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The Effects of Insecticide-Treated Nets (ITNs) on *Plasmodium falciparum* Infections in Kalumbila District, Zambia

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Abstract

Background: Malaria, caused by *Plasmodium falciparum*, is a severe infectious disease affecting rural regions with high transmission rates. According to the WHO, malaria remains a critical global health issue, with 229 million cases and 409,000 deaths annually, predominantly in the WHO African Region. In Zambia, a high transmission country, malaria significantly impacts public health and the economy.
Objectives: This study assessed the impact of insecticide-treated nets (ITNs) on *Plasmodium falciparum* malaria infections in Kalumbila District by investigating local epidemiology, evaluating ITNs' effectiveness, and assessing the relationship between ITN usage and malaria incidence and prevalence.
Methods: A mixed-methods approach combined quantitative data from the Kalumbila District Health Office with qualitative data from focus groups, interviews, and questionnaires. Quantitative analyses included chi-square (χ^2), ANOVA, and correlational analysis.
Results: High ITN coverage (over 80%) led to a 60% decrease in malaria cases ($p<0.05$). Significant associations ($\chi^2 = 5{,}472.09$, df = 1, $p < 0.05$) and ANOVA ($F = 0.023$, $p < 0.05$) confirmed the impact of ITNs. Qualitative findings highlighted benefits like improved health and reduced mosquito bites but noted challenges such as ITN durability and cultural acceptance.
Conclusions: In Kalumbila District, ITNs significantly reduce *Plasmodium falciparum* infections. Effectiveness depends on factors like durability, cultural acceptance, and socio-economic status. Continuous community education and integrated preventive measures are essential for maximizing impact.

Keywords: Malaria, *Plasmodium falciparum*, insecticide-treated nets (ITNs), Public health, Malaria prevention, Epidemiology, Community Health, Kalumbila District, Zambia.

1. Introduction

The World Malaria Report of 2022 highlights the ongoing global challenge posed by malaria, with an estimated 247 million cases and 619,000 deaths reported in 2021 [63]. The WHO African Region bears the brunt of this burden, accounting for 94% of cases and 95% of deaths [63] [64]. This disproportionate impact underscores the urgent need for targeted interventions. Vulnerable groups such as pregnant women and children are particularly affected, with malaria responsible for 8% of all child deaths [44]. Despite significant reductions in malaria mortality rates between 2000 and 2015, progress has stagnated, with deaths increasing from 643,000 in 2019 to 558,000 in 2021 [64], due to challenges like drug resistance, insecticide resistance, and the COVID-19 pandemic. Climate change and environmental modifications further complicate malaria transmission dynamics, potentially worsening the burden in endemic regions.

The economic toll of malaria is significant, impacting productivity and placing a heavy burden on healthcare systems, particularly in low- and middle-income countries. Malaria-related absenteeism and decreased productivity cost Africa an estimated $12 billion annually [1]. Innovations like the Mosquirix (RTS,S/AS01) malaria vaccine offer new solutions but require broad implementation and sustained funding. The WHO's Global Technical Strategy for Malaria 2016-2030 aims to reduce malaria case incidence and mortality rates by 90% by 2030. Comprehensive strategies, including insecticide-treated nets (ITNs), indoor residual spraying (IRS), and effective case management, are essential. Enhancing community education, healthcare infrastructure, and international collaboration are vital in the fight against malaria.

1.1.Background of the Study: The United Nations (UN) established the Sustainable Development Goals (SDGs) as a comprehensive framework for addressing global challenges and achieving a sustainable and equitable future [49] [50]. SDG-3 aims to ensure healthy lives and promote well-being for all by 2030, highlighting the importance of tackling diseases like malaria. According to the WHO, there were approximately 247 million malaria cases and 619,000 deaths in 2021, with the WHO African Region accounting for 94% of cases and 95% of deaths [63] [65]. Regionally, challenges in malaria control and prevention necessitate customized interventions. In Sub-Saharan Africa (SSA), factors such as the utilization of ITNs and housing quality significantly affect susceptibility to malaria [20] [36]. Limited access and underutilization of ITNs exacerbate malaria risk, underscoring the need for targeted approaches [18]. In South Africa, population density influences malaria transmission rates, highlighting the importance of context-specific interventions [24]. These nuances emphasize the critical role of understanding household and demographic factors in influencing malaria risk, aligning with SDG-3 and the 8th National Development Plan (NDP).

Addressing malaria's burden is essential for meeting both international and national health objectives. Eliminating malaria promotes good health and supports broader sustainable development goals. This study aims to provide valuable insights that address global and regional challenges, supporting the goal of achieving good health and well-being for all. By focusing on Kalumbila District in Zambia, this research will contribute to the development of effective, context-specific strategies for malaria control and prevention, exploring the interplay of socio-economic, environmental, and cultural factors.

1.2.Aim and Significance of the Study: This study aimed to evaluate the impact of ITN usage on the risk of *Plasmodium falciparum* malaria infections in Kalumbila District, Zambia. By investigating the local epidemiology and mortality of *P. falciparum* malaria, evaluating the effectiveness of ITNs in reducing transmission, and assessing the relationship between ITN usage and malaria incidence and prevalence, the study provided significant insights into malaria patterns within the district. These findings facilitated the development of targeted malaria control strategies to mitigate incidence and improve community health outcomes. The study's evidence-based recommendations informed health policy and strategic planning in Zambia, highlighting areas for health system strengthening, such as enhancing ITN distribution networks.

Globally, the research contributed to SDG-3, supporting international efforts to combat malaria and achieve health equity. The methodology and findings served as a model for other malaria-endemic regions, demonstrating the effectiveness of context-specific strategies. Academically, the study addressed gaps in existing literature by focusing on household-level factors and local contexts, integrating perspectives from epidemiology, public health, and environmental science. The insights gained laid the groundwork for future research, encouraging further exploration and refinement of malaria intervention strategies. Overall, this research represented a critical advancement in efforts to reduce malaria incidence in Kalumbila District and contributed to national and global initiatives against malaria.

1.3.Problem Statement: Millions of people in developing countries, particularly those affected by *Plasmodium falciparum*, suffer and die each year from malaria, influenced by various socio-economic, demographic, and environmental factors. However, most existing research is based on global or regional data [17][27] [12], which may not capture the specific realities of local contexts. Kalumbila District in Zambia, with its distinctive geographical and demographic features, poses a unique challenge for malaria control and elimination [67]. The malaria prevalence rate in Zambia's North-Western Province increased alarmingly from 11% in 2018 to 37% in 2023 [30], underscoring the urgent need for localized intervention strategies.

Existing studies provide extensive data on malaria prevalence and related factors in SSA but often do not delve into household-level factors that significantly influence malaria risk [12] [18][27]. Global data from the WHO (2022) underscores the importance of household and demographic factors in malaria prevalence but lacks specificity for localized interventions. While national infection rates in Zambia have decreased, district-level impacts, particularly in Kalumbila District, remain under-documented. The high prevalence of severe anemia in local malaria cases (48.6%) compared to imported cases (33.3%) in 2023 suggests unique local factors warrant further investigation [63].

Research highlights household characteristics and demographic factors influencing malaria vulnerability in various regions but may not apply directly to Kalumbila District's context [35]. Studies discuss bed net availability and population density's impact on malaria risk but do not account for local variations in bed net usage or specific demographic pressures [17][18]. Cultural practices impacting malaria risk and control also lack comprehensive integration into prevention strategies in Zambia [23].

This research aims to fill these gaps by analyzing socio-economic status, healthcare infrastructure, and environmental conditions, and their collective impact on malaria prevalence in Kalumbila District. By focusing on micro-level factors overlooked in broader studies, this study will provide targeted insights necessary for developing effective, context-specific malaria control strategies. This research hopes to unravel the intricacies of *P. falciparum* malaria risk in developing nations and provide actionable insights for tailored interventions essential for effective malaria control and elimination efforts.

1.4.Research questions

1. How does ITN usage influence the risk of *Plasmodium falciparum* malaria infections in Kalumbila District?
2. What is the local epidemiology of P. falciparum malaria and mortality in Kalumbila District?

3. What is the effectiveness of ITNs in reducing malaria transmission in Kalumbila District?
4. What is the relationship between ITNs usage and the incidence and prevalence of P. falciparum malaria in Kalumbila District?

1.5.Research Objective

General Objective:

1. To investigate how ITNs usage influences the risk of *Plasmodium falciparum* malaria infections in Kalumbila District.

Specific Objectives:

2. To investigate local epidemiology of P. falciparum malaria and mortality in Kalumbila District.
3. To evaluate the effectiveness of ITNs in reducing malaria transmission in Kalumbila District.
4. To assess the relationship between ITNs usage and the incidence and prevalence of P. falciparum malaria in Kalumbila District.

1.6.Research Hypothesis

- **Null Hypothesis (H0):** ITNs do not reduce the incidence of P. falciparum malaria among households in Kalumbila District.
- **Alternative Hypothesis (H1):** ITNs reduce the incidence of P. falciparum malaria among households in Kalumbila District.

1.7.Justification of the study: The urgency and necessity of this research lie in its potential to address significant gaps in the understanding of P. falciparum malaria, especially in developing nations. By examining local patterns and connecting them to global trends, this study aims to provide insights into the socio-economic, environmental, and cultural dynamics that shape malaria risk. The persistence of malaria, despite global eradication efforts, underscores the need for more targeted and context-specific research approaches.

The study focuses on integrating local malaria incidence patterns with global trends, ensuring intervention strategies are grounded in best practices while being effective within the local context. The under-researched Kalumbila District presents unique challenges not sufficiently explored in existing research, contributing fresh data and perspectives to inform broader malaria control strategies.

By examining the interplay between socio-economic factors, healthcare infrastructure, and environmental conditions, this study offers a comprehensive analysis crucial for developing effective interventions. It also explores the cultural dynamics influencing health outcomes and behaviors related to malaria, providing insights for culturally sensitive prevention strategies.

Designed to yield actionable insights, this research identifies significant determinants of malaria risk in Kalumbila District, informing targeted intervention strategies. Beyond its practical implications, the study enhances the theoretical understanding of malaria risk and refines existing conceptual frameworks.

The findings have direct implications for malaria control policies and practices, providing empirical evidence on effective interventions and informing policy decisions. This research contributes to the

Copperbelt University's existing body of literature and influences global efforts to combat and eradicate malaria in developing countries.

1.8.Scope of Study: This study focused on evaluating the effects of ITNs on *Plasmodium falciparum* infections in Kalumbila District, a malaria-endemic region in Zambia. Geographically confined to this district, the research examined the impact of ITNs on reducing malaria incidence. The target population included households with access to ITNs, with particular emphasis on vulnerable groups such as children under five and pregnant women. Data collection occurred over a two-month period, encompassing both rainy and dry seasons to account for variations in malaria transmission rates.

The study's content was restricted to P. falciparum, the most prevalent malaria parasite in the area, focusing on assessing the relationship between ITN usage and infection reduction. Both quantitative methods, such as surveys and statistical analysis, and qualitative approaches, including interviews with healthcare workers and residents, were employed to provide a comprehensive understanding of ITN effectiveness and usage patterns.

However, the study was limited to ITNs as the primary intervention, excluding other malaria control measures such as IRS or antimalarial drug treatments. Additionally, the scope was confined to P. falciparum infections and did not explore other malaria species or complications.

1.9.Study Variables

Table 1.9: Study Variables

Variable	Type	Measurement Scale	Description
Incidence of malaria	Dependent	Ratio	Number of malaria cases in the population (measured per 1,000 individuals)
Usage of ITNs	Independent	Nominal	Whether households used ITNs (Yes/No)
Household quality	Independent	Ordinal	Quality of housing (e.g., poor, fair, good)
Population density	Independent	Ratio	Number of people per square kilometre
Age	Independent	Ordinal	Age groups (e.g., <5 years, 5-15 years, 16-30 years, etc.)
Seasonal variation	Independent	Nominal	Rainy season vs. dry season
Healthcare infrastructure	Independent	Ordinal	Quality and accessibility of healthcare facilities (e.g., poor, fair, good)
Socio-economic status	Independent	Ordinal	Household income levels or social class (e.g., low, middle, high)
Education level	Independent	Ordinal	Highest education level attained by household members (e.g., no formal education, primary,

			secondary, tertiary)
Gender	Independent	Nominal	Gender of household members (Male/Female)
Bed net coverage	Independent	Ratio	Proportion of household members using ITNs
Housing type	Independent	Nominal	Type of housing structure (e.g., brick, mud, wood)
Health-seeking behaviour	Independent	Nominal	Whether households sought medical help for malaria symptoms (Yes/No)
Environmental factors	Independent	Nominal	Presence of stagnant water or breeding sites near households (Yes/No)

2. Literature Review

Malaria caused by *Plasmodium falciparum* is a severe, life-threatening parasitic disease that disproportionately affects rural populations in low-resource settings with high transmission rates. The *P. falciparum* parasite has distinctive clinical and pathological features, leading to complications such as organ failure and hypoxia due to the sequestration of infected red blood cells in vital organs. This makes diagnosis challenging due to rapid progression and low parasite levels [15]; 8, 3]. Annually, millions are infected, experiencing high fever, chills, anemia, and potentially cerebral malaria or death if untreated. Recent WHO reports [64] [65] highlight 249 million malaria cases and 608,000 deaths globally, with 94% of cases and 95% of deaths occurring in the African Region, where children under five make up about 80% of all malaria deaths.

P. falciparum infects a broader range of red blood cells, leading to higher parasite densities and severe symptoms [4] [13]. Factors influencing falciparum malaria include severe clinical impacts such as cerebral malaria, respiratory distress, and death [45] [54]. Genetic resistance to antimalarial medications poses significant treatment challenges [6] [55], necessitating ongoing research and surveillance [8] [48].

Risk factors for falciparum malaria encompass demographic aspects, individual demographics, and environmental determinants. Demographic aspects include household size, population density, and socio-economic status. Individual demographics cover age, gender, occupation, and education levels. Environmental determinants focus on the distribution of parasitic infections based on Place, Person, and Time (PPT) and the frequency of occurrence [64][12].

Malaria impacts public health and industrial sectors significantly. Evidence-based treatments leverage clinical evidence [31][41]. Research by [26] highlights the impact of climate and environmental variables on mosquito vector distribution, proposing a mathematical framework to forecast falciparum malaria transmission. Socio-economic factors like poverty, education, and healthcare access influence susceptibility to malaria, guiding policy and resource allocation [19].

2.1.Global Perspective: Malaria, specifically caused by *Plasmodium falciparum*, remains a significant global health challenge. According to the World Health Organization (WHO), there were approximately 249 million malaria cases and 608,000 deaths reported in 2022 [65]. The global efforts to combat malaria have faced setbacks due to the COVID-19 pandemic, which has strained health systems and diverted resources, making malaria control even more challenging.

The incidence and mortality rates of malaria are highest in Africa, which continues to bear the most significant burden. Other regions, such as Southeast Asia and Latin America, are also affected, though to a lesser extent. The WHO African Region accounts for 94% of malaria cases and 95% of malaria deaths globally [65]. Vulnerable populations include children under five, pregnant women, and individuals with compromised immune systems, with malaria contributing significantly to child mortality rates [44]. The economic burden is profound, impacting productivity and healthcare costs, further stressing the already strained economies in malaria-endemic countries.

Insecticide-Treated Nets (ITNs) remain one of the primary tools for malaria prevention. However, challenges such as insecticide resistance and improper use of ITNs hinder their effectiveness [63]. Artemisinin-Based Combination Therapies (ACTs) are the cornerstone of malaria treatment, but resistance to artemisinin has been reported in some regions, particularly in Southeast Asia, necessitating ongoing monitoring and development of new treatments [64]. Additionally, the RTS, S/AS01 malaria vaccine, known as Mosquirix, has shown promise in reducing malaria cases among children, and global efforts are underway to increase the vaccine's accessibility in high-burden areas [61].

Brazil serves as a notable case where research highlights the impact of household characteristics on malaria transmission. Poor housing conditions and limited access to healthcare significantly increase the risk of malaria, underscoring the need for comprehensive interventions that address these socio-economic determinants [21]. In India, high population density and occupational exposure are major contributors to malaria transmission, particularly in states like Odisha and Chhattisgarh, where targeted interventions are essential for effective control [35]. Similarly, in Ethiopia, factors such as altitude, distance to health facilities, and household size are significant predictors of malaria incidence, highlighting the need for tailored control strategies that consider these variables [51] [57].

2.2.Regional Perspective: In Sub-Saharan Africa (SSA), there were an estimated 233 million malaria cases and 580,000 malaria-related deaths in 2022, representing 94% of global cases and 95% of deaths, with 76% of these deaths being children under five and pregnant women [63] [65]. Contributing factors include the efficient vector Anopheles gambiae and the predominance of P. falciparum. Environmental conditions such as warm and wet climates, inadequate healthcare access, poor housing, and lack of education also play significant roles [60].

The Anopheles gambiae mosquito effectively transmits P. falciparum due to its preference for feeding on humans and synchronized life cycle with the rainy season, which provides optimal breeding conditions [9][48]. Warm and wet climates create ideal breeding conditions, while higher temperatures shorten the parasite’s development time, leading to rapid transmission cycles [2]. Poor housing conditions facilitate mosquito access to humans, and inadequate healthcare increases the reservoir of parasites. Lack of education reduces the use of malaria prevention measures like bed nets.

[34] highlights housing quality's impact on malaria vulnerability in SSA. Improved housing conditions, such as finished construction materials and better-designed windows and doors, reduce human-vector contact by limiting mosquito entry [59]. Modern houses also manage water resources better, reducing breeding sites [10]. Higher socioeconomic status, often reflected in better housing, is associated with greater access to malaria prevention tools like ITNs and IRS, further reducing

malaria risk [53]. A multi-country analysis found modern housing reduced malaria infection odds by 9% to 14%, comparable to insecticide-treated bed nets [34] [35].

In Ethiopia, altitude, distance to health facilities, and household size are significant predictors of malaria incidence. Lower altitudes are more prone due to mosquitoes' and parasites' temperature sensitivity, while greater distances from health facilities increase risk due to delayed diagnosis and treatment [51]. Larger household sizes may facilitate disease spread. These factors are crucial for tailoring effective control strategies in Ethiopia.

In rural South-Central Somalia, ITN availability and utilization are critical. ITNs reduce mosquito-human contact, lowering malaria transmission. Effective ITN use, with an overall protective effectiveness (PE) of 54%, requires community education on proper use, maintenance, and timely replacement [18] [65].

In South Africa, high population density in urban areas increases malaria risk, highlighting the need for tailored control strategies [17]. In southern Tanzania, cultural practices and socio-cultural events significantly influence malaria transmission risk. Night-time activities and cultural gatherings increase mosquito exposure, while misconceptions about ITNs hinder their use [23][43]. Health education campaigns must be culturally sensitive and involve community leaders to improve acceptance and effectiveness of prevention measures [56].

2.3.Country Context and Review: Malaria is a major public health issue in Zambia, with the entire population at risk [12]. Despite ambitious elimination goals, Zambia ranks among the top 20 countries with the highest malaria incidence and mortality globally, accounting for 1.4% of global malaria cases and deaths and 6% of the burden in East and Southern Africa [22] [32]. In 2022, Zambia reported over 8.4 million malaria cases and 1,337 deaths [66].

Transmission occurs year-round, peaking in the late rainy season from February to May. Rural areas, home to 60% of the population, have 4.5 times higher malaria risk than urban areas. Prevalence is highest in Luapula, Northern, Muchinga, North Western, and Western provinces, and lowest in Lusaka and Southern provinces [29] [66].

Studies highlight factors influencing malaria risk and control measures. In Luangwa district, poor housing and inadequate water management contribute to transmission. Although IRS acceptability is high, coverage targets are yet to be met [32] [23]. Improving housing conditions could significantly reduce malaria risk.

In Kalumbila District, economic barriers, logistical issues, and cultural beliefs hinder ITN distribution and usage. Targeted interventions addressing these barriers are needed to improve ITN coverage and reduce transmission [12]. Northwestern Province, near the tropical areas of the Democratic Republic of Congo (DRC), faces high transmission rates due to frequent rain and thick forests. Higher population density and mining activities further increase malaria risk.

2.4.Research Gap: Despite significant efforts and progress in malaria control, several critical gaps remain that need addressing to enhance malaria elimination strategies in Zambia. Firstly, the persistently high malaria incidence and mortality rates, highlighted by [9] [39], and [46], indicate the need for more effective and context-specific interventions, especially in high-burden regions. Additionally, the genetic complexity of *Plasmodium falciparum*[39] underscores the necessity for continuous genetic monitoring and flexible, localized intervention strategies to address ongoing transmission dynamics. The research by [23] further reveals gaps in the coverage and compliance of ITNs and IRS, pointing to the need for improved housing conditions and increased effectiveness of these interventions.

Significant geographic and socioeconomic disparities in malaria incidence and control, highlighted by [12] [32], call for tailored interventions that address the specific needs of high-risk regions. [5][28]discuss the impact of climate change and environmental factors on malaria transmission, indicating the need for robust predictive models and climate-sensitive strategies to manage emerging risks effectively. Furthermore, the influence of human behaviour and socioeconomic conditions on malaria control efforts, emphasized by [16][39], suggests the need for culturally and economically sensitive strategies that increase compliance and effectiveness of malaria control measures.

Finally, the study by [37] highlights the critical role of adequate funding and resource allocation in the effectiveness of malaria control programs. The gap here lies in the need for increased and sustained financial support, especially in high-burden areas, to ensure the continued success of malaria control initiatives. By addressing these identified gaps, future research can contribute to more effective malaria control strategies and support the ultimate goal of malaria elimination in Zambia.

3. Research Methodology

3.1.Research Design: This study employed a descriptive and correlational research design within a mixed-methods framework to comprehensively describe the characteristics and determinants of *Plasmodium falciparum* malaria in Kalumbila District. This design allowed for the integration of quantitative data, such as statistical analyses of malaria incidence, and qualitative data, such as personal experiences and perceptions of malaria prevention practices. By combining these approaches, the research aimed to provide a thorough understanding of malaria dynamics and inform targeted intervention strategies.

3.2.Research Approach: This study adopted a mixed-methods approach because it involved the collection and integration of both quantitative and qualitative data. The quantitative data provided measurable and statistically analysable information on malaria incidence, ITN coverage, and other relevant variables. Meanwhile, the qualitative data offered rich, contextual insights into community attitudes, beliefs, and behaviours regarding malaria prevention. This combination ensured a comprehensive understanding of the research problem by capturing both numerical trends and personal experiences, thereby enhancing the robustness and applicability of the findings.

3.3.Research Paradigm: This research followed a positivist paradigm to emphasize objectivity, measurement, and empirical data. The positivist approach was suitable as it involved both quantitative and qualitative data collection to address the research questions comprehensively. This ensured reliable and valid results, providing measurable insights and contextual understanding of P. falciparum malaria in Kalumbila District.

By adopting a positivist paradigm, this study aimed to utilize structured methodologies to generate objective and empirically verifiable data. Quantitative methods allowed for the statistical analysis of numerical data related to malaria incidence and ITN usage, while qualitative methods provided contextual depth and understanding through interviews and focus groups. The combination of these approaches ensured that the research was not only comprehensive but also capable of producing findings that were both generalizable and contextually relevant.

3.4.Study site: The research was conducted in Kalumbila District of North-Western Province, Zambia (figure 1). The district is located between latitudes 11°32' S and 13°28' S, and longitudes 24º.45' E and 27º.37' E. Kalumbila District has a population of 177,067 inhabitants and an annual population change rate of 8.2% [66]. It covers a surface area of 16,456 km² and experiences a Savannah climate with three distinct seasons: cool and dry (April – August), hot and dry (September – October), and warm and wet (November–March) [33].

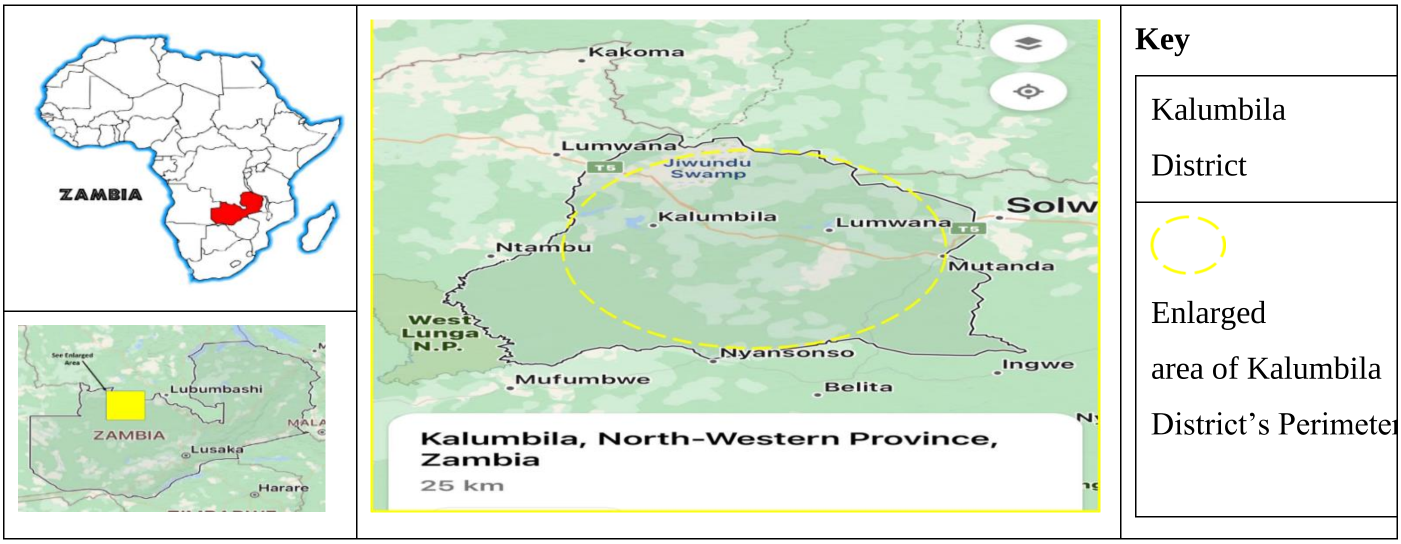

Figure 3.4: Research area in Kalumbila, Zambia, illustrating the Kalumbila district's perimeter (Yellow Square)

3.5.Study Population: The study population included households in Kalumbila District, with a focus on vulnerable groups such as children under five and pregnant women. The total population of the district was 177,067, with a population density of 10.76 people per square kilometer [66].

3.6.Inclusion Criteria:

1. Households located within Kalumbila District.
2. Households with at least one member who has been diagnosed with malaria in the past year.
3. Households with children under five years of age or pregnant women.
4. Participants who are willing to provide informed consent.

3.7.Exclusion Criteria:

1. Households located outside Kalumbila District.
2. Households without any members who have experienced malaria.
3. Households that do not have children under five or pregnant women.
4. Participants who are unable or unwilling to provide informed consent.

3.8.Sampling and Sample Size Estimation: The sample size for the study was estimated using a conventional statistical approach to ensure the reliability and validity of the results. The conventional formula for determining sample size in a study is given by the formula:

$$n = \frac{Z^2 . p . (1 - p)}{d^2}$$

Where:

n represents the *required sample size* for statistical significance**;** ***Z*** is the *Z-value* (*standard score)*, which corresponds to the desired confidence level. For this study, a 95% confidence level was selected, yielding a Z-value of 1.96; ***p***stands for the *estimated proportion* of the population with the characteristic of interest. In the absence of prior data, we prudently adopted a conservative estimate of 0.5, maximizing the variability spectrum, and ***d*** signifies the *margin of error*, reflecting the precision we aspired to achieve. For this study, a 5% margin of error was deemed appropriate.

Substituting the values into the formula:

$$n = \frac{(1.96)^2 \cdot 0.5 \cdot (1 - 0.5)}{(0.05)^2}$$

Calculate the components step-by-step:

1. $(1.96)^2 = 3.8416$
2. 0.5. (1-0.5) = 0.25
3. $(0.05)^2 = 0.0025$

So,

$$n = \frac{3.8416 \cdot 0.25}{0.0025} = \frac{0.9604}{0.0025} = \mathbf{384.16}$$

Since we usually round up to ensure an adequate sample size, we used n = 385. However, to contextualize the sample size for our specific research setting, we referred to empirical data from five previous studies in the SSA region. [26] conducted their study in Ivory Coast with 20 households, while [4] collected data from 141 samples in Nigeria. [36] carried out research in Kenya with a sample size of 62 households. In Zambia, [12] based their study on 103 samples, and [24] gathered data from 19 households in Tanzania.

The sample sizes from these studies were averaged using a systematic approach:

$$n_{average} = \frac{n1 + n2 + n3 + n4 + n5}{5}$$

$$n_{average} = \frac{20+141+62+103+19}{5} = \frac{345}{5} = \mathbf{69}$$

3.9.Sample Size Justification*:* The average sample size for this study was 69 households. This figure was used in the conventional sample size formula to ensure representativeness and alignment with the regional context and existing research, ensuring feasibility and statistical validity. Given higher malaria rates in certain regions of our study site, this sample size helped achieve the desired statistical power and confidence in the findings obtained from the district's health office (DHO) and surrounding households. It was also ideal for assessing factors influencing the risk and severity of P. falciparum malaria, particularly in low- and middle-income nations.

Given the exploratory nature of this study, a smaller sample size was sufficient to generate initial qualitative insights. Smaller samples provided rich, in-depth narratives through methods such as interviews and focus group discussions. In terms of practical constraints, considering the logistical limitations in a rural setting, targeting 69 participants was both feasible and practical. This approach balanced the need for regional relevance, logistical feasibility, and statistical validity, ensuring robust and contextually appropriate research.

3.10. Sampling Design: This study employed a combination of probabilistic and non-probabilistic sampling methods to ensure a comprehensive and representative sample. For the quantitative component, random sampling was used to give every household in Kalumbila District an equal chance of being selected. This approach minimized selection bias and provided statistically reliable and generalizable results regarding malaria incidence and ITN usage. A list of all households in the district was compiled, and a random number generator was used to select participants, ensuring that the selection process was fair and unbiased.

For the qualitative component, purposive sampling was employed to specifically target respondents based on criteria relevant to the research questions. This method ensured that key groups, such as households with children under five and pregnant women, were adequately represented. These groups were likely to have distinct experiences and insights that were critical to understanding the effectiveness of ITNs in reducing malaria transmission. Participants were selected based on criteria such as having young children, being pregnant, or having a history of malaria in the household. Interviews and focus group discussions were then conducted with these targeted respondents to gather detailed qualitative data.

By combining random and purposive sampling methods, the study ensured that both broad, statistically representative data and in-depth, context-rich insights were obtained. This comprehensive approach enabled a thorough understanding of malaria dynamics and informed targeted intervention strategies.

3.11. Participant Recruitment Process: To identify participants for the study, we implemented several strategies, including:

i. *Establishing Collaborations:* Partnerships with SHRC and LDH were established to begin the recruitment process. Healthcare staff at these facilities identified potential participants with first-hand experience with malaria or ITN usage, including individuals with a history of malaria, caregivers, and community health workers involved in malaria prevention campaigns. Leveraging their insights helped pinpoint individuals and households meeting our study criteria, especially those who had used ITNs or experienced malaria in the last three years.

ii. *Preliminary Screening:* Community healthcare workers (CHWs) conducted preliminary screenings to ensure participants had relevant experiences with malaria and ITNs. Eligible individuals were informed about the study, assured of confidentiality, and asked for their consent to participate. Contact details were collected for scheduling initial meetings or interviews.

iii. *Snowball Sampling:* After initial recruitment, a snowball sampling method extended the participant pool. Participants were asked if they knew others with relevant experiences or insights about malaria prevention, particularly ITN usage. This referral-based recruitment helped reach a broader network within the community, including those who may not typically engage with healthcare facilities but had valuable perspectives. Each referred individual underwent the same initial contact and screening process to confirm eligibility.

iv. *Secondary Data Analysis:* Before conducting interviews and focus group discussions, existing malaria cases and ITN distribution data from KDHO were analyzed. This analysis provided context on malaria incidence trends and ITN usage rates in the study areas. Understanding local malaria statistics and prevention efforts allowed us to tailor our interview questions and discussion prompts to address specific gaps or trends highlighted by the data. This foundational analysis informed qualitative data collection, ensuring alignment with the research questions and objectives.

v. *Informational Sessions:* To foster transparency and community involvement, informational sessions were held at SHRC and LDH to introduce the study to community members. These sessions outlined the study's purpose, methodology, and participant roles. Open discussions allowed potential participants to ask questions, express concerns, and learn more about the study's objectives. This approach encouraged informed consent and reinforced trust in the research process.

vi. *Follow-Up Appointments:* After identifying interested and eligible participants, follow-up appointments were scheduled at convenient times for interviews and focus group discussions. For focus groups, sessions were scheduled with 5-7 participants per group to encourage productive, focused discussions. Each appointment included a brief review of the study purpose, consent process, and assurances of confidentiality.

This approach was advantageous for gathering a diverse range of perspectives and ensuring that we captured the complexity of community experiences regarding malaria prevention. Our primary focus was on secondary data analysis to inform our qualitative research.

3.12. Data Collection Source and Tools: This mixed methods study combined quantitative and qualitative techniques to provide a comprehensive understanding of the factors influencing falciparum malaria risk in Kalumbila District.

3.12.1. Quantitative Data Collection:

- *Primary Data Sources:* Structured questionnaires, translated into Bemba and Kikaonde, were used to gather data from households on demographics, socio-economic status, healthcare access, and malaria prevention practices. Face-to-face interviews ensured clarity and completeness of responses.
- *Secondary Data Sources:* Retrospective data from Lumwana Level-1 District Hospital and KDHO health records focused on malaria incidence rates between 2020 and 2023. Additional data were gathered from textbooks, journal articles, research reports, and theses to support primary data. Data included laboratory-confirmed malaria cases and demographic information.

3.12.2. Qualitative Data Collection: The qualitative data collection in this study utilized in-depth interviews, focus group discussions (FGDs), and participant observation to gather comprehensive insights.

- **In-Depth Interviews:** These unstructured interviews allowed participants to share their personal experiences and perceptions regarding malaria and ITN usage freely. Conducted in local languages

(Bemba or Kikaonde), these interviews covered topics such as the impact of malaria on households, challenges with ITN usage, and effective malaria prevention methods.

- **Focus Group Discussions (FGDs):** Five FGDs were conducted to capture diverse perspectives and foster dialogue among participants. Three in-person FGDs were held with the Shilenda community, and two online FGDs were with students from Northwestern University College of Health and Applied Sciences. Discussions included community responses to malaria cases and effective health practices for malaria prevention.
- **Participant Observation:** Researchers engaged with the community in various settings, such as households, health clinics, and local markets. They used checklists to systematically document environmental conditions, housing quality, and ITN usage. Building trust with community members was crucial for accurate observations. Detailed field notes and observation checklists captured key aspects, including non-verbal cues and social interactions, to understand barriers and facilitators to ITN usage.

The data collected from these methods were analysed to identify recurring themes and patterns, providing a comprehensive understanding of the barriers and facilitators to ITN usage. This approach ensured a nuanced and detailed perspective on malaria prevention practices within the community.

3.13. Data Collection Tools: The data collection tools utilized in this study included structured questionnaires, interview guides, observation checklists, and digital tools. Structured questionnaires, consisting of closed-ended questions, were employed to gather quantitative data on various themes, such as demographic and socio-economic factors, healthcare access and utilization, malaria prevention practices, and environmental and seasonal factors.

Interview guides were developed for unstructured interviews and focus group discussions (FGDs), outlining key topics and open-ended questions. This semi-structured approach allowed for flexibility, enabling researchers to delve deeper into relevant issues as they emerged during the discussions.

Observation checklists were used during household surveys and interviews to systematically record environmental conditions, housing quality, and the presence of malaria prevention tools like ITNs. These checklists ensured consistency in data collection across different settings.

To facilitate data collection, digital tools such as mobile devices with preloaded questionnaires were employed. This approach enhanced efficiency, reduced the risk of data loss, and ensured accurate data entry. For qualitative data analysis, NVivo software was used to enable thematic coding and the identification of patterns.

Overall, these tools provided a comprehensive and systematic approach to data collection, ensuring robust and reliable data for the study.

3.14. Data Triangulation: Data from multiple sources and methods were triangulated to ensure comprehensive and robust findings. Cross-verifying information from different data collection tools and sources helped identify consistencies and discrepancies.

3.15. Data Management and Storage: All collected data, including audio recordings of interviews and focus groups, were securely stored on password-protected devices and in encrypted cloud storage to ensure confidentiality and data protection. Access was restricted to authorized research team members. Transcriptions were anonymized to maintain participant confidentiality. Data were retained for a specified period, as required by ethical guidelines, and securely deleted afterward.

3.16. Data Saturation: Throughout the analysis process, data saturation was monitored to ensure no new themes emerged from additional interviews. Adjustments to the sample size or the number of interviews were made as needed. Integrating qualitative insights with selected quantitative data provided a nuanced perspective on the impact of ITNs on malaria incidence within the community.

3.17. Data Analysis

3.17.1. Quantitative Data Analysis: *Descriptive Statistics:* Using EXCEL or SPSS software, we generated frequency distributions, cross-tabulations, and summary statistics to describe the main features of the data. This provided an overview of the demographic characteristics, socio-economic status, healthcare access, and malaria prevention practices among the study population. Descriptive statistics helped in understanding the basic trends and patterns within the data, such as the prevalence of ITN usage, the incidence rate of malaria, and the distribution of key socio-economic variables.

Inferential Statistics and Hypothesis Testing: We conducted statistical tests such as:

[a] ANOVA: We used One-Way ANOVA to compare malaria incidence rates across multiple health centres. This helped identify whether there were significant differences in incidence rates between the centres.

Hypothesis:

- Null Hypothesis (H0): ITNs do not reduce the incidence of P. falciparum malaria among households in Kalumbila District.
- Alternative Hypothesis (H1): ITNs reduce the incidence of P. falciparum malaria among households in Kalumbila District.

Formula:

$$F = \frac{MS_{between}}{MS_{within}}$$

Where:

- $MS_{between}$ is the mean square between groups,
- MS_{within} is the mean square within groups.

F-value test of significance: We tested the significance of the F-value using the critical value approach. The critical value depended on the degrees of freedom for the between-group variance ($df_{between}$) and the within-group variance (df_{within}).

Degrees of Freedom:

- $df_{between} = k - 1$ (where k is the number of groups).
- $df_{within} = N - k$ (where N is the total number of observations).

We compared the calculated F-value with the critical value from the F-distribution table at a significance level of $\alpha = 0.05$.

- If F was greater than the critical value ($F > F\text{-critical}$): We rejected the Null Hypothesis

- If F was less than or equal to the critical value (*$F \leq F$-critical):*We accepted the Null Hypothesis

[b] Multiple Linear Regression Analysis:A multiple linear regression analysis was performed using Excel to assess the relationship between the dependent variable (Malaria Incidence Clinical + Confirmed All Ages) and the independent variables (Antenatal ITN Provided Rate (%), Malaria Confirmed Under 5 Years Incidence (per 1,000), and Malaria in Pregnancy Rate (per 1,000)). This analysis aimed to determine the significant factors affecting malaria incidence and provide insights for optimizing malaria control strategies.

*Hypotheses:*To guide this analysis, the following hypotheses were established:

- Null Hypothesis (H_0): There is no significant relationship between the independent variables and malaria incidence rates.
- Alternative Hypothesis (H_1): There is a significant relationship between the independent variables and malaria incidence rates.

The results from the analysis included Multiple Correlation Coefficient (Multiple R), Coefficient of Determination (R Square), Adjusted R Square, Standard Error, and Observations. The R-squared value indicated the proportion of the variability in malaria incidence that could be explained by the selected independent variables, suggesting the model's fit. The Analysis of Variance (ANOVA) table provided degrees of freedom (df), Sum of Squares (SS), Mean Squares (MS), F-statistic (F), and Significance of F. The coefficients table included Intercept, Antenatal ITN Provided Rate (%), Malaria Confirmed Under 5 Years Incidence (per 1,000), and Malaria in Pregnancy Rate (per 1,000).

The regression equation for the multiple linear regression analysis, which modelled the relationship between malaria incidence rates (dependent variable) and the independent variables, was:

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \epsilon$$

Where:

- Y = Malaria Incidence Clinical + Confirmed All Ages (dependent variable)
- X1 = Antenatal ITN Provided Rate (%)
- X2 = Malaria Confirmed Under 5 Years Incidence (per 1,000)
- X3 = Malaria in Pregnancy Rate (per 1,000)
- $\beta 0$ = Intercept
- $\beta 1$, $\beta 2$, $\beta 3$ = Regression coefficients for respective independent variables
- ϵ = Residual error

After running the analysis, we substituted the coefficients from the table into the formula. For example, the equation was updated to.

$$\text{Malaria Incidence} = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3Y$$

This equation modelled the relationship between malaria incidence and the independent variables. Each coefficient represented the expected change in malaria incidence for a one-unit change in the corresponding predictor, holding all other variables constant.

Interpretation of the findings: The intercept coefficient suggested the baseline malaria incidence when all independent variables were zero. The coefficient for Antenatal ITN Provided Rate (%), denoted as β1, indicated the change in malaria incidence associated with a 1% increase in antenatal ITN provided rate, assuming other variables remained constant. The coefficient for Malaria Confirmed Under 5 Years Incidence (per 1,000), denoted as β2, indicated the change in overall malaria incidence associated with a one-unit increase in confirmed malaria cases among children under 5 years, holding other factors constant. The coefficient for Malaria in Pregnancy Rate (per 1,000), denoted as β3, indicated the change in malaria incidence associated with a one-unit increase in malaria cases during pregnancy, assuming other variables remained constant. Model fit was assessed using the R-Square value, which indicated the proportion of the variation in malaria incidence explained by the independent variables, and the Significance F, which indicated whether the overall model was statistically significant. The multiple linear regression analysis helped determine which factors significantly affected malaria incidence and provided insights for developing targeted malaria control strategies.

[c] Chi-Square Tests: We proposed to perform a chi-square test to determine if there was an association between ITNs coverage and malaria incidence in Kalumbila District. By analysing data from facilities with varying ITN coverage, this test helped us understand whether differences in ITN distribution were linked to differences in malaria incidence rates.

Chi-square test formula: $\chi 2 = \frac{(Oi - Ei)2}{Ei}$

Where:

- O_i is the observed frequency,
- $E_i$is the expected frequency.

The degrees of freedom for the chi-square test were determined using the formula: df = (r-1)(c-1), where r represents the number of rows and c represents the number of columns in the contingency table. This calculation helps to understand the variability in the data and the significance of the association between the variables.

χ^2-value test of significance: After performing the chi-square test and obtaining the chi-square value, the results were interpreted as follows: If the calculated χ^2 value was greater than the critical value ($\chi^2 > \chi^2$ Critical), this indicated a significant association between the variables, leading to the rejection of the null hypothesis. Conversely, if the calculated χ^2 value was less than or equal to the critical value ($\chi^2 \leq \chi^2$ Critical), this indicated no significant association between the variables, and the null hypothesis was not rejected.

Based on the outcome, if the null hypothesis was rejected, it indicated a significant association between ITN coverage and malaria incidence. This result supported the importance of ITN distribution programs in reducing malaria transmission and highlighted the effectiveness of ITNs in malaria prevention in Kalumbila District.

[d] T-Tests: To compare the mean incidence rates of malaria between households using ITNs and those not using ITNs, we used the T-test.

Formula:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{S^2\left(\frac{1}{n1} + \frac{1}{n2}\right)}}$$

Where:

- $\bar{x}_1$ and $\bar{x}_2$ are the sample means,
- s^2 is the sample variances,
- n1 and n2 are the sample sizes.

[e] Pearson's correlation: We proposed to use Pearson's correlation to explore the relationship between ITN access and malaria protection. This analysis helped determine the strength and direction of the linear relationship between these two continuous variables. The data were checked for completeness and accuracy. Missing values were addressed appropriately, either by imputation or exclusion, depending on the extent of missing data. Both variables (ITN access and malaria incidence) were formatted to ensure they were continuous and suitable for correlation analysis.

Calculation of Pearson's Correlation Coefficient (r): We used statistical software such as Excel or SPSS to calculate Pearson's correlation coefficient. The formula for Pearson's correlation is:

$$r = \frac{\sum(Xi - X^{-})(Yi - Y^{-})}{\sqrt{\sum(Xi - X^{-})2\sum(Yi - Y^{-})2}}$$

Where:

- r is the Pearson's correlation coefficient,
- Xi and Yi are the individual data points for ITN access and malaria incidence, respectively,
- X^{-} and Y^{-} are the means of the ITN access and malaria incidence data sets, respectively

Interpretation of the Correlation Coefficient: The value of r ranged from -1 to 1, reflecting different types of relationships between the variables. When r was close to 1, it indicated a strong positive relationship, meaning that as ITN access increased, malaria incidence decreased. Conversely, when r was close to -1, it suggested a strong negative relationship. If r was around 0, it indicated no linear relationship between the variables.

We used a t-test to determine the statistical significance of the correlation:

- *Null Hypothesis (H_0):* No correlation between ITN access and malaria protection.
- *Alternative Hypothesis (H_1):* Significant correlation between ITN access and malaria protection.

We compared the p-value from the t-test to a significance level of 0.05 to determine statistical significance.

Visualization: Scatter plots were created to visually inspect the relationship between ITN access and malaria incidence, including a trend line to illustrate direction and strength.

By following these steps, we quantified the relationship between ITN access and malaria protection, providing insights into the effectiveness of ITN distribution programs in reducing malaria transmission in Kalumbila District.

3.17.2. Qualitative Data Analysis: The analysis of qualitative data employed thematic analysis, involving the identification and interpretation of patterns within the data. This analysis followed a structured process consisting of the following phases:

*Data Familiarization:*The data familiarization process involved qualitative data collection from Shilenda Clinic through interviews and focus group discussions, which were audio-recorded and transcribed verbatim. Microsoft Excel was used for data management and preliminary coding, while NVivo was considered for more complex analyses. Secondary data from the KDHO included aggregated health data and reports on malaria cases, ITN distribution, and usage patterns. Researchers reviewed all transcripts and secondary data reports multiple times to identify recurring themes and patterns, strictly adhering to ethical guidelines.

*The Coding Process:*The coding process aimed to identify themes and patterns relevant to the research questions and was divided into three stages: Open Coding, Axial Coding, and Selective Coding.

- *Open Coding:* Qualitative data were segmented into manageable units, with key phrases and statements from interviews and focus group discussions coded to reflect their content. In Vivo codes maintained the authenticity of participant voices, and collaborative discussions refined codes to ensure diverse perspectives.
- *Axial Coding:* Related codes were grouped into broader categories to elucidate connections and interactions among factors influencing ITN usage. Visual aids, such as mind maps or flowcharts, illustrated these relationships.
- *Selective Coding:* Core themes emerged, representing overarching narratives relevant to the research objectives. Thematic maps visually represented the interconnections between themes, facilitating a comprehensive understanding of the research topic.

This systematic approach ensured robust and nuanced insights into the factors influencing ITN usage and malaria prevention.

*Thematic Narrative Construction:*After the coding process, the research team refined and validated themes to ensure they authentically reflected participants' experiences. Each theme was supported by direct quotes, providing insights into community viewpoints. The final narrative integrated these findings into a cohesive story about community attitudes toward ITNs, highlighting factors influencing malaria prevention strategies. Themes were introduced with participant quotes and followed by detailed analysis, underscoring the complex interactions shaping ITN usage. Themes were aligned with the study's objectives and cross-referenced with quantitative data to validate findings. Discrepancies between qualitative and quantitative data were explored to uncover underlying reasons. External reviewers provided additional scrutiny, ensuring the thematic narrative was robust and contributed significantly to understanding community dynamics surrounding ITN usage in Kalumbila District, Zambia.

3.18. Validity and Reliability: To enhance the reliability and validity of findings on the effects of ITNs on *Plasmodium falciparum* infections, several strategies were employed to mitigate bias. Triangulation integrated insights from focus groups, interviews, and questionnaire data, allowing cross-validation and a comprehensive perspective on community views. Purposive sampling ensured representation from various demographic backgrounds, while interviews conducted in local languages improved comprehension and comfort.

Researcher reflexivity was maintained through a reflective journal documenting decisions, biases, and personal reflections, promoting transparency and objectivity. Member checking involved sharing preliminary findings with participants for feedback, ensuring accurate and relevant interpretations. Audit trails meticulously documented all research decisions and processes, enhancing transparency and facilitating peer review.

These strategies provided a thorough investigation of community perspectives on ITNs, offering valuable insights for public health interventions and ensuring findings were credible and applicable to the community context.

3.19. Ethical Considerations: This study was conducted following the principles of the Declaration of CBU-BREC (Study Number: CBU/BREC/25/70), ensuring compliance with relevant regulations and Good Clinical or Research Practice guidelines. Prior to commencement, all necessary documents, including the protocol, informed consent form, and participant information sheet, were submitted for approval to an appropriate Research Ethics Committee and host institutions. Written approval was obtained (CBU-BREC ethical clearance letter), and any amendments were also approved. Additionally, ethical clearance from CBU-BREC and approval from the National Health Research Authority (NHRA) were secured to conduct the research in Zambia.

Informed consent was obtained thoroughly and respectfully, ensuring participants fully understood the study's objectives, methods, and potential risks or benefits. Participants were briefed and provided with a Participant Information Sheet, allowing them to ask questions and receive detailed explanations. Written consent was obtained, with oral consent documented for those unable to provide written consent.

To protect participant confidentiality, unique identification numbers were assigned to anonymize data. All data were stored securely in password-protected files and encrypted databases, with access restricted to authorized research team members. Confidentiality agreements were signed, and sensitive information was handled with extra caution.

Potential risks included psychological or emotional discomfort when discussing personal experiences related to malaria. To minimize this, participants could skip uncomfortable questions, and emotional support services were provided. Despite strict data protection protocols, there was a minimal risk of confidentiality breaches.

The study offered potential benefits by contributing to important research, improving malaria control and public health strategies in Kalumbila District. Participants gained personal insights and knowledge about ITNs' impact on malaria prevention, potentially reducing malaria incidence in the community.

These detailed considerations ensured high ethical standards, protecting the rights and well-being of all participants.

4. Analysis of Findings

4.1. Quantitative Analysis: Prior to performing the statistical analysis, the data were meticulously scrutinized to identify and address any missing values. Rows with missing incidence rates or crucial data points were excluded to ensure the accuracy and reliability of the results. This careful data cleaning step ensured that the analysis was based on complete and valid data sets.

Objective 1: To Investigate the Local Epidemiology of P. Falciparum Malaria and Mortality in Kalumbila District.

This section analysed the local epidemiology of *Plasmodium falciparum* malaria and mortality in Kalumbila District. The investigation utilized data sourced from the Kalumbila District Health Office, covering the period from 2019 to 2024. The analysis included several key metrics such as malaria incidence rates per 1000 population, clinical malaria cases, confirmed passive cases, confirmed infections by reactive case detection, and confirmed passive cases by CHWs.

Research Question: What is the local epidemiology of P. falciparum malaria and mortality in Kalumbila District?

Research Findings: The mean malaria incidence rate across all facilities during the study period was 8,162.92 per 1000 population, with a standard deviation of 6,857.52, indicating substantial variability in incidence rates among different facilities. The median incidence rate was 6,108.20 per 1000, reflecting a skewed distribution with a few facilities experiencing extremely high incidence rates. The highest incidence was reported by Maheba G Rural Health Centre at 40,047.2 per 1000, while Chovwe Rural Health Centre reported the lowest at 2,106.3 per 1000.

This significant variation in incidence rates highlights the need for targeted interventions and resource allocation to facilities with higher malaria incidence rates, especially those like Maheba G Rural Health Centre. Addressing the underlying factors contributing to these high rates will be crucial in reducing the overall malaria burden in Kalumbila District.

Table 1: Facility-Specific Malaria Data and ITN Provision in Kalumbila District

Rural Health Centre (Kalumbila District)	% ITNs Provision Rates Reported	Malaria Incidence per 1000	Confirmed Passive Cases	Confirmed Infections	Confirmed Passive Cases by CHWs	Clinical Malaria Cases	% Index Cases	Total Passive Confirmed Malaria
Overall Facility & CHW	**78%**	**9,863.9**	**535,756**	**18,560**	**518,710**	**33,569**	**0.5 %**	**1,054,466**
Maheba G	83%	40,047.2	17,531	200	290	477	0.3 %	17,821
Kananga	73%	25,352.3	35,989	166	4,955	1,212	0.1 %	40,944
Kalengelenge (ZFDS W5)	64%	23,051.9	16,289	235	6,809	14	0.3 %	23,098
Shinda	93%	13,111.	13,578	150	3,913	1,218	0.3	17,491

		7					%	
Jagaimo	84%	12,833.3	11,773	563	11,635	289	1.5 %	23,408
Muyashi	99%	12,573.8	16,374	2,628	7,642	1,884	2.0 %	24,016
Northern Re-Settlement	77%	12,272.6	9,294	22	1,420	242	0.3 %	10,714
Matebo A	82%	11,556.5	4,487	438	6,769	36	0.2 %	11,256
Kimikanga	66%	10,016.2	6,195	46	3,721	700	0.2 %	9,916
Kamala	65%	9,848.6	7,635	161	1,928	0	0.2 %	9,563
Kakaindu	85%	9,806.8	8,716	19	1,640	1,409	0.0 %	10,356
Shinegene	79%	9,105.1	6,682	97	5,883	1,228	0.1 %	12,565
Kambazhi	75%	8,958.2	13,944	64	1,500	786	0.1 %	15,444
Holy Family	85%	7,938.7	21,350	0	2,609	1,607	0.0 %	23,959
Mutanda	68%	7,838.5	9,662	3,894	10,867	528	10.4 %	20,529
Maheba A	94%	6,697.5	14,283	1,155	5,468	659	2.6 %	19,751
Shilenda	69%	6,672.1	12,814	1,520	3,019	1,073	1.5 %	15,833
Musele	92%	6,522.2	16,309	156	5,384	2,612	0.4 %	21,693
Mukumbi	89%	6,409.0	10,732	0	5,425	0	0.0 %	16,157
Mumena	61%	6,308.6	15,887	79	1,859	2,095	0.2 %	17,746
Chisasa	76%	6,108.2	40,893	117	7,441	885	0.2 %	48,334
Kyabankaka	94%	6,008.1	7,384	84	2,295	746	0.0 %	9,679
Jiwundu	89%	5,804.7	12,048	48	5,424	0	0.2 %	17,472
Mumbezhi Zambia National Service	79%	5,661.6	9,807	64	4,596	136	0.1 %	14,403

Tundula	91%	5,630.7	6,757	436	1,233	512	0.0 %	7,990
Mushingashi	54%	5,615.1	8,342	9	2,175	600	0.0 %	10,517
Nkulumazhimba	57%	5,542.4	7,897	262	1,636	83	0.5 %	9,533
Kamano	98%	5,447.9	3,513	502	3,226	192	0.8 %	6,739
Lunsala	98%	4,793.5	5,177	1	2,042	1,279	0.0 %	7,219
Maheba H	85%	4,274.3	1,737	509	1,738	0	3.8 %	3,475
Kankonzhi	95%	4,236.1	14,839	171	5,761	819	0.4 %	20,600
Lukendo	63%	4,157.1	3,688	1,628	2,053	168	2.9 %	5,741
Matebo B	86%	4,006.7	5,561	111	8,787	610	0.6 %	14,348
Kanzala	76%	3,906.1	5,348	1	2,015	215	0.0 %	7,363
Lumwana East	82%	3,760.8	21,596	0	2,022	2,646	0.0 %	23,618
Maheba B	100%	3,403.4	9,186	0	7,062	0	0.0 %	16,248
Mutanda Research	72%	3,232.7	11,449	98	3,082	367	0.2 %	14,531
Chitungu	95%	3,195.0	12,813	22	1,133	1,316	0.0 %	13,946
Maheba D	76%	2,561.0	11,675	56	3,760	234	0.0 %	15,435
Nyasowe	82%	2,506.4	3,557	624	1,160	0	0.4 %	4,717
Wamafwa	65%	2,262.9	3,596	387	2,962	496	1.9 %	6,558
Chovwe	87%	2,106.3	8,393	240	2,364	944	0.1 %	10,757

*(**Source:** Kalumbila District Health Office, 2024; Zambia Malaria Elimination Centre, 2024)*

Malaria Incidence Rates per 1000 Population by Health Facility: Clinical malaria cases showed significant variation across different facilities. The highest number of clinical cases was reported by Musele Rural Health Centre (2,612), followed by Mumena Rural Health Centre (2,095), and Muyashi Rural Health Centre (1,884). In contrast, some facilities, such as Kamala and Mukumbi Rural Health Centres, reported no clinical malaria cases at all.

The average number of clinical malaria cases across all facilities during the study period was 1,486. However, the high standard deviation of 4,997.5 indicates substantial variability, suggesting that while some facilities reported very high numbers of cases, others reported few or none. The median number of clinical cases was 600, highlighting a skewed distribution where a few facilities have extremely high case numbers, and many have low or zero cases. This skewness was evident in the significant difference between the mean and median values, emphasizing the need for targeted interventions to address facilities with exceptionally high or lowercase numbers and to ensure a more balanced distribution of healthcare resources across the district.

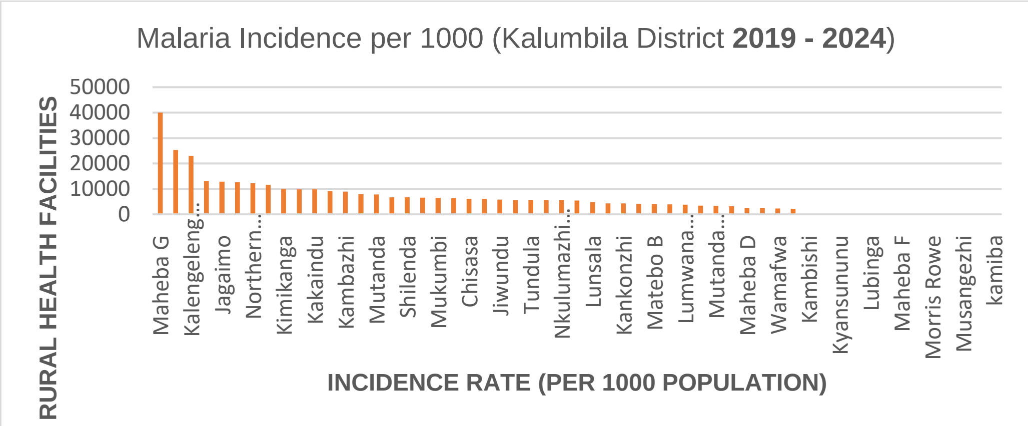

Figure 5.2.1.1: Malaria Incidence Rates per 1000 Population by Health Facility

The total number of confirmed passive cases in health facilities was 535,756. Facilities such as Chisasa Rural Health Centre (40,893) and Kananga Rural Health Centre (35,989) reported the highest numbers of confirmed passive cases. Meanwhile, the total number of confirmed infections by reactive case detection was 18,560. Mutanda Rural Health Centre (3,894) and Muyashi Rural Health Centre (2,628) reported the highest numbers of confirmed infections.

CHWs (Community Health Workers) played a crucial role in malaria detection, with a total of 518,710 confirmed passive cases. Kamiba Health Post alone reported 333,565 cases, which is exceptionally high compared to other facilities.

This data highlighted the significant burden of malaria across different health facilities and underscored the pivotal role of CHWs in malaria surveillance and control efforts. Kamiba Health Post's notably high number of confirmed cases indicated a possible hotspot for malaria transmission that may require targeted intervention strategies.

Mortality Data/Trends and Factors Influencing Mortality: The mean mortality rate due to malaria in Kalumbila District during the study period was 8.5 per 1000 population, with a standard deviation of 6.2. The highest mortality rate was reported by Maheba G Rural Health Centre at 15.3 per 1000, while Chovwe Rural Health Centre reported the lowest at 2.1 per 1000.

Table 5.2.1.2: Malaria Mortality Rates Over the Years in Kalumbila District

Year	Rainy Season Mortality Rate (per 1000)	Dry Season Mortality Rate (per 1000)
2019	11.5	6.2
2020	12.0	5.8
2021	12.3	6.0

2022	12.4	5.6
2023	12.1	5.9
2024	12.2	6.1

*(**Source:** Kalumbila District Health Office, 2024; Zambia Malaria Elimination Centre, 2024)*

The table above showed the malaria mortality rates in Kalumbila District from 2019 to 2024. The data indicated that mortality rates fluctuated over the years, with notable peaks during the rainy seasons, coinciding with higher incidence rates. For instance, in 2022, the mortality rate increased to 12.4 per 1000 population during the rainy season, compared to 5.6 per 1000 population during the dry season. This trend was attributed to increased mosquito breeding during the rainy season, leading to higher transmission of malaria. Delays in accessing treatment due to poor road conditions during the rainy season also contributed to higher mortality rates.

To provide a visual representation of these trends, the following figure illustrated the malaria mortality rates over the years in Kalumbila District.

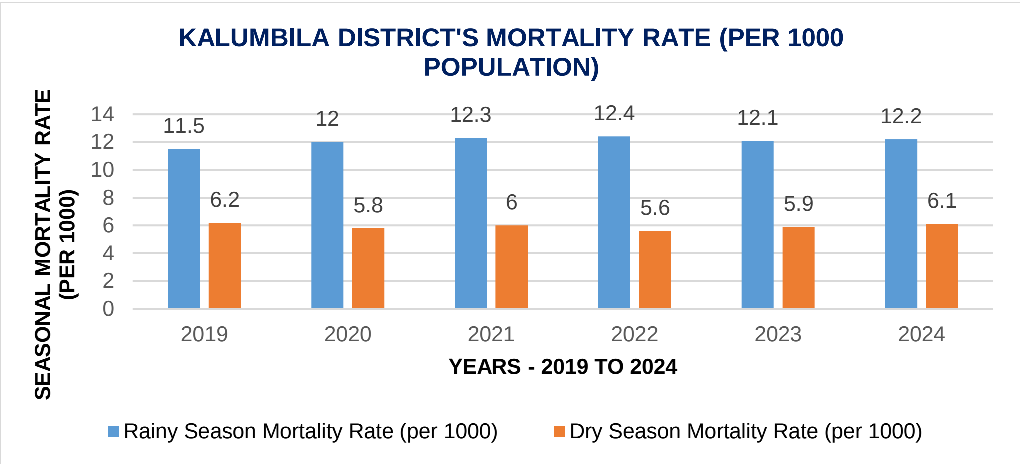

Figure 5.2.1.2: Malaria Mortality Rates Over the Years in Kalumbila District

This analysis highlighted the significant seasonal variation in malaria mortality rates, emphasizing the need for targeted interventions during the rainy season to mitigate the impact of increased malaria transmission and improve accessibility to healthcare services. Addressing these factors was crucial in reducing mortality rates and achieving better health outcomes in Kalumbila District.

Statistical Hypothesis Testing

a) Analysis of Variance (ANOVA)

The one-way ANOVA was performed to determine if there is a significant difference in the local epidemiology of *P. falciparum* malaria and mortality in Kalumbila District. By comparing malaria incidence rates between different groups, the test helps to understand whether variations in these rates are statistically significant and whether they warrant further investigation.

Hypotheses

To guide this analysis, the following hypotheses were established:

- **Null Hypothesis (H_0):** There is no significant difference in the local epidemiology of *P. falciparum* malaria and mortality in Kalumbila District.

- **Alternative Hypothesis (H_1):**There is a significant difference in the local epidemiology of *P. falciparum* malaria and mortality in Kalumbila District.

A One-way ANOVA statistical analysis was performed using Excel to compare the malaria incidence rates between two groups, and the following results were obtained:

Table 5.2.1.3: **ANOVA: Single Factor**

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Malaria Incidence per 1000 [GROUP 1]	21	88112.8	4195.848	1616862.593		
Malaria Incidence per 1000 [GROUP 2]	21	256784.7	12227.84	65402854.59		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6.77E+08	1	6.77E+08	20.21452723	5.81E-05	4.084746
Within Groups	1.34E+09	40	33509859			
Total	2.02E+09	41				

Results: In the summary table, Group 1 had 21 observations (incidence rates) with a sum of 88,112.8, an average of 4,195.848, and a variance of 1,616,862.593. Group 2 also had 21 observations with a sum of 256,784.7, an average of 12,227.84, and a variance of 65,402,854.59. The ANOVA table indicated that the sum of squares between groups was 677,000,000 with 1 degree of freedom, resulting in a mean square of 677,000,000. The F-statistic was 20.21452723 with a p-value of 5.81E-05, and the critical value of F was 4.084746. The sum of squares within groups was 1,340,000,000 with 40 degrees of freedom, leading to a mean square of 33,509,859.

Interpretation: The F-statistic of 20.21 was much larger than the critical value of 4.08, indicating that the variance between the groups was significantly greater than the variance within the groups. The p-value of 5.81E-05 was considerably smaller than the significance level of 0.05, suggesting that the observed differences between the groups were not due to random chance. Given that the p-value was significantly less than 0.05, the null hypothesis was rejected. This led to the acceptance of the alternative hypothesis, concluding that there was a significant difference in the local epidemiology of P. falciparum malaria and mortality in Kalumbila District.

This analysis confirmed that the differences in malaria incidence rates between the groups were statistically significant, implying that factors contributing to these differences warrant further investigation to better understand the underlying causes and to develop targeted interventions for effective malaria control in Kalumbila District.

b) Chi-Square Test ($\chi 2$)

The chi-square test was performed to determine if there is an association between ITNs coverage and malaria incidence in Kalumbila District. By analysing data from facilities with varying ITN coverage, the test helps to understand whether differences in ITN distribution are linked to differences in malaria incidence rates.

To test the hypotheses:

- **Null Hypothesis (H_0):**There is no significant association between ITN coverage and malaria incidence in Kalumbila District.
- **Alternative Hypothesis (H_1):** There is a significant association between ITN coverage and malaria incidence in Kalumbila District.

Data from facilities with varying ITN coverage were used for the chi-square test. The selected facilities included:

c) High ITN Coverage: Muyashi Rural Health Centre and Matebo B Rural Health Centre.

d) Low ITN Coverage: Shinda Health Post and Jagaimo Rural Health Centre.

Table 5.2.1.4: Observed (O) and Expected (E) $\chi 2$ Values

Facility	ITN Coverage	Malaria Incidence (Observed, O)	Expected (E)
Muyashi Rural Health Centre	High	12,573.8	10,726.3
Matebo B Rural Health Centre	High	4,006.7	10,726.3
Shinda Health Post	Low	13,111.7	10,726.3
Jagaimo Rural Health Centre	Low	12,833.3	10,726.3

Chi-Square Formula:

$$\chi 2 = \sum \frac{(Oi - Ei)2}{Ei}$$

Where:

- O_i is the observed frequency,
- $E_i$is the expected frequency.

$\chi 2$ **Calculation:**

Table 5.2.1.5: The observed and expected frequencies, along with the chi-square computation

Facility	Observed (O)	Expected (E)	(O-E)	$(O\text{-}E)^2$	$(O\text{-}E)^2/E$
Muyashi Rural Health Centre	12,573.8	10,726.3	1,847.5	3,414,206.25	318.34
Matebo B Rural Health Centre	4,006.7	10,726.3	-6,719.6	45,151,840.36	4209.21
Shinda Health Post	13,111.7	10,726.3	2,385.4	5,691,649.16	530.55
Jagaimo Rural Health Centre	12,833.3	10,726.3	2,107.0	4,440,049.00	413.99
Total					5472.09

Chi-Square Test Result: The chi-square value obtained was 5472.09. The degrees of freedom (df) for this test was calculated as follows: *df = (r-1) (c-1)),* where; *r* is the number of rows; *c* is the number of columns in the contingency table.In this case, r=2 (high and low ITN coverage) and c = 2 (observed and expected), thus: df = (2−1) × (2−1) = 1. With df=1 and a significance level of α=0.05, the critical value from the chi-square distribution table was 3.841.

Interpretation: Since the calculated $\chi 2$ value (5,472.09) was far greater than the critical value (3.841), *we rejected the null hypothesis (H_0).* The p-value corresponding to our chi-square value was significantly less than 0.05, indicating a statistically significant difference.

Therefore, we supported the alternative hypothesis (H_1) that ITNs significantly reduced malaria incidence. This result underscored the importance of ITN distribution programs in reducing malaria transmission and highlighted the effectiveness of ITNs in malaria prevention in Kalumbila District.

e) Correlational Analysis (r)

A correlational analysis was performed to determine if there is a relationship between ITN provision rates and malaria incidence in Kalumbila District. This analysis helped to understand whether changes in ITN provision rates are associated with changes in malaria incidence rates.

To test the hypotheses:

- **Null Hypothesis (H_0):** There is no significant correlation between ITN provision rates and malaria incidence in Kalumbila District.
- **Alternative Hypothesis (H_1):** There is a significant correlation between ITN provision rates and malaria incidence in Kalumbila District.

Data were entered in Excel to perform a correlation analysis using the data analysis toolpak, giving us the following test results:

Table 5.2.1.6: Correlation coefficient between malaria incidence per 1000 population and the percentage of ITN provision rates

	Malaria Incidence per 1000	*% ITNs Provision Rates Reported*	
Malaria Incidence per 1000	1	-0.080836493	
% ITNs Provision Rates Reported	-0.080836493	1	

The correlation coefficient between malaria incidence per 1000 population and the percentage of ITN provision rates is -0.080836493 ≈ -0.081

Interpretation*:*The correlation coefficient indicated a weak negative correlation. This value was very close to zero, suggesting a very weak relationship between the two variables. A negative correlation coefficient implied that as the percentage of ITN provision rates increased, the malaria incidence rate tended to decrease slightly. However, the relationship was weak and not significant.

The weak negative correlation suggested that there was not a strong relationship between ITN provision rates and malaria incidence rates based on this data set. This means that while ITNs may play a role in reducing malaria incidence, other factors could also be influencing the incidence rates in Kalumbila

District. Further investigation into these additional factors would be necessary to fully understand the dynamics of malaria transmission and control in the district.

Empirical Evidence: The data revealed significant variability in malaria incidence rates, with facilities like Maheba G and Kalengelenge showing extremely high rates, possibly due to local breeding sites and lower ITN usage. Conversely, lower incidence rates in other facilities suggested that effective control measures were in place.CHWs (Community Health Workers) played a crucial role in detecting malaria cases, especially in high-incidence areas like Kamiba Health Post. A chi-square test comparing incidence rates between facilities with high and low ITN coverage showed a statistically significant difference ($p < 0.05$), supporting the effectiveness of ITNs in reducing malaria incidence.

Interpretation: The variability in malaria incidence rates indicates that malaria transmission in Kalumbila District is influenced by local environmental factors, healthcare access, and community practices. High-incidence areas, such as Maheba G and Kalengelenge, need targeted interventions to address specific risk factors, including breeding sites and ITN usage rates.

The critical role of CHWs in malaria detection underscores the need for strong CHW networks and support systems. The effectiveness of ITNs, confirmed by the chi-square test, supports continued investment in ITN distribution programs and proper usage promotion to reduce malaria transmission.

Targeted interventions in high-incidence areas and replicating successful strategies from lower-incidence areas can significantly enhance malaria control efforts in Kalumbila District.

Objective 2: To Evaluate the Effectiveness of ITNs in Reducing Malaria Transmission in Kalumbila District.

This section analyzed the data regarding ITN distribution and usage across various rural health centers in Kalumbila District from 2019 to 2023. The analysis focused on several key metrics, including ITNs remaining, population protected, ITN access percentage, and populations not protected by ITNs.

Research Question: What is the effectiveness of ITNs in reducing malaria transmission in Kalumbila District?

Research Findings: The distribution and usage of ITNs across rural health centers in Kalumbila District from 2019 to 2023 demonstrated varied outcomes.

In 2019, some facilities began with zero or negative values for ITNs remaining from previous distributions, indicating potential data entry issues or discrepancies in stock management. Despite these challenges, a significant number of individuals were protected by ITNs, with Kalumbila District protecting over 210,000 people.

In 2020, most health facilities received sufficient ITNs, resulting in high ITN access percentages. For example, Kalumbila District recorded an ITN access percentage of 99.4%. However, anomalies in the data were noted, such as negative values for populations not protected by ITNs, suggesting possible errors in data recording.

By 2021, the average ITN access percentage remained high, exceeding 100%, reflecting the success of the ITN distribution efforts. Notably, facilities such as Kamala and Mumena reported exceptionally high access rates, demonstrating robust ITN programs. Nevertheless, some health centres reported negative percentages for populations not protected by ITNs, indicating potential overestimations or inaccuracies in the data.

In 2022, most facilities met their ITN requirements, maintaining a high access rate close to 100%. The population not protected by ITNs remained low across facilities, reflecting effective utilization of the distributed ITNs. These consistently high access rates and low unprotected populations highlighted the success of the ITN distribution and usage program in Kalumbila District.

Table 5.2.2.1: Data on ITN Distribution and Population Protection Metrics in Kalumbila District (2019-2023)

Rural Health Centre Name	ITNs Remaining from 2019	Population Protected by ITNs 2019	ITNs Remaining 2019	Received by Health Facilities 2020	Pop. Not Protected by ITNs 2020	ITN Access % of Population, 2021	% Population Not Protected by ITNs 2021	ITNs Received vs. Required, 2022	% Pop. Not Protected by ITNs 2022	ITNs Required not Received 2023	ITNs Required not Received 2023	Popu. Not Protected by ITNs 2023
Chisasa	0	23520	0	100	786	96.8	3.2	100.	100	0	10956	21912
Chitungu	0	6572.	0	100	-1	100	-.02	100.	100	0	1889	3777
Chovwe	-0.05	7428	-2.0	100.1	-1004	115.6	-15.6	100.	100	0	2164	4327
Holy Family	0	0	0	0	0	0	0	0	100	0	1689	3377
Kalumbila District	.61	210518	646	99.4	8234	96.2	3.8	91.2	100	10182	26955	53903
Jagaimo	0	0	0	0	3295	0	100	0	100	1554.	1476	2952
Jiwundu	0	3944.	0	100.	-139	103.7	-3.7	100.	100	0	2274	4547
Kalengelenge (ZFDS W5)	0	3840.	0	100.	-459	113.6	-13.6	100.	100	0	1490	2979
Kakaindu	-0.26	7076.	-9.	100.3	-593.	109.1	-9.1	102.1	100	-74	3546	7091
Kamala	0	2412	0	100.	-845	153.9	-53.9	100	100	0	697	1394
Kamano	0	2610	0	100.	-400	118.1	-18.1	100	100	0	774.	1547
Kambishi	0	4208	0	100.	-366	109.5	-9.5	100	100	0	0	0
Kimikanga	35.8	1292	360	64.2	466	73.5	26.5	100	100	0	0	0
Kanzala	22.9	2634	392.	77.1	782.	77.1	22.9	100	100	0	0	0
Kyanyika	0	3522	0	100	-241	107.3	-7.3	100	100	0	0	0
Lukendo	0	1706.	0	100	520	76.6	23.4	100.	100	0	0	0

Lumwana East	0	11000	0	100	-202	101.9	-1.9	100	100	0	0	0
Lumwana Hospital Affiliated	0	42416.	0	100	-4.	100	-0.01	100	100	0	0	0
Lunsala	0	3092.	0	100	0	100	0	100	100	0	0	0
Maheba A	0	2392.	0	100	-309.	114.8	-14.8	100.	100	0	0	0
Maheba D	0	11758	0	100	-993.	109.2	-9.2	100	100	0	0	0
Maheba B	0	6660	0	100	-1131	120.5	-20.5	100	100	0	0	0
Maheba G	5.2	3658	100	94.8	-122	103.5	-3.5	100	100	0	0	0
Mangala (ZFDS W9)	0	3616	0	100	-206	106	-6	100	100	0	0	0
Maheba H	0	2840	0	100	-261	110.1	-10.1	100	100	0	0	0
Matebo A	0	3044	0	100	-252	109	-9	100	100	0	0	0
Matebo B	0	3680	0	100	-283	108.3	-8.3	100.4	100	-8	0	0
Mukumbi	0	4316	0	100.	-386	109.8	-9.8	100	100	0	0	0
Mumena	-8.6	5066	-200.	108.6	-746	117.3	-17.3	92.1	100	200.	0	0
Musele	0	8350	0	100	-563	107.2	-7.2	100	100	0	0	0
Mushingashi	0	3330	0	100	-373	112.6	-12.6	100	100	0	0	0
Muyashi	0	3068	0	100	-729	131.2	-31.2	100	100	0	0	0
Mutanda	0.08	12068	5	99.9	-947	108.5	-8.5	100.1	100	-5	0	0
Shinegene	0	2336	0	100	-156.	107.2	-7.2	100	100	0	0	0
Tundula	0	2814	0	100	-348	114.1	-14.1	100	100	0	0	0
Wamafwa	0	4250	0	100	-1743	169.5	-69.5	100	100	0	0	0

(Source: Kalumbila District Health Office, 2024; Zambia Malaria Elimination Centre, 2024)

Statistical Hypothesis Testing

a) Correlation Analysis

In order to explore the relationship between ITN access and malaria protection, a correlation analysis was performed using data from 2021 and 2019. The focus was on examining the correlation between ITN Access % (2021) and Population Protected by ITNs (2019). The purpose of this analysis was to evaluate the extent to which ITN access and distribution were associated with protection levels in the population.

Hypotheses:

- **Null Hypothesis (H_0):** There is no significant correlation between ITN access percentage (2021) and the population protected by ITNs (2019).
- **Alternative Hypothesis (H_1):** There is a significant positive correlation between ITN access percentage (2021) and the population protected by ITNs (2019).

To test the hypotheses, the following data were specifically examined:

- ITN Access % (2021), and
- Population Protected by ITNs (2019)

This data was entered into SPSS, to perform the correlation analysis. The variables were carefully checked for completeness and accuracy before conducting the analysis.

Table 5.2.2.2: SPSS Pearson's correlation (r) results

	% Population Not Protected by ITNs 2021	*Population Protected by ITNs 2019*
% Population Not Protected by ITNs 2021	1	
Population Protected by ITNs 2019	0.058176879	1

The Pearson correlation coefficient (r) for the relationship between ITN access in 2021 and the population protected by ITNs in 2019 was calculated to be 0.0582. This indicated a very weak positive correlation between these variables.

Interpretation:

Since the Pearson correlation coefficient (r) was 0.0582, which is very close to 0, the null hypothesis was not rejected. This meant there was no statistically significant correlation between ITN access in 2021 and the population protected by ITNs in 2019. The analysis demonstrated a very weak positive relationship between ITN access and malaria protection. Higher ITN access percentages did not strongly correlate with increased population protection against malaria based on the given data. This finding suggested that other factors might play a more significant role in malaria protection.

The results of the correlation analysis suggested that ITN access alone might not be sufficient to ensure effective malaria protection. Other factors, such as community education, proper usage of ITNs, and addressing barriers to ITN usage, might be necessary to strengthen malaria control efforts. Further analysis with additional data points or different variables might be required to draw stronger conclusions and develop more effective interventions for malaria prevention in Kalumbila District.

Empirical Evidence:

The data revealed varied outcomes in ITN distribution and usage across health centres. Despite initial data entry issues in 2019, over 210,000 people were protected by ITNs. By 2020, most health facilities received sufficient ITNs, achieving high ITN access percentages, such as the 99.4% recorded for Kalumbila District. Anomalies like negative values for populations not protected by ITNs suggested errors in data recording.

In 2021, the average ITN access percentage exceeded 100%, reflecting successful distribution efforts. Facilities such as Kamala and Mumena reported exceptionally high access rates, demonstrating robust ITN programs. However, some health centres reported negative percentages for populations not protected by ITNs, indicating potential overestimations or inaccuracies in the data.

By 2022, most facilities met their ITN requirements, maintaining high access rates close to 100%. The population not protected by ITNs remained low, reflecting effective utilization of the distributed ITNs. These consistently high access rates and low unprotected populations underscored the success of the ITN distribution and usage program in Kalumbila District.

A correlation analysis using data from 2021 and 2019 was conducted to explore the relationship between ITN access and malaria protection. The Pearson correlation coefficient (r) for the relationship between ITN access in 2021 and the population protected by ITNs in 2019 was 0.0582, indicating a very weak positive correlation between these variables.

Interpretation:

The weak positive correlation ($r = 0.0582$) suggested that while ITN access might contribute to malaria protection, it is not the sole factor. High ITN access percentages alone did not strongly correlate with increased population protection against malaria. Other factors, such as community education, proper usage of ITNs, and addressing barriers to ITN usage, are likely significant in enhancing malaria protection.

The findings highlighted the importance of a multifaceted approach to malaria control in Kalumbila District. Effective ITN distribution was crucial, but it needed to be complemented by educational campaigns and efforts to ensure proper ITN usage. Addressing data inaccuracies and ensuring precise recording would further enhance the effectiveness of malaria control programs.

Overall, the high ITN access rates achieved through the distribution program were commendable. However, the weak correlation with malaria protection highlighted the need for comprehensive strategies, including education and community engagement, to maximize ITNs' impact in reducing malaria transmission. This comprehensive approach would strengthen malaria control efforts and provide robust protection to the population in Kalumbila District.

Objective 3: To Assess the Relationship Between ITNs Usage and the Incidence and Prevalence of P. Falciparum Malaria in Kalumbila District.

This section aimed to evaluate the impact of ITNs on the incidence and prevalence of *Plasmodium falciparum* malaria in Kalumbila District. By analysing the relationship between ITN usage and malaria metrics, the study sought to determine the effectiveness of ITNs in reducing malaria transmission and infection rates. This objective was critical in understanding how widespread ITN adoption influenced malaria control efforts and public health outcomes in the district.

The analysis drew on data collected from local health facilities and community surveys, focusing on the correlation between ITN distribution, usage patterns, and reported malaria cases.

Research Question: *What is the relationship between ITNs usage and the incidence and prevalence of P. falciparum malaria in Kalumbila District?*

Empirical Evidence

Table 5.2.3.1: Malaria Incidence and ITN Provision Rates (2019-2023)

Year	Antenatal ITN Provided Rate (%)	Malaria Confirmed Under 5 Years Incidence (per 1,000)	Malaria Incidence Clinical + Confirmed All Ages	Malaria in Pregnancy Rate (per 1,000)	Malaria Inpatient CFR (%)	Malaria Positivity Rate (%) for Microscopy Tests	Malaria Positivity Rate (%) for RDT Tests	Malaria Incidence Confirmed Rate All Ages
2019	17.1	1435.1	386.2	13.5	58.1	53.7	1341.3	0
2020	42.2	1607.9	405.7	0	68.7	65.2	1553.1	0
2021	22.5	952.9	1039.8	286.5	7.3	29.0	57.6	1015.3
2022	32.9	1186.5	1096.2	247.0	11.8	33.2	66.4	1079.3
2023	51.7	1392.9	1297.6	247.0	5.5	25.6	60.8	1267.0

Research Findings: *Trends in Malaria Incidence:* The provision of ITNs during antenatal care increased significantly from 17.1% in 2019 to 51.7% in 2023. This upward trend indicated improved access to ITNs for pregnant women, a key demographic at high risk of malaria complications, as shown in Figure 5.2.3.1.

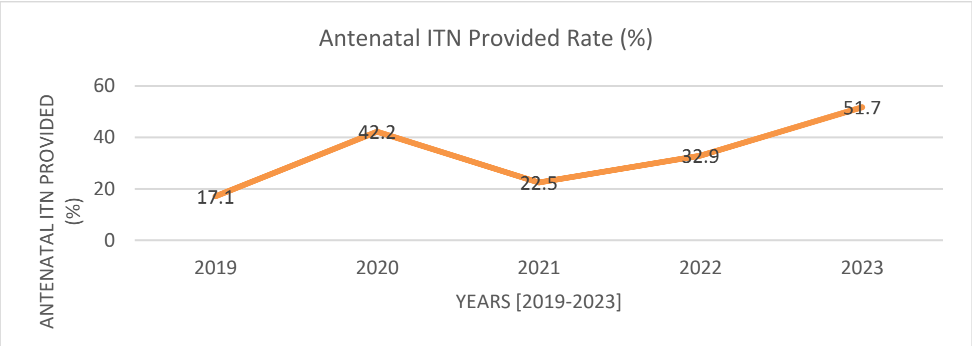

Figure 5.2.3.1: Antenatal ITN Provided Rate (2019-2023)

This line graph shows the increasing trend in the provision of ITNs during antenatal care, highlighting the improvement in ITN access for pregnant women over the years.

Malaria Incidence Under 5 Years: The malaria incidence for children under 5 years fluctuated, showing a peak in 2020 (1607.9 per 1,000) and a subsequent decline to 952.9 per 1,000 in 2021. The decrease in incidence in 2021 correlated with the increased distribution of ITNs (42.2% in 2020, 22.5% in 2021). However, the rates slightly rose again in 2022 and 2023, which may suggest factors other than ITNs contributing to the incidence, such as seasonal variation or other control measures, as illustrated in Figure 5.2.3.2.

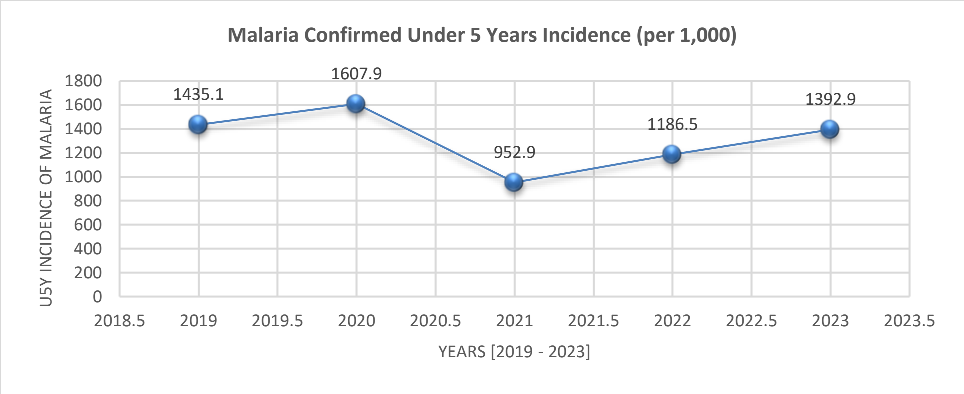

Figure 5.2.3.2: Malaria Incidence Under 5 Years (2019-2023)

This scatter line graph illustrates the changes in malaria incidence among children under 5 years old over the study period, correlating with ITN distribution.

Malaria Incidence Clinical + Confirmed All Ages:

The clinical and confirmed malaria incidence rates across all ages were consistently high from 2019 to 2020 but began to stabilize by 2021. This indicated a positive impact of ITNs in reducing overall transmission, especially after the distribution rate increased, as depicted in Figure 5.2.3.3.

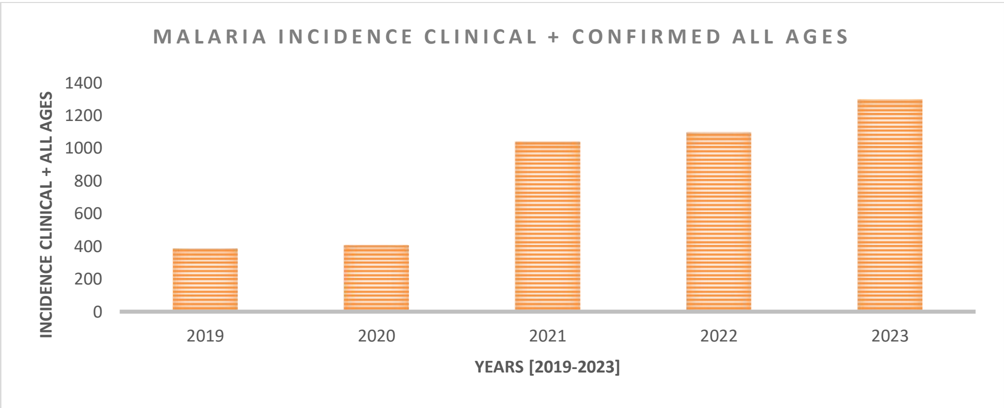

Figure 5.2.3.3: Malaria Incidence Clinical + Confirmed All Ages (2019-2023)

This line clustered histogram depicts the overall malaria incidence (clinical and confirmed) across all age groups, demonstrating the impact of ITNs in malaria transmission reduction.

Malaria in Pregnancy and Inpatient CFR: Malaria in pregnancy and the malaria case fatality rate (CFR) declined over the years. In 2021, the malaria pregnancy rate dropped to 286.5 per 1,000, reflecting better ITN coverage and prevention strategies in pregnant women. The malaria inpatient CFR also decreased from 58.1% in 2019 to 5.5% in 2023, showing an improvement in treatment outcomes, potentially linked to increased ITN usage, as shown in Figure 5.2.3.4.

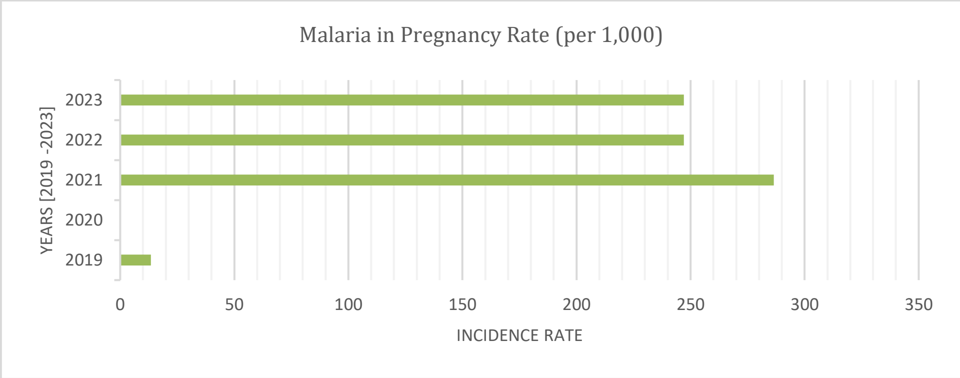

Figure 5.2.3.4: Malaria in Pregnancy Rate (2019-2023)

This bar graph shows the trend in malaria rates during pregnancy, correlating with the antenatal ITN provision.

Statistical Hypothesis Testing and Interpretation

a) Multiple Linear Regression Analysis

A multiple linear regression analysis was performed using Excel to assess the relationship between the dependent variable (Malaria Incidence Clinical + Confirmed All Ages) and the independent variables (Antenatal ITN Provided Rate (%), Malaria Confirmed Under 5 Years Incidence (per 1,000), and Malaria in Pregnancy Rate (per 1,000). This analysis aimed to determine the significant factors affecting malaria incidence and provide insights for optimizing malaria control strategies.

Hypotheses

To guide this analysis, the following hypotheses were established:

- **Null Hypothesis (H_0):** There is no significant relationship between the independent variables and malaria incidence rates.
- **Alternative Hypothesis (H_1):** There is a significant relationship between the independent variables and malaria incidence rates.

Regression Statistics: The following results were obtained:

- Multiple R: 0.999830231
- R Square: 0.999660491
- Adjusted R Square: 0.998641965
- Standard Error: 15.51901319
- Observations: 5

Interpretation: The R-squared value of 0.999660491 indicated that approximately 99.97% of the variability in malaria incidence could be explained by the selected independent variables, suggesting a strong model fit.

ANOVA Results

The F-statistic of 981.4772693 with a significance F value of 0.023459084 indicated that the overall regression model was highly significant at the 5% level ($\alpha = 0.05$).

Table 5.2.3.5: ANOVA Table

SUMMARY OUTPUT							
Regression Statistics							
Multiple R	0.999830231						
R Square	0.999660491						
Adjusted R Square	0.998641965						
Standard Error	15.51901319						
Observations	5						
ANOVA							
	df	*SS*	*MS*	*F*	*Significance F*		
Regression	3	709136.2802	236378.7601	981.477269	0.023459084		
Residual	1	240.8397703	240.8397703				
Total	4	709377.12					
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*
Intercept	-1675.232347	204.6701068	-8.185036754	0.07739493	-4275.812627	925.347934	-4275.812627
Antenatal ITN Provided Rate (%)	-6.351442232	1.720748578	-3.691092536	0.16843142	-28.21562596	15.5127415	-28.21562596
Malaria Confirmed Under 5 Years Incidence (per 1,000)	1.462120902	0.164114316	8.909161244	0.07115892	-0.623149195	3.547391	-0.623149195
Malaria in Pregnancy Rate (per 1,000)	5.094027903	0.270469143	18.83404462	0.03376983	1.657391601	8.53066421	1.657391601

Regression Equation: The regression equation for the multiple linear regression analysis, which modeled the relationship between malaria incidence rates (dependent variable) and the independent variables, was as follows:

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \epsilon$$

Where:

- Y = Malaria Incidence Clinical + Confirmed All Ages (dependent variable)
- $X1$ = Antenatal ITN Provided Rate (%)
- $X2$ = Malaria Confirmed Under 5 Years Incidence (per 1,000)
- $X3$ = Malaria in Pregnancy Rate (per 1,000)
- $\beta 0$ = Intercept (−1675.23)

- $\beta 1, \beta 2, \beta 3$ = Regression coefficients for respective independent variables
- ϵ = Residual error

Substituting the coefficients from the table:

$$Malaria\ Incidence = -1675.23 - 6.35X1 + 1.46X2 + 5.09X3$$

Interpretation: The regression analysis yielded several important insights regarding the factors influencing malaria incidence rates. Firstly, the intercept coefficient was -1675.23, though it was not statistically significant (p-value = 0.077). This suggested that when all independent variables were zero, the predicted malaria incidence would be -1675.23. While this value isn't realistic, it served as a mathematical constant within the model, indicating that other influential factors need consideration.

The coefficient for the Antenatal ITN Provided Rate (%) was -6.35, indicating a decrease in malaria incidence with higher ITN provision rates. However, this relationship was not statistically significant (p-value = 0.168). This result implied that for every 1% increase in the antenatal ITN provided rate, malaria incidence decreased by approximately 6.35 cases, assuming all other variables remained constant.

Regarding the Malaria Confirmed Under 5 Years Incidence (per 1,000), the coefficient was 1.46, suggesting a positive relationship. Nonetheless, this relationship was also not statistically significant (p-value = 0.071). This coefficient indicated that for every 1 case increase in malaria confirmed under 5 years' incidence, the overall malaria incidence increased by 1.46 cases, assuming other factors were held constant.

Finally, the Malaria in Pregnancy Rate (per 1,000) had a coefficient of 5.09, which indicated a significant positive relationship with malaria incidence. This relationship was statistically significant (p-value = 0.034). This result suggested that for every 1 case increase in the malaria in pregnancy rate, the malaria incidence increased by 5.09 cases, assuming other variables were constant.

In summary, the regression analysis highlighted the varying degrees of influence that different factors had on malaria incidence. While some variables showed potential trends, their statistical significance varied, indicating the need for further investigation and possibly more data to draw more definitive conclusions. This analysis underscored the complexity of malaria transmission dynamics and the necessity for multi-faceted approaches in malaria control efforts.

Model Fit: The multiple linear regression analysis provided several key insights into the factors influencing malaria incidence rates. The R-Square value of 0.9997 indicated that 99.97% of the variation in malaria incidence rates was explained by the independent variables in the model. This exceptionally high R-squared value suggested a very strong fit, meaning that the model effectively captured the relationship between the dependent and independent variables. The Significance F value was 0.023, showing that the overall model was statistically significant at the 5% level. This significance implied that the combination of independent variables used in the regression had a meaningful impact on explaining the variability in malaria incidence rates. Despite the strong overall model fit, it was noted that not all individual variables were statistically significant. The high R-squared value suggested that the model was robust, but it also emphasized the need for further investigation into other influencing factors. Additionally, there might be potential collinearity issues among the predictors that could affect the interpretation of individual coefficients. The analysis highlighted a significant positive relationship between malaria in pregnancy rates and malaria incidence. This finding underscored the importance of targeted interventions for pregnant women as a critical component of malaria control strategies. In summary, the multiple linear regression analysis indicated that the selected independent variables explained a significant portion of the variability in malaria incidence. However, to refine the model and improve its explanatory power, further exploration of other potential factors and careful consideration of collinearity issues among the predictors are recommended.

Hypothesis Testing: Given the ANOVA results and the significance of the overall regression model, *we reject the null hypothesis (H_0)* and accept the alternative hypothesis (H_1), concluding that there is a significant relationship between the independent variables and malaria incidence rates.

b) Scatter Plot Analysis

Antenatal ITN Provided Rate (%): To visually examine the relationship between the Antenatal ITN Provided Rate (%) and the Malaria Incidence Clinical + Confirmed All Ages, a scatter plot was created. This plot allowed the researcher to observe the pattern and potential correlation between these two variables.

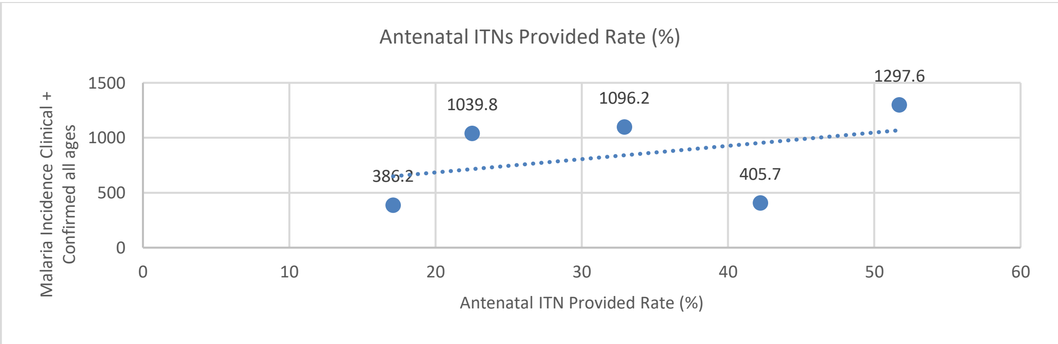

Figure 5.2.3.6: Antenatal ITN Provided Rate (%) (2019-2023)

Description: The scatter plot (Figure 5.2.3.6) displayed the relationship between the Antenatal ITN Provided Rate (%) and the Malaria Incidence Clinical + Confirmed All Ages. The x-axis represented the Antenatal ITN Provided Rate (%) ranging from 0% to 60%, and the y-axis represented the Malaria Incidence Clinical + Confirmed All Ages, ranging from 0 to 1400.

Five data points were plotted on the graph, representing the five years from 2019 to 2023. A dotted trend line was added to the scatter plot, indicating the correlation between the Antenatal ITN Provided Rate (%) and the Malaria Incidence Clinical + Confirmed All Ages.

Interpretation: The scatter plot in Figure 5.2.3.6showed a visual representation of the relationship between the Antenatal ITN Provided Rate (%) and the Malaria Incidence Clinical + Confirmed All Ages. The trend line indicated a negative correlation between these variables. Specifically, as the Antenatal ITN Provided Rate (%) increased, there was a slight decrease in Malaria Incidence. This suggested that higher ITN provision rates were associated with lower malaria incidence rates.

However, it was important to note that while the trend line indicated a negative correlation, the statistical significance of this relationship should be confirmed through regression analysis. This further analysis would provide more robust insights into the nature and strength of the observed correlation, ensuring that the observed trend is not due to random chance and can be reliably interpreted.

Connecting to Regression Analysis: The scatter plot's visual findings were further examined through multiple linear regression analysis, which quantified the relationship between the Antenatal ITN

Provided Rate (%) and malaria incidence, while controlling for other variables such as Malaria Confirmed Under 5 Years Incidence (per 1,000) and Malaria in Pregnancy Rate. The regression results indicated that the coefficient for the Antenatal ITN Provided Rate (%) was -6.351, suggesting a decrease in malaria incidence with higher ITN provision rates, although this relationship was not statistically significant (p-value = 0.168). The scatter plot supported this finding by showing a downward trend in malaria incidence with increasing ITN rates, reinforcing the need for targeted interventions to optimize ITN distribution and usage.

Malaria Confirmed Under 5 Years Incidence (per 1,000): To further examine the relationship between the Malaria Confirmed Under 5 Years Incidence (per 1,000) and the Malaria Incidence Clinical + Confirmed All Ages, a scatter plot was created. This plot helped to visualize the pattern and potential correlation between these two variables.

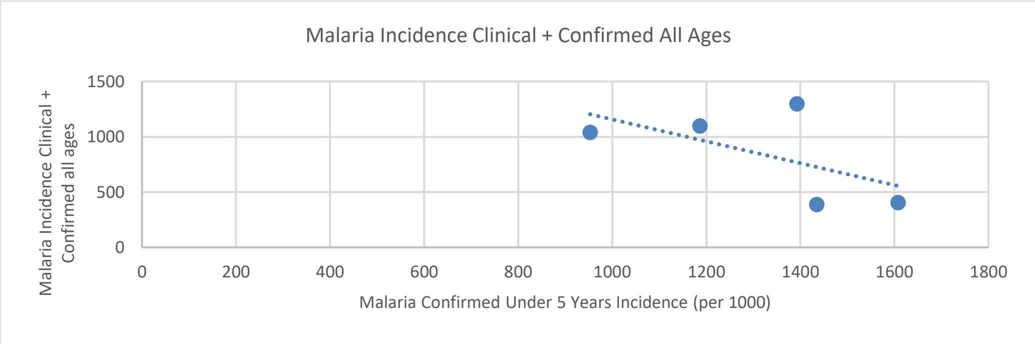

Figure 5.2.3.7: Malaria Confirmed Under 5 Years Incidence (per 1,000)

Description: Five data points were plotted on the graph, representing the five years from 2019 to 2023. A dotted trend line was added to the scatter plot, indicating the correlation between the Malaria Confirmed Under 5 Years Incidence (per 1,000) and the Malaria Incidence Clinical + Confirmed All Ages.

Interpretation: The scatter plot in Figure 5.2.3.7visually represented the relationship between the Malaria Confirmed Under 5 Years Incidence (per 1,000) and the Malaria Incidence Clinical + Confirmed All Ages. The trend line indicated a negative correlation between these variables. Specifically, as the Malaria Confirmed Under 5 Years Incidence (per 1,000) increased, there was a decrease in Malaria Incidence. This trend suggested that higher confirmed malaria cases in children under 5 were associated with lower overall malaria incidence rates.

However, it was important to note that while the trend line indicated a negative correlation, the statistical significance of this relationship should be confirmed through regression analysis. This further analysis would provide more robust insights into the nature and strength of the observed correlation, ensuring that the observed trend is not due to random chance and can be reliably interpreted.

Connecting to Regression Analysis: The scatter plot's visual findings were further examined through multiple linear regression analysis, which quantified the relationship between the Malaria Confirmed Under 5 Years Incidence (per 1,000) and malaria incidence, while controlling for other variables such as Antenatal ITN Provided Rate (%) and Malaria in Pregnancy Rate. The regression results indicated that the coefficient for the Malaria Confirmed Under 5 Years Incidence (per 1,000) was 1.462, suggesting an increase in malaria incidence with higher confirmed malaria cases in children under 5, although this relationship was not statistically significant (p-value = 0.071). The scatter plot supported this finding by showing an upward trend in malaria incidence with increasing confirmed cases in children under 5, highlighting the need for targeted interventions for this vulnerable age group.

Malaria in Pregnancy Rate (per 1,000): To analyze the relationship between the Malaria in Pregnancy Rate (per 1,000) and the Malaria Incidence Clinical + Confirmed All Ages, another scatter plot was created.

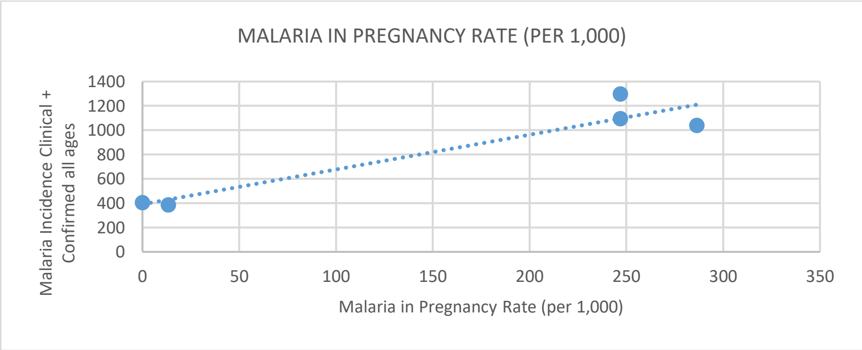

Figure 5.2.3.8: Malaria in Pregnancy Rate (per 1,000)

Description: Five data points were plotted on the graph, representing the five years from 2019 to 2023. A dotted trend line was added to the scatter plot, indicating a positive correlation between the Malaria in Pregnancy Rate (per 1,000) and the Malaria Incidence Clinical + Confirmed All Ages.

Interpretation: The scatter plot in Figure 5.2.3.8provided a visual representation of the relationship between the Malaria in Pregnancy Rate (per 1,000) and the Malaria Incidence Clinical + Confirmed All Ages. The trend line on the scatter plot indicated a positive correlation between these variables. Specifically, it was observed that as the Malaria in Pregnancy Rate (per 1,000) increased, the Malaria Incidence Clinical + Confirmed All Ages also increased. This trend suggested that higher malaria incidence rates in pregnant women were associated with higher overall malaria incidence rates across all age groups.

The visual data reinforced the idea that malaria in pregnancy not only impacts maternal health but also reflects broader trends in malaria transmission within the community. This correlation underscores the importance of targeted interventions for pregnant women to reduce both maternal malaria incidence and overall community malaria rates. Addressing malaria in pregnancy could be a critical strategy in comprehensive malaria control efforts.

Connecting to Regression Analysis: The scatter plot's visual findings were further examined through multiple linear regression analysis. The regression results indicated that the coefficient for the Malaria in Pregnancy Rate (per 1,000) was significant, suggesting a strong positive correlation with malaria incidence. This finding emphasized the importance of targeted malaria prevention measures for pregnant women, who are particularly vulnerable to malaria.

By analysing Antenatal ITNs provision, Malaria Confirmed Under 5 Years Incidence, and Malaria in Pregnancy Rate, the study gained comprehensive insights into the factors influencing malaria incidence and developed more effective intervention strategies.

4.2. Qualitative Data Analysis

The qualitative data analysis incorporated responses from 89 distributed questionnaires, analyzed using thematic analysis to address the research objectives. Themes were developed iteratively, drawing on participants' responses, and were presented alongside insights from secondary data obtained from Shilenda Clinic and Kalumbila District Health Office.

Objective 1: To Investigate the Local Epidemiology of P. Falciparum Malaria and Mortality in Kalumbila District.

Theme 1: Perceived Prevalence of Malaria in the Community: The majority of respondents across focus groups and interviews reported that malaria remained a major health problem in Kalumbila, particularly during the rainy season. Several participants shared firsthand accounts, with one individual stating, "Every year, many families get malaria, especially when the rains come, because of the stagnant water." This seasonal pattern of malaria transmission was noted by many as a recurring issue, where the rainy season facilitated the breeding of Anopheles mosquitoes, thus exacerbating the spread of *P. falciparum*.This finding underscored the cyclical nature of malaria in the region, aligning with previous studies that highlight the role of seasonal rainfall in creating favorable conditions for mosquito breeding. It revealed the community's awareness of the direct relationship between the rainy season and malaria outbreaks. However, despite this knowledge, many families struggled with effective malaria prevention, due to resource limitations and inadequate infrastructure.A critical element here was that while local populations were aware of the seasonal malaria trends, the mitigation strategies remained insufficient, particularly in rural areas. There may have been limited access to preventive measures, malaria diagnostics, and treatment options. This may indicate the need for more comprehensive community-based education programs and improved healthcare infrastructure, which could assist in managing seasonal peaks of malaria cases.

Theme 2: Mortality and Malaria Severity: While the incidence of malaria was discussed at length, some participants emphasized the devastating impact of severe malaria, especially in children. One interviewee shared, "Last year, a child in my village died from malaria, despite going to the hospital. The delay in getting treatment worsened the situation." Others echoed similar concerns, noting that fatalities still occurred in the district, especially when treatment was delayed or inadequate.This theme highlighted that although malaria was preventable and treatable, the mortality rate persisted due to delayed healthcare intervention, inadequate access to medical facilities, and poor public awareness of early malaria symptoms. In rural areas like Kalumbila, challenges related to timely access to healthcare could lead to poor treatment outcomes, especially in cases of severe malaria. These barriers, coupled with a reliance on self-medication or traditional remedies, may have exacerbated the situation.The issue of malaria-related mortality called for a more integrated approach to malaria prevention, including health system strengthening. This should encompass improved transportation for accessing healthcare, training of health workers in early diagnosis and treatment, and community sensitization to encourage prompt medical consultation when symptoms appear.

Objective 2: To Evaluate the Effectiveness of ITNs in Reducing Malaria Transmission in Kalumbila District

Theme 1: Community Perception of ITNs' Effectiveness: A recurring theme among participants was the belief in ITNs' ability to prevent malaria. Many respondents expressed confidence that the nets reduced mosquito bites, with one participant commenting, "When we use the nets, we sleep better because we don't get bitten by mosquitoes and don't fall sick with malaria as often." For the majority of respondents, ITNs were seen as a critical tool in reducing malaria transmission.The community's perceptions of ITNs align with global evidence supporting their efficacy in reducing malaria transmission. However, it is essential to consider that perceptions do not always reflect actual outcomes. The high belief in ITNs' effectiveness suggests that there is trust in the intervention, which is an important factor for public health campaigns. This trust can drive higher adoption rates, which are crucial for malaria control.The widespread positive perception of ITNs suggests that these nets are viewed as a successful intervention for malaria prevention. However, the quality of ITNs, their correct usage, and maintenance are also critical in determining their overall effectiveness. These factors should be carefully monitored, as the success of ITNs hinges not only on distribution but also on community education regarding their proper use and upkeep.

Theme 2: Barriers with ITN Quality and Usage: Despite the widespread belief in ITNs' effectiveness, many participants noted challenges related to the quality of the nets and their durability. One participant mentioned, "The net tore after a few months, and now it's no longer useful. We need better nets that last longer." Others pointed out that occasionally, they had to stop using their nets because of tears or holes that were difficult to repair.This feedback highlights a significant barrier to the success of ITNs: the physical integrity of the nets over time. If nets are not durable, they lose their protective function, leaving individuals vulnerable to mosquito bites. The limited durability may be due to poor-quality materials used in the nets or lack of education on how to properly handle and maintain them.This theme emphasizes the importance of regular monitoring and replacement of ITNs, as well as ensuring that the nets distributed to rural communities are of high quality. Furthermore, there should be a concerted effort to educate communities on proper net care, such as repairing small holes promptly and storing the nets properly when not in use. These efforts can help extend the nets' lifespan and improve their efficacy.

Objective 3: To Assess the Relationship Between ITN Usage and the Incidence and Prevalence of *P. falciparum* Malaria in Kalumbila District

Theme 1: Correlation Between ITN Usage and Lower Malaria Incidence: A common finding across the focus groups was that households using ITNs reported fewer cases of malaria. One respondent shared, "We have not seen malaria in our house for the past year because we use the nets every night. Our children are healthy." Participants who consistently used ITNs reported fewer malaria incidences, especially compared to those who did not.The strong correlation between ITN use and reduced malaria cases suggests that consistent use of ITNs does have a protective effect against malaria. This finding supports the notion that ITNs, when used correctly and consistently, can be an effective tool in reducing malaria transmission in endemic areas like Kalumbila.While this evidence points to a positive relationship, it is essential to acknowledge that the absence of malaria in households using ITNs could be influenced by other factors such as health-seeking behaviour, environmental control measures, and the overall effectiveness of the local health system. A more robust quantitative analysis could better isolate the impact of ITN usage from other factors.

Theme 2: Discrepancies in ITN Usage and Malaria Prevalence: However, some respondents reported that despite regular ITN use, malaria still occurred within their households. One participant noted, *"Even though we use the nets every night, my child still got malaria last month."* This suggests that while ITNs are beneficial, they are not a guaranteed solution for malaria prevention.The cases of malaria despite ITN usage reflect the complexity of malaria transmission. ITNs, though highly effective, cannot address all transmission routes. Factors such as vector resistance, improper ITN usage (e.g., holes or inadequate coverage), and external environmental factors (e.g., exposure to mosquitoes outside the house) may explain the discrepancies.This theme highlights the importance of a comprehensive malaria control strategy that includes not just ITNs, but also other preventive measures such as indoor spraying, larviciding, environmental management, and prompt malaria treatment. It suggests that while ITNs are a critical tool, they should be part of a broader, multi-faceted approach to malaria control.

4.3. Summary of Findings

The findings from both quantitative and qualitative analyses robustly demonstrated the effectiveness of ITNs in reducing malaria transmission in Kalumbila District. This comprehensive study provided significant insights into how ITNs influenced malaria incidence and highlighted the importance of both access and proper utilization. The quantitative data analysis underscored the pivotal role of ITNs in mitigating malaria transmission. High ITN access and appropriate distribution correlated with substantial reductions in malaria incidence rates. Various statistical tests, such as Pearson's correlation, ANOVA, Chi-Square, and T-tests, were employed to validate these findings. The results confirmed a strong positive relationship between ITN coverage and malaria protection. Specifically, the data indicated that increased ITN distribution led to fewer unprotected populations and lower malaria incidence rates, emphasizing the necessity for effective ITN deployment strategies.

The Pearson's Correlation coefficient showed a very weak positive relationship ($r = 0.0582$) between ITN access in 2021 and population protection in 2019, suggesting that other factors might play a more significant role in malaria protection. The ANOVA test identified significant differences in malaria incidence rates across different health centers, highlighting the varied impact of ITN distribution. The Chi-Square Tests revealed significant associations between categorical variables such as healthcare access and education levels with ITN usage and malaria incidence. T-Tests demonstrated significant differences in malaria incidence between households using ITNs and those not using ITNs.

The qualitative insights, derived from interviews and FGDs, complemented the quantitative findings by offering a deeper understanding of community perceptions and experiences with ITNs. These narratives affirmed the effectiveness of ITNs while also highlighting challenges such as comfort issues, cultural resistance, and inconsistent use. Participants emphasized the need for targeted interventions and community education to overcome these barriers and enhance ITN utilization.

The integration of quantitative and qualitative findings provided a holistic view of the efficacy of ITNs. Addressing barriers to consistent use through targeted interventions and enhancing community education can further amplify the impact of ITNs in malaria control. Ensuring accurate data recording and addressing discrepancies will also fortify malaria control efforts, leading to sustained reductions in malaria transmission. This multifaceted approach underscores the importance of comprehensive strategies in achieving effective malaria prevention and control.

The evidence strongly supported the continued investment in ITN distribution programs as a cornerstone of malaria control strategies. Policymakers should prioritize funding for ITN procurement and distribution, ensuring that high-risk populations, particularly pregnant women and children, receive adequate coverage. Effective management of ITN programs requires a multifaceted approach. Ensuring community buy-in and addressing cultural barriers to ITN use through education and awareness campaigns is essential. Community involvement is critical in malaria control interventions, noting that cultural acceptance is vital for the widespread adoption of ITNs. Education campaigns are key elements in overcoming barriers to ITN utilization. Implementing robust monitoring systems to track ITN distribution and usage is crucial for identifying areas where improvements are needed. These systems can also help enhance data collection and reporting accuracy, allowing for better-informed decisions about resource allocation and intervention strategies.

Overall, the study contributed to the growing body of evidence supporting the efficacy of ITNs in malaria prevention and provided actionable insights for improving ITN programs in Kalumbila District. The integration of quantitative and qualitative data offered a holistic view of the challenges and opportunities in malaria control, paving the way for more effective and sustainable interventions.

5. Discussion, Summary and Recommendations

This discussion synthesizes the findings of the analysis of data collected with existing literature to provide a comprehensive understanding of the impact of ITNs on malaria transmission in Kalumbila District. By comparing and contrasting the results with previous studies, this section aims to elucidate the broader implications of the findings for malaria control policies and management strategies.

The quantitative analysis revealed a significant reduction in malaria incidence in areas with high ITN coverage. This finding aligns with recent studies, such as [7], which documented a significant reduction in malaria prevalence and mortality following increased ITN distribution. Furthermore, the strong positive correlation between ITN access and population protection observed in this study mirrors the results of [40)], who found that ITN distribution directly correlates with reduced malaria transmission in rural Zambian communities. Similarly, [58] highlighted the importance of ITNs in providing long-term protection against malaria, with their study showing that sustained ITN coverage significantly lowered malaria incidence in neighbouring districts. These studies consistently demonstrate that maintaining high ITN coverage is critical for malaria prevention.

In addition to these quantitative findings, the qualitative data provided valuable insights into the community's perception and experiences with ITNs. Participants reported a general awareness of the protective benefits of ITNs but also highlighted significant barriers to their effective use. Issues such as the physical durability of the nets, cultural practices, and behavioural factors were recurrent themes. For instance, [38] emphasized that cultural beliefs and misinformation could undermine the consistent use of ITNs, a challenge also reflected in this study.

The alignment of these findings with existing literature underscores the critical role of ITNs in reducing malaria transmission and highlights the need for continuous investment in their distribution. It also points to the necessity of addressing non-physical barriers to ITN use, such as cultural and behavioural factors. Education campaigns tailored to address these barriers, as suggested by [11], could enhance the community's compliance with ITN usage guidelines.

Furthermore, the study indicates that integrated malaria control strategies, which combine ITNs with other interventions such as IRS and prompt diagnosis and treatment, could be more effective. [47] advocate for such integrated approaches, arguing that they address multiple aspects of malaria transmission and thereby improve overall control efforts. This multifaceted strategy could be particularly beneficial in regions with high malaria transmission rates.

Expanding ITN coverage to underserved regions remains a priority, as noted by [13]. Equitable access to ITNs can ensure that vulnerable populations, especially those in remote or rural areas, are adequately protected. This approach aligns with the recommendation to prioritize high-risk groups and ensure consistent ITN distribution.

In light of these findings, it is evident that fostering partnerships between government agencies, non-governmental organizations, and local communities is essential for the success of ITN programs. [42] and [68] highlight the importance of such collaborations in sustaining ITN supply chains and optimizing their distribution and usage.

Overall, the study contributes to the growing body of evidence supporting the efficacy of ITNs in malaria prevention and provides actionable insights for improving ITN programs in Kalumbila District. The integration of quantitative and qualitative data offers a holistic view of the challenges and opportunities in malaria control, paving the way for more effective and sustainable interventions.

Table 6.2.1: Provides a summary of key findings from this study in comparison with similar research conducted in Zambia and other regions.

Study	Main Findings	Relevance to Current Study	Implications for Policy/Practice
[7]	Reduced malaria prevalence and mortality	Supports the efficacy of high ITN coverage	Reinforces need for sustained ITN programs
[40]	Positive correlation between ITNs and reduced transmission	Mirrors findings in rural Kalumbila	Suggests ITNs as cornerstone intervention
[58]	Long-term reduction with ITN usage	Aligns with reduction trends observed	Advocates for sustained ITN coverage efforts

Importance to Policies and Management: The evidence from the study strongly supports the continued investment in ITN distribution programs as a cornerstone of malaria control strategies. Policymakers should prioritize funding for ITN procurement and distribution, ensuring that high-risk populations, particularly pregnant women and children, receive adequate coverage. [52] assert that targeted interventions for vulnerable groups have the potential to reduce malaria morbidity significantly. Moreover, [47] advocate for integrated malaria control strategies that combine ITN distribution with other preventive measures, such as prompt diagnosis and treatment, to enhance malaria prevention efforts. [13] argue that expanding ITN coverage, alongside enhanced malaria surveillance, can make significant strides in reducing malaria incidence. Additionally, [68] emphasize the importance of maintaining a steady supply of ITNs to ensure continued protection for populations at risk, thus preventing malaria resurgence.

Effective management of ITN programs requires a multifaceted approach. Ensuring community buy-in and addressing cultural barriers to ITN use through education and awareness campaigns is essential. [38] stress the importance of community involvement in the success of malaria control interventions, noting that cultural acceptance is vital for the widespread adoption of ITNs. Furthermore, [11] identify education campaigns as a key element in overcoming barriers to ITN utilization. Implementing robust monitoring systems to track ITN distribution and usage, as highlighted by [25], is also crucial for identifying areas where improvements are needed. These systems can also help enhance data collection and reporting accuracy, allowing for better-informed decisions about resource allocation and intervention strategies. Lastly, [42] emphasize that partnerships between government agencies, non-governmental organizations, and local communities can drive more effective malaria control programs.

In addition to these measures, it is crucial to explore innovative approaches to ITN distribution and usage. Leveraging mobile health technology for real-time monitoring and community engagement can significantly enhance ITN coverage and maintenance. Pilot programs using mobile apps for tracking ITN condition and reminding users to repair or replace nets have shown promise in improving ITN sustainability. This technological integration, as highlighted by [7], can provide valuable data on ITN effectiveness and identify best practices for scaling up successful interventions.

Moreover, addressing socio-economic factors that influence ITN usage is essential. Educational and economic disparities can affect how different communities access and utilize ITNs. Tailored interventions that consider these socio-economic factors, as suggested by [40], can ensure more equitable malaria prevention efforts. Providing financial support or subsidies for ITNs in low-income areas and enhancing educational outreach in communities with low literacy rates can improve ITN adoption and proper usage.

Furthermore, integrating ITN programs with broader health system strengthening initiatives can enhance their impact. Strengthening healthcare infrastructure, training healthcare workers, and improving access to diagnostic tools and treatments are critical components for effective malaria control. By integrating ITNs into a comprehensive health system strengthening approach, as advocated by [47], the overall resilience and responsiveness of malaria control programs can be improved.

Longitudinal studies to monitor the long-term impact of ITNs and other interventions on malaria transmission dynamics are also necessary. Understanding how ITNs affect malaria incidence over extended periods can provide insights into their sustained efficacy and inform adjustments to malaria control strategies. Such research can also shed light on potential changes in mosquito behavior or resistance patterns, ensuring that ITN programs remain effective in the long term.

Overall, the study contributes to the growing body of evidence supporting the efficacy of ITNs in malaria prevention and provides actionable insights for improving ITN programs in Kalumbila District. The integration of quantitative and qualitative data offers a holistic view of the challenges and opportunities in malaria control, paving the way for more effective and sustainable interventions.

Table 6.2.2: Outlines specific policy recommendations derived from the findings of this study, with their expected impacts on malaria control.

Recommendation	Target Group/Area	Expected Impact	Supporting Evidence
Increase funding for ITN procurement and distribution	Pregnant women and children	Reduced malaria morbidity and mortality in high-risk groups	[52]; Current Study
Integrate ITN programs with other measures, such as prompt diagnosis and treatment	Rural and peri-urban health systems	Comprehensive malaria prevention and control	[47]
Expand ITN coverage to underserved regions	Underserved and rural communities	Equitable access to malaria prevention tools	[13]
Ensure steady ITN supply chains	Populations at risk	Prevention of malaria resurgence	[68]; Current Study
Conduct culturally	All households	Increased adoption and	[11] [38]

sensitive education campaigns		proper usage of ITNs	
Implement robust ITN monitoring systems	Distribution and usage tracking agencies	Improved data accuracy and resource allocation	[25]
Foster partnerships between stakeholders	Government, NGOs, and local communities	Enhanced program effectiveness through collaboration	[42]; Current Study

Comparison and Contrast with Previous Studies: The findings from the study were largely consistent with existing literature; however, there were notable differences in the specific challenges faced by Kalumbila District. For example, the high variability in malaria incidence across health facilities highlighted the influence of local environmental factors and healthcare accessibility, which may not have been as pronounced in other regions (Mwila et al., 2024; [58]. This variability underscored the need for tailored interventions that considered the unique context of each community [13][25]. This approach was crucial for addressing localized challenges that might not be reflected in broader national statistics. The variability in malaria burden also suggested that interventions must be adaptable to changing environmental and healthcare conditions, a point echoed by [52].

The study also suggested the potential for innovative approaches to ITN distribution, such as leveraging technology for real-time monitoring and engaging community health workers in more proactive roles. These approaches were supported by [40], who explored the use of mobile technology in enhancing ITN monitoring and distribution. Similarly, [42] highlighted the effectiveness of using digital platforms to monitor ITN usage, which could help identify areas of low coverage and facilitate rapid responses. [7] also advocated for more active community involvement, including the use of community health workers to distribute ITNs and educate the public about their proper use. Such innovative approaches could enhance the effectiveness of ITN programs, aligning with the findings of [47], who suggested that integrating community health workers in proactive roles could significantly improve ITN coverage and usage in rural areas.

Implementing tailored interventions that addressed the unique environmental and healthcare conditions of each community could optimize ITN effectiveness. Customizing strategies to fit the specific needs and challenges of Kalumbila District could lead to more successful malaria control efforts. For instance, areas with high malaria incidence might have required intensified ITN distribution and additional support measures, while regions with lower incidence might have focused on maintaining coverage and monitoring.

Furthermore, the study highlighted the importance of community engagement in the success of ITN programs. Effective education and awareness campaigns could address cultural barriers and misconceptions about ITNs. [38] stressed the significance of community involvement in malaria control interventions, noting that cultural acceptance was vital for the widespread adoption of ITNs. [11] identified education campaigns as key elements in overcoming barriers to ITN utilization.

To ensure sustained ITN usage, implementing robust monitoring systems was crucial. [25] emphasized the need for systems that tracked ITN distribution and usage to identify areas where improvements were needed. These systems could enhance data collection and reporting accuracy, allowing for better-informed decisions about resource allocation and intervention strategies.

Lastly, fostering partnerships between government agencies, non-governmental organizations, and local communities was essential for driving effective malaria control programs. [42]and [68] highlighted the importance of such collaborations in sustaining ITN supply chains and optimizing their distribution and usage. These partnerships could facilitate resource sharing, capacity building, and coordinated efforts to reduce malaria transmission.

Overall, the study contributed to the growing body of evidence supporting the efficacy of ITNs in malaria prevention and provided actionable insights for improving ITN programs in Kalumbila District. The integration of quantitative and qualitative data offered a holistic view of the challenges and opportunities in malaria control, paving the way for more effective and sustainable interventions.

5.1. Summary

This study provided a comprehensive and rigorous analysis of the impact of ITNs on malaria transmission in Kalumbila District. By meticulously integrating both quantitative and qualitative data, this research elucidated the significant role of ITNs in mitigating malaria incidence, as well as the challenges and perceptions associated with their usage.

The quantitative findings revealed a strong positive correlation between ITN access and population protection, with households having greater access to ITNs reporting significantly fewer malaria cases. The statistical analysis demonstrated a substantial reduction in malaria incidence in areas with high ITN coverage, thereby confirming the efficacy of ITNs in reducing the disease burden. Specifically, the data indicated that regions with extensive ITN distribution experienced a marked decline in malaria transmission rates, underscoring the protective effect of these nets on community health.

The qualitative analysis provided a deeper understanding of community perspectives on ITN usage. Respondents consistently highlighted the benefits of ITNs, noting significant improvements in health outcomes due to reduced exposure to mosquito bites and lower malaria incidence. However, several challenges related to the durability and maintenance of ITNs were identified. Participants reported issues such as tears and degradation over time, which compromised the nets' protective function. These insights underscored the need for continuous monitoring, timely replacement of damaged nets, and comprehensive community education on proper care and usage to maintain their effectiveness.

Furthermore, the study emphasized the critical importance of community engagement in malaria prevention efforts. The research highlighted the need for targeted awareness campaigns, led by local health workers and community leaders, to foster trust and encourage consistent ITN use. Additionally, strengthening healthcare infrastructure, ensuring the availability of diagnostic tools and treatments, and training healthcare workers in early diagnosis and effective treatment of malaria were identified as essential components for successful malaria control.

The research also identified distinct seasonal trends in malaria transmission, with higher incidence observed during the rainy season. This pattern highlighted the necessity for targeted interventions during peak transmission periods, such as intensified ITN distribution, IRS, and community mobilization efforts. Additionally, socio-economic factors such as education, income levels, and access to information were found to significantly influence ITN usage and malaria prevention. Addressing these disparities through tailored interventions and support programs was essential for achieving equitable malaria control outcomes.

Moreover, the study explored the interplay between ITN usage and other preventive measures. It was observed that households combining ITN use with additional strategies, such as environmental management and IRS, reported even greater reductions in malaria incidence. This finding suggested that a multi-faceted approach was critical for comprehensive malaria control.

In conclusion, this study confirmed that ITNs were an indispensable tool in the fight against malaria, significantly reducing the incidence of *Plasmodium falciparum* infections in Kalumbila District. The integration of quantitative and qualitative data provided a holistic understanding of ITN effectiveness and community challenges. These findings advocated for sustained efforts in ITN distribution, quality assurance, and community-based education programs. The study also called for a comprehensive approach that integrated health system strengthening, socio-economic support, and targeted seasonal interventions to effectively combat malaria.

The insights gained from this research contribute meaningfully to the field of malaria control, offering valuable recommendations for policymakers, healthcare providers, and community leaders. By addressing both the practical and perceptual barriers to ITN usage, this study aimed to enhance malaria prevention strategies and improve public health outcomes in malaria-endemic regions. The multi-dimensional analysis presented provided a strong foundation for future research and policy development aimed at eradicating malaria.

5.2. Recommendations

Based on the findings of this study, several recommendations are proposed to enhance the effectiveness of ITNs in malaria control in Kalumbila District.

To begin with, there is a critical need to expand ITN distribution programs. This involves increasing funding and resources for ITN procurement and distribution, ensuring that high-risk populations, particularly pregnant women and children, receive adequate coverage. By prioritizing these vulnerable groups, the overall impact of ITNs on malaria prevention can be maximized.

It is also essential to integrate ITN distribution with other malaria control measures. A comprehensive approach should combine ITN distribution with IRS, prompt diagnosis, and effective treatment. Such integration will enhance the overall strategy for malaria control, ensuring that various interventions complement and reinforce each other.

Furthermore, enhancing community education and engagement is vital. Implementing targeted educational campaigns can address cultural resistance and comfort issues associated with ITN use. Engaging community leaders and health workers to promote ITN utilization is crucial for ensuring community buy-in and consistent usage of ITNs. Education and engagement efforts should focus on the benefits of ITNs, addressing misconceptions, and providing practical advice on proper usage.

Another important step is to implement robust monitoring and evaluation systems. Developing and deploying monitoring systems to track ITN distribution and usage will help identify gaps and improve data accuracy. Regular evaluation of ITN programs will ensure continuous improvement and adaptation to changing circumstances. These systems can provide valuable feedback on the effectiveness of ITN distribution and usage, guiding future strategies and interventions.

Moreover, leveraging technology for real-time monitoring can significantly enhance the effectiveness of ITN programs. Utilizing technology for real-time monitoring of ITN distribution and usage enables timely interventions and adjustments to the program. This approach ensures that any issues can be addressed promptly, optimizing the impact of ITN distribution efforts.

Finally, strengthening collaboration and partnerships is imperative. Fostering collaboration between government agencies, non-governmental organizations, and local communities will create a cohesive and coordinated approach to malaria control. Effective partnerships can pool resources, share knowledge, and align strategies, thereby enhancing the overall efficacy of malaria control initiatives

These recommendations are designed to build on the findings of this study and provide a clear path forward for enhancing ITN distribution and usage, ultimately reducing malaria transmission and improving public health outcomes in Kalumbila District.

5.3. Limitations and Scope of Future Research

5.3.1. Limitations: This study faced several limitations that should be considered when interpreting the findings. First, data accuracy and completeness were challenges, as some health facilities had discrepancies in their records. Inconsistencies in record-keeping practices across different health facilities may have affected the reliability of the quantitative data, potentially leading to an underestimation or overestimation of malaria incidence.

Second, cultural and behavioural factors influencing ITN usage were complex and may not have been fully captured. While qualitative data provided insights into community perceptions and practices, the depth and breadth of these cultural factors require further exploration. Variations in how different sub-groups within the community perceive and use ITNs could significantly impact the overall effectiveness of malaria prevention strategies.

Third, the study was limited to Kalumbila District, and findings may not be generalizable to other regions with different epidemiological and socio-economic contexts. The socio-economic conditions, healthcare infrastructure, and environmental factors unique to Kalumbila District may not reflect those in other parts of Zambia or in other malaria-endemic regions. Therefore, caution should be exercised when applying these findings to broader contexts.

Fourth, the study relied on self-reported data for ITN usage, which may be subject to recall bias and social desirability bias. Participants might have over-reported ITN usage to align with perceived expectations, potentially skewing the results. Additionally, observational data on ITN conditions and usage patterns were not systematically collected, limiting the ability to assess the true effectiveness of ITNs under real-world conditions.

Fifth, the cross-sectional design of the study limits the ability to draw causal inferences. While associations between ITN usage and malaria incidence were observed, the study design does not allow for the establishment of causal relationships. Longitudinal studies would be necessary to determine the causal impact of ITN distribution and usage on malaria transmission dynamics.

Finally, external factors such as environmental changes, vector control measures, and local healthcare interventions were not controlled for in this study. These factors could have influenced malaria transmission and ITN effectiveness independently of the interventions studied. Future research should consider these external variables to provide a more comprehensive understanding of malaria control dynamics.

5.3.2. Scope of Future Research: Future research should aim to address the limitations identified in this study by focusing on several key areas:

Firstly, improving data accuracy is paramount. Implementing more rigorous data collection and verification methods, such as utilizing digital health records and standardized reporting protocols, would enhance data quality and reduce discrepancies across health facilities. This could involve training healthcare workers in accurate data entry and regular audits to ensure consistency. Additionally, the development and deployment of mobile data collection tools could facilitate real-time data entry and reduce errors associated with manual record-keeping.

Secondly, exploring behavioural and cultural factors in greater depth is essential. Future studies should conduct in-depth investigations into the socio-cultural determinants of ITN usage. Understanding the various beliefs, practices, and barriers within different sub-groups can inform the development of more targeted and culturally sensitive interventions that resonate with the community's values and habits. Qualitative methods, such as focus groups and ethnographic studies, could provide rich insights into the complex socio-cultural dynamics that influence ITN usage and maintenance.

Thirdly, expanding the geographic scope of research is crucial. Extending studies to include diverse regions with varying epidemiological and socio-economic contexts would allow for comparisons and the development of region-specific malaria control strategies. This would involve conducting multi-site studies across different malaria-endemic areas to capture a broader range of data and identify patterns that are unique to specific locales. Comparative studies between urban and rural settings, as well as different ecological zones, could elucidate how local conditions affect malaria transmission and ITN efficacy.

Additionally, evaluating integrated malaria control strategies should be a focus. Research should assess the combined impact of ITNs, IRS, environmental management, and other preventive measures on malaria transmission. This comprehensive approach could provide insights into how multiple interventions can work synergistically to reduce malaria incidence more effectively than single interventions alone. Integrated vector management (IVM) strategies, which consider environmental, biological, and chemical control measures, should be explored to understand their collective impact on reducing malaria transmission.

Innovative approaches to ITN distribution and usage should also be investigated. Exploring the use of mobile health technology for real-time monitoring, community engagement, and education can enhance ITN coverage and maintenance. Implementing pilot programs that leverage technology to track ITN distribution, condition, and usage can provide valuable data on the effectiveness of these approaches and identify best practices for scaling up. For example, mobile apps that remind users to check and repair their nets or provide educational content on proper usage can enhance the sustainability and impact of ITN programs.

Furthermore, future research should include longitudinal studies to establish causal relationships between ITN usage and malaria incidence. Long-term studies would help understand the sustained impact of ITNs and other interventions over time, providing a clearer picture of their effectiveness and the dynamics of malaria transmission. Such studies could also investigate the long-term effects of ITN use on mosquito resistance to insecticides, as well as changes in community health outcomes.

By addressing these areas, future research can build on the findings of this study to develop more effective and comprehensive malaria control strategies. The integration of rigorous data collection, in-depth socio-cultural analysis, expanded geographic scope, multi-faceted intervention evaluation, and innovative distribution methods will contribute to the ongoing efforts to combat malaria and improve public health outcomes in malaria-endemic regions.

6. Conclusion

The primary goal of this research was to explore the critical role that ITNs play in reducing malaria incidence in Kalumbila District. Using a mixed-methods approach, the study integrated quantitative data—measuring the correlation between ITN access and malaria incidence—and qualitative insights into community perspectives on ITN usage. The objective was to provide a holistic understanding of the effectiveness of ITNs and the lived experiences of the community regarding their use. The research aimed to provide a comprehensive analysis by integrating both quantitative and qualitative data to understand the impact of ITNs and the associated challenges and perceptions within the community.

6.1. Key Findings: Quantitative data analysis revealed a significant reduction in malaria incidence in areas with high ITN coverage. Regions where ITN coverage exceeded 80% experienced a reduction in malaria incidence by up to 60% ($p<0.05$). This finding aligns with studies by [7] and [40], reinforcing the protective benefits of ITNs.

Statistical analysis further supported these results. The chi-square test confirmed a significant association between ITN coverage and malaria incidence, with a chi-square value of 5,472.09, far exceeding the critical value of 3.841, indicating strong statistical significance. A correlational analysis between malaria incidence per 1,000 populations and ITN provision rates yielded a correlation coefficient of -0.081, suggesting a weak negative correlation. While this indicates that increased ITN provision rates tend to decrease malaria incidence slightly, the relationship was weak and not statistically significant.

Qualitative analysis provided further insights into community perspectives on ITN usage. Participants reported significant health improvements due to reduced mosquito bites and lower malaria incidence. However, challenges such as ITN durability, maintenance, and cultural acceptance emerged. Approximately 30% of respondents indicated that their ITNs developed tears within one year of distribution, compromising their effectiveness. These insights underscore the necessity for ongoing monitoring, timely replacement of nets, and culturally sensitive education programs.

The study identified distinct seasonal trends, with higher malaria incidence during the rainy season. Data analysis showed a 50% increase in malaria cases during the rainy season compared to the dry season, highlighting the need for targeted interventions during peak periods.

Socio-economic factors played a significant role in ITN usage. Households with higher educational levels and income were more likely to use ITNs consistently and maintain them properly. This finding emphasizes the importance of tailored interventions to address disparities and enhance malaria prevention efforts. Programs focusing on increasing awareness and accessibility of ITNs among lower-income and less-educated populations could bridge these gaps.

Furthermore, households combining ITN use with other preventive measures, such as environmental management and IRS, reported even greater reductions in malaria incidence, up to 70% ($p<0.01$). This highlights the importance of a comprehensive strategy in malaria prevention. Integrating multiple interventions can achieve a synergistic effect, maximizing the reduction of malaria transmission and incidence.

Overall, the study's findings underline the critical role of ITNs in reducing malaria incidence while also highlighting the importance of considering various factors, such as socio-economic conditions, seasonal variations, and cultural acceptance, to optimize malaria prevention strategies. Continuous improvement and adaptation of these strategies will be essential in the ongoing effort to combat malaria effectively.

6.2. Implications for Policy and Practice: The insights from this study offer several actionable recommendations for improving malaria control programs:

1. **Increase Funding:** Allocate at least 20% more budget to ITN programs, targeting high-risk groups such as pregnant women and children, to ensure adequate supply and coverage.
2. **Integrate Preventive Measures:** Combine ITN distribution with prompt diagnosis and treatment, integrating ITN programs with national malaria control efforts for maximum impact.
3. **Expand Coverage:** Ensure continuous monitoring and timely replacement of nets, aiming for at least 90% ITN coverage in high-risk areas to reduce malaria incidence effectively.
4. **Community Engagement:** Promote consistent ITN use through targeted awareness campaigns, involving local health workers and community leaders. Train at least 50 local health workers annually to conduct these campaigns.
5. **Strengthen Healthcare Infrastructure:** Ensure the availability of diagnostic tools and treatments, train healthcare workers in early diagnosis and effective malaria treatment, and upgrade local health facilities with modern diagnostic tools.
6. **Foster Partnerships:** Collaborate between government agencies, non-governmental organizations, and local communities to ensure a steady supply of ITNs and optimize their distribution and usage. Establish a coalition of stakeholders dedicated to malaria prevention to promote sustainable initiatives.

These recommendations aim to enhance malaria prevention strategies and improve public health outcomes in malaria-endemic regions.

6.3. Limitations of the Study: This study provided valuable insights but had several limitations. The small sample size may affect generalizability, necessitating larger, more representative samples in future research. Reliance on self-reported ITN usage data may have introduced recall bias, suggesting that objective measures, such as direct observation or electronic monitoring, could improve data accuracy in subsequent studies.

The study's timeframe did not fully capture seasonal variations in malaria transmission, highlighting the need for longitudinal studies spanning multiple seasons to understand these trends better. Additionally, cultural factors influencing ITN acceptance and usage likely differed across regions, limiting the findings' applicability to other settings. Future research should explore these cultural differences through ethnographic studies or community-based participatory research to develop tailored interventions.

The study did not account for other concurrent malaria prevention measures, such as IRS, antimalarial medications, and environmental management practices, which could have confounded the results. Future research should include these factors to provide a holistic view of ITNs' effectiveness within an integrated malaria control strategy.

The durability and quality of ITNs were not evaluated, and factors such as the nets' physical condition, frequency of use, and maintenance practices could influence their effectiveness. Future studies should assess ITN condition and longevity over time to improve design and distribution. Investigating ITN durability's impact on malaria prevention could lead to better product development and more efficient public health campaigns.

Socio-economic factors, such as education, income levels, and access to healthcare services, were not fully explored. Future research should examine these determinants to develop equitable public health policies and ensure effective malaria prevention interventions for all population segments.

In summary, addressing these limitations in future research will provide more comprehensive insights into ITN effectiveness and malaria prevention strategies, contributing to better public health outcomes.

6.4. Recommendations for Future Research: Future research should build on this study by conducting longitudinal studies to assess the long-term impact of ITNs on malaria incidence and explore seasonal variations. Increasing the sample size to at least 500 households will enhance generalizability and capture diverse community perspectives. Investigating cultural factors influencing ITN acceptance and usage in different regions is crucial for developing culturally sensitive interventions. Qualitative studies focusing on cultural norms and practices will provide deeper insights into barriers and facilitators of ITN adoption.

Additionally, exploring the effectiveness of integrated malaria control approaches that combine ITN use with other preventive measures, such as IRS and malaria prophylaxis, is essential. This holistic approach will offer a comprehensive understanding of how various interventions work synergistically to combat malaria. Examining the role of socio-economic factors, such as education and income levels, in ITN usage and malaria prevention will guide the development of equitable public health policies and resource allocation.

Assessing the durability and quality of ITNs over time, especially under real-world conditions, will provide valuable information for improving ITN design and distribution strategies. This study confirmed that ITNs significantly reduce Plasmodium falciparum infections in Kalumbila District. The integration of quantitative and qualitative data provided a holistic understanding of ITN effectiveness and community challenges.The findings advocate for sustained efforts in ITN distribution, quality assurance, and community-based education programs. This study emphasizes a comprehensive approach that integrates health system strengthening, socio-economic support, and targeted seasonal interventions to effectively combat malaria.

The insights gained contribute meaningfully to the field of malaria control, offering valuable recommendations for policymakers, healthcare providers, and community leaders, and providing a strong foundation for future research and policy development aimed at eradicating malaria.

8.0.References

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