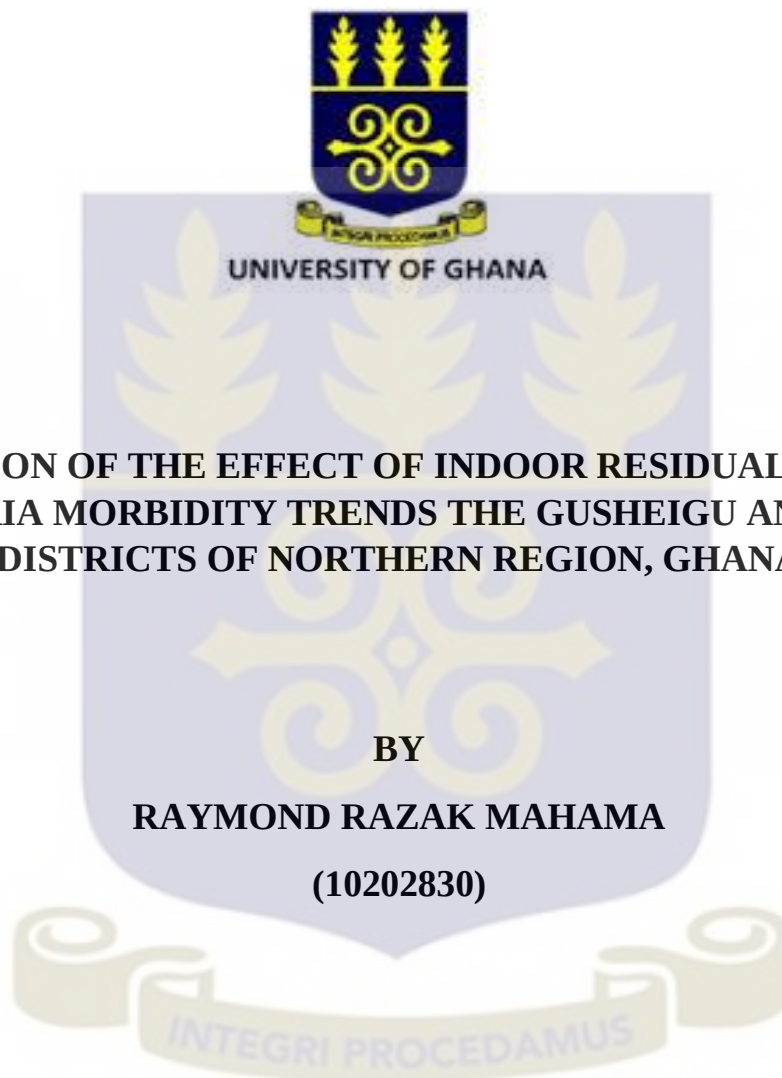


**SCHOOL OF PUBLIC HEALTH
COLLEGE OF HEALTH SCIENCES
UNIVERSITY OF GHANA**



**EVALUATION OF THE EFFECT OF INDOOR RESIDUAL SPRAYING
ON MALARIA MORBIDITY TRENDS THE GUSHEIGU AND KARAGA
DISTRICTS OF NORTHERN REGION, GHANA**

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**A THESIS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN
PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD
OF MASTER OF PHILOSOPHY IN APPLIED EPIDEMIOLOGY AND
DISEASE CONTROL DEGREE**

JULY, 2019

DECLARATION

I, RAYMOND RAZAK MAHAMA declare that this research is my original work. Portions of studies from other researchers used, have been duly referenced. This research has also not been presented elsewhere for the purpose of another degree.

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DEDICATION

I dedicate this research to my lovely wife, Nadia and children, Wunpini and Nasara for their love, sacrifice, prayers, support and encouragement.

ACKNOWLEDGEMENT

I am extremely grateful to the almighty Allah for the grace, guidance and strength granted me.

I would like to thank my supervisor, Dr. Adolphina Addo-Lartey and my co-supervisor, Dr. Priscillia Nortey for their valuable inputs throughout this project.

Also, my heartfelt gratitude goes to Prof. E. A. Afari and the entire family of the Ghana Field Epidemiology and Laboratory Training Programme (GFELTP) secretariat for their guidance.

A special thank you goes to the: National Malaria Control Program, Northern Regional Directorate of Health Services and Africa Indoor Residual Spraying group in Tamale, for providing me with malaria data and relevant support documents for this research.

Special acknowledgment goes to Mr. Hippolyte Kye-iiboh and Dr. Chrysantus Kubio for their immense contributions to the preparation of this write-up.

Lastly, I thank my family, friends and colleagues for their patience, continued encouragement and support.

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LIST OF ABBREVIATIONS

ACTs	Artemisinin Based Combination Therapies
AIRS	Africa Indoor Residual Spraying
DHS	Demographic and Health Survey
DHIMS-2	District Health Information Management System II
GHS	Ghana Health Service
IPTp	Intermittent Preventive Treatment in Pregnancy
IPTp-SP	Intermittent Preventive Treatment in pregnancy with Sulfadoxine-Pyrimethamine
IRS	Indoor Residual Spraying
ITNs	Insecticide Treated Mosquito Nets
ITS	Interrupted Time Series
LLINs	Long-Lasting Insecticidal Nets
NMCP	National Malaria Control Programme
OPD	Out Patient's Department
PMI	President's Malaria Initiative
RBM	Roll Back Malaria
SMC	Seasonal Malaria Chemoprevention
SP	Sulfadoxine-Pyrimethamine
TPR/ SPR	Test/Slide Positivity Rate
WHO	World Health Organization

ABSTRACT

Background

Malaria is endemic in Ghana with pronounced seasonal variations in the northern parts. Several efforts have been made to control malaria in Ghana including implementation of indoor residual spraying (IRS). This study assessed the effect of IRS reintroduction on malaria morbidity trends in the Karaga and Gusheigu districts in the midst of other interventions.

Method

A controlled Interrupted Time Series Analysis (itsa) design was used for the study. Routine data on monthly suspected and monthly confirmed cases of malaria were retrieved from the National Malaria Control Programme (NMCP). Data span a four year period (2015-2018). The outcome variable is test positivity rate (TPR), calculated as a percentage proportion of confirmed malaria cases out of the number tested in a month. The exposure variable is time (categorized into pre-implementation and post-implementation segments). Line graphs of TPR were plotted to show seasonal trends of malaria in the districts. Segmented regression was used to estimate the immediate and temporal changes in TPR following IRS implementation. Yendi and Tolon districts were used as controls. A change in TPR is considered significant if p-value is less than 0.05

Results

The study revealed that monthly TPR in the Gusheigu and Karaga districts followed seasonal patterns with peaks between July and October each year, and decreasing trends between November of a particular year and February of the ensuing year. Following the first and second rounds of IRS in the Gusheigu district, there appeared to be immediate decreases in TPR of 13.9% and 23.7% respectively. In the Karaga district, there was a reduction in TPR of 5.2% and 12.7% following the first and second cycles of spraying respectively.

Conclusion

There was an immediate decrease in malaria TPR following the first and second rounds of IRS in the Gusheigu and Karaga districts. The magnitude of decrement was greater in the second round of IRS than the first. Also, the decrease following the second cycle was sustained with an average of two percentage point reduction in monthly malaria TPR.

Recommendation

Based on the positive indications of IRS intervention revealed by this study, it is recommended that the NMCP and its partners sustain the intervention in these districts so as to maximize the benefits thereof.

CHAPTER ONE

INTRODUCTION

1.1 Background

Malaria continues to be the number one cause of morbidity in most endemic regions in the world. Similarly, malaria is one of the major causes of death primarily among children below five years in sub-Saharan Africa (WHO, 2018). Though preventable, malaria is habitually present in all parts of Ghana, with pronounced variations in incidence relative to seasons in the northern parts of the country. The 2016 annual report of National Malaria Control Programme's (NMCP) indicated that, 38.7% of OPD morbidity, 24.8% of all admissions and 7.0% of all age mortalities were attributed to malaria in 2016 (NMCP, 2016).

Ghana has made considerable efforts over the past two decades to fight malaria by adopting and implementing several malaria control interventions. These intervention include: distribution of long-lasting insecticidal nets (LLINs), Indoor Residual Spraying (IRS), accurate diagnosis and prompt treatment with artemisinin-based combination therapies (ACTs). The rest are: intermittent preventive treatment of pregnant women (IPTp) with sulfadoxine-pyrimethamine (SP) and Seasonal Malaria Chemoprevention (SMC)

Presently, the two most broadly applied malaria vector control interventions are the distribution of LLINs and mass application of IRS. These vector control interventions are key to achieving the global malaria control and elimination efforts. The malaria vector control interventions aim at reducing human contact with the malaria vector and these strategies are critical for controlling malaria transmission (WHO, 2015). Successful implementation of IRS has led to drastic decrease

or complete removal of malaria in various parts of Latin America, Asia, and Europe (Pluess, Tanser, & Sharp, 2010). Likewise, several reviews in Africa have also documented programmatic benefits of successful IRS implementation (Eckert et al., 2017; Edwin & Ernest, 2016; Mumbengegwi et al., 2018).

Indoor Residual Spraying is a process of applying long-lasting, residual insecticide to surfaces such as internal walls, eaves, and ceilings of all houses or structures (including domestic animal shelters). When mosquitoes rest on sprayed surfaces, they pickup lethal doses and eventually die. This intervention is most effective when the vector feeds indoor (endophagic) and rest indoor (endophilic) (WHO, 2015). IRS is more effective when high proportion of households are sprayed in an implementing area (usually >80%). The objectives of IRS are to reduce, and ultimately interrupt malaria transmission by reducing vector survivorship, vector density and eventually human-vector contact, in a manner that is safe for human health at the same time, not harmful to the environment (WHO, 2015). In 2013, an estimated 124 million people at risk of malaria worldwide (4% of the global population at risk) were protected with IRS intervention (WHO, 2015).

AngloGold Ashanti (a mining company) in 2006, was first in Ghana to implement IRS in Obuasi in the Ashanti Region as a measure to reduce the threats malaria posed to its operations. However, in 2007, Ghana benefited from the U.S President's Malaria Initiative (PMI) funding to extend IRS application to selected districts with high prevalence of malaria (>40% parasitemia prevalence) in the northern region. In 2008, five districts were sprayed (Gushegu, Karaga, Savelugu-Nanton, Tolon-Kumbungu, and West Mamprusi), however, East Mamprusi district was added to the

existing number for the 2009 spray season. Chereponi and Saboba districts were also added to the six implementing districts for the 2010 spray year. In 2011 and 2012, United States Presidents' Malaria Initiative (PMI) expanded IRS operations in the region from eight to nine districts (adding Bunkpurugu-Yunyoo district to the existing number). In 2013 and 2014, however, the number of districts selected to implement IRS were reduced to four (East Mamprusi, West Mamprusi, Savelugu-Nantong and Bunkpurugu-Yunyoo). In 2015 and 2016, IRS was implemented in five districts of the region (Bunkpurugu-Yunyoo, East Mamprusi, Kumbungu, Mamprugu-Moaduri, and West Mamprusi). In the 2017 and 2018 spray years, Karaga and Gushegu districts were again considered for spraying in addition to the districts sprayed in 2016.

1.2 Statement of Problem

Malaria continues to pose a great public health threat especially amongst pregnant women and children below five years, especially in poor tropical and subtropical regions of the world despite sustained efforts to control the disease. In 2017, an estimated 219 million cases of malaria occurred worldwide, causing about 438000 deaths (most of whom were children below fives), of which 92% of cases and 93% of deaths occurred in Africa. Ghana recorded about 5.58 million cases of malaria resulting in about 599 deaths in the same year (WHO, 2018).

Ghana has not relented in her efforts to fight malaria. Currently, the NMCP has a seven-year (2014-2020) strategic plan to reduce malaria morbidity and mortality by 75% with reference to 2012 as a baseline. Among its objectives is to cover at least 80% of the population at risk with several malaria control interventions including IRS. This concerted struggle has led to a decline in

incidence of malaria in Ghana. Total admissions attributable to malaria in Ghana, reduced from 51.8% in 2015 to 33.3% in 2017 (NMCP, 2017).

The Karaga and Gusheigu districts were among the maiden districts to implement IRS in the northern region in 2008, but the intervention was later withdrawn in 2013. However, in 2017 spray season, IRS was reintroduced in these districts as a result of increasing malaria cases. Implementation of IRS is thought to be more resource intensive than even distribution of ITNs (Raouf et al., 2017), hence there is the need to periodically evaluate the effectiveness of the intervention on the population level in order to optimize the malaria control efforts. This study assessed the effect of the reintroduction of IRS on malaria morbidity trends in the Karaga and Gusheigu districts in the midst of other malaria control interventions.

1.3 Justification

The availability of surveillance data on malaria morbidity offers us the opportunity to retrospectively evaluate the effectiveness of public health interventions implemented at the population level. Evaluating public health interventions is key to ensuring that the purposes of implementation are achieved. This is especially important in the case of the Karaga and Gusheigu districts where the intervention was withdrawn and subsequently reintroduced. Findings from this evaluation will enable the NMCP to assess the effectiveness of the IRS intervention while optimising the malaria control efforts.

1.4 Conceptual Framework

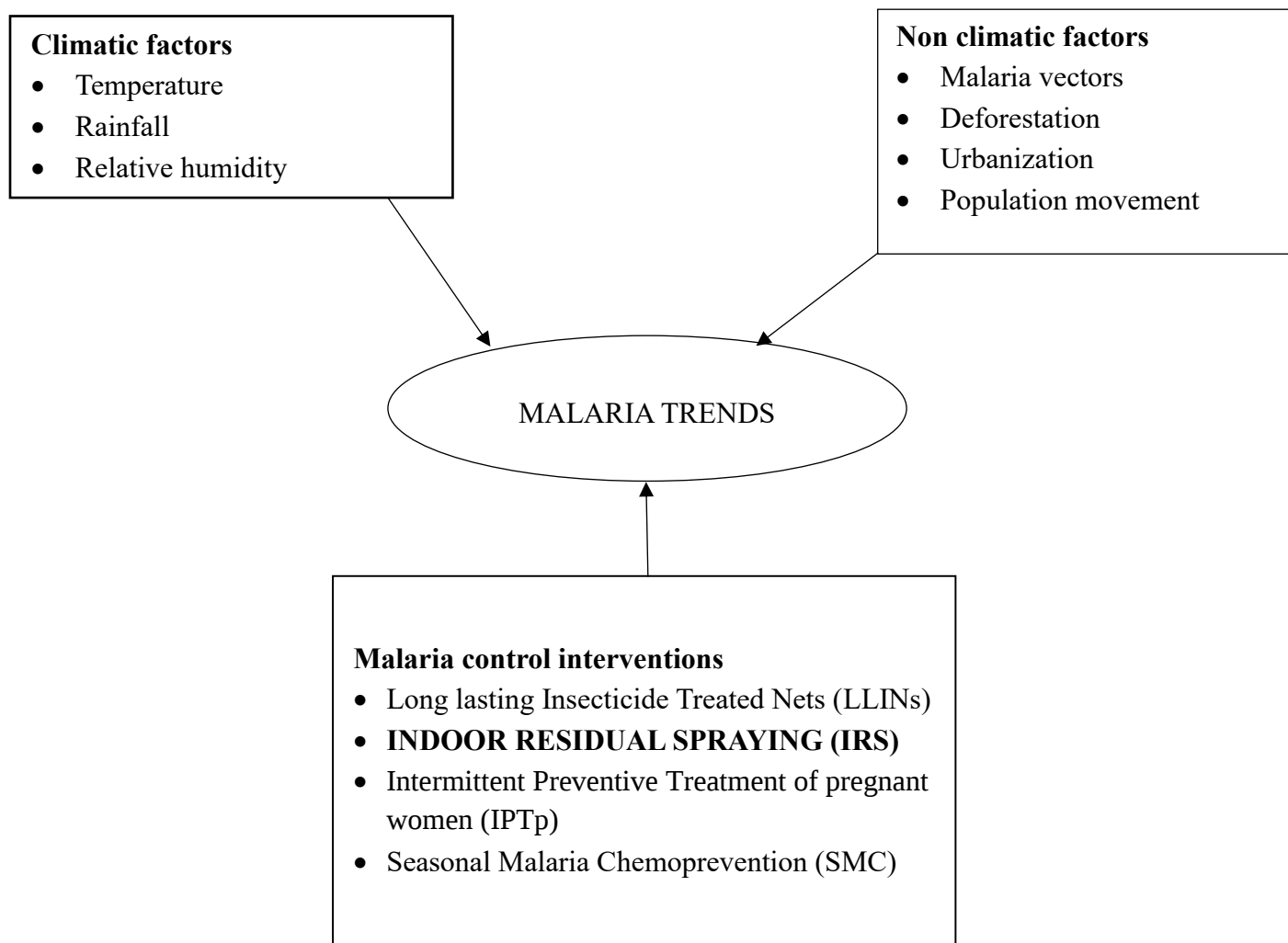


Figure 1: Conceptual framework for Effect of IRS on Malaria Trends

1.4.1 Narration of Conceptual framework

As shown in figure 1 above, several factors affect the trends of malaria in endemic areas. Aside from climatic factors such as rainfall, relative humidity and temperature, other non-climatic factors e.g. population movement, urbanization, deforestation and type of mosquito vector affect malaria transmission. Malaria control interventions such as IRS, LLINs, IPTp and SMC, reduce malaria

transmission. The study assessed the impact of IRS on malaria trends in the midst of these other factors.

1.5 Objectives

1.5.1 Main Objective

To determine the effect of Indoor Residual Spraying on trends of malaria in the Gusheigu and Karaga districts of the northern region

1.5.2 Specific Objectives

1. To determine trends of malaria morbidity in the Gusheigu and Karaga districts from 2014 to 2018.
2. To compare trends of malaria before and after the IRS reintroduction in the Gusheigu and Karaga districts.
3. To estimate the immediate and temporal effects of IRS reintroduction on malaria trends in the Gusheigu and Karaga districts.

CHAPTER TWO

LITERATURE REVIEW

2.1 Malaria Background

Malaria is a mosquito-borne disease caused by Plasmodium parasites. Infected female Anopheles mosquitoes when they bite a human, transmit the parasites into the blood stream. The Plasmodium parasites invade the liver where they mature and eventually infect the red cells and destroy them. If left untreated, malaria can be life-threatening especially in children below five years and pregnant women due to lowered immunity. Five Plasmodium parasite species are found to cause malaria in humans, and two of these species- *P. falciparum* and *P. vivax* pose the greatest threat. The others are *P. malaria*, *P. ovale*, and *P. knowlesi*. *P. falciparum* is regarded as the deadliest malaria parasite. In 2017, *P. falciparum* accounted for 99.7% of estimated malaria cases in the WHO African Region and was responsible for almost all malaria mortalities in the region (WHO, 2018).

2.2 Global Malaria Burden

Malaria, though preventable, continue to pose great global health threat to mankind; exerting a significant burden in endemic areas with premature deaths, disability from illness and impediments to socio-economic development (Ngomane, 2012). Sub-Saharan African countries are most affected by malaria as approximately 70% of the population live in areas infested with potential malaria vectors (Hay et al., 2011). The World malaria report 2018, estimates that 219 million cases of malaria occurred in 2017, higher than the 216 million cases recorded in 2016. Majority of the cases (200 million or 92%) were recorded in the WHO African Region. This led to an estimated

435 000 people losing their lives in 2017, the majority of whom were from Africa (93%) (WHO, 2018).

Malaria morbidity causes a huge economic burden to individuals, families and nations due to loss in working hours, cost of prevention and control as well as treatment. Globally, an estimated US\$ 3.1 billion was invested in malaria control and elimination efforts by governments of malaria endemic countries and international partners in 2017 (WHO, 2018). This huge investment in malaria prevention and control efforts has yielded dividends over the years. Between 2000 and 2012, global malaria incidence fell by 29% with similar trends in malaria mortality rates which reduced by 45% across all age groups, and by 51% in children below the age of five years (WHO, 2013). In Rwanda, it was estimated that, malaria morbidity and mortality in health facilities declined by over than 50% between the years 2005 and 2007 in both inpatient and outpatient slide-confirmed cases (Otten et al., 2009).

2.3 Malaria situation in Ghana

Malaria is endemic and perennial in all parts of the country, with a heterogeneous transmission which differs along varying ecological zones (Awine, 2017). Although, the entire population of Ghana is at risk of malaria infection, pregnant women and children below five years are at the highest risk of complications of severe malaria since they have relatively lowered immunity (PMI Ghana, 2018).

Malaria incidence still remains the leading cause of morbidity in Ghana, accounting for 40.0% of all outpatient attendance (Ameme, Afari, Nyarko, & Sackey, 2015). Data from the District Health

Information Management System (DHIMS-2) suggest that, from 2012-2016, malaria cases attended to at health facilities' OPDs increased from about 300 per 1,000 population in 2012, to about 316 per 1,000 population in 2016 (PMI Ghana, 2018). Nationwide surveys conducted between 2011 and 2014 estimated 28% average population parasite prevalence in children below five years (DHS, 2014). Aside health implication, malaria also poses great economic and developmental challenges in Ghana (Asare & Amekudzi, 2017). Malaria morbidity has a great toll on productivity in the country as a result of loss in workdays. A research conducted by Nonvignon et al., estimated that, in 2014, businesses in Ghana lost about US\$6.58 million to malaria illness, about 90% of which were direct costs due to lost workdays (Nonvignon, Aryeetey, Malm, et al., 2016). In a study by Asante and Asenso-Okyere, they found an inverse relationship between the number of malaria cases and gross domestic product (GDP) in Ghana (Asante, 2015). In a similar study, Sicuri and others estimated the total cost of malaria prevention and treatment for children below five years in Ghana for 2009 to be US\$37.8 million (Sicuri, Vieta, Lindner, Constenla, & Sauboin, 2013). Quite a huge part of Ghana's budget on health is channeled to malaria prevention and treatment efforts e.g. between 2008 and 2015, about US\$880 million was budgeted for the NMCP (NMCP, 2016).

Prevalence of malaria parasites is highly seasonal in Ghana, with a single peak in the wet season (June–October) in the northern savannah area while peaking twice a year in both forest and coastal ecological areas (Awine, 2017). Among the variety of mosquito species identified in Ghana, *Anopheles gambiae* species complex and *An. funestus* are the major species responsible for malaria transmission in the country. Generally, these mosquitoes which are more abundant in the rural and peri-urban areas, bite late in the night, and rest either indoors or outdoors (Awine, 2017; PMI

Ghana, 2018). *Plasmodium falciparum* accounts for more than 95.0% of the malaria parasite species in Ghana, however, low-level infections of *P. malariae* and *P. ovale*, mostly occur as mixed infections with *P. falciparum* (Awine, 2017).

2.4 Factors Influencing Malaria Transmission and Incidence

Several factors affect transmission and morbidity of malaria. These factors vary from place to place. Different climatic and non-climatic factors influence transmission of malaria. Climatic factors such as rainfall, temperature and relative humidity influence the life cycle of the vector as well as the parasites' (Rao & Neelapu, 2014). Population movement or migration, urbanization, human host factors, change in vector behaviors, drug and insecticide resistance, agricultural activities and socio-economic factors are among the non-climatic variables that influence the pattern of malaria transmission (Ngomane et al., 2012; Rao & Neelapu, 2014).

2.4.1 Climatic factors and Malaria Transmission

Climate is an established determinant of the spatio-temporal distribution of vectors and pathogen (Ngomane et al., 2012). A number of climatic factors affect the patterns of transmission of malaria. The main climatic factors influencing malaria transmission are temperature, rainfall and relative humidity. Increased climatic variability, floods and droughts can all potentially affect incidence of malaria either positively or negatively (Rao & Neelapu, 2014). Similar to other sub-Saharan African countries, *Anopheles gambiae sensu lato complex* and *Anopheles funestus* are the predominant mosquito vector species in Ghana and their distribution varies with the climatic and ecological conditions in Ghana (Asare & Amekudzi, 2017). Rainfall provides the right condition for mosquitoes to breed since surface water is required for laying of eggs and larval stages of the mosquito life cycle. Therefore, variability in rainfall pattern influences the variety of mosquito

vectors present, for instance, *Anopheles arabiensis* are predominant in arid areas whereas high rainfall environment has *Anopheles gambiae* as the predominant mosquito vector species (Kibret, Wilson, Ryder, Tekie, & Petros, 2019). Also, *Anopheles funestus sensu stricto*, the only sub-group that transmit malaria, is predominant in the savanna ecological zone of Ghana. The range of temperature suitable for malaria parasite development is 18 °C to 40 °C (Rao & Neelapu, 2014) and Ghana generally has air temperature that is ideal for malaria transmission (Asare & Amekudzi, 2017). Climatic conditions are also interlinked with altitude. For example, higher altitudes goes with reduced air temperature and this can significantly change the abundance and species composition of malaria vector (Kibret et al., 2019).

2.4.2 Population Movement

Movement of people is a contributory factor to the spread of malaria. Historically, movement of people has tremendously affected the global malaria situation and failures of the global efforts to eradicate malaria in the 1950s and 60s are partly due to the interrelation of population movement and malaria transmission (Ngomane et al., 2012; Rao & Neelapu, 2014). Human mobility is considered as the major cause of persistence of malaria in majority of areas with high risk of malaria transmission. Movement of humans, regardless of the type or motive of migration, can become source of passive or active transmission of both infectious and vector-borne diseases and this presents major threat to public health.

2.4.3 Agricultural Activities

Agricultural and land use practices affect transmission of malaria. The development of agricultural projects such as water sources, irrigation, and deforestation, provide suitable environment for the

breeding of anophelines and therefore, enhance malaria transmission (Ngomane et al., 2012). For example, dams have been shown to facilitate the transmission of malaria in areas of unstable malaria transmission. Overall, dams have been shown to account for over a million cases of malaria in sub-Saharan Africa (Kibret et al., 2019). In a study by Janko and others to determine the links between agriculture, *Anopheles* mosquitoes, and malaria transmission among children below five years in the Democratic Republic of Congo, they came to the conclusion that increased exposure to agriculture, increases the risk of malaria in children under five years in rural and ecological diverse settings in the DR Congo (Janko et al., 2018). Forest is a reservoir for a high density of mosquito population, hence deforestation generally reduces mosquito density at the site of deforestation. However, mosquitoes travel relatively short distance to places of human settlements, thereby increasing the risk of transmission of malaria among humans (Rao & Neelapu, 2014).

2.4.4 Changes in vector behaviors and Insecticide resistance

The two most abundant mosquito vectors (*An. gambiae complex* and *An. funestus*) that are responsible for transmission of malaria in sub-Saharan Africa are known to be the most efficient. They adopt behaviors that help them to circumvent efforts especially the use of insecticide to control their populations. For instance, in the case of *An. gambiae* s.s which dominates the savanna regions of Ghana, they switch from endophagic to exophagic as well as exophilic behaviors, thereby circumventing the effectiveness of malaria vector control interventions such as IRS (Gatton et al., 2013). In a routine entomological survey conducted by the PMI in districts implementing IRS in the Northern region, Ghana, *Anopheles gambiae*, exhibited higher outdoor biting rates in all implementing districts compared to the control site (PMI Ghana, 2018). Equally alarming is the growing evidence of physiological resistance of mosquitoes to pyrethroid in

Anopheles gambiae (Ranson et al., 2011). In Ghana, a number of studies have reported evidence of increasing resistance of the major malaria vectors to pyrethroid and organochlorides (Anto et al., 2009; Augustina et al., 2014; Brooke, Kaiser, Koekemoer, Coetzee, & Hunt, 2010; Coetzee, Wyk, Booman, Koekemoer, & Hunt, 2005). Understanding both behavioral and physiological resistance of malaria vectors to insecticides is key to realizing the maximum benefits of IRS intervention.

2.4.5 Host and Socio-economic factors

Age, pregnancy, immunity, genetic differences are among the human host factors that affect the transmission and severity of malaria. In general, children below five years and pregnant women are at greater risk of complications of malaria (Rao & Neelapu, 2014). Also, scarce resources and poor socio-economic status are major hindrance to efficient malaria control activities and some studies have shown that, the poorest citizens bear the severe consequences of malaria in malaria-endemic areas (Ngomane et al., 2012). Lack of education, living in poorly constructed houses, low income, low wealth and farming occupation are among the factors that increase the risk of people with poor socio-economic status to malaria transmission and its complications (Degarege, Fennie, Degarege, & Madhivanan, 2019).

2.5 Malaria Prevention and Control in Ghana

Ghana's effort to control malaria began in the 1950s with the aim of reducing malaria until it is no longer of public health importance. Strategies that were employed to achieve this goal included residual insecticide spraying, mass distribution of chemoprophylaxis with Pyrimethamine medicated salt and improvement in drainage (NMCP, 2017). The current national malaria control strategy targets to by 2020, cover over 80% of the at risk population with effective malaria

prevention strategies such as ITNs, IRS, larviciding methods and environmental management, Seasonal Malaria Chemoprevention (SMC) and IPTp with SP.

Preventing human contact with the mosquito vector is one of the surest way to prevent and reduce malaria transmission. The WHO recommends all people at risk of malaria to be protected with effective vector control interventions. Successful vector control measures depend on the vector species, mosquito biology, epidemiological context, cost and acceptability by the populations. These measures are focused on reducing human contact with mosquitoes, destruction of larvae by environmental management, larvicides or mosquito larvae predators, and destruction of adult mosquitoes by indoor residual spraying and long-lasting insecticidal nets. This two most widely used malaria vector control measures are LLINs and IRS. These two interventions together accounts for about 60% of global investments in malaria control (WHO, 2013). IRS as well as bed nets have been in use in Ghana since the pre-independence era, though on a limited scale. In 2004, however, there was a nationwide distribution of ITNs due to proof of effectiveness from field trials in Ghana and elsewhere in 1996. Consequently, a policy to subsidize ITNs was formulated in 2007 (Awine, 2017; Ghana Health Service, 2013).

2.5.1 Insecticide-Treated Bed Net Use and Malaria Prevention

Insecticide-treated net use is one of the most effective and readily available malaria vector control method (Ricotta, Oppong, Yukich, & Briët, 2019), having prevented about 68% of malaria transmission between 2000 and 2015 (Bhatt et al., 2016). LLINs and IRS are two key interventions needed to achieve the WHO's recommendation of complete coverage of populations at risk of malaria with effective vector control interventions (Masaninga et al., 2018). In a survey to evaluate

the two primary indicators of successful ITNs program, it was reported that on average since 2010, in sub-Saharan Africa, 54% of households own at least one ITN and 33% of the population reported to have used the net a night prior to the interview (Koenker, Ricotta, & Olapeju, 2018). In 2010, a campaign for free distribution LLINs was rolled out with an intention to achieve universal coverage in 2012 (Gakpey, Baffoe-wilmot, Malm, Dadzie, & Bart-plange, 2016). Ghana was ranked 25th in ITN use relative to access (ratio of use to access of 0.63) out of 27 PMI focus countries in the Malaria Indicator Survey in for the period of 2010 to 2017 period (Koenker et al., 2018). It is shown that appropriate use of ITNs decrease malaria transmission by about 90%, and proper use of ITN during pregnancy has been shown to cause a decline in miscarriages and stillbirths by about 33% (MICS, 2011). However, several factors hinders the effective use of LLINs in Ghana. A couple of self-reported hindrance to use of LLINs include, discomfort (as a result of heat), low perception of need to use a net when mosquito density is low, and frequent change in sleeping arrangement (Ricotta et al., 2019).

2.5.2 Intermittent Preventive Treatment of Malaria in Pregnant Women

Malaria in pregnancy is an important cause of spontaneous abortions, preterm deliveries, low birth weight, and increased risk of perinatal mortality in sub-Saharan Africa (Oppong et al., 2019). An effective strategy to prevent malaria during pregnancy is the intermittent preventive treatment of malaria in pregnancy (IPTp) with sulfadoxine-pyrimethamine (SP) (Anto, Agongo, Asoala, Awini, & Oduro, 2019). The World Health Organization upon updating their recommendations in 2012, recommends all pregnant women to take SP at each antenatal visit until delivery, regardless of whether the recipient is positive for malaria parasites or not (WHO, 2016). In a review by Kayento

and other in 2014, it is indicated that, use of IPTp-SP in pregnant women has reduced about 42% low birth weight, 65% placental malaria and 38% neonatal deaths (Kayentao et al., 2014).

2.5.3 Seasonal Chemoprevention

The burden of malaria still remains high in most endemic regions despite the availability of several malaria prevention and control measures. To augment the available malaria control measures, new effective preventive/control measures such as the seasonal malaria chemoprevention (SMC) was considered in 2015 for implementation in Ghana. The SMC was piloted in the Upper West region (one of the regions that records the highest prevalence of malaria in the country—37.8 %) from July to October 2015, with support from the Department for International Development of the UK (DFID) and the Global Fund. SMC has been shown to be effective especially in areas of short malaria transmission season (Nonvignon, Aryeetey, Issah, et al., 2016). In a systematic review by Wilson, it was shown that, giving sulfadoxine-pyrimethamine with amodiaquine (SP-AQ) per month to children under five years during the peak period of malaria transmission, reduced malaria transmission by 83% and severe malaria by 77% (Wilson, 2011).

2.5.4 Indoor Residual Spraying and Malaria Trends

Evidence of IRS efficacy had been established since the 1940s: IRS has historically, played a key role in the prevention of malaria. Several countries in sub-Saharan Africa have recently included IRS as part of their malaria control strategies in conformity with the Global Malaria Action Plan launched by the WHO-Roll Back Malaria Partnership (Kigozi et al., 2012). An assessment of the impact IRS had on malaria incidence in Western Uganda, showed a consistent decrease in the prevalence of malaria in children below five years after implementing IRS. The study revealed that, the proportion of patients diagnosed with clinical malaria reduced from 50% to 26% among

children below five years and from 36% to 23% in patients older than five years. This decrease was more prominent within the first 4 months following the application of IRS (Bukirwa et al., 2009).

Raouf and others in 2017, evaluated the effect of IRS implementation on malaria trends following a period of active implementation and subsequent withdrawal of the intervention in Apac district in Uganda, through surveillance data analysis. In outpatients below five years, the baseline TPR reduced from a range of 60%-80% to 15%-30% during active implementation, however, after discontinuation of IRS in the district, absolute values of TPR resurged by an average of 3.29% per months, returning to baseline values. Similar trends were observed in outpatients aged ≥ 5 years and paediatric admissions (Raouf et al., 2017).

In their assessment of the effect of IRS on malaria morbidity in northern Uganda, Tukei et al., 2017, observed that, the percentage point (p.p.) changes in slide positivity rate (SPR) followed a decreasing trend in malaria morbidity in the first three months following each round of IRS. The highest p.p. (9.5%) in SPR was observed in the second month after IRS application among patients above five years (Tukei, Beke, & Figueroa, 2017).

Ngomane assessed the impact of IRS on malaria prevalence for a period between 2001 and 2009 in Mpumalanga province, South Africa. The study showed a drastic decrease in malaria transmission in the province from 385 in 2001/02 to 50 cases per 100,000 populations in

2008/09 following a decade of continuous IRS application. A notable decline of above 50% in malaria morbidity and mortality was observed following expanded IRS coverage (Ngomane et al., 2012).

CHAPTER THREE

METHODS

3.1 Study Area

The study involved selected districts of the northern region. The region is bordered on the north by the North East region, on the south by the Oti region, to the east by the Ghana-Togo border and to the west by the Savannah region. The region is generally dry, with a single rainy season which spans from May to October, with an average annual rainfall of 750 to 1050 mm. The Northern region is one of the warmest regions in Ghana with an average daily temperature of 34⁰ Celsius. The study focused on the Gusheigu and Karaga districts as the intervention-implementing districts. Both districts are located in the northernmost part of the region and share borders to the southern part of the North East region. Karaga district was carved out of the Gusheigu district and officially inaugurated in August, 2004. The Gusheigu and Karaga districts were among the first districts selected for IRS implementation in the Northern region in 2008, and continued to implement the intervention until 2014 when it was withdrawn due to funding constraints. However, in 2017, both districts were added to benefit from the intervention again.

3.2 Study Design

A controlled Interrupted Time Series (ITS) design was used for the study. ITS is among the strongest quasi-experimental methods which is increasingly used to evaluate public health interventions introduced at a population level over a clearly defined time period. It offers a potentially-high degree of internal validity (Bernal, Cummins, & Gasparrini, 2017; Linden, 2017). This design is more appropriate in evaluating the longitudinal effects of IRS implementation at the community levels in the selected districts of the region since there are available aggregate data on

malaria incidence routinely collected at equally spaced intervals (monthly) during both the pre-intervention and post-intervention periods.

The design involves analyzing trends of malaria positivity rates and estimating the change in the trends following the implementation of IRS in the implementing districts. Including control districts (districts that do not implement IRS), greatly influenced the internal validity of the design. The advantage of this design is that it controls time-varying confounders such as co-interventions and other events concurrent to the intervention that can influence malaria test positivity rate. Segmented regression analysis with ordinary least squares was used to estimate the changes in level and trajectory of malaria test positivity rate following the intervention. Changes in both the level and trends were considered statistically significant if p-values are less than 0.05.

3.3 Study Variables

The table 1 below shows the study variables and their operational definitions.

Table 1: Study variables, their operational definition and scale of measurement

Variable	Operational definition	Measurement	Type
Uncomplicated malaria suspected tested	Number of uncomplicated malaria tested in a month	Continuous	Outcome
Uncomplicated malaria tested positive	Number of uncomplicated malaria tested positive in a month	Continuous	Outcome
Test Positivity Rate (TPR)	The proportion of confirmed malaria cases out of the number tested in a month	Continuous	Outcome
Time in relation to IRS implementation	Pre-implementation period and post-implementation period	Categorical	Independent
IRS spray months	Months in which spraying was carried out	Discrete	Independent

3.4 Selection of Case Districts

Gusheigu and Karaga were purposively selected as IRS implementing districts for the study. Both districts were undergoing the IRS intervention until 2013 when the intervention was truncated due to funding constraints. In 2017, however, the IRS was reintroduced in these districts. These districts were therefore selected as case districts to determine the effects of the reintroduction of IRS intervention on malaria trends.

3.5 Selection of Control Districts

In order to reduce the threats of confounding, and to enhance the internal validity of the study, control districts that are comparable to the case districts were selected. The comparability was on both the level and trajectory of the malaria TPR before the reintroduction of IRS intervention. Selection of control districts was based on an iterative process where non-IRS intervention districts were compared separately with case districts in a multiple-group ITS analysis. Comparable control districts were selected based on p-values associated with β_4 and β_5 . The β_4 and β_5 represent the differences in the level (intercept) and trend of malaria TPR respectively, between the control and case districts prior to the introduction of the intervention. In this context, comparability of the case and control districts was defined as having both p-values associated with β_4 and β_5 to be greater than 0.10. Yendi district was selected as a control for the Gusheigu district, whereas Tolon and Yendi districts were selected as controls for the Karaga district.

3.5 Data Collection

ITS analysis requires data collected at equally spaced intervals of time. The study utilized exclusively secondary data from routine malaria surveillance in the northern region. Routine data collected for the study consisted of all malaria cases tested in a month, and cases confirmed for the same period. The data was collected from all districts in the northern region for the period of January 2015 to December 2018. This data was obtained from the DHIMS-2 database and the NMCP. Data span a four year period (2015-2018). The pre-implementation period span from January 2015 to April 2017, whereas the post-implementation was from May 2017 to December 2018. Data on IRS activities (months of spraying and type of insecticides used) was also retrieved from the end of spray year reports of the Africa Indoor Residual Spraying (AIRS) group.

3.6 Statistical Analysis

Data were obtained in a Microsoft Excel format and cleaned for analysis. The primary outcome was the test positivity rate (TPR) defined as a proportion of confirmed malaria cases out of the number tested and expressed as a percentage. The exposure variable is time (categorized into pre-implementation and post-implementation segments). The pre-implementation period consisted of 28 data points whilst post-implementation comprised of 20 data points (one data point represents TPR for a calendar month). Visual comparison of trends of TPR for the pre-intervention and post-intervention segments was done after plotting graphs of their respective data points on the same rectangular co-ordinates system using Microsoft Excel.

Data was imported to Stata 15 for interrupted time series analysis (itsa). The ordinary least squares segmented regression with Newey-West standard errors was used to estimate the immediate and

temporal changes in the trends of malaria TPR following the implementation of IRS in the districts. The selected control districts, were used in a multiple-group interrupted time series analysis to cater for time-varying confounders such as seasonality of malaria, simultaneous malaria control interventions being implemented in the districts and other factors that affect malaria positivity rate. Multiple-group analysis assumes that these confounders affect both the cases districts and the control districts similarly. Hence a difference in the outcome variable (both in level and trajectory) between the case and control districts, post-implementation of the intervention is attributable to the intervention (Linden, 2017).

Autocorrelation, a major occurrence in time series data where consecutive data points tend to be similar to another was accounted for in the model. The Cumby-Huizinga test was used to test for autocorrelation up to the sixth order, and significant autocorrelation, up to the fourth-order, was observed. An autoregressive term at the appropriate lag was included to adjust for the detected autocorrelation.

In the final multiple-group ita, a change in the level or trajectory of malaria TPR was considered statistically significant if the p-value of the coefficient was less than 0.05

3.7 Ethical Issues

Ethical clearance was obtained from the Ghana Health Service (GHS) Ethics Review Committee (ERC) with a protocol number: **GHS-ERC 034/02/19**. Administrative authorization was also obtained from the Regional Director of Health Services, Northern Region as well as the National Malaria Control Programme to access the malaria surveillance data. Permission was also sought from the Africa Indoor Residual Spraying (AIRS) office in Tamale for data on IRS activities in the northern region. Data obtained was used for the purpose of this research only.

CHAPTER FOUR

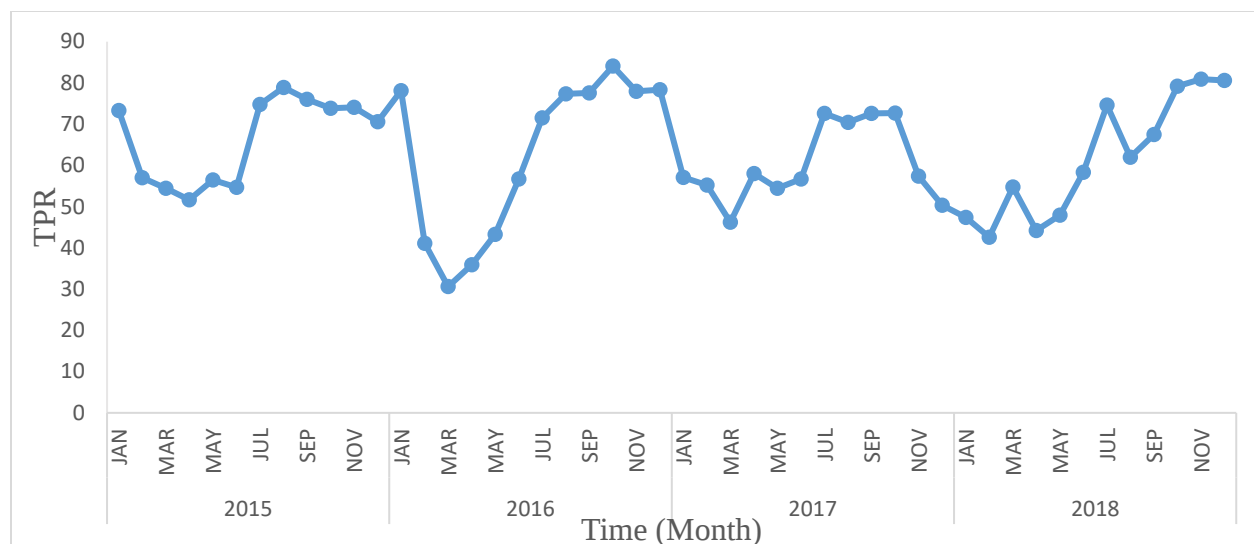
RESULTS

4.1 Effect of IRS on Gusheigu District

A total of 87,261 suspected cases of malaria were recorded in the Gusheigu district from 2015 to 2018, of which 46,049 cases representing 52.8% were tested for malaria. Of the malaria cases tested, 30,848 were confirmed positive for malaria resulting in a cumulative TPR of 67.0% (30,848/46,049) for the period of review. During the pre-intervention period (January 2015 to April 2017), a total of 26,730 cases of suspected malaria were tested, of which 18,510 (69.2%) were confirmed malaria positive. About 12,338 cases (63.9%) of the 19,319 suspected cases of malaria recorded in the post-intervention period (May 2017 to December 2018) were confirmed positive.

4.1.1 Underlying Trend of TPR in Gusheigu

Although malaria is prevalent in the Gusheigu district throughout the year, it can be seen from figure 2 that monthly TPR followed seasonal trends, peaking between July and October in 2015. In 2016, however, there was a sharp decline in TPR, within a short interval, from January to March. From the lowest point in March, there was a gradual increase in the outcome variable to another peak between July and November that year. Also at the beginning of 2017, malaria TPR began to decline to the lowest point again in March. Thereafter, a gradual irregular rise in TPR was again observed with a peak between July and October. This pattern of rise followed by a fall, then a rise, is observed throughout the period under review. Figure 2 below shows the seasonal trends of malaria TPR for the Gusheigu district from January, 2015 to December, 2018.

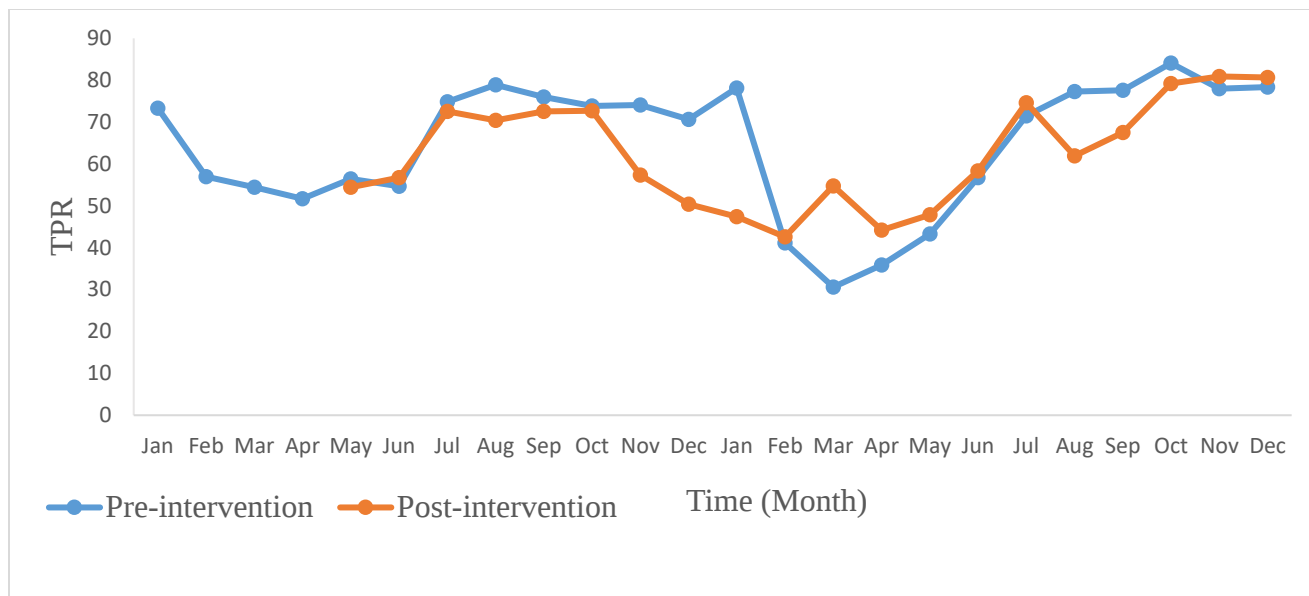


TPR= (Confirmed malaria cases in a month/Suspected malaria cases in a month)*100

Figure 1: Monthly trends of malaria test positivity rate for Gushegu district from 2015-2018.

4.1.2 Pre-intervention and Post-intervention Trends Compared in Gushegu District

Visual comparison of patterns of TPR in both the pre-intervention and post-intervention periods did not show marked differences in the trends. For the two graphs in figure 3, peaks and troughs (even though appears less prominent compared to that of figure 2) are observed between July and October, and February to May, respectively. The peaks observed in the pre-intervention period were higher compared to those of the post-intervention period. It was however noted that, the pre-intervention trough was lower than that of the post-intervention. Figure 3 below shows the pre-intervention and post-intervention line graphs plotted on the same axes.



TPR= (Confirmed malaria cases in a month/Suspected malaria cases in a month)*100

Figure 2: Comparison of Pre-implementation and Post-implementation trends in Gusheigu, 2015-2018.

4.1.3 Segmented regression for Effect of IRS implementation on TPR in Gusheigu

The table 2 below contains parameter estimates from the multi-group segmented regression of the effect of the reintroduction of IRS in the Gusheigu district. The results indicate that, the starting level of malaria TPR was estimated at 54.4% and appeared to decrease insignificantly every month prior to the intervention by 0.4% ($p=0.568$).

In the first month of the intervention (May, 2017), there appeared to be a decrease in malaria TPR of 13.9% followed by an increase in monthly trends of the outcome variable (relative to the pre-intervention trends) of 1.8%, after controlling for confounding effects in a multiple-group *itsa*. These changes in the level and trends of malaria TPR following the first round of IRS were however, not statistically significant ($p=0.492$ and $p=0.480$).

Similarly, at the point of implementation of the second round of IRS (May, 2018), there appeared to be an immediate decrease in TPR of 23.7% followed by an average decrease in monthly malaria TPR of 2.1% after controlling for time-varying confounders in a multiple group analysis. The immediate and temporal decreases in malaria test positivity rate following the second cycle of IRS in the Gusheigu district were also statistically insignificant ($p=0.227$ and $p=0.632$ respectively).

Table 2: Temporal Changes in Malaria Test Positivity Rates in Relation to IRS in Gusheigu District, 2014-2018

Parameter	Δ TPR (95% CI)	Newey-West Std. error	p-value
Baseline level	54.4 (31.4– 77.3)	11.5	<0.0001
Baseline trend	-0.4 (-1.7-0.9)	0.7	0.568
Level change IRS 1	19.3 (-15.5-54.1)	17.5	0.273
Trend change IRS 1	-3.7 (-8.4-1.0)	2.4	0.125
Dif. in level case and control district IRS1	-13.9 (-54.0-26.2)	20.2	0.492
Dif. in trend case and control district IRS1	1.8 (-3.3-6.9)	2.6	0.480
Level change IRS 2	31.8 (-5.2-68.7)	18.6	0.091
Trend change IRS 2	8.2 (-0.1-16.6)	4.2	0.052
Dif. in level case and control district IRS 2	-23.7 (-62.4-15.0)	19.5	0.227
Dif. in trend case and control district IRS 2	-2.1 (-10.8-6.6)	4.36	0.632

Δ TPR= change in malaria test positivity rate; Dif.= difference; IRS1= first round of spraying (May, 2017); IRS2= second round of spraying (May, 2018)

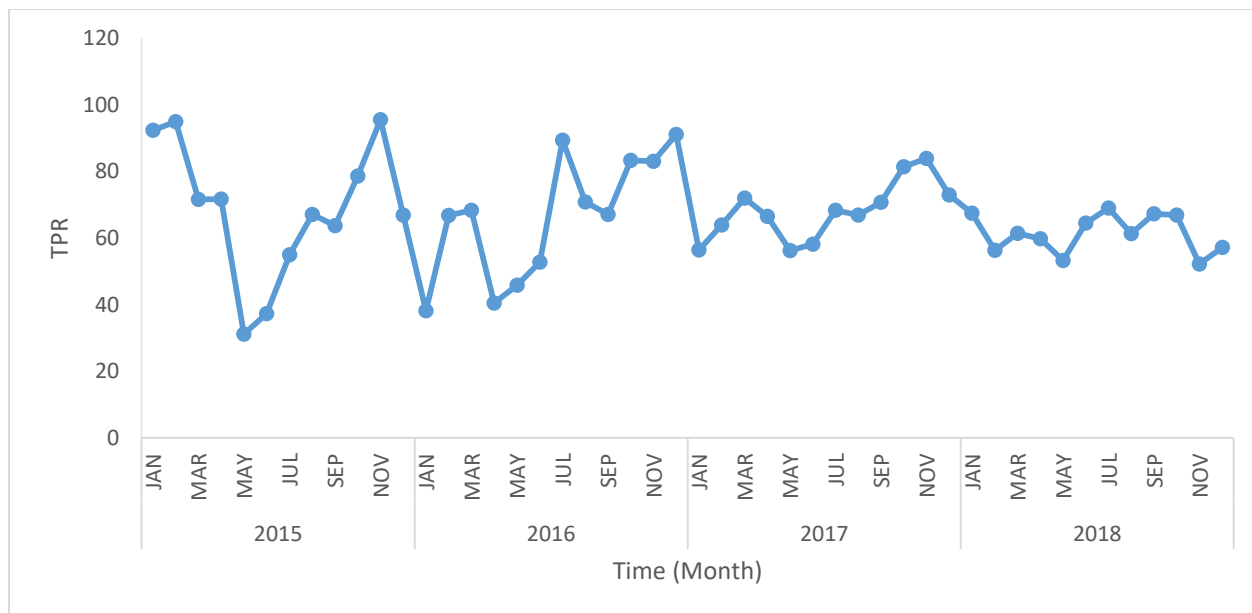
4.2 Effect of IRS on Karaga District

The Karaga district recorded 78,276 cases of suspected malaria from January, 2015 to December, 2018 of which 38,762 (49.5%) were tested for malaria. A total of 26,160 cases were confirmed positive for malaria parasites resulting in a cumulative TPR of 67.5% (26,160/38,762). About 20,980 of the cases tested were recorded during the pre-intervention period of which 14,302 (68.2%) were confirmed positive whereas 17,782 cases were tested during the post-intervention period of which 11,858 (66.7%) were tested positive.

4.2.1 Underlying Trend of TPR in Karaga District

Monthly malaria TPR for the Karaga district also followed a seasonal pattern peaking between July and November in 2015. In 2016 also, malaria TPR peaked between July and December. In 2017, however, malaria TPR peaked between October and November. Subsequently in 2018, a moderate peak occurred between July and October. Less prominent peaks were also observed between February and March each year in the period under review.

In 2015, a decrease in TPR was observed from January to May and also in November to February of 2016. Also, in 2016, there was a moderate decrease in TPR between March and May followed by a sharp decrease between November and February of the following year. In a fashion similar to the previous year, there was a moderate decrease in malaria TPR between March and May as well as a sharp decrease of the outcome variable between November 2017 and February 2018. Figure 4 below shows the line graph of malaria TPR for the period under review in the Karaga district.

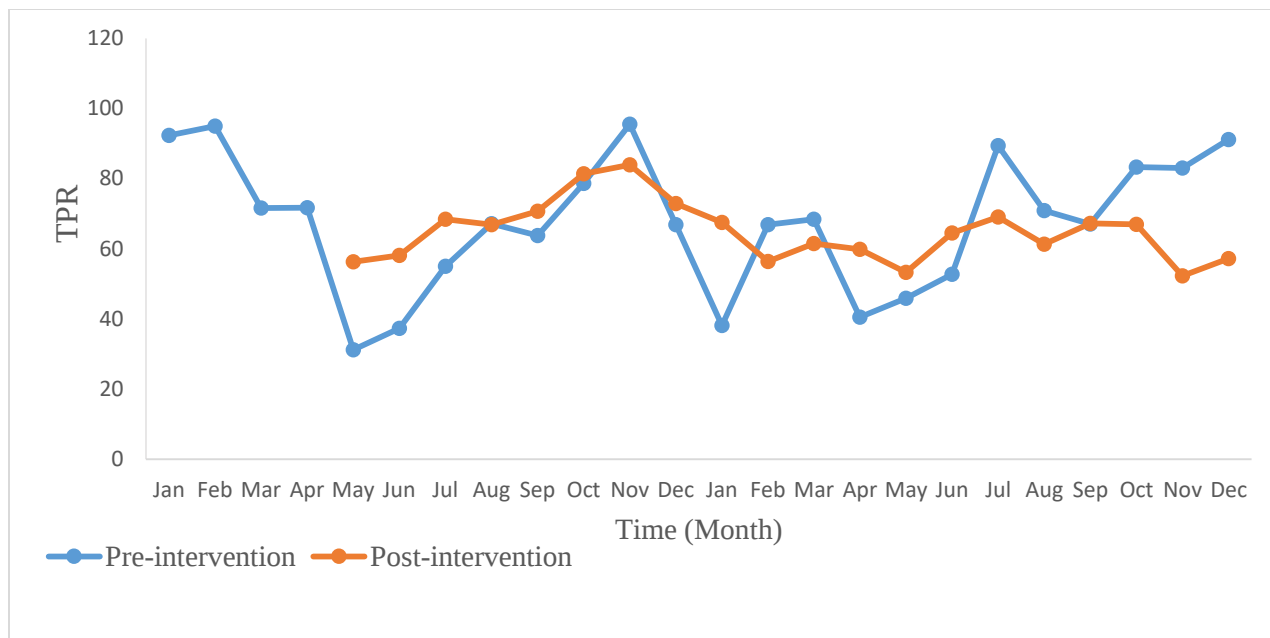


TPR= (Confirmed malaria cases in a month/Suspected malaria cases in a month)*100

Figure 3: Monthly trends of malaria test positivity rate for Karaga district from 2015-2018

4.2.2 Pre-intervention and Post-intervention Trends Compared in Karaga District

Comparatively, trends of TPR before and after the reintroduction of IRS intervention in the Karaga district exhibited some difference, even though minimal. The peaks observed in the pre-intervention period were higher compared to those of the post-intervention period. It was also noted that, the pre-intervention troughs were comparatively lower than those in the post-intervention segment. Figure 5 below shows trends of TPR for the pre-intervention and post-intervention periods in the Karaga district.



TPR= (Confirmed malaria cases in a month/Suspected malaria cases in a month)*100

Figure 4: Comparison of Pre-implementation and Post-implementation trends in Karaga district, 2015-2018

4.1.3 Segmented regression for Effect of IRS implementation on TPR in Karaga District

As shown in the segmented regression in table 3, the starting level of TPR for the Karaga district was estimated at 57.2%, followed by a stable trend in monthly TPR prior to the reintroduction IRS in the district. Following the first spraying cycle in May 2017, there appeared to be a decrease in TPR of 5.2%, and afterwards monthly trends of TPR (relative to the pre-intervention trends) increased by 0.9% taking into consideration seasonality of malaria and other confounders. The changes in the level as well as the trajectory of malaria TPR following the first round of IRS were however not statistically significant ($p=0.710$ and $p=0.629$ respectively).

Similarly, following the second spray season in May 2018, there appeared to be a decrease in both the level of malaria TPR of 12.7%, and monthly TPR trends (relative to the pre-intervention trends) of 1.4% whilst controlling for confounding effect in a multiple group analysis. The decreases in

the level and trend following the second spray season were also not statistically significant ($p=0.489$ and $p=0.699$ respectively).

Table 3: Temporal Changes in Malaria Test Positivity Rates in Relation to Indoor Residual Spraying in Karaga district, 2014-2018

Parameter	Δ TPR (95% CI)	Newey-West Std. error	p-value
Baseline level	57.2 (42.9-71.4)	7.2	0.000
Baseline trend	0.0 (-0.9-0.9)	0.5	0.531
Level change IRS 1	9.6 (-12.9-31.9)	11.3	0.401
Trend change IRS 1	-2.3 (-6.0-1.4)	1.9	0.221
Dif. in level case and control district IRS1	-5.2 (-32.9-22.5)	14.0	0.710
Dif. in trend case and control district IRS1	1.0 (-3.1-5.1)	2.1	0.629
Level change IRS 2	17.9 (-15.0-51.0)	16.7	0.283
Trend change IRS 2	4.8 (-1.5-11.1)	3.2	0.134
Dif. in level case and control district IRS 2	-12.7 (-48.8-23.5)	18.3	0.489
Dif. in trend case and control district IRS 2	-1.4 (-8.6-5.8)	3.6	0.699

Δ TPR= change in malaria test positivity rate; Dif.= difference; IRS1= first round of spraying (May, 2017); IRS2= second round of spraying (May, 2018)

CHAPTER FIVE

DISCUSSION

Malaria is endemic in Ghana with pronounced seasonal variations in the northern part of the country. The study revealed that monthly malaria TPR in the Gusheigu and Karaga districts for the period under review (January 2015 to December 2018) followed a seasonal trends with peaks between July and October each year. Also, decreasing trends were observed between November of a particular year and February of the ensuing year. The patterns observed appear to have a direct correlation to the rainfall pattern of the savanna region of Ghana. The savanna regions of Ghana have a single rainfall season which begins between May and June and ends between September and October each year. This is the period in which the population of mosquitoes peak in the region (PMI, 2017). Several studies have also documented variations in malaria incidence relative to rainfall patterns in various parts of Africa. In a study by Bra and others in 2018 to determine the association between rainfall and malaria transmission in the northern part of Cote d'Ivoire, they found a strong correlation between rainfall pattern and clinical malaria transmission (Bra et al., 2018). In a three-time repeated cross-sectional surveys in Mendela, a village near Sikasso, Mali to explore malaria transmission dynamics during dry and wet seasons, a significant difference in the prevalence of malaria between the rainy season and the dry season was observed (Ardiet et al., 2014). These findings corroborate the conclusion by Ngomane, 2018 that, the climate is an important determinant of the spatial and temporal distribution of malaria (Ngomane, 2012).

The application of IRS in the Northern region coincides with the beginning of the rainy season so that the chemical residue remains potent during the season in order to derive maximum benefits of the intervention. Comparing the trends of malaria TPR before and after the reintroduction of IRS in both districts, it is observed that, peaks of the period after IRS application were generally lower than those before IRS implementation. These data points are not taken within the same period of time, therefore variations in environmental factors over the period cannot be ruled out. But it may be safe to say that the trend observed could be as a result of the intervention.

Also, in this study, there appeared to be an immediate reduction in malaria test positivity rate following both cycles of IRS implementation in the two districts evaluated. This immediate reduction was more pronounced after the second cycle of spraying. After the second cycle of IRS application in both districts, there appeared to be an average of two percentage point reduction in monthly malaria TPR. Though the reductions in malaria TPR were statistically insignificant, there are indications of positive benefits of IRS intervention in the Gusheigu and Karaga districts, and these benefits are likely to be more pronounced if the intervention is sustained.

The programmatic benefits of IRS in malaria prevention have been reported in both high and low malaria-endemic areas. Indoor residual spraying has been touted to contribute to the drastic reduction and elimination of malaria in certain parts of Latin America, Asia, and Europe as well as certain parts of Africa (Eckert et al., 2017; Edwin & Ernest, 2016; Mumbengegwi et al., 2018; Pluess B et al., 2010).

Several studies have reported similar reductions on malaria morbidity trends following the implementation of IRS especially in instances of sustained application of the intervention. In a study by Raouf et al., 2017, they reported a significant reduction in monthly TPR of 5.84% in children below five years following the second cycle of IRS application in the Apac District of Uganda unlike the first round of IRS application which did not yield a significant change in malaria TPR. Beyond the second cycle, there was a sustained decrease in monthly malaria TPR of 0.4% throughout a period of six rounds of sustained IRS application. However, after discontinuation of the intervention in the district, malaria positivity resurged, returning to the baseline values within a period of 4-18 months (Raouf et al., 2017). Similar studies by Tukei and others in 2017, have also reported a decline in malaria TPR as high as 9.5% in the third month following each cycle of IRS application in northern Uganda (Tukei et al., 2017). Likewise in Mpumalanga province, South Africa, there was a reported decline of over 50% in malaria morbidity and mortality following expanded IRS coverage (Ngomane, 2012).

Comparatively, this study has revealed relatively smaller reductions in malaria TPR following the first and second cycles of IRS application. Behavioral and physiological resistance of malaria vectors to insecticides are key to realizing the maximum benefits of IRS intervention. The effectiveness of IRS was based on the feeding and resting behaviors of mosquitoes as well as their resistance to insecticides used for spraying. The resistance of mosquito to insecticides is an evolving threat to the gains made using LLINs and IRS interventions which are currently, the key components of vector management strategies used in the malaria control efforts (Gatton et al., 2013). There is growing evidence of physiological resistance to pyrethroid in *Anopheles gambiae*, a major vector of malaria in Africa (Ranson et al., 2011), and this poses a major public health

concern as pyrethroid is a major insecticide used in LLINs and IRS application. In Ghana, several studies have reported evidence of increasing resistance of the major malaria vectors to pyrethroid and organochlorides (Anto et al., 2009; Augustina et al., 2014; Brooke et al., 2010; Coetzee et al., 2005).

In other instances, mosquito vectors modify their behavior in order to facilitate avoidance or circumvention of the insecticides. There is evidence of the development of early, outdoor feeding and outdoor resting anopheline populations in areas of extensive indoor insecticide use (Gatton et al., 2013). Both physiological and behavioral resistance of the malaria vectors to insecticides may be responsible for the comparatively low benefits of IRS as determined in this study. In a routine entomological survey conducted by the PMI in districts implementing IRS in the Northern region, Ghana, *Anopheles gambiae*, the most abundant mosquito species in the region, exhibited higher outdoor biting rates in all implementing districts compared to the control site. IRS application, as well as the high coverage of LLINs, were the reported reasons for the exophagic and exophilic tendencies of the mosquito vector in these sites. However, the PMI reported that, the reintroduction of IRS in the Gusheigu and Karaga districts has contributed to reduced longevity and malaria transmission intensity of *Anopheles gambiae* in the sprayed communities (PMI, 2017).

An observation that is common to both districts is that less prominent peaks of malaria TPR occur between February and April each year. This is the period of intense heat in the Savanna zone. It is a common phenomenon for inhabitants in these areas to tend to sleep outdoor, for example, open yards, all in a bit to avoid the heat. Yet another practice that is common in these areas is hunting expeditions often organized within this period, involving large numbers of men who spend nights

in the bush and are therefore exposed to mosquitos. A combination of these practices exposes the people to the malaria vector, increasing the chances of malaria transmission.

LIMITATIONS

It is worth noting that this study has some limitations given that it relies mainly on routine surveillance data. Primarily, there are a number of factors that hinder on the accuracy of routine surveillance data some of which are reporting inconsistencies and incompleteness, as well as lack of systematic inclusion of data from other sources such as pharmaceutical service providers (Pharmacies and Chemical shops), traditional healers, faith-based organizations and self-treatment cases. The outcome variable in this study relies on laboratory-confirmed malaria cases, therefore, the laboratories' level of adherence to standard operating procedures have a direct bearing on the quality of data generated. Due to poor laboratory in study districts, most of the cases were not tested.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

In conclusion, monthly malaria TPR in both Gusheigu and Karaga districts for the period under review followed seasonal trends with peaks between July and October each year, and decreasing trends between November each year and February of the ensuing year. Comparatively, peaks of TPR after IRS application were generally lower than those before IRS implementation.

Finally, the study reveals an immediate decrease in malaria TPR following both cycles of IRS implementation in the two districts evaluated. However, the magnitude of the reduction was greater following the second cycle of spraying than the first. Also, the decrease in TPR following the second cycle was sustained with an average of two percentage point reduction in monthly malaria TPR.

6.2 Recommendation

Based on the positive indications of IRS intervention revealed by this study, it is recommend that the National Malaria Control Programme and its partners sustain the intervention in these districts so as to maximize the benefits thereof.

REFERENCE

- Ameme, D., Afari, E., Nyarko, K. M., & Sackey, S. O. (2015). Direct observation of outpatient management of malaria in a rural Ghanaian district.
<https://doi.org/10.11604/pamj.2014.19.367.4719>
- Anto, F., Agongo, I. H., Asoala, V., Awini, E., & Oduro, A. R. (2019). Intermittent Preventive Treatment of Malaria in Pregnancy : Assessment of the Sulfadoxine-Pyrimethamine Three-Dose Policy on Birth Outcomes in Rural Northern Ghana, 2019.
- Anto, F., Asoala, V., Anyorigiya, T., Oduro, A., Adjuik, M., Owusu-agyei, S., Hodgson, A. (2009). Insecticide resistance profiles for malaria vectors in the Kassena-Nankana district of Ghana, 8, 1–8. <https://doi.org/10.1186/1475-2875-8-81>
- Ardiet, D., Graz, B., Szeless, T., Mauris, A., Falquet, J., Doumbo, O. K., Motamed, S. (2014). Patterns of malaria indices across three consecutive seasons in children in a highly endemic area of West Africa : a three times-repeated cross-sectional study, 1–8.
- Asante, F. (2015). Economic Burden of Malaria in Ghana Economic Burden of Malaria in Ghana By, (January).
- Asare, E. O., & Amekudzi, L. K. (2017). Assessing Climate Driven Malaria Variability in Ghana Using a Regional Scale Dynamical Model. <https://doi.org/10.3390/cli5010020>
- Augustina, A. A., Ellis, O., Sandra, B., Sarpong, N., Ayimbire, A. G., Salifu, S. P., Ohene, B. K. (2014). East African Journal of Public Health Volume 11 Number 4 D ecember 2014
INSECTICIDE RESISTANCE IN MALARIA VECTOR MOSQUITOES AT 5
SELECTED DISTRICTS IN GHANA , WEST AFRICA East African Journal of Public

Health Volume 11 Number 4 December 2014, 11(4).

Awine, T. (2017). Towards malaria control and elimination in Ghana : challenges and decision making tools to guide planning. *Global Health Action*, 0(0).

<https://doi.org/10.1080/16549716.2017.1381471>

Belachew, T. (2012). The impact of indoor residual spraying on malaria incidence in East Shoa Zone, Ethiopia, 1, 1–8.

Bernal, J. L., Cummins, S., & Gasparrini, A. (2017). Interrupted time series regression for the evaluation of public health interventions : a tutorial, (June 2016), 348–355.

<https://doi.org/10.1093/ije/dyw098>

Bhatt, S., Weiss, D. J., Cameron, E., Bisanzio, D., Mappin, B., & Dalrymple, U. (2016). Europe PMC Funders Group The effect of malaria control on *Plasmodium falciparum* in Africa between 2000 and 2015, 526(7572), 207–211. <https://doi.org/10.1038/nature15535>.The

Bra, R. K. M., Kone, B., Soro, D. P., Raymond, T. A., N, S., Soro, N., Ceccato, P. (2018). Impact of climate variability on the net transmission risk of malaria in northern Côte d'Ivoire, 1–15.

Brooke, B. D., Kaiser, M. L., Koekemoer, L. L., Coetzee, M., & Hunt, R. H. (2010). Larval time-to-hatch and insecticide resistance in the major malaria vector *Anopheles gambiae* from Ghana, (June 2014), 8–10. <https://doi.org/10.1186/1475-2875-9-S2-O5>

Bukirwa, H., Yau, V., Kigozi, R., Filler, S., Quick, L., Lujemwa, M., Dorsey, G. (2009). Short Report : Assessing the Impact of Indoor Residual Spraying on Malaria Morbidity Using a Sentinel Site Surveillance System in Western Uganda, 81(4), 611–614.

<https://doi.org/10.4269/ajtmh.2009.09-0126>

Chanda, E., Coleman, M., Kleinschmidt, I., Hemingway, J., Hamainza, B., Masaninga, F., Coleman, M. (2012). Impact assessment of malaria vector control using routine surveillance data in Zambia : implications for monitoring and evaluation, 1–8.

<https://doi.org/10.1186/1475-2875-11-437>

Coetzee, M., Wyk, P. Van, Booman, M., Koekemoer, L. L., & Hunt, R. H. (2005). malaria control . I nsecticide resistance in malaria vector mosquitoes E NTOMOLOGIE MÉDICALE, (3), 400–403.

Degarege, I., Fennie, K., Degarege, D., Id, S. C., & Madhivanan, P. (2019). Improving socioeconomic status may reduce the burden of malaria in sub Saharan Africa : A systematic review and meta-analysis, 1–26.

DHS. (2014). *Ghana Demographic and Health Survey*.

Eckert, E., Florey, L. S., Tongren, J. E., Ren, S., Rukundo, A., Habimana, J. P., Karema, C. (2017). Impact Evaluation of Malaria Control Interventions on Morbidity and All-Cause Child Mortality in Rwanda , 2000 – 2010, 97(Suppl 3), 99–110.

<https://doi.org/10.4269/ajtmh.17-0281>

Edwin, M., & Ernest, F. A. (2016). Indoor Residual Spraying (IRS) and Its Impact on Malaria Prevalence in West Africa Using the Panel Data Regression Model, 4(1), 12–20.

<https://doi.org/10.11648/j.sjams.20160401.12>

- Gakpey, K., Baffoe-wilmot, A., Malm, K., Dadzie, S., & Bart-plange, C. (2016). Strategies towards attainment of universal coverage of long lasting insecticide treated nets (LLINs) distribution : experiences and lessons from Ghana. *Parasites & Vectors*, (December). <https://doi.org/10.1186/s13071-016-1328-5>
- Gatton, M. L., Chitnis, N., Churcher, T., Donnelly, M. J., Ghani, A. C., Charles, H. J., Lindsay, S. W. (2013). THE IMPORTANCE OF MOSQUITO BEHAVIORAL ADAPTATIONS TO MALARIA CONTROL IN AFRICA, 1218–1230. <https://doi.org/10.1111/evo.12063>
- Ghana Health Service. (2013). *Ghana Health Service. Ghana malaria programme review final report.*
- Hay, S. I., Omumbo, J. A., Craig, M. H., Snow, R. W., Wellcome, K., & Arma, M. (2011). Europe PMC Funders Group Earth Observation , Geographic Information Systems and Plasmodium falciparum Malaria in Sub-Saharan Africa, 1–40.
- Hershey, C. L., Florey, L. S., Ali, D., Bennett, A., Luhanga, M., Mathanga, D. P., Yazoume, Y. (2017). Malaria Control Interventions Contributed to Declines in Malaria Parasitemia , Severe Anemia , and All-Cause Mortality in Children Less Than 5 Years of Age in Malawi , 2000 – 2010, 97(Suppl 3), 76–88. <https://doi.org/10.4269/ajtmh.17-0203>
- Janko, M. M., Irish, S. R., Reich, B. J., Peterson, M., Doctor, S. M., Mwandagalirwa, M. K., Emch, M. E. (2018). Articles The links between agriculture , Anopheles mosquitoes , and malaria risk in children younger than 5 years in the Democratic Republic of the Congo : a population-based , cross-sectional , spatial study. *The Lancet Planetary Health*, 2(2), e74–e82. [https://doi.org/10.1016/S2542-5196\(18\)30009-3](https://doi.org/10.1016/S2542-5196(18)30009-3)

Kayentao, K., Fo, K., Sinclair, D., Garner, P., Kayentao, K., Fo, K., Garner, P. (2014). any drug regimen versus placebo or no treatment (Review).

<https://doi.org/10.1002/14651858.CD000169.pub3>.www.cochranelibrary.com

Kibret, S., Wilson, G. G., Ryder, D., Tekie, H., & Petros, B. (2019). Environmental and meteorological factors linked to malaria transmission around large dams at three ecological settings in Ethiopia. *Malaria Journal*, 1–16. <https://doi.org/10.1186/s12936-019-2689-y>

Kigozi, R., Baxi, S. M., Gasasira, A., Sserwanga, A., Kakeeto, S., Nasr, S., Dorsey, G. (2012). Indoor Residual Spraying of Insecticide and Malaria Morbidity in a High Transmission Intensity Area of Uganda, 7(8). <https://doi.org/10.1371/journal.pone.0042857>

Koenker, H., Ricotta, E., & Olapeju, B. (2018). ITN Access and Use Report - 2018, (April).

Linden, A. (2017). Conducting interrupted time-series analysis for single- and multiple-group comparisons, (March).

Masaninga, F., Mukumbuta, N., Ndhlovu, K., Hamainza, B., Wamulume, P., Chanda, E., Chizema, E. K. (2018). Insecticide - treated nets mass distribution campaign : benefits and lessons in Zambia. *Malaria Journal*, 1–12. <https://doi.org/10.1186/s12936-018-2314-5>

MICS. (2011). Multiple Indicator Cluster Survey *Final report*.

Mumbengegwi, D. R., Sturrock, H., Hsiang, M., Roberts, K., Kleinschmidt, I., Nghipumbwa, M., Gosling, R. (2018). coverage in western Zambezi region , Namibia ?, I(September 2017).

Ngomane, L. M., Of, M., & In, S. (2012). The impact of indoor residual spraying (IRS) on malaria prevalence between 2001 and 2009 in Mpumalanga province , South Africa

- NMCP. (2016). *2015 ANNUAL REPORT NATIONAL MALARIA CONTROL Centre for Health Information Management*.
- Nonvignon, J., Aryeetey, G. C., Issah, S., Ansah, P., Malm, K. L., Ofosu, W., Aikins, M. (2016). Cost - effectiveness of seasonal malaria chemoprevention in upper west region of Ghana. *Malaria Journal*, 1–13. <https://doi.org/10.1186/s12936-016-1418-z>
- Nonvignon, J., Aryeetey, G. C., Malm, K. L., Agyemang, S. A., Aubyn, V. N. A., Peprah, N. Y., Aikins, M. (2016). Economic burden of malaria on businesses in Ghana : a case for private sector investment in malaria control. *Malaria Journal*, 1–10. <https://doi.org/10.1186/s12936-016-1506-0>
- Oppong, F. B., Gyaase, S., Zandoh, C., Netey, O. E. A., Amenga-etego, S., Anane, E. A., Asante, K. P. (2019). Intermittent preventive treatment of pregnant women in Kintampo area of Ghana with sulphadoxine- pyrimethamine (SP): trends spanning 2011 and 2015. <https://doi.org/10.1136/bmjopen-2018-027946>
- Otten, M., Aregawi, M., Were, W., Karema, C., Medin, A., Bekele, W., Grabowsky, M. (2009). Initial evidence of reduction of malaria cases and deaths in Rwanda and Ethiopia due to rapid scale-up of malaria prevention and treatment, 8, 1–8. <https://doi.org/10.1186/1475-2875-8-14>
- Pluess B, Tanser FC, L. c, & Sharp BL. (2010). Indoor residual spraying for preventing malaria (Review), (4). <https://doi.org/10.1002/14651858.CD006657.pub2>. www.cochranelibrary.com
- PMI, A. (2017). Indoor Residual Spraying (IRS 2) Task Order Six PMI | Africa IRS (AIRS) Project ENTOMOLOGICAL MONITORING OF THE PMI IRS PROGRAM, (Irs 2).

PMI Ghana. (2018). *PRESIDENT ' S MALARIA INITIATIVE GHANA*.

Ranson, H., Guessan, R. N., Lines, J., Moiroux, N., Nkuni, Z., & Corbel, V. (2011). Pyrethroid resistance in African anopheline mosquitoes : what are the implications for malaria control ? *Trends in Parasitology*, 27(2), 91–98. <https://doi.org/10.1016/j.pt.2010.08.004>

Rao, N., & Neelapu, R. (2014). FACTORS AFFECTING MALARIA DISEASE TRANSMISSION AND INCIDENCE : A of Recent Scientific RESEARCH ARTICLE
FACTORS AFFECTING MALARIA DISEASE TRANSMISSION AND INCIDENCE : A SPECIAL FOCUS ON VISAKHAPATNAM DISTRICT, (April).

Raouf, S., Mpimbaza, A., Kigozi, R., Sserwanga, A., Rubahika, D., Katamba, H., Dorsey, G. (2017). Resurgence of Malaria Following Discontinuation of Indoor Residual Spraying of Insecticide in an Area of Uganda With Previously High-Transmission Intensity, 65, 453–460. <https://doi.org/10.1093/cid/cix251>

Ricotta, E., Oppong, S., Yukich, J. O., & Briët, O. J. T. (2019). Determinants of bed net use conditional on access in population surveys in Ghana. *Malaria Journal*, 1–9. <https://doi.org/10.1186/s12936-019-2700-7>

Sicuri, E., Vieta, A., Lindner, L., Constenla, D., & Sauboin, C. (2013). The economic costs of malaria in children in three sub-Saharan countries : Ghana , Tanzania and Kenya, 1–14.

Tukei, B. B., Beke, A., & Figueroa, H. L. (2017). Assessing the effect of indoor residual spraying (IRS) on malaria morbidity in Northern Uganda : a before and after study. *Malaria Journal*, 1–9. <https://doi.org/10.1186/s12936-016-1652-4>

WHO. (2013). *AN OPERATIONAL MANUAL FOR INDOOR RESIDUAL SPRAYING (IRS) FOR MALARIA TRANSMISSION CONTROL AND ELIMINATION.*

WHO. (2015). *AN OPERATIONAL MANUAL FOR INDOOR RESIDUAL SPRAYING (IRS) FOR MALARIA TRANSMISSION CONTROL AND ELIMINATION.*

WHO. (2018). *World malaria report 2018.*

Wilson, A. L., & Taskforce, I. (2011). A Systematic Review and Meta-Analysis of the Efficacy and Safety of Intermittent Preventive Treatment of Malaria in Children (IPTc), 6(2).

<https://doi.org/10.1371/journal.pone.0016976>