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**Malaria Resurgence and Associated Risk Factors at Bonga town,
Kaffa zone, Southwest Ethiopia**

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Abstract

*Currently, unpredicted rapid resurgence of malaria is happening in almost all endemic areas of Ethiopia, after decline in the few past years. This study was thus aimed at investigating malaria resurgence and associated risk factors, and challenges encountered in the process of implementing the interventional activities at Bonga town, Kaffa zone, Southwest Ethiopia. Health facility-based retrospective and cross-sectional study design was employed. Data was analyzed using SPSS software version 26. Multiple linear and logistic regression models utilized. Qualitative data was thematically analyzed. The finding of the present cross-sectional study revealed that the current malaria positivity rate (from January to May, 2024) in the study area was 50.72% (315/621). The study identified a resurgence of malaria was linked to weakened control measures ($p=0.006$), limited awareness of the population ($p<0.001$), and socio-demographic factors such as education ($p=0.037$), housing condition ($p<0.0001$), low income level ($p<0.001$), and travel history to malaria endemic areas ($p=0.001$) and weakened health care system. The findings of retrospective analysis also showed an increasing malaria positivity trend between 2010 and 2023, where the overall 30.18% (19,582/64, 885) malaria positivity rate. *Plasmodium falciparum* was the dominant malaria parasite 12,730 (19.62%). Age >14 years ($p=0.008$), male patients ($p=0.018$), year increment from 2010 to 2023 ($p=0.013$), and some months: September to November was strongly and positively associated with malaria positivity in the area. On the other hand, statistically significant negative association between intervention activities and malaria positivity rate was observed. As ITNs distribution increased by 1-unit, malaria positivity rate was decreased by 0.533 ($p=0.001$). Similarly, as IRS activity increased by 1-unit, malaria positivity rate was decreased by 0.781 ($p=0.004$). Although Ethiopia was aggressively working on the malaria control activities in the past years, the recent interruption of implementing interventional activities (distribution of ITN and IRS) could contributed for the observed high malaria positivity rate. In addition, the limited knowledge and awareness of patients observed on the malaria infection calls the need for immediate community sensitization activities, besides designing integrated interventional strategies to tackle the current terrible situation.*

Keywords: Malaria, Resurgence, Bonga kaffa, IRS, ITNs, *Plasmodium*, Ethiopia

Abbreviations and acronyms

ACT -	Artemisinin-based Combination Therapy
AOR-	Adjusted odd ratio
COR-	Crude odd ratio
HRP -	Histidine-rich Proteins
IRS -	Indoor Residual Spraying
ITNs -	Insecticide-treated Bed Nets
LSM-	Larval source management
PCR -	Polymerase Chain Reaction
QT-NASBA -	Quantitative Nucleic Acid Sequence Based Amplification
RBC -	Red Blood Cells
RDTs -	Rapid Diagnostic Tests

Chapter One: Introduction

1.1 Background of the study

Malaria remains public health problem in the world. Globally in 2022, around 249 million cases and 608 000 death reported (WHO, 2023a). As evidence in various studies revealed, there was a significant decline in malaria mortality and morbidity from 2000 to 2015. However, from 2016 to 2018, the rate of reduction slowed compared to the period of 2010-2015. From 2019 to 2021, an increase in cases and deaths of malaria was recorded. Malaria is a disease caused by protozoan parasites belongs to genus *Plasmodium*, and the parasites transmitted to humans via the bite of infected female *Anopheles* mosquito (Ross, 1897). There are five *plasmodium* parasite species that cause malaria in human; among those, 2 species *P. falciparum* and *P. vivax* are most commonly cause malaria (WHO, 2023a). The disease is preventable and curable (WHO, 2023a). However, if left untreated, it can cause serious complications, such as severe anemia, cerebral malaria, acute renal failure, and hypoglycemia, even death among infected individuals by disrupting blood supply to vital organs (CDC, 2023).

Infants, children under 5 years, pregnant women, travellers and people with HIV or AIDS are at higher risk of malaria (WHO, 2023a). Symptoms of malaria can be mild or severe. Mild symptoms include fever, chills and headache. Severe symptoms include extreme tiredness and fatigue, impaired consciousness, multiple convulsions, difficulty of breathing, dark or bloody urine, jaundice (yellowing of the eyes and skin), abnormal bleeding (WHO, 2023a), liver and spleen enlargement, pale heart blood, emaciation, and schizonts in tissues (Stephen *et al.*, 2017).

Central to malaria prevention efforts are the use of long-lasting insecticidal nets (LLINs) and indoor residual spraying (IRS), alongside improved treatment regimens and expanded testing programs. For example, widespread use of LLINs and IRS has been significantly decline *Anopheles gambiae sensu stricto* (s.s.) in many areas of Africa (Nalinya *et al.*, 2022). Different studies revealed that, malaria prevalence vary over time due to different factors, such as change in weather conditions, intervention measures, environmental factors like, availability of stagnant water, vector, parasite itself, human behavior and socioeconomic conditions (Meresa *et al.*, 2018). Other factors, such as covid-19, conflict, healthcare infrastructure, El Niño

(Lancet Microbe, 2022).

Most malaria cases and death occur in African countries (WHO, 2022a). However, between 2000 and 2015, there was a significant decline in malaria cases and deaths in Africa too (WHO, 2022a). Currently, malaria is a major concern, and it can cause much damage to the health and socioeconomic development in Ethiopia due to the occurrence of malaria during harvesting seasons which reduces agricultural productivity and hence leads to food insecurity and poverty (Bezuayehu *et al*, 2018). As evidence, there was a reduction of malaria case and deaths between 2000 and 2015. While, the rate of reduction not uniform in the same period (Girum *et al.*, 2019). Factors contributed to the reduction of malaria in the same period include, increased access to effective malaria prevention and control measures such as insecticide-treated bed nets, indoor residual spraying, and antimalarial drugs, improvement in healthcare infrastructure, increased funding for malaria control programs, and expanded efforts in public health education and awareness (Taffese *et al.*, 2018). Despite, currently about 75% of the country's land is malarious and about 68%–70% of the total population living in areas at risk of malaria. *Plasmodium falciparum* and *P.vivax* are the most dominant malaria parasites in Ethiopia accounting for 60% and 40% of malaria cases, respectively (Adugna *et al.*, 2022).

Ethiopia has working to achieve the malaria eradication goal set by World Health Organization by 2030 and to achieve this goal, the public health authorities in the country have been engaged in the enforcement of massive interventional activities (Tefera *et al.*, 2022). Some of the tools employed in the intervening activities are the use of insecticide-treated bed nets (ITNs), indoor residual spraying (IRS), rapid diagnosis and treatment with artemisinin-based combination therapy, periodic inspection and continuous nation-wide malaria surveillance, enhancing awareness of treatment seeking behavior of the population. Furthermore, malaria situation analysis program have been in practice for long at most malaria endemic regions of the country (Tefera *et al.*, 2022).

However, studies have shown an increase in malaria cases in certain regions of the country, for example, the study conducted at Decha and Gimbo districts of the Kaffa zone, Ethiopia revealed that, from 2017 to 2021, there was an overall increase in malaria cases, but no consistent pattern was observed over this time-period. *Plasmodium falciparum* was the

dominant parasite, followed by *Plasmodium vivax*, while mixed infections were the least common. Microscopy and rapid diagnostic tests (RDT) were used to identify the parasites (Duguma *et al.*, 2022). Also study conducted at Metehara Health Centre in Central Ethiopia found that malaria resurged in 2022/23 after a 5-year decline. Males were more affected than females. This study also found that, malaria cases peaked between September and November and were lowest from March to May (Mandefro *et al.*, 2024).

A study conducted in Simada District, Northwest Ethiopia found that, the presence of mosquito breeding sites, poor bed net utilization, poor environmental management, and lack of awareness on malaria transmission and control were significantly associated with the occurrence of malaria outbreaks (Workineh *et al.*, 2019). A study conducted in Argoba District, South Wello Zone, Northeast Ethiopia found that travel history was associated with the outbreak of malaria (Tesema & Akalu, 2019). A study conducted in the Afar region of Ethiopia revealed that, those sleeping outside of their home during night and absence of indoor residual spray were attributed for the malaria outbreak. Age group above 15 years were more affected than other age groups (Mitiku *et al.*, 2018).

Despite the factors contributing to the malaria resurgence in various regions were identified, it has not been studied specifically in the context of Bonga town, Kaffa zone, Southwest Ethiopia, creating a gap in understanding regarding these factors. Additionally, existing studies conducted at different regions have predominantly utilized a single study design, limiting the in-depth of analysis. In contrast, this study tends to address this methodology gap by employing both retrospective and cross-sectional study designs. This comprehensive approach which enabled the analysis of long-term trends in malaria prevalence and provided a deeper insight into the factors contributing to the current resurgence of malaria in the study area.

1.2 Statement of the Problem/rationale

Despite malaria control efforts in Ethiopia, the disease remains a significant public health concern in many parts of the country, particularly in Bonga, located in Kaffa zone. Although malaria is recognized as a global challenge, its burden on the livelihood of population of Ethiopia, Kaffa zone, Bonga, isn't known and While long-term trends in prevalence of malaria and associated factors well recognized globally, it remains unclear in Ethiopia, Kaffa zone,

Bonga. Implementing targeted malaria intervention requires the proper identification of factors influencing malaria risk in the community (Ethiopian Federal Ministry of Health, 2018).

Bonga has unique characteristics, example, a warm and humid climate, abundant rainfall and stagnant water, the movement of peoples, including traders, workers, and visitors because of the town is a center for the buying of honey and coffee as source of income, majority of populations with low income level, most population with lower educational status. Evidence-based and area-specific interventions require the information of trends in malaria prevalence, risk factors (Duguma *et al.*, 2022). Therefore, this study aims to assess the malaria resurgence and associated factors at Bonga town over 15-year period (2010-2024 G.C.) to inform stakeholders like, local health authorities, policy makers and community leaders for evidence-based and targeted future strategies for malaria prevention and control in the region. Furthermore, understanding trends in malaria prevalence and associated factors like, current interventions situation and others in the study area is crucial for optimizing resource allocation and reduce malaria burden in the community in the region, thereby contribute to achievement of the goal of Ethiopia's malaria elimination plan by 2030.

Research Question:

This study was guided by the following questions:

- What were the annual and seasonal trends of malaria prevalence?
- What was the distribution and proportion of *Plasmodium* species (*Plasmodium falciparum*, *Plasmodium vivax*, mixed) among malaria cases?
- What was the relationship between socio-demographic, behavioral factors, and malaria status?
- What was the distribution and coverage of malaria interventions (ITNs, IRS) and larval source management?
- What was the level of awareness community about malaria transmission, symptoms, and prevention and healthcare system?
- Were there any associations between identified factors and changes in malaria prevalence over time?
- What were the key challenges and limitations faced in implementing malaria control interventions in Bonga town, kaffa zone southwest Ethiopia?

1.3 Objectives of the study

1.3.1 General Objective

- To assess malaria status, and the factors associated with the resurgence of malaria at Bonga town, Kaffa zone, Southwest Ethiopia

1.3.2 Specific Objectives

- To determine the annual and seasonal trends of malaria prevalence,
- To examine the distribution and proportion of *plasmodium falciparum*, *Plasmodium` vivax*, and mixed malaria cases,
- To evaluate the socio-demographic characteristics and behavioral factors of individuals diagnosed with malaria,
- To evaluate interventional activities (distribution and coverage of insecticide treated bed nets, indoor residual spraying) and larval source management,
- To evaluate awareness of individuals about (malaria transmission, common symptoms and prevention) and healthcare system,
- To identify any associations between identified factors and changes in malaria prevalence, and
- To identify challenges and limitations faced in implementing malaria control interventions at Bonga town.

1.4 Relevance of the study

This study highly relevant and significant for several reasons. Firstly, it addresses the urgent public health concern of malaria in the study area. Secondly, the study's mixed-methods approach, combining quantitative and qualitative analysis, ensures a comprehensive understanding of malaria dynamics and associated factors. This understanding could guide targeted malaria control efforts, and ensures effective resource allocation. Thirdly, the findings of this study enable evidence-based decision-making, leading to improved malaria control efforts, within the community in the study area. Lastly, the study contributes to the existing knowledge base on malaria control in Southwest Ethiopia, enhancing the overall understanding of similar settings and providing insights for future research and practices.

1.5 Scope of the study

The study's geographical scope is limited to Bonga Town in the Kaffa Zone of Southwest Ethiopia. The time frame of analysis spans from January, 2010 to May, 2024 G.C. Due to its nature of mixed-method approach, this study provide a comprehensive understanding of the trends in malaria prevalence, risk factors, and the challenges faced in malaria control efforts in the specified region and time period.

Chapter Two: Literature Review

2.1 Malaria

Malaria is mosquito-borne infectious disease that affects humans and other animals. It is caused by parasites, specifically those belonging to the genus *Plasmodium*. The disease cycle begins when an individual is bitten by an infected female *Anopheles* mosquito (WHO, 2022b). During the mosquito's bite, it injects the parasite into the bloodstream through its saliva. From there, it travel to the liver, where they mature and reproduce (Stephen *et al.*, 2017). It is preventable and curable (WHO, 2023a). If left untreated, malaria might become death by disrupting blood supply to vital organs (CDC, 2023). Among the parasites of the genus *Plasmodium*, five species have been identified which can cause disease in humans: *Plasmodium falciparum*, *Plasmodium vivax*, *Plasmodium ovale*, *Plasmodium malariae*, *Plasmodium knowlesi* (Stephen *et al.*, 2017), and two of those species, *Plasmodium falciparum* and *Plasmodium vivax*, pose the greatest threat (WHO, 2023a). *Plasmodium falciparum* is the most virulent species in terms of morbidity and mortality (Topics, 2023).

Malaria is most commonly found in tropical and subtropical regions around the world, including Sub-Saharan Africa, Asia, and the Central and South America. But Most of the malaria cases occur in African region (90%) followed by the Southeast Asia (7%) (Topics, 2023). Because, these areas provide suitable habitats for the *Anopheles* mosquito, which acts as a vector for the transmission of the disease (Stephen *et al.*, 2017).

2.2 Global prevalence of Malaria

According to the latest World malaria report, there were 249 million cases of malaria in 2022 compared to 244 million cases in 2021. The estimated number of malaria deaths stood at 608,

000 in 2022 compared to 610, 000 in 2021 (WHO, 2023a). The WHO African Region continues to carry a disproportionately high share of the global malaria burden. In 2022 the Region was home to about 94% of all malaria cases and 95% of deaths. Children under 5 years of age accounted for about 78% of all malaria deaths in the Region (WHO, 2023a).

Four African countries accounted for just over half of all malaria deaths worldwide: Nigeria (26.8%), the Democratic Republic of the Congo (12.3%), Uganda (5.1%) and Mozambique (4.2%) (WHO, 2023a). Malaria in Africa is present in both rural and urban areas, though the risk is lower in the larger cities (Stephen *et al.*, 2017). Significant increases were also observed in Ethiopia, Nigeria, Papua New Guinea and Uganda (WHO, 2023b).

Different studies revealed that the *Plasmodium* species compositions and the number of malaria cases vary over time due to different factors, such as change in weather conditions, intervention measures, environmental or human behavior and socioeconomic conditions of the population (Meresa *et al.*, 2018). Climate variability is expected to have indirect effects on malaria trends through, for example, reduced access to essential malaria services and disruptions to the supply chain of insecticide-treated nets, medicines and vaccines (WHO, 2023b). Changes in temperature, humidity and rainfall can influence the behavior and survival of the malaria-carrying *Anopheles* mosquito (WHO, 2023b).

The prevalence of malaria influenced by factors such as climate (Rainfall, Consistent high temperatures and High humidity), along with stagnant waters in which mosquito larvae readily mature, mosquito population, and human behavior. Malaria is more common in rural areas than in cities (Stephen *et al.*, 2017). Globally, nearly half of the population lives in areas at risk of malaria transmission (WHO, 2022b). Infants, children under 5 years, pregnant women, travellers and people with HIV or AIDS are at higher risk of malaria (WHO, 2023a).

2.3 Prevalence of Malaria in Ethiopia

About 2.9 million cases of malaria and 4782 related deaths have been reported annually, and the rate of morbidity and mortality dramatically increases during epidemics. Malaria is a significant concern in Ethiopia, affecting both health and socioeconomic development. The occurrence of malaria during harvesting seasons reduces agricultural productivity, leading to food insecurity and poverty (Daba *et al.*, 2023).

In Ethiopia, malaria cases have decreased from 3.8 million to 1.2 million between 2010 and 2021, but a 34% increase was observed in 2020 compared to the previous year and the country has experienced an increase in malaria cases, with 253,056 cases reported in 2022 compared to 195,984 cases in 2021 (President & Initiative, 2020). Adults and children aged five years and above bear over 80% of the malaria burden. Sustained efforts are needed to combat malaria and reduce transmission in high-risk areas (President & Initiative, 2020). About 75% of the country's land is malarious and about 68%–70% of the total population living in areas at risk of malaria (Bugssa & Tedla, 2020).

The distribution and transmission pattern of malaria in Ethiopia differ from place to place depending on climate, rainfall patterns, and altitude (Gebreselassie *et al.*, (2022). The transmission of malaria is generally unstable and seasonal; transmission peak occurs between September and December (following the rain from June to August), and slower transmission between April and June (due to the February and March rain) (Alemu *et al.*, 2011a). *Anopheles arabiensis* is the primary malaria vector, with secondary vectors including *Anopheles funestus*, *Anopheles pharoensis*, and *Anopheles nili*. *Anopheles coustani* and *Anopheles stephensi* are also potential vectors (President & Initiative, 2020).

The disruption of malaria interventions in conflict-affected regions, including Tigray, Afar, Amhara, and other regions has contributed to the rise in cases. An invasive malaria vector, *Anopheles stephensi*, has been detected in various locations across Ethiopia, including urban, peri-urban, and rural areas. Ethiopia faces challenges due to parasite deletions in genes encoding histidine (amino acid)-rich proteins (HRP-2 and HRP-3), affecting the detection of malaria using rapid diagnostic tests (RDTs) (Muluye *et al.*, 2024). The return of seasonal migrant workers with malaria infections from high-risk areas to low or eliminated malaria areas poses a challenge to malaria elimination efforts in Ethiopia (President & Initiative, 2020). In Ethiopia, malaria transmission and incidence rates are influenced by environmental, human host, parasite, and vector factor and other factors, such as, socio-demographic, house conditions, breeding site of mosquitoes, malaria control and prevention practices, human sleeping behavior and knowledge of people about malaria have been identified as risk factors for malaria infection (Alemu *et al.*, 2011b).

2.4 Life Cycle of plasmodium species

Life cycle of *Plasmodium* species is complex and involves both human and female *anopheles* mosquito hosts. In humans, a female *Anopheline* mosquito injects the parasite in the form of "Sporozoites" during a blood meal. This initiates the Pre-Erythrocytic Schizogony phase, where the sporozoites enter liver cells and develop into "Merozoites." The duration of this phase varies depending on the *Plasmodium* species: 6 days for *Plasmodium falciparum*, 9 days for *Plasmodium ovale*, 8 days for *Plasmodium vivax*, and 15 days for *Plasmodium malariae* (Stephen *et al.*, 2017).

Next is the Erythrocytic Schizogony phase, where merozoites released from infected hepatocytes attack red blood cells (RBCs). Various changes occur during this phase: trophozoites, characterized by blue cytoplasmic rings with a red nuclear mass and active amoeboid movements appear (Stephen *et al.*, 2017). In *Plasmodium falciparum*, trophozoites attach to the periphery of the RBC and show dark brown or black pigment granules known as "Maurer's dots." In *Plasmodium vivax*, RBCs become distorted and double in size, exhibiting yellow pigment granules called "Schuffner's granules." In *Plasmodium malariae*, the trophozoite stretches across the infected RBC, and coarse black pigment granules known as "Ziemann's granules" are present. The fully grown trophozoite is referred to as a schizont (Ortiz-Ruiz *et al.*, 2018). In *Plasmodium falciparum*, the schizont nucleus divides several times to form merozoites. In *Plasmodium vivax*, the merozoites formed from schizonts are arranged in a rosette (circular arrangement of merozoites formed during the schizont stage) form with a pigmented mass in the center.

Additionally, there is an Exo-erythrocytic Schizogony phase where the pre-erythrocytic phase persists in the liver as local schizogony in *Plasmodium vivax*, *Plasmodium ovale*, and *Plasmodium malariae*, leading to relapses. The merozoites released in this phase are called "Hypnozoites" (Stephen *et al.*, 2017). The sexual cycle begins with the formation of "Gametocytes" in the human host, which further develops inside the female *Anopheline* mosquito. In the mosquito hosts, the development of mature sexual forms takes place. Microgametocytes (male gametocytes) give rise to 5-8 microgametes, while macrogametocytes (female gametocytes) produce only one macrogamete (Svihrova *et al.*, 2012). Fusion of male and female gametes results in the formation of a "Zygote," which develops into an "Ookinete"

and then further into an "Oocyst" inside the mosquito's gut cells. The oocyst matures and releases a large number of Sporozoites (Stephen *et al.*, 2017).

On the 10th day of infection, the oocyst ruptures, liberating sporozoites into the body cavity of the mosquito. These sporozoites migrate to the salivary glands and concentrate in the ducts. At this stage, the mosquito can transmit the sporozoites to humans through a bite (Stephen *et al.*, 2017) (Figure 1).

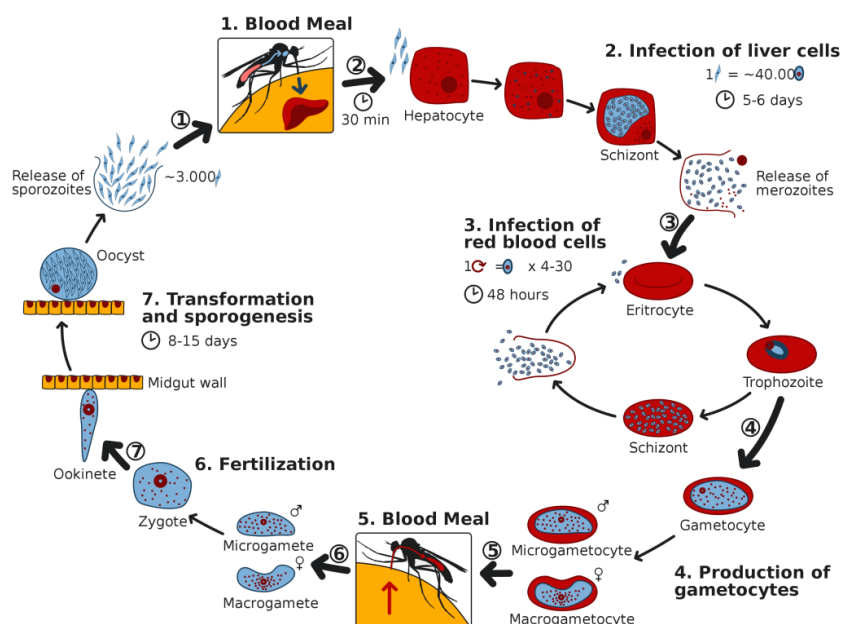


Figure 1: Life cycle of malaria parasite.

Source: https://commons.wikimedia.org/wiki/File:Life_Cycle_of_the_Malaria_Parasite.svg

The approximate incubation periods for different *Plasmodium* species are as follows: *Plasmodium falciparum* (9 to 14 days), *Plasmodium vivax* (12 to 18 days), *Plasmodium ovale* (12 to 18 days), and *Plasmodium malariae* (18 to 40 days). It's important to note that the incubation period can vary, and in some cases, it can be shorter or longer than the typical ranges mentioned. For *Plasmodium vivax* and *Plasmodium ovale*, the incubation period may be extended to several months, particularly if the individual is taking malaria prevention medication (chemoprophylaxis) (Stephen *et al.*, 2017).

Malaria symptoms include paroxysms (cyclical episodes of coldness, rigor, fever, and

sweating), which occur every two days in *Plasmodium vivax* and *Plasmodium ovale* infections, every three days in *Plasmodium malariae* infection, or every 36-48 hours in *Plasmodium falciparum* infection (CDC, 2022). Other symptoms can include decreased consciousness, weakness, convulsions (episodes of involuntary muscle contractions that can cause various physical movements), low blood pressure, breathing problems, kidney failure, bleeding issues, and enlarged spleen. Severe cases may show liver and spleen enlargement, pale heart blood (anemia), emaciation (extreme thinness), and schizonts in tissues. Symptoms can vary depending on the *Plasmodium* species and individual factors (Stephen *et al.*, 2017).

2.5 Malaria Transmission

Malaria parasites are transmitted from person to person through female *Anopheles* mosquitoes. When a mosquito bites, blood containing the parasites is taken into the mosquito's gut. Over a period of 10 or more days, the parasites undergo a complex development, the mature parasite eventually coming to reside in the mosquito's salivary glands, ready for transmission to a new person when it bites again (CDC, 2022). In the next human host, the parasite first infects the liver, undergoes rapid replication in this site for at least five days, and then infects red blood cells. In the blood, that the parasites causes the most serious symptoms of malaria, including cerebral malaria initiated by parasitized blood cells blocking blood capillaries in the brain (Stephen *et al.*, 2017). Human-to-human transmission of malaria as the parasite exists in human red blood cells, malaria can be passed on from one person to the next through organ transplant, shared use of needles/syringes, and blood transfusion. An infected mother may also pass malaria on to her baby during delivery (birth) - this is called 'congenital malaria' (Topics *et al.*, 2022).

2.6 Pathologies of malaria

There are different pathologies of malaria. Some of them are cerebral malaria, severe anemia, hypoglycemia, organ failure, extreme tiredness and fatigue, impaired consciousness, multiple convulsions, difficulty of breathing, dark or bloody urine,

jaundice (yellowing of the eyes and skin), abnormal bleeding (WHO, 2023a), liver and spleen enlargement, pale heart blood, emaciation, and schizonts in tissues (Gahrn-Hansen & Pedersen, 2000). However, symptoms can vary depending on the *Plasmodium* species and individual factors (Stephen *et al.*, 2017).

2.7 Diagnosis of Malaria

Malaria is typically diagnosed through laboratory tests, specifically the microscopic examination of blood using blood films or antigen-based rapid diagnostic tests (RDTs). The preferred and economically viable method is the microscopic examination of blood films (Stephen *et al.*, 2017). A skilled microscopist can identify the presence of malaria parasites and determine parasite levels, with a sensitivity as low as 5 parasites per microliter of blood. However, species identification can be challenging as the early trophozoites ("ring form") of all four major parasite species appear similar, and multiple trophozoites need to be examined to accurately identify the species (Health Organization, 2010). Molecular methods, such as PCR (polymerase chain reaction), are available in certain clinical laboratories and are more accurate than microscopy for diagnosing malaria (Stephen *et al.*, 2017). These methods involve detecting the genetic material of the malaria parasite in the patient's blood sample. Rapid real-time assays, like QT-NASBA (Quantitative Nucleic Acid Sequence-Based Amplification), are also being developed with the aim of deploying them in areas where malaria is prevalent (Stephen *et al.*, 2017).

2.8 Treatment of malaria

Treatment of malaria depends on the following factors: type of infection, severity of infection, status of the host, associated conditions/ diseases. For *Plasmodium vivax* malaria infection, the recommended treatment is Chloroquine at a dosage of 25 mg/kg, along with Primaquine for a duration of 14 days (CDC, 2013). For *Plasmodium falciparum* malaria infection, the treatment approach depends on the severity of the infection and the sensitivity of the parasite to anti-malarial drugs. Primaquine is essential in treating *Plasmodium falciparum* to eliminate gametocytes and prevent further transmission (Stephen *et al.*, 2017). In cases of mixed infection with both *Plasmodium falciparum* and *Plasmodium vivax* malaria, the recommended treatment involves using blood schizonticides to target the *P. falciparum* parasite and Primaquine to

address the *P. vivax* parasite (Stephen *et al.*, 2017).

Severe cases of malaria are treated with injectable antimalarials such as chloroquine, quinine, or artemisinin. These medications are administered through injections to ensure optimal absorption and effectiveness in combating the severe form of the disease (CDC, 2013). Severe complications are usually associated with *Plasmodium falciparum* malaria, and treated with quinine or artemisinin if unsure (Cheaveau *et al.*, 2018). For pregnant women, Chloroquine is safe to use in all trimesters, while artemisinin has not shown harmful effects on the fetus, they must be used under medical supervision. Quinine can be used but requires monitoring for hypoglycemia. Mefloquine, pyrimethamine/sulphadoxine, halofantrine, tetracycline, doxycycline, and primaquine are generally contraindicated or not recommended for use during pregnancy due to potential risks to the fetus (Stephen *et al.*, 2017). Artemisinin derivatives: Artemisinin-based combination therapies (ACTs), which include artemether-lumefantrine and artesunate-mefloquine, are recommended for the treatment of malaria in non-pregnant individuals (Stephen *et al.*, 2017).

2.9 Malaria Interventional strategies in Ethiopia

It is evident that Ethiopia has been trying to control and eliminate malaria for more than 60 years. The Malaria eradication service was established in 1959 making Ethiopia one of the pioneering countries in Africa to embark on a malaria eradication effort (Bugssa & Tedla, 2020). Some of the current tools employed in the intervening activities were: the use of insecticide-treated bed nets (ITNs), indoor residual spraying (IRS), rapid diagnosis and treatment with artemisinin-based combination therapy, periodic inspection (a systematic process of actively searching for potential mosquito breeding sites and malaria parasites within a specific area) and continuous nation-wide malaria surveillance, enhancing awareness of treatment seeking behaviour of the population. Further-more, malaria situation analysis program have been in practice for long at most malaria endemic regions of the country (Tefera *et al.*, 2022).

In Ethiopia, rapid diagnostic tests and artemisinin-based combination therapy (ACT) are implemented for malaria diagnosis and treatment (Ethiopian Federal Ministry of Health, 2018). Malaria control strategies in Ethiopia include indoor residual spraying (IRS) and long-

lasting insecticidal nets (LLINs), which are crucial vector control strategies. However, insecticide resistance in major malaria vectors, particularly *Anopheles arabiensis*, challenges the effectiveness of indoor residual spraying (IRS) and long-lasting insecticidal nets (LLINs) in different regions of the country (WHO, 2010).

2.10 Risk Factors Associated with Malaria Resurgence

There are several factors contributing to the resurgence of malaria include, low level of income, poor housing conditions, limited education and awareness, limited financial resources can restrict access to preventive measures like insecticide-treated bed nets (ITNs) and prompt healthcare for diagnosis and treatment. Inadequate housing, with limited protection against mosquito bites, can increase exposure risk. Lack of awareness about malaria transmission, prevention methods, and the importance of seeking treatment can hinder individual and community-level efforts to control the disease (Baird, 2008). Other risk factors, such as, change in weather conditions, intervention measures, like ITN, IRS, larval source management, environmental factors like, availability of stagnant water, vector, parasite itself, human behavior and socioeconomic conditions (Meresa *et al.*, 2018). Covid-19, conflict, healthcare infrastructure, El Niño (Lancet Microbe, 2022). The emergence of malaria parasites resistant to commonly used antimalarial drugs can significantly hinder treatment effectiveness and recognized as risk factor (Ashley *et al.*, 2016). Further, weakened healthcare system, often availability of health care workers and medication, lack robust surveillance and monitoring systems to combat malaria cases effectively, hindering early detection of outbreaks and limits the ability to implement targeted control measures (Gebreselassie *et al.*, 2022).

Chapter Three: Materials and Methods

3.1 Description of the study area

The study was conducted at Bonga town found in kaffa zone, southwest Ethiopia from Sep-May, 2024. Bonga town is the administrative center of kaffa zone, Southwest Ethiopia and surrounded by Gimbo from north, Decha from south, Chena from west and Telo from east. According to the information gathered from local health office during preliminary study, the current total number of population of the region accounts for 54,369, of which male 27,075, and female was 27,295. Bonga is geographically situated at coordinates of approximately 7°16'N latitude and 36°14'E longitude. The town sits at an elevation of around 1,714 meters above sea level. It is approximately 110 km away from Jimma, 449 km from Addis Ababa (the capital city of Ethiopia). Health facilities in the town include, Bonga Gebiretsadik Showa General Hospital, one Health center and five private clinics. Its source of economy is agriculture and trade. It experiences a warm and humid climate with moderate temperature. It has rainy and dry seasons. Temperature ranges from 12 to 27°C (53.6 to 80.6°F), with rare instances below 6.1°C (43°F) or above 30°C (86°F). Bonga receives abundant rainfall, an average of 163.21 millimeters (6.43 inches) annually, spread over 203.01 rainy days, accounting for approximately 55.62% annually (Figure 2).

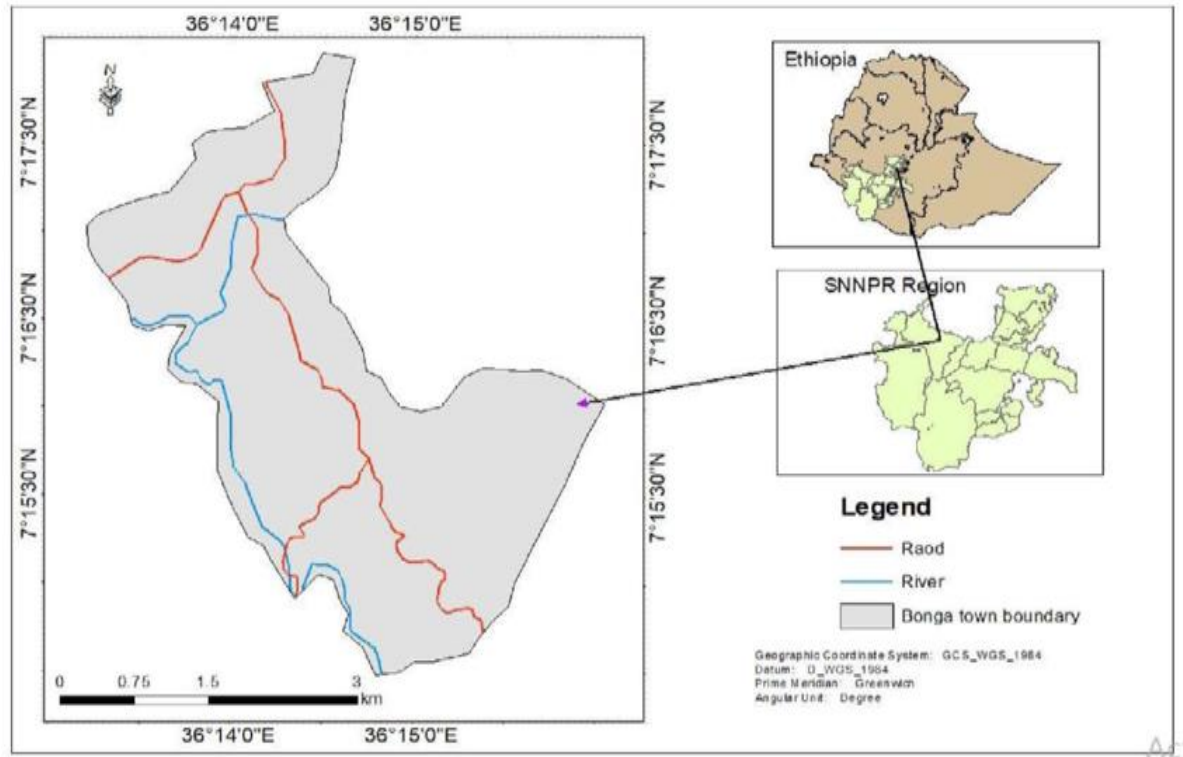


Figure 2: Map of Bonga town (source: <https://en.wikipedia.org/wiki/Bonga>)

3.2 Study Design

Health facility - based cross-sectional and retrospective study design was employed.

3.3. Study variables

Dependent variables: Malaria positivity rate

Independent variables

- Interventional activities (distribution and coverage of insecticide treated bed nets, indoor residual spraying, and larval source management), healthcare system, climate change, socio-demographic and behavioral characteristics of the population

3.4 Target population

- Target population of the study was all patients seeking medication at Bonga Gebiretsadik Showa General Hospital, Health center and five clinics during the study period

3.5. The Study Population

For Retrospective Analysis

- All individuals who diagnosed and treated for malaria at Bonga Gebiretsadik Showa General Hospital, Health center and five clinics during the period from January, 2010 to December, 2023 G.C.

For Cross-sectional Study

- Individuals suspected for malaria and visited at Bonga Gebiretsadik Showa General Hospital, Health center and five clinics from (January to May, 2024 G.C).

3.6 Sample size determination and sampling techniques

- **Retrospective Analysis:** The study included all malaria cases diagnosed and treated at Bonga Gebiretsadik Showa General Hospital, Health center and five clinics during the retrospective study period.
- **Cross-sectional Study:** Probability (simple random sampling) and non-probability (purposive) sampling techniques used for survey and interview respectively. Number of participants was determined by using single population proportion formula by considering the following assumptions: $Z_{\alpha/2}=1.96$ for the standard scales of 95% level of confidence, level of precision = 0.05, and the prevalence of 50 %.

Sample size (n),

The sample size formula (Daniel, 1995) was used,

$$n = \frac{\left(Z_{\alpha/2}\right)^2 P(1-P)}{d^2}$$

Where, n = minimum sample size,

p = estimated prevalence rate in previous study was 50% = 0.5

d = margin of error (0.05)

Z value at 95% CI (1.96)

$$n = \frac{(1.96)^2 \cdot 0.5(1-0.5)}{0.05^2} = 385$$

To adjust the sample size for potential non-response, the formula:

$$n_{\text{new}} = n / (1 - L),$$

Where: n_{new} = adjusted sample size; n = original sample size = 385;

L = expected non-response rate (as a proportion), Let's $L = 0.38$ (38%),

$$n_{\text{new}} = 385 / (1 - 0.38)$$

$$n_{\text{new}} = 385 / 0.62$$

$$n_{\text{new}} \sim 621$$

Therefore, total adjusted sample size was 621 participants.

3.7. Inclusion and exclusion criteria

3.7.1. Inclusion Criteria

Individuals who were sought medical care for malaria at Bonga Gebiretsadik Showa General Hospital, Health center and five Clinics during the specified time period, all ages and sex, who were diagnosed with malaria and received treatment at the specified health facilities. Individuals who participated in malaria prevention and control activities or interventions implemented in Bonga town, Kaffa zone, Southwest Ethiopia during the same period and representative of the broader study populations were included in the study.

3.7.2. Exclusion Criteria

Individuals who were not diagnosed with malaria or did not receive treatment at the specified health facilities, individuals who did not participate in malaria prevention and control activities or interventions implemented in Bonga town, Kaffa zone, Southwest Ethiopia during the study time period. Individuals who have moved out of Bonga town, Kaffa zone, Southwest Ethiopia during study period, and individuals who were unable or unwilling to participate in the study, none representative of the broader study populations were excluded from the study.

3.8. Data sources and collection tools

3.8.1 Data sources

Retrospective Analysis: Document analysis, patient medical records, and intervention reports from local health office was used.

Cross-Sectional Study: Structured questionnaires, patients' clinical examinations, observation, checklists-to collect data for ongoing intervention activities, key Informant Interviews was used.

3.8.2 Data collection and Processing

Secondary data was collected from all available data sources such as medical records, laboratory reports, diagnostic records, and intervention reports related to malaria cases and intervention activities and socio-demographic characteristic records in relevant local health bureau. Primary data was collected from the specified health facilities. Current data on malaria prevalence and intervention activities was collected using a cross-sectional survey. In addition, medical record review, laboratory reports, diagnostic records, intervention reports, program documents, and interviews or surveys with healthcare providers and program managers at Bonga Gebiretsadik Showa General Hospital, Health center and five Clinics and relevant health authorities.

3.9. Data Analysis

Collected data was reviewed and checked for completeness, accuracy, and consistency. Any duplicate or irrelevant record was removed. Any missing data or inconsistencies were addressed by referring back to the original sources, and contacting relevant personnel. Accuracy of data entry was double-checked to minimize errors. Data (quantitative) was analyzed by using Statistical package for social sciences (SPSS) software version 26 and qualitative was analyzed thematically. Statistical techniques such as descriptive statistics, correlation analysis, and regression models were used. For the logistic regression model the following equation was used: multiple linear regression model which was used to assess the impact of different variables on the positivity rate of malaria was computed using the following formula; Y (malaria positivity rate) = $\beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \dots + \beta_nX_n$, where: Y is the dependent variable; $x_1, x_2, \dots, x_n$ were the independent variables; β_0 is the y-intercept, which represents the value of Y when all x variables are equal to 0; $\beta_1, \beta_2, \dots, \beta_n$ are the regression coefficients, which represent the change in Y associated with a one-unit change in the

corresponding x variable, while holding all other x variables constant. Accordingly the malaria positivity rate (%) = $14.584 + 726.838(\text{Year}) - .140 (\text{Age } 5\text{to}14) + .158(\text{Age } >14) + .442(\text{Male}) - .533(\text{ITN}) - 0.781(\text{IRS}) + 8.763(\text{Sep}) + 8.984(\text{Oct}) + 8.559(\text{Nov}) + 1.142 (\text{Pf}) + 1.204 (\text{Pv})$ was used for analyze effect of retrospective variables on malaria positivity rate. Further, Logit (P) = $\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \dots + \beta_n X_n$, Where: P is the probability of the binary outcome occurring (e.g., the probability of a person having a disease or not). β_0 is the intercept term. $\beta_1, \beta_2, \dots, \beta_n$ are the regression coefficients for the independent variables $x_1, x_2, \dots, x_n$ was utilized. The logit was computed by using a formula; Logit (P) = $265.262 + 32.748 (\text{Age } 5-14) + 91.867 (\text{Age } >14) + .492 (\text{Male}) - .075 (\text{Educated}) - .090 (\text{Corrugated sheet roof}) + 4.167 (\text{Travel History } =\text{Yes}) - .066 (\text{Awareness}=\text{Aware}) - .591 (\text{Intervention}=\text{Good})$. A P-value less than 0.05 were considered to have statistical significance.

3.10 Ethical Considerations

Before data collection, ethical approval was obtained from the Research and Ethical and Research review committee of college of Natural Sciences, Jimma University. Informed consent was obtained from participants involved in interview and privacy and confidentiality was ensured. Right and well-being of respondents was protected.

Chapter 4 Result and discussion

4.1 Result

4.1.1 Retrospective Analysis

In the years between 2010 and 2023, a total of 64,885 clinically malaria suspected patients were diagnosed using a microscope in the selected health facilities. Among the suspected cases, 19,582 (30.18%) were found positive for malaria. Malaria positivity rate fluctuated significantly over the 14-years (2010-2023), indicating the annual and seasonal fluctuation trend in malaria positivity in the study area. Prevalence initially decreased from 20.65% in 2010 to around 10% in 2013-2014 and further decreased until 2015. However, it then increased sharply, reaching a peak of nearly 25.7% in 2018 before decline slightly in 2019. Then it was increased again in 2020, with prevalence reaching 27.09% and then sharply increased reaching a peak of 35.42% from 2022-2023 (Table 1). Also, malaria cases by sex in the study population identified. Among

gender groups, about 15.68% of the malaria cases among males were reported, while 14.50% were reported among females. The distribution of malaria cases among age groups showed the highest proportion was observed among individuals aged greater than 14 years old (12.40%) followed by those in the age group of 5 to 14 years (9.02%) and under 5 years of age (8.76%) (Table 1).

As the information obtained from local health bureau, ITNs and IRS were implemented once per a year, but during 2010, 2013, 2016, 2017, 2019, 2022 and 2023, there was no ITN distribution totally; during 2022 and 2023, there was no IRS spraying; overall, from 177,480 required ITN, only 49,086 (27.66%) was implemented; as well as from 77,325 household (needed to IRS spraying, only 28,789 (37.23%) households were sprayed during study period (2010-2023); and also there was no LSM throughout specified study period. In relation to ITN distribution and coverage, malaria prevalence rate was peaked at 10.42% in 2016 from 6.2% in 2015; and it was increased to 28.26% and 35.42% in 2022 and 2023 respectively from 21.59% in 2021. Additionally, meteorological data has shown variability in annual average temperature (°C) and amount of precipitation (mm) over 14 years (2010-2023) with increasing pattern in recent years (Table 1).

Table 1: Prevalence of malaria between 2010 and 2023 in relation to socio-demographic, Plasmodium species and malaria control efforts from document review in local health Bureau in Bonga town, Kaffa zone, Southwest Ethiopia.

Year	Total tested	Malaria +ve	Positivity rate (%)	Plasmodium spp			Age (year)			Sex		Min.temp (°C)	Max.temp (°C)	Av.temp. (°C)	Av.prec (millimeter)	ITN		IRS	
				P.f (%)	P.v (%)	Mixed* (%)	<5 (%)	5-14 (%)	>14 (%)	Male (%)	Female (%)					Req.	Dist. (%)	Req.	Spr. %
2010	988	204	20.65	143 (14.47)	14 (1.42)	47 (4.76)	48 (4.86)	69 (6.98)	87 (8.81)	106 (10.73)	98 (9.92)	11.35	27.58	19.46	6.25	8960	NI	2234	1583 (70.86)
2011	1154	180	15.6	124 (10.75)	13 (1.13)	43 (3.73)	39 (3.38)	44 (3.81)	97 (8.41)	106 (9.19)	74 (6.41)	12.03	23.86	17.95	6.24	8192	352 (4.3)	1012	758 (74.9)
2012	762	108	14.17	71 (9.32)	9 (1.18)	28 (3.67)	24 (3.15)	35 (4.59)	49 (6.43)	63 (8.27)	45 (5.91)	10.85	28.19	19.52	4.54	9299	557 (5.99)	1600	1008 (63)
2013	845	126	14.91	70 (8.28)	13 (1.54)	43 (5.09)	31 (3.67)	35 (4.14)	60 (7.10)	70 (8.28)	56 (6.63)	11.72	28.10	19.91	5.07	8663	NI	1881	993 (52.8)
2014	820	72	8.78	45 (5.49)	7 (0.85)	20 (2.44)	19 (2.32)	21 (2.56)	32 (3.90)	47 (5.73)	25 (3.05)	5.73	13.93	9.83	2.04	9221	4887 (53)	1900	887 (46.68)
2015	774	48	6.2	30 (3.88)	4 (0.52)	14 (1.81)	13 (1.68)	18 (2.33)	17 (2.20)	26 (3.36)	22 (2.84)	4.39	9.24	6.82	2.25	10330	4890 (47.34)	2000	1890 (94.5)
2016	691	72	10.42	41 (5.93)	8 (1.16)	23 (3.33)	16 (2.32)	20 (2.89)	36 (5.21)	51 (7.38)	21 (3.04)	6.09	14.39	10.24	5.05	10378	NI	2023	1744 (86.21)
2017	1198	195	16.28	119 (9.93)	18 (1.50)	58 (4.84)	36 (3.01)	60 (5.01)	99 (8.26)	119 (9.93)	76 (6.34)	5.80	10.72	8.26	6.36	10410	NI	12549	9185 (73.19)
2018	1299	334	25.71	239 (18.40)	26 (2.00)	69 (5.31)	62 (4.77)	99 (7.62)	173 (13.32)	192 (14.78)	142 (10.93)	9.97	19.99	14.98	3.55	10712	2950 (27.5)	8481	2210 (26.06)
2019	2134	322	15.09	210 (9.84)	24 (1.12)	88 (4.12)	70 (3.28)	92 (4.31)	160 (7.50)	191 (8.95)	131 (6.14)	12.90	27.84	20.37	6.74	10960	NI	8481	3315 (39.09)
2020	764	207	27.09	137 (17.93)	18 (2.36)	52 (6.81)	51 (6.68)	63 (8.25)	93 (12.17)	119 (15.58)	88 (11.52)	12.93	29.13	21.03	5.17	17056	14600 (85.6)	3184	1958 (61.49)
2021	2784	601	21.59	384 (13.79)	56 (2.01)	161 (5.78)	147 (5.28)	204 (7.33)	250 (8.98)	341 (12.25)	260 (9.34)	12.91	27.79	20.35	3.78	27438	20850 (76)	10463	3258 (31.14)
2022	11642	3290	28.26	2651 (22.77)	112 (0.96)	527 (4.53)	663 (5.69)	1098 (9.43)	1529 (13.13)	1825 (15.68)	1465 (12.58)	12.52	28.20	20.36	6.75	17738	NI	10643	NI
2023	39030	13823	35.42	8466 (21.69)	2928 (7.50)	2429 (6.22)	4465 (11.44)	3995 (10.24)	5363 (13.74)	6920 (17.73)	6903 (17.69)	12.26	31.40	21.83	7.56	18123	NI	10874	NI
Total	64885	19582	30.18	12730 (19.62)	3250 (5.01)	3602 (5.55)	5684 (8.76)	5853 (9.02)	8045 (12.40)	10176 (15.68)	9406 (14.50)	141.44	320.37	228.90	71.36	177480	49086 (27.66)	77325	28789 (37.23)

During the Tseday season, which spans from September to November, the malaria positivity rate was the highest at 32% compared to other seasons. In contrast, the Kiremt season from June to August had a lower positivity rate of 20%; the Belg season from March to May saw a positivity rate of 26% and during Bega season from December to February the malaria prevalence was 22%. These seasonal variations in malaria prevalence are crucial information for implementing targeted control strategies in the Bonga town area. Identifying seasonal variations in malaria is crucial for implementing targeted control strategies in Tseday. This knowledge can inform focused interventions, where public health efforts like ITN distribution, IRS spraying or awareness campaigns can be strategically timed to the high-risk season. It can also guide resource allocation, as diagnostic, treatment, and preventive resources can be prioritized during high transmission season to maximize their impact. By understanding seasonal trends and their drivers, healthcare officials and communities can work together more effectively to control malaria transmission (Figure 3).

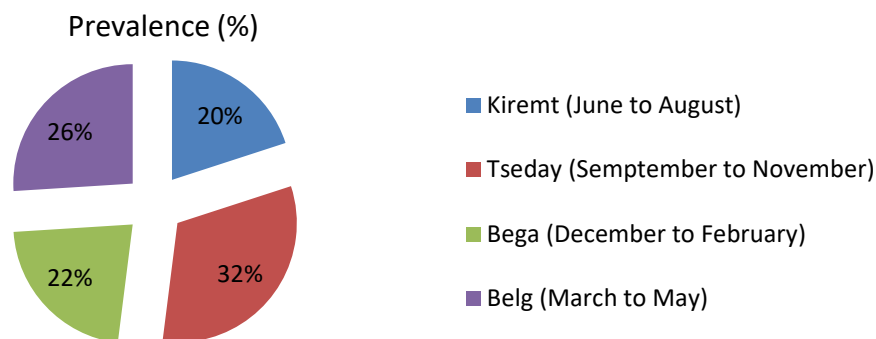


Figure 3: Seasonal trend of malaria positivity rate in study area from (2010-2023)

Plasmodium falciparum was the dominant malaria parasite species, 12,730 (19.62%), with a low proportion of *plasmodium vivax* 3250 (5.01%) and the significant proportion of mixed infections 3,602 (5.55%) in the study area. Individuals aged less than 5 years were 5,684 (8.76%), while 5 to 14 years were 5,853 (9.02%) and above 14 years were 8,045 (12.4%). The distribution of *plasmodium vivax* also exhibits fluctuations, but it was lower than *Plasmodium falciparum* and mix of both throughout the specified time period. And also distribution of the mixed infection was relatively low compared to *Plasmodium falciparum* and higher than *Plasmodium vivax*, but also has shown variation over time (Figure 4).

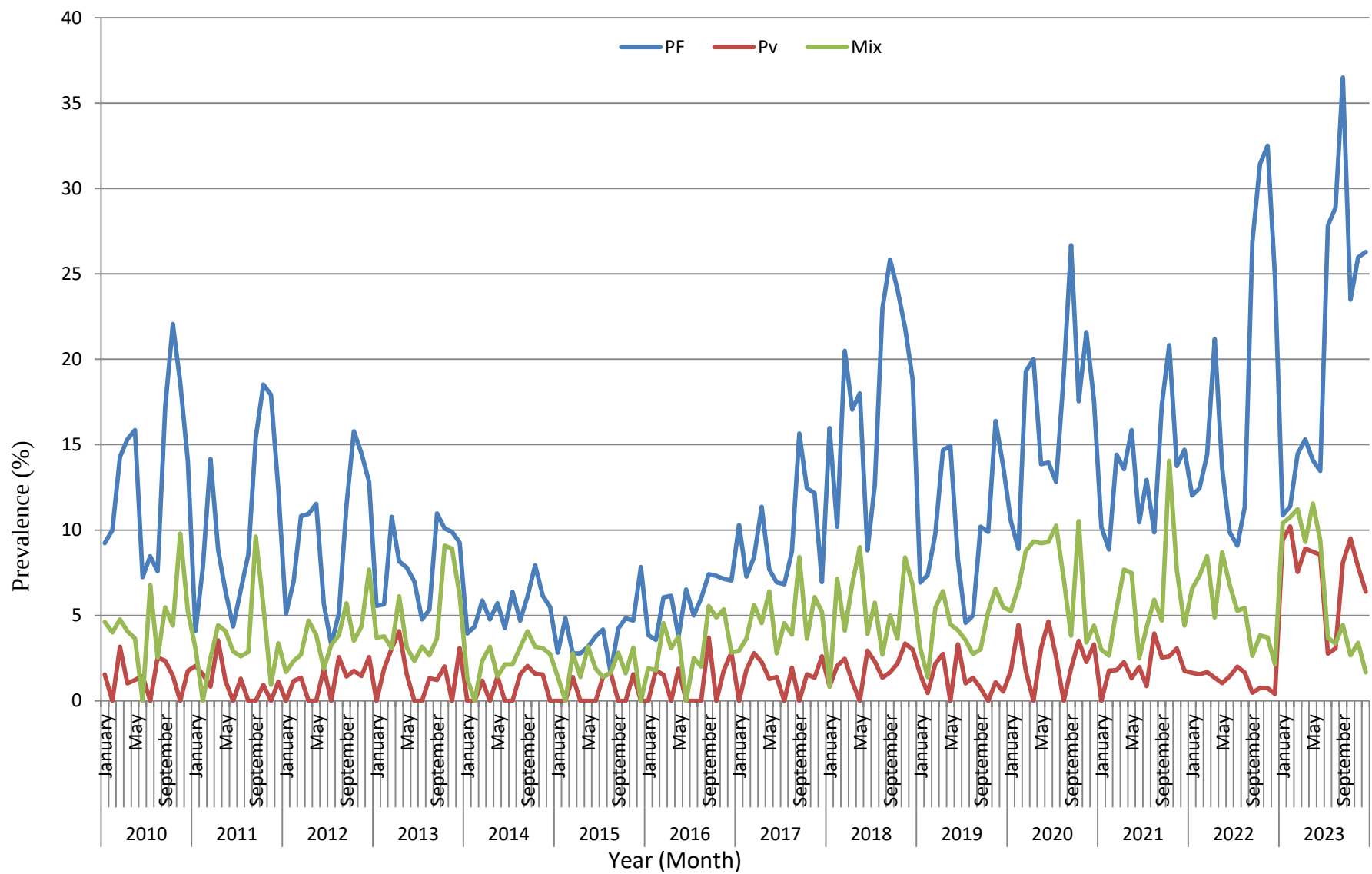


Figure 4: Distribution of *plasmodium* species over the past 14-years in study area from (2010-2023)

4.1.1.1. Impact of sociodemographic characteristics on malaria positivity rate

Effect of socio-demographic variables, season, malaria control efforts and *plasmodium* spp on the malaria positivity rate showed that, individuals with age above 14 years positively associated with increase in malaria positivity rate as compared to individuals aged <5, age considered as biologically risked group ($\beta = 0.158$, 95%CI: -0.462, 0.147 $p=0.008$) suggested that, as age increase by one-unit, malaria prevalence increase by 0.158, holding all other variables constant. Males had significantly positively associated with increase in malaria prevalence than females, this was statistically significant ($\beta = 0.442$, 95% CI: 0.077, 0.808, $p=0.018$). Also, the analysis has shown that, the significant effect of time change on malaria positivity rate, indicating as year increase by one-unit, malaria positivity rate increase by 1.273 ($\beta = 1.273$, 95% CI: 0.322, 2.224, $p=0.013$). In some months such as September ($\beta = 8.763$, 95% CI: 2.565, 14.96 $p=0.006$), October ($\beta = 8.984$, 95% CI: 2.79, 15.2, $p=0.005$), and November ($\beta = 8.559$, 95% CI: 2.36, 14.76, $p=0.007$) malaria positivity rate was significantly and positively and statistically increased in these months. In addition, statistically significant negative association between intervention activities and malaria positivity rate was observed. As ITNs distribution increased by 1-unit, malaria positivity rate was decreased by 0.533 ($\beta = -0.533$, 95% CI: -0.63, -0.43 $p=0.001$). Similarly, as in door residual spraying (IRS) activity increased by 1-unit, malaria positivity rate is decreased by 0.781 ($\beta = -0.781$, 95% CI: -1.08, -0.48 $p=0.004$). Furthermore, there was positive and statistically significant association between proportion of *Plasmodium falciparum* and *Plasmodium vivax* and malaria prevalence. This indicating that, as *Plasmodium falciparum* increase by 1- unit, malaria prevalence increase by 1.142 (95% CI: $P<0.001$), holding all other variables constant. As *Plasmodium vivax* increase by 1-unit, malaria prevalence increase by 1.204 (95% CI: $P<0.001$). As minimum temperature increase by 1-unit, malaria positivity rate increase by 0.713 ($p= 0.009$), maximum temperature increase by 1-unit, malaria positivity rate increase by 1.747 ($p= 0.01$) and as average temperature increase by 1-unit, malaria positivity rate increase by 0.987 ($P=0.017$) ; as the amount of precipitation increase by 1-unit, malaria positivity rate increase by 2.7 ($p=0.039$) (Table 2).

Table 2: Impact of various factors on malaria positivity rate in Bonga Town,

Variables	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	14.584	2.180		6.69	0.000	10.28	18.9
Year	1.273	0.437	0.644	2.916	0.013	.322	2.224
*<5							
5-14	-0.140	0.103	-0.44	-1.36	0.177	-0.344	0.064
>14	0.158	0.154	0.47	1.92	0.008	-0.462	0.147
Male	0.442	0.185	1.3	2.39	0.018	0.077	0.808
*Female							
ITNs	-0.533	0.031	-1.74	-16.96	0.000	-0.63	-0.43
IRS	-0.781	0.095	-0.90	-8.25	0.004	-1.08	-0.48
*Jan							
Feb	-1.028	3.138	-0.03	-0.33	0.744	-7.226	5.17
Mar	4.737	3.138	0.15	1.51	0.133	-1.461	10.94
Apr	4.944	3.138	0.15	1.58	0.117	-1.253	11.14
May	3.631	3.138	0.11	1.16	0.249	-2.57	9.83
Jul	-0.392	3.138	-0.01	-0.125	0.901	-6.590	5.81
Aug	0.959	3.138	0.03	0.31	0.760	-5.239	7.16
Sep	8.763	3.138	0.27	2.79	0.006	2.565	14.96
Oct	8.984	3.138	0.28	2.86	0.005	2.79	15.19
Nov	8.559	3.138	0.26	2.73	0.007	2.36	14.76
Dec	5.360	3.138	0.16	1.71	0.090	-0.838	11.56
Pf	1.142	0.053	0.83	21.52	0.000	1.025	1.259
Pv	1.204	0.186	0.25	6.46	0.000	0.794	1.614
Min.temp (°C)	0.713	0.566	0.665	3.087	0.009	0.514	2.979
Max.temp (°C)	1.747	0.234	0.660	3.043	0.01	0.203	1.224
Av.temp (°C)	0.987	0.357	0.624	2.764	0.017	0.209	1.765
Av.prec (mm)	2.700	1.167	0.555	2.314	0.039	0.158	5.242

NB: Age group *<5, *Female, and *January refers to reference category, Min.temp = minimum temperature, Max.temp = maximum temperature, Av.temp = average temperature, Av.prec = average precipitation.

4.1.2. Cross-sectional analysis

In the cross-sectional study, a total of 621 (315 were males and 306 were females) clinically malaria suspected patients were included and among which 315 (50.72%) were microscopically confirmed malaria positive patients. The proportion of males tested malaria positive was 187

(30.11%), were tested malaria positive. Also, in terms of age; 25.4% were under 5 years old, 84 (13.5%) were 5-14 years old, and 379 (61%) were above 14 years old. The proportion of males and females positive to malaria infection were 187 (30.11) and 128 (20.61) respectively. The travel history data indicated that, individuals with no travel history had 586 (94.36%) cases, with 299 (48.15%) negative and 287 (46.22%) positive cases. Those with travel history had 5.64% cases, with 1.13% negative and 4.51% positive cases. A low income category had higher positivity rate (24.3%) compared to the medium (16.26%) and high (0.87%) categories and it also high among merchant occupation (35.91%) followed by farmer (30.59%), illiterate educational background (33.01%) (Table 5).

The data analysis revealed a critical link between a potentially weakened healthcare system and the rise in malaria cases. The data on healthcare worker availability, medication availability, and healthcare facility infrastructure suggested a potentially weakened system struggling to handle the malaria burden in the region. Healthcare worker shortage (doctors, nurses) could lead to delays in diagnosis, treatment, and overburdened existing staff, hindering effective case management. Lack of robust surveillance and monitoring systems, and limited access to RDTs to enhance prompt malaria diagnosis also observed. Regarding health care infrastructure, the number of clinics, hospitals, bed availability, and equipment did not sufficient, and factors like insufficient bed capacity or outdated equipment could limit the system's ability to handle the outbreaks in malaria cases in the region (these findings were through analysis of key informant interview data and observation of the real situation). Restricted medication access just only four antimalarial drugs provided a picture of lack of access to a wider range of antimalarials or essential medications limit treatment options and negatively impact overall healthcare deliver (Table 3).

Regarding availability of mosquito breeding sites, 16 (80%) of key informants reported that there were many mosquito breeding sites in the region. A large proportion, 602 (96.94%) of the study participants response has shown the absence of traditional methods used for larval source control. Additionally, all participants, 621 (100%) reported as there was no any traditional practices that focus on eliminating or modifying mosquito breeding sites in the study area during study period. The dominant *Plasmodium* species in the study area was *Plasmodium falciparum* (79%) and *Plasmodium vivax* have shown limited distribution (3.5%). Malaria positivity rate was

higher among patients with ≥ 5 family size (56.68%). Malaria positivity in pregnant women was 6.44% (Table 3).

Table 3: Health care system, traditional indigenous knowledge, and other factors in Bonga town, Kaffa zone, Southwest Ethiopia, 2024.

Variables	Parameters	Malaria test		Total (%)
		Negative (%)	Positive (%)	
Diagnostic tool used	Microscope	306 (49.27)	315(50.72)	621 (100)
All relevant healthcare workers were available*	No	8 (40)	7 (35)	15 (75)
	Yes	2 (10)	3 (15)	5 (25)
All relevant medications available*	No	7 (35)	6 (30)	13 (65)
	Yes	3 (15)	4 (20)	7 (35)
Existing healthcare facilities were sufficient	No	10 (50)	6 (30)	16 (80)
	Yes	0 (0)	4 (20)	4 (20)
Were there robust surveillance and monitoring systems*	No	8 (40)	9 (45)	17 (85)
	Yes	2 (10)	1 (5)	3 (15)
Were there sufficient equipment and bed in the health facilities*	No	7 (35)	10 (50)	17 (85)
	Yes	3 (15)	0 (0)	3 (15)
Drug used	Coartem		100(31.75)	100 (31.75)
	Coartem + Primaquine		26 (8.25)	26 (8.25)
	Artesunate		184 (58.41)	184 (58.41)
	Chloroquine + Primaquine		5 (1.59)	5 (1.59)
Prompt diagnosed with malaria**	No	239 (38.56)	250(40.26)	489(78.74)
	Yes	67(10.89)	65 (10.56)	132 (21.26)
Plasmodium species	<i>P. falciparum</i>		248 (39.94)	248 (79)
	<i>P.vivax</i>		11 (1.77)	11 (3.5)
	Mixed		56 (9.02)	56 (17.5)
Availability of mosquito breeding sites	No	11(55)	9 (45)	20 (100)
	Yes	0 (0)	0 (0)	0 (0)
Number of mosquito breeding sites around patient`s house	<3	1 (5)	3 (15)	4 (20)
	>3	10(50)	6(30)	16(80)
Any traditional methods used to control larval source*	No	296 (47.67)	306 (49.28)	602 (96.94)
	Yes	10 (1.61)	9 (1.45)	19 (3.06)
Any traditional practices that focus on eliminating or modifying mosquito breeding sites*	No	415 (66.83)	206 (33.17)	621 (100)
	Yes	0(0)	0 (0)	0 (0)
Family size	<5	138 (22.22)	131 (21.10)	269 (43.32)
	≥ 5	168 (27.05)	184 (29.63)	352 (56.68)
Pregnancy	No	262 (42.19)	275 (44.28)	537 (86.47)
	Yes	44 (7.09)	40 (6.44)	84 (13.53)

* Refers to 2023-2024 ** refers to before study period.

4.1.2.1. Factors associated with malaria resurgence

The result highlighted a concerning levels of awareness among the respondents. A majority, 423 (68.12%) were not aware of malaria transmission, 454 (73.11%) were not aware of the importance of completing the full course of treatment, 274 (44.12%) were not aware of common malaria symptoms, and 460 (74.07%) were not aware of proper bed net utilization and maintenance. Additionally, a large proportion, 592 (95.33%) were not aware of traditional plant-based remedies. All 621 (100%) respondents reported that among them, no one participated in intervention during study period (Table 4). All participants, 621 (100%) had reported that ITN distribution; IRS spraying, and larval source management did not implemented since 2023-2024 and were indoor sleeping. However, their status of old ITN utilization (sleeping under the bed net), 572 (92.11%) respondents were did not have enough ITN for all family members to sleep under bed nets. Regarding, the perception of participants about the ITN distribution, majority of the participants, 446 (71.82%), strongly disagree with sufficiency of the bed nets distribution (Table 4).

Table 4: Interventional activities and awareness and/or knowledge of patients about malaria and control measures in Bonga town, kaffa zone, Southwest Ethiopia from (Jan-May, 2024) (n= 621)

Variables	Parameters	Malaria test		Total (%)
		Negative (%)	Positive (%)	
Larval source management*	No	306 (49.28)	315 (50.72)	621 (100)
All family members sleep under bed net	No	264 (42.51)	308 (49.59)	572 (92.11)
	Yes	42 (6.76)	7 (1.13)	49 (7.89)
ITN distributed*	No	306 (49.28)	315 (50.72)	621(100)
IRS sprayed*	No	306 (49.28)	315 (50.72)	621 (100)
Sleeping behavior	Indoor	306 (49.28)	315 (50.72)	621 (100)
	Outdoor	0 (0)	0 (0)	0 (0)
ITN distributed per household were sufficient	Neutral	38 (6.12)	45 (7.25)	83 (13.37)
	Disagree	52 (8.37)	40 (6.44)	92 (14.81)
	Strongly disagree	216 (34.78)	230 (37.04)	446 (71.82)
Awareness about malaria transmission	No	207 (33.33)	216 (34.78)	423 (68.12)

	Yes	99 (15.94)	99 (15.94)	198 (31.88)
Awareness about completing full course of treatment	No	226 (36.39)	228 (36.71)	454 (73.11)
	Yes	80 (12.88)	87 (14.01)	167 (26.89)
Awareness about utilization and maintenance of bed net	No	225 (36.23)	235 (37.84)	460 (74.07)
	Yes	81 (13.04)	80 (12.88)	161 (25.93)
Awareness about common symptoms of malaria	No	140 (22.54)	134 (21.58)	274 (44.12)
	Yes	166 (26.73)	181 (29.15)	347 (55.88)
Knowledge about plants or plant extracts traditionally used	No	292 (47.02)	300 (48.31)	592 (95.33)
	Yes	14 (2.25)	15 (2.42)	29 (4.67)
Respondent`s participation in intervention activities *	No	306 (49.28)	315 (50.72)	621 (100)

* Refers to 2023-2024

Regression analysis shown that, males significantly, 0.492 times higher chance of getting malaria infection compared to females (AOR = 0.492, 95% CI: 0.36-0.68, $p<0.001$). Compared to the illiterate group of individuals, the educated group had 0.075 times lower chance of having a positive malaria test (AOR = -0.075, 95% CI: 0.007-0.85, $p=0.037$). Compared to <5 age group, those found in age between 5-14 had 32.75 times higher chance of having a positive malaria test (AOR =32.75, 95% CI: 1.93-554.4 $p=0.016$). Patients age >14 years had 91.87 times higher risk of malaria infection compared to those under 5 (AOR =91.87, 95% CI: 1.74-4846.53, $p=0.025$), individuals living in good housing condition had 0.09 times lower chance of having a positive malaria test (AOR = -0.090, 95% CI: 0.002-0.33, $p<0.001$). Similarly, those patients with a travel history had 4.17 times higher risk of malaria infection compared to those without a travel history (AOR = 4.17, 95% CI: 1.79-9.7, $p=0.001$). Those patients with good awareness about malaria (transmission, common symptoms and prevention methods) had 0.066 times lower chance of having malaria infection compared to those without awareness (AOR = -0.066, 95% CI: 0.03-0.13, $p<0.001$) and availability of malaria control activities in the study area was significantly associated with lower risk to malaria infection (AOR = -0.591, 95% CI: 0.41-0.86, $p=0.006$), compared to poor malaria control measures, holding all other variables constant (Table 5).

Table 5: Effect of some factors on the malaria positivity rate in Bonga town, Kaffa zone, Southwest Ethiopia, 2024

Variables	Alternatives	Negative (%)	Positive (%)	COR	AOR (95% C.I)	P-value
Constant				5.58	265.262	0.033
Age	<5	89 (14.33)	69 (11.11)	Ref	Ref	Ref
	5-14	36 (5.80)	48 (7.73)	-3.49	32.75 (1.93-554.4)	0.016
	>14	181 (29.15)	198 (31.88)	-4.52	91.87 (1.74-4846.53)	0.025
Sex	Male	128 (20.61)	187 (30.11)	-0.71	0.492 (0.36-0.68)	0.000
	Female	178 (28.66)	128 (20.61)	Ref	Ref	Ref
Occupation	Farmer	99(15.94)	91(14.65)	Ref	Ref	Ref
	Merchant	108 (17.39)	115 (18.52)	-0.85	1.08 (0.7-1.66)	0.734
	Student	61 (9.82)	70 (11.27)	-17.3	0.97 (0.54-1.74)	0.926
	Employed	28 (4.51)	29 (4.67)	-18.14	0.94 (0.38-2.35)	0.893
	Unemployed	10 (1.61)	10 (1.61)	1.42	0.86 (0.59-1.27)	0.457
Household Income level	Low	151 (24.32)	248 (39.94)	Ref	Ref	Ref
	Medium	101 (16.26)	61 (9.82)	-2.693	-.068 (.028-.161)	.000
	High	54 (8.70)	6 (0.97)	-2.693	-.068 (.028-.161)	.000
Educational level	Illiterate	107 (17.23)	98 (15.78)	Ref	Ref	Ref
	Educated	87 (14.01)	99 (15.94)	-2.59	-0.075 (0.007-0.85)	0.037
Type of house	Thatch roof	9 (1.45)	303 (48.79)	Ref	Ref	Ref
	Corrugated sheet roof	297 (47.83)	12 (1.93)	-8.62	-0.09 (0.002-0.33)	0.000
Travel history to malaria endemic area	No	299 (48.15)	287 (46.22)	Ref	Ref	Ref
	Yes	7 (1.13)	28 (4.51)	1.43	4.17 (1.79-9.7)	0.001
*Awareness	Not aware	241 (38.81)	155 (24.96)	Ref	Ref	Ref
	Aware	64 (10.31)	160 (25.76)	-2.72	-0.07 (0.03-0.13)	0.000
**Malaria control measures	Poor	231 (37.20)	264 (42.51)	Ref	Ref	Ref
	Good	75 (12.08)	51 (8.21)	-0.525	-0.59 (0.41-0.86)	0.006

NB: * refers to awareness about malaria transmission, common symptoms and prevention, ** refers to knowledge on the ITN distribution, utilization, coverage of IRS, indigenous knowledge and LSM in the locality, COR= crude odd ratio, AOR = adjusted odd ratio, Ref = represents reference category, * Mixed refers to infection by both *p. falciparum* and *P. vivax*.

4.1.2.2 Response of key informants on malaria and challenges encountered

According to the information collected through interview of the key informants, the main challenges encountered include, low awareness among communities about how malaria transmitted, lack of information regarding malaria prevention and control measures, carelessness among individuals regarding malaria transmission and prevention, belief among communities that malaria is not a life-threatening disease, misuse of insecticide-treated bed nets (ITNs) or using it for the purposes other than malaria prevention, lack of attention and prioritization to malaria control efforts, misconceptions among communities that chemical cannot effectively kill mosquitoes, resource shortage in relation to the size of the population, unwillingness of communities to remove household items during indoor residual spraying, insufficient emphasis on sanitation practices, low attention among stakeholders such as health extension workers, community leaders mainly on the larval source management activities, health extension workers and other health care workers failing to raise awareness among the communities about LSM, and professionals seeking personal benefits instead of supporting the community, were challenges encountered during the implementing of intervention activities. In addition, the availability of many mosquitoes' breeding sites in the locality was reported as the main challenges to ensure prevention and control of malaria in the study area.

4.2 Discussion

The findings of this study from analysis of annual and seasonal trends of malaria prevalence of the 14-years malaria data (2010-2023) revealed that, the significant increase in malaria positivity rate from 10.42% in (2016) to 35.42% in (2023) after 6 years decline from 2010 to 2015, with unpredicted peak in the number of patients; this finding in line with the finding of the study which showed a rise in the malaria positivity rate in central Ethiopia in 2022/23 after a 5-year decline and elsewhere in Ethiopia (Mandefro *et al.*, 2024; Duguma *et al.*, 2022). Also, in this year the increment was very sharp and about half (50.72%) of the clinically suspected patients were found positive, which implies a substantial malaria burden rise in the study area. The positivity rate documented in this study was too far from earlier reports, 22.4% from Dembiya district, North-western Ethiopia in 2018 (Tarekegn *et al.*, 2021). This suggested that, the malaria situation in the Bonga district has been worsening in the recent years, with the disease becoming more widespread.

This study also identified significant seasonal fluctuation in malaria prevalence, with higher rates observed during the months of September, October, and November; after heavy rainy season in the country (Tigu *et al.*, 2021). Similar study conducted at Metehara Health Centre in Central Ethiopia, indicated a peak in malaria cases was between September and November (Mandefro *et al.*, 2024). This seasonal variation of malaria prevalence might be due to the favorable environmental conditions and increased mosquito breeding sites during the post-rainy months, which leads to higher malaria transmission. This seasonal pattern of malaria prevalence is an important consideration for the planning and implementation of malaria control interventions, as it can help target resources and strategies during the high-transmission seasons to effectively address the malaria burden in the study area. The diagnostic tool used to identify *plasmodium* species was microscope and *Plasmodium falciparum* was the dominant parasite compared to *Plasmodium vivax* in the study area; this finding supported by the recent study conducted in neighboring Decha and Gimbo districts, indicated *Plasmodium falciparum* was the dominant parasite than *plasmodium vivax* (Duguma *et al.*, 2022). The dominant presence of *Plasmodium falciparum*, the deadly parasite, in the study area could increase the susceptibility of patients to severe life threatening malaria symptoms (Song *et al.*, 2022), thereby the number of mortality due to this parasite could increase, malaria associated public, economic, and social impacts could be increase (Schiess *et al.*, 2020).

The socio-demographic and behavioral characteristics substantially associated with malaria infection such as being male, illiterate people, low income level and patients with poor living condition, and limited knowledge/awareness about malaria (transmission, prevention, and control). This finding was in agreement with report from sub-Saharan Africa, where low quality of knowledge, and living condition significantly impact malaria transmission dynamics (Degarege *et al.*, 2019), although occupation was not found to be significantly associated with malaria burden in this study. The gender disparity could be attributed to differences in outdoor activities and occupational exposures, which may increase the risk of mosquito bites for male individuals than female. Patients' age above 14 years also associated with higher vulnerability. This finding, the gender and age-related patterns observed in this study supplemented by studies from Metehara in Central Ethiopia, where males were more affected than females and Afar region of Ethiopia, where a higher burden of malaria was reported to older age groups (Mitiku *et al.*, 2018).

The type of house was also identified as a factor for risk of malaria, which supported by study from Ethiopia and elsewhere (Patrick *et al.*, 2023). According to Ayele *et al.* (2012), the construction material of the walls, roof and floor of a house and toilet facilities and availability of electricity were risk factors identified with malaria infection. Although evidences are limited, housing condition is an important risk factor for malaria risk. The presence of a ceiling possibly provides the protective effect (Tusting *et al.*, 2015). Screening doors and windows can help to directly block vector entry, while modern wall and roof materials may contain fewer gaps, alter the attractiveness of the interior environment to mosquitoes or provide fewer resting sites for mosquitoes than traditional materials such as mud or thatch (Tusting *et al.*, 2015). Patients travel history was another significant factor associated with increased risk to malaria infection, as it was reported in a study from Argoba District, Northeast Ethiopia (Tesema & Akalu, 2019) as there is a potential exposure risk in endemic regions of the same country.

The most popular and globally accepted interventional methods of malaria transmission prevention and control of its widespread are the use of insecticide treated bed nets and the application of indoor residual spraying (Okumu *et al.*, 2011). ITN recognized as a higher preventive measure. It works by killing or repelling mosquitoes that try to feed on human while sleeping. Similarly, IRS involves spraying the indoor walls and eaves of homes with a residual insecticide. This creates a long-lasting insecticidal effect that kills mosquitoes that land on the treated surfaces (WHO, 2023a). In the past few decades, because of the wider implementation of these interventional strategies, malaria has been significantly decreased and was reached to the verge of eradication (Taffese *et al.*, 2018). However, the insufficiency implementation and absence of distribution in the recent years, since 2022 to date, of these core interventions was identified as one of the significant factor for the current malaria outbreak or resurgence in study area. According to the study participants response none of them have received ITN and were get IRS service in the recent three years (2022 to 2024). This aligns with study from Afar region, Ethiopia, which reported absence of IRS spraying and poor utilization of ITNs were attributed for the malaria outbreak (Mitiku *et al.*, 2018). Those old ITN used by very few participants could lose its potency and might not be protective against the mosquitos' bites (Lawson *et al.*, 2016).

Thematic analysis of data obtained from interview of key informants revealed the key challenges hindering control efforts, including low awareness among communities, carelessness regarding

prevention, misconceptions about interventions, and resource limitations. These findings were similar to those findings reported by (Paaijmans & Lobo, 2023). These results suggested that lack of awareness about malaria prevention, treatment, and control may have contributed to the malaria burden in the study population. Addressing these gaps through targeted education and awareness campaigns could be crucial in developing more effective malaria prevention and control strategies in the study area. Weak healthcare systems also identified as risk factor linked with resurgence of malaria were limited healthcare worker and medication availability, lack of robust surveillance and monitoring systems and healthcare facility infrastructure suggested a potentially weakened system, similarly with study in northwest Ethiopia, which showed a poor healthcare system often lack robust surveillance and monitoring systems to combat malaria cases effectively. This hinders early detection of outbreaks and limits the ability to implement targeted control measures (Gebreselassie *et al.*, 2022). The study in New England revealed inadequate resources for proper malaria diagnosis also attributed poor health care system. Limited access to rapid diagnostic tests (RDTs) can lead to delayed diagnoses and treatment to malaria infected individuals, allowing the parasite to replicate in the human body for longer, increasing transmission risk and potentially contributing to the emergence of drug-resistant strains (Ashley *et al.*, 2016).

This study also identified presence of mosquito breeding sites, lack of larval source management (LSM), lack of awareness of individuals on malaria transmission, common symptom and control (these findings were more supported by information gained from interview) but the factor such as lack of awareness was statistically significant and associated with resurgence of malaria in this study area, and this finding aligned with the recent study conducted in Simada District, Northwest Ethiopia, which reported presence of mosquito breeding sites, poor environmental management like, LSM, and lack of awareness on malaria transmission and control were significantly associated with the occurrence of malaria outbreaks in different locality (Workineh *et al.*, 2019). Climate change (temperature and rainfall variability) identified as the key risk factors associated with resurgence of malaria in study area. This finding similar with the finding of the study in elsewhere in the world, which reported climate change influencing mosquito population, which in turn affects malaria transmission rates. Studies suggest a temperature range of 20-30°C is ideal for adult mosquito survival and 32-33°C is optimum for the parasite development, and temperature exceeding these ranges or extremely low can hinder mosquito

survival and parasite development ; high rainfall also associated with a rise in malaria cases due to increased mosquito populations in relation to increasing mosquito breeding grounds (stagnant water) (Abunyewah *et al.*, 2022). However at the temperature value below the range mentioned above, the increment of malaria transmission was observed in study area and this may be due to other risk factors in the region. Absence of traditional methods used for larval source management also identified as risk factor linked with the resurgence of malaria in the region, this finding in line with the finding of the study conducted at nine malaria eliminating countries, which reported several countries with successful malaria reduction had countries employed traditional larval control methods alongside other interventions like ITNs distribution and IRS spraying (Kolaczinski *et al.*, 2006). Consequently, the presence of mosquito breeding sites and absence of LSM might be more aggravated malaria outbreak in the study setting.

Strength of the study and challenges

Strength-employing of the mixed-methods, a health facility-based retrospective and cross-sectional study designs were employed to assess the annual and seasonal trends of malaria prevalence and relationship between various socio-demographic, behavioral, and interventional factors and malaria status; furthermore, this study work was done via quantitative and qualitative data analysis. This combined approach of the study provided opportunity for a more holistic assessment of the malaria resurgence and associated factors in study area. A challenges of the study were shortage of time and resources.

Chapter 5 Conclusion and recommendations

5.1 Conclusion

The findings from this mixed-methods study highlighted the multi-faceted nature of factors contributing to the resurgence of malaria in the study area. The study showed clear malaria burden rise in Bonga town, in the retrospective study, although the pattern was not consistent throughout all the years, and the current study through cross-sectional design also showed malaria was currently a serious issue in the region. This resurgence was associated with factors such as presence of mosquito breeding sites, lack of larval source management, poor and lack of

control measures in the recent years, lack of awareness/knowledge about (malaria transmission, common symptoms and prevention methods), seasonal variability, weakened health care system, climate change, absence of traditional methods used for larval source management, some socio-demographic and behavioral factors including age (older age above 14 years), male sex (male, due to outdoor occupational nature, travel history to malaria endemic areas without the use of protective methods), illiteracy, low income level, poor housing condition. The dominant *Plasmodium* species in the study area was *Plasmodium falciparum*. In general, finding of this study emphasizes on the increasing malaria positivity rates in Bonga town, where *Plasmodium falciparum* (dangerous parasite) was identified as the dominant parasite, this condition could increase a burden of potential life threatening conditions due to severe malaria complications such as cerebral malaria, severe anemia and others to the malaria patients. This is an alarm to the health care providers in the health facilities to have a close observation and monitoring of their malaria patients to take early measure before patients fall into severe condition.

5.2 Recommendations and Future Directions

The findings of this study underscore the urgent need to address the resurgence of malaria in Bonga town, Kaffa zone, Southwest Ethiopia. To revert this concerning trend and achieve substantial malaria burden reduction, a multifaceted approach targeting the identified contributing factors, such as seasonal variation, socio-demographic and behavioral factors, malaria history, vulnerable groups of population, strengthening the implementation of malaria control interventions, improving the healthcare system through increased healthcare worker availability, ensuring adequate medication supplies, and improving infrastructure and overcoming existing challenges is crucial to meet the national eradication goal and thereby contributing to the malaria elimination target by 2030. Also, the implementation strategies should be enhanced to ensure effective and equitable coverage of these core vector control measures. In addition, improving awareness and community engagement is critical as the study highlighted the need to develop culturally appropriate and targeted communication strategies to improve community awareness about malaria transmission, prevention, common symptoms and control. Mobilizing the community and providing information on malaria control strategies, including larval source management, can also contribute to the success of the control efforts. Also, addressing implementation challenges, such as solving the problem of resource limitations,

improving collaboration between stakeholders, enhancing surveillance and monitoring systems, addressing community concerns related to the interventional strategies should be taken as a top agenda by concerned health authorities. Furthermore, the specific reasons behind the decline in the control efforts in Bonga town and elsewhere should be investigated. Other determinants not covered by this study such as effect of expansion of urbanization, and resistance to insecticides or entomological factors, should be studied to gain a more comprehensive understanding of the driving force of malaria resurgence in the region.

Dissemination Plan

Findings of this study and recommendations will be shared with local health authorities, policymakers, and stakeholders in Bonga town to facilitate the implementation of effective malaria control strategies and based on advisor's interest, research article will be prepared for publication in peer-reviewed journals, targeting the field of public health, tropical medicine, or infectious diseases.

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Appendices (English version)

Questionnaire for cross-sectional study from (January – May, 2024 G.C)

Instruction: Fill the spaces provided below by selecting appropriate options according to the context of each questions and your perspective where appropriate.

Appendix 1: Socio-demographic and behavioral characteristics

1. Name of Participant: _____.
2. Age: _____ years. <5 / 5-14 / >14
3. Gender: (_____) Male / Female
4. Occupation: (_____) Farmer/ Merchant/ Student / Employed / Unemployed / Dependent
5. Type of house: (_____)
 - a. Poor house condition (house with poor ventilation, open roof, cracked wall, poor window screens)
 - b. Good house condition (house with well-sealed roof and wall, well-ventilated, good window screens)
6. Educational level: (_____) Illiterate / 1^{ry} school / 2^{ry} school / Diploma / BSc/BA / MSc/MA and above
7. Household income level: (_____) low(daily income <50 birr per person) / medium(daily income 50-200 birr per person) / High(daily income >200birr per person)
8. Residence (_____) 01kebele / 02 kebele / 03kebele
9. How many people live in your household? _____.
10. Bed net utilization:
 - a. Bed net distributed per household were sufficient (_____) Strongly agree / Agree / Neutral / Disagree / Strongly disagree
 - b. Do all family members are sleep under bed net? (_____) Yes / No
 - c. What do you do with old/repurposing bed nets?_____
11. Sleeping behavior: (_____) outdoor / Indoor / both

Appendix 2: Intervention Activities Questionnaire

1. Are you aware of any intervention activities implemented to control and prevent malaria in your village during 2024? (_____) Yes / No

2. If yes, please describe the time and type of intervention activities implemented:
_____.
3. How many insecticide-treated net did you get as household level in this year? _____.
4. Have you personally participated in any of intervention activities during 2010-2024? (_____) Yes / No
5. If yes, please describe your role or involvement in the intervention activities:
_____.
6. What challenges or limitations have you observed or experienced in implementing these intervention activities during study period? Please provide details:
_____.

Appendix 3: Malaria Parasite Species Questionnaire

Section 1: Malaria History

1. Have you traveled to malaria-endemic areas outside the study area during the period from 2010 to 2024? (_____) Yes / No
2. If yes, please provide details (e.g., countries visited, approximate dates):_____.

Section 2: Malaria Testing

1. Have you undergone malaria testing during the period from 2010 to 2024?
(_____) Yes / No
2. If yes, please provide details (e.g., number of tests conducted, approximate dates):
_____.
3. Which type of malaria testing method (s) used?
 - a. Microscopy (blood smear examination)
 - b. Rapid diagnostic test (RDT)
 - c. Polymerase chain reaction (PCR)
 - d. Other (please specify):_____.

Section 3: Malaria Parasite Species

1. Do you know the specific malaria parasite species you were infected with during the period from 2010 to 2024? (_____) Yes / No
2. If yes, please specify the malaria parasite species:_____.
3. Were you infected with multiple malaria parasite species simultaneously (mixed infection) during the period from 2010 to 2024? (_____) Yes / No
4. If yes, please specify the malaria parasite species involved in the mixed infection:_____.

Section 4: Symptoms and Treatment

1. Did you experience any symptoms of malaria during the period from 2010 to 2024? (_____) Yes / No
2. If yes, please describe the symptoms you experienced:_____.
3. By which type of drug your malaria infection treated?
 - a. Artemisinin-based combination therapy (ACT (coartem, artesunate))
 - b. Chloroquine
 - c. Quinine
 - d. Traditional/herbal remedies
 - e. No treatment received
4. Have you aware about the importance of completing the full course of antimalarial treatment, even if symptoms improve? (_____) Yes / No

Appendix 4: Larval source management

Section 1: General knowledge and practice

1. Was larval source management intervention carried out in your village during this year? (_____) Yes / No
2. If yes, how frequently was larval source management carried out?_____.

3. Please describe if educational sessions conducted to provide information on the importance of larval source management in this year alongside methods utilized to do so
_____.

Section 2: Traditional indigenous knowledge and practice

1. Were there any of traditional methods used by your community to control mosquito larvae and prevent malaria transmission during specified study period? (____) Yes / No
2. If yes, please describe the type of traditional methods used and time_____.
3. Were there any traditional practices in your community that focus on eliminating or modifying mosquito breeding sites during specified study period? (_____) Yes / No
4. Are you aware of any plants or plant extracts traditionally used in your community to control mosquito larvae? (_____) Yes / No
5. If yes, how were they implemented, and how effective do you believe these traditional larvicidal plants were in controlling mosquito larvae? Please describe, along with specific examples and time periods

_____.

6. Appendix 5: Knowledge and Awareness

1. Do you have knowledge about the transmission of malaria? (_____) Yes / No
2. Do you know how to properly use and maintain the bed net? (_____) Yes / No
3. Do you know the common symptoms of malaria? (_____) Yes / No

Appendix 6: Additional Comments

1. Please provide any additional comments or information related to your experience with malaria infection and parasite species during the period from 2010 to 2024:_____.

Thank you for your participation in this study! Your input is valuable in understanding the malaria resurgence and associated factors in the specified time period!

አባሪዎች (Amharic version- used for clarity of questionnaire for respondents)

ለዝህ ጥናት የምያስፈልጉ መጠይቆች

መመሪያ፡ ከዚህ በታች ያሉትን ጥያቄዎች በጥንቃቄ በማንበብ እንደየጥያቄዎቹ አውድ መሰረት ተስማምዉን አማራጮች በመምረጥ ባዶ ቦታዎችን ይሙሉ።

አባሪ 1፡- ሶሲዮዲሞግራፊ እና ተያያዥ ባህሪያት

1. የተሳታፊው ስም፡- _____ ።

2. ዕድሜ፡- _____ ዓመት ።

3. ጾታ፡- (_____) ወንድ / ሴት

4. ሥራ፡- (_____) ገበሬ / ነጋዴ / ተማሪ / ተቀጣሪ / ሥራ የለለዉ / ጥገኛ

5. የቤት ዓይነት፡- (_____)

ሀ. ምቹ ያልሆነ የቤት ሁኔታ (ምቹ ያልሆነ የአየር ማናፈሻ ፣ የተከፈተ ጣሪያ ፣ ቀዳዳ ያለበት ግድግዳ እና

ምቹ ያልሆኑ የመስኮች ስክሪኖች ያሉበት ቤት)

ለ. ጥሩ የቤት ሁኔታ (ጥሩ የአየር ማናፈሻ ፣ ጥሩ የመስኮች ስክሪኖች ፣ በደንብ የታሸገ ጣሪያ እና ግድግዳ ያለው ቤት)

6. የትምህርት ደረጃ፡ (_____) ያልተማረ / 1ኛ ደረጃ / 2ኛ ደረጃ / ዲፕሎማ / ድግሪ / ማስተርስ እና ከዚያ በላይ

7. መኖሪያ (_____) 01ቀበሌ / 02 ቀበሌ / 03ቀበሌ

8. የቤተሰብ አባላት መጠን በቁጥር? _____

9. የአጎበር አጠቃቀምን ከግንዛቤ በማስገባት የምከተሉትን ጥያቄዎች ይመልሱ፡-

ሀ. ከቤተሰብ አባላት አንዳንድ የተሰራጨዉ አጎበር በቂ ነበር (_____) በጣም እስማማለሁ / እስማማለሁ / ገለልተኛ / አልስማማም / በጣም አልስማማም

ለ. በቤታችሁ ዉስጥ ስንት አጎበር አለ? እባኩን ይግለጹ። _____

ሐ. ሁሉም የቤተሰብ አባላት በአጎበር ይጠቀማሉ? (_____) አዎ / አይ

መ. በአረጌ ዎይም እንደገና ጥቅም ላይ በሚውሉ አጎበር ምን ያደርጋሉ? እባኩትን ይግለጹ_____

11. ሌሊት ምያድሩበት ቦታ፡- (_____) ከቤት ውጭ / ቤት ውስጥ / ሁለቱም

አባሪ 2፡ የጣልቃ ገብነት ተግባራት መጠይቅ

1. በ2024 ወባን በመንደርዎ ለመቆጣጠር እና ለመከላከል የተደረጉትን ማንኛውንም ጣልቃገብነት ተግባራት ያውቃሉ? (_____) አዎ / አይ

2. አዎ ከሆነ፣ እባክዎ የተተገበሩትን የጣልቃ ገብነት ተግባራት ጊዜ እና አይነት ይግለጹ፡-

3. በቤተሰብ ደረጃ በዚህ አመት ምን ያህል አጎበር አግኝተዋል? እባክዎትን ይግለጹ _____ ።

4. ከ2010-2024 ባለው ጊዜ ውስጥ በማንኛውም የጣልቃ ገብነት ተግባራት እርስዎ ተሳትፈዋል? (_____)

አዎ / አይ

5. አዎ ከሆነ፣ እባክዎትን በጣልቃ ገብነት እንቅስቃሴዎች ውስጥ የነበረዎትን ሚና ወይም ተሳትፎ ይግለጹ፡

_____ ።

6. በተጠቀሰው በጥናት ግዜ ውስጥ እነዚህን የጣልቃ ገብነት ተግባራትን በምያከናውኑበት ወቅት ምን ተግዳሮቶችን ወይም እጥረቶችን ተመልክተዋል? እባክዎትን ይዘርዝሩ ፡-

_____ ።

አባሪ 3፡ የወባ ተዉሳክ ዝርያዎች መጠይቅ

ክፍል 1፡ የወባ ታሪክ

1. ከ2010 እስከ 2024 ባለው ጊዜ ውስጥ ከጥናት ቦታ ውጭ ወባ ወደሚገኝባቸው አካባቢዎች ህደዉ

ነበር? (_____) አዎ / አይ

2. አዎ ከሆነ፣ እባክዎትን የሄዱባቸውን አካባቢዎች እና ቀናት

ይግለጹ_____ ።

ክፍል 2፡ የወባ ምርመራ

1. ከ2010 እስከ 2024 ባለው ጊዜ ውስጥ የወባ ምርመራ አድርገዉ ያዉቃሉ?

(_____) አዎ / አይ

2. አዎ ከሆነ፣ እባክዎትን ዝርዝሩን ያስቀምጡ (ለምሳሌ :- ስንት ጊዜ ተመርምሯል ፣ መቼ) ፡

_____ ::

3. የወባ መመርመሪያ መሳርያ?

ሀ. ማይክሮስኮፕ

ለ. ፈጣን ምርመራ (RDT)

ሐ. የፖሊሜራዝ ሰንሰለት ምላሽ (PCR)

መ. ሌላ (እባክዎትን ይግለጹ _____ ::

ክፍል 3: የወባ ተውሳክ ዝርያዎች

1. ከ 2010 እስከ 2024 ባለው ጊዜ ውስጥ የተያዙባቸውን የወባ ተውሳክ ዝርያዎች ያውቃሉ? (_____)
አዎ / አይ

2. አዎ ከሆነ፣ እባክዎትን የወባ ተውሳክ ዝርያውን ይግለጹ፡ _____ ::

3. ከ2010 እስከ 2024 ባለው ጊዜ ውስጥ የወባ ተውሳክ ዝርያዎች ቅልቅል ኢንፌክሽን አጋጥሞዎት ያዉቃል? (_____) አዎ / አይ

4. አዎ ከሆነ፣ እባክዎትን በቅልቅል ኢንፌክሽን ውስጥ የተካተቱትን የወባ ተውሳክ ዝርያዎች ይግለጹ፡-

ክፍል 4: ምልክቶች እና ህክምና

1. ከ2010 እስከ 2024 ባለው ጊዜ ውስጥ የወባ በሽታ ምልክቶች ታይተዉበት ያዉቃል? (_____) አዎ / አይ

2. አዎ ከሆነ፣ እባክዎትን ያጋጠሙዎትን ምልክቶች ይዘርዝሩ _____ ::

3. በወባ በሽታ ስታመሙ በየትኛው መድሃኒት ነዉ የታከሙት?

ሀ. በአርቴሚሲንን ላይ የተመሰረተ ጥምር ሕክምና (ACT)

ለ. ክሎሮኩዊን

ሐ. ኩዊንን

መ. በባህላዊ መድኃኒቶች

ሠ. ምንም አይነት ህክምና አልተደረገም

4. የበሽታ ምልክቶች ቢሻሻሉም የፀረ ወባ ሕክምናን ሙሉ ኮርስ ማጠናቀቅ አስፈላጊ ወይም ግዴታ መሆኑን ያውቃሉ? (_____) አዎ / አይ

አባሪ 4፡ የእጭ ምንጭ ቁጥጥር መጠይቅ

ክፍል 1፡ ነባራዊ እውቀት እና ልምድ

1. በዚህ አመት ውስጥ የእጭ ምንጭ ቁጥጥር ጣልቃ ገብነት ሥራ በእርስዎ መንደር ውስጥ ተካሂዷል? (_____) አዎ / አይ

2. አዎ ከሆነ፣ ምን ያህል ጊዜ ተካሂዷል? እባክዎትን ይግለፁ፡

_____ ::

3. በዚህ አመት ውስጥ ስለ እጭ ምንጭ የግንዛቤ ማስጨበጫ ስራዎች ካሉ እባክዎትን ከተጠቀሙባቸው ዘዴዎች ጋር ያብራሩ፡ _____ ::

ክፍል 2፡ ባህላዊ አገር በቀል እውቀት እና ልምድ

1. በዝህ የጥናት ጊዜ ውስጥ የወባ ትንኞችን ለመቆጣጠር እና የወባ ስርጭትን ለመከላከል ማህበረሰብዎ የተጠቀሙባቸው ባህላዊ ዘዴዎች ነበሩ? (_____) አዎ / አይ

2. አዎ ከሆነ፣ እባክዎትን የተጠቀሙባቸውን ባህላዊ ዘዴዎች አይነት እና ጊዜ ያብራሩ፡

_____ ::

3. በማህበረሰብዎ ውስጥ የወባ ትንኝ መራቢያ ቦታዎችን በማጥፋት ወይም በማሻሻል ላይ የሚያተኩሩ ልማዳዊ ድርጊቶች ነበሩ? (_____) አዎ / አይ

4. የወባ ትንኝ እጮችን ለመቆጣጠር በማህበረሰብዎ ውስጥ በባህላዊ መንገድ ጥቅም ላይ የሚውሉትን የእፅዋት ወይም የእፅዋት ተዋጽኦዎችን ያውቃሉ? (_____) አዎ / አይ

5. አዎ ከሆነ፣ እንዴት ነው ምትገበሩት? እነዚህ ተክሎች የወባ ትንኝ እጮችን በመቆጣጠር ረገድ ምን ያህል ውጤታማ ናቸው ብለው ያምናሉ? እባክዎትን ምሳሌዎችን ከነ ግዜ ይጥቀሱ _____ ::

6. በማህበረሰብዎ የወባ ትንኝ እጮችን ለመቆጣጠር የሚጠቀሙባቸው የተፈጥሮ ነፍሳቶች አሉ? (_____)

አዎ / አይ

7. አዎ ከሆነ፣ እባክዎትን የእነዚህን ነፍሳት ምሳሌዎች፣ጊዜ እና ወደ ትንሻ መራቢያ ቦታዎች እንዴት እንደምያስገቡ ይግለጹ_____ ::

አባሪ 5፡ እውቀት እና ግንዛቤ

1. ስለ ወባ ስርጭት እውቅ አለዎት? (_____) አዎ / አይ

2. አጎበሩን በትክክል መጠቀም እና በአግባቡ እንዴት እንደምያዝ ያውቃሉ? (_____)

አዎ / አይ

3. የተለመዱ የወባ ምልክቶችን ያውቃሉ? (_____) አዎ / አይ

አባሪ 6፡ ተጨማሪ አስተያየቶች

1. እባክዎትን ከ2010 እስከ 2024 ባለው ጊዜ ውስጥ ከወባ ኢንፌክሽን እና ተዉሳክ ጋር በተያያዘ ያላችሁን ተጨማሪ አስተያየት ወይም መረጃ ይስጡ።

_____ ::

በዚህ ጥናት ተሳታፊ ስለሆኑ እናመሰግናለን! በተጠቀሰው ጊዜ ውስጥ የወባ መነቃቃትን (መልሶ መከሰትን) እና ተያያዥ ምክንያቶችን ለመረዳት የእርስዎ ተሳትፎ አስተዋፅኦ አለዉ !