < 0.001$, $\chi^2 = 101.53$), with the biggest difference occurring in the 18 to 30 years age bracket (Figure 6). The eighteen to 30 years age bracket was predominantly secondary school/college attending individuals. However, this age group has been previously found to be highly economically productive (NBS, 2009) in which case, conventionally, males become more occupied hence more frequently absent from houses compared to females.

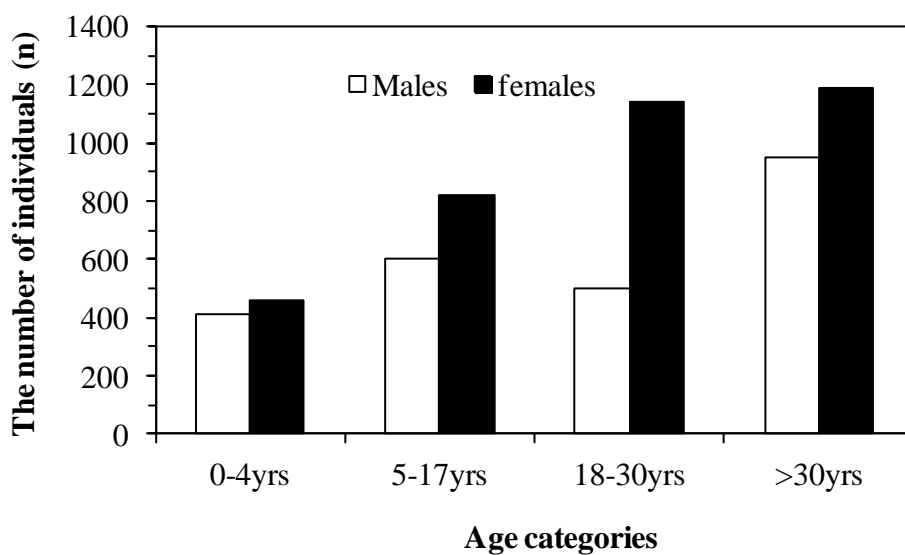


Figure 6: Graphical representation of the age and sex characteristics of the study population

3.2 The timing of house entry for the evenings, sleeping, waking up, and leaving the house in the morning for individuals.

As described in Figure 7, individuals reported entering their houses for the evenings as early as 6pm. The majority, however, entered their houses between 7pm and 9pm and essentially the rest entered their houses later in the night, with barely any ($\approx 0.1\%$) reporting to enter their houses after 1am. Almost two thirds of respondents, 61.9% (3755/6071) reported going to bed by 11pm the previous night, and over a fifth, 20.1% (1218/6071) reported spending up to two hours after entering the house before going to bed with the median time spent being 1 hour. Considering the relatively rare use of indoor protective measures other than bednets among Dar es Salaam's households (Table 2), staying indoors but out of bed exposed individuals who used bednets to greater risk of malaria infection (Figure 7).

More than three quarters of participants, 80.6% (4897/6071) reported to have got out of bed between 6am and 8am and almost everyone, 99.7% (6053/6071) had already left their houses by 9am (Figure 7). More than three fifths, 65.1% (3951/6071) of respondents hardly spent an hour after getting out of bed before leaving the house in the morning with the median time spent being less than an hour (<1 hours). Generally, individuals spent more time indoors after entering their houses for the evening before going to bed than they did after waking up before leaving their houses in the morning.

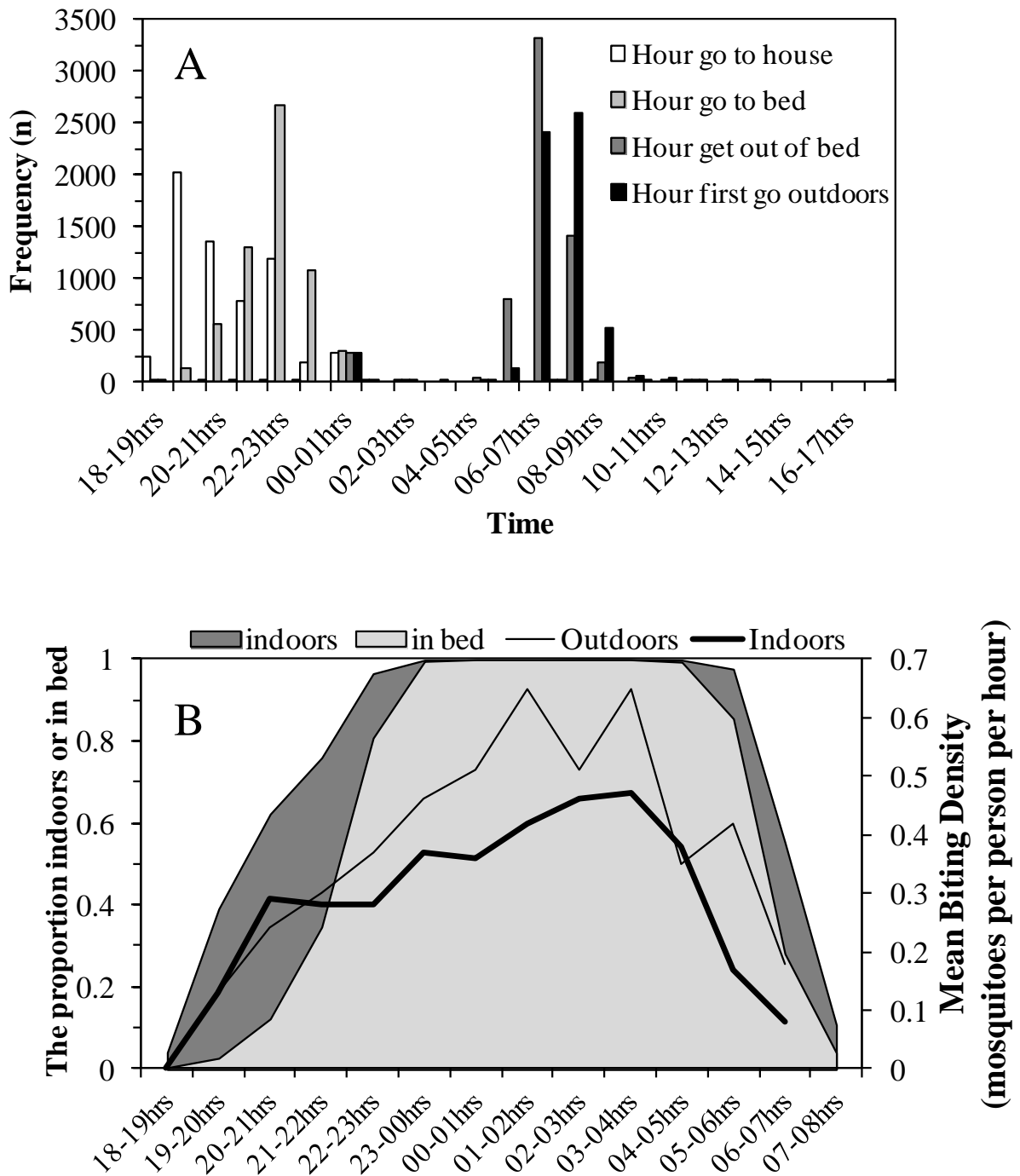


Figure 7: (A) Individuals' timing of entering the house for the evenings, going to bed, getting out of bed and leaving the house in the morning. (B) The proportions of individuals in the house but out of bed or in bed and the malaria vector individual human indoor and outdoor biting rates.

3.3 Mosquito control practices in Dar es Salaam

Many regions of Dar es Salaam experience high densities of malaria vectors and other mosquitoes. Consequently, residents of Dar es Salaam attempt to protect themselves by screening houses to prevent mosquito entry but also use bednets, insecticide sprays and repellents to avoid mosquitoes that enter the houses (Table 2).

Table 2: The level of coverage of indoor protective measures among residents of urban Dar es Salaam, Tanzania (n = 6071).

Indoor protective measure	Frequency	
	N	%
Mosquito-proofed housing	2720	26.2
Bednet	5062	48.7
Insecticide spray	2062	19.8
Mosquito coil	445	4.3
Repellent	109	1
Total	10398	100

The high coverage of bednets could be attributed to strategic initiatives by the government and other public health agencies to beef-up coverage particularly for infants and pregnant mothers over the years. Besides, bednets offer users direct physical barrier against mosquitoes thus readily persuasive as a means of protection against malaria infection. Previously, bednets have been used to prevent debris falling from the roof onto beds, as decorations, but also as a way of creating privacy for users in shared single-roomed houses (Aikins *et al.*, 1994) reminiscent of most Dar es Salaam informal dwellings. Mosquito proofing of houses and indoor residual spraying were also relatively common probably being the most suitable protection measures supplementary to bednets. Safety, availability, affordability, awareness and perceptions regarding protection efficiency could be some of the reasons behind non-populous use of mosquito coils and repellents.

3.4 The proportion of human exposure occurring indoors (π_i) and while sleeping in bed (π_s) for individuals

The proportions of exposure indoors (π_i) and in bed (π_s) were estimated for 5790 individuals. Most individuals had relatively high values for both estimates, with median values of 0.96 and 0.81 for π_i and π_s , respectively (Figure 8).

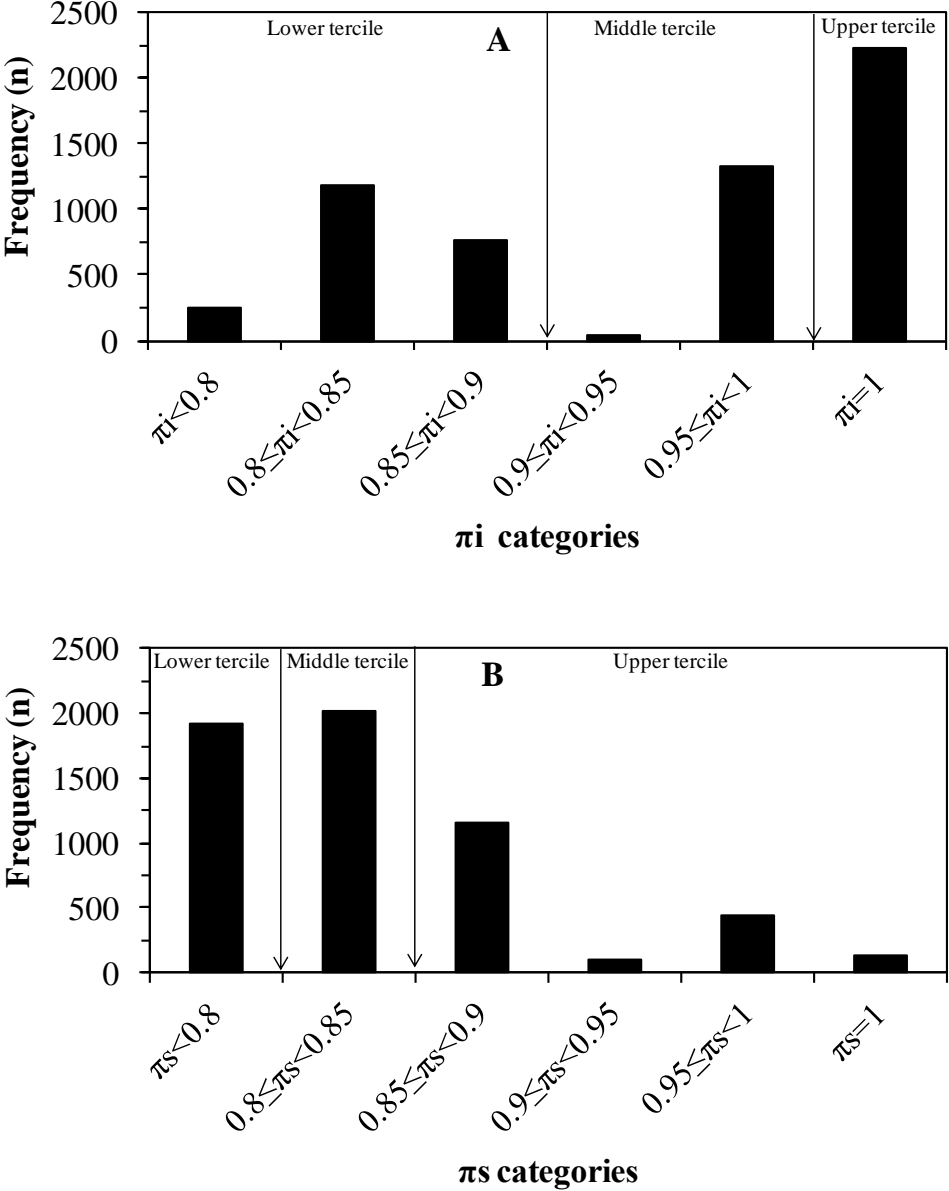


Figure 8: The calculated values for **A**, the proportion of exposure occurring indoors (π_i), and **B**, in bed (π_s) for individuals.

High π_i and π_s values demonstrate that the bulk of the risk of malaria infection occurred inside the house and when individuals were sleeping. Essentially, both figures 7 and 8 indicate that more individuals spent most of the night in the house sleeping when intensive vector biting activity occurred. Certainly, even the low π_i and π_s values were only relatively low but were indeed meaningfully high outlining the relative importance of indoor malaria transmission. Consequently, efficient and widespread use of indoor protective measures, particularly bednets would have great potential of reducing malaria cases. Nevertheless, although occurring on a relatively low scale, the risk of malaria transmission while outdoors constitutes a major component of the residual transmission system due to the apparent infrequent use of protective measures appropriate for use while outdoors among this population.

3.5 Timing of house entry and exit, as well as going to bed, as determinants of malaria risk among all age groups

A total 4000 valid blood test results were obtained, 10.3% (412/4000) gave positive results for malaria. Five hundred and twenty thin blood film samples were examined by microscopy and these exhibited 100% concordance with the results obtained through rapid diagnosis (RDT), (Table 3).

Table 3: A comparison of blood test results obtained by both rapid diagnostic testing (RDT) and microscopy for the same samples.

Test results	Diagnostic method	
	Microscopy	RDT
Positive	54	54
Negative	466	466

The age of household members, usage of bednets, and the relative proportions of exposure occurring indoors (π_i) and while sleeping in bed (π_s) were all found to be significant predictors of malaria prevalence (Tables 4 and 5).

Table 4: The relative risk of malaria infection estimated by age, bednet usage, and the proportion of exposure occurring indoors (π_i).

Test variables	Prevalence			
	%(n/N)	β	OR(95% CI)	P value
Age categories				
<i>0-4 years</i>	13.1(96/734)	0 ^a	1 ^a	NA ^a
<i>5-17 years</i>	11.2(123/1097)	-0.255	0.775(0.579,1.037)	0.087
<i>18-30 years</i>	9.9(100/1012)	-0.504	0.604(0.441,0.828)	0.002
<i>>30 years</i>	8.2(89/1091)	-0.707	0.493(0.358,0.679)	<0.001
Bednet usage				
<i>No nets</i>	5.4(52/962)	0 ^a	1 ^a	NA ^a
<i>Untreated nets</i>	11.5(158/1372)	0.743	2.101(1.510,2.924)	<0.001
<i>ITNs</i>	12.1(201/1666)	0.681	1.977(1.427,2.737)	<0.001
π_i terciles				
<i>Upper tercile</i>	7.8(121/1560)	0 ^b	1 ^b	NA ^b
<i>Middle tercile</i>	10.2(152/1494)	0.250	1.284(0.958,1.721)	0.095
<i>Lower tercile</i>	15.3(135/880)	0.771	2.162(1.685,2.773)	<0.001

1^a = Reference category.

CI = Confidence Interval.

OR = Odds Ratio (The exponential of β estimated by generalised linear models).

NA = Not Applicable because this is the reference variable.

0^a = Set to zero because this parameter is redundant.

ITNs = Insecticide treated bednets

π_i = The proportion of individual human exposure to malaria vectors occurring indoors.

Table 5: The relative risk of malaria infection estimated by age, bednet usage, and the proportion of exposure occurring while sleeping in bed (π_s).

Test variables	Prevalence			
	%(n/N)	β	OR(95% CI)	P value
Age categories				
<i>0-4 years</i>	13.1(96/734)	0 ^a	1 ^a	NA ^a
<i>5-17 years</i>	11.2(123/1097)	-0.141	0.868(0.648,1.163)	0.343
<i>18-30 years</i>	9.9(100/1012)	-0.275	0.759(0.549,1.050)	0.096
<i>>30 years</i>	8.2(89/1091)	-0.497	0.608(0.437,0.847)	0.003
Bednet usage				
<i>No nets</i>	5.4(52/962)	0 ^a	1 ^a	NA ^a
<i>Untreated nets</i>	11.5(158/1372)	0.776	2.150(1.546,2.991)	<0.001
<i>ITNs</i>	12.1(201/1666)	0.776	2.151(1.557,2.972)	<0.001
π_s terciles				
<i>Upper tercile</i>	11.2(166/1481)	0 ^a	1 ^a	NA ^a
<i>Middle tercile</i>	11.9(164/1380)	0.218	1.244(0.968,1.598)	0.088
<i>Lower tercile</i>	7.3(78/1073)	-0.216	0.806(0.594,1.092)	0.164

π_s = The proportion of individual human exposure to malaria vectors occurring while in bed/sleeping.

Malaria prevalence reduced with increasing age, adults above 30 years having approximately half less risk as 0 to 4 year olds, possibly due to acquired immunity among older individuals. Ironically, bednets, including ITNs were associated with increased risk of infection with users being approximately twice as likely to get infected as non-users. Besides, ITNs provided no additional personal protection benefit than untreated bednets (Table 4 and 5). However, along with established evidences supporting the impact of bednets in reducing malaria prevalence, there probably only occurred basic correlation between bednet use and higher risk possibly due to the widespread use of nets among risk groups. Bednet users were likely younger individuals ($p < 0.001$, $r^2 = -0.078$) and were also likely to spend longer times sleeping in bed

($p < 0.001$, $r^2 = -0.123$). Indoor exposure (π_i) was a relatively stronger predictor of malaria prevalence than in bed exposure (π_s) apparently because of larger variation in the intensity of vector biting activity across the indoor and outdoor than across the in-bed and out of bed compartments. However, both π_i and π_s were associated with reduced risk of infection.

Nevertheless, whereas going to sleep was associated with reduced prevalence, both house entry and getting out of bed were associated with increased risk of malaria infection (Table 6). Essentially, individuals became more vulnerable to infections upon entering the house but were safer once they went to bed although again they were likely to contract infection once they got out of bed before leaving the house in the morning. Thus, time spent inside the house but out of bed exposed bednet users to greater danger of malaria infection. Household protection measures including mosquito house-proofing ($p = 0.12$), mosquito coils ($p = 0.06$), and chemical insecticide spraying ($p = 0.09$) were all not statistically associated with the prevalence of malaria infection.

Table 6: The variation of the risk of malaria parasite infection by age, bednet use, the timing of house entry, going to bed and getting out of bed.

Test variables	Prevalence			
	%(n/N)	β	OR(95% CI)	P value
Age categories				
<i>0-4 years</i>	13.1(96/734)	0 ^a	1 ^a	NA ^a
<i>5-17 years</i>	11.2(123/1097)	-0.101	0.904(0.670,1.220)	0.510
<i>18-30 years</i>	9.9(100/1012)	-0.277	0.758(0.544,1.057)	0.103
<i>>30 years</i>	8.2(89/1091)	-0.465	0.628(0.448,0.881)	0.007
Bednet usage				
<i>No nets</i>	5.4(52/962)	0 ^a	1 ^a	NA ^a
<i>Untreated nets</i>	11.5(158/1372)	0.672	1.958(1.418,2.704)	<0.001
<i>ITNs</i>	12.1(201/1666)	0.613	1.846(1.323,2.577)	<0.001
Event timing				
<i>Going indoors</i>	NA	0.261	1.298(1.185,1.422)	<0.001
<i>Going to bed</i>	NA	-0.160	0.852(0.749,0.969)	0.015
<i>Getting out of bed</i>	NA	0.139	1.149(1.034,1.277)	0.010

The contemporary discourse reveals that the use of bednets was central in the reduction of the risk of malaria infection. Despite having approximately one in every three houses being relatively properly mosquito-proofed, this measure was not sufficiently protective. Probably, encouraging extensive use of insecticide sprays, mosquito coils and other supplementary control measures would further abate the indoor risk of malaria infection in Dar es Salaam.

3.6 Outdoor activities as determinants of malaria risk among adults

An estimated 46.3% (1746) of all adults interviewed responded to the questions regarding participation in outdoor activities around dusk and night hours. Out of these, 91.9% (1605) reported to have engaged in these activities within a period of a fortnight prior to the interviews. Indeed 80.9% (1413) had engaged in one or more of these events the eve of the

interviews. This would possibly imply that outdoor activities in this community were a common, rather than occasional, experience. The range of outdoor activities reported was readily divided into two distinct categories on the basis of whether they took place in the immediate vicinity of the house or not ($p < 0.001$; $\chi^2 = 742.70$), (Figure 9 and Table 7). It was evident however, that almost half (47%; 767/1605) of respondents reported having participated in more than one of the stated outdoor activities (Figure 9). Of the outdoor activities reported, the most populous 62.6% (1505/2403) were resting; 66.8% (1072) and sleeping; 26.6 % (427) within the immediate surroundings of houses. Other activities consisting a smaller proportion 37.4% (898/2403) included visiting public leisure and entertainment centers; 23.4% (375), attending socio-cultural; 12.3% (197), religious; 8.3% (134), educational; 6% (97) and sporting/exercising; 5.6% (90) events away from the immediate vicinity of houses.

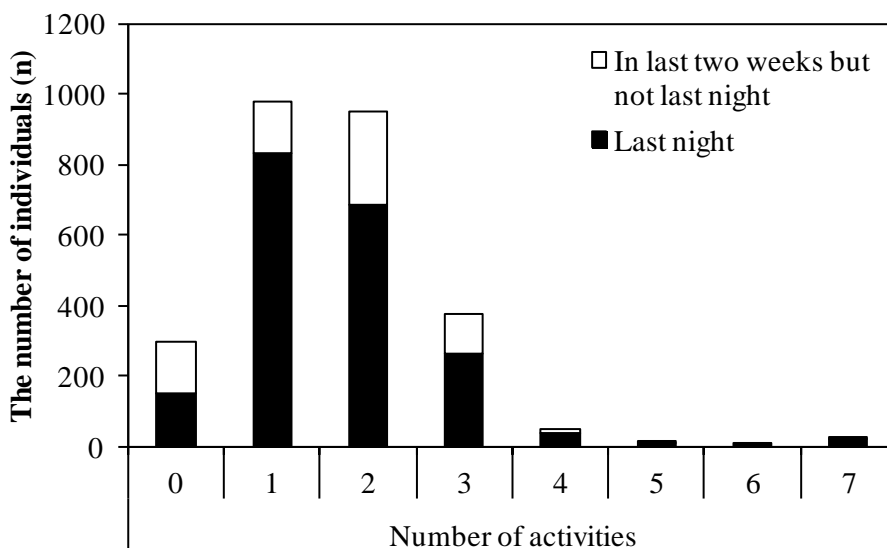


Figure 9: The frequency of participation of individuals in different outdoor activities and the time of occurrence of the activities prior to the surveys. Mostly individuals either only rested or slept outdoors too and fewer individuals did extra activities.

Table 7: The frequency of occurrence of the individual routine outdoor activities (N = 2278) expressed as weighted percentages (%) and the duration of the activities prior to the surveys.

Outdoor activity	Peri-domicile areas		Away from the immediate vicinity of homes					Total
	Rested	Slept	Religious events	Cultural events	Sports & exercise	Educational activities	Public leisure centres	
Frequency	%(n)	%(n)	%(n)	%(n)	%(n)	%(n)	%(n)	%(N)
In last two weeks but not last night	6.4(153)	6.0(143)	1.1(26)	2.5(61)	1.0(24)	0.4(11)	5.4(130)	22.8(548)
Last night	38.4(923)	11.9(286)	4.5(108)	5.9(140)	2.7(66)	3.6(86)	10.2(246)	77.2(1855)
Total	44.8(1076)	17.9(429)	5.6(134)	8.4(201)	3.7(90)	4.0(97)	15.6(376)	100(2403)

Resting outdoors had significant association to the prevalence of malaria infection (Table 8).

Table 8: Variation of the risk of malaria infection by age, bednet use and resting outdoors.

Test variables	Prevalence			
	%(n/N)	β	OR(95% CI)	P value
Age categories				
<i>0-4 years</i>	13.1(96/734)	0 ^a	1 ^a	NA ^a
<i>5-17 years</i>	11.2(123/1097)	-0.161	0.851(0.160,4.519)	0.850
<i>18-30 years</i>	9.9(100/1012)	-0.826	0.438(0.118,1.619)	0.216
<i>>30 years</i>	8.2(89/1091)	-0.820	0.440(0.120,1.615)	0.216
Bednet usage				
<i>No nets</i>	5.4(52/962)	0 ^a	1 ^a	NA ^a
<i>Untreated nets</i>	11.5(158/1372)	0.724	2.062(1.121,3.795)	0.020
<i>ITNs</i>	12.1(201/1666)	1.093	2.983(1.601,5.561)	0.001
Activity				
<i>Did not rest outdoors</i>	5.9(28/475)	0 ^a	1 ^a	NA ^a
<i>Resting outdoors</i>	9.7(67/690)	0.597	1.817(1.146,2.882)	0.011

Individuals who reported resting outdoors had about double the risk as those who did not (Table 8). Moreover, resting outdoors was a significant determinant of π_i with those who rested outdoors being likely to belong to the lower π_i tercile as those who did not (Table 9). Generally, individuals who rested outdoors had reduced indoor risk and consequently experienced higher outdoor risk. Resting outdoors was thus a significant risk factor for outdoor exposure. Sleeping outdoors, religious and cultural events, sports and exercise, educational activities and leisure and entertainment were not statistically associated with prevalence ($p \geq 0.06$) probably due to infrequency of their occurrence.

Table 9: Membership of lower π_i tercile by age, bednet use and resting outdoors.

Test variables	Prevalence			
	%(n/N)	β	OR(95% CI)	P value
Age categories				
<i>0-4 years</i>	13.1(96/734)	0 ^a	1 ^a	NA ^a
<i>5-17 years</i>	11.2(123/1097)	1.116	3.054(0.709,13.148)	0.134
<i>18-30 years</i>	9.9(100/1012)	0.874	2.396(0.663,8.656)	0.182
<i>>30 years</i>	8.2(89/1091)	1.082	2.950(0.818,10.636)	0.098
Bednet usage				
<i>No nets</i>	5.4(52/962)	0 ^a	1 ^a	NA ^a
<i>Untreated nets</i>	11.5(158/1372)	-1.208	0.263(0.207,0.333)	<0.001
<i>ITNs</i>	12.1(201/1666)	-1.336	0.299(0.229,0.390)	<0.001
Activity				
<i>Did not rest outdoors</i>	5.9(28/475)	0 ^a	1 ^a	NA ^a
<i>Rested outdoors</i>	9.7(67/690)	0.457	1.579(1.275,1.956)	<0.001

3.7 Common livelihoods and survey type as determinants of malaria risk among adults.

A total 1746 adults were interviewed regarding their sources of livelihood and over half 50.9% of them reported to have had at least some employment and paid occupations. The remainder reported to have either had no specific income-generating occupation and so either did casual labour, were engaged in occupations that did not earn any income such as childcare domestic chores, were still in school, or had retired (Table 10). Reminiscent of most urban regions in developing countries (UN, 2008a), most of Dar es Salaam's economically productive population relied on self employment. Partly owing to unemployment from formal sectors of the economy, small-scale enterprises comprising, restaurants and bars, motor-vehicle repair, carpentry, masonry, tailoring, building and construction become common urban livelihoods (Kohlert, 2007, NBS, 2009, Sutton, 1970). "Rurban" (Rural-urban hybrid) farming is also practised (Dongus *et al.*, 2009, Mlozi, 1997) but is nevertheless a relatively rare source of urban employment and household income.

Table 10: The common livelihoods among adults in urban Dar es Salaam showing respective occupational sectors and employment status.

Occupational status	Employment status					
	Voluntary	Unemployed	Employed	Self-Employed	None	Total
	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)
Agriculture	0(0)	0(0)	0.3(6)	1.7(30)	0(0)	2.1(36)
Beauty industry	0(0)	0(0)	0.06(1)	0.3(5)	0(0)	0.3(6)
Capentry	0(0)	0(0)	0.06(1)	0.3(6)	0(0)	0.4(7)
Clerical	0.1(1)	0(0)	4.9(85)	0.7(12)	0(0)	5.6(98)
Construction	0(0)	0(0)	0.4(7)	1.9(34)	0(0)	2.3(41)
Domestic	0(0)	0(0)	1.3(23)	0.2(4)	0(0)	1.5(27)
Education	0(0)	0(0)	0.5(8)	0.2(4)	0(0)	0.7(12)
Entertainment	0(0)	0(0)	0.2(4)	0.3(6)	0(0)	0.6(10)
Faith & religion	0(0)	0(0)	0.06(1)	0.06(1)	0(0)	0.1(2)
Fishing	0(0)	0(0)	0.06(1)	0.3(5)	0(0)	0.3(6)
Health	0(0)	0(0)	0.06(1)	0.1(2)	0(0)	0.2(3)
Hotel industry	0(0)	0(0)	0.3(6)	0(0)	0(0)	0.3(6)
Manufacturing	0(0)	0(0)	0.3(6)	0.06(1)	0(0)	0.4(7)
Motor-mechanic	0(0)	0.06(1)	0.1(2)	0.7(13)	0(0)	0.9(16)
Security	0(0)	0(0)	1.5(26)	0.3(5)	0(0)	1.8(31)
Textile & cloth	0(0)	0(0)	0.06(1)	1.3(23)	0(0)	1.4(24)
Trading	0.06(1)	0(0)	2.2(38)	27.5(481)	0(0)	29.8(520)
Transport	0(0)	0(0)	0.9(16)	1.1(20)	0(0)	2.1(36)
Other	0(0)	0.1(2)	0(0)	0(0)	0(0)	0.1(2)
None	0(0)	0(0)	0(0)	0(0)	49(856)	49.1(856)
Total	0.1(2)	0.2(3)	13.3(233)	37.3(652)	49.1(856)	100(1746)

Trading was the predominant occupational sector and was mostly based on self-employment (Table 10). In fact, self-employment accounted for twice as many livelihoods as all forms of formal employment combined. This is neither novel nor unique as is the expectation of most

urban regions in developing nations where the population of the economically productive, employable individuals exceeds the scarcely available formal employment opportunities (UN, 2008b). Moreover, a significant other proportion of the population is normally unskilled and thus not readily admissible to formal employment. Growing urban population provides ready market for the small-scale business ventures (UN, 2008a). Frequently, the obligation of household livelihoods rests on a few household members who in most cases lead busy lifestyles and frequently are absent from their houses (NBS, 2008, NBS, 2009). In Table 11, age, sex and the likelihood of having paid occupations were highly significantly associated.

Table 11: The relative chance of one having a paid occupation with regard to their age and sex as estimated by binary logistic regression.

Test variables				
Sex	Frequency %(n/N)	β	OR(95% CI)	P value
Female	12.0(145/1213)	0 ^a	1 ^a	NA ^a
Male	72.8(388/533)	1.559	4.756 (3.731, 6.062)	<0.001
Age categories				
18-30 years	40.8(335/822)	0 ^a	1 ^a	NA ^a
31-45 years	66.4(356/536)	1.080	2.945(2.319, 3.740)	<0.001
46-60 years	58.1(111/191)	0.593	1.810(1.289, 2.542)	<0.001
>60 years	31.9(46/144)	-0.742	0.476(0.316, 0.716)	<0.001

Males were more likely than females to have paid occupations and individuals aged between 31 and 45 years were the most likely to have paid occupations among all age groups. Generally, none of the livelihoods were found to be significantly associated with the prevalence of malaria parasite infection ($p \geq 0.99$).

3.8 The demographic characteristics and livelihoods of adults interviewed during follow-up surveys

Under-sampling of adults, particularly males, in household surveys has previously been attributed to frequent and prolonged absence from houses (NBS, 2011). Approximately a third 28.8% (1746/6071) of the respondents were unavailable during the daytime baseline survey and were thus followed-up in supplementary surveys during evenings. Out of these follow-up respondents, 616 were adults among which over half 56.5% reported to have had paid occupations. There was significant variation in the distribution of adults across the two survey time categories with regard to age; ($p < 0.001$; $\chi^2 = 16.33$), sex; ($p < 0.001$; $\chi^2 = 30.35$) and the paid occupation status; ($p < 0.001$; $\chi^2 = 16.90$). The highest proportion of the interviewees were younger adult females (18-45 years) while older males (≥ 46 years) were the least commonly sampled, probably because of their respective occupations and livelihoods (Tables 11 and 12). Slightly more individuals had paid occupations in the evening follow-up surveys than in the daytime baseline surveys ($p < 0.001$; $\chi^2 = 16.9$). Moreover, more females than males interviewed during the major survey had paid occupations but the reverse was true for those interviewed during the follow-up survey ($p < 0.001$; $\chi^2 = 15.79$), (Table 13). Possibly females participated in occupations and livelihoods in the vicinity of their homes and would thus be likely available in their houses during the daytime survey.

Although both sex and age were found to have been significantly associated with paid occupations (< 0.001), in contrast, the time an individual was interviewed (daytime baseline versus evening follow-up survey) was not statistically associated with paid occupations ($p = 1$).

Table 12: The age, sex and paid occupation status of adults interviewed by the respective surveys.

	Age categories	With paid occupation			Without paid occupation			Total
		Male	Female	Sub-total	Male	Female	Sub-total	
		%(n)	%(n)	%(n)	%(n)	%(n)	%(n)	
Baseline survey	18-30 yrs	3.8(68)	8.3(147)	12.1(215)	2.8(50)	16.9(300)	19.7(350)	31.7(565)
	31-45 yrs	4.3(76)	7.8(139)	12.1(215)	0.5(9)	6.6(117)	7.1(126)	19.2(341)
	46-60 yrs	2.4(43)	2.5(44)	4.9(87)	0.5(9)	2.9(51)	3.4(60)	8.3(147)
	>60 yrs	1.1(19)	0.4(8)	1.5(27)	1.3(24)	3.4(60)	4.8(84)	6.2(111)
	Sub-total	11.6(206)	19.0(338)	30.6(544)	5.2(92)	45.5(528)	34.8(620)	65.4(1164)
Follow-up survey	18-30 yrs	4.0(71)	4.3(76)	8.3(147)	2.2(40)	7.4(131)	9.6(171)	17.9(318)
	31-45 yrs	4.6(81)	3.7(66)	8.3(147)	0.2(3)	3.2(57)	3.4(60)	11.6(207)
	46-60 yrs	1.0(18)	1.1(19)	2.0(37)	0.3(5)	1.0(18)	1.3(23)	3.4(60)
	>60 yrs	0.6(11)	0.3(6)	1.0(17)	0.3(6)	0.4(8)	0.8(14)	1.7(31)
	Sub-total	10.2(181)	9.4(167)	19.6(348)	8.8(54)	34.8(214)	15.1(268)	34.6(616)
Total	21.8(387)	28.4(505)	50.2(892)	16.8(146)	80.3(742)	49.9(888)	100(1780)	

4.0 CHAPTER FOUR: DISCUSSION, CONCLUSION AND RECOMMENDATION

4.1 Discussion

Malaria risk is heterogeneous among populations and is fundamentally associated with lifestyles of individuals (Bruce Chwatt, 1985, Prothero, 1977). But most important are the individual human behavioural aspects that influence their exposure to malaria transmitting mosquitoes (Stoddard *et al.*, 2009, Geissbuhler *et al.*, 2007). The proper understanding of human risk factors of malaria infection is essential for developing effective malaria control interventions (Killeen *et al.*, 2006, McKenzie, 2000). Movements constitute a crucial aspect of human risk factors in many vector borne disease systems (Stoddard *et al.*, 2009, Prothero, 1963, Gonzalez *et al.*, 2008). Both migratory and transitional or circulatory movements across geographically separate regions or within human settlements could be important risk factors of malaria (Stoddard *et al.*, 2009, Geissbuhler *et al.*, 2007, Gonzalez *et al.*, 2008).

There was generally low prevalence of malaria in the population depicting a low supersaturated stable malaria transmission scenario. However, heterogeneities in malaria risk based upon various individual level risk factors occurred among the study participants. Age was a significant predictor of malaria risk, with younger individuals bearing the highest risk of getting infection. Age-driven heterogeneity of prevalence in malarious populations is often characteristic of protection among older individuals due to acquired malaria immunity especially within low stable malaria transmission systems (Cohen, 1979, Gupta *et al.*, 1999). Bednet use was most common among younger individuals particularly children below the age of five being apparently suggestive of coverage and usage prioritization for the vulnerable group (Bruce Chwatt, 1985, Bates *et al.*, 2004).

The timing of house entry for the evening, going to bed and getting out of bed in the morning had significant influence upon the risk of malaria infection. Generally, individuals entered

their houses relatively earlier during the evenings and remained there longer for most of the night sleeping in bed. Consequently, individuals became highly susceptible to malaria infection since malaria vectors predominantly bite at night within houses. Surprisingly, individuals who spent longer in the house and also longer in bed were less likely to get infected. However, whereas entering the house earlier for the evening was associated with increased prevalence of malaria infection, going to bed earlier was protective against malaria infection. Since most individuals reported using bednets while sleeping and that the bednet users were more likely than non-users to go to bed earlier once they entered the house and also stayed in bed longer, it was evident that almost entirely bednets provided the resilience experienced against indoor malaria risk. Mosquito house-proofing was not sufficiently effective and apparently mosquitoes entered houses but because insecticide sprays, mosquito coils and repellents were less frequently used, bednet users were more vulnerable to malaria infection while out of bed.

Contrary to the preceding discussion, bednets were associated with increased prevalence of malaria. However, bednets have been widely and rigorously proven to be effective individual protective measures (Lindsay and Gibson, 1988, Okrah *et al.*, 2002, Govella *et al.*, 2010), the anomaly would thus have resulted from basic correlation between bednet use and prevalence, where, probably, risk groups were the most common bednet users. Treated bednets had no additional personal protection to users compared to untreated nets. Normally, bednets provide physical barriers against pursuing mosquitoes but ITNs can also kill mosquitoes. Therefore, the additional benefit of ITNs is appreciable in terms of their ability to control mosquitoes and would probably be evident upon evaluating their long-term and communal protection.

Outdoor activities were habitual rather than occasional experiences. However, individuals mostly spent time in the immediate vicinity of their houses resting or sleeping as opposed to

moving away from their houses. Resting outdoors was overwhelmingly the activity of choice greatly accounting for the delay in entering the house and increased risk of malaria infection.

A wide range of common urban livelihoods were reported. Generally, older males were the most likely to have paid occupations; dominating as heads of households, the vast obligation of household livelihood needs rests with them. However, individuals aged between 31 and 45 years were the most likely to have paid occupations as they constitute the optimal economically productive age group. Majority of livelihoods included small-scale trading activities based on self employment. Developing economies experience unemployment crises particularly in the typically densely populated urban regions where individuals straight from academic institutions overwhelm the scarcely available formal employment opportunities. As a result, individuals find alternative means of livelihoods but most frequently the ready choice is small-scale trading (Sutton, 1970, Kohlert, 2007). However, livelihoods had no significant association with the prevalence of malaria infection.

Although not entirely accountable, occupational commitments were a significant reason for the absence of individuals from houses during the daytime. Faced with household occupations like childcare, adult females would likely engage in livelihood activities near their homes where they would be available most of the time during the day (Tripp, 1989).

4.2 Conclusion and Recommendations

Further reductions in malaria transmission require supplementary control tools suitable for use while individuals are out of bed both within and outside the house. Because habitual resting outdoors in the immediate proximity of houses was shown to increase malaria risk, going to sleep in bed earlier in the evenings and staying there most of the night under a properly set mosquito bednet could help alleviate malaria risk. Livelihoods among the adult population do not influence the risk of malaria infection in urban Dar es Salaam. In as much as livelihoods and occupational commitments are among the primary reasons for the absence of individuals in houses during the day, they do not entirely account for the absence of individuals in the regular daytime household surveys. Nevertheless, evening follow-up surveys are imperative for comprehensive data collection during cross-sectional household baseline surveys.

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APPENDIX 1: CROSS-SECTIONAL SURVEY QUESTIONNAIRE

Form Information

Form Serial Number (IC1): [Copy from Informed Consent agreement of respondent]	
Date (DT):	
Interviewer Name:	
Interviewer signature:	
Supervisor Name:	
Supervisor signature:	

Study Information:

Site (SE):	101 (Dar es Salaam, United Republic of Tanzania)		
Name of head of household		House number:	

Part I-Household Information-Fill out once for each household with one or more participants

1. Enumeration area (EA; concatenated numeric codes for Municipality-Ward-Neighbourhood)

Geographic area unit:	Municipality	Ward	Neighbourhood/Street
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Digits:	1	2	2
Code:			

2. House location and identity within the sampling frame

Housing unit:	Ten-cell unit cluster (CR)	Compound or Plot (CP)	Household (HH)
Digits:	3	3	3
Code:			

3. Registered House Number _____

4. Name _____ of _____ Head _____ of Household _____

5. For the head of household, what is the highest level of education received? []

- a. NONE
- b. PRIMARY
- c. SECONDARY
- d. HIGHER

6. What type of wall was primarily used for the construction of the living space occupied by this household?

- a. MUD
- b. BRICK/CONCRETE
- c. PLASTERED BRICK/CONCRETE
- d. PAINTED BRICK/CONCRETE
- e. WOOD, IRON SHEETS

- f. OTHER:_____
7. What type of roof covers the house or building occupied by this household?
- a. GRASS THATCH/PLASTIC SHEETING/FLATTENED OIL TINS
 - b. IRON SHEETS
 - c. TILES, CEMENT, REINFORCED CONCRETE
 - d. OTHER_____
8. Are the eaves of the house or building occupied by this household open or closed?
- a. OPEN
 - b. CLOSED
 - c. PARTIALLY OPEN
9. Does the part of the house or building occupied by the household have a ceiling?
- a. NONE (Go direct to question 11)
 - b. PARTIAL/POORLY SEALED/WORN OUT
 - c. COMPLETE AND SEALED
10. If a ceiling is present, what type of material is the ceiling primarily constructed of?
- a. WOOD/PLYWOOD BOARDS
 - b. GYPSUM/PLASTERCAST
 - c. MUD AND WATTLE
 - d. WOVEN PALM THATCH
11. Are the windows and any airbrick gaps in the house or building boarded up, glazed or screened against mosquito entry with netting?
- a. COMPLETE
 - b. COMPLETE WITH HOLES
 - c. INCOMPLETE OR BADLY DAMAGED
 - d. ABSENT (Go direct to question 13)

12. If windows are boarded up, glazed or screened, what primary material is used to do so?

- a. WOODEN BOARDS
- b. GLASS
- c. METAL NETTING
- d. FABRIC NETTING
- e. PLASTIC NETTING

13. What is the main material of the floor of the part of the house or building occupied by the household?

- a. EARTH/SAND
- b. WOODEN BOARDS
- c. PARQUET OR POLISHED WOOD
- d. VINYL, ASPHALT OR PLASTIC SHEETING
- e. CERAMIC TILES
- f. CEMENT/CONCRETE
- g. CARPET
- h. OTHER _____

14. At any time in the past 12 months, has anyone sprayed the interior walls of the part of the house or building occupied by the household?

- a. YES
- b. NO (Go direct to question 17)
- c. DON'T KNOW (Go direct to question 17)

15. How many months ago was this living space sprayed? (IF LESS THAN ONE MONTH, RECORD '00' MONTHS AGO) _____

16. Who sprayed the house?

- a. GOVERNMENT WORKER/PROGRAM
- b. PRIVATE COMPANY
- c. HOUSEHOLD MEMBER
- d. OTHER (specify)_____
- e. DON'T KNOW

17. Have any of the following been used in your living space over the last week?

- a. Mosquito coils?
- b. Insecticide sprays (e.g. DOOM)?
- c. Repellents?

Part II-Household Listing-Fill out questionnaire for each participant.

1. Name of respondent_____

2. Is (NAME) male or female?

- a. MALE
- b. FEMALE

3. What is the date of birth of (NAME)? []

4. How many years old is (NAME)? []

5. Is (NAME) currently living with his/her biological mother?

- a. YES
- b. NO, MOTHER DIED
- c. NO, MOTHER LIVES ELSEWHERE

6. Is (NAME) currently living with his/her biological father?

- a. YES
- b. NO, FATHER DIED
- c. NO, FATHER LIVES ELSEWHERE

7. Are there any other persons living in this house that we have not listed?

- a. YES (Go back to QUESTION 1 and fill out this form for that person)
- b. NO

Part III-Malaria infection status and risk factors for each participant

(Fill out for each participant upon acquisition of informed consent)

1. Assigned individual identifier number (II) of respondents within the household: []
2. Serial number from Informed Consent agreement for this individual (IC1):_____
3. Assigned individual identity number (IIN) within the household: []
4. RDT Result
 - a. Positive
 - b. Negative
5. Blood smear taken?
 - a. YES
 - b. NO
6. Dried blood spot sample on filter paper taken?
 - a. YES
 - b. NO
7. Did (NAME) stay here last night?
 - a. YES
 - b. NO
8. To the nearest hour, what time last night did (NAME) go indoors for the evening? []
9. To the nearest hour, what time last night did (NAME) go to bed? []
10. To the nearest hour, what time this morning did (NAME) get out of bed? []
11. To the nearest hour, what time this morning did (NAME) first go outdoors? []

12. In the past month, has (NAME) slept somewhere outside of this house?

- a. YES
- b. NO
- c. NOT SURE

13. Did (NAME) sleep under a net last night?

- a. YES
- b. NO (Go to question 17)
- c. NOT SURE

14. How long ago was the net obtained?

Months: [] Years: [] Don't know: []

15. What is the brand of net used:

- a. PermaNet
- b. Olyset
- c. SupaNet
- d. Safinet
- e. Mbu net
- f. Afya net
- g. Other_____
- h. Don't know

16. Since you got the mosquito net, was it ever soaked or dipped in a liquid to repel mosquitoes or bugs?

- a. YES
- b. NO (Go to question #17)
- c. NOT SURE (Go to question #17)

17. How long ago was the net last soaked or dipped? (If less than 1 month, enter '00')

Months: [] Years: [] Not sure: []

18. Has (NAME) been ill with a fever at any time in the last 2 weeks?

- a. YES
- b. NO
- c. DON'T KNOW

19. Has (NAME) had a fever in the last 24 hours?

- a. YES
- b. NO
- c. DON'T KNOW

20. Has (NAME) taken any drugs in the last 2 weeks? (Check all that apply)

- a. SP/FANSIDAR []
- b. CHLOROQUINE []
- c. AMODIAQUINE []
- d. QUININE []
- e. COARTEM []
- f. OTHER ANTIMALARIAL (SPECIFY)_____ []
- g. ASPIRIN []
- h. ACETAMINOPHEN/PARACETAMOL []
- i. IBUPROFEN []
- j. OTHER (SPECIFY)_____ []
- k. YES BUT DON'T KNOW WHAT TYPE []

APPENDIX 2: QUESTIONNAIRE FOR EVENING FOLLOW-UP SURVEYS

Form Information

Form Serial Number (IC1): [Copy from Informed Consent agreement of respondent]	
Date (DT):	
Interviewer Name:	
Interviewer signature:	
Supervisor Name:	
Supervisor signature:	

Study Information:

Site (SE):	101 (Dar es Salaam, United Republic of Tanzania)		
Name of head of household		House number:	

Part I-Personal Information -Fill out questionnaire for each participant.

(Fill out for each participant upon acquisition of informed consent)

1. Name of respondent _____
2. Is (NAME) male or female?
 - a. MALE
 - b. FEMALE

3. What is the date of birth of (NAME)? []

4. How many years old is (NAME)? []

Part II-Occupational Information – Fill out for each participant 18 years and above

1. What is the occupational sector of (NAME) _____

2. Select the correct employment status of (NAME)

a. EMPLOYED

b. SELF-EMPLOYED

c. UNEMPLOYED

d. VOLUNTEER

e. CASUAL LABOURER

f. NONE

g. Any other (specify) _____

3. Does (NAME) work from home?

a. YES

b. NO

4. What time, to the nearest hour, does (NAME) leave home for work each day? (Use the 24 hr clock system) [] HRS

5. What time, to the nearest hour, does (NAME) return home after work each day? (Use the 24 hr clock system) [] HRS

6. Indicate whether (NAME) has been outdoors last night, within the last two weeks or both doing any of the mentioned activity(ies) or any other activity(ies) not mentioned

LAST NIGHT WITHIN A FORTNIGHT

- | | | | |
|-------|--------------------------|-------|-------|
| i. | Sleeping | [] | [] |
| ii. | Resting/socialising | [] | [] |
| iii. | Religious activities | [] | [] |
| iv. | Cultural activities | [] | [] |
| v. | Sports/games | [] | [] |
| vi. | Educational activities | [] | [] |
| vii. | Leisure/entertainment | [] | [] |
| viii. | Any other (specify)_____ | [] | [] |

7. Are there any other persons living in this house that we have not listed?

- a. YES (Go back to QUESTION 1 and fill out this form for that person)
- b. NO