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FACTORS INFLUENCING MALARIA TRANSMISSION IN GOKWE SOUTH DISTRICT, MIDLANDS PROVINCE, ZIMBABWE, 2021

BY

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Abstract

Malaria continues to be an ongoing problem in African countries south of the Sahara. Although a lot has been achieved in the past 15 years, millions of people still remain at risk. Correct identification of disease vectors is the first step towards implementing an effective malaria control programme. In the past few years, there has been an increase in the incidences of cases of malaria in Gokwe South district. The study sought to investigate the cases of malaria despite the interventions that were in place in the district through a correlational study in which data was recorded on exposures to mosquito bites and compared to outcome variables of those who have had malaria in 2020. Social and economic activities for those who contracted malaria were compared to those who had not contracted in the same year. A pretested, interviewer-administered questionnaire was also used to determine the sleeping habits of the participants, the known feeding habits, and the biting patterns of the anopheles mosquitoes. The Centre for Disease Control (CDC) light traps were used to capture mosquitoes for morphological identification. Data was analyzed using Epi info 7. Descriptive statistics were calculated and multiple logistic regression analysis was used to establish independent factors for residual malaria. Mosquitoes were found feeding mostly outside the house as well as both indoors and outdoors. Only *Anopheles gambiae sensu lato (s.l)* (100% of all captured Anopheles mosquitoes) were captured using the CDC light traps. Mosquitoes were found to be more active at dusk and at dawn for both indoor and outdoor biting. The key drivers of residual malaria transmission in Gokwe South District were established as: resting/relaxing outdoors at night (adjusted Odds Ratio (aOR): 11.5; 95%CI: 3.3-40.2), sleeping outdoors at night (aOR: 5.4; 95%CI: 1.7-17.7) and bathing outdoors before sleep (aOR: 5.1, 95%CI: 1.1-22.7). The results showed that human behaviour exposed people to An. *gambiae s.l.* biting. The sleeping patterns tend to be the major driver of residual malaria among the inhabitants of Gokwe south district. Health education and behavioural change communication should target adoption of malaria control measures when outdoors. Focus must be placed on dealing with the key drivers of residual malaria as established in this study.

Key words: *Gokwe south, malaria, mosquito, sleeping patterns, anopheles, residual*

Declaration

I declare that this research study is my original work except where sources have been cited and acknowledged. The work has never been submitted nor will it ever be submitted to another university for the award of a degree.

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Dedications

I dedicate this whole project to my two sons, Tanaka and Tinevimbo Mavhiya, you are my reason in undertaking this project. To the almighty Lord, I have every reason to praise you for you pulled me through even when I felt like giving up at times. Thank you, Lord, in you I trust.

List of Acronyms and Abbreviations

AUREC	Africa University Research Ethics Committee
CDC	Centre for Disease Control
DDT	Dichlorodiphenyltrichloroethane
DHIS	Demographic Health Indicator Survey
HBI	Human Blood Index
GVCR	Global Vector Control Response
IRS	Indoor Residual Spraying
ITNs	Insecticide Treated Nets
LLIN	Long-lasting Insecticide-treated Net
LLINs	Long Lasting Insecticidal Treated Nets
NMCP	National Malaria Control Programme
SADC	Southern African Development Community
USAID	United States Aid
WHO	World Health Organisation
ZIMSTATS	Zimbabwe Statistics Office

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CHAPTER 1

INTRODUCTION

1.0 Introduction

Mosquito-host interactions are a critical factor in the dynamics and epidemiology of vector-borne diseases (Navia-Gine et al., 2013) such as malaria. The knowledge on human-vectors contact is of great importance in order to tackle the point of transmission of mosquito-borne diseases through relevant control measures and interventions (Ombugadu et al., 2020).

Malaria is rated as the third most common cause of illness in Zimbabwe (USAID on Global Health Zimbabwe, 2020). Approximately 1 in 12 children die before their fifth birth day as a result of malaria infection (Demographic and Health Survey, 2010). In Zimbabwe, vector control is a central, critical component of all malaria control strategies. Indoor Residual Spraying (IRS) program and the use of Long Lasting Insecticidal treated Nets (LLINs) have increased in recent years.(Pryce et al., 2018) The increased use of insecticides in LLINs and in IRS can also lead to high levels of insecticide resistances that can lead to failure of these vector control methods in place and thereby having an epidemiological significant effect on malaria incidence. Despite the fact that vector mosquitoes are well documented across the world, there might be a revolutionary behavior change to mosquitoes in response to the control measures in place.

The Global Vector Control Response (WHO, 2017) for the period 2017 – 2030 has four pillars in which the third pillar is built on two foundations, one of the foundations being to increase basic and applied research, and innovation and the other foundation is to enhance vector control capacity and capability. While one of the pillars on these foundations (3rd pillar) talk about enhancing vector surveillance and monitoring and evaluation of interventions on vector control.

It is against this background that the researcher undertook this study to determine the malaria vectors biting times in Gokwe South district. Understanding the biting behaviour of malaria vectors plays a crucial role in their control (Milali et al., 2017) and prevention of malaria. The purpose of this study is to morphologically identify all female anopheles' mosquitoes and determine their biting times for both indoor and outdoor biting with an ultimate goal of informing the vector control system which is currently in place. Furthermore, the human sleeping behaviour was determined and assessed as a driver of residual malaria in the district.

In Gokwe south district, Long Lasting Insecticidal Treated Nets distribution and utilization is currently one of the vector control programs in place and the district is now in the pre-elimination phase. The program's success or lack of it could only be realized when there are checks and balances to see the effectiveness of LLINs and a robust vector surveillance system that encompasses entomological surveillance in which mosquito human biting times and host biting preferences are critical to inform the vector control program in the district to check if the control systems are on track or if there is still total protection to mosquito nets users. It is also imperative to understand the human sleeping patterns and the dynamics in terms of their economic and social activities.

Mosquito biting times and host biting preferences are a critical part of vector bionomics to evaluate vector control system since this can ascertain the relationship between vector biting times and the Long Lasting Insecticidal Treated Nets (LLINs) protection times in relation to human sleeping patterns as well. The information obtained in this regard could as well help program implementers to understand if the malaria vectors have developed some behavioral resistances through avoiding treated nets during the nights which is very important in programing.

The researcher therefore determined the anopheles mosquito biting times. The anopheles family will be identified through the use of dichotomous keys for malaria vector morphological identification created by Gilles and Coetzee (1987), while the vector biting times will be ascertained by the use of a number of tools such as CDC light traps and the questionnaire. The research was conducted in two rural wards of the 33 rural wards of Gokwe South district. The two wards were purposively included basing of the high malaria incidences in the district in the past 3 years.

1.1 Background to the study

Gokwe South District is situated in the Northern part of Midlands province at a 140-kilometre peg along the Kwekwe-Siyabuwa highway. The district has 33 administrative rural wards, covering a surface area of 11257.67 square kilometres and lying in the region 4 and 5, with the average annual rainfall received in the area being in the range 450 - 650mls. Soils are sandy and clay in most of the areas. Subsistent farming is the main activity for the peasant farmers while crops such as cotton, maize, sorghum and ground nuts are grown.

The district lies 970 metres above sea level giving in to Mapfungautsi plateau. Gokwe South district share boarders with 6 districts Kadoma, Lupane, Kwekwe, Gokwe North, Binga and Nkayi. The district population stands at 330036 according to the 12 ZIMSTAS.

In Zimbabwe malaria incidence declined by 84% from 136/1000 population in 2000 to 22/1000 population in 2020 (ZNMS, 2021) Gokwe South transitioned to malaria pre-elimination phase in 2017 after recording an Annual Parasite Incidence (API) below 4/1000 population in 2016. This has led to a successful transition from malaria control interventions to malaria pre-elimination activities in the continued fight against malaria. However, the District has recorded an increase in the number of Malaria cases in the year 2020, with many cases being seen between week 13 and week 16 of that year.

The district recorded an incidence of 2/1000 population in 2020 compared to 0.4/1000 in 2016 (DHIS STATS, 2021). The case distribution was seen to be sporadic in most of the wards with almost all health facilities reporting at least one malaria positive case (DHI statistics, 2020). Currently the District contributes 24% of the total Malaria burden in the Province.

LLINs are a cornerstone to the prevention of malaria transmission in the district, and the district is a beneficiary of Ministry of the Health and Child Care LLINs distribution for both continuous and mass distributions which is being rolled out with assistance from Plan Zimbabwe as an implementing partner since 2016. The past three years saw the district achieving over 90 percent LLINs uptake that is for the years 2018, 2019 and 2020 LLINs distributions respectively. However, the key drivers to an upsurge in the malaria incidence for the year 2020 were noted in a district malaria update report (August, 2020) as underutilisation of LLINs, misconception and religious interpretations, poor health seeking behaviours and gardening activity especially at dusk and dawn but other risk factors like mosquito behaviour which include biting times to ascertain active periods of Anopheles mosquitoes has not been much researched in the district. Determining anopheles mosquito behaviour and human behaviour to find where the two might be interacting could provide a good literature for the district in ascertaining the points of malaria transmission. These two dynamics can only be understood when the vector bionomics, including biting times in this case are also understood.

The WHO (GVCR, 2017) indicated that 80% of the world's population is at risk of one or more vector borne diseases, it also indicated that 17% of the global burden of communicable diseases is vector borne diseases and that over 700 000 of deaths are caused by vector borne-diseases.

Malaria control in Zimbabwe and in the whole of SADC region depends heavily on Indoor Residual Spraying and LLINs to target the vector mosquitoes. IRS and LLINs depend on the four most common WHO recommended classes of insecticides which are organochlorides, organophosphates, pyrethroids and carbamates. Pyrethroids are also used for the LLINs treatment as per the WHO recommendations but vector mosquitoes have over the years kept evolving in response insecticides and their behaviour in resisting chemicals is becoming complex by each passing day.

1.2 Statement of the Problem

Gokwe South District has been rolling out LLINs since 2016 and the uptake has always been very high. Records indicate an uptake of above 85 %, unfortunately the district saw an upsurge in malaria cases lately. The district recorded an incidence of 2/1000 population in 2020 (DHIS STATS, 2021). From January to May 2020, the district recorded 426 malaria cases, an increase of 114 cases compared to the same period in 2019 (DHIS STATS, 2021). The causes of the upsurge in cases in the district is not known, whether it is the change in mosquito behaviour or it is the human behaviour leading to malaria transmission.

1.3 Broad objective

To morphologically identify female anopheles' mosquitoes and determining their biting times, indoor/outdoor biting preferences and human sleeping patterns.

1.4 Specific objectives

i. To conduct morphological identification of female Anopheles mosquitoes in every CDC collected lot in the Nemangwe wards 12 and 13 in 2021

ii. To determine the preference of host feeding habits for all captured blood fed mosquitoes in the CDC collected lots in the year 2021.

iii. To identify the specific biting preferences of the female mosquitoes as to whether indoor/ outdoor biting against each period of collection.

iv. To determine the biting times of the female anopheles mosquitoes in the selected 2 wards of Gokwe district in 2021.

v. To determine human sleeping patterns in relation to social and economic activities and residual malaria transmission the year 2021

1.5 Research questions

i. What are the female Anopheles types of mosquitoes that are found in the 2 wards of Gokwe South District in the year 2021?

ii. What are the mosquitoes' host feeding preferences in Gokwe South's wards 12 and 13?

iii. What are the preferable biting places of the identified female anopheles mosquitoes in the selected wards 12 and 13 of Gokwe South District?

iv. What are the biting times for the identified vector mosquitoes in Gokwe South district in the selected wards 12 and 13?

v. What are the human sleeping patterns in relation to socioeconomic activities and residual malaria?

1.6 Justification of the study

The purpose of the project was to carry out a fact-finding mission in order to have an informed decision on how vector mosquito behaviour can contribute to malaria incidence thereby informing vector control programmers on the best possible control system to be put in place, whether the control system needs to be complemented with other novel tools and at what point to introduce these in the control system. The research project is important in promoting entomological surveillance for the Ministry of Health and Child Care.

The significance of the study was to come up with a tracking and evaluation system to vector control methods in Midlands province which future activities would be evidence based, as a result of the research outcomes. This research was a potential eye opener on issues related to entomological surveillance in Zimbabwe, it can also be used to compare and contrast the outcome from other previous similar researches and it can as well be taken as a basis for further researches in the field of vector bionomics. Mosquito behaviour data can be used as initial data in developing effective and well-targeted control strategies.

1.7 Delimitations

The research project was contacted in Gokwe South wards 12 and 13. Only people who were residing in the two wards were eligible participants. The research was only focusing on factors which predispose them to mosquito bites such as the sleeping patterns as well as the biting patterns of the mosquitoes.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Despite a strong decrease in incidence and mortality in the last decade, malaria continues to be a largest contributor to the burden of disease and premature death in many parts of sub-Saharan Africa (Barja et al., 2016) (Malaria & Project, 2010) . The purpose of this section is to review and document literature on female anopheles mosquito species, their biting times and biting preferences. Also the socio economic activities that influence certain sleeping patterns that in turn expose the people to the malaria vector (Masendu, Sharp, Appleton, Chandiwana, & Chitono, 1997). Malaria is one of the leading causes of illness and deaths globally, (Maliti et al., 2016) and the female Anopheles mosquito has been implicated as the vector contributing to its spread. There have been interventions that have been put in place in countries where it is endemic to put this disease under control (Erlank et al., 2018).

Bionomics is a term used to cover the ecology of a mosquito species (e.g. larval habitats) and its behaviour (host biting preferences) (Massey et al., 2016). Anopheles vector species exhibit distinct bionomics, which are required for selecting appropriate vector control strategies (Massey et al., 2016). Hence this literature review will look at studies from different scholars on morphological identification of female mosquitoes, feeding preferences of mosquitoes, biting times and their biting preferences. Residual malaria transmission (also referred to as persistent orb ongoing transmission) after high coverage has been achieved with core interventions such as long-lasting insecticidal nets (LLINs) presents a challenge to malaria control and elimination efforts (Sherrard-Smith et al., 2019) .

2.2 Conceptual framework

The theoretical framework that was adopted for the study was one for malaria transmission adapted from Duchemin and Beier (2003).

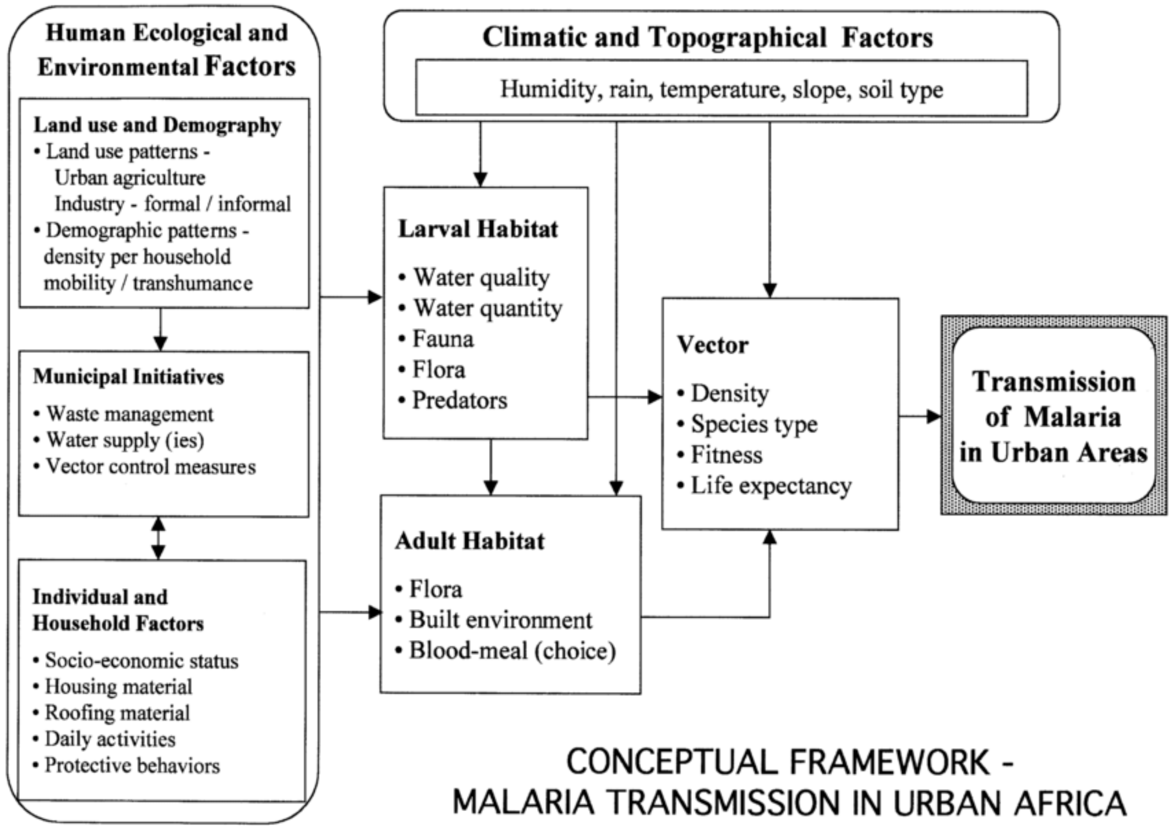

Figure 2.1: The Theoretic Framework-Malaria Transmission

2.2 Methods Used and the relevance of the conceptual framework

Methods used included peer reviewed electronic research databases such as BMC, PubMed, PlosOne among others. Further search or grey or not listed information such as docs, abstracts, reports, were obtained from freely accessible search engines like Google. The conceptual framework fits in with this study because it captures the keys issues involved in the continued spread of malaria even in the presence of interventions, such as IRs and LLINs.

2.3 Morphological identification of vector mosquitoes

Morphology is a branch of biology that deal with shape and structure of organisms, including vector mosquitoes. Image-based automatic classification of vector mosquitoes has been investigated for its practical applications such as early detection of potential mosquito-borne diseases (Junyoung P. et al., 2020). They however went on to indicate that the classification accuracy of previous approaches has never been close to human experts' and often images of mosquitoes with certain postures and body parts, such as flatbed wings, are required to achieve good classification performance.

Wilke et.al (2016) point out that morphological taxonomic keys are the most reliable way of identifying mosquitoes by studying 12 mosquitoes under the three species namely Aedes, Anopheles and Culex. From the results, these species were correctly distinguished by their wing shape (Wilke et al., 2016). The dichotomous keys developed Gilles and Cortzee(1987) distiquished different mosquito species through using different organs on the mosquito body. Some of the organs used for differentiation included the head, banding of the proboscis, banding of the legs, leg speculations, number and position of veins on wing and the stomach appearance as well.

Lorenz et.al (2012) argued that morphology is the gold standard that is used to identify mosquito species. However, they noted that the process of identifying mosquito species is challenging as expertise is required to properly handle the specimen. Lorenz et.al (2012) collected and analysed 128 adult mosquito specimens belonging to 45 species. Wing geometric morphometrics were used to properly identify the species as done by Wilke et.al (2016). Lorenz et.al (2012) used discriminant analysis to quantify wing shape variation. From the analysis it was revealed that the wings of *An. homunculus* were narrower than those of *An. cruzii* and that *An. bellator* was different from both of the congeneric species (Lorenz et al., 2012). Meanwhile,Fanioudakis et al (2818) acquired a light amplitude variation of light recording cases from 6 mosquito specieces, and trained a deep learning model to achieve 96 % classification accuracy.

2.4 Importance of correct identification of malaria vectors

Considering that the genus *Anopheles* contains over 500 species globally, of which only a few are considered important species for malaria transmission Garros et al (2013). Erlank, Koekemoer and Coetzee (2018) emphasised that the morphological identification of species is crucial in order to target scarce resources for controlling the malaria vectors only. They went on to say that the correct identification of the vectors that cause malaria is vital in implementing a robust malaria control program. As Lorenz et.al (2012), Erlank, Koekemoer and Coetzee (2018) used morphological keys for identification of 150 mosquitoes belonging to 11 morphological species (Erlank et al., 2018). Species groups and species complexes are common within the genus *Anopheles* *(*Harbach, 2013) and this complicates vector control since not all species within a complex have similar behaviours or similar roles in malaria transmission (Wiebe et al 2017). In the *An. gambiae* complex, for example, species range from the non-vectors *Anopheles quadriannulatus* and *Anopheles amharicus* to minor vectors *Anopheles melas, Anopheles merus* and *Anopheles bwambae*, to the major vectors *An. gambiae, An. coluzzii* and *An. Arabiensis (*Wiebe et al 2017). However, they concluded that processing mosquitoes for molecular identification was expensive and scarce resources should be limited to those specimens that require them (Lorenz et al., 2012).

2.5 Feeding preferences of the vector mosquitoes

Extensive knowledge of the vector's biting behaviour is significant for better understanding and implementation of tailor-made control measures to reduce malaria transmission. From many studies that have been conducted it is quite apparent that anopheline species have unique biting time and preferred biting hosts and resting places (Sinka et al. 2010). Whilst endophagic species take their blood meal predominantly inside human dwellings, exophagic species feed mostly outdoors (Monroe, 2015). Similarly, with regard to resting behavior, endophilic species commonly prevail indoors while exophilic species rest mostly outdoors (Azizi et al., 2011).

Thomas et.al (2017) carried out a study to understand the feeding and resting preferences of *Anopheles stephensi. Plasmodium vivax* in the Indian city of Chennai. They carried out a yearlong survey on cattle sheds and human dwellings. From their study adult vector mosquitoes were found to feed on cattle and cattle sheds due to the availability of blood meal source. The study by Thomas et.al (2017) had its limitations as it was centred on human dwellings and cattle sheds and the latter was found to be preferred resting place of the local vector (Thomas et al., 2017).

In Zimbabwe, there has been slight efforts to assemble information on resting behaviour of malaria vectors, especially *An. funestus* species. Masendu (1996), perceived partial exophilic behaviour in *An. gambiae s.l.* in Gokwe and Binga Districts, Zimbabwe which is diametrically opposed to the findings of Dandalo (2007), who reported major exophilic tendencies in *An. gambiae s.l.* and *An. merus* in Gokwe South District, Zimbabwe.

Indoor residual spraying is likely to be effective only if the vector mosquito concerned is endophilic, because the mosquito needs to rest on the insecticide-treated surfaces for a sufficient time for it to pick a lethal dose (Pates and Curtis, 2005).

2.6 Resting preferences of Anopheles mosquitoes

Sande et.al (2016), affirmed in their study in Mutare that the endophilic *Anopheles* mosquitoes caught were most collected from the roofs/ceiling rather than the walls and other household goods. This is contrary to the notion generally held that mosquito species that rest indoors, generally prefer to rest in the dark, low areas of the walls and therefore application of residual insecticides on the walls alone would reduce survival rates of indoor resting species to greatly reduce the chance of malaria transmission (Pates and Curtis, 2005)._The observations made by Sande et. al (2016), brought to the fore the urgent need for NMCP to reintroduce the abandoned technique of using spray extension lances, to facilitate spraying of high roofs/ceiling and other high sprayable locations not usually reachable without extension lance tubes. The study has shown that apart from roofs and walls as resting locations indoors, a small proportion of the *An. funestus* mosquitoes have the affinities to rest on unsprayable surfaces such as furniture and other household equipment. This particular behaviour of resting on unsprayable surfaces by *Anopheles* mosquitoes is of prime importance for vector control, indicating that there might be slight persistent transmission of malaria in sprayed housed and even if high spray coverages have been achieved in an area Sande et.al (2016).

Another issue of brought to the light by Sande et.al (2016) was that *An. funestus* exhibited largely endophilic behaviour whereas 16% of the sample shown exophilic habits. It is this small propotion of 16% which worries much the NMCP. This behaviour is of practical importance because it makes this proportion of vector less vulnerable to IRS, consequently reducing effectiveness of IRS as a strategy to combat malaria transmission.

Knowledge on the trends by mosquitoes to exit sprayed or unsprayed structures is of considerable importance in determining mosquito movement from inside to outside and the degree of irritability as well as toxic effect on species populations leaving the treated houses (WHO, 1975). In Burma Valley and Zindi areas, where IRS is a major malaria intervention tool, a larger proportion of *An. funestus* populations was caught in exit traps fixed on recently pyrethroid-treated structures, suggesting a possible pyrethroid resistance by this malaria vector Sande et.al (2016). More so high proportion of gravid mosquito collected in exit window traps in both sprayed and unsprayed structures confirmed the naturally endophilic behaviour of *An. funestus* (Pates and Curtis, 2005).

2.7 Biting times for the vector mosquitoes

Exploring host-seeking behaviour, host preferences and presence of sporozoites in *Anopheles* mosquitoes is necessary for appreciating their probability as vectors of malaria. Sharp (1983) demonstrated that the biting behaviour of *Anopheles* mosquitoes can be markedly disrupted by changes in environmental factors during the night, especially rain and wind. Wind is known to have a direct effect on mosquito flight (Snow, 1980; Gillies and Wilkes, 1981).

Gutiérrez-López et.al (2019) carried out a study on the biting times for mosquitoes. They established that the biting rates depend on factors such as the mosquito species and host related characteristics such as ordor, heat and behaviour. The study by Gutiérrez-López et.al (2019) established that *Ochlerotatus caspius* had significantly higher biting rates than *Cx. pipiens* on jackdaws, but non-significant differences were found on house sparrows. Exposed bare skin positively correlated with body mass, and affected mosquito feeding success (Gutiérrez-López et al., 2019). However, the study failed to find a significant relationship between the biting rate of mosquitoes and bird body mass.

Kabbale et.al (2016) also studied on the biting times of malaria vectors in Uganda. The study area was divided into one intervention zone which had five villages, where bed nets had been used for more than five years. Kabbale et.al (2016) found that the biting by vectors occurred throughout the night, while peak infective bites occurred after 22:00 hours in both zones.

Mburu et.al (2019) conducted a study on biting patterns of malaria vectors of the lower Shire valley, southern Malawi, which was conducted in the dry and wet seasons. Mosquitoes were collected indoors and outdoors for 24 nights in six houses per night using the human landing catch and data was analyzed using Poisson log-linear models.The results indicated that during the dry season, the biting activity for *An. gambiaes.l* ranged from 18:00 h to 08:45 h) and was 21:00 h to 23:45 h during the wet season. On the contrary, the biting activity of *An. funestus s.l.* was highest during the late evening hours (21:00 h to 23:45 h) and 03:00 hours to 05:45 hours during the wet season (Mburu et al., 2019).

In Burma Valley and Zindi, *An. funestus* was found to be the major anopheline in the two areas and the species demonstrated chiefly indoor flight patterns and that the CDC light catches set near humans in the study demonstrated that the majority of the mosquitoes collected were unfed, suggesting that the mosquitoes were caught in the act of host-seeking Sande et al., (2016) Moreover, The CDC light catches in this study demonstrated that mosquitoes were more abundantly indoors (68%) than outdoors (32%), suggesting that the indoor nocturnal host-seeking tendencies of *An. funestus* and *An. gambiae s.l.* could be interrupted by the intra-domiciliary use of LLINs by the majority of residents of Burma Valley and Zindi areas. However, the relevance of outdoor host-seeking behaviour of mosquitoes to vector control might depend immensely on the coincidence between outdoor biting intensity and human outdoor activity (Kabbale et al., 2016).

2.8 Indoor and outdoor biting preferences of anopheles mosquitoes

Comparative historical indoor and outdoor biting profiles for malaria vector mosquitoes in Zimbabwe are lacking from published literature. However, the results of Sande et.al (2016) are consistent with other previous studies conducted in Uganda in which most *An. funestus* populations and *An. gambiae s.l.* fed indoors (Kabbale et al., 2016). Contrary to these findings, studies conducted in other areas showed outdoor host-seeking profiles in *An. arabiensis* from Nigeria (Oyewole *et al*., 2007), and *An. neivai* in Colombian Pacific, fed outdoors following exposure to insecticide pressure (Escovar *et al*., 2013).

The densities of *An. funestus* populations and *An. gambiae s.l.* were higher during the wet season than dry season which, in Zimbabwe, corresponds with the period of the year, usually February/March when vector density is generally at its peak following abundance of breeding sites, suitable temperatures and relative humidity (Masendu, Sharp, Appleton, Chandiwana, & Chitono, 1997). Little is known about the seasonal host-seeking behaviour of malaria vectors in Zimbabwe for comparative purposes. However, similar results have been reported in Nigeria for *An. Gambiae* but with *An.*

funestus having high dry seasonal biting tendencies (Oyewole *et al*., 2007). Sande et.al (2016) suggests that while it is important to conduct mass and continuous net distribution campaigns all year round, it is critical to intensify net hang-up campaigns in wet season, but this should not preclude this activity the rest of the year.

Acquaintance on the biting times of anopheline mosquitoes is crucial in determining whether peak biting period coincides with that part of the night after the inhabitants retired to bed. Sande et.al (2016) noted the first flight activity peak which occurred prior to midnight suggests the possibility_of continued malaria transmission despite net ownership and use as this was a period when probably a fairly small proportion of the rural population might still be out of bed. Most of the participants in the study would wake up in early morning. Time spent outdoors in the evenings and time of leaving the house in the mornings rather than living in a quality house alone (Tusting et al., 2015) , appeared to matter significantly in determining human infection risk (Msellemu et al., 2016)

2.9 Biting times of anopheles mosquitoes

Further, the second peak was observed towards dawn, a period which might put some people at risk of mosquito bites as they might be out of bed for early morning household chores. This suggests that the use of mosquito repellents would be effective to complement LLINs during the double peaks when some people would not be bed under LLINs. In contrast, in Masakadza area, Zimbabwe, Dandalo (2007) reported that biting of *An. gambiae* complex mosquitoes commenced at 19:00 hours and ceased at 05:00 hours with biting peaks at 22:00 hour

The nocturnal mosquito flight cycles commenced at 20:00 hours, with double peaks between 22:00 and 23:00 hours during the first six hours of the night, and between 02:00 and 04:00 hours for the second six hours. By 06:00 hours, flight activities would have almost completely ceased. As such, it is clear from the results of this study that consistent use of nets every night all year round, use of personal protective clothing and repellents during peak mosquito densities might suppress malaria transmission

The jeopardy of spread of mosquito-borne diseases to human populations depends greatly on the degree of human biting by vector mosquitoes, which is largely influenced by abundance, distribution, and host blood source preferences. In relation to the host blood meal sources, the degree of risk would depend largely on the anthropophilic or zoophilic profile of the vector mosquito. Sande et. al (2016) identified that more than 64% of the blood meals from *An. funestus* collected from Burma Valley and Zindi were obtained from human host, suggesting that this population of *An. funestus* is highly anthropophilic, and this tendency to feed on human blood increases vectorial capacity (Animut *et al*., 2013)

2.10 Impact of outdoor resting mosquitoes

In Burma Valley and Zindi areas Zimbabwe, malaria control strategies have greatly targeted intradomiciliary vector mosquitoes largely through the provision of LLINs with net ownership of about 100% apiece. This tool has been proven effective against epidemiologically important anopheline vectors targeting prominently indoor biting behaviour. However, where human biting occurs outdoors and/or before midnight and/or towards dawn when people are not protected by LLINs, indoor-based mosquito net intervention might not be sufficient to reduce malaria incidence to a point where it is no longer a public health problem.

Behavior variations in mosquitoes from indoor to outdoor biting presents a continual risk of malaria infection acquired from outdoor activities. Moshi et.al (2018) identified the range of socio-cultural and economic activities which were conducted outdoors and their associated risks for mosquito bites. In this study it was found that most of the religious, cultural and social community gatherings were conducted outdoors at night till dawn. Events like Holy Communion, weddings, Easter, Christmas, cultural male circumcision and girl initiation ceremonies as well as rituals to remember the dead were cited as chief overnight gatherings where there is minimal or no use of interventions to prevent bites (Moshi et.al, 2018).

2.11 Human sleeping patterns in relation to social and economic activities for malaria transmission

Monroe et al. Malar J (2019) articulated that there are social and economic activities that influence human sleeping patterns these include routine household chores and entertainment occurring in the evening hours before bed, routine livelihood activities that lasted throughout the night such as security and fishing, and large-scale socio-cultural events, such as weddings and funerals which lasted throughout the night. Circumstances that could temporarily disrupt usual sleeping patterns were also described including travel, illness, and house guests, as well as seasonal changes to sleeping patterns associated with farming practices and outdoor sleeping.

Chirebvu et.al (2014) contented that the type of houses resided by the occupants had a significant implication on malaria incidence as poorly constructed houses allows mosquitoes to find their way into the dwelling through open eaves even if the doors and windows have been closed. In the study it was evident that the occupants of traditional huts/houses with large eave gaps present in Tubu village played a role in allowing free movement in and out of the huts/houses and providing suitable shelter for mosquitoes that eventually attacked the bedroom occupants. Consequently, the occupants of traditional houses experienced malaria attack episodes more than those who used modern houses/huts with virtually no eave openings.

This is supported by other previous study which had shown that traditional grass thatched houses with open eaves and lacking ceilings provided more favorable resting places for mosquitoes and put the occupants at risk of contracting malaria than houses with closed eaves, iron corrugated/ asbestos covered roofs, and having ceilings (M. J. Kirby, C. Green, P. M. Milligan et al, 2008). These findings are of prime importance because it showed that the community was equally exposed to mosquito bites anytime of the night regardless of the size of eaves and therefore closing doors early in the evening did not provide any protection since mosquitoes could still freely enter the dwellings through the eaves as was evident from the *Anopheles* and Culicine mosquitoes caught resting indoors (Chirebvu et.al 2014).

Similarly, another study concurs with the findings of Tubu study confirming that most people who suffered from malaria lived in houses that were made of mud, had grass-thatched houses or houses with opened eaves. These types of house design or construction likely allow mosquitoes to fly in and bite and thus offer less protection compared to those made of cement blocks and iron roofing sheets with closed eves. The house characteristics have been shown to be a risk factor for incidence of malaria (Wanzirah et.al, 2015).

Another important issue which was brought to the fore was, outdoor human nocturnal behavior plays an important role in malaria transmission. The documented peak biting period coincided very well with the time that most of the individuals in Tubu village would be involved in late outdoor activities since the vector mosquito is also known to bite humans both outdoors and indoors (Chirebvu et.al 2014)

In two studies, Bradley et al. investigated the association between time spent outdoors and malaria infection on Bioko Island, Equatorial Guinea. In a 2012 publication, Bradley analysed data from an annual malaria indicator survey, which includes a question asking whether a child spent time outside between 10p.m. and 6a.m. Children aged two to fourteen were tested for Plasmodium falciparum using rapid diagnostic tests (RDT). Only 4% of children were reported to spend time outside during this time and no significant difference in prevalence was observed for children who spent time outside verses those who did not.

Mwesigwa et al., (2019) assessed incidence of P. falciparum infection using a cohort study in the Gambia. The study included a household survey that asked about outdoor sleeping among household members. The potential value of ITNs to significantly reduce malaria-related morbidity and mortality is well known (Eisele et al., 2009). However outdoor sleeping can affect the impact of ITNs.

Outdoor sleeping

Interviewees reported that outdoor sleeping is common throughout the dry season, which runs from approximately December to March in the study area. Participants mentioned heat as the most frequent reason for sleeping outdoors, explaining that during hot weather the outside air is cooler and fresher (Monroe, 2015). Observation confirmed that sleeping outside, primarily within the compound and often on the veranda, was common throughout the data collection period. A total of 42% of participants were observed sleeping outdoors at some point during the night. Participants noted that the veranda and similarly smooth, elevated surfaces inside the compound made comfortable sleeping spaces. Many brought mats or mattresses into the compound courtyard. In these locations, people could sleep safe from snakes and other dangerous animals that might be encountered on the ground outside the compound (Monroe, 2015). Less frequently, male participants slept outside the compound on log beds known in the Kambagu area as fioks

2.12 Sociocultural activities

In the early evening, household members of all ages participated in outdoor activities. During this time, 99% of study participants were observed to be outdoors at some point. Adults were returning from work in the fields and children coming home from school. Women and older girls were fetching water, gathering firewood, preparing the evening meal, and brewing alcohol, a local alcoholic beverage (Monroe, 2015). Sweeping the compound and doing laundry were also common. Men and older boys were driving animals into the compound and feeding them. Most activities took place in the courtyard or outside the compound. After completing chores, household members would eat dinner and bathe, activities that sometimes occurred indoors and sometimes outdoors, with variation both within and between households (HT Masendu et al., 1997).

Early evening was also an important time for socializing among family, friends and neighbours. Younger children played in the courtyard or outside the compound, singing, dancing, resting, and eating. They helped with chores and watched their mothers cook. Mothers carried infants on their backs while doing chores and socializing. Teens strolled around the village, meeting and talking with friends. Some junior high and high school students walked to and from night school. Classes took place indoors, but with windows open to let in fresh air.

Men gathered at outdoor bars and around local food stalls to watch football matches. Some people continued working: selling food and alcohol, sewing or working in small shops or kiosks. Most activities took place outside or in partially enclosed structures (Monroe, 2015). In addition to funerals, participants identified weddings and festivals as times when people might stay out late. Others noted illnesses or medical emergencies as reasons, whether travelling to a health facility or caring for someone who is ill.

Early morning (04.00-06.00 hours)

Household members began to rise as early as 04.00. Morning chores included fetching water and firewood, feeding animals, cooking and bathing(HT Masendu et al., 1997). Children under five generally woke up later, with some still sleeping at 06.00. Sixty-one per cent of adults and 39% of children under five were observed to be outside at some time during this period(Monroe, 2015).

Early night-time (20.00-23.00 hours)

As the night progressed, outdoor activity gradually decreased. Between 20.00 and 23.00, 85% of observation household members were observed to be outdoors at some point. Seventy-five per cent of children under five were outside (HT Masendu et al., 1997). Some household participants continued doing chores, eating dinner and socializing within the compound. Students returned from night school. Some continued to study, generally also in the courtyard. Some men remained at bars, and some men and women went out dancing (Monroe, 2015). On market days, some youths also stayed out socializing and dancing thus several observers documented hearing music from bars during these hours (HT Masendu et al., 1997).

2.13 Breeding preferences of the mosquito vectors

Okwa et.al (2018) studied the breeding preferences of mosquito vectors as they are a source of malaria. They investigated on the preferred oviposition and breeding water sites of mosquitoes. Okwa et.al (2018) collected 100 CL of water from five water samples Daily temperature and hydrogen ion concentration checks were also recorded (Okwa & Savage, 2018). The investigators found that the mosquitoes oviposited in the containers and were able to identify two mosquito genera which were *Anopheles and Culex*. Polluted water was found to have more *Culex* specie while the rain water had more *Anopheles* species (Okwa & Savage, 2018). They also found that the green colour did not have a significant colour cue for oviposition for both *Anopheles* and *Culex*. However, the study failed to observe *Aedes* mosquito because they prefer to lay eggs on damp soil which is flooded by water.

2.14 Outdoor malaria prevention

Complementary malaria control measures must be developed for times when people are active outdoors during vector biting hours in northern Ghana and elsewhere (Tchouassi et al., 2012). Consistent use of outdoor prevention methods could help address gaps in protection that occur where people spend some or all of the night outside (Killeen,GF & Moore, 2012). This might include insecticide-treated clothing or topical or spatial repellents(Killeen, 2014) . Repellents represent a potential complementary strategy to

ITN use and IRS, and could be helpful in reducing residual outdoor transmission(Solomon et al., 2019) .

Personal (topical) repellents have been shown to be effective at reducing malaria prevalence and have a high user acceptance rate in field tests in northern Ghana(Worrall et al., 2020) . However, topical repellents can be cost-prohibitive and difficult to find. They also require frequent application. Current use in sub-Saharan Africa is low. Large-scale use would require that repellents be available, affordable, safe for continuous daily use, and perceived to be effective (Monroe et al., 2015). Spatial repellents, designed to shield a space rather than an individual, could be useful at large-scale outdoor events by protecting a group of people without requiring individual application (Killeen et al., 2001). Combined with personal use of topical repellents, this community-level protection could produce the greatest overall impact. Although several promising technologies are currently undergoing efficacy testing, spatial repellents are not yet available for large-scale use (Okumu et al., 2010)[35,36]. Therefore, development and evaluation of outdoor prevention strategies should be prioritized in order to sustain and increase gains in malaria control (Azizi et al., 2011) .

In 2012, WHO recommended seasonal malaria chemoprevention (SMC) in the Sahel region for infants under 12 months and children under 59 months of age. SMC could serve as a complement to vector control for outdoor malaria prevention, but to date the WHO

recommendation covers only children under five and only during peak transmission season (Erlank et al., 2018).

2.15 Current malaria Control strategies

The control strategies for malaria include Insecticide Impregnated Mosquito nets and IRS. Furthermore the malaria control strategy include early and timely treatment of cases with atermisin based combination therapy (Eisele et al., 2009). Until recently the two main indicators recommended for the assessment of progress in malaria prevention with insecticide-treated nets (ITN) have been the "proportion of households owning at least one ITN" and the "proportion of children under five (or pregnant women) sleeping under an ITN the previous night" [1].

These indicators have been used to monitor progress in the early years [2] as well as following the scale-up of mass distributions of ITN around 2005 [3-6] and consistently found a considerable gap between ownership of at least one ITN at household level and actual use of ITN by children which has often been interpreted as a failure to convince people to use available nets and triggered calls for better behavioural change communication (BCC) programmes [2] and/or assistance in hanging the nets [7]. While undoubtedly there is need for BCC programmes to strengthen net use and strategies have been developed for these [8], it has been pointed out as early as 2009 by Eisele and colleagues that the most important determinant of use is ownership of enough ITN, and that BCC programmes should address the gap that remains once sufficient intra-household access to ITN has been achieved [3]. This was confirmed by Hetzel et al. in Papua Guinea who observed that 99.5% of household members not using a net did not have access to one within the household [6] and pointed to the need to better differentiate between a lack of ITN within the household and the behavioural failure to use a net that was available

2.15.1 Use Long Lasting Insecticide Treated Nets

A decline in malaria morbidity and mortality has been documented in sub-Saharan Africa
since 2000, where an estimated 90% of global malaria cases and deaths have occurred [1, (Solomon et al., 2019)2].The use of the long-lasting insecticidal nets (LLINs) and indoor residual spraying (IRS) are considered the two main vector control interventions that played a role in the reduction of the malaria burden. Studies from sub-Saharan Africa showed that the use of LLINs alone has reduced malaria incidence rates by 50% and malaria mortality rates by 55% in children under the age of 5 years (Eisele et al., 2010).

The distribution of LLINs through a community-level free mass distribution was expected
to increase the national levels of LLIN ownership and usage. Wide use of LLINs was shown to reduce incidence and provide significant protection in children against overall mortality, mortality attributed to malaria, clinical attacks of malaria and malaria infection.

The World Health Organization (WHO) recommends full coverage of populations at risk of malaria with effective vector control, which may be achieved through the use of long-lasting insecticidal nets (LLINs) and/or indoor residual spraying (IRS)(Eisele et al., 2009). After the mass distribution of LLINs, there was a marked decline in malaria incidences in the district as well as in the state and the malaria control programme exceeded the national target of 80% reduction in malaria morbidity and mortality within one and half years by the end of 2018(Pradhan & Meherda, 2019) . To maintain the impact of this vector control strategy, timely monitoring and evaluation of LLINs is considered most important which helped the malaria control programme for timely replacement of worn out nets(Yukich et al., 2013).

2.15.2 Indoor Residual Spraying

Evaluations of the early campaigns found that use of LLINs tended to lag behind ownership(Eisele et al., 2009) . Novel and more intensive sensitization activities are now being integrated in to mass campaigns such as house-to-house visits to ensure hang-up of campaign LLINs is completed and to encourage higher LLIN usage. It is recognized that inclusion of hang-up activities requires additional resources (both financial and human) and there is particular interest in the cost effectiveness of the 'hang-up' component of LLIN campaigns(Paintain et al., 2014). one factor that might help explain the persistence of malaria in northern Ghana is that ITNs and IRS primarily address endophagic (indoor-feeding) and endophilic (indoor-resting) vectors(Monroe et al., 2015)The presence of exophagic (outdoor-feeding) and exophilic (outdoor-resting) mosquitoes may limit their effectiveness(Monroe et al., 2015)

2.15.3 Mass Campaigns

During the past decades, numerous large-scale initiatives have been undertaken with the goal of reducing or eradicating the burden of malaria in the developing world. However, the ambitious goals set by these programmes for reducing the burden of malaria in the near future appear unlikely to be met [4]. Mortality from malaria is the major burden in under-five children. Most deaths occur at the community level, outside the health institution. Effective treatment exists, but it must be administered promptly and timely by trained personnel in order to be effective (Getahun et al., 2010). The expected behaviour is that once people own LLINs, they should use them (Wanzira et al., 2018). However, that is not the case in a lot of households (Dunn et al., 2011)[18].

This undermines efforts made by governments, local and international bodies to control malaria through LLINs distribution (Bannor et al., 2020). However, it was not apparent as to the extent that the mass campaigns contributed to these estimates because of a lack of definitive baseline, especially considering that there have always been other channels from which the community population receive LLINs including the routine antenatal clinics and private health care facilities (Wanzira et al., 2018) [7]. The LLIN mass campaign was successful in ensuring that at least eighty-five prevent of the population had access to an LLIN and over eighty percent of these slept under an LLIN the night before (Wanzira et al., 2018).

Health literacy acquired through appropriate health education provides the necessary action-stimulating impetus to engage in preventive health (Atulomah & Atulomah, 2012). It is noteworthy that education intervention had been observed by various studies as a valuable tool in malaria prevention and control (Protopopoff et al., 2007). It is now well established that health behaviour has links to health outcomes and these links in turn are dependent on factors associated with cognitive processes of reasoning and health literacy, quality of health care services, available health related information and decision-making process at the individual level (Atulolmah et al., 2014). Long-lasting insecticidal nets (LLINs) are one of two core vector control interventions recommended for universal coverage (UC) by the WHO (the other being indoor residual spraying) (WHO, 2015) .

Efforts to scale-up LLIN coverage have had dramatic results (Worrall et al., 2020). Inappropriate treatment seeking behaviour and self-treatment prior to visiting health facilities were the main causes of progressing of disease and death (Barja et al., 2016). The treatment seeking behaviour of people, especially following the onset of fever, a common symptom of malaria, is important for the effective case management and control of malaria (Barja et al., 2016).

2.16 Performance targets

Targeting pregnant women and children (Wanzira et al., 2018) . An integrated campaign which distributed both free LLINs on a large scale for the first time during a national campaign to provide measles vaccination, mebendazole, and vitamin A to children under five resulted in household ownership of at least one LLIN of 76.8% and LLIN use by pregnant women, children under 5, and all household members in the targeted districts at 68.5%, 80.8% and 59.9%, respectively (Paintain et al., 2014). Compared to these previous efforts, the stand-alone 2009 free universal mass distribution campaign increased LLIN ownership by >30% and LLIN use by >25% (see S1 Table).

Furthermore, using the pre-existing LLIN coverage estimate as a baseline, the campaign increased household ownership of at least two LLINs by 68% and increased household ownership of at least one LLIN per two people from 10.2%, immediately pre-campaign, to 58.6% post-campaign, representing more than a fivefold increase, moving towards the result-based management goal. The average number of LLINs owned per household was two overall, meeting the national strategy target; however, only 70.1% of households reported receiving two or more campaign LLINs during the 2009 distribution and it remains concerning that 13% of households were not reached at all, highlighting distribution weaknesses (Grabowsky et al., 2005).

Campaign supervisors reported distribution sites that ran out of nets or had to further ration nets during the campaign indicating that several sites did not have enough to provide two LLINs for every household in their communities. After the campaign, compiled data from the household registration process revealed that the registered population of the 19 districts was 116% of that projected from the adjusted census estimates that were used to plan and quantify nets needed for the campaign, which corroborates the theory that there were insufficient nets and could further explain why the campaign goal of two LLINs per household was not met.

Analysis using indicators measuring access to LLINs based on the recommended ratio of one LLIN for every two persons reveals the fixed “two nets per household” distribution approach during the campaign fell short of the result based management goal of one LLIN for every two persons (Solomon et al., 2019). The fixed distribution methodology of two LLINs per household, regardless of size, is likely to have led to inequitable distribution of nets given the variation in household size.

The mean household size in the survey was 4.1 with a wide range and 36% of households had more than four members sleeping in the household indicating that two LLINs would provide suboptimal coverage in this group. LLIN use was over 90% among households with a LLIN to person ratio of 1:3 (0.33), moreover, the average number of people reported sleeping under each LLIN was 2.6. Thus, in order to ensure all household members are adequately protected one LLIN for every two persons is needed (Randriamaherijaona et al., 2017).

2.17 Evaluation of effectiveness

The value which the mass campaigns for LLINs offers (in terms of increasing net ownership) corroborates findings from multi-country studies in different African countries, including Nigeria, Ghana and Uganda, where mass campaigns increased ownership of at least one ITN irrespective of a strategy (i.e., whether standalone or combined with ANCs) (Zegers de Beyl et al., 2016)[18]. Tis multi-country study further showed that delivery, distribution or allocation strategy was not associated with receipt of at least one ITN, and that mass campaign for universal coverage allocation, especially based on the sleeping space allocation were more effective in increasing the proportion of households with adequate ITN (Zegers de Beyl et al., 2016). The value of mass ITNs has been recognized previously in other studies in the African region (Teklehaimanot et al., 2007) . Pioneer studies conducted in Ghana and Zambia have also shown that integrating ITN distribution into measles vaccination campaign increased levels of ownership, equity at a low cost to the provider and consumer (Grabowsky et al., 2005) . In the study the ratio of ITN ownership in poorest household compared with least poor rose from 0.32 to 0.88, with the cost per child reducing from 0.89 to 0.57 (Grabowsky et al., 2005) . Mass campaigns are a vital intervention not only for malaria prevention but for other arthropod-borne diseases, such as filariasis and viral infections whose distribution overlaps with that of malaria as documented in the African sub-region including Zambia (Masaninga et al., 2014) . A recent study in Zambia demonstrated significant decline in lymphatic filariasis associated with nationwide scaleup of insecticide treated nets, attesting to the added (spin-of) value of the use of LLINs against other arthropod-borne diseases in the African region (Masaninga et al., 2014).

As national disease programmes continue to benefit from LLIN use, they should recognize the challenges and potential risks associated with the use of this intervention (Masaninga et al., 2014). One such challenge is the development of vector resistance to insecticides (pyrethroids), which has been documented in various countries including Zambia, with the potential to reverse the gains made through vector control (Chanda et al., 2016) . Unfortunately, options for insecticide in use for LLINs are limited. the developments of new formulations in combination with non-pyrethroid insecticides to mitigate the challenges in vector control are being explored as measures to address these challenges (Masaninga et al., 2014).

Unlike conventional insecticide-treated nets (ITNs), which loses the effectual insecticidal content after 1–2 washes and requires re-treatment after every 6–12 months, LLINs are designed to sustain the physical barrier for 3 years in household conditions and can retain the residual efficacy up to 20 washes (WHO, 2013) [3]. Physical integrity and survivorship are two important indicators determining the regularity of the mass distribution campaigns of LLINs. The poor physical condition of the net may offer little-to-no protection to the users and then survivorship data alone will, most likely, underestimate net loss (Sahu et al., 2020). The reduction did not show a sharp declining trend. This may be due to the impact of LLINs on malaria morbidity and mortality, which depends mainly on the usage of mosquito nets and their durability (survivorship, fabric integrity and bio-efficacy) (Sahu et al., 2020). Malaria control programmes implementing LLINs as primary vector control strategy are required to monitor the survival of nets, fabric integrity and insecticidal efficacy so as to ensure timely replacement of nets (Randriamaherijaona et al., 2017) . Understanding LLINs attrition rate gives an important insight into survival, usage practice and quality of LLINs in terms of fabric integrity (Sahu et al., 2020). Malaria transmission that can persist in the context of high levels of ITN or IRS coverage is known as residual transmission (Durnez & Coosemans, 2013). It represents a key challenge across a range of malaria-endemic countries (Monroe et al., 2015).

2.18 Research gap

From the above literature review research data on entomological surveillance has not been routinely provided especially as companying evidence to support current vector control programs in Gokwe South district. Furthermore, there has been no study focusing on the study of sleeping partners in Gokwe district in Zimbabwe. The residual malaria in Gokwe South district has never been studied in Zimbabwe. And there is no documentation to it. Thus, a research on the mosquitoes and human behaviour was necessary enable the researcher to come up with recommendations that can be used to control mosquitoes and ensure human protection to prevent the spread of malaria in Gokwe district, in particular.

CHAPTER 3

RESEARCH METHODOLOGY

3.0 Introduction

This chapter looks at the research methods, design, study setting and rationale for selection, study population, sample size and sampling procedure, data collection instruments, data collection procedure, plan for information dissemination and ethical considerations.

3.1 Research Design

The study design was a was correlational study in which data was record on exposures to mosquito bites and compared to the outcome variables of those who have had malaria in year 2020 were compared against those who did not. Statistical relationship on exposure and outcome was compared between the two groups. A positive correlation was retrospectively assessed on participants who had had malaria in 2010, their social and economic activities were compared to those who had not contracted malaria in the same year. A backward-looking correlational study was conducted to compare exposure to mosquito bites and suffering from malaria. Data on mosquito biting times, bitting preferences and human sleeping patterns was collected on the population at household levels and community level. Archived data on malaria cases was collected from the outpatient registers from Svisvi Clinic which is the clinic that serve both ward 12 and 13 while observation was conducted to collect data on mosquito biting behaviour. The cross-sectional survey was a snapshot of the population on how vector feeding preferences and biting times might affect their protective mechanisms at their disposal.

Furthermore, the human sleeping patterns, socio-economic activities associated with contracting malaria were assessed. Additionally, in order to determine the key drivers of residual malaria, multiple logistic analysis was carried. The research designs have an advantage that they give results quickly while at the same time, are very important in giving basis for undertaking longitudinal surveys.

3.2 Research Method

Both qualitative and quantitative research methods which are ways of collecting and analysing non-numerical and numerical data were used for this study. They were used to test relationships and generalise the results to the wider populations.

3.3 Study setting

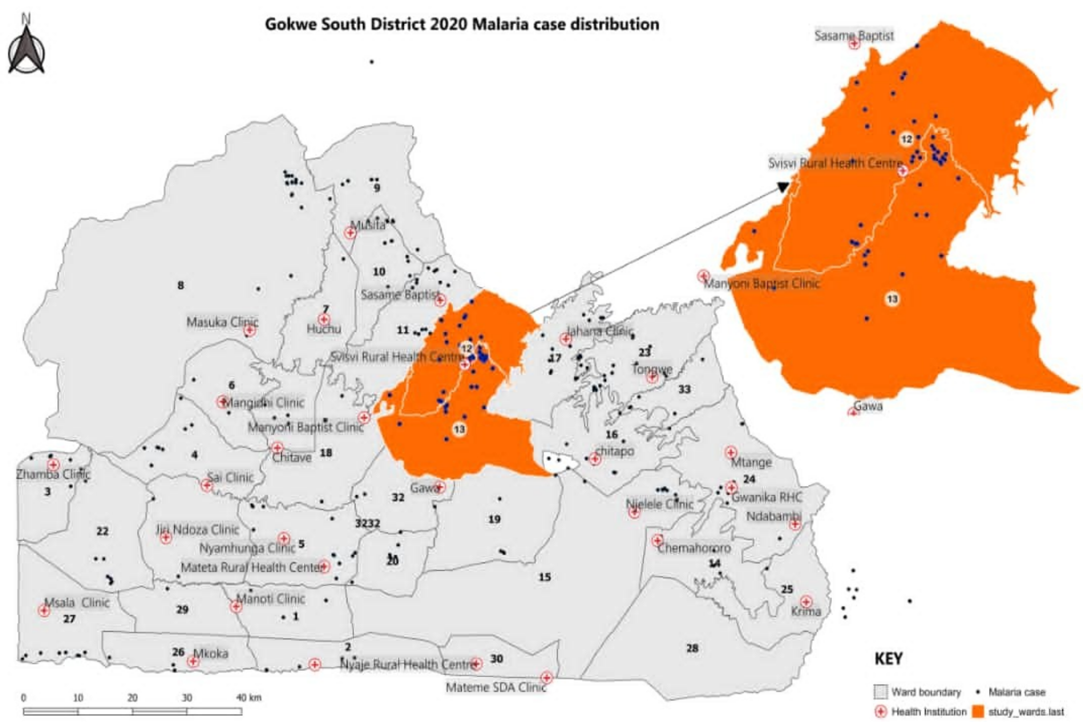

Figure 3.2 Study site

The study was done in Gokwe South District, Midlands Province and two rural wards (12 and 13) of the district constitute the study population. All the households in the 2 selected rural wards of Gokwe South district constituted the study sites.

3.4 Study population and sample size calculation

The study site consisted of 5048 households derived from the two wards. All the inhabitants of these household constituted the study population from which the sample was drawn. The households per sentinel were: ward 12 (2716) and ward 13(2332). Using sample size calculator, 84 households were selected out of the 5048 households at 95% confidence, 0.05 margin of error and 0.05 sample proportion.

$$Formular: n = N¿ \frac{Z^2 * P * (1-p)}{e^2} \diagup [N-1 \frac{+ Z^2 * p * (1-p)}{e^2}]$$

The sample households per each sentinel site were chosen proportionally. The sample households per sentinel were: ward 12 (43) and ward 13(41). From each household, one participant was selected randomly into the study.

3.5 Sampling procedure

The two wards were wards 12 and 13. Households were included basing on proportional representation and systematically sampled. Households in the two wards were separately allocated numbers and the researcher took 41 households in ward 12 which has a total of 2716 households where every 60th household was selected to reach a total of the selected 43. For ward 13 which had a total of 2332 household, every 55th household was selected to come up with the required 41 households in that ward. A Kish Grid method was used to select the interviewees within those households.

3.6 Data collection procedure

Morphological identification of female anopheles mosquitoes was done using identification keys developed by Gilles and Coetzee (1987) as well as on morphological characteristics using published keys according to the nomenclature of Wilkerson et al(Wilkerson et al., 2015).

Catchers were trained to collect landing mosquitoes through CDC light traps for both indoor and outdoor collection during dusk, night and dawn to determine indoor and outdoor biting preferences.

Indoor and outdoor human biting anopheles mosquitoes were collected every hour from 17:00 to 07:00 hours to determine biting times for both outdoor and indoor biting. The Kish grid was used to select members within a household to be interviewed. The Kish grid uses a pre-assigned table of random numbers to find a person to be interviewed on sleeping patterns within the selected household. Only members of the households who are 18 years and above were included for participation.

A questionnaire was administered to participants to determine the mosquito biting times and to corroborate the results of the CDC trap findings on the biting times. The questionnaire, also captured information on the malaria status i.e whether the participant suffered from malaria or not. Furthermore, the sleeping patterns in relation to socioeconomic factors associated with contracting malaria were collected using the questionnaire.

3.7 Ethical Considerations

Permission was sought from the Provincial Medical Director and Africa University Research Ethics Committee (AUREC). Written informed consent before participating in the study was sought from all participants. All matters of confidentiality were included in the informed consent forms which were completed by all the study participants. To personal identity data was sought captured or sought.

3.8 Inclusion criteria and exclusion criteria

All households with adults who were 18 years and above were included in the study while all households found locked during data collection were excluded. The selected participant was supposed to be a resident in the selected village. The study excluded children who were under the age of 18 for ethical reasons and furthermore most of them were not heads of the household. Both, those who suffered from malaria in 2021 and those who did not suffer from malaria were eligible to participate in the study. Visitors, non-consenting participants and people who are very sick were not be included in the study.

3.9 Data collection instruments

CDC light traps were used to collect mosquitoes for both outdoors and indoors. A structured closed-ended questionnaire was be used for collecting data. The questionnaire was prepared in English and was translated to Shona, the language that most of the residents in the area understands. The questionnaire included questions about the respondent's socio-demographic characteristics, sleeping patterns for both outdoor and indoor, household chores for both dawn and dusk times, LLINs use and their socio-economic activities during the various risk hour of the day.

4.0 Research participants

Total number of human participants enrolled for questionnaire on sleeping patterns were derived from 84 households selected for CDC light catches and the participants were residents of those selected 84 households in wards 12 and 13 in Gokwe South district.

4.1 Source of recruitment/ study site

The study site included households in Gokwe South District's wards 12 and 13.

4.2 Age range and sex

The study included people who were 18 years and above. Both males and females were included in the study.

4.2 Special/ Vulnerable population

The study included pregnant women if they were selected in the Kish grid selection at household level.

4.3 Payment

There was no payment given to any person who participated in this study.

4.4 Informed Consent Procedure

After being authorized to conduct the study in the district by the District Medical Officer, the researcher further sought authority to conduct the study from the village heads of the selected villages. The researcher then visited the selected households sought permission from the head of the household and then the participant. Participants were interviewed basing on the questions written on the pretested questionnaire while at the same time asking for permission to set CDC light traps at the same households where questionnaires were administered.

4.6 Potential Benefits of the research

Participants would benefit on knowledge on issues that would predispose them to malaria transmission and help them change their behaviour and attitudes. The shared knowledge would result in improvement in malaria prevention response through Social Behaviour Change Communication. This would enhance the health of the participants and the general public. Furthermore, after data collection, participants were educated on ways to prevent contracting malaria.

4.7 Potential risk

The research involved collecting mosquitoes hourly inside households using the CDC light traps during the night which might disturb their sleeping patterns. Some people would not feel comfortable for the researcher to enter into the house. To mitigate this, the researcher first sought consent from the head of the household and would only enter the house when allowed to do so.

4.8 Confidentiality/privacy

The information obtained from the study was only accessed by the investigator and records were kept confidential and all data will be coded to represent household names. The collected data was used strictly for the purpose of this study and was pass-word protected. Participants were given an individual identification number, so there was no personal identifiable information attached to the data.

4.9 Data analysis and presentation

Quantitative data was analyzed using Epi-info 7. Descriptive variables were presented using frequencies and proportions. Bivariate analysis was carried out to determine the odds ratios (ORs) for contracting malaria, while multiple logistic regression analysis was used to determine independent factors associated with residual malaria. For the bivariate analysis and multiple logistic regression analysis, the outcome variable was: having suffered from malaria and thus a case was defined as a participant selected into the study who contracted malaria in Gokwe South District in in the year 2021, while a control was a respondent who did not contract malaria in the same period. Data was presented in the form of tables and graphs.

CHAPTER 4 RESULTS

4.1 Introduction

This chapter presents the results of the study.

4.2 Demographic characteristics of participants, Gokwe South district

Females constituted 56% (47), while males constituted 44 % (37) of all the participants (Table 4.1, below). On level of education, 45.2 % (38) had reached secondary school, 40.5 % (38) had attained primary education, while 2.4 % (2) had reached tertiary education while 11.9% (10) had no education at all. In terms of employment, 10.7 % (9) were involved in buying and selling, 53.6 % (45) were involved in farming, one was involved in mining, 8.3% (7) were involved in peddling while 26.2 (22) were unemployed.

Table 4.1: Demographic characteristics of participants, Gokwe South

Characteristic	Variable	Frequency(n)	Percentage (%)
Sex	Female	47	56 .0
	Male	37	44 .0
Level of education	None	10	11 .9
	Primary	34	40 .5
	Secondary	38	45 .2
	Tertiary	2	2 .4
Employment	Buying and Selling	9	10 .7
	Farming	45	53 .6
	Mining	1	1 .2
	Peddling	7	8 .3
	Unemployed	22	26 .2

4.3 Morphological identification of female Anopheles mosquitoes

The mosquitoes were identified morphologically. All the mosquitoes identified were *the Anopheles gambiae sensu lato (s.l)* species and the example of *Anopheles gambiae sensu lato* (Figure 4.1, below).

Figure 4.3 : Anopheles mosquito caught in Gokwe south district: *An. gambiae s.l*

4.4 Preference of host feeding habits for all captured blood fed mosquitoes in the CDC collected lots

The preference for of host feeding for blood fed anopheles mosquitoes could not be assessed. Most of the mosquitoes captured were unfed due to the fact that most of the mosquitoes were captured before their blood meal. However, the pie chart below shows some of the feeding preferences that the community members indicated for the mosquitoes that usually attack them. Of all the participants, 41.7 indicated that the mosquitoes that bite them also bites cattle, while, 27.4 said they prefer to bite humans and 27.4 said they prefer to bite poultry, while only 3.6 % said they prefer to bite goats.

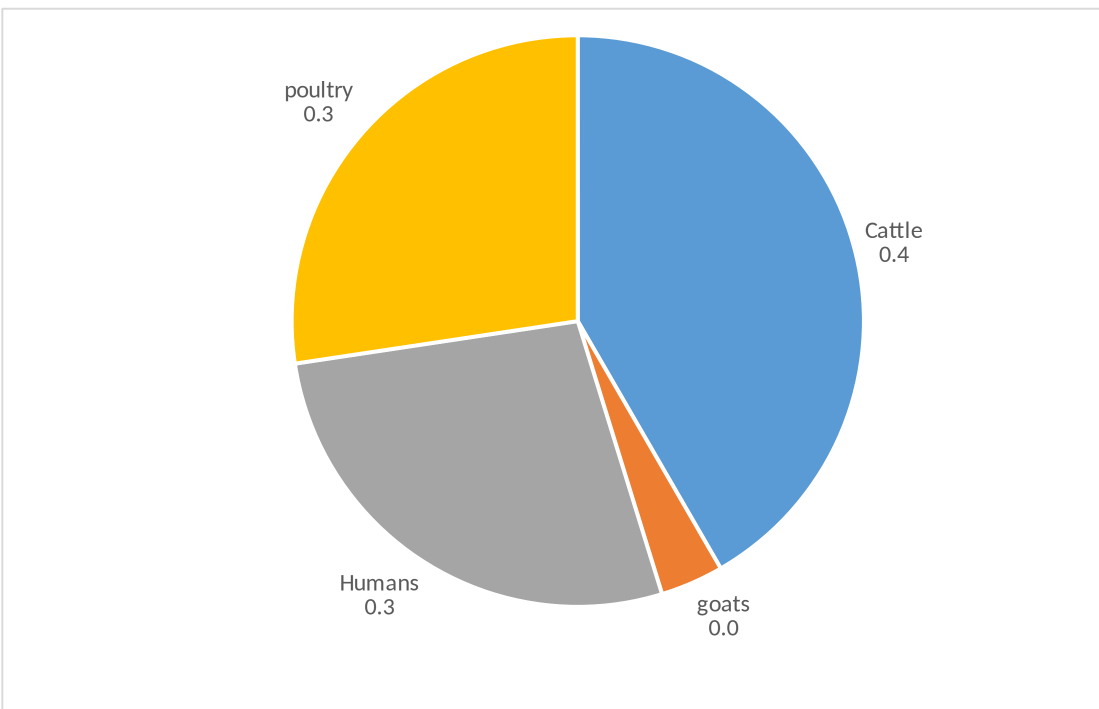

Figure 4.4: Mosquito feeding preferences as suggested by participants

4.5 Biting preferences of the female mosquitoes as to whether indoor/ outdoor biting against each period of collection.

The peak collection time outdoors for the *An. gambiae sensu lato* species was at 8-9 pm as well as at 4-5 am (Fig 4.1, below). From 5 to 7 pm there were no Anopheles mosquitoes caught both indoors and outdoors, as well from 12-2 am. The peak collection times for indoor was 9 to 10 pm, followed by 7 to 8 pm. There were no mosquitoes that were caught indoors between 11pm to 2 am.

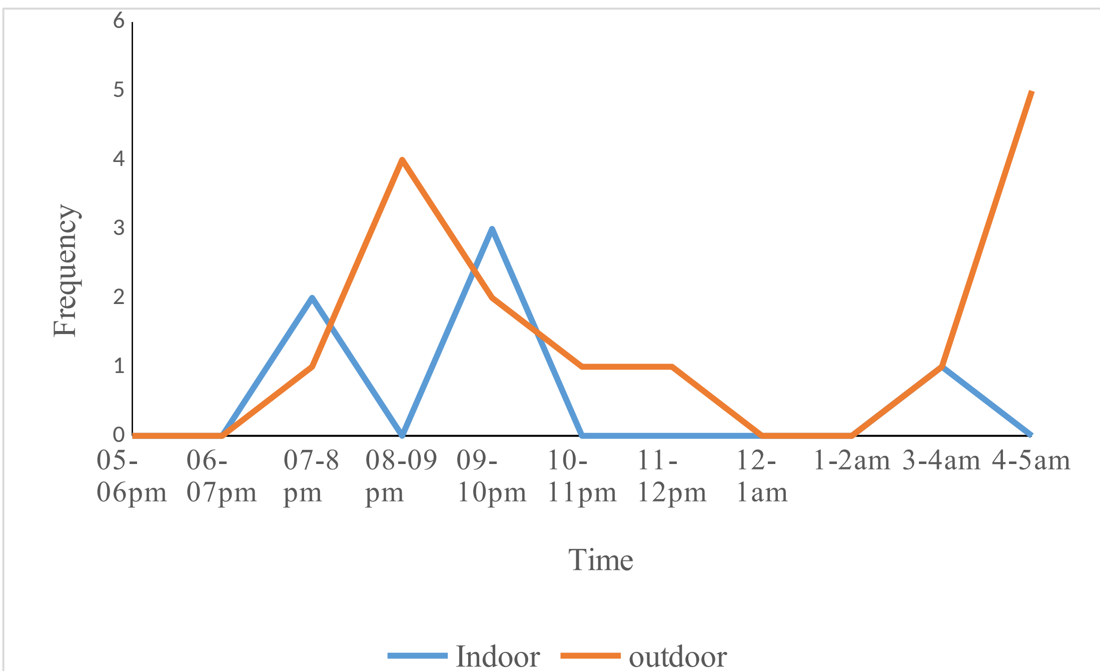

Figure 4.5 : Indoor/outdoor biting preferences of *Anopheles gambiae sensu lato,* Gokwe south District

4.6 Biting times of the female anopheles mosquitoes in the selected 2 wards of Gokwe district.

The biting times of the mosquitoes as indicated by the participants were found to be: night time 42.86% (36), followed by dusk at 39.3% (33) while the lowest number (3.6%) of mosquito bites were experienced during daytime *(Figure 4.2, below)*. Some bites were experienced early morning as indicated by 14.3% of the participants. Night time represented the largest number of mosquito bites experienced by the participants.

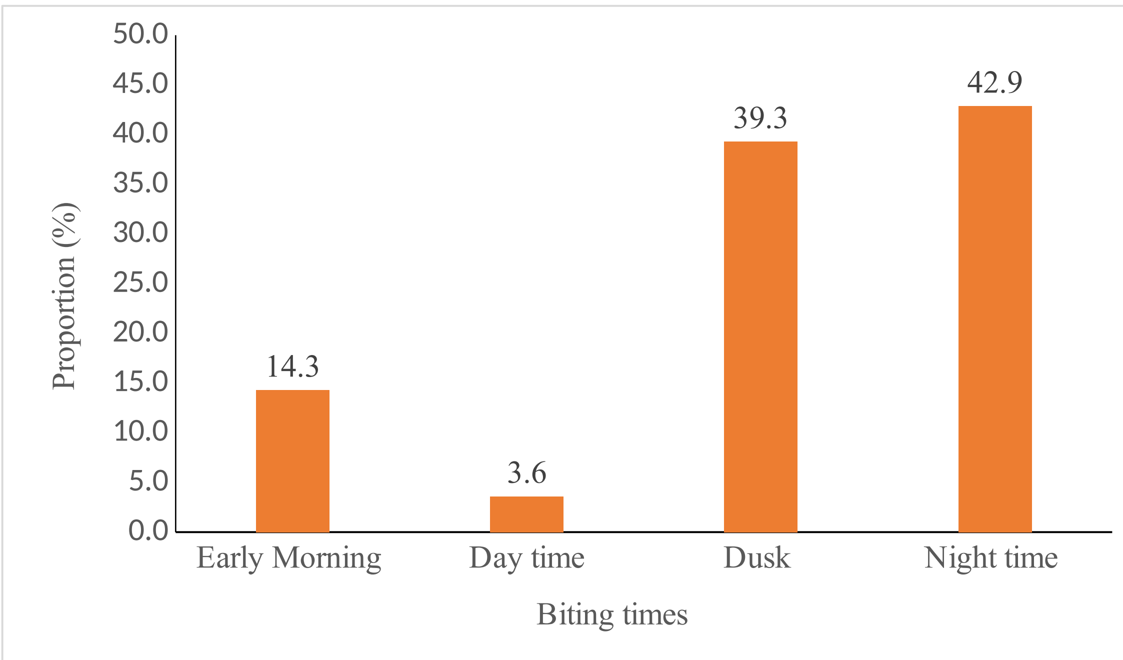

Figure 4.6 Biting times of the female anopheles mosquitoes in 2 selected wards of Gokwe south district

4.6 Human sleeping patterns in relation to social and economic activities and the risk of contracting malaria in Gokwe South District

The human sleeping patterns in relation to socio-economic activities are documented in table 4.4, below. Those who relaxed outdoors before sleep were more likely to contract malaria (OR 6.4; CI: 2.3-18.3) than those who did not, while those who bathed outside before sleep where 5.16 times more likely to contract malaria (OR:5.2; CI: 1.5-17.9), than those who did not. The odd of contracting malaria were higher among those who woke up in the morning to do some activity such as farming or going to work (OR 4.5; CI: 1.5-13.7) than those who did not while those who's sometimes slept outdoors (OR: 2.1; CI: 1.2-8.5), were 2.1 times more likely to develop malaria than those who do not. Farming late into the night (OR: 3.5; CI: 1.1-11.5) and going to church (OR: 2.3; CI: 0.9-5.9) were statistically significant risk factors for contracting malaria, while visiting a beer hall before sleep was not a statistically significant risk factor (OR: 2.6; CI: 1.1-6.6).

Table 4.4: Human sleeping patterns, social and economic activities as risk factors for contracting malaria in Gokwe South District

Factor		Case n=35(%)	Control n=49(%)	Total n=84(%)	OR	95C.I	p-value
Rests /Relaxes outdoors before sleep	Yes	29(82 .9)	21(42 .9)	50(59 .5)	6 .4	2 .3 -18 .3	<0 .010
	No	6(17 .1)	28(57 .1)	34(40 .5)			
Baths outdoors before sleep	Yes	11(31 .4)	4(8 .2)	15(17 .9)	5 .2	1 .5 -17 .9	<0 .010
	No	24(68 .6)	45(91 .8)	69(82 .1)			
Wakes up early to do some activity	Yes	30(85 .7)	28(57 .1)	58(69 .0)	4 .5	1 .5 -13 .6	<0 .010
	No	5(14 .2)	21(42 .9)	26(31 .0)			
Farming late into the night before sleep	Yes	10(28 .6)	5(10 .2)	14(16 .7)	3 .5	1 .0 -11 .5	0 .031
	No	25(71 .4)	44(89 .8)	70(83 .3)			
Going to church before sleep/ for an all night	Yes	17(48 .6)	13(26 .5)	29(34 .5)	2 .6	1 .1 -6 .6	0 .040
	No	18(51 .4)	36(73 .5)	55(65 .5)			

Sometimes sleeps out doors	Yes	27 (77 .1)	25(51 .0)	52(61 .9)	2 .1	1 .23 -8 .53	0 .010
	No	8 (22 .9)	24(49 .0)	32(38 .1)			
Visits the beer hall before sleep	Yes	10 (28 .6)	12(24 .5)	22(26 .2)	1 .2	0 .5 - 3 .3	0 .341
	No	25 (71 .4)	37(75 .5)	37(73 .8)			

4.7 Independent Factors Associated with Residual Malaria in Gokwe South District

Multiple logistic regression analysis was carried out to determine the key drivers of residual malaria in Gokwe South District. These are tabulated in table 4.5 below. The major drivers of residual malaria in Gokwe District were established as: resting/relaxing outdoors at night (aOR: 11.5; CI: 3.3-40.2), at times sleeping outdoors (aOR: 5.4; CI: 1.7-17.7) and bathing outdoors before sleep (aOR: 5.1; CI: 1.1-22.7)

Table 4.5 Independent Factors Associated with Residual Malaria in Gokwe South District

Independent factor	aOR	95% C. I	P-Value
Resting/relaxing outdoors at night	11 .5	3 .3-40 .2	<0 .010
Sometimes sleeping outdoors	5 .4	1 .7-17 .7	<0 .010
Bathing outdoors before sleep	5 .1	1 .1-22 .7	0 .030

*aOR: adjusted odds ratio

CHAPTER 5

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Discussion

5.1.1 Anopheles species In Gokwe South District

Most of the mosquitoes caught were the *Anopheles gambiae sensu lato(s.l.)* species. In Africa, the prominent malaria vector species include *An. Gambiae s.l species* (Maliti et al., 2016). The major anopheline malaria vectors across sub-Saharan Africa are *Anopheles funestus s.s*. and *Anopheles gambiae s.l* complex (Erlank et al., 2018). *An. gambiae s.l* is naturally endophilic (Pates & Curtis, 2005) most efficient anthropophilic vector species (Hamon, 1963). Most of the An. gambie species were picked outside the homesteads. *Anopheles gambiae s.l.* complex, mosquitoes are responsible for the transmission of malaria in the country(Mpofu, 1985). Presence of *An. arabiensis* mosquitoes was reported in the urban towns of Kwekwe, Chirundu, Kariba and Binga(H Masendu et al., 2005). In this study *An. arabiensis* was not found in Gokwe south district. No *An. funestus* were picked in this study but were reported mosquitoes in

Honde Valley (Choi et al., 2014). This may show the geographical limitation of *An. arabiensis* and *An. funestus.*

The resistance of *An. gambiae* mosquitoes to DDT in Gokwe has also been attributed to the high usage of organochlorines by villagers, as well as a long history of DDT usage in this area for agricultural (especially cotton farming) and public health purposes, mainly tsetse and mosquito control (Munhenga et al., 2008). Thus, this may explain the continued presence of *An. gambiae s.l.* and thus being the major driver of sustained malaria incidence in Gokwe south district.

5.1.2 Feeding Preferences of Anopheles mosquitoes in Gokwe South District

The anopheles mosquitoes were said to feed on humans and cattle and poultry. This agrees with other researches elsewhere (Clements, 1992; Chaves et al., 2010). Most mosquito species were found to share at least one host species (Chaves et al., 2010). Many mosquito species are anthropophilic, including the *An. Gambiae s.l* with respect to host preference and play an important role in the global transmission of the pathogens responsible for diseases such as malaria (Bashar et al., 2015).

The propensity of malaria vectors such as *An. Gambiae s.l.* to feed on humans rather than nonhuman hosts has important epidemiological consequences for malaria transmission (Zimmerman et al., 2006). The pattern of feeding is influenced by several factors, including the intrinsic host preference of the species, nutritional requirements, host availability, vector density, and social and cultural practices of the human population (Loyola et al., 1993).The human-biting habits and mean longevity are the most important epidemiological factors in malaria transmission by anopheles that can transmit human malaria parasites (Zimmerman et al., 2006).

Anopheles gambiae s.l. , is the major malaria vector that has been suggested to be highly anthropophilic (Killeen et al., 2001) and does have a strong preference for humans even when given other choices of blood hosts under controlled field settings. Elsewhere such as in areas of Burkina Faso *Anopheles gambiae*, uses cows as its primary blood source, because of the widespread use of bed nets, humans are not available as blood source (Lefèvre et al., 2009). These findings are consistent with the findings of this current study in that the participants reported that the mosquitoes feed on other animals such as cattle and poultry. The blood meal test could not yield any positive result. This could be because the mosquitoes were not yet fed after the catches. This is because the CDC light traps usually catch unfed mosquitoes.

5.1.3 Indoor and outdoor biting behaviour anopheles mosquitoes

Most of the mosquitoes were caught outdoors than indoors. A similar study elsewhere showed that the outdoor point had higher abundance than the indoor one (Ombugadu et al., 2020). Adult men and women were elsewhere reported to be awake before 6 am suggesting additional potential exposure in the early morning (Rodríguez-Rodríguez et al., 2021). Outdoor exposure in the early hours of the evening and in some settings early in the morning, highlight the need for complementary interventions offering outdoor protection (Thomsen et al., 2017). The considerable amount of time spent outdoors presents a window of potential exposure to malaria-carrying mosquitoes because LLINs primarily prevent indoor biting (Rodríguez-Rodríguez et al., 2021).

In this study the maximum activity of *An. Gambiae s.l* was recorded during the 8-9pm. *An. Gambiae (s.l.)* is highly endophagic (preference to feed indoors) and anthropophagic (preference for biting humans) (Maliti et al., 2016) and feeds predominantly between 9 pm–3 am (Maxwell et al., 1998). Feeding site may be exophagic and/or endophagic, depending on local circumstances (e.g., vegetation cover, type of house) and host availability (Abonuusum et al., 2011).

The fact that most of the mosquitoes were caught outdoors indicates that *An. gambie* has got some exophagic potential. This is further confirmed by the fact that some of the participants indicated that they were bitten by mosquitoes outdoors due to the anthropophilic nature of the mosquitoes (Moreno et al., 2017). Anopheles mosquitoes that bite or rest outdoors are not readily tackled by LLINs or IRS, and therefore can perpetuate residual disease transmission (Thomsen et al., 2017). This, together with poor LLINs usage explains the continued high incidence of malaria in Gokwe south district.

5.1.4 Biting times of Anopheles mosquitoes in Gokwe South District

Historically, human malaria infections in sub-Saharan Africa occur mainly during late hours of the night (Milali et al., 2017). In this study *An. gambiae s.l* was picked during the early hours of the night (8-9 pm) and early hours of the morning (4-5am). This period coincides with the peak biting behaviour of the primary malaria vector: *Anopheles gambiae sensu lato* (Milali et al., 2017).

Participants showed a huge activity in the early morning and early evening. This study also established that the participants were being bitten by mosquitoes outdoors. Within the *An. gambiae (s.l.)* there have been reports of shifts in their behaviours such as increased tendency to feed outdoors (Thomsen et al., 2017). This is corroborated by other studies elsewhere including in countries such as Tanzania (Gryseels et al., 2015). Early evening and morning outdoor exposure of humans to mosquito bites has epidemiological importance in terms of controlling transmission in this setting, and possibly across sub-Saharan Africa and beyond (Moiroux et al., 2012) where ITNs and/or indoor residual spraying (IRS) remain the only interventions (Milali et al., 2017).

5.1.5 Sleeping patterns of participants in Gokwe South District and independent factors for residual malaria

Most of the participants in this study were bitten by mosquitoes whilst having some outdoor activities. Documenting human activity at night is crucial to understanding human-vector interaction and its effect on malaria control (Monroe et al., 2015). *Matowo et al.* in southern Tanzania, described evening, night-time and early morning activities comparable to those observed in this study and described *An. Funestus* biting patterns (Matowo et al., 2013).To curtail residual malaria transmission, it is essential to identify malaria prevention strategies compatible with human behaviour (Monroe et al., 2015) social, cultural and livelihood activities on malaria control (Alaii et al., 2003). Outdoor activities may expose people to mosquito bites (Choi et al., 2014), even under conditions of full coverage, IRS and ITNs provide minimal protection when people are both outdoors and active during anopheles biting periods. In a study carried out in Ghana most of the entire population was outdoors and active during the early evening when biting began (Monroe et al., 2015). Studies done elsewhere in Ghana show that significant transmission can occur during the early evening hours (Abonuusum et al., 2011).

Most of the participants were active during the early hours of the morning. While biting rates are lowest during this time, a large percentage of the population is at risk (Monroe et al., 2015). Most of the participants indicated that they would be outdoors during the night. Some common large-scale events, such as funerals last the entire night (Monroe et al., 2015). The persistence of malaria in Gokwe south district could be due to the fact that ITNs and IRS primarily address endophagic (indoor-feeding) and endophilic (indoor- resting) vectors. The presence of exophagic (outdoor- feeding) and exophilic (outdoor-resting) mosquitoes may limit their effectiveness (Monroe, 2015), resulting in residual malaria despite interventions being in place in Gokwe South district.

In this study most of the participants had some numerous outdoor activities in the evening and at night. The most common reason for staying awake was found to be at church, having some all-night and being at beer halls. Other studies done elsewhere indicated that the most frequent motive for staying awake was funeral attendance (Monroe et al., 2015) , doing chores, eating dinner and socializing within the compound (Monroe et al., 2015). In this study the key drivers for the residual malaria were established as: sleeping outdoors, bathing outdoor before sleep and resting and relaxing outdoors. These outdoor activities could explain the persistence of the high malaria cases in Gokwe south district. Elsewhere studies have indicated similar findings (Milali et al., 2017; Monroe, 2015). The major reasons given in this study for staying out doors, resting/ relaxing, were that it would be too hot indoors and the need to attend some social functions. Due to the changing malaria epidemiology, outdoor transmission is becoming an important focus for malaria control strategies today (Gryseels et al., 2015).

Social patterns and human behavior may determine exposure to Anopheles mosquitoes and have an effect on transmission (Rodríguez-Rodríguez et al., 2021). Early evening was also an important time for socializing among family, friends and neighbors (Monroe et al., 2015). The findings of this study are in agreement those of others such as in India (Pandian & Chandrashekaran, 1980) in which socializing during the times of pick mosquito activity was responsible for residual transmission.

Most of the participants could not sleep under mosquito nets. While the potential of LLINs to reduce malaria morbidity is well known (Pryce et al., 2018) , inconsistent or low use limits their effectiveness and may lead to differential impact of this intervention in different sites (Rodriguez-Rodriguez et al., 2019) .

More recently, it has been reported that a substantial change in species composition of malaria vectors (Bayoh et al., 2010) and a shift in biting time (Azizi et al., 2011) is associated with the widespread use of ITNs across Africa (Milali et al., 2017). Elsewhere, consistent with the findings of this study, non-usage of ITNs was one of the major factors associated with an increased risk of malaria infection (Fana et al., 2015). Failure to use ITNs is associated with malaria prevalence and parasite density, and those who do not use ITNs regularly have a high occurrence of malaria infection with a high parasite density, as compared to those who use ITNs on a daily basis (Fana et al., 2015). Inconsistent use or use for only a fraction of the hours when malaria transmission occurs limits their effectiveness (Monroe et al., 2015).

Most the participants in this study indicated that they would wake up in the morning. Early evening and morning outdoor exposure of humans to mosquito bites has epidemiological importance in terms of controlling transmission in this setting, and possibly across sub-Saharan Africa and beyond (Moiroux et al., 2012) where ITNs and/or indoor residual spraying (IRS) remain the only interventions (Milali et al., 2017). High community compliance in ITN use, timely case diagnosis and treatment, and maintenance of the existing surveillance and response system will be critical to the goal of achieving and sustaining malaria elimination in the future (Chan et al., 2021).

5.2 Conclusion

It can be concluded that the most common mosquito species in Gokwe South is *An. Gambie sensu lato*. This mosquito is most incriminated in the spread of malaria. The mosquitoes are most active during the early hours of the night and the early hours of the morning. The increase in the number of people affected with malaria in Gokwe south district could be due to the socioeconomic activities they perform during the early hour of the night as well as during the early hours of the morning. Thus, sleeping patterns, as affected by socioeconomic activities could be causing sustenance of high malaria incidence in Gokwe south district. Controlling malaria with LLINs and IRS has certain fundamental limitations in regions such as Gokwe South district, characterized by early and outdoor biting, thus improving coverage of LLINs alone might not achieve malaria elimination. The peak biting activity by *An. Gambiae s.l* coincides with the times most people would be outside and not able use bed nets, calls for optimization of vector control and behavioural change strategies. Overall, malaria control measures are failing to effectively control and eliminate malaria in Gokwe South district due to the biting behaviour of the *An. gambie s.l.* coupled by the human behaviour related to the sleeping patterns which act as the major drivers of residual malaria in the district.

5.3 Recommendations

It is recommended that a number of interventions, implemented together, aiming for personal protection during evening and night activities are essential and should be implemented in Gokwe south district to reduce the continued occurrence of malaria in the district. Novel tools in malaria and mosquito control should be incorporated into the Integrated Vector Management system in Gokwe South district. There is need for an increase in the number of mosquito nets, to cater for outdoor use as well, for the control of mosquito bites in Gokwe south district coupled with behaviour change and communication. Thus, further education of the community members in Gokwe district has to be implemented. During the night the, residents of Gokwe should be advised to put on long covering clothes and use mosquito nets when sleeping outdoors at night. Furthermore, they should be advised to bath indoors when it is dark or to bath before it becomes dark. These interventions will help curtail the spread of malaria Gokwe South district by addressing the key drivers of residual malaria in the district. Regular education and training of community health workers in the education and training of the community members on prevention and control of mosquitoes and malaria should be done.

Promoting outdoor LLINs use may help, but community-based participatory research will be essential to assess feasibility and acceptability. Complementary methods to LLINs are needed to prevent outdoor biting in the evenings and the morning. New interventions should focus on disrupting malaria transmission beyond bedtime hours, specifically before and immediately after bedtime. Interventions such as insecticide-treated clothing, topical and spatial repellents are recommended.

From an epidemiological standpoint, it is crucial to be able to accurately identify mosquito blood-meals for studies of transmission dynamics of parasitic pathogens such as malaria. Further research is needed using other methods, such as pyrethrum spray catches, to determine the Human Blood Index (HBI), formerly known as the anthropophilic index or human blood ratio which determines the proportion of blood that has been taken from a human being, is recommended. This index will help in the determination of the vectoral capacity of *An. gambiae s.l.* in Gokwe district and allow a more focused control of this malaria vector.

Spatial repellents in Gokwe south district, designed to shield a space rather than an individual, could be useful at large-scale outdoor events by protecting a group of people without requiring individual application. Furthermore, these spatial repellents may be useful as well for use when on the fields as well as when they are at church.

REFERENCES

Abonuusum, A., Owusu-Daako, K., Tannich, E., May, J., Garms, R., & Kruppa, T. (2011). Malaria transmission in two rural communities in the forest zone of Ghana. *Parasitology Research*, *108*, 1465–71.

Alaii, J., Hawley, W., Kolczak, M., ter Kuile, F., Gimnig, J., & Vulule, J. (2003). Factors affecting use of permethrin-treated bed nets during a randomized controlled trial in western Kenya. *American Journal of Physiology J Trop Med Hyg.*, *68*, 137–41.

Atulomah, B. C., & Atulomah, N. O. (2012). Health literacy, perceived-information needs and preventive-health practices among individuals in a rural community of Ikenne Local Government Area, Nigeria. *Ozean J. Soc. Sci.*, *5*(3), 95–104.

Azizi, S., Drakeley, C., Kachur, S., & Killeen, G. (2011). Russell TL, Govella NJ, Increased proportions of outdoor feeding among residual malaria vector populations following increased use of insecticide-treated nets in rural Tanzania. *Malaria Journal*, *10*, 80.

Barja, M. R., Cano, J., Ncogo, P., Nseng, G., Morales, M. A. S., Valladares, B., Riloha, M., & Benito, A. (2016). Determinants of delay in malaria care - seeking behaviour for children 15 years and under in Bata district , Equatorial Guinea. *Malaria Journal*, 1–8. https://doi.org/10.1186/s12936-016-1239-0

Bashar, K., Khondoker, Z. R., & Razzak, M. (2015). Biting Rhythms of Selected Mosquito Species (Diptera : Culicidae) in Open Access Biting Rhythms of Selected Mosquito Species (Diptera : Culicidae) in Jahangirnagar University , Bangladesh. *Journal of Mosquito Research*, *5*(8), 1–5.

https://doi.org/10.5376/jmr.2015.05.0008

Bayoh, M., Mathias, D., Odiere, M., Mutuku, F., Kamau, L., & Gimnig, J. (2010). Anopheles gambiae: historical population decline associated with regional distribution of insecticide-treated bed nets in Western Nyanza Province, Kenya. *Malaria Journal*, *9*, 62.

Chan, C. W., Iata, H., Yaviong, J., Kalkoa, M., & Yamar, S. (2021). *SHORT REPORT Surveillance for malaria outbreak on malaria-eliminating islands in Tafea Province , Vanuatu after Tropical Cyclone Pam in 2015*. *2017*, 41–45. https://doi.org/10.1017/S0950268816002041

Chanda, E., Thomsen, E., Musapa, M., Kamuliwo, M., Brogdon, W., & Norris, D. (2016). An operational framework for insecticide resistance management planning. *Emerg Infect Dis.*, *22*, 773–9.

Chaves, L. F., Harrington, L. C., Keogh, C. L., Nguyen, A. M., & Kitron, U. D. (2010). Blood feeding patterns of mosquitoes : random or structured ? *Frontiers in Zoology*, *7*, 3.

Choi, K., Christian, R., Nardini, L., Wood, O., Agubuzo, E., & Muleba, M. (2014). Insecticide resistance and role in malaria transmission of Anopheles funestus populations from Zambia and Zimbabwe. *Parasites & Vectors*, *7*, 464.

Dunn, C., Le Mare, A., & Makungu, C. (2011). Malaria risk behaviours, socio-cultural practices and rural livelihoods in southern Tanzania: implications for bednet usage. *Soc Sci Med.*, *72*(3), 408–417.

Durnez, L., & Coosemans, M. (2013). Residual transmission of malaria: an old issue for new approaches. *Manguin Science InTechnology*, *3*, 1.

Eisele, T., Keating, J., Littrell, M., Larsen, D., & Macintyre, K. (2009). Assessment of insecticide-treated bednet use among children and pregnant women across 15 countries using standardized national surveys. *American Journal of Tropical Medicine and Hygiene*, *80*, 209–14.

Eisele, T., Larsen, D., & Steketee, R. (2010). Protective efficacy of interventions for preventing malaria mortality in children in Plasmodium falciparum endemic areas. *Int J Epidemiol.*, *39*(i88–i101), 5, 6.

Erlank, E., Koekemoer, L. L., & Coetzee, M. (2018). The importance of morphological identification of African anopheline mosquitoes (Diptera : Culicidae) for malaria control programmes. *Malaria Journal*, 1–8. https://doi.org/10.1186/s12936-018-2189-5

Fana, S. A., Danladi, M., Bunza, A., Anka, S. A., & Imam, A. U. (2015). Prevalence and risk factors associated with malaria infection among pregnant women in a semi-urban community of north-western Nigeria. *Infectious Diseases of Poverty*, 4–8. https://doi.org/10.1186/s40249-015-0054-0

Getahun, A., Deribe, K., & Deribew, A. (2010). Determinants of delay in malaria treatment- seeking behaviour for under-five children in south-west Ethiopia : a case control study. *Malaria Journal*, *9*(1), 320. https://doi.org/10.1186/1475-2875-9-320

Grabowsky, M., Farrell, N., Hawley, W., Chimumbwa, J., Hoyer, S., & Wolkon, A. (2005). Integrating insecticide-treated bednets into a measles vaccination campaign achieves high, rapid and equitable coverage with direct and voucher-based methods. *Trop Med IntHealth*, *10*, 1151–60.

Gryseels, C., Durnez, L., Gerrets, R., Uk, S., Suon, S., Set, S., & Phoeuk, P. (2015). Re-imagining malaria : heterogeneity of human and mosquito behaviour in relation to residual malaria transmission in Cambodia. *Malaria Journal*, *14*(April), 165.

https://doi.org/10.1186/s12936-015-0689-0

Gutiérrez-López, R., Martínez-de la Puente, J., & Gangoso, L. et al. (2019). Effects of host sex, body mass and infection by avian Plasmodium on the biting rate of two mosquito species with different feeding preferences. *Parasites Vectors*, *12*, 87. https://doi.org/https://doi.org/10.1186/s13071-019-3342-x

Hamon, J. (1963). Les moustiques anthropophiles de la r´egion de Bobo Dioulasso (R ´epublique de Haute-Volta). Cycles d'agressivit´e et variations saisonni`eres. *Annual Society of Entomologiy France*, *132*, 85–144.

Kabbale, F., Akol, A., Kaddu, J., Matovu, E., & Onapa, A. (2016). Biting times of Plasmodium falciparum infected mosquitoes and transmission intensities following five years of insecticide-Treated bed nets use in Kamuli District, Uganda: Implications for malaria control. *International Journal of Mosquito Research*, *3*(4), 30–38.

Killeen,GF, & Moore, S. (2012). Target product profiles for protecting against outdoor malaria transmission. *Malaria Journal*, *11*, 17.

Killeen, G. (2014). Characterizing, controlling and eliminating residual malaria transmission. *Malaria Journal*, *13*, 330.

Killeen, G., McKenzie, F., Foy, B., Bøgh, C., & Beier, J. (2001). The availability of potential hosts as a determinant of feeding behaviours and malaria transmission by African mosquito populations. Transactions of the Royal. *Society of Tropical Medicine and Hygiene*, *95*, 469–476.

Lefèvre, T., Gouagna, L., Dabire, K., Elguero, E., Fontenille, D., Renaud, F., & Costantini , C, Thomas, F. (2009). Beyond nature and nurture: phenotypic plasticity in blood-feeding behavior of Anopheles gambiae s.s. when humans are not readily accessible. *American Journal of Tropical Medicine and Hygiene*, *81*, 1023–1029.

Lorenz, C., Marques, T. C., & Sallum, M. A. . (2012). Morphometrical diagnosis of the malaria vectors Anopheles cruzii, An. homunculus and An. bellator. *Parasites and Vectors*, *5*, 257. https://doi.org/https://doi.org/10.1186/1756-3305-5-257

Loyola, E. G. L., Gonzalez Cero´ n, M. H. Rodrı´guez J. I. Arredondo Jimenez, S., S, B., & Bown, D. N. (1993). Anopheles albimanus (Diptera: Culicidae) host selection patterns in three ecological areas of the coastal plains of Chiapas, southern Mexico. *Journal of Medical Entomology*, *30*(518), 523.

Malaria, P., & Project, C. (2010). *Mosquito Nets Distribution Report*. *November*.

Maliti, D. V., Marsden, C. D., Main, B. J., Govella, N. J., Yamasaki, Y., Collier, T. C., Kreppel, K., Chiu, J. C., Lanzaro, G. C., Ferguson, H. M., & Lee, Y. (2016). Investigating associations between biting time in the malaria vector Anopheles arabiensis Patton and single nucleotide polymorphisms in circadian clock genes : support for sub-structure among An . arabiensis in the Kilombero valley of Tanzania. *Parasites and Vectors*, *9*, 109. https://doi.org/10.1186/s13071-016-1394-8

Masaninga, F., Muleba, M., Masendu, H., Songolo, P., Mweene-Ndumba, I., & Mazaba-Liwewe, M. (2014). Distribution of yellow fever vectors in Northwestern and Western Provinces, Zambia. *Asian Pac J Trop Med.*, *7S1*, S88–92.

Masendu, H, Hunt, R., Koekemoer, L., Brooke, B., Govere, J., & Coetzee, M. (2005). Spatial and temporal distributions and insecticide susceptibility of malaria vectors in Zimbabwe. *African Entomology*, *13*, 25–34.

Masendu, HT, Sharp, B., Appleton, C., Chandiwana, S., & Chitono, C. (1997). Community perception of mosquitoes , malaria and its control in Binga and Gokwe

Districts , Zimbabwe. *The Central African Journal of Mediicine*, *43*(3), 71.

Massey, N., Garrod, G., Wiebe, A., Henry, A., Huang, Z., Moyes, C., & Sinka, M. (2016). A global bionomic database for the dominant vectors of human malaria. *Scientific Data 3*. https://doi.org/160014. https://doi.org/10.1038/sdata.2016.14

Matowo, N., Moore, J., Mapua, S., Madumla, E., Moshi, I., & Kaindoa, E. (2013). Using a new odour-baited device to explore options for luring and killing outdoor-biting malaria vectors: a report on design and field evaluation of the Mosquito Landing Box. *Parasites and Vectors*, *6*, 137.

Maxwell, C., Wakibara, J., Tho, S., & CF, C. (1998). Malaria-infective biting at different hours of the night. *Medical and Veterinary Entomology*, *12*, 325–7.

Mburu, M., Mzilahowa, T., Amoah, B., & Chifundo, D. (2019). Biting patterns of malaria vectors of the lower Shire valley, southern Malawi. *Acta Tropica*, *197*. https://doi.org/https://www.who.int/news-room/fact-sheets/detail/malaria

Milali, M. P., Lord, M. T. S., & Govella, N. J. (2017). Bites before and after bedtime can carry a high risk of human malaria infection. *Malaria Journal*, 1–10. https://doi.org/10.1186/s12936-017-1740-0

Moiroux, N., Gomez, M., Pennetier, C., Elanga, E., Djenontin, A., & F, C. (2012). Changes in Anopheles funestus biting behavior following universal coverage of long-lasting insecticidal nets in Benin. *Journal of Infectious Diseasies*, *206*, 1622–9.

Monroe, A. (2015). Outdoor-sleeping and other night-time activities in northern Ghana : implications for residual transmission and malaria prevention. *Malaria Journal*, *14*, 35. https://doi.org/10.1186/s12936-015-0543-4

Monroe, A., Asamoah, O., Lam, Y., Koenker, H., Psychas, P., Lynch, M., Ricotta, E., Hornston, S., Berman, A., & Harvey, S. A. (2015). Outdoor-sleeping and other night-time activities in northern Ghana: Implications for residual transmission and malaria prevention. *Malaria Journal*, *14*, 35. https://doi.org/10.1186/s12936-015-0543-4

Moreno, M., Saavedra, M. P., Bickersmith, S. A., Prussing, C., Michalski, A., Rios, C. T., Vinetz, J. M., & Conn, J. E. (2017). Intensive trapping of blood-fed Anopheles darlingi in Amazonian Peru reveals unexpectedly high proportions of avian blood-meals. *PLOS Neglected Tropical Diseases*, *11*(2), 1–19. https://doi.org/10.1371/journal.pntd.0005337

Mpofu, S. (1985). Seasonal vector density and disease incidence patterns of malaria in an area of Zimbabwe. *Tropical Medicine and Hygiene*, *79*, 169–75.

Msellemu, D., Namango, H., Mwakalinga, V., Ntamatungiro, A., Mlacha, Y., & Mtema, Z. (2016). The epidemiology of residual Plasmodium falciparum malaria transmission and infection burden in an African city with high coverage of multiple vector control measures. *Malaria Journal*, *15*, 288.

Munhenga, G., Masendu, H., Brooke, B., Hunt, R., & Koekemoer, L. (2008). Pyrethroid resistance in the major malaria vector Anopheles arabiensis from Gwave, a malaria-endemic area in Zimbabwe. *Malaria Journal*, *7*, 247.

Navia-Gine, W. G., Loaiza, J. R., & Miller, M. J. (2013). Mosquito-host interactions during and after an outbreak of equine viral encephalitis in eastern Panama. *PLoS ONE*, *8*(12). https://doi.org/10.1371/journal.pone.0081788

Okumu, F., Madumla, E., John, A., Lwetoijera, D., & Sumaye, R. (2010). Attracting, trapping and killing disease-transmitting mosquitoes using odor-baited stations - The Ifakara Odor_Baited Stations. *Parasit Vectors*, *3*, 1.

Okwa, O. O., & Savage, A. A. (2018). Oviposition and Breeding Water Sites Preferences of Mosquitoes within Ojo area, Lagos State, Nigeria. *Biomed J Sci&Tech Res*, 7(5)-BJSTR MS.ID.001565. DOI: 10.26717/ BJSTR.201.

Ombugadu, A., Ra, E., Sa, O., Si, I., Luka, J., Hl, N., Lj, A., Va, A., Em, M., Bo, E., Ks, D., Ho, A., Jo, A., Pe, E., Op, A., Mj, M., Gi, Y., Dd, P., Mp, L., … Ga, A. (2020). Feeding Behaviour of Mosquito Species in Mararraba-Akunza , Lafia Local Government Area , Nasarawa State , Nigeria. *Biomedical Journal of Science and Technology*, *25*(1), BJSTR. MS.ID.004133. https://doi.org/10.26717/BJSTR.2020.25.004133

Paintain, L. S., Awini, E., Addei, S., Kukula, V., Nikoi, C., Sarpong, D., Manyei, A. K., Yayemain, D., Rusamira, E., Agborson, J., Baffoe-wilmot, A., Bart-plange, C., Chatterjee, A., Gyapong, M., & Mangham-jefferies, L. (2014). Evaluation of a universal long-lasting insecticidal net (LLIN) distribution campaign in Ghana : cost effectiveness of distribution and hang-up activities. *Malaria Journal*, *13*, 71.

Pandian, R. S., & Chandrashekaran, M. K. (1980). Rhythms in the Biting Behaviour of a Mosquito Armigeres subalbatus. *Springer-Verlag*, *47*, 89–95.

Pates, H., & Curtis, C. (2005). Mosquito behavior and vector control. *Annual Review of Entomology*, *50*(February 2005), 53–70. https://doi.org/10.1146/annurev.ento.50.071803.130439

Pradhan, M., & Meherda, P. (2019). Malaria elimination drive in Odisha: hope for halting the transmission. *J Vector Borne Dis.*, *56*(1), 53.

Protopopoff, N., Van-Herp, M., Maes, P., Reid, T., Baza, D., & D'Alessandro, U. (2007). Vector control in a malaria epidemic occuring within a complex emergency sit_uation in Burundi: a case study. *Malar. J.*, *6*, 93–101.

Pryce, J., Richardson, M., & Lengeler, C. (2018). Insecticide-treated nets for preventing malaria. *Cochrane Database Syst Rev*, *11*, CD000363.

Randriamaherijaona, S., Raharinjatovo, J., & Boyer, S. (2017). Durability monitoring of long-lasting insecticidal (mosquito) nets (LLINs) in Madagascar: physical integrity and insecticidal activity. *Parasit Vectors.*, *10*, 564.

Rodríguez-Rodríguez, D., Katusele, M., Auwun, A., Marem, M., Robinson, L. J., Laman, M., Hetzel, M. W., & Pulford, J. (2021). Human Behavior, Livelihood, and Malaria Transmission in Two Sites of Papua New Guinea. *Journal of Infectious Diseases*, *223*(Suppl 2), S171–S186. https://doi.org/10.1093/infdis/jiaa402

Rodriguez-Rodriguez, D., Maraga, S., & Lorry, L. (2019). Repeated mosquito net distributions, improved treatment, and trends in malaria cases in sentinel health facilities in Papua New Guinea. *Malaria JournalJ*, *18*, 364.

Sahu, S. S., Keshaowar, A. V., Thankachy, S., & Panigrahi, D. K. (2020). Evaluation of bio - efficacy and durability of long - lasting insecticidal nets distributed by malaria elimination programme in Eastern India. *Malaria Journal*, 1–9. https://doi.org/10.1186/s12936-020-03260-2

Sherrard-Smith, E., Skarp, J., & Beale, A. (2019). Mosquito feeding behavior and how it influences residual malaria transmission across Africa. *National Academy of Science*, *116*, 15086–95.

Solomon, T. I., Loha, E., Deressa, W., Gari, T., Overgaard, H. J., & Lindtj, B. (2019). *Low use of long-lasting insecticidal nets for malaria prevention in south-central Ethiopia : A community-based cohort study*. 15–24.

Tchouassi, D., Quakyi, I., Addison, E., Bosompem, K., Wilson, M., Appawu, M., & Al. (2012). Characterization of malaria transmission by vector populations for improved interventions during the dry season in the Kpone-on-Sea area of coastal Ghana. *Parasit Vectors*, *5*, 212.

Teklehaimanot, A., Sachs, J., & Curtis, C. (2007). Malaria control needs mass distribution of insecticidal bednets. *Lancet*, *369*, 2143–6.

Thomas, S., Ravishankaran, S., & Justin, N. A. J. A. (2017). Resting and feeding preferences of Anopheles stephensi in an urban setting, perennial for malaria. *Malar J*, 16, 111 https:/. https://doi.org//doi.org/10.1186/s12936-017-1764-5

Thomsen, E., Koimbu, G., & Pulford, J. (2017). Mosquito behavior change after distribution of bednets results in decreased protection against malaria exposure. *Journal of Infectious Diseases*, *215*, 790–7.

Tusting, L., Ippolito, M., Willey, B., Kleinschmidt, I., Dorsey, G., & Gosling, R. (2015). The evidence for improving housing to reduce malaria: a systematic review and meta-analysis. *Malaria Journal*, *14*, 209.

Wanzira, H., Eganyu, T., Mulebeke, R., Bukenya, F., Echodu, D., & Adoke, Y. (2018). Long lasting insecticidal bed nets ownership , access and use in a high malaria transmission setting before and after a mass distribution campaign in Uganda. *PLoS ONE*, 1–14.

WHO. (2013). Guidelines for laboratory and feld testing of long-lasting insecti_cidal nets. *Geneva: World Health Organization*.

WHO. (2015). Global technical strategy for malaria 2016-2030. *World Health Organization*.

Wilke, A., Christe, R., Multini, L., Vidal, P., Wilk-da-Silva, R., & de Carvalho, G. (2016). Morphometric Wing Characters as a Tool for Mosquito Identification. *PLoS ONE*, *11*, 8. https://doi.org/e0161643. doi:10.1371/journal.pone.0161643)

Wilkerson, R., Linton, Y., Fonseca, D., Schultz, T., Price, D., & Strickman, D. (2015). Making mosquito taxonomy useful: a stable classification of tribe Aedini that balances utility with current knowledge of evolutionary relationships. *PLoS One*, *10*, e0133602.

Worrall, E., Were, V., Matope, A., Gama, E., Olewe, J., Mwambi, D., Desai, M., Kariuki, S., Buff, A. M., & Niessen, L. W. (2020). Coverage outcomes (effects), costs , cost- effectiveness , and equity of two combinations of long-lasting insecticidal net (LLIN) distribution channels in Kenya : a two-arm study under operational conditions. *BMC Public Health*, 1–16.

Yukich, J., Bennett, A., Keating, J., Yukich, R., Lynch, M., & Eisele, T. (2013). Planning long lasting insecticide treated net campaigns: should households' exist_ing nets be taken into account? *Parasit Vectors*, *6*, 174.

Zegers de Beyl, C., Koenker, H., Acosta, A., Onyefunafoa, E., Adegbe, E., & McCartney-Melstad, A. (2016). Multi-country comparison of delivery strategies for mass campaigns to achieve universal coverage with insecticide_treated nets: what works best? *Malar J.*, *15*, 58.

Zimmerman, R. H., Galardo, A. K. R., Lounibos, L. P., Arruda, M., & Wirtz, R. (2006). Bloodmeal hosts of Anopheles species (Diptera: Culicidae) in a malaria-endemic area of the Brazilian Amazon. *Journal of Medical Entomology*, *43*(5), 947–956. https://doi.org/10.1603/0022-2585(2006)43[947:BHOASD]2.0.CO;2

APPENDIX I: QUESTIONNAIRE

Questionnaire for social and economic activities

Questionnaire Number [ ]

Introduction

My name is Regis Mavhiya. I am a Public Health Officer (PHO) attached in Midlands province based in Gokwe South District. I am carrying out *an investigation into high malaria cases despite intervention in place – a case of Gokwe south district, Midlands province, Zimbabwe 2021*. Recommendations from this study will help reduce the spread of the disease and also ensure that effective measures are put in place. I would like to assure you that privacy and confidentiality will be strictly observed in this study.

In view of the above explanations, may I then proceed to ask you the questions on the said issue? Yes______No________

1. What is your age? ________
2. Sex: Male [ ] Female [ ]
3. Level of education None [ ] Primary [ ] Secondary [ ] Tertiary [ ]
4. Type of employment

   Farming [ ] Buying and Selling [ ] peddling [ ] Others *(specify)* ____________________
5. Did you suffer from Malaria this year? Yes [ ] No [ ]
6. If yes to the above,
   a. Was it severe? Yes [ ] No [ ]
   b. Did you receive immediate treatment (within 24 hours from the onset of symptoms? Yes [ ] No [ ]
   c. Were you hospitalised? Yes [ ] No [ ]
   d. Number of times you suffered from malaria once [ ] twice [ ] thrice [ ] more*(specify number)* _____________________
7. Do you think the mosquitoes that are biting you are the usual mosquitoes that have been here for some time? Yes [ ] No [ ]
8. From your own view, do you think the mosquitoes differ? Yes [ ] No [ ]

9. If yes to the above, why do you say so? ______________________________________

10. Do you think the mosquitoes bite animals as well? Yes [ ] No [ ]

11. If yes to the above, which animals do they bite? Cattle[ ] goats[ ] poultry[ ] others ________________

12. Which of the following places do you normally experience mosquito bites?

    At the water source [ ] at church [ ] at the beer hall [ ]

    resting outside [ ] in the bushes [ ] others__________________________

13. Where do you normally experience mosquito bites? Outdoors [ ] Indoors [ ]

14. What will you be doing when you get bitten by the mosquitoes? Farming [ ]

    Playing [ ] Resting [ ] Herding cattle [ ] Fetching water [ ] Bathing [ ]

    Church [ ]

15. Which part of the body do the most mosquito bites occur? ________________________

16. When outside, do you usually put on clothes that cover the whole body? Yes [ ]

    No [ ]

17. Which months of the year do you normally experience mosquito bites? All months? [ ] Specific months *(specify)* ______________

18. Which times do you normally experience mosquito bites

    Daytime [ ] Dusk [ ] Early Morning [ ] Night time [ ]

19. How many times do the mosquitoes bite you per day? _________________________

20. What is the peak mosquito biting time at night *(specify)* _________________________

21. What activities do you normally do in the evening?

    Farming [ ] Herding cattle [ ] Resting/ Relaxing outdoors [ ] Bathing out doors

    Going to church [ ] Going to beer hall [ ] Others ___________________

22. When doing the above activity, do you experience mosquito bites? Yes [ ] No [ ]

23. When sleeping, do you use insecticide treated nets? Yes [ ] No [ ]

24. If yes to the above, what is the frequency of use? Rarely [ ] Always [ ] Sometimes [ ]

25. Do you wake up early to go to work or do some activity when it is still dark?

    Yes [ ] No [ ]

26. What time do you usually sleep? _____________

27. What time do you usually wake up? ___________________________________

28. When asleep, what time do you usually experience most mosquito bites? ______________

29. What other activities that you do at night that expose you to mosquito bites? ______________________________________

APPENDIX II: AUREC APPROVAL LETER

Investing in Africa's future

AFRICA UNIVERSITY RESEARCH ETHICS COMMITTEE (AUREC)

P.O. Box 1320 Mutare, Zimbabwe, Off Nyanga Road, Old Mutare-Tel (+263-20) 60075/60026/61611 Fax: (+263 20) 61785 website: www.africau.edu

Ref: AU2211/21 4 October, 2021

Regis Mavhiya
C/O CHANS
Africa University
Box 1320
Mutare

RE: **AN INVESTIGATION INTO HIGH MALARIA CASES DESPITE INTERVENTION IN PLACE – A CASE OF GOKWE SOUTH DISTRICT, MIDLANDS PROVINCE, ZIMBABWE 2021**

Thank you for the above titled proposal that you submitted to the Africa University Research Ethics Committee for review. Please be advised that AUREC has reviewed and approved your application to conduct the above research.

The approval is based on the following.

a) Research proposal
b) Data collection instruments
c) Informed consent guide

- **APPROVAL NUMBER** AUREC AU2211/21
- This number should be used on all correspondences, consent forms, and appropriate documents.
- **AUREC MEETING DATE** NA
- **APPROVAL DATE** October 4, 2021
- **EXPIRATION DATE** October 4, 2022
- **TYPE OF MEETING** Expedited
  After the expiration date this research may only continue upon renewal. For purposes of renewal, a progress report on a standard AUREC form should be submitted a month before expiration date.
- **SERIOUS ADVERSE EVENTS** All serious problems having to do with subject safety must be reported to AUREC within 3 working days on standard AUREC form.
- **MODIFICATIONS** Prior AUREC approval is required before implementing any changes in the proposal (including changes in the consent documents)
- **TERMINATION OF STUDY** Upon termination of the study a report has to be submitted to AUREC.

AFRICA UNIVERSITY
RESEARCH ETHICS COMMITTEE (AUREC)
APPROVED
P.O. BOX 1320, MUTARE, ZIMBABWE

Yours Faithfully

Chinzou

MARY CHINZOU – A/AUREC ADMINISTRATORFOR CHAIRPERSON, AFRICA UNIVERSITY RESEARCH ETHICS COMMITTEE

APPENDIX III: DISTRICT APPROVAL LETTER

Telephone 0592321
Fax 0592265
All correspondences to be addressed to The District Medical Officer.

ZIMBABWE

Reference:
MINISTRY OF HEALTH AND
CHILD WELFARE
Gokwe South District Hospital
P O Box 55
Gokwe

18 February 2021

To Whom It May Concern

Re: **MAVHIYA REGIS (MPH STUDENT ATTACHEE)**

You are hereby granted the authority to conduct research in Gokwe South District on a topic titled "Study on morphological identification of vector mosquitoes and their bionomics".

Thank you

DISTRICT MEDICAL OFFICER
GOKWE SOUTH DISTRICT HOSPITAL
2021 -02- 18
BOX 55, GOKWE

Dr N Chiridza
DISTRICT MEDICAL OFFICER

APPENDIX IV: INFORMED CONSENT FORM (ENGLISH VERSION)

APPROVAL NUMBER AUREC AU2211/21

Evaluation of the Effectiveness of Malaria Interventions in Gokwe South District, Midlands province, Zimbabwe, 2021

My name is Regis Mavhiya. I am a post-graduate student studying towards Master of Public Health at Africa University, Zimbabwe. The aim of this study is to improve malaria control interventions in Gokwe South District. You were selected for the study because you are a resident of this area where there is a problem of Malaria.

Improvement in Malaria control interventions will subsequently result in reduced burden of malaria in the district. As one of the selected respondents, your views are of paramount importance and will go a long way in exploring the reasons for high malaria cases in the district and come up with ways to redress the problem.

Procedures and duration

If you agree to participate in this study, you will be given a questionnaire to answer. It is expected that the procedure will take about 15 - 20 minutes.

Risks and discomforts

Some participants may not feel comfortable in talking to strangers or to give confidential information for security reasons. The data collectors may also use one of your sleeping spaces to trap mosquitoes for the whole night. To mitigate this, the researcher will first seek consent from the head of the household and he will enter the house only if allowed.

Benefits and/or compensation

The study will help in improving net use in the area and this will subsequently lead to reduction in the burden of malaria in Gokwe South district.

Confidentiality

Any information obtained in this study will not be disclosed without the permission of the study participants. Names and any other identification will not be asked for in the questionnaires.

Voluntary participation

Participation in this study is voluntary. Your decision not to participate in this study will not affect your future relationship with the organization. You are free to withdraw your consent and there will be no penalty for that.

Authorisation

Please sign in the spaces provided below to indicate that you have read and understood the information provided above and have agreed to participate.

-- --------------------------------

Name of Research Participant (please print) Date

Signature of Research Participant or legally authorised representative

If you have any questions concerning this study or consent form beyond those answered by the researcher including questions about the research, your rights as a research participant, or if you feel that you have been treated unfairly and would like to talk to someone other than the researcher, please feel free to contact the Africa University Research Ethics Committee on telephone (020) 60075 or 60026 extension 1156 email aurec@africau.edu

APENDIX V: INFORMED CONSENT FORM (SHONA VERSION)

APPROVAL NUMBER AUREC AU2211/21

Bepa reMvumo patsvakurudzo yezvikonzero zvirikuita kuti tirambe tiine vanhu vanehudzamu varikurwara nechirwere CheMarariya nyangwe zvazvo tiinezvirongwa zvakawanda zvekudzivirira chirwere ichi munharaunda ino yeGokwe South mugore rino ra2021.

Zita rangu ndinonzi Regis Mavhiya. Ndirikuita zvidzidzo zveMaster of Public Health pa Africa University muno mu Zimbabwe. Chinangwa chetsvakurudzo ino ndechekuvandudza nokuona nzira dzatinadzo dzekudzivirira chirwere cheMarariya kana dzichirikushanda zvakaka uye kana panezvimwe zvingaitwe kuvandudza dziviriro yechirwere ichi. Imi masarudzwa kupinda mutsvakurudzo iyi nekuti muri mugari vemuno mu Gokwe South district munharaunda yeNemangwe mumawards maviri anoti 9 uye 10.

Kana zvigozhero zvikawanikwa panzira dzekudzivirira marariya kuchavandudzwa nziraidzi nedzimwe kuti dambudziko remalaria ridzikire muno mu Gokwe South district. Maonero enyu akakosha pakuti anobatsira kuburitsa pachena zvigozhero zvinoita kuti kudzivirirwa kwemarariya zvidzikire.

Maitirwo anenge achiitwa tsvakurudzo iyi

Muchapiwa gwaro rinenge rine mibvunzo yamuchapindura. Zvinogona kutora nguva ingakwana maminetsi gumi neshanu kusvika makumi maviri kupindura mibvunzo iyi. Shure kwaizvozvo, kwehusiku hwese. Hutunga huchabatwa usiku vabati vachitarisa hwavabata pese panopera hour rimwe nerimwe vachinyora pasi. Izvi zvinoitwa shure mekunge matendera kuti titsvage humbowo uhu.

Zvingangokanganisa nokusadekara

Zvinozivikana kuti vamwe vanhu vanogona kunzwa kusasununguka kupindirwa mumba, asi muongorori anongopinda mumba chete kana atenderwa nemuridzi vemba.

Zvinobatsira patsvakurudzo iyi

Hapana mubairo wamunopiwa pakupinda mutsvagurudzo ino asi mutsvakurudzo ichabatsira kuwana ruzivo maringe nenzira dzekubatsira kudzivirira chirwere chemalaria munharaunda ino yeGokwe South.

Kuchengetedzwa kwemhinduro

Zvichawanikwa patsvakurudzo iyi hazviudzwe mumwe munhu kunze kwekuti imi matendera. Patsvakurudzo iyi hapana pamuchabvunzwa zita renyu kana mimwe mibvunzo inoita kuti muzivikane.

Hapana kumanikidzwa

Hapana anomanikidzwa kupindura mibvunzo. Hapana mhosva yamunopiwa kana mukasapindura mibvunzo iyi. Saka hamumanikidzwe kupinda mutsvagurudzo ino uye makasununguka kubuda mutsvagurudzo ino paneipi zvayo nguva yamafunga kubuda uye amupihwe mhosva papfungwa dzenyu.

Kana mabvuma kupinda mutsvagurudzo

Isai zita renyu rizere uye kusaina pazasi apa semucherechedzo wekuti mabvuma.

---   --------------------------------

Zita   Zuva rechibvumirano

Siginecha yekubvuma

Kana muine mibvunzo maererano netsvakurudzo iyi kana chibvumirano ichi, munekodzero kana kuti muchinzwa kuti kodzero dzenyu dzatyorwa, sunungukai kufona kuAfrica University

Research Ethics Committee panhamba dzinoti (020) 60075 or 60026 extension 1156 email aurec@africau.edu