AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT

MALARIA EPIDEMIOLOGY AND DYNAMICS IN THE MAMPONG MUNICIPALITY OF GHANA, (2015-2023).

ENOCH OWUSU YEBOAH

2025

AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT

MALARIA EPIDEMIOLOGY AND DYNAMICS IN THE MAMPONG MUNICIPALITY OF GHANA, (2015-2023).

BY

ENOCH OWUSU YEBOAH

(8222030008)

A thesis submitted to the School of Graduate Studies, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development in partial fulfilment of the requirements for the award of a Master of Philosophy degree in Public Health.

MAY, 2025

DECLARATION

Candidate's Declaration

I hereby declare that this thesis, with the exception of quotation and references contained in published works which have been duly acknowledged; is the result of own original work and that no part of it has been presented for another degree in this university or elsewhere.

Enoch Owusu Yeboah

Signature: …………………………………… Date:...………………………………

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on thesis supervision laid down by the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development.

Rev. Dr. Denis Dekugmen Yar (PhD) (Principal Supervisor)

Signature: …………………………………… Date:...………………………………

Dr. Robert Bagngmen Bio (PhD) (Co-Supervisor)

Signature: …………………………………… Date:...………………………………

ABSTRACT

This study examined malaria trends using data from health facilities in the Asante Mampong Municipality of the Ashanti Region, assessing different age groups, genders, and geographical clusters (rural, peri-urban, urban) settings. A retrospective cross-sectional study was employed to analyze the disease trends, patterns, and dynamics in incidence and prevalence and the implications for future malaria control and elimination planning from 2015 to 2023. Results showed that malaria prevalence cumulatively stood at 15.38% and exhibited significant year-on-year increases, with children under five and those aged 5-14 being the most affected groups (29.67% and 32.77%), respectively, far above the national prevalence (8.36%). Malaria prevalence peaked in 2020 (19.73%), with a significant reduction in 2021 (15.70%) and 2022 (14.88%), spiking in 2023 (17.15%). Geographical cluster analysis revealed substantial differences in malaria risk, with towns in the Ejura Cluster (Rural) having the highest relative risk (RR = 10.99), followed by the Kofiase Cluster (Peri-urban) (RR = 5.93) and the Jamasi Cluster (Peri-urban) (RR = 4.22), compared to Mampong Town (Urban) (RR = 1.00), the reference cluster. Gender disparities were also significant, with females showing slightly higher incidence (55.93%) but lower prevalence (12.77%) compared to (20.76%) for males. Seasonal variation analysis indicated higher malaria prevalence during the rainy season (April-July). The findings also revealed a strong association between climate and vegetative factors, topography and human activities, and malaria transmission. A forecast analysis showed a continued upward trend in malaria cases if the current intervention strategies remain unchanged. The model projected an increase in prevalence from 2024 through 2026, estimating values of approximately 18.7%, 19.4%, and 20.1% for these years, respectively. Therefore, enhanced tailored community-based intervention strategies should be deployed to improve access to healthcare, environmental management and vector control initiatives, and targeted interventions for high-risk groups. These findings provide essential data to guide future regional malaria control efforts.

ACKNOWLEDGEMENT

Glory to God Almighty. I am deeply grateful to my supervisors, Rev. Dr. Denis Dekugmen Yar (PhD) and Dr. Robert Bagngmen Bio (PhD), for their invaluable guidance and support throughout my research journey. Their expertise and encouragement have been essential in shaping this thesis, and their constructive feedback and insights have strengthened this work.

I am grateful for the technical assistance provided by the human relations officer and the health information officer at the Mampong Municipal Health Directorate. Their help was instrumental in accessing and cleaning the municipal health records, with the approval of the Municipal Health Director and the Regional Health Director.

Finally, I extend my heartfelt thanks to my family (Timoo, Amonu, El-Macho, & Tres bien) and friends, especially Mr. Samuel A. Ofori and Mr. Denis Bardoe, whose unwavering support and understanding allowed me to dedicate myself to this project. Their encouragement has been a source of motivation and inspiration throughout this journey. Thank you.

DEDICATION

This thesis is dedicated to my parents. By the grace of God, getting me this far hasn't been easy, yet your unwavering support and belief in me have been my constant source of strength and motivation. Furthermore, it may serve as a stepping stone in our shared pursuit of knowledge for my future self, family, and others like me.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS (ABBREVIATIONS)

ACT	Artemisinin-Based Combination Therapy
AIDS	Acquired Immuno-deficiency Syndrome
CHWS	Community Health Worker Support
DHIMS	District Health Information Management System
DHS	Demographic and Health Survey
EST	Ecological Systems Theory
GHS	Ghana Health Service
GIS	Geographic Information System
HBHI	High Burden High Impact
HBM	Health Belief Model
iCCM	Integrated Community Case Management
IPT	Intermittent Preventive Treatment
IRS	Indoor Residual Spraying
ITN	Insecticide Treated Net
IVM	Integrated Vector Management
MOH	Ministry of Health
OPD	Outpatients Department
RDT	Rapid Diagnostic Test
RR	Relative Risk
SARIMA	Seasonal Autoregressive Integrated Moving Average
SEM	Social Ecological Model

SES	Socio-Ecological System
SSA	Sub-Saharan Africa
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Malaria infection persists as a significant worldwide public health problem, responsible for several morbidities, mortality, and substantial economic loss, despite the renewed commitment and implementation of interventions towards elimination and eradication in recent years (Dabaro et al., 2020; Deku et al., 2019; Frank et al., 2016). The global burden of malaria saw a substantial decline, recording a significant decrease in morbidity and mortality rate from 2000 – 2015 (40%), but has since stalled, recording fluctuating rates between 2016 and 2022 (Awine et al., 2017; Ketema et al., 2021; Mao et al., 2023). Nonetheless, progress toward malaria elimination by country status is increasing. In 2021, there were 84 malaria-endemic countries compared with 108 in 2000, a significant reduction that provides hope and encouragement for the future (World Health Organisation (WHO), 2021), evidenced among the malaria-eliminating countries for 2025 [E-2025 countries such as China, Algeria, Kyrgyzstan, Uzbekistan, and Argentina] (WHO, 2023).

The WHO's Global Malaria Program (GMP) serves as the lead technical institution for malaria control and elimination worldwide. It has provided strategic guidance, developed evidence-based policies, and monitored progress toward global targets (WHO, 2023). Central to its work is the implementation of the *Global Technical Strategy for Malaria 2016–2030*, which aims to reduce malaria incidence and mortality by at least 90% by

2030, eliminate malaria in 35 countries, and prevent re-establishment in malaria-free regions (WHO, 2021). The program supports countries in aligning national strategies with global goals while addressing emerging threats such as drug and insecticide resistance and climate-related transmission dynamics (WHO, 2023a).

Nonetheless, there are remarkable regional variations in malaria burden, and it remains a significant public health problem affecting developing countries, Africa bearing the most significant share (WHO, 2023). In 2021, an estimated 247 million malaria cases were recorded among the 84 malaria-endemic countries, an increase from 245 million in 2020, most occurring in the WHO African Region (Hsiang et al., 2013, WHO, 2021).

Ghana, as part of the WHO African Region, is among the 15 highest-burden malaria countries, globally accounting for 4% of malaria cases in West Africa (Doumbe-Belisse et al., 2021; Joseph Osarfo et al., 2022). Malaria is endemic and perennial in Ghana, with pronounced seasonal variations, especially in the northern part of the country, with half of the sixteen regions recording malaria prevalence above 10%. The length of these transmissions varies by geographic region in Ghana (Joseph Osarfo et al., 2022; Shretta et al., 2020). Ghana Demographic and Health Survey (DHS) in 2022 indicated that the prevalence of malaria by microscopy in children aged 6 to 59 months is 8.6%. However, the prevalence of malaria in rural Ghana (12.8%) is about three times higher than that of urban Ghana (4.3%) (Ghana Health Survey, 2023).

In Ghana, the Ghana Malaria Elimination Program (GMEP), formerly the National Malaria Control Program (NMCP) is the principal agency under the Ghana Health Service responsible for national malaria control and elimination efforts. Guided by the *National Malaria Strategic Plan 2021–2025*, the program aims to attain pre-elimination status by 2025 and full elimination by 2030 (GHS, 2021). GMEP deploys a combination of interventions including mass distribution of insecticide-treated nets (ITNs), indoor residual spraying (IRS), intermittent preventive treatment for vulnerable groups, and the use of artemisinin-based combination therapies (ACTs). Emphasis is also placed on strengthening health systems, improving surveillance and data use, and tailoring interventions to regional transmission patterns, particularly in high-burden rural and peri-urban settings (GHS, 2021; WHO, 2023b).

Overall, records in the District Health Information Management System (DHIMS) have shown a decline in the total number of Outpatient Department (OPD) malaria cases from 6.1 million in 2019 to 5.2 million in 2022, in which eight in every ten districts have more than 10,000 OPD malaria cases (Ghana Statistical Service, 2023). With these figures, specific vector distributions, the rapid evolution of the insect, anti-malaria drug resistance, climate change and the discovery of the new vector species (*Anopheles stephensi*) in Ghana pose a significant public health threat, reversing years of progress and informing the current case dynamics and varying results (Nolen, 2023; WHO, 2021).

1.2 Statement of Problem

Malaria remains a significant public health challenge in Ghana despite ongoing elimination efforts by the government through the Ministry of Health (MOH) and the Ghana Health Service (GHS) in collaboration with the WHO. The WHO Global Malaria Program and the Ghana Malaria Elimination Program aim to eliminate malaria by 2030. However, the feasibility of this current trajectory of malaria elimination locally is uncertain, with success hanging by a thread due to several factors and potential drawbacks (Kaehler et al., 2019; WHO, 2021; Yaro et al., 2021). Although Ghana is amongst the highest-burden malaria nations, local and sub-district epidemiological studies are limited in the literature to ascertain the current malaria elimination status. Moreover, there are limited epidemiological studies in the Mampong Municipality in particular. This thus calls for a study to understand the current status of the national and local malaria elimination program, its current trajectory, and to best forecast local prevalence and disease burden using the municipality's unique climate and topography in the region. These studies are crucial for describing and analyzing trends, making informed projections about future malaria cases, and filling the gap in literature.

1.3 Objectives of the Study

The main aim of this study was to determine malaria epidemiology, trends and dynamics in the Mampong Municipality and its implications for future malaria control and elimination program.

1.3.1 Specific Objectives

1. To describe the epidemiological characteristics of malaria in the municipality from 2015 to 2023.
2. To evaluate malaria trends and dynamics as a proxy for the effectiveness of control interventions for 2015 to 2023.
3. To forecast future trends of malaria prevalence in the municipality.

1.4 Research Questions

1. What is the prevalence of malaria and associated demographic characteristics in the municipality from 2015 to 2023?
2. How effective are malaria control interventions in reducing malaria over the years in the municipality?
3. What are the projected trends in malaria prevalence in the municipality?

1.5 Research Hypothesis

Null Hypothesis (H_o):

There was no significant change in malaria prevalence in the Mampong Municipality from 2015 to 2023, and future trends do not indicate a decline, suggesting no measurable impact.

Alternative Hypothesis (H_1):

Malaria prevalence in the Mampong Municipality significantly decreased from 2015 to 2023, with epidemiological trends projecting a continued decline in future prevalence.

1.6 Justification of the Study

Malaria remains a significant public health challenge, particularly in tropical and subtropical regions. Understanding the epidemiology of malaria is crucial for designing targeted interventions and monitoring progress towards the global health community's malaria control and elimination goals. A retrospective cross-sectional study examining the epidemiology and dynamics of malaria in the Mampong Municipality over nine years (2015-2023) offers a critical evaluation of the progress made towards malaria elimination. Such studies help measure the effectiveness of current interventions and guide future efforts through disease mapping, trend analysis, and predictive modelling. This study therefore would analyze cumulative data on malaria incidences and prevalence, understanding the spatial and demographic patterns of malaria cases in the Mampong Municipality. This would be better clue to know the progress of the Malaria Elimination Program. The findings would provide valuable insights into targeted malaria prevention, control, deployment of resources, interventional and elimination strategies applicable to similar regions in Ghana. Thus, contributing to the overall goal of malaria eradication. The data available and results generated will inform the development of a predictive model for better surveillance and control strategies to combat the disease effectively and efficiently in the future.

1.7 Significance of the Study

This study improves the understanding of malaria trends and transmission dynamics within the Mampong Municipality. By analyzing data from 2015 to 2023, the study provides critical insights into the temporal and spatial patterns of malaria incidence and prevalence, highlighting the influence of local demographic, geographic, and environmental factors. Understanding these patterns is essential for evaluating the effectiveness of existing control interventions and informing the design of a more targeted strategy. The findings also offer evidence-based guidance for local policymakers and public health practitioners, contributing to more effective malaria control and elimination efforts. Moreover, the study fills a vital knowledge gap in the literature by documenting the progress of malaria elimination at the sub-national level, serving as a valuable reference for similar epidemiological studies in other regions.

1.8 Scope of the Study

This study comprehensively analyzed malaria epidemiology and control interventions in the Mampong Municipality from 2015 to 2023. With three primary objectives, the scope includes: Firstly, epidemiological characteristics of malaria were described, including incidence, prevalence, and demographic distribution of cases. Secondly, a trend analysis was done to examine changes in malaria incidence and prevalence over the study period. Using a spatial distribution map, the geographic distribution of malaria cases at the municipal level identified high-risk areas. Thirdly, it forecasted future trends in malaria incidence and prevalence.

1.9 Limitations of the Study

The study was limited by some missing data points, including a well-documented coverage of the different malaria control interventions over the period, and the availability of data only from 2015 to 2023. Additionally, there was no accurate and specific data points on the climate and weather of the municipality for the study period, limiting the association of case and prevalence to climate change. In contrast, the analysis was constrained to the Mampong Municipality, potentially limiting the generalizability of the findings to other regions with different ecological and socio-economic factors. That notwithstanding, adequate measures for data cleaning, imputations, and adjustments were carefully undertaken for a standardized analysis and to enhance the robustness of the results.

1.10 Thesis Organization

The study is structured into six chapters to provide a coherent exploration of the research topic. Chapter One introduces the study, outlining the background, problem statement, objectives, research questions, study hypothesis, justification, study significance, scope of the study, study limitations, and organizational structure. Chapter Two presents a relevant literature review related to this research topic thoroughly examined. Discussing theoretical frameworks related malaria epidemiology and dynamics in a developing country and in the local context. Chapter Three details the methodology, including the study design, study area and population, data collection and analysis plan. Chapter Four presents the results from data analysis. Chapter Five offers a discussion, interpreting the results, and comparing them with existing literature. Finally, Chapter Six concludes the study, summarizing key findings and providing recommendations for stakeholders and suggestions for future research.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

Malaria remains a global health issue, particularly affecting tropical and subtropical regions, mainly in Africa. Despite numerous efforts to control and eliminate the disease, several challenges impede progress.

According to the World Malaria Report 2023 by the WHO, there were an estimated 247 million malaria cases worldwide in 2022, resulting in approximately 619,000 deaths. Most of these cases and deaths occur in Sub-Saharan Africa (SSA), where children under five years old are specifically vulnerable. The report highlights several key issues, including climate change, conflict, and resistance to drugs and insecticides, which hinder efforts to combat malaria effectively (Benjamin et al., 2023; Ketema et al., 2021; WHO, 2023).

A study in Uganda demonstrated that improved housing can significantly reduce malaria transmission by limiting mosquito entry, underscoring the importance of environmental and infrastructural interventions in malaria control strategies (Epstein et al., 2025; Okiring et al., 2024). In Ethiopia, several studies have reported similar patterns and trends; a five-year surveillance data analysis revealed persistent malaria transmission, highlighting the need for continuous monitoring and adaptive strategies to address changing patterns of malaria spread (Dabaro et al., 2020; Solomon et al., 2020; Tesfa et al., 2018). Furthermore, research in Mali explored the relationship between nutritional status and malaria in children, suggesting that malnutrition may exacerbate the risk and severity of malaria episodes; thus, integrating nutritional support with malaria control could be beneficial (Anwar et al., 2019; Konaté et al., 2020; Touré et al., 2022). Efforts to eliminate malaria now include innovative approaches like the Malakit intervention, which provides malaria testing and treatment kits to remote populations not reached by the healthcare system, ensuring broader coverage and timely treatment (Douine et al., 2023; Sanna et al., 2024).

Overall, while significant progress has been made in reducing the global burden of malaria, the disease remains a public health challenge (Liu et al., 2021). Continued investment in research, healthcare infrastructure, and innovative solutions is crucial to achieving long-term malaria control and eventual eradication (Boyce et al., 2021).

2.1 Conceptual Review

The conceptual framework for measuring and evaluating malaria trends and dynamics in line with the epidemiological study from 2015 to 2023 integrates various theoretical and empirical insights from public health, socioeconomics, and environmental science (Athirah Naserrudin et al., 2022). Acknowledging these key concepts, theories, and relationships underpinning the study provides a structured approach to understanding and analyzing the multifaceted nature of malaria control (Savi et al., 2021). In addition, several concepts and theories address public health concerns, vector-borne infectious diseases, and health behaviour concerns, which are all inclusive in malaria epidemiology

(Athirah Naserrudin et al., 2022). However, the stated objectives of this study permit the discussion of only a few of these concepts. Taking into consideration **Malaria Control Interventions:** Insecticide-Treated Nets (ITNs), Indoor Residual Spraying (IRS), Rapid Diagnostic Tests (RDTs), and Artemisinin-Based Combination Therapies (ACTs) (Taffese et al., 2018). **Intervention Coverage, Effectiveness, and Utilization:** The extent to which malaria control measures are distributed and used by the target population (K Galactionova et al., 2015). **Socioeconomic and Environmental Determinants:** Factors such as poverty, education, housing quality, climate change, and migration patterns influence malaria transmission and the effectiveness of control measures (Rouamba et al., 2019). **Health Systems Strengthening:** Building robust health systems that can support the delivery and sustainability of malaria interventions, including healthcare infrastructure, workforce, and supply chains (Lourenço et. al. 2019, Sahu et. al. 2020). **Community Engagements and Behavioral Change:** Involving the community in malaria control efforts through educational campaigns to increase knowledge about malaria prevention and treatment. Such initiatives aim to promote behaviours that reduce malaria transmission, such as consistently using bed nets and seeking timely medical care (Baltzell et. al. 2019, Awasthi et. al. 2021). **Monitoring and Surveillance:** Building systems for tracking malaria cases and intervention outcomes. Thus, collecting and analyzing data on malaria incidence, prevalence, and mortality (Lourenço et. al. 2019).

Collectively, these concepts can be visualized as Inputs (Implementation of ITNs, IRS, RDTs, and ACTs, Socioeconomic data, Environmental data), Processes (Distribution and coverage of interventions, community education and engagement effort), Outputs (Utilization rates of malaria interventions, community behavior changes regarding malaria prevention and treatment), and Outcomes (changes in malaria incidence and mortality rates, improved overall public health and economic productivity) (Hasyim et. al. 2024).

Over the years, these key concepts addressing malaria epidemiology in endemic, developing countries have evolved significantly due to advancements in scientific understanding, technology and public health strategies (Parkhurst et. al. 2021; WHO, 2021). Considering socioeconomic and environmental factors, we no longer consider the basic role of water bodies in mosquito breeding, but are now implementing environmental management strategies, leveraging climate and environmental data for predictive modelling to pre-emptively tackle malaria outbreaks (Ryan et al., 2023).

This study, therefore, provides a comprehensive framework for understanding the trend and patterns together with the unique dynamics accompanied with malaria epidemiology in the municipality. These concepts integrate with empirical data and guide the study in understanding the complex interactions between interventions, socioeconomic and environmental factors, and malaria outcomes. This structured approach ensures a holistic evaluation of the efforts made to combat malaria from 2015 to 2023, ultimately contributing to the goal of reducing the malaria burden in the municipality.

2.2 Conceptual Framework

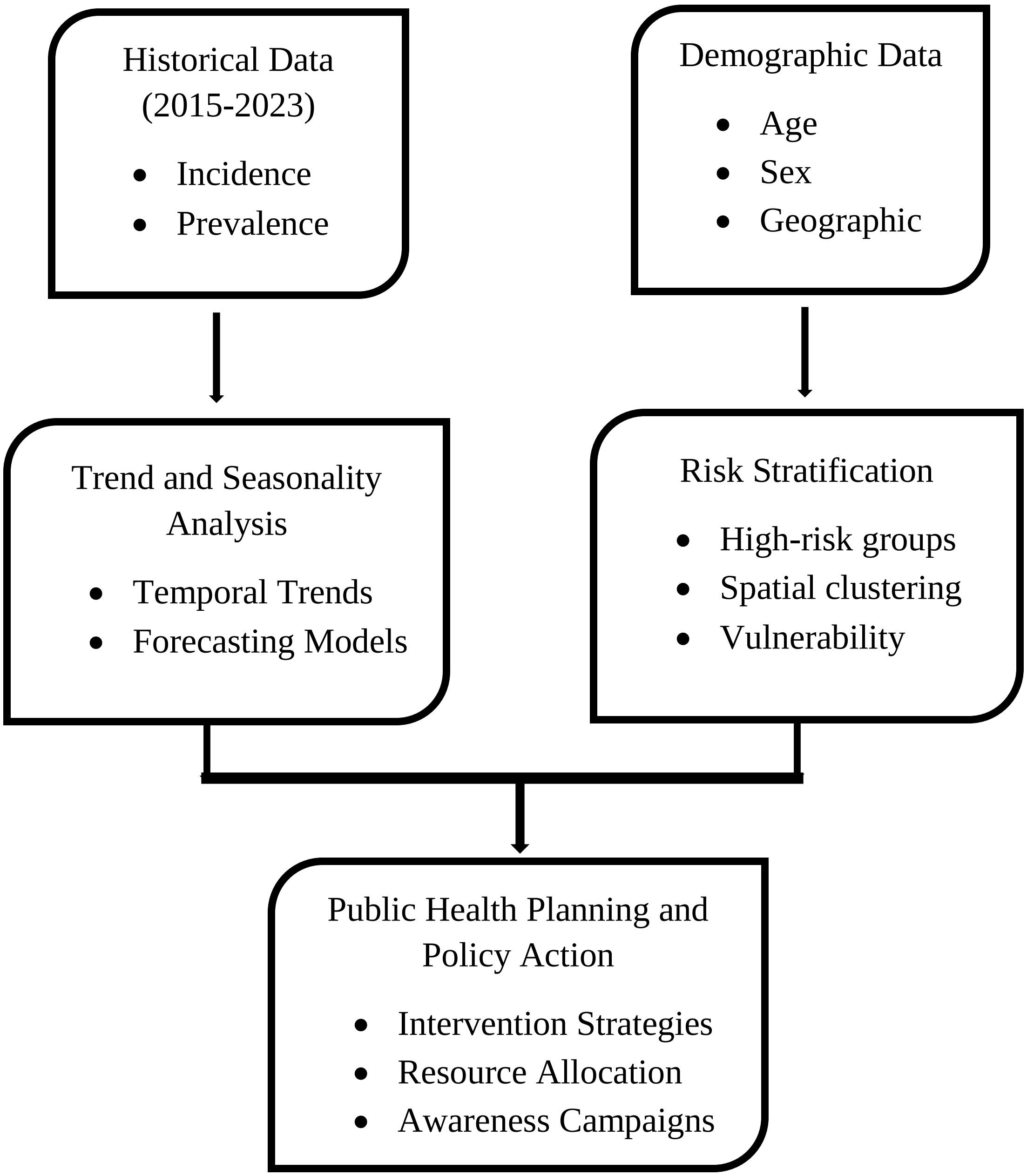


Figure 2.1: Author's construct; Integrated Epidemiological-Demographic Framework for Trend Analysis and Forecasting of Malaria

The conceptual framework is grounded in an integrated epidemiological modeling approach, which combines elements from epidemiology, demography, and forecasting theory. The framework consists of four interconnected components:

1. Disease Surveillance and Historical Trend Analysis: It uses retrospective epidemiological data to identify patterns, seasonal variations, and temporal trends. Informed by **Time Series Epidemiology** and **Public Health Surveillance Theory**.
2. Demographic Determinants and Risk Stratification: This integrates population-based variables such as age, sex, location, and socio-economic status to understand group-specific vulnerabilities. It also draws on **Population Health Theory** and **Social Determinants of Health Framework**.
3. Statistical Modeling and Forecasting: It employs statistical models (Holt-Winter's Exponential Smoothing) to forecast future malaria cases based on past trends and seasonality. Underpinned by **Forecasting Theory** and **Stochastic Process Theory**.
4. Public Health Response and Policy Implication: Provides evidence-based projections to guide malaria control interventions, resource allocation, and health system planning, aligned with **Health Systems Strengthening** and **Decision Theory in Public Health**.

This conceptual framework equips the study with a robust and multidisciplinary lens through which malaria epidemiology in Mampong Municipality can be examined. It allows for a comprehensive analysis of past patterns, demographic influences, and future scenarios, ensuring that findings are not only descriptive but also predictive and policy-relevant.

The integration of demographic analysis, and public health systems thinking ensures that the research aligns with national and global malaria control strategies and contributes meaningfully to the knowledge base for malaria elimination.

2.3 Theoretical Review

In recent times, several theoretical frameworks have been employed to approach malaria epidemiology, particularly in underdeveloped and endemic regions (Naserrudin et. al. 2022). These frameworks integrate various disciplines including public health, epidemiology, sociology, and environmental science (Naserrudin et. al. 2022). Among these is the Social Ecological Model (SEM), which considers multiple levels of influence on health behaviors and outcomes, such as individual level, interpersonal level, community level, institutional level, and policy level (Uchendu, C., Windle, R., & Blake, H. 2020; Lee, Y., & Park, S. 2021). The Diffusion of Innovations Theory: used to understand how new malaria control interventions (e.g., long-lasting insecticidal nets, rapid diagnostic tests) are adopted within communities (Dearing, J. W., & Cox, J. G. 2018). The Integrated Vector Management (IVM) Framework: promotes the coordinated use of multiple vector methods based on local context (Chanda et. al. 2017). The Health Systems Strengthening Framework: emphasizes improving the overall health system to enhance malaria control efforts (AlJaberi, O. A., Hussain, M., & Drake, P. R. 2020, Sahu et. al. 2020). The Climate and Health Framework: examines the impact of climate change and environmental factors on malaria transmission (Boylan et. al 2018), and The Socio-Ecological Systems (SES) Framework: explores the interactions between human and environmental systems (Berrouet, L. M., Machado, J., & Villegas-Palacio, C. 2018).

These theoretical frameworks provide a comprehensive approach to understanding and addressing malaria epidemiology in underdeveloped, endemic regions. They emphasize the importance of considering multiple factors and levels of influence, integrating scientific knowledge with community engagements and policy support. By using these frameworks, researchers and practitioners can and have develop more effective and sustainable strategies for malaria control and prevention (Katya Galactionova et al., 2015; Savi et al., 2021).

2.3.1 Theoretical Underpinnings for the Conceptual Framework

Understanding the epidemiology, trends, and future burden of malaria requires a multidimensional conceptual approach. This study adopts an integrated framework that combines epidemiological theory, statistical modeling, demographic analysis, and public health decision-making to explore the historical and future dynamics of malaria in the Mampong Municipality. The framework is anchored in both classical and contemporary theories to support the study’s core objectives: describing malaria patterns, evaluating temporal dynamics, and projecting future prevalence for informed control and elimination strategies.

Time Series Epidemiology and Public Health Surveillance Theory

Aligned with Objective 1 and Objective 2, time series epidemiology enables the study of temporal patterns, seasonality, and long-term trends in malaria incidence from 2015 to 2023. This approach supports the identification of epidemiological shifts and peak transmission periods, which are essential for evaluating intervention effectiveness. **Public Health Surveillance Theory** provides the basis for systematically collecting, analyzing, and interpreting malaria data over time. It reinforces the study's foundation by ensuring that retrospective surveillance records are used not just descriptively, but analytically, to infer the performance of malaria control strategies within the municipality. These frameworks directly contribute to Objective 1 by offering tools to describe the epidemiological characteristics of malaria (e.g., incidence rates, seasonal peaks, and mortality), and to Objective 2 by supporting the evaluation of control efforts based on observed changes in trends.

Population Health Theory and the Social Determinants of Health Framework

To contextualize malaria patterns within the broader demographic and social environment, the study incorporates Population Health Theory and the Social Determinants of Health (SDH) Framework. These perspectives are critical in interpreting the role of age, sex, geography, sanitation, and socio-economic conditions on malaria outcomes.

By integrating demographic variables, the study recognizes that malaria is not only biologically driven but also shaped by systemic inequities and living conditions, such as access to healthcare or vector exposure due to geography or land use in the broader sense. These frameworks underpin Objective 1 by explaining the differential distribution of malaria cases across population subgroups, thus offering a nuanced understanding of malaria epidemiology beyond simple incidence figures.

Forecasting Theory and Stochastic Process Theory

Objective 3 requires predictive capacity. Forecasting Theory provides the methodological foundation for projecting malaria prevalence using historical data. Techniques such as Exponential Smoothing will be applied to generate future estimates of malaria cases in the municipality.

Complementing this, Stochastic Process Theory models the randomness and uncertainty in disease transmission, accounting for environmental variability, vector behavior, and human interactions. This allows the forecasting model to incorporate uncertainty and risk, which is particularly relevant in dynamic settings like malaria-endemic regions. These theories are crucial for Objective 3, which seeks to forecast malaria prevalence and inform anticipatory planning. The insights derived support timely interventions and strategic resource allocation.

Health Systems Strengthening and Decision Theory in Public Health

While not explicitly stated in the objectives, the implications of this study are meant to guide future malaria control and elimination programs. Therefore, the conceptual framework also integrates Health Systems Strengthening (HSS) and Decision Theory to translate findings into actionable public health policy.

HSS focuses on ensuring that core functions, such as data systems, supply chains, trained workforce, and financing are capable of implementing adaptive malaria interventions. Whereas Decision Theory supports optimal policy choices by applying logic, evidence, and probabilistic reasoning to select interventions with the highest expected utility (e.g., targeted indoor residual spraying vs. mass net distribution).

These theories provide the foundation for translating the findings from Objectives 1–3 into programmatic recommendations, ensuring that evidence from surveillance and modeling is actionable.

2.4 Empirical Review

2.4.1 Epidemiology: Concept and Scope in the Malaria Research

Epidemiology, as a core discipline of public health, focuses on the systematic analysis of the patterns and determinants of diseases in human populations. It serves as both a theoretical and practical tool for disease prevention and control. Classically defined as: "The study of the distribution and determinants of health-related states or events in specified populations, and the application of this study to the control of health problems"

(WHO, 2021). Moreso, it is a foundational discipline in public health that involves the systematic study of the distribution and determinants of health-related states or events in specified populations, and the application of this study to control health problems (Centers for Disease Control and Prevention [CDC], 2021).

According to Rothman et al. (2021), modern epidemiology has evolved to incorporate both traditional risk factor analysis and advanced modeling tools, allowing for more precise and timely responses to disease outbreaks. It has expanded to integrate molecular, genetic, and social determinants, allowing for a more holistic approach to disease control. Especially in sub-Saharan Africa where climatic and ecological conditions favor year-round transmission. A 2023 study by Kumar et al. used spatial epidemiology to analyze malaria trends in sub-Saharan Africa and demonstrated how geographic information systems (GIS) can improve targeted vector control strategies. To effectively address the burden of malaria, public health researchers and practitioners rely on the science of epidemiology. In the context of malaria, this involves investigating the patterns of disease occurrence, risk factors, and evaluating control measures such as insecticide-treated nets, antimalarial drugs, and vector control programs.

According to Guerra et al. (2024), integrating real-time climate and land-use data can enhance malaria early warning systems. Additionally, the COVID-19 pandemic underscored the need for resilient health systems and reinforced the critical role of epidemiology in managing co-epidemics and maintaining surveillance (WHO, 2022).

The relevance of epidemiology to malaria control cannot be overemphasized. It provides the foundation for understanding who is affected, when, where, and why, and for assessing the effectiveness of interventions over time. With advances in geospatial technologies, molecular biology, and climate modeling, epidemiology now plays an even more critical role in informing targeted interventions and malaria elimination strategies (Kumar et al., 2023; Guerra et al., 2024). Thus, this research applies epidemiological principles to assess malaria trends, risk factors, and control measures in the Mampong Municipality.

2.4.2 Epidemiology of Malaria

Efforts to combat malaria on a global scale have included widespread distribution of insecticide-treated bed nets (ITNs), indoor residual spraying (IRS), and the introduction of artemisinin-based combination therapies (ACTs) (Bhatt et al., 2015). These interventions have contributed to a 40% decline in global malaria mortality rates since 2000 (WHO, 2020). However, the emergence of drug-resistant malaria strains and insecticide-resistant mosquito vectors poses significant challenges to sustained progress (Nwe et al., 2017).

The WHO has consistently reported on the global burden of malaria. There were an estimated 207 million cases of malaria in 2012, and 77% occurred in children under five (WHO, 2013). In 2015, the WHO reported 212 million new cases of malaria worldwide (WHO, 2015). By 2019, this number had increased to an estimated 229 million malaria cases, with 409,000 deaths globally (WHO, 2020). The upward trend continued, and in

2020, there were 245 million recorded cases of malaria. This number increased to 247 million cases in 2021 (WHO, 2022). These statistics further highlight the persistent and growing challenge of malaria, particularly in regions like sub-Saharan Africa (SSA).

Africa continues to be the epicenter of malaria transmission, accounting for approximately 94% of all malaria cases and deaths globally (WHO, 2020). Countries such as Nigeria, the Democratic Republic of the Congo, and Uganda have some of the highest malaria burdens. In these regions, children under five and pregnant women are the most vulnerable (Snow et al., 2017).

Recent studies highlight the variability in malaria transmission across different African regions, influenced by factors such as climate, topography, and human behavior (Cibulskis et al., 2016, Ryan et. al. 2020, Villena et. al. 2024). For example, West Africa experiences intense seasonal transmission corresponding with the rainy season, while parts of East Africa, such as the highlands, have lower transmission rates due to cooler temperatures and less favorable breeding conditions for mosquitoes (Sherrard-Smith et al., 2019). Ghana, being a malaria-endemic country, has witnessed significant shifts in malaria infection patterns over the past decade. The trends and dynamics of malaria in Ghana are influenced by various factors including climate change, healthcare interventions, and socio-economic conditions (Awine et al., 2017; Bempah et al., 2020; Boadu et al., 2020).

2.4.3 Trends and Dynamics of Malaria Cases:

The trends in malaria infections, including incidence and prevalence, mortality rates, and seasonal variations, paint a complex and concerning picture but also provides essential insights into the evolving dynamics of this disease (Dabaro et al., 2020; Katya Galactionova et al., 2017; Savi et al., 2021). The documented global trend of malaria reveals some alarming curves over the past decade, underscoring the persistent and escalating challenge posed by malaria, despite significant advancements in malaria control (Deku et al., 2019). Similarly, the trends and dynamics of malaria infection in Ghana over the past decade reflect both progress and ongoing challenges (Joseph Osarfo et al., 2022).

2.4.3.1 Global Trends and Dynamics

The global and regional dynamics of malaria are increasingly shaped by environmental, biological, and socio-political factors. Malaria continues to pose a substantial threat to public health globally, particularly in low- and middle-income countries. Despite decades of control efforts, recent data show a troubling resurgence in malaria incidence in many parts of the world. According to the WHO (WHO, 2023), there were an estimated 263 million malaria cases worldwide in 2023, representing an increase of approximately 11 million cases compared to the previous year. Malaria-related deaths were estimated at 597,000, highlighting the continuing high disease burden globally despite the availability of preventive and curative interventions.

Several factors are driving these trends. First, climate change has been identified as a critical determinant of malaria transmission. Rising temperatures, altered precipitation patterns, and expanding mosquito habitats are contributing to increased malaria transmission in previously non-endemic areas (El-Sayed & Kamel, 2020; Jabeen et al., 2022). Second, **drug and insecticide resistance** pose a growing challenge, especially the emergence of *Plasmodium falciparum* strains resistant to artemisinin-based therapies and the spread of insecticide-resistant mosquito vectors (Basu et al., 2017). Third, **funding shortfalls** continue to hinder control efforts; in 2023, malaria control programs received only $4 billion globally, less than half of the $8.3 billion estimated to be needed for effective control (WHO, 2023).

2.4.3.2 Sub-Saharan Africa Trends and Dynamics

In sub-Saharan Africa, which bears the greatest share of the malaria burden, these challenges are even more pronounced. The region accounted for approximately 94% of all global malaria cases and 95% of deaths in 2023 (WHO, 2023). The high transmission intensity is partly attributed to a combination of climatic suitability, weak health infrastructure, poverty, and limited access to effective malaria interventions (Benjamin et al., 2023). Children under five years remain the most vulnerable population, with malaria being a leading cause of mortality among this group. Furthermore, the spread of *Anopheles stephensi*, a mosquito species adapted to urban environments, has further complicated urban malaria control (El-Sayed & Kamel, 2020).

2.4.3.3 Malaria in Ghana: Trends and Dynamics

In early 2017, Ghana recorded 2.3 million malaria cases, which was a 1.5% increase from the same period in 2016 (Anaba et. al. 2019). By 2018, Ghana was among the African countries with the highest jump in malaria cases, with an 8% rise from the previous year (WHO, 2019). In response, the country became one of the ten African nations supported by the WHO's High Burden to High Impact (HBHI) approach, aimed at improving malaria control and eventually eliminating the disease (WHO, 2024). To combat malaria, Ghana joined the African Union's "Zero Malaria Starts with Me" campaign in 2019 (Sarpong et. al. 2022). This initiative involved working with parliament members, increasing private sector involvement, using local funds more efficiently, and tracking progress through a national malaria scorecard (Sarpong et. al. 2022). Thanks to these efforts, malaria incidence rates have dropped significantly in recent years, from 375 cases per 1,000 people in 2011 to 158.8 in 2022 (WHO, 2022).

In Ghana, significant progress has been made in reducing malaria morbidity and mortality over the past decade (Osarfo et al., 2022). Nationally, the malaria mortality rate declined from 2,799 deaths in 2012 to 151 in 2022, while malaria prevalence among children under five dropped from 27.5% in 2011 to 8.6% in 2022 (Ghana Health Service (GHS), 2023; WHO, 2023). Key interventions include the nationwide distribution of long-lasting insecticidal nets (LLINs), seasonal malaria chemoprevention (SMC), prompt diagnosis and treatment with artemisinin-based combination therapies (ACTs), and indoor residual spraying in selected districts. Additionally, Ghana was among the first countries to pilot the RTS,S/AS01 (Mosquirix) malaria vaccine, which has contributed to a measurable reduction in malaria incidence among young children (Cowman et al., 2016; K Galactionova et al., 2017).

Nonetheless, malaria remains a significant cause of morbidity and mortality with several other challenges. (Kolekang et. al. 2022). While LLIN ownership is relatively high, actual utilization remains suboptimal, largely due to behavioral and environmental factors (GHS, 2023). Regions, municipals and districts across the country still face enormous challenges in fighting the disease (Kolekang et. al. 2022), largely due to the disproportionate access to resources, unique weather and climatic conditions and socio-economic and cultural influences (Osarfo et al., 2022). Urban malaria is also on the rise, partly due to population density, inadequate drainage systems, and poor urban planning. The emergence of insecticide resistance in local *Anopheles* populations further underscores the need for integrated vector management approaches. While Ghana's efforts have yielded commendable results, sustained progress will depend on continuous investment, innovation in control strategies, and effective adaptation to emerging threats such as climate variability and urban transmission. This breakdown, highlights the individual battles each region, municipal, district, and health facility faces in eliminating malaria (Awine et al., 2017).

2.4.4 Incidence and Prevalence

Recording the number of new and persistent cases, the incidence and prevalence of malaria have shown worrying trends over the past decade, with data from the WHO's report from 2013 to 2023. These figures highlight the persistent challenge malaria poses and underscore the need for sustained intervention efforts.

Recent studies corroborate these findings. Oladipo et. al. (2022) and Sarpong et. al. (2022) demonstrated that despite significant reductions in malaria incidence in some regions, overall global prevalence has not declined at a comparable rate, primarily due to high transmission rates in sub-Saharan Africa (SSA). Similarly, Gething et al. (2016) noted that while some countries have made substantial progress, malaria prevalence remains high in areas with inadequate healthcare infrastructure and vector control measures.

In 2022, Ghana reported over 5.2 million confirmed malaria cases, a decrease from 6.1 million in 2019. The national malaria prevalence declined from 14.1% in 2019 to 8.6% in 2022. Children under five years old are particularly affected, with a prevalence rate of 8.6% in 2022, down from 26.7% in 2014. Rural areas experience higher prevalence rates (12.8%) compared to urban areas (4.3%). Regionally, the Oti Region recorded the highest prevalence at 15.0%, while the Greater Accra Region had the lowest at 2.0% (Aidoo et. al. 2024).

2.4.5 Mortality Rates

Malaria-related mortality rates have also exhibited concerning trends. In 2019, the WHO reported 409,000 deaths globally due to malaria (WHO, 2020). This figure, while slightly lower than in previous years, still represents a significant burden. SSA accounts for the majority of these deaths, reflecting the region's high transmission rates and the vulnerability of its population, particularly children under five and pregnant women (WHO, 2023).

Efforts to reduce malaria mortality have seen mixed results. According to WHO (2022), the number of deaths increased slightly in 2020 and 2021, correlating with the rise in incidence. This increase may be attributed to disruptions in malaria control programs due to the COVID-19 pandemic, which hampered access to preventive measures and treatments (Sherrard-Smith et al., 2020). Studies by Weiss et al. (2019) and Battle et al. (2019) emphasize the importance of sustained investment in healthcare infrastructure and the development of new interventions to reduce mortality rates effectively.

Malaria-related deaths have significantly decreased over the past decade in Ghana. In 2012, there were 2,799 reported deaths, which declined to 151 in 2022, representing a 95% reduction. This improvement is attributed to enhanced interventions, including the introduction of the RTS,S/AS01 malaria vaccine, distribution of insecticide-treated nets, indoor residual spraying, and improved case management (Peprah et. al. 2024).

2.4.5 Seasonal Variations

Seasonal variation is a critical dimension of malaria epidemiology, particularly in regions where transmission is not perennial but follows distinct climatic patterns (Donkor et al., 2021). In such areas, malaria cases often peak during and shortly after the rainy season, corresponding to increased vector breeding and survival (Kawaguchi et al., 2022).

Accurately measuring and analyzing these seasonal trends is essential for designing timely and effective interventions, such as SMC and IRS.

Malaria transmission is highly sensitive to environmental and climatic variables, particularly rainfall, temperature, and humidity, which directly influence mosquito vector abundance and parasite development (Midekisa et al., 2015). In sub-Saharan Africa and similar tropical regions, these seasonal factors lead to marked fluctuations in transmission intensity, which must be considered in surveillance and intervention planning (Caminade et al., 2014).

Seasonal variations significantly influence malaria transmission dynamics (Adetokunboh et al., 2021; Doumbe-Belisse et al., 2021). Malaria incidence often peaks during rainy seasons when mosquito breeding sites proliferate. For instance, in many parts of Sub-Saharan Africa, the highest transmission rates occur during and after the rainy season, which can last from several weeks to several months, depending on the region (Benjamin et al., 2023).

Research indicates that climate change and environmental modifications are altering these seasonal patterns. Parham and Michael (2010) found that rising temperatures and changing precipitation patterns are extending the transmission season in some areas, potentially increasing the burden of malaria. Furthermore, studies by Caminade et al. (2014) and Paaijmans et al. (2010) suggest that these climatic changes may lead to malaria transmission in previously unaffected regions, complicating eradication efforts.

2.4.6 Risk Factors for Malaria Transmission

While biological factors and climate conditions play significant roles in malaria transmission, anthropogenic activities and topography are also critical determinants. The impact of human activities and geographical features on malaria transmission (Rouamba et. al. 2019).

2.4.6.1 Anthropogenic Activities

Anthropogenic activities significantly influence malaria transmission dynamics. Human actions such as deforestation, agricultural practices, urbanization, and mining create environments conducive to mosquito breeding, thereby increasing malaria risk (Rouamba et. al. 2019).

Deforestation: Deforestation is a well-documented factor that alters local ecosystems and facilitates malaria transmission. The removal of forest cover changes the microclimate and creates breeding sites for Anopheles mosquitoes, the primary vectors of malaria. A study by Myers et al. (2017) indicate that deforestation leads to increased mosquito populations and higher malaria transmission rates. These studies highlight that areas experiencing rapid deforestation often see a concomitant rise in malaria incidence.

Agricultural Practices: Agricultural activities, particularly those involving irrigation and water storage, can significantly impact malaria transmission (Fornace et. al. 2021). Irrigated fields and water reservoirs create breeding grounds for mosquitoes. Research by

Fornace et. al. (2021) demonstrates that agricultural irrigation schemes have led to a notable increase in malaria cases due to the abundance of water sources.

Urbanization: Urbanization and the expansion of human settlements also play a crucial role in malaria dynamics. Urban areas can provide both challenges and opportunities for malaria control. While improved infrastructure and healthcare can reduce malaria incidence, poor urban planning and inadequate drainage systems can create mosquito breeding habitats. This unplanned urbanization, particularly in developing countries, often leads to increased malaria risk due to poor sanitation and water management (Doumbe-Belisse et al., 2021; Frank et al., 2016).

Mining: Mining activities, especially in remote and forested areas, are associated with increased malaria transmission. Mining operations often involve water storage and excavation, creating breeding sites for mosquitoes. Additionally, mining workers may come from malaria-endemic regions, bringing the disease with them and facilitating its spread.

2.4.6.2 Topography

Topography, or the physical features of a landscape, plays a crucial role in malaria transmission by influencing climate, vegetation, and human habitation patterns. Variations in altitude, slope, and landforms can create diverse microenvironments that affect mosquito breeding and survival.

Altitude: Altitude is a significant determinant of malaria risk. Higher altitudes generally have lower temperatures, which can inhibit mosquito development and reduce malaria transmission (Dabaro et al., 2020). However, climate change is causing temperatures to rise, allowing mosquitoes to survive at higher altitudes. Malaria transmission is occurring at altitudes previously considered too cold for mosquito survival, particularly in the East African highlands (Sarkar et al., 2019).

Slope and Drainage: The slope of the land affects water drainage and the formation of mosquito breeding sites. Flat and poorly drained areas are more likely to harbor stagnant water, providing ideal conditions for mosquito breeding. Regions with poor drainage and flat topography have higher malaria prevalence due to the abundance of breeding sites (Githeko et al., 2012).

Vegetation and Land Use: The type and distribution of vegetation also influence malaria transmission (Beke et. al. 2023). Forested areas can provide shade and humidity, creating favorable conditions for mosquito breeding. However, agricultural and urban land use changes can either reduce or increase malaria risk depending on how they alter the landscape (Fornace et. al. 2021). Beke et. al. (2023) also demonstrated that changes in land use and vegetation cover significantly impact mosquito populations and malaria transmission dynamics.

2.4.7 Malaria Interventions

Effective malaria interventions have been and remain an essential component for reducing transmission, achieving control, and elimination. Over the past few decades, various interventions have been developed and implemented to combat malaria. This fight has made significant progress, including vector control measures, antimalarial medications, vaccination efforts, and community-based strategies (Kleinschmidt et al., 2018, Owusu-Agyei et al., 2020). Each breakthrough has reduced malaria incidence and mortality, particularly in high-burden regions. Some of these primary strategies employed include:

2.4.7.1 Vector Control Measures

One of the most significant advances in malaria control has been the implementation of vector control measures. The use of ITNs and IRS as a vector control measure has substantially reduced malaria transmission. ITNs are one of the most effective tools for preventing malaria. They provide a physical barrier against mosquito bites and are treated with insecticides to kill mosquitoes on contact. Studies have shown that widespread ITN distribution has significantly reduced malaria incidence in various regions (Bhatt et al., 2015). According to the World Health Organization (WHO, 2020), ITNs alone have been responsible for preventing approximately 68% of malaria cases in SSA from 2000 to 2015.

IRS involves spraying the interior walls of homes with long-lasting insecticides to kill mosquitoes that rest there. This method has been particularly effective in high-transmission areas and has contributed to significant declines in malaria cases (Kleinschmidt et al., 2018).

A landmark study by Bhatt et al. (2015) estimated that ITNs, IRS, and ACTs collectively prevented 663 million malaria cases in Africa between 2000 and 2015. The study emphasized that ITNs contributed the most to this decline, showcasing the effectiveness of these interventions. Additionally, a review by Strode et al. (2014) highlighted the sustained impact of ITNs in reducing malaria incidence, particularly in high-transmission areas.

2.4.7.2 Antimalarial Medications

The development and deployment of ACTs have been a breakthrough in malaria treatment. ACTs are the first-line treatment for uncomplicated malaria caused by Plasmodium falciparum. They combine artemisinin with another antimalarial drug to increase efficacy and reduce the risk of resistance. The widespread use of ACTs has been a cornerstone of malaria treatment and has saved millions of lives (Boyce et al., 2021; Fornace et al., 2022; Yaro, Ouedraogo, et al., 2021). ACTs have proven highly effective in treating Plasmodium falciparum malaria, the most lethal strain. ACTs had significantly improved treatment outcomes, reducing mortality rates by more than 90% in some regions (Boyce et al., 2021; Fornace et al., 2022; Yaro, Ouedraogo, et al., 2021).

Despite the success of ACTs, the emergence of artemisinin resistance in Southeast Asia poses a significant threat to malaria control efforts. Research by Ashley et al. (2014)

identified genetic mutations associated with artemisinin resistance, emphasizing the need for continuous monitoring and the development of new treatment strategies. In response, the WHO has recommended combination therapies that include partner drugs to which resistance has not yet developed, maintaining the efficacy of treatment regimens (WHO, 2019).

Intermittent Preventive Treatment (IPT) on the other hand involves administering antimalarial drugs at regular intervals to vulnerable populations, such as pregnant women (IPTp) and infants (IPTi), to prevent malaria infection. This strategy has been shown to reduce malaria-related morbidity and mortality in these groups (Kayentao et al., 2013).

2.4.7.3 Vaccination Efforts

The development of malaria vaccines has been a critical focus in recent years (Stanisic, D., & Good, M. F. 2023). The RTS,S/AS01 (RTS,S) vaccine, also known as Mosquirix, is the first malaria vaccine to show significant efficacy in large-scale clinical trials (Morrison, C. 2015, Laurens, M. B. 2020). A study on the RTS,S demonstrated that the vaccine provided protection against malaria in young children, drastically reducing the incidence of clinical malaria and mortality (El-moamly, A. A., & El-Sweify, M. A 2023).

In 2019, the WHO initiated a pilot implementation of the RTS,S vaccine in Ghana, Kenya, and Malawi, aiming to evaluate its real-world impact and feasibility (Asante et. al. 2024). The early results have been promising, showing a substantial reduction in malaria cases and hospitalizations among vaccinated children (WHO, 2021). However, the vaccine's relatively low efficacy and the need for a multi-dose regimen highlight the ongoing need for improved vaccines (Duffy et. al. 2024).

2.4.7.4 Integrated Community Case Management (iCCM)

Integrated Community Case Management (iCCM) has been another innovative approach to malaria control, particularly in remote and underserved areas. iCCM involves training community health workers to diagnose and treat malaria, pneumonia, and diarrhea, improving access to essential healthcare services.

A study by Duffy et. al. 2024, found that iCCM significantly increased the coverage of malaria diagnostic and treatment services, leading to improved health outcomes in children under five. The study emphasized the importance of community-based interventions in bridging healthcare gaps and reducing malaria-related morbidity and mortality. Building on these achievements and addressing emerging threats, moves the global community closer to the ultimate goal of malaria eradication.

2.4.8 Malaria Elimination and Eradication Plan

Malaria control has made progress over the past decades, with effective interventions such as ITNs, IRS, ACTs, and IPT proven successful in reducing malaria transmission. The global malaria elimination and eradication plan aims to reduce malaria cases and deaths to zero, ultimately achieving a world free of malaria (WHO, 2022). This ambitious goal requires coordinated efforts at national, regional, and global levels, and also emphasizes the need for strengthened surveillance, integrated vector management, development of new tools, community engagement, and international collaboration as the key components (WHO, 2023).

2.4.8.1 Strengthening Surveillance Systems

Robust surveillance systems are crucial for tracking malaria cases, identifying outbreaks, and targeting interventions. Improved data collection and analysis help in making informed decisions and allocating resources effectively (WHO, 2021).

2.4.8.2 Integrated Vector Management (IVM)

IVM involves combining multiple vector control strategies, such as ITNs, IRS, larval source management, and environmental management, to reduce mosquito populations and interrupt malaria transmission (WHO, 2020).

2.4.8.3 Development of New Tools

Research and development of new tools, including vaccines, diagnostic tests, and novel insecticides, are essential for overcoming resistance and achieving sustainable malaria control. The RTS,S/AS01 malaria vaccine, for example, has shown promise in reducing malaria cases among children in pilot programs (Genton et al., 2021).

2.4.8.4 Community Engagement and Education

Engaging communities and educating them about malaria prevention and treatment is critical for ensuring the success of interventions. Community-based approaches help to build trust, address misconceptions, and encourage the adoption of preventive measures (Amoako et al., 2021).

2.4.8.5 International Collaboration and Funding

Achieving malaria elimination and eradication requires sustained international collaboration and adequate funding. Global initiatives, such as the Roll Back Malaria Partnership and the Global Fund to Fight AIDS, Tuberculosis, and Malaria, play a pivotal role in coordinating efforts and providing financial support (Shretta et al., 2017). By addressing adhering to these key components on all levels, and sustaining efforts, it is possible to move closer to a malaria-free world.

CHAPTER THREE

METHODOLOGY

3.1 Research Design and Strategy

A retrospective cross-sectional design was used to analyze malaria epidemiological data from 2015 to 2023 in the Mampong Municipality to quantify the impact of control interventions over the period. The available data was analyzed to determine malaria morbidity and prevalence as a metric across the municipality and between its various towns. Geographic Information System (GIS) was used to map incidence and prevalence and correlate them with environmental variables.

3.2 Study Area

The study area, the Mampong Municipality, marks a special territory within the Ashanti Region. It forms about 2.2% of the region's total land area and covers an area of about 23.9 km. The municipality is in the transitional zone between the forest and the Savanna Region of Ghana (Draft Strategic Environmental Assessment Report, 2010).

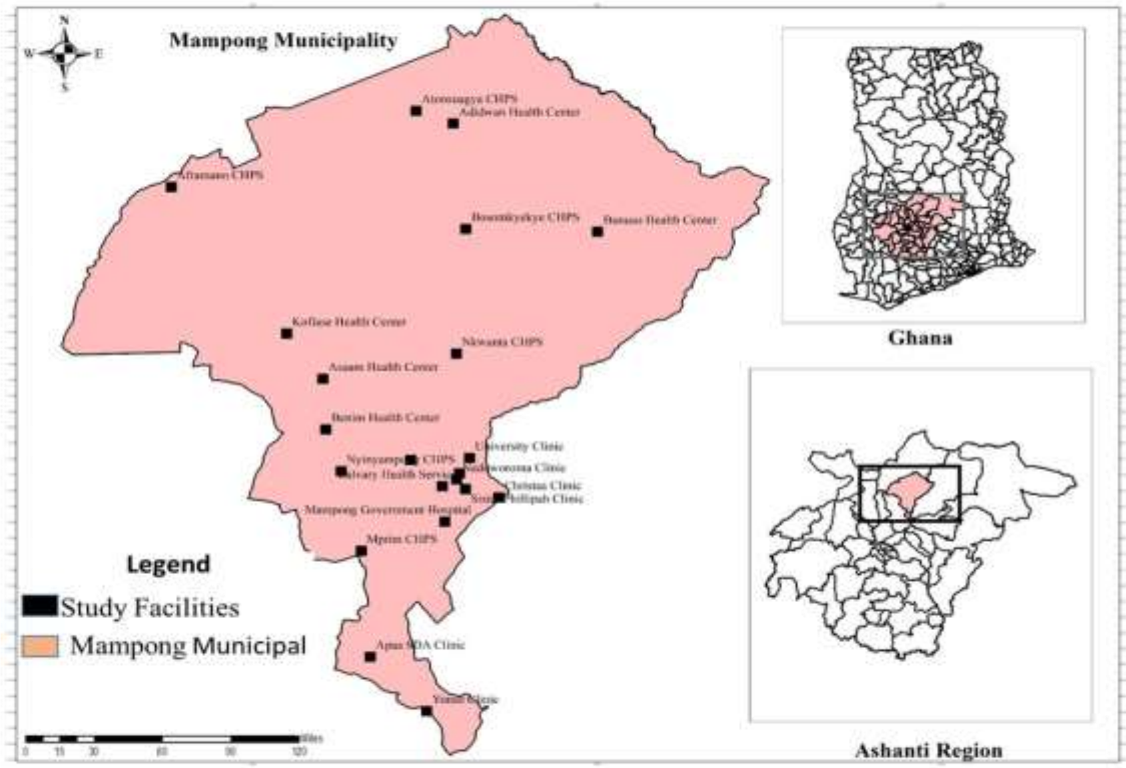


Figure 3.1: An area map of the Asante Mampong Municipality showing the study facilities.

3.2.1 Population

Administratively, the Mampong Municipality, which is the study area, is a subsidiary of the Ashanti Regional Health Directorate and is among the forty-three (43) administrative districts in the Ashanti Region. Its total population is 116,632, a significant fraction of the entire population (Annual Health Report, 2019).

3.2.2 Economic Activities

The Asante Mampong Municipality is known for its agricultural production capacity; over 30% of the population are farmers. Mampong is a major urban vegetable producer in the Ashanti region, 59km from the regional capital, Kumasi. As a key economic hub and educational destination, the municipality has over sixty educational institutions, from the basic to the tertiary level. It has demographic characteristics stemming from the diverse backgrounds of people and students in the community. This study area is and continues to be necessary, especially in disease epidemiological studies, because of its unique climate and landscape (GSS, 2021).

3.2.3 Healthcare Facilities

The municipality has twenty-one (21) health facilities, one (1) Municipal Hospital, seven (7) private Hospital, seven (7) Health Centers, one (1) CHAG, two (2) Quasi-Government, five (5) Private Hospitals, and six (6) CHPS compounds. The municipality has four hundred and seventy-three (473) health staff, including eight (8) Doctors, fifty-seven (57) Midwives, fifty (50) Community Health Nurses, seventy-four (74), one (1) Public health Nurses, and other health staff. The year 2019 witnessed a reduction in the stillbirth rate per 1,000 deliveries from 15 to 10; maternal mortality has also reduced from 66.9% per 100,000 live births to 65.1% by the end of 2019 (GHS, 2021).

3.2.4 Climate

Climatically, the municipality has two rainy seasons, with an average temperature of about 27^0C, and lies within the wet semi-equatorial forest zone. Topographically, the land is relatively low at the south and undulates at the north, and this provides the best ecological zone for the study of malaria transmission dynamics and epidemiology, taking into account the vector breeding sites, density and behavior, human-mosquito interaction, parasite development, and epidemiological patterns (Draft Strategic Environmental Assessment Report, 2010, Annual Health Report, 2019). As warmer temperatures accelerate the development of mosquito larvae into adults and shorten the parasite's incubation period within the mosquito, heavy rains create numerous breeding sites. At the same time, intermittent rainfall maintains them, and with the high humidity levels, the lifespan of adult mosquitoes is extended.

3.3 Data Source and Processing

All public and private health facilities within the municipality (hospitals, health centres, clinics, and CHPS) that provided malaria diagnosis and treatment services were included in the study. The malaria morbidity data from these health facilities captured in the National Health Database (District Health Information Management System) from 2015 to 2023 were extracted and transferred from the DHIMS on a prepared Excel spreadsheet. All topographical data (elevation, land use patterns) were sourced from Google Earth.

3.3.1 Study Facilities

Twenty-three (23) health facilities scattered across the municipality with malaria data (2015-2023) served as the sites for the study. The health facilities were grouped into four geographical clusters (urban, peri-urban, and rural). The geographical clusters and facilities included in Table 3.1.

Table 3.1: Study facilities and towns arranged in geographical clusters

Geographical Cluster	Facilities	Local Towns
Ejura Cluster (EC) (Rural)	*Adidwan Health Center*	Adidwan
	Atonsuagya CHPS	Atonsuagya
	Bosomkyekye CHPS	Bosomkyekye
	Bunuso Health Center	Bunuso
	Nkwanta CHPS	Nkwanta
Jamasi Cluster (JC) (Peri-Urban)	*Yonso Clinic*	Yonso
	Apaa SDA Clinic	Apaa
	Mampong Government Hospital	Asante Mampong
	Mprim CHPS	Mprim
Kofiase Cluster (KC) (Peri-Urban)	*Krobo (Mampong) Health Center*	Krobo
	Asaam Health Center	Asaam
	Benim Health Center	Benim
	Kofiase Health Center	Kofiase
	Nyinyampong CHPS	Nyinyampong
	Aframano CHPS	Aframano
Mampong Town (MT) (Urban)	*Sister Phillipah Clinic*	Asante Mampong
	Calvary Health Services Mampong	Asante Mampong
	Quality Health Care Clinic	Asante Mampong
	Nadoworoma Clinic	Asante Mampong
	Mamtech CHPS	Asante Mampong
	Christaa Clinic	Asante Mampong
	AAMUSTED Clinic	Asante Mampong
	Takyiwaa Clinic	Asante Mampong

Source: District Health Information Management System (2024).

3.3.2 Inclusion and Exclusion Criteria

The primary study variables used in setting the criteria included dates in months (Jan-Dec) and years (2015-2023) of diagnosis and patient care per facility. A facility data set should have at least seven (≥7) monthly data points for that year to be included in the analysis to better maintain the variability of the data and limit any biases or skewness. A facility of less than seven (≤7) monthly data points was excluded the analysis. Furthermore, a facility with four (4) years missing data points is exclude from the yearly trend analysis.

3.3.3 Handling Missing Data with Mean Imputation

In this study, the data obtained across the various months from 2015 to 2023 had some data points missing. To ensure the robustness of the statistical analysis, a combination of mean imputation and seasonal adjustment was employed to address these issues.

A test for normality of the data was assessed ahead of handling missing data. Missing data points were identified in the monthly malaria incidence dataset. To address this, mean imputation was chosen to replace missing values. The arithmetic mean of the available data was calculated for each missing data point. This approach was selected because it preserves the central tendency and maintains the overall distribution of the dataset, thereby minimizing bias introduced by missing values. Mathematically expressed as;

$$\boldsymbol{x = x_1, x_2, \dots, x_n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

(representing the set of observed data values, excluding missing data ($\boldsymbol{x_j}$))

$$\bar{x} = \frac{1}{n_{obs}} \sum_{i=1}^{n_{obs}} x_i \ \ldots\ldots \ (2)$$

Where $\boldsymbol{\bar{x}}$ is the mean of the observed data, $\boldsymbol{n_{obs}}$ is the number of observed (non-missing) values and, $\boldsymbol{x_i}$ is the observed value. Therefore, $\boldsymbol{x_j = \bar{x}}$**,** for all missing values.

3.3.4 Seasonal Adjustment

Given the seasonal fluctuations in malaria incidence, seasonal adjustment was performed to isolate the underlying trend. The seasonal component was estimated using *a moving average method.* This component was then subtracted from the original data, resulting in *de-seasonalized values.* The presence of negative values in the *de-seasonalized data* indicated periods where the actual incidence was below the seasonal expectation, providing valuable insights into the **non-seasonal factors affecting malaria prevalence**. Missing data in the *deseasonalized values* were now replaced using the mean imputation method to better preserve its original variability. The seasonal component (monthly average) was added to the complete *de-seasonalized values* for an overall complete dataset to be used for further analysis. Mathematically expressed as;

$$Y_t = T_t + S_t + I_t \text{ ………… (3)}$$

Give a time series of malaria prevalence $\boldsymbol{Y_t}$, the decomposition model as an additive process. The seasonal component $\boldsymbol{S_t}$ for each month is estimated as the average prevalence for that month across multiple years:

$$S_{Month} = \frac{1}{n}\sum_{y=1}^{n} Y_{Month,y} \text{ ……… (4)}$$

To remove the seasonal effect and obtain the de-seasonalized prevalence Y_t^{adj}, the seasonal component is subtracted from the observed values (for the additive model):

$$Y_t^{adj} = \frac{Y_t}{S_t} \text{ ……… (5)}$$

Finally, the trend component T_t is estimated using moving average for smoothing.

3.3.5 Combination of Mean Imputation and Seasonal Adjustment

The process of mean imputation was applied prior to seasonal adjustment with facility data that had greater than or equal to seven (7) time points (months) per year on Out Patients Department (OPD) records. This ensured that all data points were present for the calculation of the seasonal component, after applying the inclusion and exclusion criteria. This sequence was critical for maintaining the accuracy of the seasonal adjustment, as missing values could have skewed the estimation of the seasonal pattern. By imputing the missing values first, consistent dataset was ensured, which allowed for more accurate de-seasonalization.

The application of mean imputation and seasonal adjustment in this study was crucial for addressing missing data and seasonal variations. These processes enhanced the dataset's completeness and allowed for a more accurate analysis of the underlying trends in malaria incidence, thereby strengthening the study's conclusions.

3.4 Data Analysis

The study analyzed secondary data of patients who reported to every health facility within the Mampong Municipality for care, and were recorded as malaria patients, subsequently referred to the Clinical Laboratory for testing and confirmation during the study period (January 2015-December 2023). This was also done with the GIS data to better identify the hotspots and geographical variations in the disease incidence and prevalence.

3.4.1 Objective One

With descriptive statistics, the data was summarized on epidemiological characteristics (malaria incidence, prevalence, and demographic distributions) using Excel and R 4.4.1 with R Studio 2024.04.2-764.

For specific character (Age, Sex, Facilities) percentages, the total cases attributed to the category was divided by the total number of cases recorded within the period and multiplied by a hundred, mathematically represented as:

$$Percentages\ (\%) = \left(\frac{Total\ attibuted\ malaria\ cases}{Total\ no.of\ \ cases\ recorded\ within\ the\ period}\right) \times 100\ \ldots\ldots\ldots\ (6)$$

For malaria prevalence, the point prevalence and period prevalence, depending on the aggregation, were calculated. Since the data span multiple years, the cumulative prevalence was the average across the study period. Mathematically represented as:

$$Malaria\ Prevalence\ (\%) = \left(\frac{Number\ of\ confirmed\ malaria\ cases}{Total\ no.of\ \ (OPD)\ attendance}\right) \times 100\ \ldots\ldots\ldots\ (7)$$

3.4.2 Objective Two

A trend analysis was conducted analyzing the overall trend, and the yearly percentage change in malaria prevalence. A seasonal variation, and geographical differences in malaria incidence and prevalence was analyzed to assess the impact of control interventions on each town, and in geographical clusters in the municipality.

This metric for the yearly percentage change was derived by taking the percentage difference between each year's prevalence and the previous year's prevalence, calculated as:

$$(Percentage\ Change) = \left(\frac{Prevalence_{Year} - Prevalence_{Previous\ Year}}{Prevalence_{Previous\ Year}}\right) \times 100\ \ldots\ldots\ldots\ (8)$$

And with ArcGIS software, malaria hotspots in the municipality were mapped using the yearly prevalence rate for each facility, and compared with environmental data to identify spatial patterns and correlations.

3.4.3 Objective Three

From literature, many models and data cleaning methods and approach have been employed in recent years. ARIMA and SARIMA models was used to predict influenza in 2012 (Song, 2016). Liu et al. (2020) used Bayesian time-series framework to predict the number of COVID-19 infection cases in USA. Satrio et al. (2021) utilized Facebook's Prophet Model and the ARIMA model to forecast the trend of the COVID19 diseases in Indonesia. The COVID-19 pandemic in Saudi Arabia was analyzed using modified singular spectrum analysis or SSA (Alharbi, 2021).

Similar to this study, Least Square Method, Moving Average Method, Single Exponential Method, Double Exponential Method and Winter's Method were used in forecasting agricultural products prices (Ruekkasaem & Sasananan 2018). Moreso, Gecili et al. (2021) applied four time series models (Holt, ARIMA, TBATS, and cubic smoothing spline model) to publicly available daily COVID-19 data for both the USA and Italy.

This paper mainly focused on using Holt-Winters Exponential Smoothing in time series forecasting as a common and usual method used by Gecili et al. (2021). The model takes into account the trend and seasonality while doing the forecasting (Solar Winds Worldwide, 2021). HW method is used for short term forecasts (Goodwin, 2010). Depending on the type of seasonality (the nature of the seasonal component), it can either be additive or multiplicative. The additive method is preferred when the seasonal variations are roughly constant through the series, while the multiplicative method is preferred when the seasonal variations are changing proportional to the level of the series.

The forecast analysis was developed using Holt-Winters Exponential Smoothing method, which captured the observed trend over time, including an additive trend component which captured the linear increase observed in the yearly malaria prevalence rates to align closely with the historical data. The forecast mathematically represented:

Level Update; The level component, L_t, captures the smoothed estimate of the series at time t:

$$L_t = \alpha Y_t + (1 - \alpha)(L_{t-1} + T_{t-1}) \text{ ………… (9)}$$

Where $\boldsymbol{Y_t}$**:** Observed value at time t, $\boldsymbol{L_{t-1}}$**:** Previous level estimate, $\boldsymbol{T_{t-1}}$**:** Previous trend estimate, $\boldsymbol{\alpha}$**:** Smoothing parameter for the level $(0 < \alpha < 1)$

Trend Update; The trend component;

$$T_t = \beta(L_t - L_{t-1}) + (1 - \beta)T_{t-1} \text{ ………… (10)}$$

Where $\boldsymbol{\beta}$: Smoothing parameter for the trend $(0 < \beta < 1)$

Forecast equation; Using the updated level and trend, the forecast F_{t+h} for h steps ahead is given by:

$$F_{t+h} = L_t + h \cdot T_t \text{ ……… (11)}$$

Where h: Forecast horizon (number of periods ahead).

CHAPTER FOUR

RESULTS

4.0 Introduction

This chapter presents the findings of this study in a comprehensive analysis of the epidemiological trends, intervention impacts, and projected trends of malaria incidence and prevalence in the Mampong Municipality from 2015 to 2023.

The findings are presented through a combination of quantitative data analyses and qualitative insights, supported by relevant up-to-date publications. They are structured around the key research questions, beginning with a detailed examination of malaria incidence, prevalence and demographic characteristics. This is followed by an analysis of the overall trends in seasonal patterns and geographical differences, as it explores the effectiveness of various interventions implemented during this period and their implications for malaria transmission dynamics in the region. Finally, the chapter presents the projected trends in malaria incidence and prevalence based on historical data, climate patterns, and current intervention strategies in the municipality.

The chapter concludes with a synthesis of the key findings and their relevance to the overarching goal of malaria eradication, setting the stage for the subsequent discussion and recommendations outlined in chapter five.

4.1 Epidemiological Characteristics of Malaria from 2015 to 2023

4.1.1 Demographic characteristics and malaria prevalence

Table 4.1 presents the demographic data analyzed from the DHIMS during the period from 2015 to 2023, showing the distribution and burden of malaria across different population groups. There were age and gender variations, children (5-14) and children under five showed the highest disease burden rates, with adults (15-49) and the elderly reporting lower prevalence. Gender based analysis indicated that males had higher disease burden rates.

Table 4.1: Demographic presentation of malaria prevalence (2015-2023)

Character	Frequency	Cases	Percentage	Prevalence
Sex				
Male	370696	76962	44.07	20.76
Female	764797	97663	55.93	12.77
Total	**1135493**	**174625**	**100**	**15.38**
Age				
< 5	181124	53742	30.78	29.67
Children (5-14)	126480	41447	23.74	32.77
Adults (15-49)	545764	56299	32.24	10.32
Elderly (50 ≥)	282125	23121	13.24	8.20
Total	**1135493**	**174609**	**100**	**15.38**

Source: District Health Information Management System (2024).

4.1.2 Gender-Specific Annual Malaria Prevalence among Patients across the Municipality

Table 4.2 shows a significant gender variation in malaria burden for the cumulative nine-year period ($p < 0.0001$), with male patients recording a greater percentage of confirmed cases than their female counterparts. Female patients recorded the highest number of attendees, but recorded the lowest in prevalence in all the years. In general, a significantly higher infection burden occurred among the male group, year-on-year for the entire period (2015 - 2023). Irrespective of sex, the infection density peaked in 2020 but dropped in 2022, with significant changes within and across the years.

Table 4.2: Year-on-year sex distributed trends of malaria confirmed cases and prevalence

Years	Male			Female		
	Total	**Positives**	**Prevalence**	**Total**	**Positives**	**Prevalence**
2015	46109	6410	**13.9**	95610	8306	**8.69**
2016	41645	7338	**17.62**	92924	9081	**9.77**
2017	43214	9286	**21.49**	93404	12002	**12.85**
2018	48829	10464	**21.43**	99675	13127	**13.17**
2019	47320	11055	**23.36**	92457	13725	**14.84**
2020	37655	9311	**24.73**	72055	12375	**17.17**
2021	38072	7984	**20.97**	77575	10208	**13.16**
2022	30460	6100	**20.03**	60035	7429	**12.37**
2023	37392	9014	**24.11**	81062	11410	**14.08**

Source: District Health Information Management System (2024).

4.1.3 Age-Specific Annual Malaria Prevalence among Patients

Table 4.3 shows that children under five recorded a steady and significant increase in malaria prevalence starting at 18.10% in 2015 and peaking at 40.35% in 2020, before slightly decreasing to 36.55% in 2023. School-aged children (5-14 years) also saw an increase in malaria prevalence, rising from 21.69% in 2015 to 39.85% in 2023, highlighting their role in the transmission of the disease. Adults aged 15-49 experienced lower prevalence rates, beginning at 7.02% in 2015 and gradually increasing to 11.97% by 2023. The elderly population (50 years and above) consistently had the lowest rates, rising from 5.45% in 2015 to 9.13% in 2023. These trends emphasize the need for age-specific strategies in malaria control, tailored to address the unique risks and challenges each group faces.

Table 4.3: Year-on-year age-distributed trends of malaria prevalence

Years	**Age**			
	< 5	**Children (5-14)**	**Adults (15-49)**	**Elderly (50 ≥)**
2015	18.10	21.69	7.02	5.45
2016	22.46	26.02	7.78	5.59
2017	28.95	31.01	11.10	8.85
2018	31.69	30.17	10.20	8.81
2019	34.39	37.42	11.50	10.07
2020	40.35	44.45	13.28	10.52
2021	32.07	35.95	10.08	8.66
2022	33.07	35.29	10.40	6.60
2023	36.55	39.85	11.97	9.13

Source: District Health Information Management System (2024).

4.2 The Overall Trends, Seasonal Variations, and Geographical Differences

4.2.1 Trend Relationship between OPD Attendance and Positive Cases

The trend established a relationship between OPD attendance and the number of positive cases, helping to understand if changes in OPD visits were associated with changes in positive cases.

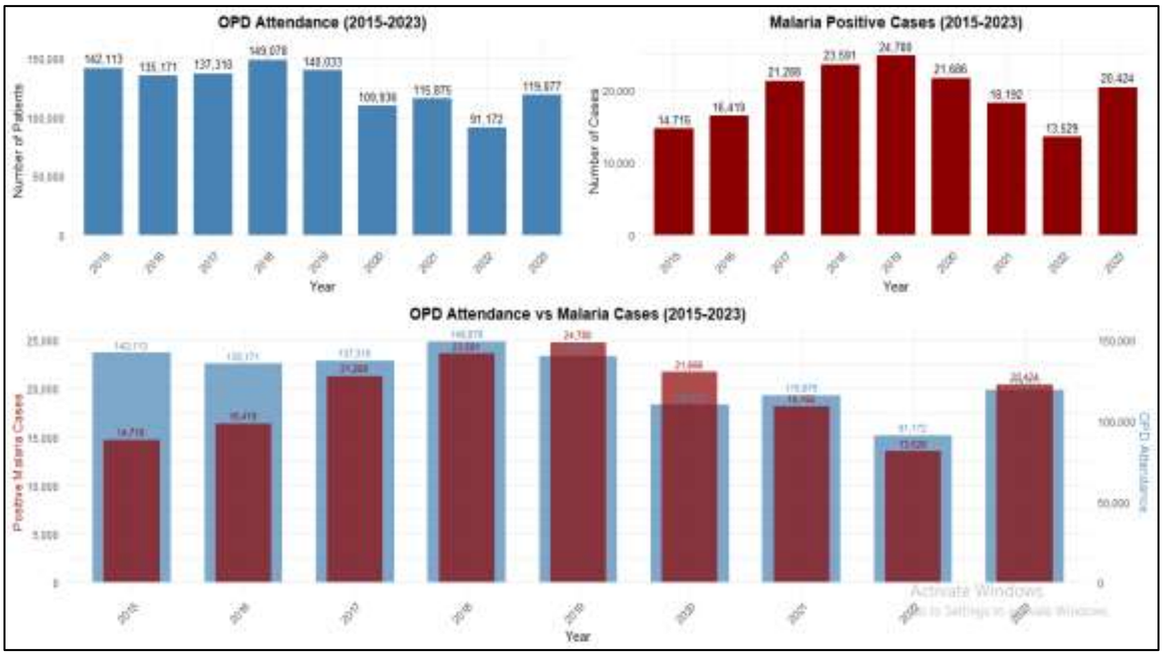


Figure 4.1: Trend relationship between OPD attendance and positive cases (2015 – 2023)

This plot established the relationship between OPD attendance and positive malaria cases from 2015 to 2023 in this study. With a Pearson correlation (r) = 0.45, indicating a moderate positive linear relationship between OPD attendance and malaria cases. An R^2 = 0.20 associated about 20% of the variation in malaria cases to OPD attendance, shown in figure 4.2

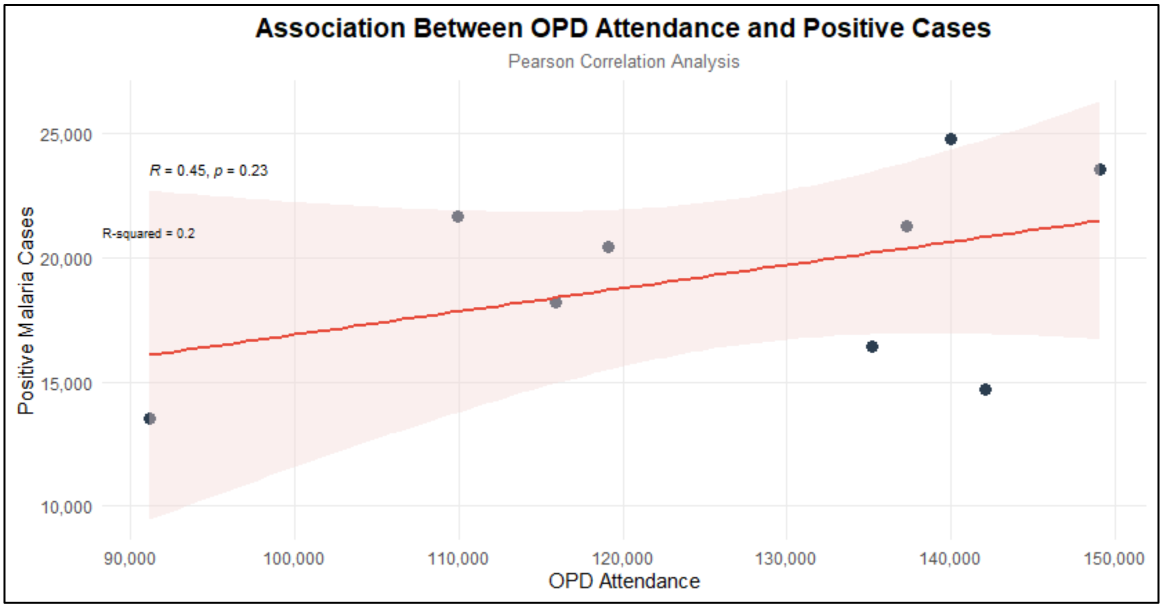


Figure 4.2: Association between OPD attendance and positive cases (2015 – 2023)

These suggest that while there is a relationship between OPD attendance and positive cases, it is not very strong. Therefore, OPD attendance alone does not account for all the variability in positive cases. The remaining 80% is likely due to other factors like seasonality, vector control measures, climate, and behavior. This suggests that while there's some association, OPD attendance alone is not a strong predictor of malaria cases.

4.2.2 Overall Malaria Prevalence Trend

The prevalence of malaria-confirmed cases throughout the period ranged from 10.36% to 19.73% among the total population. Deductively, the entire municipality registered and observed a steady increase, with fluctuations including a peak in 2020 (19.73%), a decline between 2021 (15.7%) and 2022 (14.88%), and a rebound in 2023 (17.15%) as shown in Figure 4.3.

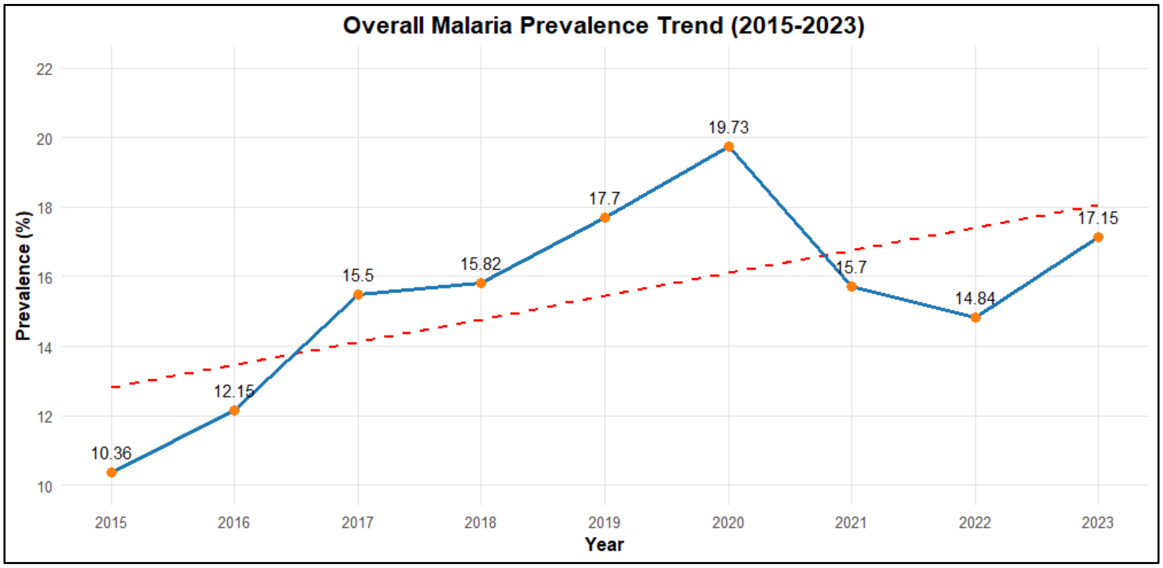


Figure 4.3: Yearly trend of malaria prevalence in the Mampong Municipality for the period

4.2.3 The Yearly Percentage Change in Malaria Prevalence in the Mampong Municipality (2015-2023)

The yearly percentage change in malaria prevalence was calculated to understand the rate of increase or decrease year over year, providing insight into the relative change rather than the absolute increase, helping to normalize differences in scale over time.

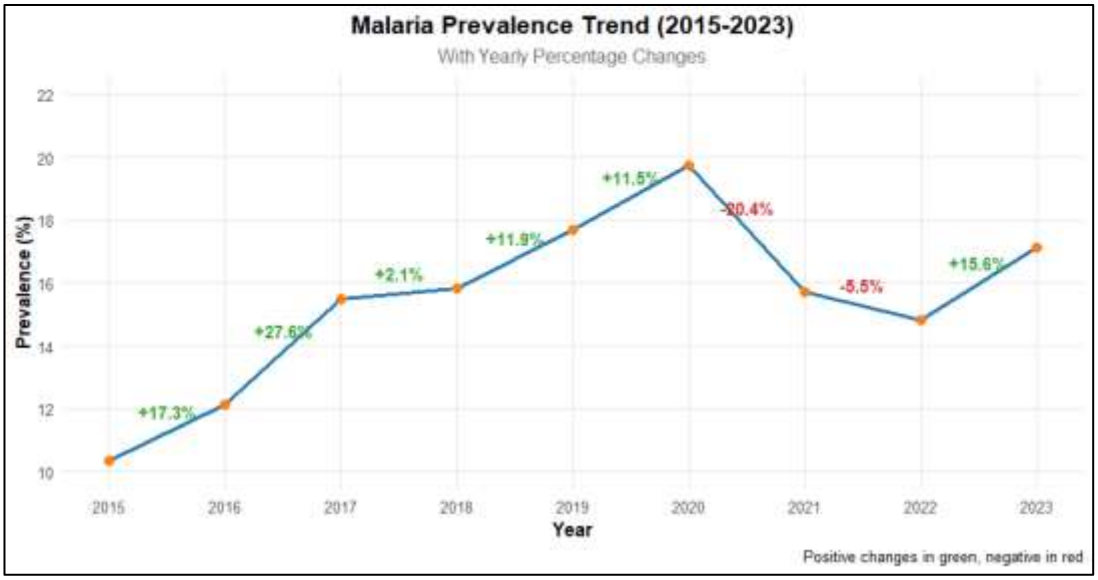


Figure 4.4: A yearly percentage change in malaria prevalence in the general population

This approach enabled a clear view of the fluctuations in prevalence, highlighting both the magnitude and direction of change. The malaria prevalence fluctuated over the years, with the highest increase in 2017 (27.57%) and the largest decrease in 2021 (-20.43%). On average, malaria prevalence increased by **7.49%** per year from 2015 to 2023.

4.2.4 Seasonality and Patterns in Malaria Prevalence

The month-on-month trends of malaria prevalence in the Mampong Municipality from 2015 to 2023 displayed a significant and well-defined seasonal variation, closely tied to Ghana's rainy and dry seasons. The data showed an increase in malaria cases during the rainy season, particular from May to July, where prevalence consistently peaked across all years observed, representing a significant increase in case density. In general, the pattern saw a rise in the infection burden each year with one peak from May through to July, a slight peak in October, and then a decline in the infection burden onward through to March, as shown in Figure 4.5.

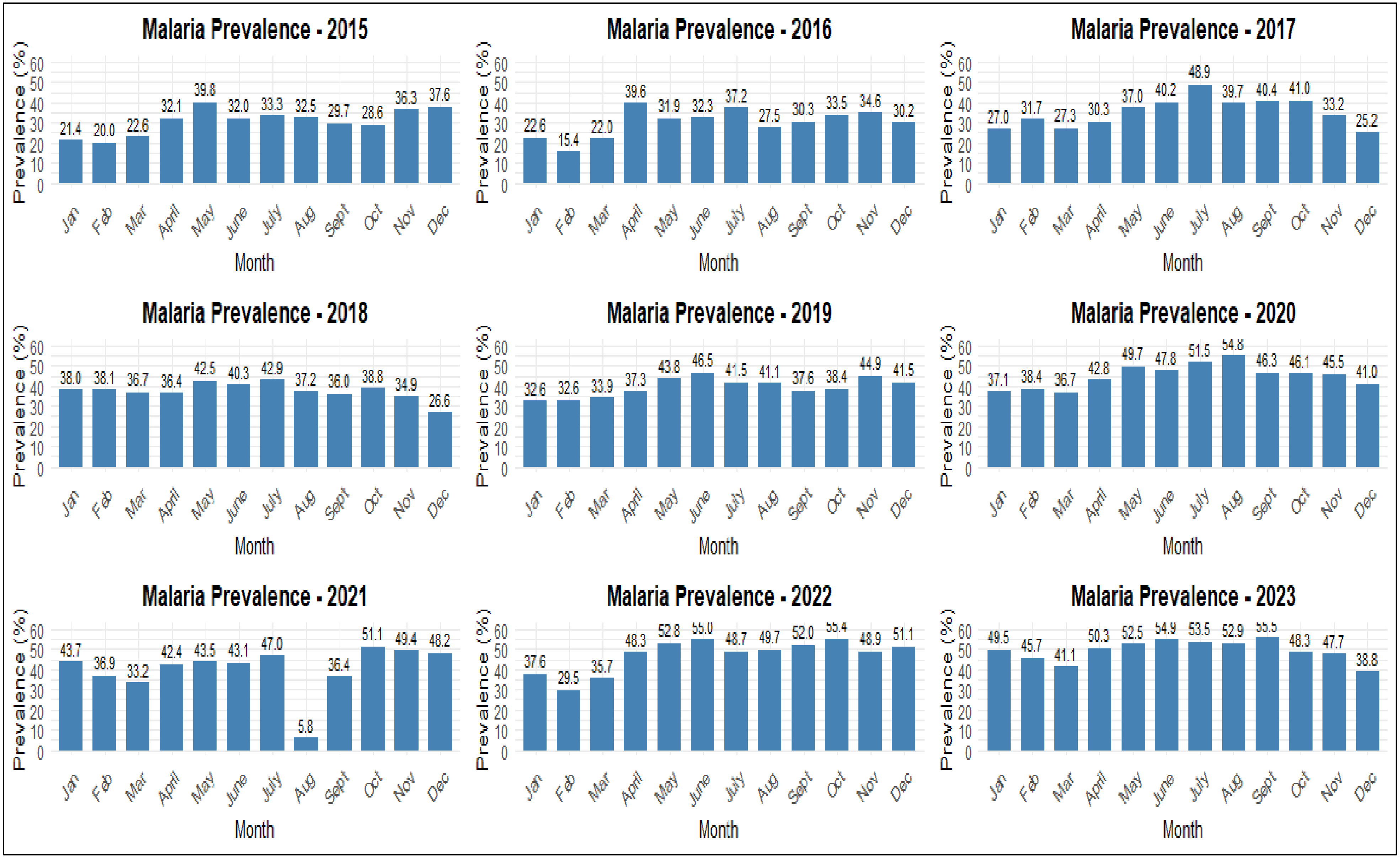
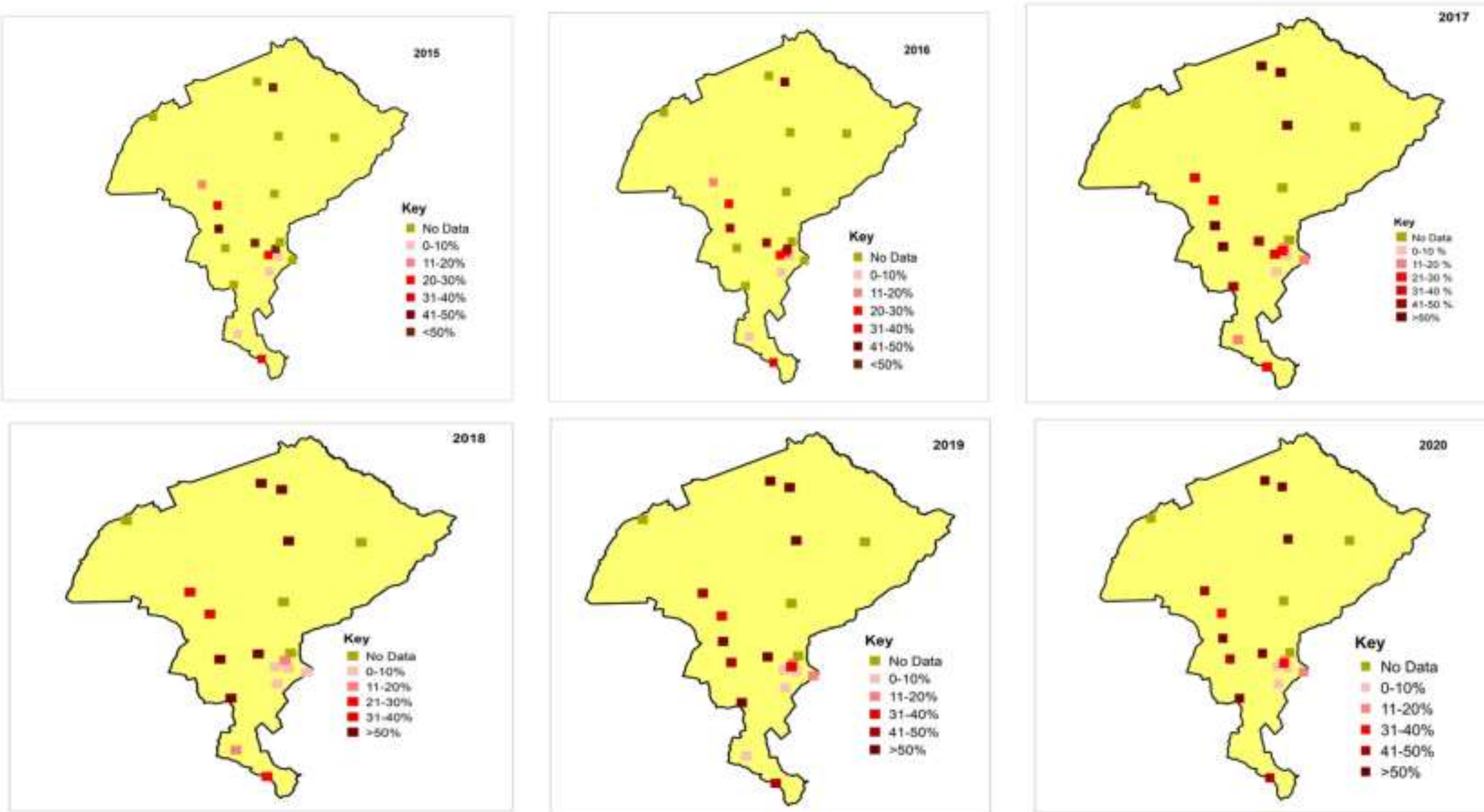


Figure 4.5: Month-on-month trend of malaria reported cases and prevalence in the Asante Mampong Municipality for the period.

4.2.5 Facility and Geographical Differences in Malaria Prevalence

The data revealed the facility and geographical differences in malaria burden recorded over the period from 2015 to 2023.



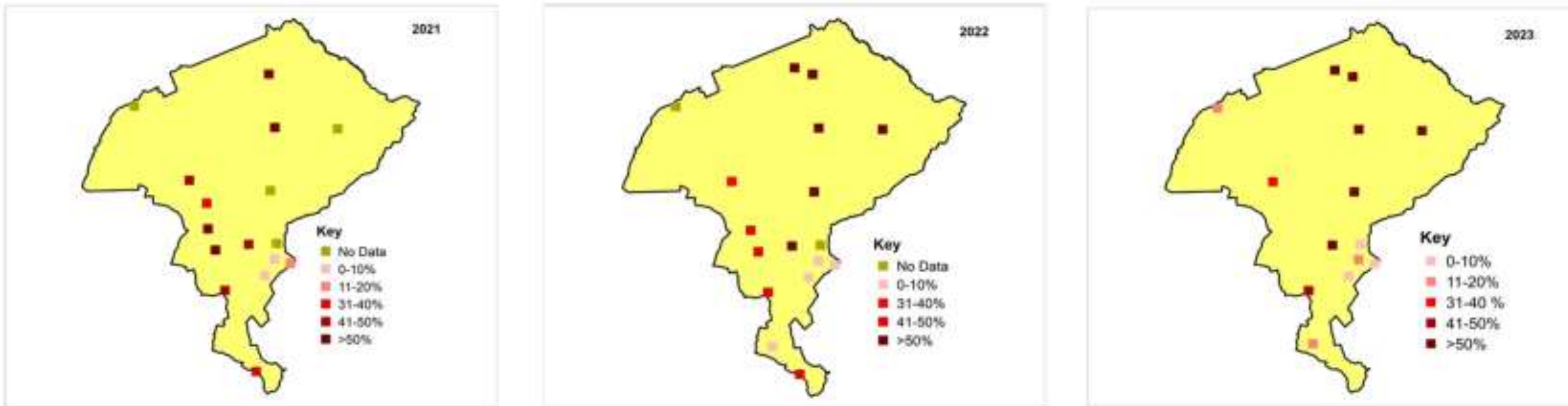


Figure 4.6: Yearly trends in malaria prevalence per facility in the Asante Mampong Municipality.

Differences in malaria prevalence across the various areas are shaped by varying environmental and socio-economic factors. Rural areas often face higher risks due to poor infrastructure and proximity to mosquito breeding sites. Understanding these variations is essential for designing targeted, effective malaria interventions and ensuring equitable disease control and prevention.

Cumulatively, Table 4.4 shows the overall disease burden and the totals for each facility within the study period, indicating the individual percentage contributed per facility and their respective prevalence.

Table 4.4: Malaria prevalence per facility

Facilities	Total OPD	Cases	Percentage	Prevalence
AAMUSTED Clinic	3788	31	0.02	0.82
Adidwan Health Center	31337	20318	11.64	64.84
Aframano CHPS	872	0	0.00	0.00
Apaa SDA Clinic	33887	3501	2.01	10.33
Asaam Health Center	35313	10977	6.29	31.08
Atonsuagya CHPS	3248	2418	1.39	74.45
Benim Health Center	16468	8517	4.88	51.72
Bosomkyekye CHPS	9083	6600	3.78	72.66
Bunuso Health Center	1165	1135	0.65	97.42
Calvary Health Services	48803	9371	5.37	19.20
Christaa Clinic	62784	7223	4.14	11.50
Kofiase Health Center	135738	46481	26.63	34.24
Krobo Health Center	10890	5658	3.24	51.96
Mampong Gov.t Hospital	560946	22432	12.85	4.00
Mamtech CHPS	1537	250	0.14	16.27
Mprim CHPS	7161	3581	2.05	50.01
Nadoworoma Clinic	7766	999	0.57	12.86
Nkwanta CHPS	2280	1443	0.83	63.29
Nyinyampong CHPS	5597	3269	1.87	58.41
Quality Health Care Clinic	10112	1472	0.84	14.56
Sister Phillipah Clinic	130849	9131	5.23	6.98
Takyiwaa Clinic	140	46	0.03	32.86
Yonso Clinic	23604	9718	5.57	41.17
Total	**1143368**	**174571**	**100**	**15.27**

Source: District Health Information Management System (2024).

Aframano CHPS had no captured data on the DHIMS, except for an OPD attendance record from February 2022. This resulted in the recorded zero (0) malaria cases for the facility.

4.2.6 Geographical clusters and topography in Malaria Prevalence.

Table 4.5: Malaria prevalence per facility in geographical clusters

Geographical Cluster	Facilities	Total	Cases	Percentage	Prevalence
Ejura Road (ER)	Adidwan Health Center	31337	20318	63.66	64.84
	Atonsuagya CHPS	3248	2418	7.58	74.45
	Bosomkyekye CHPS	9083	6600	20.68	72.66
	Bunuso Health Center	1165	1135	3.56	97.42
	Nkwanta CHPS	2280	1443	4.52	63.29
Total		**47113**	**31914**	**100**	**67.74**
Jamasi Road (JR)	Yonso Clinic	23604	9718	57.85	41.17
	Apaa SDA Clinic	33887	3501	20.84	10.33
	Mprim CHPS	7161	3581	21.32	50.01
Total		**64652**	**16800**	**100**	**25.99**
Kofiase Road (KR)	Krobo Health Center	10890	5658	7.55	51.96
	Asaam Health Center	35313	10977	14.66	31.08
	Benim Health Center	16468	8517	11.37	51.72
	Kofiase Health Center	135738	46481	62.06	34.24
	Nyinyampong CHPS	5597	3269	4.36	58.41
	Aframano CHPS	872	0	0.00	0.00
Total		**204878**	**74902**	**100**	**36.56**
Mampong Town (MT)	Mampong Gov.t Hospital	560946	22432	44.02	4.00
	Sister Phillipah Clinic	130849	9131	17.92	6.98
	Calvary Health Services	48803	9371	18.39	19.20
	Quality Health Care Clinic	10112	1472	2.89	14.56
	Nadoworoma Clinic	7766	999	1.96	12.86
	Mamtech CHPS	1537	250	0.49	16.27
	Christaa Clinic	62784	7223	14.18	11.50
	AAMUSTED Clinic	3788	31	0.06	0.82
	Takyiwaa Clinic	140	46	0.09	32.86
Total		**826725**	**50955**	**100**	**6.16**

Source: District Health Information Management System (2024).

Geographically, the data identified the rural regions within the municipality to have malaria prevalence particularly high (Ejura Road Cluster = **67.74%).** This rural cluster is associated with the population's proximity to water bodies, and agricultural activities, and reflects disparities in healthcare access, and socio-economic factors. These differences coupled with malaria reporting and case detection rates between rural and urban settings within the municipality could also be contributing factors, offering insights into how location-specific factors contributed to the observed disparities observed in Table 4.5.

4.2.7 Reporting Relative Risk of Malaria in Geographical Clusters

Providing crucial insight into how the different geographical regions are affected by malaria, comparisons were made to identify areas where individuals are at a higher risk of contracting malaria within the municipality. The relative risk for each geographical cluster was calculated based on malaria incidence from 2015 to 2023, using the urban area (Mampong Town) as the reference group (Table 4.6).

Table 4.6: Malaria prevalence and relative risk among geographical clusters.

Geographical Cluster	Population	Cases	Prevalence	Relative Risk
Ejura Road (ER)	47113	31914	**67.74**	**10.99**
Jamasi Road (JR)	64652	16800	**25.99**	**4.22**
Kofiase Road (KR)	204878	74902	**36.56**	**5.93**
Mampong Town (MT)	826725	50955	**6.16**	**1.00**
P-Value			***	***

Source: District Health Information Management System (2024).

The relative risk for rural (Ejura Cluster) and peri-urban (Jamasi Cluster, Kofiase Cluster) compared to the urban (Mampong Town) demonstrates that malaria risk is significantly higher in rural areas with an RR of 10.99, indicating individuals in rural areas are 11-fold more likely to contract malaria. Peri-urban areas also exhibit an elevated RR of value 4.22 and 5.93, showing a 5-6-fold increase in malaria risk compared to the urban areas.

4.3 Future Trends in Malaria Incidence and Prevalence

4.3.1 Forecasted values for malaria prevalence for the Mampong Municipality

Presenting the annual trend in malaria prevalence in the Mampong Municipality from 2015 to 2023 and a projection of future prevalence for 2024–2026. The annual malaria prevalence data from 2015 to 2023 obtained, represented the proportion of diagnosed cases relative to the population.

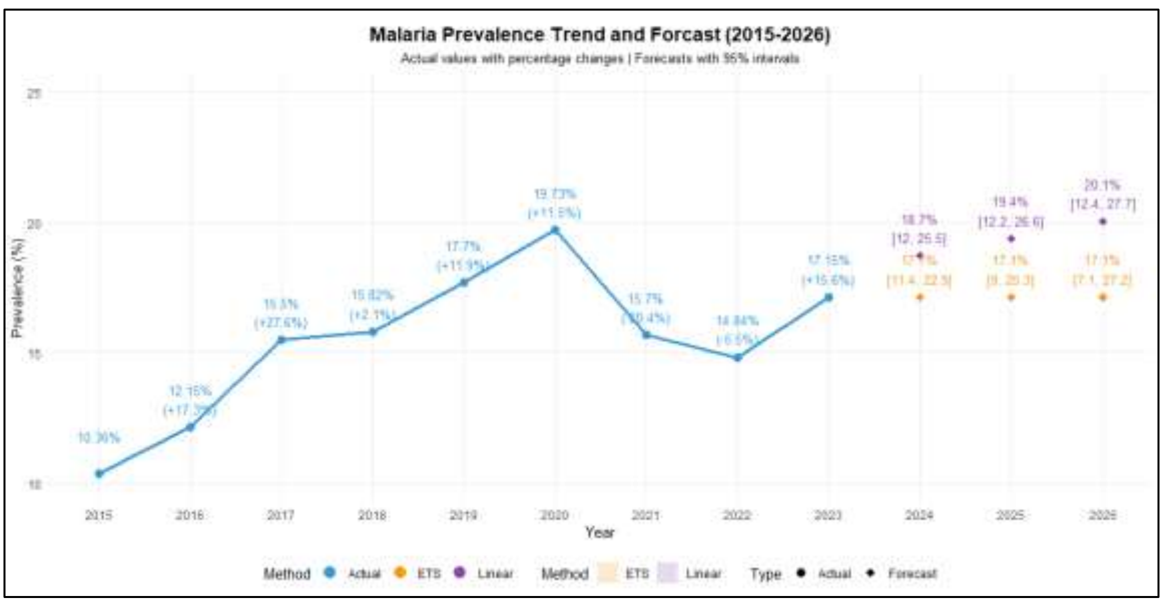


Figure 4.7: Malaria prevalence trend and forecast in the Mampong Municipality (2015-2026)

The malaria prevalence trend from 2015 to 2023 indicates a general increase. The linear regression forecast projects a continued upward trend, with prevalence expected to rise steadily from 18.7% in 2024 to 20.1% by 2026. This suggests that, in the absence of intensified control measures, malaria may remain a persistent public health burden in the coming years. The forecast underscores the need for sustained and enhanced interventions to reverse the upward trajectory and move toward elimination goals.

CHAPTER FIVE

DISCUSSION

5.1 Introduction

This retrospective study on malaria epidemiology, conducted from 2015 to 2023 in the Mampong Municipality, aimed to assess the trends in malaria prevalence, and demographic characteristics, while examining seasonal variations, the effects of facility and geographical differences, and forecasts. The study's objectives focused on understanding the dynamics of malaria transmission in different age groups and identifying potential hotspots for more focused interventions. The findings of this study reveal several important insights that align with, yet also differ from, results reported in other malaria studies conducted in similar endemic regions.

5.2 Gender-related Patterns and Differences in Malaria Prevalence

Gender plays a significant role in malaria transmission and disease outcomes. Our study's findings on gender-related malaria prevalence show distinct patterns, which are supported by existing research on how gender-specific behaviors, biological differences, and socio-economic factors influence malaria risks (Wharton-Smith et. al. 2019).

Over the study period (2015-2023), our data indicated that males generally had a slightly higher malaria prevalence than females across most age groups. This finding aligns with studies by (Kalyesubula et al., 2019), which highlight the increased malaria risk in males, particularly in outdoor environments where exposure to Anopheles mosquitoes is higher. Men are often more likely to engage in agricultural, or night-time work that expose them to mosquito bites during peak transmission hours, particularly in rural settings (Ding et al., 2020). Typically, in our study area, men's activities like farming and evening gatherings increase their vulnerability to mosquito bites compared to women who tend to stay indoors (Ding et al., 2020). A study by Naserrudin et. al. (2023) supports this by reporting that males in rural environments are disproportionately affected by malaria due to these behavioral factors. However, this trend is not uniform across all regions, as gender norms and daily activities vary in different communities (Deku et al., 2019). Although behavioral patterns explain part of the gender discrepancy, biological differences between men and women may also influence malaria susceptibility (Briggs et. al. 2023). Research by Baines, K. J., & West, R. C. (2023) suggests that hormonal differences and immune system responses may play a role, with some studies hypothesizing that estrogen levels could influence women's immunity to malaria, though the evidence is still evolving.

Given the significant role of gender in malaria transmission and health outcomes, gender-sensitive interventions are crucial for successful malaria control (Briggs et. al. 2023). Our study's findings highlight the need for targeted approaches that address the specific behaviors and vulnerabilities of both men and women.

5.3 Age-specific Malaria Trends

5.3.1 Children under 5 Years

Malaria prevalence among children under 5 is notably high and showed an upward trend from 18.1% in 2015 to a peak of 40.35% in 2020, followed by a decline in later years in this study. This pattern aligns with findings that children under five are at the highest risk of malaria morbidity and mortality due to underdeveloped immune responses and increased susceptibility to severe malaria symptoms, including cerebral malaria and severe anaemia (Osarfo et al., 2022). Interventions such as insecticide-treated bed nets (ITNs) and prompt access to artemisinin-based combination therapies (ACTs) have proven effective in reducing malaria cases among this vulnerable group (Dhiman, S. 2019).

5.3.2 Ages (5-14)

Prevalence in this age group also increased, from 21.69% in 2015 to 39.85% in 2023. Unlike younger children, children aged 5-14 tend to have more outdoor activities, increasing their exposure to malaria vectors (Penny et al., 2015). The school-age population often receives less attention in malaria control programs, which typically prioritize young children and pregnant women (Makenga et. al. 2020). As a result, children aged 5-14 may act as a reservoir for malaria transmission, contributing to sustained community transmission rates (Khagayi et. al. 2019).

5.3.3 Adults (Ages 15-49)

The adult prevalence rates are consistently lower than those in younger groups (), but there was a moderate increase from 7.02% in 2015 to 11.97% in 2023. Adults often have a degree of acquired immunity, resulting in asymptomatic or less severe cases (Cheaveau et. al. 2019, Prusty et. al. 2021), yet they can still contribute to transmission (Khagayi et. al. 2019). Studies like those by Prusty et. al. (2021) has found that adults can act as asymptomatic carriers, silently contributing to malaria's transmission cycle, particularly in endemic areas (Khagayi et. al. 2019). Urbanization, migration patterns, and occupational risks (e.g., outdoor nighttime activities) are factors that can influence adult exposure to malaria. Addressing malaria in adults may require tailored interventions, such as occupational health measures and targeted testing (Athirah Naserrudin et al., 2022).

5.3.4 Elderly (Ages 50 and above)

The elderly show the lowest prevalence rates across the years, though with a slight increase from 5.45% in 2015 to 9.13% in 2023. The relatively low prevalence may reflect lower exposure due to less outdoor activity and some level of immunity from long-term exposure in endemic areas (Cheaveau et. al. 2019). Research by Bello et. al. (2023) suggests that the elderly have reduced exposure, the impact of malaria can be more severe due to comorbidities. However, age-related immune decline (immune-senescence) may increase the risk of complications when malaria does occur in this age group (Miglar, A. 2023). The efficacy of interventions in this group might need to consider age-related health vulnerabilities.

5.4 The Overall Trends, Seasonal Variations, And Geographical Differences

Globally, malaria incidence and prevalence have shown mixed trends. While the WHO (2021) reports a decline in malaria cases in several regions due to intensified malaria control efforts, the upward trend observed in our study reflects the ongoing challenge of malaria elimination in sub-Saharan Africa (Okumu et. al. 2022).

5.4.1 Trend Relationship Between OPD Attendance and Positive Malaria Cases (2015-2023)

The trend of outpatient department (OPD) attendance and positive malaria cases from 2015 to 2023 reflects the complex interplay of healthcare utilization and disease prevalence, particularly influenced by the impact of the COVID-19 pandemic in 2020 (Dulacha et. al. 2022).

The relationship between the overall OPD attendance and positive malaria cases is an indicator of understanding the healthcare-seeking behavior in response to malaria (Dulacha et. al. 2022). Studies by Maikore, I. K. (2021) and World Health Organization (2020) emphasize the utility of OPD data in tracking malaria cases, especially in high-transmission areas, suggesting that fluctuations in OPD attendance often mirror trends in malaria incidence. A Pearson correlation coefficients analysis (0.45, $R^2 = 0.20$), although not significant indicated a moderate positive linear relationship between OPD attendance and positive cases, further revealing that only 20% of the variability in positive cases is explained by OPD attendance in this study. This suggests that additional factors may be influencing positive case counts. This further suggests that OPD attendance is a reliable, though indirect, marker for malaria prevalence, supporting continued integration of OPD data in malaria surveillance systems.

5.4.2 Overall Malaria Prevalence Trends (2015-2023)

The overall malaria prevalence trend in this study showed a steady increase, with a noticeable peak in 2020, where malaria prevalence reached 19.73%, and a subsequent decline in 2022 to 14.88%. These fluctuations may be attributed to several factors such as climate change, healthcare-seeking behavior changes (e.g., during the COVID-19 pandemic), or external interventions, including possible disruptions in malaria intervention programs due to the COVID-19 pandemic (Rogerson et. al. 2020, Awino, D. B. 2021). These have been documented to affect healthcare access in malaria-endemic regions (Weiss et al., 2021).

Pre-2020 (2015-2019): In the years leading up to 2020, both OPD attendance and malaria-positive cases exhibited a steady increase. This trend indicates a growing recognition of malaria as a pressing public health issue, prompting more individuals to seek healthcare services. The steady rise in OPD visits during this period may also reflect effective public health campaigns that encouraged healthcare utilization for malaria diagnosis and treatment. Moreover, increased access to healthcare facilities, including the distribution of insecticide-treated nets and antimalarial medications, likely contributed to this trend, creating a supportive environment for individuals experiencing malaria symptoms to seek medical attention (Ingabire et. al. 2016, Dhiman, S. 2019).

2020 (COVID-19 Impact): The year 2020 marked a turning point, characterized by a marked decrease in both OPD attendance and the number of confirmed positive malaria cases. This decline can be largely attributed to the widespread disruption caused by the COVID-19 pandemic, which led to lockdowns, resource reallocation, and increased fear of seeking medical care due to potential exposure to the virus in healthcare settings (Weiss et al., 2021, Dulacha et. al. 2022). Interestingly, while overall attendance dropped, the malaria prevalence spiked during this period, suggesting a change in healthcare-seeking behavior (Dulacha et. al. 2022). Those who did attend the OPD were more likely to be malaria-positive, indicating that even with fewer visits, the disease remained a significant threat and that symptomatic individuals continued to seek care despite the pandemic's constraints. This phenomenon emphasizes the potential for an underestimation of malaria cases during this time, as many symptomatic individuals likely remained untreated.

Post-2020 (2021-2023): In the years following the initial impact of COVID-19, OPD attendance and malaria-positive cases began to recover; however, they have not returned to pre-2020 levels. This stagnation suggests that while healthcare access improved, the lingering effects of the pandemic on public health behavior may have created a hesitance among individuals to visit healthcare facilities (Nicholson et. al. 2020). Additionally, the prevalence of malaria has remained higher than in the early years of the study, indicating that although fewer individuals are accessing OPD services, those who did are experiencing a relatively high rate of positive cases. This trend raises important questions about the effectiveness of malaria control interventions in the context of a recovering healthcare system and points to the need for sustained efforts to promote healthcare utilization and address malaria in the aftermath of the pandemic.

5.4.3 Seasonal Variation and Transmission Patterns

This data demonstrates clear seasonal trends in malaria cases, with the rainy season bringing a significant surge in cases due to increased mosquito breeding sites created by stagnant water. Such seasonal spikes align closely with findings in the literature (Mayi et. al. 2020, Nsereko et. al. 2020, Chandra, G., & Mukherjee, D. 2022). Nabatanzi et. al. (2022) discussed the role of the rainy season in amplifying malaria transmission, as wet conditions foster an ideal environment for mosquito reproduction. Rain-filled habitats serve as prolific breeding grounds, particularly in sub-Saharan Africa, where these conditions coincide with peak malaria transmission months (Nsereko et. al. 2020). This seasonal pattern is echoed in Siya et. al. (2020) research, which examines tropical regions and concludes that precipitation is a major determinant in malaria prevalence due to its direct relationship with mosquito population growth.

However, unlike other studies where malaria cases sharply decline during dry months, our data reveal a milder seasonal drop, suggesting potential "residual transmission" that persists through the dry season. This could reflect the impact of factors like irrigation, artificial reservoirs, or small, permanent water bodies that can sustain mosquito populations even in drier months (Kibret et. al. 2021). Jiang et. al. (2023) addresses this phenomenon, noting that agricultural practices and human-engineered water sources contribute to ongoing malaria transmission, as they create microhabitats for mosquito larvae that endure outside the typical rainy season.

The persistent transmission observed in our study may further reflect a shift in malaria vector ecology and behavior (Forson et. al. 2022). Hill, K. K. (2024) found that some Anopheles species adapt to dry-season conditions by seeking out alternative breeding sites like wells, irrigation channels, and other human-maintained water sources, creating a “residual” transmission environment. This adaptability is compounded by temperature and humidity variations, which can prolong mosquito survival rates even in less favorable seasons (Gimnig et al., 2020).

Our findings underscore the need for adaptive malaria control strategies that account for year-round breeding habitats. While the literature supports seasonal targeting of vector control measures, studies such as that by Stresman et al. (2022) argue for increased vigilance during the dry season, especially in areas with intensive irrigation or permanent water bodies. To combat this year-round transmission, targeted interventions like larval source management and community awareness on reducing stagnant water sources can play an essential role, addressing both natural and artificial breeding sites. Our findings advocate for a nuanced malaria control approach that considers both rainy and dry seasons to achieve more comprehensive malaria management.

5.4.4 Geographical and Facility-based Differences

The findings from our study underscore notable geographical and facility-based differences in malaria prevalence, with rural areas experiencing disproportionately higher rates of infection compared to urban centers. This urban-rural disparity aligns with existing literature, which indicates that rural populations are often at a greater risk of malaria due to several interconnected factors, including limited healthcare access, fewer prevention programs, and environmental conditions favorable for mosquito breeding. Yeka et al. (2020) explain that the remoteness of rural areas can delay access to timely medical care and reduce the likelihood of community-level interventions, such as insecticide-treated net distribution and indoor residual spraying, effectively increasing malaria vulnerability. Environmental factors unique to rural settings further exacerbate these risks. Studies show that rural communities, particularly in sub-Saharan Africa, are typically closer to stagnant water bodies and have lower levels of infrastructure, such as paved roads, which tend to be associated with better healthcare access and less mosquito breeding (Kariuki et al., 2022). Agricultural practices common in rural areas, such as irrigation, can also create additional mosquito breeding sites, which is supported by Mwakitalu et al. (2018), who report higher malaria prevalence in agricultural regions where irrigation practices are prevalent.

In light of these findings, targeted interventions that specifically address the needs of rural areas are essential. Environmental management, such as the reduction of mosquito breeding sites near rural communities, can be an effective complementary approach to medical interventions. Addressing these facility-based and geographical differences is crucial in the pursuit of equitable malaria control and elimination efforts, aligning with recommendations by the WHO to strengthen healthcare systems and adapt interventions based on local epidemiological contexts (WHO, 2022). By implementing these targeted interventions, it is possible to reduce the malaria burden more equitably and improve overall public health outcomes in endemic regions.

5.5 Forecasting Malaria Trends

Forecasting malaria trends based on retrospective data from 2015 to 2023 offers critical insights into potential shifts in malaria incidence, particularly in endemic regions like the

Mampong Municipality. Our study's projections indicate a steady increase in malaria prevalence, with an annual average growth rate of approximately 7.49%. Notably, the data suggests that without intensified interventions, prevalence rates will continue to rise, particularly affecting high-risk groups, such as children under five and adults aged 15–49. This forecast aligns with findings from similar studies, where predictive modeling has proven effective in strengthening preparedness for malaria outbreaks.

Our model's projections for the years 2024 through 2026 estimate a consistent increase in malaria prevalence, with rates of approximately 18.7%, 19.4%, and 20.1%, respectively. This upward trend points to a sustained risk of malaria if intervention efforts are not enhanced. In settings like the Asante Mampong municipality, addressing these gaps becomes essential to counter the predicted increase in malaria cases.

CHAPTER SIX

SUMMARY OF FINDINGS, CONCLUSION, RECOMMENDATION, AND POLICY IMPLICATION

6.1 Summary of Findings

In this retrospective study, we examined malaria incidence, prevalence, and demographic characteristics from 2015 to 2023. Our findings highlight significant patterns in malaria transmission, with age, gender, and seasonal variations playing critical roles in shaping malaria prevalence. Children under five and adults aged 15-49 experienced the highest burden of malaria, while males, particularly those in rural areas, were more susceptible due to occupational and behavioral factors. Seasonal variations, particularly during the rainy season, significantly influenced malaria transmission, underscoring the need for targeted interventions during peak transmission months.

The gender-specific trends and analysis revealed that males had higher malaria prevalence, likely due to increased outdoor activities. It also underscores the importance of addressing the unique vulnerabilities of both men and women in malaria control efforts. Tailoring interventions to reflect these gendered patterns will be essential in closing the malaria prevention gap and ensuring equitable access to effective prevention and treatment. Forecasting models indicate that, without further interventions, malaria cases are likely to rise in the near future, particularly during the rainy season and among the most vulnerable groups.

6.2 Conclusion

With infection rates persistently higher in rural areas and a seasonal surge during rainy periods, it is clear that current measures are insufficient to curb the spread of malaria. The slight but steady increase in cases signals a potential failure to meet the National Malaria Strategic Elimination Plan (2024–2028) and the ambitious zero-malaria goal of a 90% case reduction in high-burden areas. This study therefore underscores the urgent need for a bold re-evaluation of Ghana's malaria control strategies, particularly in the Mampong Municipality. Achieving these targets is still within reach, but it demands decisive policy changes, targeted interventions in vulnerable regions, and rigorous monitoring. Only with such transformative action can Ghana hope to make significant strides toward eliminating malaria.

6.3 Recommendation

6.3.1 Municipal Health Directorate, and the Ghana Health Service;

1. Gender-Sensitive Approaches: Malaria interventions must account for gender-specific risk factors. Programs should target males working in high-risk outdoor environments and provide women, especially those in rural areas, with improved access to prevention tools and healthcare services.
2. Strengthening Health Infrastructure: Malaria control programs should work to improve healthcare accessibility in rural areas where malaria prevalence is highest. This includes ensuring a consistent supply of antimalarial drugs, diagnostic tools, and preventive measures.

3. Community Engagement and Education: Public health campaigns should focus on educating communities about the importance of malaria prevention, particularly during the rainy season. Raising awareness about the proper use of ITNs and prompt treatment-seeking behavior can reduce the malaria burden.

6.3.2 Ghana Malaria Elimination Program;

1. Enhanced Locally Informed Surveillance and Predictive Modeling: Incorporating real-time weather and climate data into malaria surveillance systems will improve the accuracy of outbreak predictions. Thus, allowing for proactive responses during peak transmission seasons, and also ensuring that intervention programs remain responsive to evolving transmission dynamics locally. This will also reflect emerging trends and provide reliable forecasts for resource allocation.
2. Targeted Interventions for High-Risk Groups: Malaria control programs should focus on the most vulnerable populations, particularly children under five, and adults in rural areas. Interventions such as insecticide-treated nets (ITNs), indoor residual spraying (IRS), and intermittent preventive treatment in pregnancy (IPTp) should be prioritized for these groups.

6.3.3 WHO Global Malaria Program;

1. Climate Change and Malaria Transmission: Collaboration with climate experts and professionals to prepare for climate-driven shifts in malaria transmission patterns.

2. Enhanced Surveillance and Data Utilization: Continues investment in real-time digital surveillance systems to improve outbreak response and resource allocation.
3. Combatting Insecticide and Drug Resistance: An increase on alternative insecticides, treatments, and resistance tracking in real-time.

6.4 Policy Implications

The rising trend in malaria prevalence projected by the model, particularly among high-risk groups and during peak seasons, has serious implications for Ghana's malaria elimination agenda. If current patterns persist, the country risks falling short of the National Malaria Strategic Elimination Plan (2024–2028) and its goal of a 90% case reduction. Policymakers must therefore urgently strengthen localized and data-driven strategies that prioritize rural and peri-urban populations, where prevalence remains high. Interventions should be seasonally adaptive, gender-responsive, and focused on vulnerable groups such as children under five and working-age adults. Integrating predictive modeling and real-time surveillance into national and municipal health systems can support timely, targeted action. Without these shifts, elimination targets may remain aspirational rather than achievable.

6.5 Future Research Direction

Future malaria control efforts should integrate climate data to anticipate and mitigate outbreaks. By employing seasonal autoregressive integrated moving average (SARIMA) models, we can predict potential surges in malaria cases during peak transmission periods, particularly in the rainy seasons where environmental conditions favor mosquito breeding. These models, combined with demographic and behavioral data, enable public health authorities to anticipate outbreaks and allocate resources effectively.

REFERENCES

Abiodun, G. J., et al. (2021). Application of SARIMA models in malaria forecasting: A case study in Nigeria. Malaria Journal, 20(1), 102.

Adetokunboh, O. O., Mthombothi, Z. E., Dominic, E. M., Djomba-Njankou, S., & Pulliam, J. R. C. (2021). African based researchers' output on models for the transmission dynamics of infectious diseases and public health interventions: A scoping review. *PloS One*, *16*(5). https://doi.org/10.1371/journal.pone.0250086

Adigun, A. B., et al. (2017). Gender differences in malaria prevalence and behavior in rural African communities. Malaria Journal, 16(1), 301.

Adum, P., Agyare, V. A., Owusu-Marfo, J., & Agyeman, Y. N. (2023). Knowledge, attitude and practices of malaria preventive measures among mothers with children under five years in a rural setting of Ghana. *Malaria Journal*, *22*(1), 268.

Adu-Prah, S., & Tetteh, E. K. (2015). Spatiotemporal analysis of climate variability impacts on malaria prevalence in Ghana. *Applied Geography*, *60*, 266-273.

Aguirre, A. A., Basu, N., Kahn, L. H., Morin, X. K., Echaubard, P., Wilcox, B. A., & Beasley, V. R. (2019). Transdisciplinary and social-ecological health frameworks—Novel approaches to emerging parasitic and vector-borne diseases. *Parasite epidemiology and control*, *4*, e00084.

Aidoo, E. K., Aboagye, F. T., Arthur, G., Appiah, M., Botchway, F. A., Osei-Adjei, G., ... & Krogfelt, K. A. (2024). Implementation of reactive case detection strategy recommendations towards malaria elimination in the Shai Osudoku district of Ghana. *Discover Public Health*, *21*(1), 199.

Aklie, E. N. (2024). *The Ghanaian War Against Malaria: A Geospatial Approach to Malaria and Healthcare Access in Ghana* (Master's thesis, Jacksonville State University).

AlJaberi, O. A., Hussain, M., & Drake, P. R. (2020). A framework for measuring sustainability in healthcare systems. *International journal of healthcare management*.

Al-Worafi, Y. M. (2024). Malaria Management in Developing Countries. In *Handbook of Medical and Health Sciences in Developing Countries: Education, Practice, and Research* (pp. 1-40). Cham: Springer International Publishing.

Anaba, M. K., Ibisomi, L., Owusu-Agyei, S., Chirwa, T., & Ramaswamy, R. (2019). Determinants of health workers intention to use malaria rapid diagnostic test in Kintampo North Municipality, Ghana-a cross-sectional study. *BMC Health Services Research*, *19*, 1-8.

Anjorin, S., Okolie, E., & Yaya, S. (2023). Malaria profile and socioeconomic predictors among under-five children: an analysis of 11 sub-Saharan African countries. *Malaria Journal*, *22*(1), 55.

Anwar, A., Anwar, S., Ayub, M., Nawaz, F., Hyder, S., Khan, N., & Malik, I. (2019). Climate change and infectious diseases: evidence from highly vulnerable countries. *Pmc.Ncbi.Nlm.Nih.Gov*, *48*(12), 2187–2195. https://pmc.ncbi.nlm.nih.gov/articles/PMC6974868/

Athirah Naserrudin, N., Hod, R., Saffree Jeffree, M., Ahmed, K., & Rohaizat Hassan, M. (2022). The Emerging Threat of Plasmodium knowlesi Malaria Infection: A Concept Paper on the Vulnerable Factors in Human. *Mdpi.Com*. https://doi.org/10.3390/ijerph19074419

Awine, T., Malm, K., Bart-Plange, C., action, S. S.-G. health, & 2017, undefined. (2017). Towards malaria control and elimination in Ghana: challenges and decision making tools to guide planning. *Taylor & Francis*, *10*(1). https://doi.org/10.1080/16549716.2017.1381471

Asante, K. P., Mathanga, D. P., Milligan, P., Akech, S., Oduro, A., Mwapasa, V., … & Sillah, J. S. (2024). Feasibility, safety and impact of the RTS, S/AS01E malaria vaccine when implemented through national immunization programmes: evaluation of cluster-randomised introduction of the vaccine in Ghana, Kenya, and Malawi. *The Lancet*, *403*(10437), 1660-1670.

Ashley, E. A., Dhorda, M., Fairhurst, R. M., et al. (2014). Spread of artemisinin resistance in Plasmodium falciparum malaria. *New England Journal of Medicine*, 371(5), 411-423.

Awasthi, K. R., Jancey, J., Clements, A. C., & Leavy, J. E. (2021). Community engagement approaches for malaria prevention, control and elimination: a scoping review protocol. *BMJ open*, *11*(10), e049812.

Awino, D. B. (2021). *Factors Influencing Utilization of Healthcare Services During Covid-19 Pandemic Among Pregnant Women and Caregivers With Children Under Two Years in Rongo Subcounty, Migori County, Kenya* (Doctoral dissertation, KeMU).

Basu, S., Pediatrics, P. S.-T. I. J. of, & 2017, undefined. (2017). Malaria: an update. *Springer*, *84*(7), 521–528. https://doi.org/10.1007/s12098-017-2332-2

Bempah, S., Curtis, A., Awandare, G., & Ajayakumar, J. (2020). Appreciating the complexity of localized malaria risk in Ghana: Spatial data challenges and solutions. *Health \& Place*. https://www.sciencedirect.com/science/article/pii/S1353829220303488

Benjamin, G. Y., Mallam, F., Alhamdu, J. T., Yakubu, S. T., & Ladan, I. A. (2023). A review of the impact of COVID-19 pandemic on malaria control in Africa. *Microbes and Infectious Diseases*, *4*(4), 1081–1087. https://doi.org/10.21608/MID.2023.231844.1600

Boadu, I., Nsemani, W., Ubachukwu, P., & Okafor, F. C. (2020). Knowledge and Prevalence of Malaria among Rural Households in Ghana. *Journal of Community Medicine & Health Education Article in Journal of Community Medicine & Health Education*, *2020*(January), 1. https://www.researchgate.net/publication/344866667

Baines, K. J., & West, R. C. (2023). Sex differences in innate and adaptive immunity impact fetal, placental, and maternal health. *Biology of reproduction, 109*(3), 256-270.

Balasubramaniam, A., et al. (2020). Socio-cultural barriers to malaria prevention in sub-Saharan Africa. Tropical Medicine & International Health, 25(7), 820-827.

Baltzell, K., Harvard, K., Hanley, M., Gosling, R., & Chen, I. (2019). What is community engagement and how can it drive malaria elimination? Case studies and stakeholder interviews. *Malaria journal*, *18*, 1-11.

Battle, K. E., Weiss, D. J., Cameron, E., et al. (2019). Mapping the global endemicity and clinical burden of Plasmodium vivax, 2000–17: a spatial and temporal modelling study. The Lancet, 394(10195), 332-343.

Beke, O. A. H., Assi, S. B., Kokrasset, A. P. H., Dibo, K. J. D., Tanoh, M. A., Danho, M., ... & Poinsignon, A. (2023). Implication of agricultural practices in the micro-geographic heterogeneity of malaria transmission in Bouna, Côte d'Ivoire. *Malaria Journal*, *22*(1), 313.

Bello, I. S., Olajubu, T. O., Osundiya, O. O., Salami, O. T., Ibrahim, A. O., & Ahmed, A. A. (2023). Malaria among the elderly in five communities of Osun East district, Southwest Nigeria: Prevalence and association with non-communicable diseases. *SAGE Open Medicine*, *11*, 20503121231164259.

Berrouet, L. M., Machado, J., & Villegas-Palacio, C. (2018). Vulnerability of socio—ecological systems: A conceptual Framework. *Ecological indicators*, *84*, 632-647.

Bhatt, S., Weiss, D. J., Cameron, E., et al. (2015). The effect of malaria control on Plasmodium falciparum in Africa between 2000 and 2015. Nature, 526(7572), 207-211.

Bomblies, A. (2012). Modeling the role of rainfall patterns in seasonal malaria transmission. *Climatic Change*, 112(3-4), 673-685.

Boyce, M. R., Attal-Juncqua, A., Lin, J., McKay, S., & Katz, R. (2021). Global Fund contributions to health security in ten countries, 2014-20: mapping synergies between vertical disease programmes and capacities for preventing, detecting, and responding to public health emergencies. *The Lancet. Global Health*, *9*(2). https://doi.org/10.1016/S2214-109X(20)30420-4

Boylan, S., Beyer, K., Schlosberg, D., Mortimer, A., Hime, N., Scalley, B., ... & Capon, A. (2018). A conceptual framework for climate change, health and wellbeing in NSW, Australia.

Briggs, J., Murray, M., Nideffer, J., & Jagannathan, P. (2023). Sex-linked differences in malaria risk across the lifespan. *Sex and Gender Differences in Infection and Treatments for Infectious Diseases*, 185-208.

Bruxvoort, K., Goodman, C., Kachur, S. P., & Scheiienberg, D. (2014). How patients take malaria treatment: a systematic review of the literature on adherence to antimalaria drugs. Plos one, 9(1), e84555.

Caminade, C., Kovats, S., Rocklov, J., et al. (2014). Impact of climate change on global malaria distribution. Proceedings of the National Academy of Sciences, 111(9), 3286-3291.

Chanda, E., Ameneshewa, B., Bagayoko, M., Govere, J. M., & Macdonald, M. B. (2017). Harnessing integrated vector management for enhanced disease prevention. *Trends in parasitology*, *33*(1), 30-41.

Chandra, G., & Mukherjee, D. (2022). Effect of climate change on mosquito population and changing pattern of some diseases transmitted by them. In *Advances in Animal Experimentation and Modeling* (pp. 455-460). Academic Press.

Chaves, L. F., Cohen, J. M., Pascual, M., & Wilson, M. L. (2012). Social and climate conditions determine spatio-temporal malaria transmission patterns in an urban setting in sub-Saharan Africa. *Malaria Journal*, 11(1), 1-11.

Cheaveau, J., Mogollon, D. C., Mohon, M. A. N., Golassa, L., Yewhalaw, D., & Pillai, D. R. (2019). Asymptomatic malaria in the clinical and public health context. *Expert review of anti-infective therapy*, *17*(12), 997-1010.

Cohen, J. M., Civitello, D. J., Brace, P. J., Feichtinger, E. M., Ortega, C. N., & Rohr, J. R. (2017). Spatial scale modulates the strength of ecological processes driving disease distributions. *Proceedings of the National Academy of Sciences*, 114(4), E596-E602.

Cowman, A. F., Healer, J., Marapana, D., & Marsh, K. (2016). Malaria: Biology and Disease. *Cell*, *167*(3), 610–624. https://doi.org/10.1016/j.cell.2016.07.055

Dabaro, D., Birhanu, Z., & Yewhalaw, D. (2020). Analysis of trends of malaria from 2010 to 2017 in Boricha District, Southern Ethiopia. *Malaria Journal*, *19*(1). https://doi.org/10.1186/S12936-020-03169-W

Dearing, J. W., & Cox, J. G. (2018). Diffusion of innovations theory, principles, and practice. *Health affairs*, *37*(2), 183-190.

Deku, J. G., Lokpo, S. Y., Kye-Amoah, K. K., Orish, V. N., Ussher, F. A., Esson, J., Aduko, R. A., Dakorah, M. P., & Osei-Yeboah, J. (2019). Malaria Burden and Trend Among Clients Seeking Healthcare in the Western Region: A 4-Year Retrospective Study at the Sefwi-Wiawso Municipal Hospital, Ghana. *The Open Microbiology Journal*, *12*(1), 404–411. https://doi.org/10.2174/1874285801812010404

Desai, M., et al. (2020). Pregnancy-associated malaria and its impact on maternal and infant health. The Lancet Infectious Diseases, 20(2), 285-292.

Dhiman, S. (2019). Are malaria elimination efforts on right track? An analysis of gains achieved and challenges ahead. *Infectious diseases of poverty*, *8*, 1-19.

Ding, C., Huang, C., Zhou, Y., Fu, X., Liu, X., Wu, J., & ... (2020). Malaria in China: a longitudinal population-based surveillance study. *Epidemiology \& …*. https://www.cambridge.org/core/journals/epidemiology-and-infection/article/malaria-in-china-a-longitudinal-populationbased-surveillance-study/9E88D20FF2808BCF4410094AB25D9109

Dondorp, A. M., Fairhurst, R. M., Slutsker, L., et al. (2010). Artemisinin resistance: current status and scenarios for containment. Nature Reviews Microbiology, 8(4), 272-280.

Donkor, E., Kelly, M., Eliason, C., Amotoh, C., & ... (2021). A Bayesian spatio-temporal analysis of malaria in the Greater Accra Region of Ghana from 2015 to 2019. *International Journal of …*. https://www.mdpi.com/1660-4601/18/11/6080

Douine, M., Cairo, H., Galindo, M. S., Vreden, S., Lambert, Y., Adenis, A., Jimeno, I., Suarez-Mutis, M., Sanna, A., & Hiwat, H. (2023). From an interventional study to a national scale-up: lessons learned from the Malakit strategy at the French Guiana–Suriname border. *Springer*, *22*(1). https://doi.org/10.1186/S12936-023-04672-6

Douine, M., Lambert, Y., Suzanne Galindo, M., Jimeno Maroto, I., Bardon, T., Plessis, L., ... & Suarez-Mutis, M. (2024). Core principles of Malakit intervention for transferability in other contexts. *Malaria Journal, 23*, 185.

Doumbe-Belisse, P., Kopya, E., Ngadjeu, C. S., Sonhafouo-Chiana, N., Talipouo, A., Djamouko-Djonkam, L., Awono-Ambene, H. P., Wondji, C. S., Njiokou, F., & Antonio-Nkondjio, C. (2021). Urban malaria in sub-Saharan Africa: dynamic of the vectorial system and the entomological inoculation rate. *Malaria Journal*, *20*(1). https://doi.org/10.1186/S12936-021-03891-Z

Dube, E., Laberge, C., Guay, M., et al. (2013). Vaccine hesitancy: an overview. *Human Vaccines & Immunotherapeutics*, 9(8), 1763-1773.

Duffy, P. E., Gorres, J. P., Healy, S. A., & Fried, M. (2024). Malaria vaccines: a new era of prevention and control. *Nature Reviews Microbiology*, 1-17.

Dulacha, D., Were, V., Oyugi, E., Kiptui, R., Owiny, M., Boru, W., ... & Perry, R. T. (2022). Reduction in malaria burden following the introduction of indoor residual spraying in areas protected by long-lasting insecticidal nets in Western Kenya, 2016–2018. *Plos one*, *17*(4), e0266736.

Durnez, L., & Coosemans, M. (2020). Residual malaria transmission: An enduring challenge for malaria control. Malaria Journal, 19(1), 118.

El-moamly, A. A., & El-Sweify, M. A (2023). Malaria vaccines: the 60-year journey of hope and final success-lessons learned and future prospects. *Tropical Medicine and Health*, *51*(1), 29.

Ernst, K. C., Lindblade, K. A., Koech, D., et al. (2015). Environmental, socio-demographic and behavioural determinants of malaria risk in the western Kenyan highlands: a case-control study. *Tropical Medicine & International Health*, 20(9), 1258-1273.

El-Sayed, A., & Kamel, M. (2020). Climatic changes and their role in emergence and re-emergence of diseases. *Environmental Science and Pollution Research*, *27*(18), 22336–22352. https://doi.org/10.1007/S11356-020-08896-W

Epstein, A., Gonahasa, S., Namuganga, J. F., Nassali, M. J., Maiteki-Sebuguzi, C., Nabende, I., Snyman, K., Nankabirwa, J. I., Opigo, J., Donnelly, M. J., Staedke, S. G., Kamya, M. R., & Dorsey, G. (2025). Evaluating the impact of two next-generation long-lasting insecticidal nets on malaria incidence in Uganda: an interrupted time-series analysis using routine health. *Gh.Bmj.Com*, *10*, 17106. https://doi.org/10.1136/bmjgh-2024-017106

Fornace, K. M., Diaz, A. V., Lines, J., & Drakeley, C. J. (2021). Achieving global malaria eradication in changing landscapes. *Malaria journal*, *20*(1), 69.

Fornace, K. M., Senyonjo, L., Martin, D. L., & ... (2022). Characterising spatial patterns of neglected tropical disease transmission using integrated sero-surveillance in Northern Ghana. *... Tropical Diseases*. https://journals.plos.org/plosntds/article?id=10.1371/journal.pntd.0010227

Forson, A. O., Hinne, I. A., Dhikrullahi, S. B., Sraku, I. K., Mohammed, A. R., Attah, S. K., & Afrane, Y. A. (2022). The resting behavior of malaria vectors in different ecological zones of Ghana and its implications for vector control. *Parasites & Vectors*, *15*(1), 246.

Frank, C., Krumkamp, R., Sarpong, N., Sothmann, P., Fobil, J. N., Foli, G., Jaeger, A., Ehlkes, L., Owusu-Dabo, E., Adu-Sarkodie, Y., Marks, F., Schumann, R. R., May, J., & Kreuels, B. (2016). Spatial heterogeneity of malaria in Ghana: A cross-sectional study on the association between urbanicity and the acquisition of immunity. *Malaria Journal*, *15*(1). https://doi.org/10.1186/S12936-016-1138-4

Galactionova, K, Bertram, M., Lauer, J., Vaccine, F. T.-, & 2015, U. (2015). Costing RTS, S introduction in Burkina Faso, Ghana, Kenya, Senegal, Tanzania, and Uganda: a generalizable approach drawing on publicly available data. *Elsevier*. https://www.sciencedirect.com/science/article/pii/S0264410X15015224

Galactionova, K, Tediosi, F., Camponovo, F., Vaccine, T. S.-, & 2017, U. (2017). Country specific predictions of the cost-effectiveness of malaria vaccine RTS, S/AS01 in endemic Africa. *Elsevier*.

https://www.sciencedirect.com/science/article/pii/S0264410X16311033

Galactionova, Katya, Smith, T. A., de Savigny, D., & Penny, M. A. (2017). State of inequality in malaria intervention coverage in sub-Saharan African countries. *Springer*, *15*(1). https://doi.org/10.1186/S12916-017-0948-8

Galactionova, Katya, Tediosi, F., De Savigny, D., Smith, T., & Tanner, M. (2015). Effective coverage and systems effectiveness for malaria case management in sub-Saharan African countries. *Journals.Plos.Org*, *10*(5), 127818. https://doi.org/10.1371/JOURNAL.PONE.0127818

Genton, B., et al. (2021). The RTS,S/AS01 malaria vaccine: An overview of its efficacy and safety. *Tropical Medicine & International Health*, 26(5), 559-572.

Gething, P. W., Casey, D. C., Weiss, D. J., et al. (2016). Mapping Plasmodium falciparum Mortality in Africa between 1990 and 2015. New England Journal of Medicine, 375, 2435-2445.

Ghana Health Service (GHS) (2021). *National Malaria Elimination Strategic Plan 2021–2025*. Accra: Ghana Health Service

Ghana Health Service. (2022). Annual Malaria Report 2021.

Ghana Statistical Service, Monthly Press Release. (2023, April). *Malaria prevalence in children declines by a third in the past decade but the prevalence in rural areas is about three times as high compared to urban.* statsghana.gov.gh/gssmain/fileUpload/pressrelease/World Malaria Day Press Release from GSS.pdf

Githeko, A., Ototo, E., tropica, Y. G.-A., & 2012, undefined. (2012). Progress towards understanding the ecology and epidemiology of malaria in the western Kenya highlands: opportunities and challenges for control under climate. *Elsevier*, *121*(1), 19–25. https://doi.org/10.1016/j.actatropica.2011.10.002

Gonahasa, S., Nassali, M., Maiteki-Sebuguzi, C., Namuganga, J. F., Opigo, J., Nabende, I., ... & Staedke, S. G. (2024). LLIN evaluation in Uganda project (LLINEUP2): Association between housing construction and malaria burden in 32 districts. *Malaria Journal*, *23*, 190.

Green, E. C., Murphy, E. M., & Gryboski, K. (2020). The health belief model. *The Wiley encyclopedia of health psychology*, 211-214.

Guy-Evans, O. (2020). Bronfenbrenner's ecological systems theory. *Simply Psychology*.

Hanboonkunupakarn, B., & White, N. J. (2022). Advances and roadblocks in the treatment of malaria. *British journal of clinical pharmacology*, *88*(2), 374-382.

Hasyim, H., Marini, H., Misnaniarti, M., Flora, R., Liberty, I. A., Elagali, A., ... & Maharani, F. E. (2024). Evaluation of the malaria elimination programme in Muara Enim Regency: a qualitative study from Indonesia. *Malaria Journal*, *23*(1), 43.

Hay, S. I., Guerra, C. A., Tatem, A. J., Atkinson, P. M., & Snow, R. W. (2005). Urbanization, malaria transmission and disease burden in Africa. *Nature Reviews Microbiology*, 3(1), 81-90.

Hemingway, J., Ranson, H., Magill, A., et al. (2016). Averting a malaria disaster: will insecticide resistance derail malaria control? *The Lancet*, 387(10029), 1785-1788.

Hill, K. K. (2024). Short-term larval surveys reveal rainy season breeding site preferences of malaria vector Anopheles spp. in Zanzibar City.

Houngbedji, C. A., et al. (2019). Gender differences in malaria infection in rural areas of Benin. Infectious Diseases of Poverty, 8(1), 89.

Hsiang, M. S., Cotter, C., Sturrock, H. J. W., Liu, J., Phillips, A. A., Hwang, J., Gueye, C. S., Fullman, N., Gosling, R. D., & Feachem, R. G. A. (2013). The changing epidemiology of malaria elimination: new strategies for new challenges. *Elsevier*. https://doi.org/10.1016/S0140-6736(13)60310-4

Incidence of malaria (per 1,000 population at risk) [https://data.world bank.org/indicator/SH.MLR.INCD.P3]. World Health Organization, World malaria report and Global Health Observatory Data Repository/World Health Statistics (apps.who.int/ghodata)

Ingabire, C. M., Kateera, F., Hakizimana, E., Rulisa, A., Muvunyi, C., Mens, P., ... & Alaii, J. (2016). Determinants of prompt and adequate care among presumed malaria cases in a community in eastern Rwanda: a cross sectional study. *Malaria journal*, *15*, 1-11.

Jabeen, A., Ansari, J., Ikram, A., Khan, M., & ... (2022). Impact of climate change on the epidemiology of vector-borne diseases in Pakistan. *Global* …. https://www.jglobalbiosecurity.com/articles/163/

Jiang, A. L., Lee, M. C., Selvaraj, P., Degefa, T., Getachew, H., Merga, H., ... & Hsu, K. (2023). Investigating the Impact of Irrigation on Malaria Vector Larval Habitats and Transmission Using a Hydrology‐Based Model. *GeoHealth*, *7*(12), e2023GH000868.

Kaehler, N., Adhikari, B., Cheah, P. Y., Von Seidlein, L., Day, N. P. J., Dondorp, A. M., & Pell, C. (2019). Mass drug administration can be a valuable addition to the malaria elimination toolbox. *Springer*, *18*(1), 46. https://doi.org/10.1186/S12936-019-2906-8

Kalyesubula, R., Mutyaba, I., Rabin, T., Andia-Biraro, I., Alupo, P., Kimuli, I., Nabirye, S., Kagimu, M., Mayanja-Kizza, H., Rastegar, A., & Kamya, M. R. (2019). Trends of admissions and case fatality rates among medical in-patients at a tertiary hospital in Uganda; A four-year retrospective study. *PLoS ONE*, *14*(5). https://doi.org/10.1371/JOURNAL.PONE.0216060

Kawaguchi, K., Donkor, E., Lal, A., Kelly, M., & ... (2022). Distribution and Risk Factors of Malaria in the Greater Accra Region in Ghana. *International Journal of* …. https://www.mdpi.com/1660-4601/19/19/12006

Kayentao, K., et al. (2013). Intermittent preventive treatment of malaria in pregnancy: A systematic review and meta-analysis. *Lancet Infectious Diseases*, 13(9), 659-672.

Keita, S., Thiero, O., Toure, M., Kane, F., Keita, M., Sanogo, I., ... & Doumbia, S. (2024). Prognostics of multiple malaria episodes and nutritional status in children aged 6 to 59 months from 2013 to 2017 in Dangassa, Koulikoro region, Mali. *Malaria Journal, 23*, 186.

Ketema, T., Bacha, K., Getahun, K., & ... (2021). Plasmodium vivax epidemiology in Ethiopia 2000-2020: A systematic review and meta-analysis. ... *Tropical Diseases*. https://journals.plos.org/plosntds/article?id=10.1371/journal.pntd.0009781

Khagayi, S., Desai, M., Amek, N., Were, V., Onyango, E. D., Odero, C., ... & Vounatsou, P. (2019). Modelling the relationship between malaria prevalence as a measure of transmission and mortality across age groups. *Malaria journal, 18*, 1-12.

Kibret, S., McCartney, M., Lautze, J., Nhamo, L., & Yan, G. (2021). The impact of large and small dams on malaria transmission in four basins in Africa. *Scientific reports*, *11*(1), 13355.

Kibret, S., Wilson, G. G., Ryder, D., Tekie, H., & Petros, B. (2019). Malaria impact of large dams in sub-Saharan Africa: maps, estimates and predictions. *Malaria Journal*, 18(1), 1-16.

Kilanowski, J. F. (2017). Breadth of the socio-ecological model. *Journal of agromedicine*, *22*(4), 295-297.

Kleinschmidt, I., et al. (2018). Indoor residual spraying as a malaria control strategy: Challenges and potential future uses. *Malaria Journal*, 17(1), 182.

Klinkenberg, E., et al. (2018). Seasonal malaria transmission and rainfall patterns in Ghana. *International Journal of Environmental Research and Public Health*, 15(2), 303.

Knoblauch, A. M., Divall, M. J., Owuor, M., et al. (2014). Experience and lessons from health impact assessment guiding prevention and control of HIV/AIDS in a copper mining region of Zambia. *Environmental Impact Assessment Review*, 47, 45-52.

Koenker, H., Kilian, A., de Beyl, C. Z., et al. (2013). What is preventing the universal coverage of long-lasting insecticidal nets? A review of the barriers to effective usage in malaria endemic countries. *Malaria Journal*, 12, 86.

Kolekang, A. S., Afrane, Y., Apanga, S., Zurovac, D., Kwarteng, A., Afari-Asiedu, S., ... & Danso-Appiah, A. (2022). Challenges with adherence to the 'test, treat, and track'malaria case management guideline among prescribers in Ghana. *Malaria Journal*, *21*(1), 332.

Komugabe, M. A., Caballero, R., Shabtai, I., & Musinguzi, S. P. (2024). Advancing Malaria Prediction in Uganda through AI and Geospatial Analysis Models. *Journal of Geographic Information System, 16*(2), 115-135.

Konaté, D., Diawara, S. I., Touré, M., Diakité, S. A. S., Guindo, A., & ... (2020). Effect of routine seasonal malaria chemoprevention on malaria trends in children under 5 years in Dangassa, Mali. *Malaria Journal*. https://doi.org/10.1186/s12936-020-03202-y

Kweka, E. J., Kimaro, E. E., & Munga, S. (2016). Effect of deforestation and land use changes on mosquito productivity and development in western Kenya highlands: implication for malaria risk. *Frontiers in Public Health*, 4, 238.

Laurens, M. B. (2020). RTS, S/AS01 vaccine (Mosquirix™): an overview. *Human vaccines & immunotherapeutics*, 16(3), 480-489.

Lee, Y., & Park, S. (2021). Understanding of physical activity in social ecological perspective: application of multilevel model. *Frontiers in Psychology*, *12*, 622929.

Liu, Q., Jing, W., Kang, L., Liu, J., & Liu, M. (2021). Trends of the global, regional and national incidence of malaria in 204 countries from 1990 to 2019 and implications for malaria prevention. *Journal of Travel Medicine*. https://academic.oup.com/jtm/article-abstract/28/5/taab046/6185118

Lourenço, C., Tatem, A. J., Atkinson, P. M., Cohen, J. M., Pindolia, D., Bhavnani, D., & Le Menach, A. (2019). Strengthening surveillance systems for malaria elimination: a global landscaping of system performance, 2015–2017. *Malaria journal*, *18*, 1-11.

Mabaso, M. L., et al. (2019). Seasonal variation of malaria transmission in tropical regions. Parasitology Today, 17(2), 53-57.

Maheu-Giroux, M., & Castro, M. C. (2014). Impact of mining activities on malaria in the Amazon: a review. *Malaria Journal*, 13(1), 1-15.

Makenga, G., Menon, S., Baraka, V., Minja, D. T., Nakato, S., Delgado-Ratto, C., ... & Van Geertruyden, J. P. (2020). Prevalence of malaria parasitaemia in school-aged children and pregnant women in endemic settings of sub-Saharan Africa: a systematic review and meta-analysis. *Parasite Epidemiology and Control*, *11*, e00188.

Maikore, I. K. (2021). *Building Evidence on National Malaria Data Repository as a decision support tool of Use of Data for decision making in Malaria Programme, Nigeria* (Doctoral dissertation, London School of Hygiene & Tropical Medicine).

Maiti, M., & Roy, U. (2024). Space-time clusters and co-occurrence of Plasmodium vivax and Plasmodium falciparum malaria in West Bengal, India. *Malaria Journal*, *23*, 189.

Mao, W., Cooke, R., Silimperi, D., Hodges, E., … E. O.-B. G., & 2023, U. (2023). Scaling malaria interventions: bottlenecks to malaria elimination. *Gh.Bmj.Com*. https://gh.bmj.com/content/8/11/e013378.abstract

Mayi, M. P. A., Bamou, R., Djiappi-Tchamen, B., Fontaine, A., Jeffries, C. L., Walker, T., ... & Tchuinkam, T. (2020). Habitat and seasonality affect mosquito community composition in the west region of Cameroon. *Insects*, *11*(5), 312.

McCollum, R., Gomez, W., Theobald, S., et al. (2016). How equitable are community health worker programmes and which programme features influence equity of community health worker services? A systematic review. *BMC Public Health*, 16(1), 419.

Miglar, A. (2023). *The Effect of Plasmodium Infection on Cellular Aging in Humans*. Karolinska Institutet (Sweden).

Moltot, T., Bekele, G., Gebreegziabher, Z. A., Lemma, T., Sisay, M., Silesh, M., ... & Taye, B. T. (2024). A five years malaria surveillance data analysis of North Shewa zone, Amhara region, Ethiopia: July 2018 to June 2023. *Malaria Journal*, *23*, 187.

Mordecai, E. A., Cohen, J. M., Evans, M. V., et al. (2017). Detecting the impact of temperature on transmission of Zika, dengue, and chikungunya using mechanistic models. *PLoS Neglected Tropical Diseases*, 11(4), e0005468.

Morrison, C. (2015). Landmark green light for Mosquirix malaria vaccine. *Nature biotechnology*, 33(10), 1015-1017.

Mutuku, F. M., et al. (2019). Environmental and anthropogenic factors influencing mosquito breeding and malaria transmission in urban and rural Kenya. Infectious Diseases of Poverty, 8(1), 84.

Myers, S. S., Gaffikin, L., Golden, C. D., et al. (2017). Human health impacts of ecosystem alteration. *Proceedings of the National Academy of Sciences*, 110(47), 18753-18760.

Nabatanzi, M., Ntono, V., Kamulegeya, J., Kwesiga, B., Bulage, L., Lubwama, B., ... & Harris, J. (2022). Malaria outbreak facilitated by increased mosquito breeding sites near houses and cessation of indoor residual spraying, Kole district, Uganda, January-June 2019. *BMC Public Health*, *22*(1), 1898.

Naserrudin, N. A., Hod, R., Jeffree, M. S., Ahmed, K., & Hassan, M. R. (2022). The emerging threat of Plasmodium knowlesi malaria infection: a concept paper on the vulnerable factors in human. *International Journal of Environmental Research and Public Health*, *19*(7), 4419.

Naserrudin, N. A., Lin, P. Y. P., Monroe, A., Baumann, S. E., Adhikari, B., Miller, A. C., ... & Hassan, M. R. (2023). Disentangling the intersection of inequities with health and malaria exposure: key lessons from rural communities in Northern Borneo. *Malaria Journal*, *22*(1), 343.

Nicholson, E., McDonnell, T., Conlon, C., Barrett, M., Cummins, F., Hensey, C., & McAuliffe, E. (2020). Parental hesitancy and concerns around accessing paediatric unscheduled healthcare during COVID-19: a cross-sectional survey. *International Journal of Environmental Research and Public Health*, *17*(24), 9264.

Nimlang, N. H. (2024). *Diseases risk modelling and prediction using Remote Sensing and GIS: Application of malaria cases in Nigeria* (Doctoral dissertation, IMT-MINES ALES-IMT-Mines Alès Ecole Mines-Télécom).

Nkumama, I., O'meara, W., parasitology, F. O.-T. in, & 2017, undefined. (n.d.). Changes in malaria epidemiology in Africa and new challenges for elimination. *Elsevier*. Retrieved April 28, 2023, from https://www.sciencedirect.com/science/article/pii/S1471492216302008

Nolen, S. (2023). *Nolen, S., 2023 malaria - Google Scholar*. Google Scholar. https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&as_ylo=2019&as_yhi=2025&q=Nolen%2C+S.%2C+2023+malaria&btnG=

Norris, D. E., & Norris, L. C. (2011). Ecology and behavior of the principal malaria vector Anopheles gambiae complex. *Anopheles mosquitoes - New insights into malaria vectors*, 149-170.

Nsereko, G., Kadobera, D., Okethwangu, D., Nguna, J., Rutazaana, D., Kyabayinze, D. J., ... & Ario, A. R. (2020). Malaria Outbreak Facilitated by Appearance of Vector-Breeding Sites after Heavy Rainfall and Inadequate Preventive Measures: Nwoya District, Northern Uganda, February–May 2018. *Journal of environmental and public health*, *2020*(1), 5802401.

Nwe, T. W., Oo, T., Wai, K. T., Zhou, S., van Griensven, J., Chinnakali, P., Shah, S., & Thi, A. (2017). Malaria profiles and challenges in artemisinin resistance containment in Myanmar. *Infectious Diseases of Poverty*, *6*(1). https://doi.org/10.1186/S40249-017-0292-4

Oheneba-Dornyo, T. V., Amuzu, S., Maccagnan, A., & Taylor, T. (2022). Estimating the impact of temperature and rainfall on malaria incidence in Ghana from 2012 to 2017. *Environmental Modeling & Assessment*, *27*(3), 473-489.

Okiring, J., Gonahasa, S., Maiteki-Sebuguzi, C., Katureebe, A., Bagala, I., Mutungi, P., Kigozi, S. P., Namuganga, J. F., Nankabirwa, J. I., Kamya, M. R., Donnelly, M. J., Churcher, T. S., Staedke, S. G., & Sherrard-Smith, E. (2024). in Uganda Project (LLINEUP): modelling the impact of COVID-19-related disruptions on delivery of long-lasting insecticidal nets on malaria indicators in Uganda. *Springer*, *23*(1), 190. https://doi.org/10.1186/S12936-024-05008-8

Okumu, F., Gyapong, M., Casamitjana, N., Castro, M. C., Itoe, M. A., Okonofua, F., & Tanner, M. (2022). What Africa can do to accelerate and sustain progress against malaria. *PLOS Global Public Health*, *2*(6), e0000262.

Oladipo, H. J., Tajudeen, Y. A., Oladunjoye, I. O., Yusuff, S. I., Yusuf, R. O., Oluwaseyi, E. M., ... & El-Sherbini, M. S. (2022). Increasing challenges of malaria control in sub-Saharan Africa: Priorities for public health research and policymakers. *Annals of Medicine and Surgery*, *81*, 104366.

Organisation, W. H. (2021). World malaria report 2021 [Internet]. In *World Health Organization*. https://www.who.int/teams/global-malaria-programme/reports/world-malaria-report-2021

Organization, W. H. (2023). *WHO initiative to stop the spread of Anopheles stephensi in Africa*. 2020–2023.

Osarfo, Joseph, Ampofo, G. D., & Tagbor, H. (2022). Trends of malaria infection in pregnancy in Ghana over the past two decades: a review. *Malaria Journal*, *21*(1). https://doi.org/10.1186/S12936-021-04031-3

Owusu, T. M. (2023). *Evaluation of social inequalities in health on different health indicators across several social dimensions in Ghana* (Master's thesis, OsloMet-Storbyuniversitetet).

Owusu-Agyei, S., et al. (2020). Effectiveness of insecticide-treated bed nets in malaria prevention: A meta-analysis. *American Journal of Tropical Medicine and Hygiene*, 103(2), 584-590.

Paaijmans, K. P., Read, A. F., & Thomas, M. B. (2010). Understanding the link between malaria risk and climate. Proceedings of the National Academy of Sciences, 107(15), 17845-17850.

Parham, P. E., & Michael, E. (2010). Modeling the effects of weather and climate change on malaria transmission. Environmental Health Perspectives, 118(5), 620-626.

Parkhurst, J., Ghilardi, L., Webster, J., Hoyt, J., Hill, J., & Lynch, C. A. (2021). Understanding evidence use from a programmatic perspective: conceptual development and empirical insights from national malaria control programmes. *Evidence & Policy*, *17*(3), 447-466.

Penny, M. A., Galactionova, K., Tarantino, M., Tanner, M., & Smith, T. A. (2015). The public health impact of malaria vaccine RTS, S in malaria endemic Africa: country-specific predictions using 18 month follow-up Phase III data and simulation. *Springer*, *13*(1), 170. https://doi.org/10.1186/S12916-015-0408-2

Peprah, N. Y., Mohammed, W., Adu, G. A., Dadzie, D., Oppong, S., Barikisu, S., ... & L. Malm, K. (2024). Patient socio-demographics and clinical factors associated with malaria mortality: a case control study in the northern region of Ghana. *Malaria Journal*, *23*(1), 230.

Praet, N., Asante, K. P., Bozonnat, M. C., Akité, E. J., Ansah, P. O., Baril, L., ... & Pirçon, J. Y. (2022). Assessing the safety, impact and effectiveness of RTS, S/AS01E malaria vaccine following its introduction in three sub-Saharan African countries: methodological approaches and study set-up. *Malaria Journal*, *21*(1), 132.

Prusty, D., Gupta, N., Upadhyay, A., Dar, A., Naik, B., Kumar, N., & Prajapati, V. K. (2021). Asymptomatic malaria infection prevailing risks for human health and malaria elimination. *Infection, Genetics and Evolution*, *93*, 104987.

Ranson, H., & Lissenden, N. (2016). Insecticide resistance in African Anopheles mosquitoes: A worsening situation that needs urgent action to maintain malaria control. *Trends in Parasitology*, 32(3), 187-196.

Rogerson, S. J., Beeson, J. G., Laman, M., Poespoprodjo, J. R., William, T., Simpson, J. A., & Price, R. N. (2020). Identifying and combating the impacts of COVID-19 on malaria. *BMC medicine*, *18*(1), 1-7.

Rosenthal, P. J. (2022). Malaria in 2022: challenges and progress. *The American Journal of Tropical Medicine and Hygiene*, *106*(6), 1565.

Rouamba, T., Nakanabo-Diallo, S., Derra, K., Rouamba, E., & ... (2019). Socioeconomic and environmental factors associated with malaria hotspots in the Nanoro demographic surveillance area, Burkina Faso. *BMC Public Health*. https://doi.org/10.1186/s12889-019-6565-z

Ryan, S. J., Lippi, C. A., & Zermoglio, F. (2020). Shifting transmission risk for malaria in Africa with climate change: a framework for planning and intervention. *Malaria Journal*, *19*, 1-14.

Ryan, S. J., Lippi, C. A., Villena, O. C., Singh, A., Murdock, C. C., & Johnson, L. R. (2023). Mapping current and future thermal limits to suitability for malaria transmission by the invasive mosquito Anopheles stephensi. *Malaria Journal*, *22*(1), 104. https://doi.org/10.1186/s12936-023-04531-4

Sahu, M., Tediosi, F., Noor, A. M., Aponte, J. J., & Fink, G. (2020). Health systems and global progress towards malaria elimination, 2000–2016. *Malaria journal*, *19*, 1-12.

Sanna, A., Lambert, Y., Jimeno Maroto, I., Galindo, M. S., Plessis, L., Bardon, T., Carboni, C., Bordalo, J., Hiwat, H., Cairo, H., Musset, L., Lazrek, Y., Pelleau, S., White, M., Suárez Mutis, M., Vreden, S., & Douine, M. (2024). CUREMA project: a further step towards malaria elimination among hard-to-reach and mobile populations. *Springer*, *23*(1). https://doi.org/10.1186/S12936-024-05040-8

Sarfo, J. O., Amoadu, M., Kordorwu, P. Y., Adams, A. K., Gyan, T. B., Osman, A. G., ... & Ansah, E. W. (2023). Malaria amongst children under five in sub-Saharan Africa: a scoping review of prevalence, risk factors and preventive interventions. *European Journal of Medical Research*, *28*(1), 80.

Sarkar, S., Singh, P., Lingala, M. A. L., Verma, P., & Dhiman, R. C. (2019). Malaria risk map for India based on climate, ecology and geographical modelling. *Geospatial Health*, *14*(2). https://doi.org/10.4081/gh.2019.767

Sarpong, E., Acheampong, D. O., Fordjour, G. N. R., Anyanful, A., Aninagyei, E., Tuoyire, D. A., ... & Thomford, N. E. (2022). Zero malaria: a mirage or reality for populations of sub-Saharan Africa in health transition. *Malaria Journal*, *21*(1), 314.

Siya, A., Kalule, B. J., Ssentongo, B., Lukwa, A. T., & Egeru, A. (2020). Malaria patterns across altitudinal zones of Mount Elgon following intensified control and prevention programs in Uganda. *BMC Infectious Diseases*, *20*, 1-16.

Savi, M. K. (2022). An overview of malaria transmission mechanisms, control, and modeling. *Medical Sciences*, *11*(1), 3.

Savi, M. K., Callo-Concha, D., & ... (2021). Emerging properties of malaria transmission and persistence in urban Accra, Ghana: evidence from a participatory system approach. *Malaria …*. https://doi.org/10.1186/s12936-021-03851-7

Sherrard-Smith, E., et al. (2019). Mosquito feeding behavior and how it influences residual malaria transmission across Africa. *Proceedings of the National Academy of Sciences*, 116(30), 15086-15095.

Sherrard-Smith, E., Hogan, A. B., Hamlet, A., et al. (2020). The potential public health consequences of COVID-19 on malaria in Africa. Nature Medicine, 26(9), 1411-1416.

Shretta, R., Silal, S. P., Malm, K., Mohammed, W., Narh, J., Piccinini, D., Bertram, K., Rockwood, J., & Lynch, M. (2020). Estimating the risk of declining funding for malaria in Ghana: The case for continued investment in the malaria response. *Malaria Journal*, *19*(1). https://doi.org/10.1186/S12936-020-03267-9

Shretta, R., et al. (2017). The Global Fund contributions to improving health outcomes in Ghana: Evidence from the field. *BMC Public Health*, 17(1), 834.

Smith, T., et al. (2018). Malaria in adults: epidemiology and impact. Tropical Medicine & International Health, 23(4), 392-405.

Snow, R. W., et al. (2017). The burden of malaria in African children and the need for improved diagnostic methods. The Lancet Infectious Diseases, 17(9), 1029-1039.

Snow, R. W., et al. (2017). The prevalence of Plasmodium falciparum in sub-Saharan Africa since 1900. *Nature*, 550(7677), 515-518.

Solomon, A., Kahase, D., & Alemayehu, M. (2020). Trend of malaria prevalence in Wolkite health center: An implication towards the elimination of malaria in Ethiopia by 2030. *Malaria Journal*, *19*(1). https://doi.org/10.1186/S12936-020-03182-Z

Stanisic, D., & Good, M. F. (2023). Malaria vaccines: Progress to date. *BioDrugs, 37(6), 737-756.*

Stresman, G., DePina, A. J., Nelli, L., Monteiro, D. D., Leal, S. D. V., Moreira, A. L., ... & Lindblade, K. A. (2022). Factors related to human-vector contact that modify the likelihood of malaria transmission during a contained Plasmodium falciparum outbreak in Praia, Cabo Verde. *Frontiers in Epidemiology*, *2*, 1031230.

Strode, C., Donegan, S., Garner, P., et al. (2014). The impact of pyrethroid resistance on the efficacy of insecticide-treated bed nets against African anopheline mosquitoes: systematic review and meta-analysis. *PLoS Medicine*, 11(3), e1001619.

Survey, H. (2023). *Malaria prevalence in children declines by a third in the past decade but the prevalence in rural areas is about three times as high compared to urban*. *04*, 2022–2023.

Taffese, H. S., Hemming-Schroeder, E., Koepfli, C., Tesfaye, G., Lee, M. C., Kazura, J., Yan, G. Y., & Zhou, G. F. (2018). Malaria epidemiology and interventions in Ethiopia from 2001 to 2016. *Infectious Diseases of Poverty*, *7*(1). https://doi.org/10.1186/S40249-018-0487-3

Tesfa, H., Bayih, A. G., & Zeleke, A. J. (2018). A 17-year trend analysis of malaria at Adi Arkay, north Gondar zone, Northwest Ethiopia. *Malar J.*, *17*(1), 155. https://doi.org/10.1186/s12936-018-2310-9

Touré, M., Keita, M., Kané, F., & ... (2022). Trends in malaria epidemiological factors following the implementation of current control strategies in Dangassa, Mali. *Malaria …*. https://doi.org/10.1186/s12936-022-04058-0

Uchendu, C., Windle, R., & Blake, H. (2020). Perceived facilitators and barriers to Nigerian nurses' engagement in health promoting behaviors: a socio-ecological model approach. *International journal of environmental research and public health*, *17*(4), 1314.

Villena, O. C., Arab, A., Lippi, C. A., Ryan, S. J., & Johnson, L. R. (2024). Influence of environmental, geographic, socio-demographic, and epidemiological factors on presence of malaria at the community level in two continents. *Scientific Reports*, *14*(1), 16734.

Weiss, D. J., Bertozzi-Villa, A., Rumisha, S. F., Amratia, P., Arambepola, R., Battle, K. E., ... & Gething, P. W. (2021). Indirect effects of the COVID-19 pandemic on malaria intervention coverage, morbidity, and mortality in Africa: a geospatial modelling analysis. *The Lancet Infectious Diseases*, *21*(1), 59-69.

Weiss, D. J., Lucas, T. C., Nguyen, M., Nandi, A. K., Bisanzio, D., Battle, K. E., ... & Gething, P. W. (2019). Mapping the global prevalence, incidence, and mortality of Plasmodium falciparum, 2000–17: a spatial and temporal modelling study. *The Lancet*, *394*(10195), 322-331.

Wharton-Smith, A., Rassi, C., Batisso, E., Ortu, G., King, R., Endriyas, M., ... & Getachew, D. (2019). Gender-related factors affecting health seeking for neglected tropical diseases: findings from a qualitative study in Ethiopia. *PLoS neglected tropical diseases*, *13*(12), e0007840.

WHO. (2021). Global technical strategy for malaria 2016–2030: 2021 update. World Health Organization.

WHO. Ghana intensifies efforts towards malaria elimination [Internet]. World Health Organization, Regional Office for Africa. 2024 [cited 2024 Nov 7]. Available from: [Ghana intensifies efforts towards malaria elimination | WHO | Regional Office for Africa]

WHO. (2023). *World malaria World malaria report report*. https://www.wipo.int/amc/en/mediation/%0Ahttps://www.who.int/teams/global-malaria-programme/reports/world-malaria-report-2023

Wolkon, A., et al. (2010). Rapid scale-up of long-lasting insecticide-treated bed nets through integration into the national immunization program during child health week in Togo, 2004. *American Journal of Tropical Medicine and Hygiene*, 83(5), 1014-1019.

World Health Organization. (2013). "World Malaria Report 2015."

World Health Organization. (2015). "World Malaria Report 2015."

World Health Organization. (2019). "World Malaria Report 2019."

World Health Organization. (2020). "World Malaria Report 2020."

World Health Organization. (2021). "WHO pilot implementation of RTS,S malaria vaccine."

World Health Organization. (2021). WHO malaria terminology.

World Health Organization. (2022). "World Malaria Report 2022."

World Health Organization. (2023). “World malaria report 2023.”

Yamba, E. I., Aryee, J. N., Quansah, E., Davies, P., Wemegah, C. S., Osei, M. A., …& Amekudzi, L. K. (2023). Revisiting the agro-climate zones of Ghana: Are-classification in conformity with climate change and variability. PLOS Climate, 2(1), e0000023.

Yaro, J. B. (2021). *Risk factors for malaria infection and transmission in Burkina Faso, an area of high, persistent malaria transmission and high insecticide resistance* (Doctoral dissertation, Durham University).

Yaro, J. B., Ouedraogo, A., Diarra, A., Sombié, S., Ouedraogo, Z. A., Nébié, I., Drakeley, C., Sirima, S. B., Tiono, A. B., Lindsay, S. W., & Wilson, A. L. (2021). Risk factors for Plasmodium falciparum infection in pregnant women in Burkina Faso: a community-based cross-sectional survey. *Springer*, *20*(1). https://doi.org/10.1186/S12936-021-03896-8

Yaro, J. B., Tiono, A. B., Sanou, A., Toe, H. K., Bradley, J., Ouedraogo, A., Ouedraogo, Z. A., Guelbeogo, M. W., Agboraw, E., Worrall, E., Sagnon, N. ’Fale, Lindsay, S. W., & Wilson, A. L. (2021). Risk factors associated with house entry of malaria vectors in an area of Burkina Faso with high, persistent malaria transmission and high insecticide resistance. *Springer*, *20*(1). https://doi.org/10.1186/S12936-021-03926-5

Yé, Y., Hoshen, M., Louis, V. R., et al. (2017). Housing conditions and Plasmodium falciparum infection: protective effect of iron-sheet roofed houses. *Malaria Journal*, 7, 81

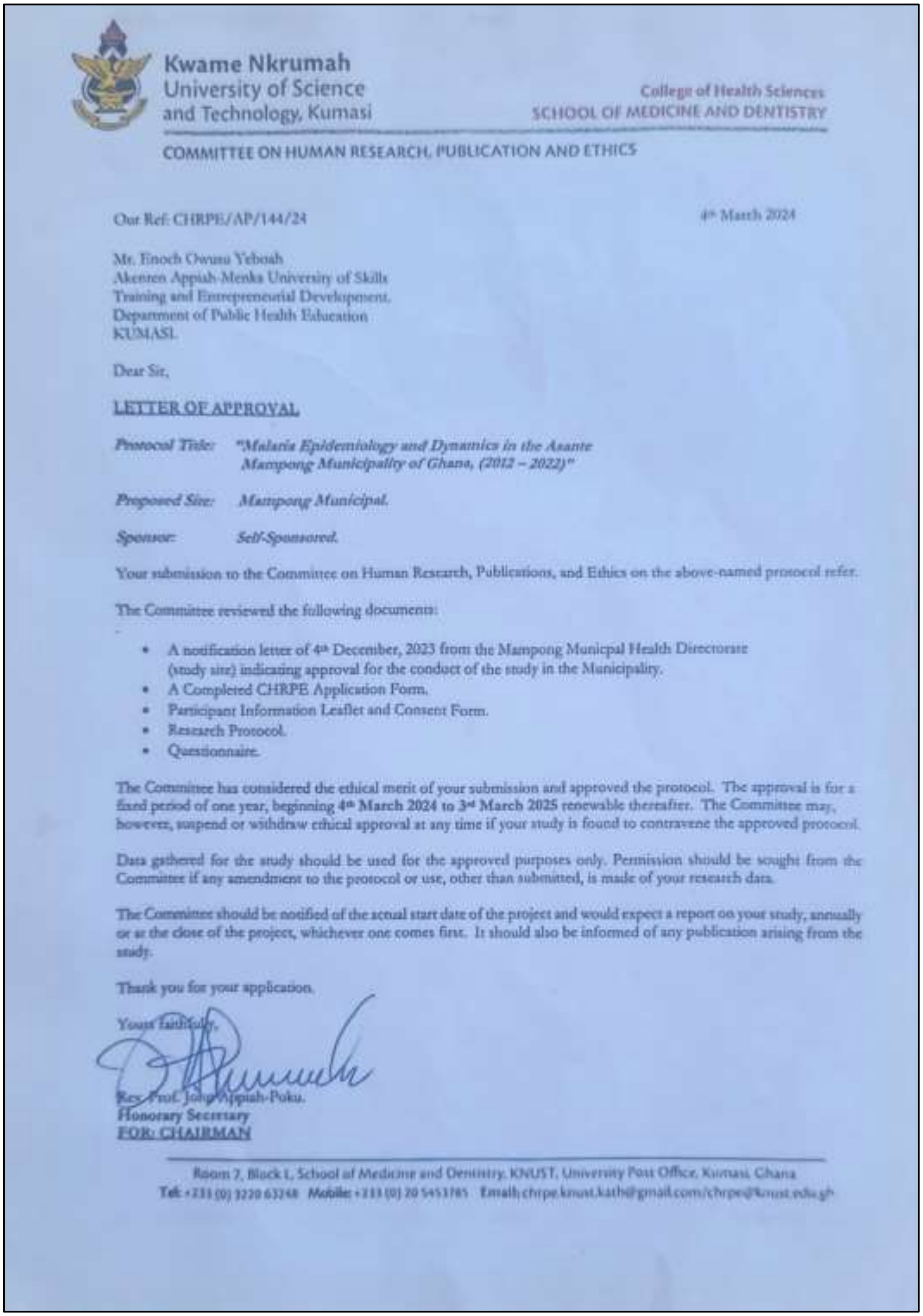
Yeboah-Antwi, K., Pilingana, P., Macleod, W. B., et al. (2010). Community case management of fever due to malaria and pneumonia in children under five in Zambia: a cluster randomized controlled trial. *PLoS Medicine*, 7(9), e1000340.

Yeka, A., et al. (2020). Malaria control in Uganda: success and challenges in rural areas. American Journal of Tropical Medicine and Hygiene, 103(3), 1230-1235.

Yeung, S., & White, N. J. (2005). How do patients use antimalarial drugs? A review of the evidence. *Tropical Medicine & International Health*, 10(2), 121-138.

APPENDICES

Appendix I: Ethical Approval



Kwame Nkrumah University of Science and Technology, Kumasi

College of Health Sciences
SCHOOL OF MEDICINE AND DENTISTRY

COMMITTEE ON HUMAN RESEARCH, PUBLICATION AND ETHICS

Our Ref: CHRPE/AP/144/24

4[th] March 2024

Mr. Enoch Owusu Yeboah
Akenten Appiah-Menka University of Skills
Training and Entrepreneurial Development.
Department of Public Health Education
KUMASI.

Dear Sir,

<u>LETTER OF APPROVAL</u>

Protocol Title: *"Malaria Epidemiology and Dynamics in the Asante Mampong Municipality of Ghana, (2012 – 2022)"*

Proposed Site: *Mampong Municipal.*

Sponsor: *Self-Sponsored.*

Your submission to the Committee on Human Research, Publications, and Ethics on the above-named protocol refer.

The Committee reviewed the following documents:

- A notification letter of 4[th] December, 2023 from the Mampong Municipal Health Directorate (study site) indicating approval for the conduct of the study in the Municipality.
- A Completed CHRPE Application Form.
- Participant Information Leaflet and Consent Form.
- Research Protocol.
- Questionnaire.

The Committee has considered the ethical merit of your submission and approved the protocol. The approval is for a fixed period of one year, beginning **4[th] March 2024 to 3[rd] March 2025** renewable thereafter. The Committee may, however, suspend or withdraw ethical approval at any time if your study is found to contravene the approved protocol.

Data gathered for the study should be used for the approved purposes only. Permission should be sought from the Committee if any amendment to the protocol or use, other than submitted, is made of your research data.

The Committee should be notified of the actual start date of the project and would expect a report on your study, annually or at the close of the project, whichever one comes first. It should also be informed of any publication arising from the study.

Thank you for your application.

Yours faithfully,

Rev. Prof. John Appiah-Poku.
Honorary Secretary
<u>FOR: CHAIRMAN</u>

Room 7, Block L, School of Medicine and Dentistry, KNUST, University Post Office, Kumasi, Ghana
Tel: +233 (0) 3220 63248 **Mobile:** +233 (0) 20 5453785 **Email:** chrpe.knust.kath@gmail.com/chrpe@knust.edu.gh

Appendix II: Letter of Introduction (Regional Health Directorate)

In case of reply the number
and the date of this letter
should be quoted

My Ref:
Your Ref. No:

Tel: 22089/23651
Fax:
E-mail: rdhs.ar@yahoo.com

GHANA HEALTH SERVICE
REG HEALTH DIRECTORATE
P. O. BOX 1908
KUMASI

28TH NOVEMBER, 2023

MUN. DIR. OF H/SERVICE
MUNICIPAL HEALTH DIRECTORATE
MAMPONG

LETTER OF INTRODUCTION

This is to introduce to you Mr. Enoch Owusu Yeboah, an MPhil. Public Health student at the Akenten Appiah-Menka University. As part of his academic requirements for the award of a Master of Philosophy Degree in Public Health, he is to undertake a research titled **A Decade of Malaria Epidemiology and Dynamics in the Asante Mampong Municipality of Ghana (2012 - 2022).**

He will collect data from the DHIMS and also from residents living close to health facilities in Mampong, Krobo, Dadease, Asaam, Kofiase, Bosomokyekye, Adidwan, Yonso, Nkwanta and Apaah in the Municipality.

Kindly give him the necessary assistance.

Thank you.

MR. ASARE-BEDIAKO MICAH
DEPUTY DIRECTOR ADMINISTRATION
for: REG. DIR. OF HEALTH SERVICE
ASHANTI

Appendix III: Letter of Approval (Mampong Municipal Health Directorate)

In case of reply the number
and the date of this letter
should be quoted

GHANA HEALTH SERVICE
MAMPONG MUNICIPAL HEALTH DIRECTORATE
P. O. BOX 424
MAMPONG – ASHANTI

My Ref. No: MHD/MA/PF/PER/2611
Your Ref. No.
mamponghdirectorate424@yahoo.com

Tel:0243123804

4TH DECEMBER, 2023

Mr. Enoch Owusu Yeboah
MPhil (Public Health Student)
Index Number: 8222030008

Dear Sir,

APPROVAL GRANTED TO CONDUCT A RESEARCH STUDY

I write to acknowledge receipt of your application to conduct research in this institution titled, **"A Decade of Malaria Epidemiology and Dynamics in the Asante Mampong Municipality of Ghana (2012 – 2022)".**

You are required to strictly adhere to the information you are seeking to work on as presented to the Directorate Management. Any further data request is subject to approval by the Management before usage based on the ethical standards of access to health information systems in the facility.

You are also entreated to present a copy of your findings to the Directorate for reference.

Thank you

Yours Faithfully

MR. JOSEPH DANSO YEBOAH
MUNICIPAL DIRECTOR OF HEALTH SERVICE
MAMPONG

Appendix IV: Letter of Introduction (Department of Public Health)

AKENTEN APPIAH-MENKA UNIVERSITY
of Skills Training and Entrepreneurial Development

FACULTY OF ENVIRONMENT & HEALTH EDU.
DEPARTMENT OF PUBLIC HEALTH EDUCATION
P.O. Box 40, Asante Mampong   0209777518

Our Ref: M/DPHE/ADM/SM/45   9 November 2023

The Municipal Health Director
Ghana Health Service
Mampong Municipal
Ashanti Region

Dear Sir,

Permission to Conduct Research: "A Decade of Malaria Epidemiology and Dynamics in the Asante Mampong Municipality of Ghana (2012 - 2022)".

We write to introduce Mr. Enoch Owusu Yeboah (Index Number: 8222030008), an MPhil. Public Health student in our Department. As part of his academic requirements for the award of a Master of Philosophy Degree in Public Health, he is to research " *A Decade of Malaria Epidemiology and Dynamics in the Asante Mampong Municipality of Ghana (2012 - 2022)* ".

We seek your official approval and permission to allow Mr. Yeboah to conduct this study under your jurisdiction. He will examine malaria epidemiological trends and dynamics in the Mampong Municipality for future malaria control and elimination planning. He will collect historical data for the stipulated period from the DHIMS and also from residents living close to health facilities in the Mampong, Krobo, Dadease, Asaam, Kofiase, Bosomkyekye, Adidwan, Yonso, Nkwanta, and Apaah in the municipality.

The outcome of this study would provide empirical data on malaria epidemiological trends and dynamics in Asante Mampong Municipality. Relevant recommendations would also be made to stakeholders for policy consideration and formulation for malaria control and elimination planning in the municipality and the nation.

Your approval letter would allow him to apply for ethical clearance before the commencement of the research. The data collected will be used solely for academic purposes. We would be grateful if your outfit would accord him the needed assistance for the successful execution of this proposed study. Your kind approval is required to conduct the study to fulfil this academic obligation.

Thank you for your kind consideration.

Yours Sincerely,

Denis Dekugmen Yar (PhD)

(HEAD OF DEPARTMENT: ddyar@aamusted.edu.gh :0243236810)

Appendix IV: Plagiarism Report (Turnitin)

MALARIA EPIDEMIOLOGY AND DYNAMICS IN THE ASANTE MAMPONG MUNICIPALITY OF GHANA, (2015-2023)

ORIGINALITY REPORT

14%	11%	7%	7%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	benthamopen.com Internet Source	1%
2	ir.knust.edu.gh Internet Source	1%
3	Yaser Mohammed Al-Worafi. "Chapter 60-1 Malaria Management in Developing Countries", Springer Science and Business Media LLC, 2024 Publication	1%
4	www.science.gov Internet Source	1%
5	ir.mu.ac.ke:8080 Internet Source	1%
6	dspace.knust.edu.gh Internet Source	1%
7	spiral.imperial.ac.uk Internet Source	<1%