TRENDS OF MALARIA INCIDENCE AND THE EFFECT OF VECTOR CONTROL COVERAGE IN MARULENG MUNICIPALITY FROM 2013 TO 2019

By

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DECLARATION

I, Seboke Rebecca Letsoalo, hereby declare that mini dissertation titled **"Trends of Malaria incidence and the effect of vector control coverage in Maruleng Municipality from 2013 to 2019"** hereby submitted to the University of Venda, School of Health Sciences, higher degree Committee has not been submitted before for any degree or examination at this or any other University; and that it is my own work in design and execution; and that all material contained herein has been duly acknowledged.

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LIST OF ACRONYMS

ACT	Artemisinin Combination Therapy
CI	Confidence interval
CFR	Case fatality rate
DDT	Dichlorodiphenyltrichloroethane
DDD	Dichlorodiphenyltrichloroethane
DALYs	Disability-adjusted life years
DOH	Department of Health
EDPT	Early Case Detection and Prompt Treatment
EHPs	Environmental Health Practitioners
IRS	Indoor Residual spraying
IMIS	Integrated malaria information system
ITN	Insecticide-treated mosquito nets
LLINs	Long-lasting insecticidal nets
NDOH	National Department of Health
NICD	National Institute for Communicable Disease
UHDC	University Higher Degree Committee
WHO	World Health Organization

ABSTRACT

Malaria remains a critical global health concern, and South Africa is not an exception. Malaria contributed to human morbidity, mortality, and economic adversity since time immemorial. It exacts an unacceptable toll on the health of people. This study sought to determine the trends of malaria incidence and effects of vector control coverage in Maruleng Municipality. The study adopted a descriptive retrospective quantitative research design using all malaria cases that have occurred and recorded in Maruleng Municipality from 2013 to 2019. Data were analysed using Statistical Package for Social Scientist (SPSS version 24.0) and the findings were present in frequencies, percentages, pie charts, and graphs. Cross-tabulation and chi-square were employed as statistical tests to verify association between variables. A total of 874 malaria cases and 15 deaths were reported within five years. The study established that Maruleng Municipality is an escalating malaria-risk area since2012-17. However, there was a significantly sharp decrease in malaria morbidity and mortality in 2018 compared to the previous years of the study. The decline was credited to indoor residual spraying (IRS). The Chi-squared test was used to calculate differences in incidence rate and CFR between both sexes and age incidence. Therefore, the study established an association between malaria incidences and biographical information. Malaria incidence was high among males than females and between 0-10 and 21-30 years were the most people at risk. The study concluded that the low death rate and varying morbidity might have been caused by different levels of vector control coverage (IRS) and interventions in different localities. The study noted two insecticides used during the IRS and recommend a holistic approach that includes a combination of other control interventions. These results highlight the need to continue with current control strategies such as IRS until interruption in local malaria transmission is completely achieved and alternative control strategies implemented.

Keywords: Incidence, Indoor residual spraying, Malaria, Mortality, Morbidity, Prevalence, Trends, Vector control.

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CHAPTER 1

INTRODUCTION AND BACKGROUND TO THE STUDY

1.1. Introduction

Malaria is one of the epidemics that the United Nations (UN) aims to end by 2030(UN, 2021). It is a disease caused by a plasmodium parasite, transmitted by infected mosquito bites. The severity of malaria varies and are determined by the species of plasmodium. Symptoms include chills, fever, and sweating, usually occurring a few weeks after the mosquito bite. In South Africa, malaria is mainly transmitted along the border areas of Limpopo, Mpumalanga and KwaZulu Natal putting at least 10% of the population (approximately 4.9 million persons) at risk of contracting the disease. However, malaria transmission is seasonal in South Africa, malaria cases rising in October, peak in January and February, and wan towards May (DOH, 2018). People travelling malaria prevalent areas typically take preventative drugs before, during and after their trip. Treatment includes antimalarial drugs. This section presents the background, the problem statement, the rationale, purpose and objectives, research questions, significance, and definitions of key concepts of the study.

1.2 Background to the study

Malaria remains the current critical global health challenge and South Africa is not exempted. The impact of seasonal and unsafe malaria transmission is seen particularly in the northern part of the country where Limpopo is situated. More than 80% of these cases are projected to occur in sub-Saharan Africa, particularly in remote rural areas with poor access to health services (WHO, 2010). In 2013 there were 198 million cases and 584 000 deaths from Malaria (WHO, 2014).

The World Malaria Report 2010 noted that malaria global prevalence was estimated at 225 million cases and 781 000 deaths (WHO 2010**).** More than a third (36%) of the world's population live in malaria-endemic areas and one billion people are estimated to carry parasites at any one time, while some three billion are estimated to live in areas at risk of malaria transmission in 109 countries (WHO 2010). In 2000, by estimation malaria contributed to the loss of nearly 45 million disability-adjusted life years (DALYs), representing about 13% of all infectious diseases (WHO 2010). However, accurately assessing the burden of malaria is a challenge in sub-Saharan Africa because most deaths occur at home. The clinical features of malaria are very like other infectious diseases and the lack of facilities for accurate diagnosis (WHO 2008). Despite these limitations, sub-Saharan Africa bears the brunt of the disease, with at least one million malaria deaths each year (90% of all cases), mainly from *P. falciparum* (WHO 2008).

Per the National Department of Health malaria policy of 2006, South Africa is not excluded from the danger of seasonal and unbalanced malaria, affecting 10% of the population living in malaria-endemic areas [NDoH, 2006]. In South Africa, malaria was limited to the north-eastern border areas, which include Mpumalanga, Limpopo, and KwaZulu-Natal provinces, with over 90% of *P. falciparum*, mainly transmitted by *Anarabiensis* [NDoH 2006]. Recently Waterberg reported malaria outbreaks in the past year.

March 2016 Limpopo Department of Health monthly report highlighted a malaria incidence increase; Mopani district was severely affected with 253 cases, while 101 of cases were reported in Ba-Phalaborwa and 232 were reported in the Greater Giyani. Maruleng Municipality is one of the sub-districts of the Mopani district Municipality, reported a malaria outbreak that in January 2016 where 2 people died (DoH, 2016).

The entire Province of Limpopo was at risk of malaria infections over a period of 65 years. The department of health successfully dealt with malaria in the eastern and northern areas of Mopani district which include Maruleng Municipality. Sustainable Malaria Control interventions per the Global Malaria control strategy (DoH, 2010). Maruleng Municipality has an outbreak response team based at Sekororo District Hospital. Due to limited financial support, the government only use the indoor residual spraying vector as a control method. Maruleng Municipality outbreak response team organise malaria awareness campaigns quarterly and whenever an outbreak occurs, which include Environmental Health Practitioners to educate the community about malaria.

The Limpopo Province department of health has malaria control programmes, to achieve a considerable decrease in Malaria incidence. The program includes:

- Early Case Detection and Prompt Treatment (EDPT)
- Vector control
- Biological control
- Personal Prophylactic Measures

1.3 Problem Statement

Despite the development and implementation of malaria control programmes, malaria remains a public health concern in South Africa. During 2014/2015, 991 malaria cases were reported at various Health Centres around Maruleng, among which 64 deaths occurred. This shows a significant increase in malaria incidence compared to 529 cases reported during 2012/2013 (DoH, 2014). The researcher noted that village community members are reluctant to use the indoor residual spraying chemicals provided by the Department of Health seasonally, because they opt for traditional methods. From the researcher's observation, Environmental Health Practitioners are denied access to most privately-owned properties like farms and lodges around Maruleng Municipality during malaria awareness campaigns. Thus, most farm communities do not receive any malaria-related health education.

Sekororo Hospital Malaria investigation task team reported of that in some cases, community members report to the Health Care Centres at a very critical stage, and some die upon arrival, where medical examinations confirm Malaria incidents. Therefore, the researcher assumed that Maruleng communities might not be fully aware of the significance of malaria control interventions due to the prevalence of late hospital visits/consultations among malaria patients. It is in this light that the researcher sought to investigate trends of malaria incidences in Maruleng.

1.4 Rationale of the Study

The scarcity and/or lack of information and studies investigating malaria-related incidence trends in Maruleng; the increasing malaria prevalence in Maruleng Municipality motivated the researcher to conduct this study.

1.5 The main purpose of the study

The sought to determine the trends of Malaria incidence and effects of vector control coverage in Maruleng Municipality.

1.6 Objectives of the study

This study had two objectives

- To assess the trends of malaria incidence in Maruleng Municipality
- To describe the effects of vector control in Maruleng Municipality

1.7 Research questions

This study attempted to answer the following questions:

- What are the trends of malaria incidence in Maruleng Municipality?
- What is the effect of vector control coverage in Maruleng Municipality?

1.8 Significance of the study

Maruleng municipality committed to reviving malaria control and move toward elimination. Therefore, this study might equip the Maruleng Municipality with relevant information to achieve its commitment. The findings might assist Maruleng Municipality and Limpopo province Department of Health to develop new malaria control policies, review existing strategies and programs to improve the management of malaria within the region. This will benefit Maruleng Municipal community and farm dwellers. It will also contribute to the body of knowledge on the burden of Malaria and contributing factors towards malaria prevalence. This information will help alleviate Malaria-related burden on the Municipality because it is mandated to provide the basis for the necessary interventions. These findings will also help Maruleng Environmental Health Practitioners to demonstrate and prove the importance of malaria vector control to the community.

1.9 Definition of key concepts

- **Malaria vector control:** is any method to limit or eradicate the mosquito which transmits disease pathogens and cause malaria, it focuses on preventative methods to control or eliminate the vector population (Webber, 1996). In this study, malaria vector control involves provision of insecticide-treated nets and indoor residual spraying and its essence as it targets mosquitoes capable of transmitting malaria.
- **Effect:** is any deviation in the normal function due to external agents or stimuli (www.buisnessdictionary.com). According to this study, effect is the power of indoor residual spraying to produce an outcome or achieve results or even the combined effect produced by the action of preventative measures placed in a place.

- **Trends:** is a general direction of change or a way of behaving, preceding that is developing and becoming more common around the same area or location or population and a pattern of gradual change in a condition, output, or process. (www.buisnessdictionary.com). In this study, trends are patterns in which cases occur overtime in the Maruleng

- **Trends of malaria incidence:** is the general direction of the way of behaving, preceding that is developing and becoming more common around the same area or population of life-threatening mosquito-borne infectious disease which is annually diagnosis rates of new cases. (Webber 1996). In this study, trends of malaria incidence are the direction or the way the incidence constantly becomes common around the area and are reported and confirmed after tests

- **Effect of vector control coverage:** is the ability of vector control coverage to influence Malaria incidence by producing results desired by control measures which are the reduction of incidence. (Webber 1996). In this study, effect of vector control coverage is the ability of indoor residual spraying and insecticides treated nets to be significant and term to reduce the number of cases desired by preventative measures.

CHAPTER 2

LITERATURE REVIEW

2.1 Introductions

A literature review discusses published information in a subject area and sometimes information in a subject area within a certain time. Literature review can be just a simple summary of sources. A literature review is an evaluative report of studies found in the literature related to the selected area one wishes to pursue. The review should describe, summarise, evaluate, and clarify this literature. It should give a theoretical basis for the research and help one determine the nature of own research. The literature review goes beyond the search for information and includes the identification and articulation of relationships between the literature and the field of research (Jesson, Matheson &Lacey 2011).

This study consists of database literature review and its purpose is to cover a wide range of issues about trends of malaria incidence and vector control. This section also highlights the global, continental, national, provincial approaches to trends of malaria incidence and vector control. This section provides a discussion on existing studies related to trends of malaria and vector control as a phenomenon. The history of malaria is also included (Jesson, Matheson &Lacey 2011).

2.2 Trends of Malaria incidence

2.2.1. Globally

Malaria globally has plagued humanity throughout history and remains one of the major challenges to global health in terms of morbidity and mortality. According to the latest estimation from WHO (2015), there were 214 million new malaria cases worldwide. The African region accounted for most global cases (88%) followed by the South-East Asia region with 10% and the Eastern Mediterranean region with 2%. In 2015 there were 438 000 malaria deaths worldwide and most of these deaths occurred in the African region with 90%, followed by the South-East Asia region with 7% and the Eastern Mediterranean region with 3% (WHO, 2015). However, between 2000 and 2015, malaria incidence rates (new cases) fell by 37% globally, and by 42% in Africa. During the same period, malaria mortality rates fell by 60% globally and 66% in Africa. Children under five are particularly susceptible to malaria infection and death. In 2015, malaria killed an estimated 306000 under-fives globally; these include 292 000 children in the African region.

During the same period, however, the mortality rate amongst children under five fell by 65% worldwide and by 71% in Africa (WHO, 2015)

2.2.2 Sub-Saharan Africa

Sub-Saharan Africa is a major site of malaria transmission due to its geographical location in the tropic zone (WHO, 2015). The tropical areas have large amounts of rainfall, creating vast breeding grounds to allow the development of egg to larvae to pupae to adult. The warm climate of sub-Saharan Africa allows the rapid development of the parasitic growth cycle. The warm temperature condenses the length of parasite development, permitting rapid transmission. Additionally, due to the warm climate, many sub-Saharans sleep outside during good weather more often, allowing the potential to be bitten to increase substantially. This is especially the case among agricultural workers who often sleep near fields during the harvest without protecting insecticide bed nets (WHO, 2015). The World Health Organisation annual report of 2015 that Malaria in Sub-Saharan Africa has affected the lives of almost all people living in Africa, defined by the southern fringes of the Sahara Desert in the north and latitude of about 28° in the south. Most people at risk of the disease live in areas of relatively stable malaria transmission – infection is common and occurs with enough frequency that some level of immunity develop (WHO 2015). Despite major progress in the fight against malaria, the mosquito-borne disease remains an acute public health problem in Sub-Saharan Africa, home to 90% of the world's malaria cases(WHO2015).

2.2.3 South Africa

Approximately 4.9 million (10%) of South Africa's total population are contracting malaria. Limpopo, Kwa-Zulu Natal and Mpumalanga account for more cases; however, recently, it was reported that Waterberg District registered 54 cases of malaria, and after investigations, it was established that those cases were not inherited but originated from that district. (NDoH, 2016). Malaria is a notifiable disease in South Africa, and *Plasmodium falciparum* accounts for most malaria cases in southern Africa and is the predominant species associated with a severe and fatal disease. Almost all South Africans lack acquired immunity, including residents of seasonal malaria transmission areas, and are, therefore, at risk for developing severe malaria.

Malaria occurs in limited areas in South Africa, mainly in the low altitude (below 1000m) areas of Limpopo, Mpumalanga and North-Eastern KwaZulu-Natal. Limited focal transmission may occasionally occur in the North-West and Northern Cape provinces along the Orange River. South

Africa is not exempt from seasonal and unstable malaria transmission, particularly in the northern and eastern parts of the country (WHO, 2010).

Large-scale malaria control operations based on house-spraying with DDT (dichlorodiphenyltrichloroethane) were initiated in South Africa during the 1940s leading to a decline in malaria transmission in large parts of the country and elimination of the major malaria vectors *Anopheles funestus* and *Anopheles gambiae*. (WHO, 2010). In South Africa, malaria transmission is seasonal and restricted to the north-eastern border areas with Mozambique, Swaziland and Zimbabwe. Malaria is endemic in the Lowveld of Mpumalanga and in Limpopo (including the Kruger Park and private game reserves, which make these provinces so popular with favourable climate). In Kwa-Zulu Natal, malaria is endemic on the coast. So, if you are travelling to the far north of South Africa, please consult a healthcare professional for the latest advice on malaria prophylaxis as it changes regularly.

2.2.4 Limpopo

Historically, the entire Limpopo Province was at risk of Malaria. Through targeted and sustainable Malaria Control interventions over 65 years, malaria is now restricted to the eastern & northern low-lying areas of the Mopani & Vhembe districts. These areas are prone to frequent explosive epidemics during the summer rainy season. Southern Sekhukhune and western Waterberg areas are also prone to low-intensity focal outbreaks during the summer rainy season (NDOH 2013).

Malaria is viewed as a priority disease in Limpopo due to its potential to cause outbreaks with high morbidity and mortality. Malaria is endemic in the low-altitude areas of the northern and eastern parts of Limpopo along the border with Mozambique and Zimbabwe. Malaria transmission is distinctly seasonal, with transmission limited to the warm and rainy summer months (September to May); hence malaria is unstable and epidemic-prone. These seasonal epidemics are mostly because of favourable climatic conditions, including floods and droughts, which are conducive to mosquito breeding and parasite development Increase in malaria drug resistance and movement of people between risk areas and control areas are also major contributing factors to increased malaria transmission (WHO, 2010)

A major threat to the success of the Limpopo malaria control programmes is the lack of control activities across country borders of Zimbabwe and Mozambique. The main Malaria Control Intervention is the indoor residual spraying programmes. This activity is carried out by malaria spray teams, divided into geographical areas called sectors. The malaria control programmes have 42 malaria teams that are responsible for spraying more than 955,000 structures each year.

The spraying of houses with residual insecticides has successfully reduced the prevalence of malaria vector mosquitoes (SAIMR, 2010).

Risk areas to be included for indoor residual spraying are determined through entomological and epidemiological data. The indoor residual spraying programmes in Limpopo are one of the most successful disease prevention programmes operational at the community level. As all community members are at equal risk of contracting malaria, this intervention provides appropriate protection at this level. The Malaria control is managed by the Provincial Malaria Control unit, based in Tzaneen (DoH, 2015).

It was reported in times live March 2017 that the National Institute for Communicable Disease (NICD) posted an alert to areas which include Vhembe and Mopani districts in Limpopo in addition to farms along the Lephalale River in Waterberg and Bushbuckridge in Mpumalanga, it was also reported that it has been busy 2017 malaria season in the Southern region which peaked in April and May and extended into June. High rainfall, humidity and the ambient temperature had provided ideal conditions for malaria mosquito breeding. (https://www.timeslive.co.za). Risk area around South Africa and other neighbouring countries: Refer to the map below.

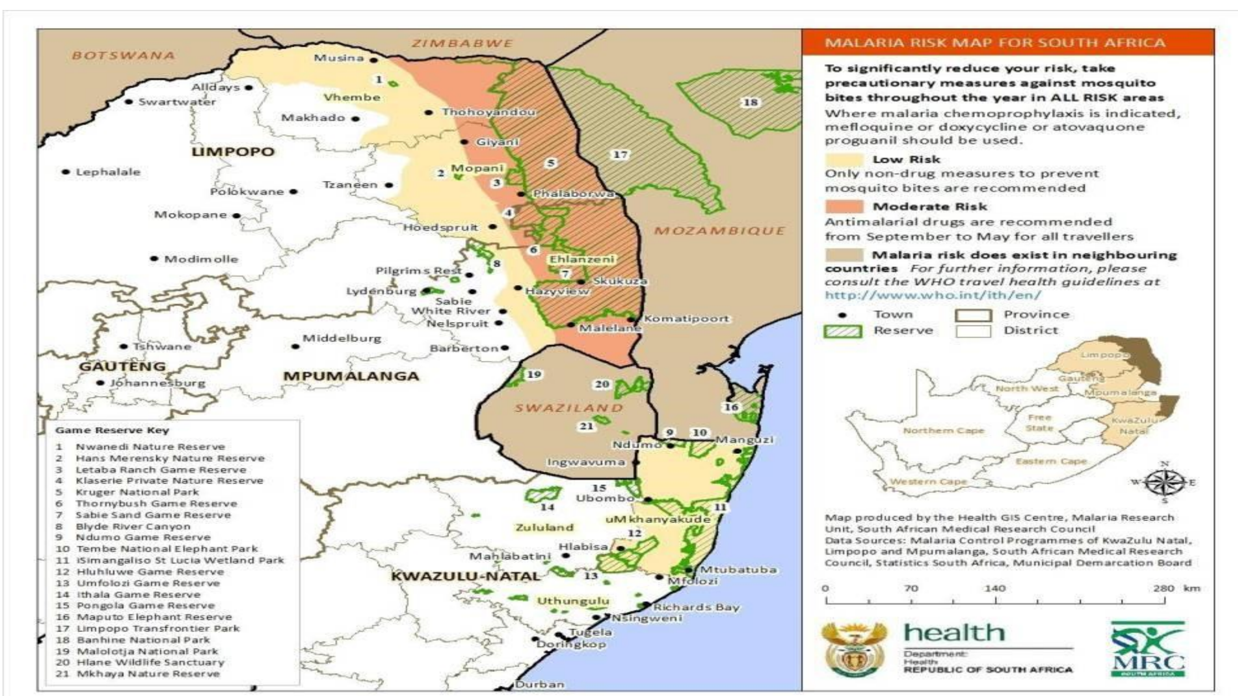


Figure 1: Malaria risk map for South Africa (MRC 2014)

2.3 Vector control

Vector control is the main way to reduce malaria transmission at the community level. It is the only intervention that can reduce malaria transmission from very high levels to zero. For individuals, personal protection against mosquito bites represents the first line of defence for malaria prevention. Antimalarial medicines can also be used to prevent malaria. Maniefisch (2015) reported that for travellers, malaria could be prevented through chemoprophylaxis, which suppresses the blood stage of malaria infections, thereby preventing malaria disease.

In addition, WHO (2014) recommends intermittent preventive treatment with sulfadoxine-pyrimethamine for pregnant women living in high transmission areas at each scheduled antenatal visit after the first trimester. Similarly, for infants living in high-transmission areas of Africa, 3 doses of intermittent preventive treatment with sulfadoxine-pyrimethamine are recommended delivered alongside routine vaccinations.

Fuckig and Ludwig (2017) attested that in 2012, WHO recommended Seasonal Malaria Chemoprevention as an additional malaria prevention strategy for areas of the Sahel sub-Region of Africa. The strategy involves the administration of monthly courses of amodiaquine plus sulfadoxine-pyrimethamine to all children less than 5 years of age during the high transmission season. The selection of the actual interventions to be made in any area should be based on its ecological and epidemiological characteristics, which may determine the effectiveness of potential interventions, and secondly on the socio-political and economic situation, which may determine whether they can be applied correctly and whether the results achieved can be maintained.

2.3.1 Current malaria control strategies

The Global Malaria Control Strategy, as adopted by the Ministerial Conference in 2013, consists of the following four basic technical elements (WHO, 2013):

- Early diagnosis and prompt treatment
- Planning and implementing selective and sustainable preventive measures including vector control
- Detecting epidemics at an early stage and containing or preventing them
- Regular assessment of a country's malaria situation, and, the ecological, social and economic determinants of the disease

Chaccour and Killeen (2016) established that making “disease diagnosis and treatment” the first general priority is based primarily on the fundamental obligation of health services to provide care for the sick. Thus, based on the extension of health services to the periphery to provide the required infrastructure for channelling the health information and education needed to improve the use of personal protection measures and eventually to deploy any new technology which may be suitable for general application, whether a vaccine or a sustainable method of vector control’s preventing mortality and reducing incapacity when it is clear that eradication is not feasible in the short term. Coulibaly (2014) established that it is also based on the extension of health services to the periphery to provide the required infrastructure for channelling the health information and education needed to improve the use of personal protection measures and eventually to deploy any new technology which may be suitable for general application, whether a vaccine or a sustainable method of vector control.

2.3.2 Available vector control methods and their classification

Maniefisch (2015) revealed that vector control methods could be classified differently for different purposes. From an epidemiological point of view, it may be advisable to classify vector control methods according to the principal effect obtained and, therefore, the link in the chain of transmission most directly affected by their application. Such a classification may be useful in the selection of a control method:

2.3.2.1 Methods of reducing human-vector contact

This category covers all methods in which a barrier is established between vectors and humans and includes the following:

- **Mosquito nets and insecticide-treated mosquito nets.**

Although untreated mosquito nets have a long history of use in controlling malaria transmission, the introduction of net treatment with pyrethroid insecticides of residual action has considerably increased their effectiveness by adding to the barrier effect of the net the repellent and killing action of the insecticide.

- **House protection with a screening of windows, eaves and doors.**

This is an effective method if properly implemented and maintained. It remains almost exclusively a method of individual and family protection since it requires a high investment and has high care and maintenance costs.

- **Use of repellents.**

These may be applied directly on the skin (as a cream, lotion or aerosol) or clothes. The use of repellents is also only a measure of individual protection that can be recommended as a complement to the use of bed nets and house protection methods, to be used after dark before retiring under the mosquito net or by people who should stay outdoors during some part of the night.

- **Fumigant insecticide dispensers.**

These are widely used throughout the tropics for individual protection, particularly in the form of mosquito coils and, in urban areas, electrically heated dispense

2.3.2.2 Methods aimed mainly at reducing vector density

Oxborough (2015) found that it is well recognised that the impact of vector control on the transmission potential (reproduction rate, vectorially capacity) is directly proportional to the reduction of the vector density. Nevertheless, in most endemic areas, reproduction rates are greatly more than those required to maintain transmission; huge reductions in density may be required to achieve effective control. These methods include all forms of larval control, as described below:

- **Source reduction by environmental management.**

This includes drainage, flushing, filling, and rendering river and lake margins unsuitable for *anopheline* breeding. These are the classical methods of malaria sanitation, which may be used for all mosquito breeding in general or targeted to the specific breeding places of malaria vectors of local importance (the so-called species sanitation), which requires, as previously mentioned, a thorough knowledge of the bionomics of the local vectors (Ranson &Lissenden, 2016). In general, these methods have relatively high investment costs and maybe cost-effective only in urban areas or some types of development projects. They are suitable for eliminating permanent breeding places, the importance of which should be assessed before embarking on the expensive process of eliminating them. Nevertheless, when properly executed and maintained, their sustainability is relatively easy.

Environmental management methods should be seriously considered in agricultural production systems and urban settings in certain areas. Moreover, in a fully artificial environment, environmental management should be the first line of defence in reducing malaria transmission risks. There is a clear link between the environmental conditions created by certain agricultural practices and the risks of vector-borne disease transmission. Irrigation in its different forms, crop selection and possibly crop rotation, together with chemical inputs into the agricultural production process, can all have an impact on these risks(Kone, 2015)

By the nature of their work, farmers are involved in environmental management on a daily basis daily and can play a crucial role in reducing them. A clear understanding of agricultural production systems where malaria transmission takes place is therefore essential in considering possible changes in such systems and in selecting right personnel (often agricultural extension workers) to ensure that farming communities take the necessary health-oriented environmental management measures.

- **Larviciding.**

This includes the use both of chemical insecticides and those of biological origin, such as the toxin of *Bacilusthuringiensisisraelensis* and insect growth regulators. It requires the treatment of all breeding places and may present the same problems as source reduction when temporary breeding places are of great epidemiological importance. In contrast to sanitation methods, larvicides normally have a little residual effect and require regular and frequent applications.

- **Biological control.**

For *anophelines,* this is practically limited to predators (mainly larvivorous fish), which are most effective in artificial breeding sites (ponds, cisterns or irrigation systems). Although such predators suffer from the same problems of coverage as all the other anti-larval measures, they may become established in a more permanent form. However, as with most natural interacting populations, they will tend to establish an equilibrium with their prey, which will have to be disturbed by frequent seeding of the predator or pathogen concerned.

- **Space spraying of insecticides.**

Although itsmain effect is a rapid reduction of vector density, when applied at relatively short intervals (less than the duration of the sporogonic cycle), the resulting increase in adult mosquito mortality will, if the required coverage can be achieved, rapidly reduce transmission. Space spraying has been extensively used for controlling epidemics of mosquito-borne diseases such as dengue and some types of encephalitis.

It has occasionally been used in malaria epidemic control and as a complementary measure against exophilic vectors. Its main limitation is the difficulty of applying them at night when vectors are flying, and the poor penetration of insecticide fogs into the daytime resting places of the vectors. In addition, it may be difficult to mobiliseall the necessary resources for space spraying before the epidemic declines naturally.

2.3.2.3 Methods aimed mainly at increasing adult vector.

Mortality increasing adult vector mortality reduces their expectation of life and, therefore, the probability that the parasite will complete its development. Although density will usually also be reduced, the reduction in the daily survival of the vector has a disproportionately greater impact on transmission. The two methods available for increasing adult vector mortality are described below.

- **Indoor residual spraying.**

Indoor residual spraying (IRS) with insecticides is a powerful way to reduce malaria transmission rapidly. Its full potential is realised when at least 80% of houses in targeted areas are sprayed. Indoor spraying is effective for 3–6 months, depending on the insecticide used and the type of surface on which it is sprayed. DDT can be effective for 9–12 months in some cases. Longer-lasting forms of existing IRS insecticides and new classes of insecticides for use in IRS programmes are under development.

This includes all methods of indoor spraying with residual insecticides, thus targeting the killing effect to house resting vectors and constituting a most efficient way of using the insecticide to kill vectors likely to transmit malaria. Although pyrethrum was the insecticide first used, indoor spraying of insecticides became the most popular method of malaria vector control with the introduction of DDT and other residual insecticides. Its main limitation is that exophilic vectors may exist and may not come into contact with sprayed surfaces. In addition, this behavioural trait may be selected due to the insecticide treatment.

- **Community-wide use of Insecticide-treated mosquito nets (ITNs)**

Long-lasting insecticidal nets (LLINs) are the preferred form of ITNs for public health distribution programmes. WHO recommends coverage for all at-risk persons; and in most settings. The most cost-effective way to achieve this is through the provision of free LLINs so that everyone sleeps under an LLIN every night. When insecticide-treated nets protect a large proportion of the population in a community, there may be a significant reduction of vector survival, density and sporozoite rate (“mass impact”) and hence of malaria transmission and a corresponding increase in community protection.

2.3.3. The role of vector control in the strategy of malaria control

As the second basic element of the Global Malaria Control Strategy, selective application of transmission control measures must be considered wherever malaria is endemic. Since no method of active immunisation is available and mass chemotherapy has very limited application, the only way of controlling transmission is usually that provided by the various vector control methods.

The WHO Study Group on Vector Control for Malaria and other Mosquito-borne Diseases (WHO, 1995) defined selective vector control as the application of targeted, site-specific control activities that are cost-effective. The principal objective of vector control is the reduction of malaria morbidity and mortality by reducing the levels of transmission.

The Study Group further defined selective vector control as the selective use of one or more of the available control methods, the decision-makers have considered:

- The disease status and risks to decide on the needs and priorities of vector control
- The vector, human behaviour, and the environment to determine which vector control methods are suitable and where they are needed
- The resources available to implement action

Vector control methods vary considerably in their applicability and cost and the sustainability of their results. While the control of transmission will be of some benefit whatever the situation, the choice of vector control will depend on the magnitude of the malaria burden, the feasibility of timely and correct application of the required interventions and, most important of all, the possibility of sustaining the resulting modified epidemiological situation.

Vector control is undoubtedly necessary to prevent an epidemic when the conditions leading to a sudden increase in transmission or human exposure have been detected in an epidemic-prone area. Nevertheless, in an attempt to reduce the vectorial capacity in an endemic area, it is necessary to consider the sustainability of the resulting change in endemicity. Most vector control operations will have a significant and obvious impact on the malaria burden of the population concerned.

However, suppose the unfavourable ecological or social conditions persist. In that case, unfavourable the discontinuation of vector control may, because of the decreased immunity of the population, result in an epidemic return of transmission, and the longer the controlled situation has been artificially maintained, the more severe will the impact be.

2.3.4. The role of the entomologist in malaria vector control

Entomological surveillance is a fundamentally important activity in a malaria vector control programme. Without skilled entomological support, analysis and decision making for IRS, particularly in terms of IRM, is impossible. Therefore, there is a need for the national and provincial malaria control programs to develop capacity within this field.

Malaria entomologists provide guidance and support to malaria vector control programmes. They should participate in the planning, implementation, monitoring and evaluation of the programme.

The skills required for adequate entomological surveillance include mosquito sampling in the field, species identification using morphological and molecular methods, vector incrimination using immunological methods, and insecticide susceptibility testing using standard biological (bioassay) techniques. Follow-up operational research activities and specialized diagnostics involve more techniques that a specialist laboratory usually understand (WHO 2012.).

2.3.5. Indications for vector control

- Prevention and control of malaria epidemics

If they can be carried out before the expected peak of transmission, residual spraying or the treatment of mosquito nets if nets are widely used in the affected area.

- Elimination of new foci of infection in malaria-free areas

Depending on the extension and number of such foci, space spraying or indoor residual spraying should be considered emergency measures.

- Prevention of seasonal peaks of malaria transmission

These may sometimes have the characteristics of seasonal epidemics. It may then be possible to institute routine seasonal application of indoor residual spraying and treatment of mosquito nets. It may also be worth considering environmental management methods, source reduction or larviciding in areas of high population density, such as urban areas or in development projects, to reduce the risk of transmission in the future.

- Control of transmission in high-risk situations

Such situations exist in labour or refugee camps, where no immunes and infected people may come together in conditions of high transmission potential.

- Reduction of transmission in areas of high drug resistance

Drug resistance may be particularly high in areas subjected to high selection pressure following the massive use of antimalaria interventions where vector control was considered difficult to organise. Perhaps the most suitable method in these situations will be insecticide-treated materials, although this may pose serious logistic problems in some areas.

- Control of endemic malaria

The method most likely to produce sustainable control is insecticide-treated materials, although indoor spraying has been and still is the most widely used.

2.3.6. Challenges for malaria vector control

- Increasing spread of resistance

This is an increasing problem in all African malaria countries. Today there are very few localities on the continent where populations of vector mosquitoes are still susceptible to the approved classes of insecticides.

Pyrethroid resistance has exploded in concert with the scale-up of pyrethroid-treated bed nets, causing concern for those countries that depend on nets for vector control. In SA, pyrethroid resistance in the Mozambican population of *An. Funestus* remains a threat, particularly in the face of changes in housing construction in rural areas are leading to less traditional-style housing. Therefore, there are fewer structures sprayed with DDT, opening the way for *An. funestus*toto return to SA once again.

- Lack of new chemicals

While this is being addressed by initiatives such as the Innovative Vector Control Consortium, the process is slow and expensive. It is likely that no new chemicals will be available for at least 5 years. WHO coordinated multi-country evaluations and further elaborated on Implications of insecticide resistance for malaria vector control November2016 that " Major gains have been made against malaria in recent years, largely through the substantial scale-up of insecticidal interventions targeting Anopheles mosquitoes. These include long-lasting insecticidal nets (LLINs) and, to a lesser extent, indoor residual spraying (IRS). However, their effectiveness is threatened by widespread mosquito resistance to insecticides. Resistance to the insecticides used in LLINs (pyrethroids) is now ubiquitous in major malaria vectors; it is difficult to find areas without resistance, and there are increasing reports of its intensification in some areas (WHO, 2015).

Resistance to the three other insecticide classes commonly used for IRS (carbamates, organophosphates and organochlorines) also increases in areas with malaria transmission (WHO, 2015). Efforts to avert this threat in line with the WHO Global plan for insecticide resistance management in malaria vectors (GPIRM) have been restricted by the lack of new vector control tools and deficiencies in financial, human, and infrastructural resources particularly at the national level. The dearth of evidence linking resistance and vector control effectiveness due to weak national surveillance systems in many endemic settings and potential confounding by other variables, such as treatment regimens or climatic factors.

However, entomological outcomes from laboratory and semi-field studies, and epidemiological outcomes from a recent field evaluation in Malawi, indicate that LLINs provide some personal protection despite pyrethroid resistance. For IRS, reports of resistance impacting effectiveness and therefore malaria transmission has not been definitive (WHO, 2015).

The absence of evidence was addressed by a multi-country evaluation undertaken in Benin, Cameroon, India, Kenya and Sudan, coordinated by WHO with primary funding from the Bill & Melinda Gates Foundation. This represents the first initiative to assemble a large data set from different settings that connect entomological and epidemiological observations to provide quantitative insights on the implications of insecticide resistance on malaria vector control (WHO, 2015).

It was stated in the Impact of Malaria Vector Control Interventions at the Beginning of a Malaria Elimination Stage in a Dominant Area of Anopheles anthropophagus, Hubei Province,
Chinaby Li KJ, Cai SX, Lin W, Xia J, Pi Q, Hu LQ, Huang GQ, Pei SJ, Zhang HX. Three towns with similar socio-ecological characteristics, malaria morbidities, and populations were selected for this study to explore economic and effective malaria control measures. The sources of infection were controlled in each town. Impregnated mosquito nets with 2.5% deltamethrin (15 mg/m(2)) combined with residual spraying of 5% cypermethrin (25 mg/m(2)) were implemented in cattle and pig pens, as well as in crowded sites in Chenji, whereas the mosquito nets were treated with 2.5% deltamethrin only in Guanqiao Town.

All the control measures implemented in Fengling (control town) were the same as those implemented in the towns of Chenji and Guanqiao, except for mosquito elimination control. Results were evaluated and compared based on pathogens and entomology. The densities of Anopheles anthropophagus mosquitoes in houses, outside houses (man bait), as well as in cattle pens and pig pens were reduced by 100%, 71.96%, 94.01%, and 67.42%, respectively at all 4 sites in ChenjiTown. In contrast, the density increased at 1 site (the outside house [man bait]) by 12.38%, while the densities at the other 3 sites (in houses, cattle pens and pig pens) were reduced by 99.63%, 18.71% and 69.44% respectively in Guanqiao Town. The biting rates of an anthropophagus in the 3 towns were 0.11, 0.22, and 1.1 respectively in Chenji, Guanqiao, and Fengling.

The incidence of malaria in the 3 towns decreased by 73.12%, 57.71%, and 65.71% in terms of the annual average. Both impregnated mosquito nets combined with residual spraying and impregnated mosquito nets only reduced An's density. Anthropophagus in houses in the 2 towns, but the reduction was more rapid in Chenji Town.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction.

According to Kothari (2015), research methods describe the steps and procedures that a researcher has followed during collecting and systematically analysing data. It is also a way of systematically solving the research problem. It may be understood as a science of studying how research is done scientifically, studying the various steps that a researcher generally adopts in studying his/her research problem along with the logic behind them.

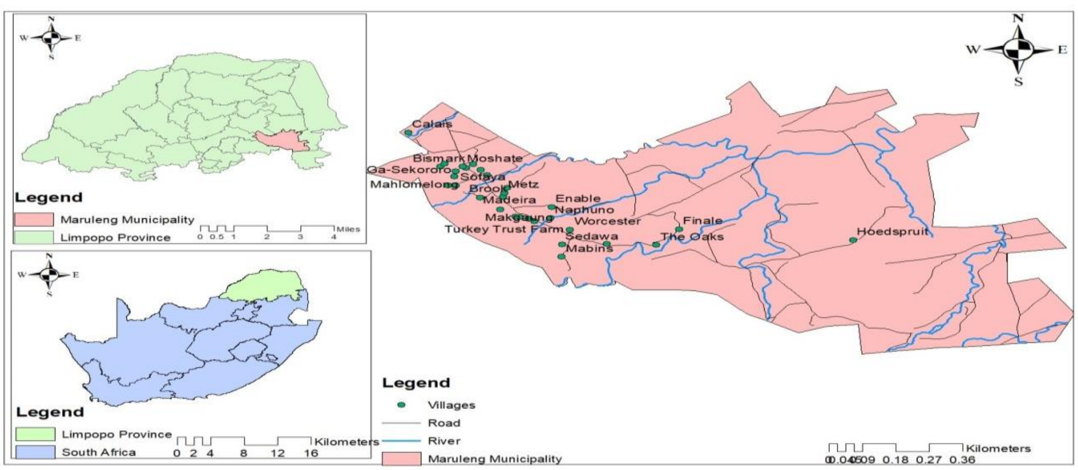
3.2 The study design

According to Creswell (2014), research designs are types of inquiry within qualitative, quantitative, and mixed methods that provide specific direction for study procedures. It's the master plan that explains the proposed research methods in terms of data collection, enhancement of data quality and data analysis. It is also a set of methods and procedures used to collect and analyse measures of variables specified in the research problem. It also defines the study type and, data collection methods and statistical analysis plan (Creswell, 2014).

For this study, a quantitative research design that is retrospective and descriptive was adopted, and data will be collected using secondary data using an audit tool. This design was found to be appropriate because of the aim of the study and the time frame considered. This is a descriptive retrospective study based on the analysis of secondary malaria surveillance data (cases and deaths) and sprays data.

3.3 The study setting

The study was conducted at Maruleng Municipality, situated in the south-eastern quadrant of the Limpopo Province within the Mopani District Municipality. The Municipal area extends over 324699ha. The Kruger National Park borders it to the east, the Ba-Phalaborwa and Tzaneen Municipalities to the north, Lepelle-Nkumpi Municipality to the west and the Tubatse and Bushbuckridge to the south. (www.maruleng.gov.za). Maruleng Municipality is demarcated into 12 wards comprising 23 villages with more than 24589 households and its surrounded but over 120 private farms. All villages still depend completely on government for malaria control intervention. Current vector control interventions in the municipality include IRS and larvicide. Regular spraying of interior walls of houses is carried out in the high-risk malaria areas, a seasonal round from August to February each year. The residual insecticides of choice for indoor application are DDT for traditional structures and, carbamates and synthetic pyrethroids for western type structures. To control mosquito larvae, larvicide operation by use of Temephos (organophosphate) is carried out on identified of breeding sites. (www.maruleng.gov.za)



3.4 Data quality

This study relied on surveillance data, possibly the quality of the data is subjected to reporting inconsistencies, incompleteness of notification forms and flawed data capturing. Therefore, presenting missing data variables. Despite these shortcomings, it is worth noting that routinely collected data through the provincial malaria surveillance system remains the basis for measuring malaria trends over time when cautiously analysed and interpreted. The findings are not expected to be substantially affected by data quality.

3.5 Data collection methods

Data (secondary data) was extracted from Provincial Integrated Malaria Information System and Patient records using data collecting tool (as stated above) developed by the researcher (see Appendix C). The above variables were obtained from the database at Malaria institution. The following retrospective information was collected:

 Malaria morbidity and mortality data.

All malaria data for the period under review (2013-2018) were obtained from the provincial Integrated Malaria Information System (IMIS) under Malaria Control Programmes of the Department of Health. Malaria morbidity and mortality data consisting of both passive and active cases based on definitive diagnosis reported from 2013 to 2018 were extracted from the IMIS. The data consisted of the following variables: date of diagnosis, age, gender, municipality, source country, source province and locality. Since malaria transmission in South Africa is seasonal, data was aggregated by season rather than by calendar year.

3.6 Data analysis.

All collected data was analysed by data analyst using the Statistical Package for Social Scientists (SPSS) version 24. Results were summarized and presented in tables, percentages, and charts pie charts. Data was captured entered and validated using Microsoft Excel and checked for errors and consistency. Descriptive statistics tests which included chi-square, cross tabulation and Case Fatality Rates are presented. The chi-square test was used to evaluate the associations between categorical variables (gender, country, province, and district) and malaria outcomes and $p < 0.005$ were regarded as statistically significant.

3.7 Ethical considerations

3.7.1 Ethics

According to Walton (2015), Ethics are a set of guidelines drawn up to protect the right of the research subjects and maintain 3 basic principles, which are principles of respect for human dignity, beneficence, and justice which guides the researcher and serve the aim or goal of research and apply to people who conduct scientific research or other activities. Ethics consideration should be adhered in research as it affects all the stages of research planning (Walton, 2015).

3.7.2 Ethical Clearance

Ethical clearance was obtained from the University of Venda Higher Degrees Ethics Committee. The permission to conduct the study was sought from Limpopo province, Department of Health as well as Maruleng Municipality.

3.8 Dissemination of the Study findings.

The results of the study in the form of dissertation will be disseminated to the University of Venda School of Health Science and the Library department

- Copies of dissertation will also be submitted to Department of Health at both provincial and district level
- Maruleng Municipality outbreak team will also receive a copy of the study in the form of dissertation
- It is also envisaged that the findings be publishing in the accredited journal so that it will be accessible to many audience

Limitations

The present study acknowledges several limitations since it relied given that it relies mainly on routine surveillance data and there was a possibility of missing or incomplete data from some of the records thus the quality of the data is comprised. The reporting health institutions data has potential for underreporting malaria cases, as some may not have presented at the health facilities. Health facility-based data can be affected by many factors including accessibility of the facilities by patients, perceptions of care and whether self-treatment is available to the patients and furthermore lack of systematic inclusion of data from other sources such as traditional healers, faith-based organisations and self-treatment cases. The instrument use to collect information did not enable us to evaluate fully the socioeconomic and environmental factors that may be inherently associated with malaria risk in Maruleng.

CHAPTER 4

RESULTS AND INTERPRETATION

4.1. Introduction

The study explored and described malaria incidence trends and determined the effect of vector control coverage in Maruleng Municipality. Retrospective data were collected and analysed using SPSS. The findings are presented in frequency, tables, and percentages. The study findings are presented according to study-specific objectives.

Malaria cases in Maruleng Municipality, Mopani District

The graph below shows the distribution of malaria cases according to the health institutions reported from the year 2013-2018. From the 874 cases reported, Sekororo Hospital (n=455) reported the highest number of malaria cases followed by Hoedspruit clinic (n=161). However, other clinics received lower, but the considerable number of cases and these include Bismark (n=43), Turkey (n=48) and The Oaks (n=39) among others.

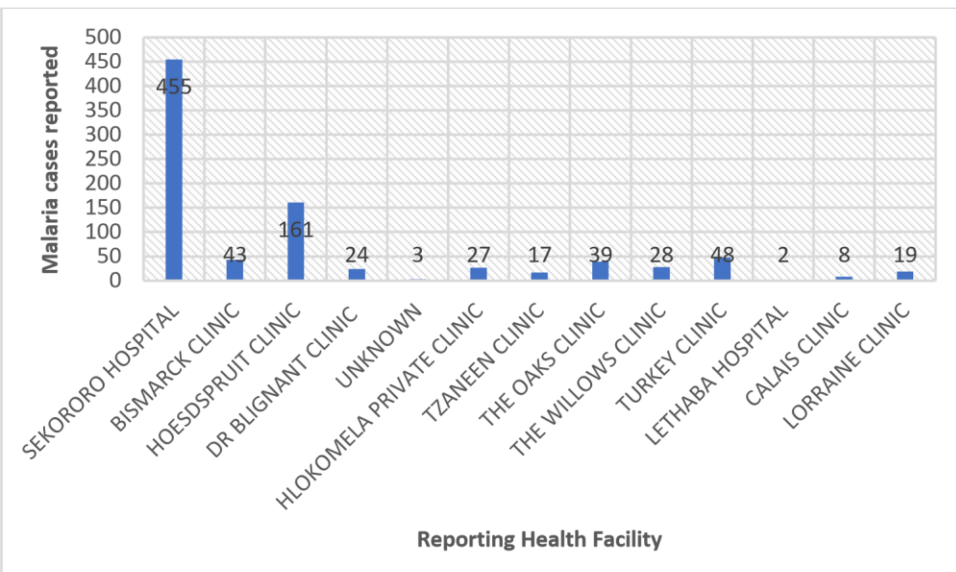


Figure 4.1: Malaria cases in Maruleng Municipality, Mopani District

4.2. Malaria case notification and incidence rate

Table 4.1 below presents the number of cases, malaria deaths, and fatality rates according to malaria seasons. From September 2013 to March 2018, a total of 874(mean cases=175) confirmed malaria cases were reported in Maruleng Municipality, Mopani District, Limpopo Province. The number of cases per malaria season ranged from 13 cases in 2013 and increased to 1637 cases in 2017.However, it then dropped to 83 cases in 2018. The total number of malaria attributed death was 15; 2017 and 2015 reported the highest number of deaths respectively.

Table 4.1: Number of reported malaria cases and malaria-attributed deaths, Maruleng Municipality, 2013 - 2018 malaria seasons.

Year	No. of reported cases	% (Percentage)	No. of Malaria Deaths	CFR (%)
2013	24	2.7	01	4.2
2015	113	12.9	04	3.5
2016	17	1.9	02	11.2
2017	637	72.9	07	1.1
2018	83	9.5	01	1.2

***CPR= Case Fatality Rate*

Figure 4.2. below shows malaria incidence rate for season 2013/14, which indicated 11 cases per 1000 population, and it dropped to 2 cases per 1000 population in 2015/16. Although it dropped in the latest period 2017/18, a notable and worrisome rise of 64 cases per 1000 population was recorded in the 2016/17period.

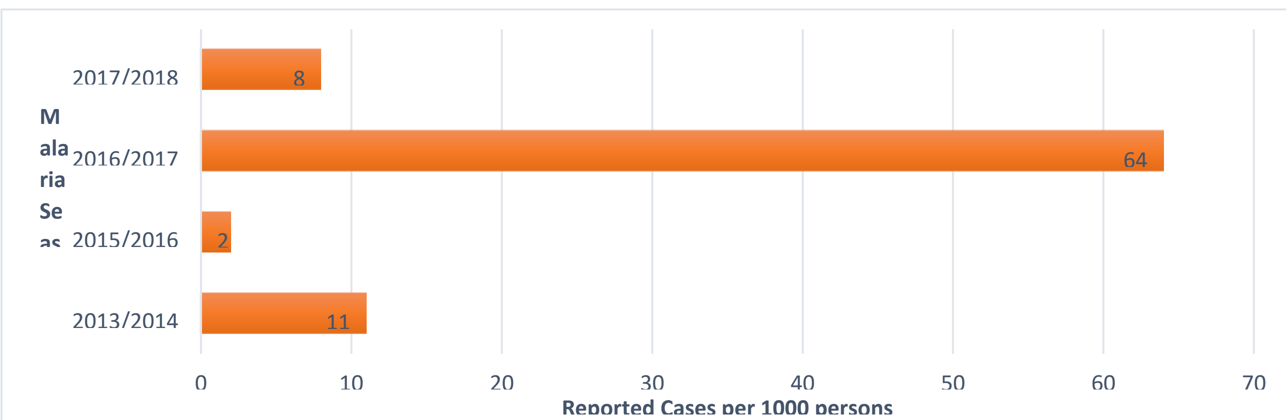


Figure 4.2 Incidence of malaria (per 1000 population) in Maruleng Municipality, 2013- 2019 malaria seasons.

4.3. Malaria incidence according to age and gender in a period of 2013-2019

Table 4.2 below shows malaria incidence estimates according to age groups. However, it clearly illustrates that all the age groups were affected, although the numbers fluctuate. The mean age was 30 years and there were significant differences in malaria incidence among the different age groups (x2 = 389.423; P < 0.003). From all the reported cases, the highest (22.4%) proportion was from the 21-30 years age group, followed by 18.1% from the 31-40 years and the shocking 16.9% from the young population aged 0-10 years old. Although malaria incidence fluctuates around other age groups as indicated in the table, the senior citizens represented more than 20% percent of malaria incidence.

Table 4.2. Age-specific malaria incidence and case fatality rate, Maruleng Municipality, 2013 - 2018 malaria seasons.

Age Group	Seasonal Notified Cases	Proportion (%)	Case Fatality Rate
0-10	148	16.9	0.7
11-20	136	15.6	0.7
21-30	196	22.4	2.6
31-40	158	18.1	1.5
41-50	108	12.4	3.7
51-60	82	9.4	1.2
>61	46	10.9	2.2

***p<0.003*

Figure **4.3a** and **b** show that during the 2013 t0 2019 malaria period males had significantly higher malaria infections than females in all age groups, accounting for 60.8% of all confirmed cases and 39.1% in females; the trend test was statistically significant (x2 = 3.353; P < 0.005). The mean incidence rate was 55.5 cases per 1000 in males and 38.8 cases per 1000 in females. As indicated in figure **4.3b** in both males and females, malaria incidence increased from age 0-10 years, reaching the peak among different age groups between 21-30 years for males and 31-40 for females. It declined thereafter.

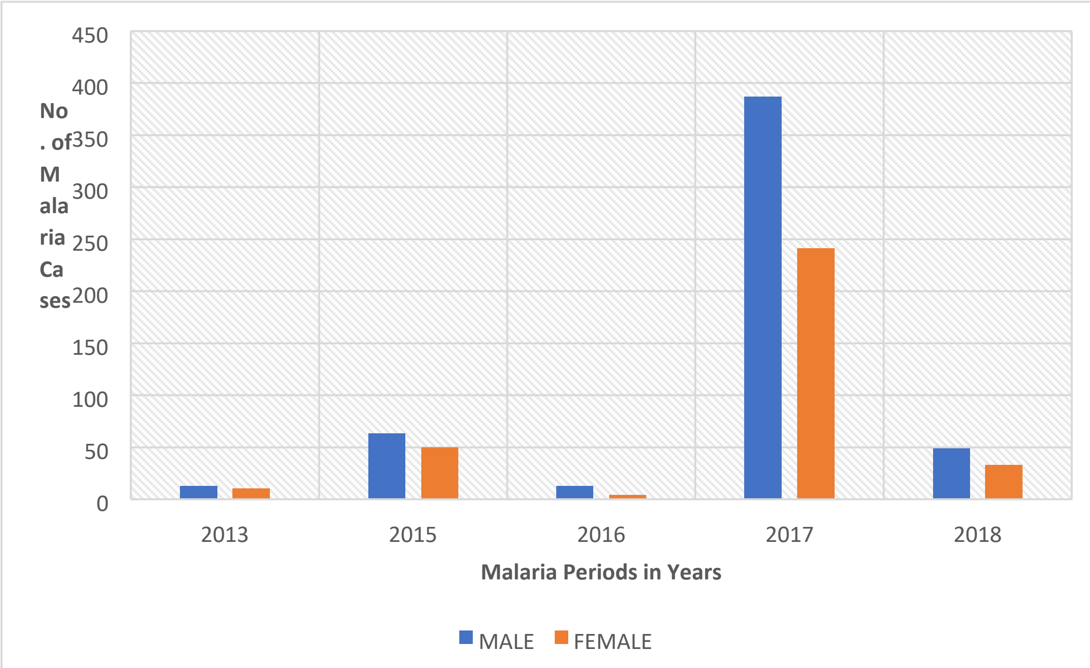


Figure 4.3a. Malaria incidence according to gender for the period 2013-2019

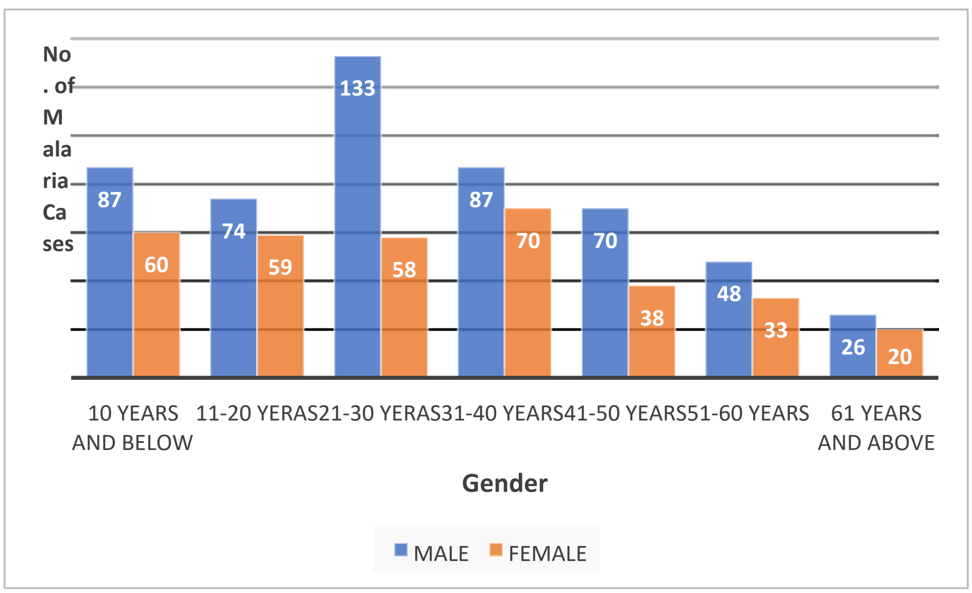


Figure 4.3 b. Malaria cases according to gender and age groups

4.4. Age and gender-specific malaria mortality

The study noted a total number of 15 deaths (10male and 5 female) from the recorded malaria cases.

5). Table 4.3 below shows malaria-attributed mortality which increased with age. However, the incident rate was more pronounced among the21-50 years age group both male and female. 21-30 years having the highest (33.3%; n=05) number of deaths. The study noted that the 31-40 years male age group was not affected. There were significant differences in the CFR among males and females. However, similarities are noted as the CPR increases with age from 0.7-3.7.

Table 4.3: Age and gender-specific malaria mortality

Age group (years)	Malaria attributed deaths (%)	Female (CFR)	Male (CFR)	CFR For Female & Male
0-10	1 (6.7)	-	1 (1.7)	0.7
11-20	1 (6.7)	-	1 (1.8)	0.7
21-30	5 (33.3)	1 (0.8)	3 (5.2)	2.6
31-40	2 (13.3)	2 (2.3)	-	1.5
41-50	4 (26.7)	2 (2.9)	2 (5.5)	3.7
51-60	1 (6.7)	-	1 (3)	1.2
>61	1 (6.7)	-	2 (10)	2.2

4.4. Seasonal malaria cases variation

Figure **4.4** below illustrates the seasonal variation of malaria cases in Maruleng Municipality between the year 2013-2019. The table shows that malaria cases followed a different pattern over the five-year study period. Even though malaria cases were prevalent throughout each year, cases increased from January to May, decreasing from June to September, and increase again in August to December. The pattern of malaria cases in Maruleng Municipality shows that it was high in 2017 followed by the 2015 malaria seasons.

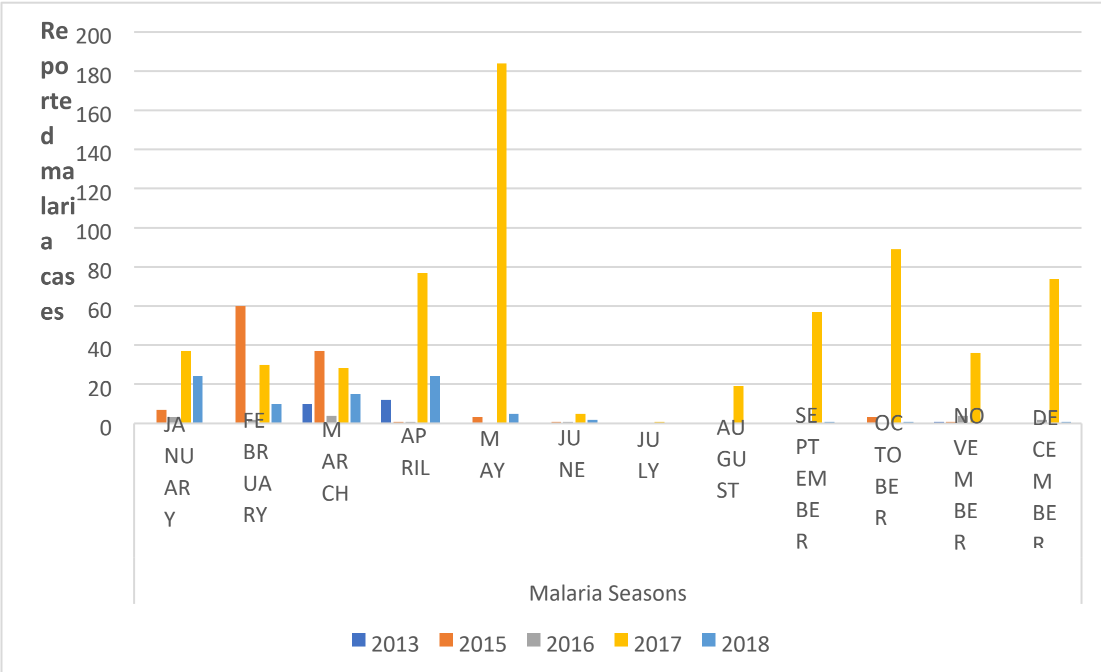


Figure 4.4. The seasonal malaria variation

4.5. Geographical sources of malaria infection

Figure 4.5 below presents the geographical sources of malaria infections in Maruleng Municipality from 2013 to 2018. 50 sources were recorded and infections from these areas varied from Metz (10.5%), Tickline (5.7%), and Turkey (5%) having the highest number of local sources of malaria infection. 3.2% of the infection was untraceable, with considerable foreign and imported sources from Zimbabwe (1.4%) and Mozambique (3.2%) respectively.

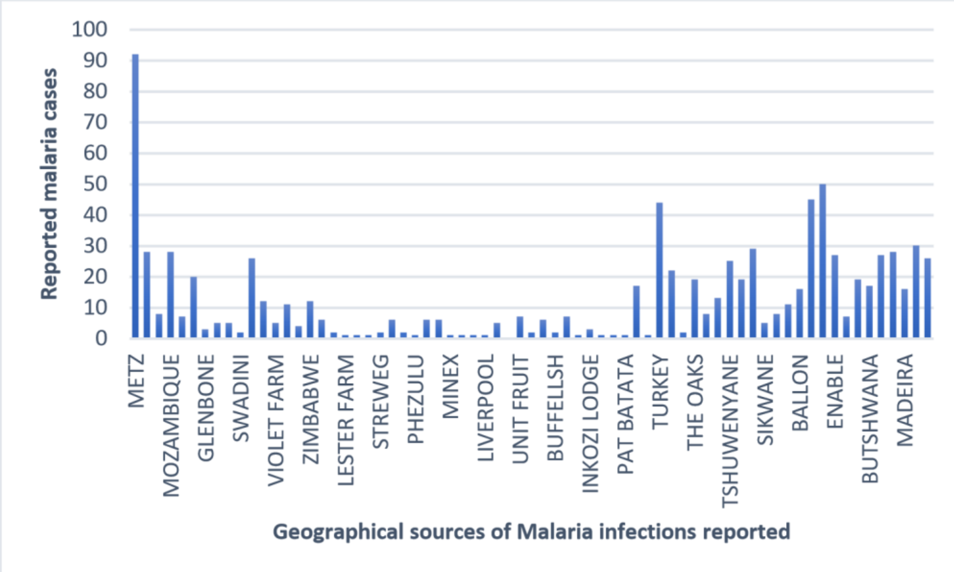


Figure 4.5. Geographical sources of the malaria infections reported.

4.6. Effects of vector control coverage

Figures 4.6a-g illustrate the vector control coverage according to localities in the Maruleng Municipality. The study indicates, the spraying efforts, which were done in every season from the 2013-2019 malaria seasons. Figure 4.6a below illustrates the vector control coverage in Maruleng Municipality in the 2012/13. From all the 19 localities, majority of the sprayed structures were rooms followed by shelters. Bismarck, Sofa, and Enable had many rooms that were sprayed to control malaria. All the sprayed shelters shared similar percentages across localities; however, a notable high number of unsprayed structures were reported in Willows, Tickyline, Lorraine, and Metz respectively.

4.6a. Vector control in the malaria season of 2012/13

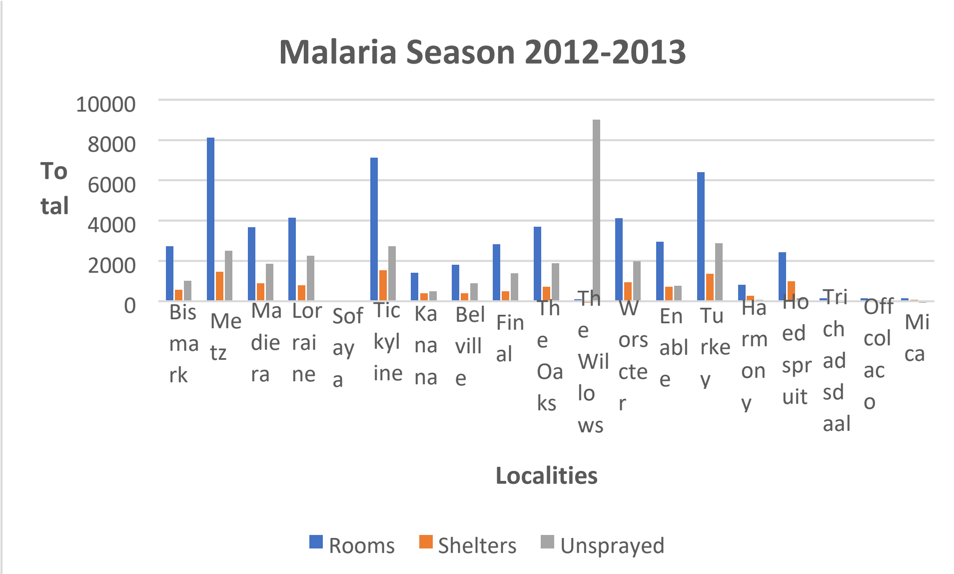


Figure **4.6b** below, established that more unsprayed structures in Maruleng Municipality were distributed across the municipal area. The areas which had a high number of unsprayed structures include Worcester, Tickline, Metz, and Turkey. However, many rooms in localities such as Finale, Bismark, and The Oaks were noticed compared to the previous malaria season.

4.6b. Malaria season 2013-2014

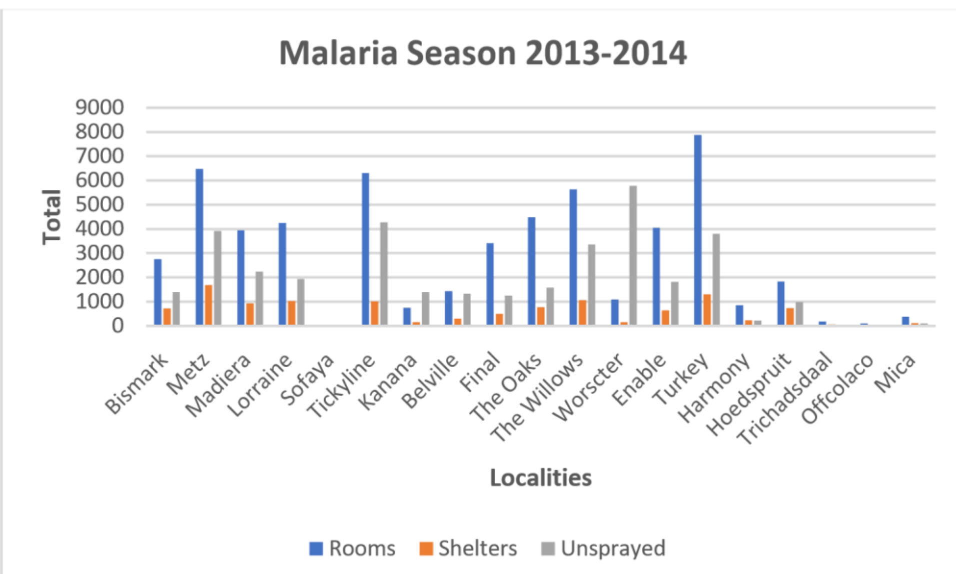


Figure **4.6c** below shows that few structures were sprayed cross Maruleng Municipality; however, many rooms were sprayed in Bismark, Sofaya, and Enable. The unsprayed structures were many in Tickline, Worcester and Turkey. This report is similar to the 201/13 malaria season vector control.

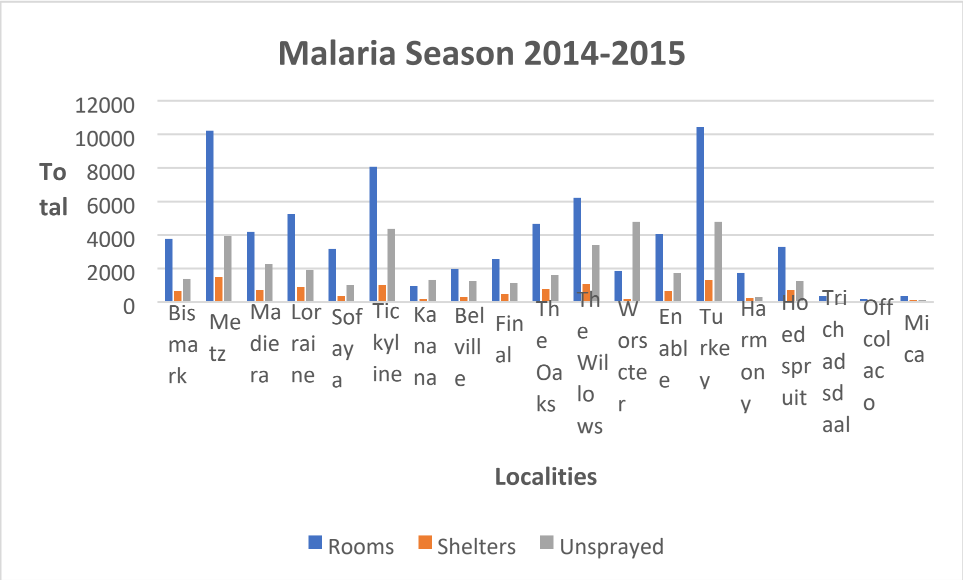


Figure 4.6c Malaria Season 2014-2015

The figure **4.6d** below indicates that The Willows community had the highest number of structures that were not sprayed and the other areas like Mica, Offcolaco and Trichadsaal nothing much was done regarding the vector control.

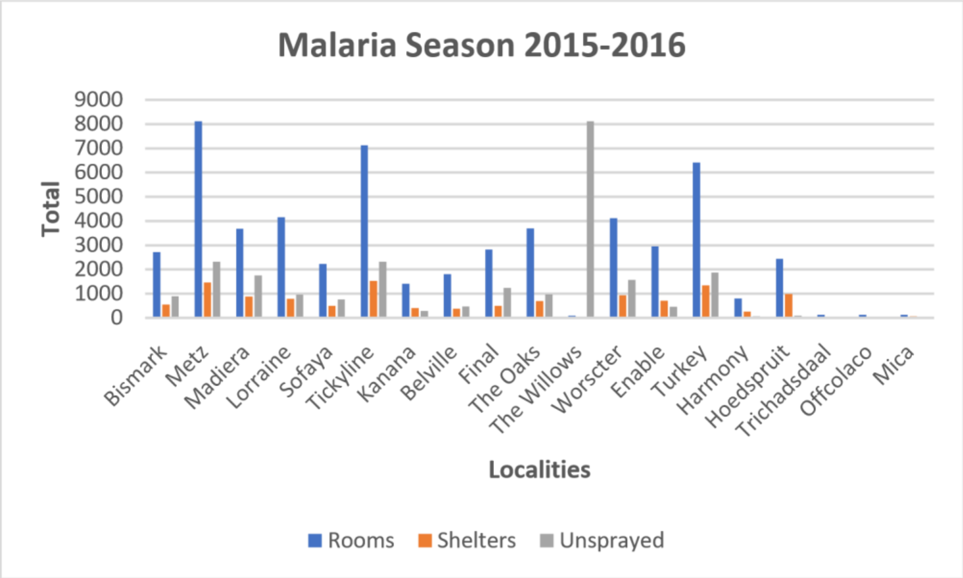


Figure 4.6d. Malaria season 2015-2016

In the malaria season 2016-2017 only 10 localities were captured, out of these localities, Hoedspruit, and the Oaks had the highest number of sprayed structures. However, there were many unsprayed localities, although the number was at average, and these include The Willows, Turkey and the Oaks.

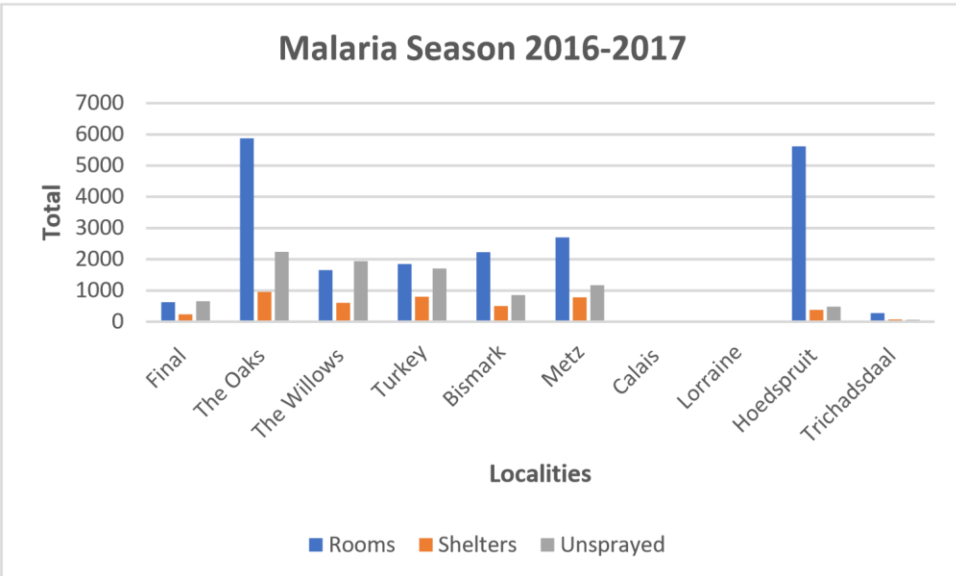


Figure 4.6e Malaria season 2016-2017

As shown below (**4.6f**) 2017-2018 malaria season a total of 17 localities were recorded during vector control; most of them were sprayed rooms. Despite the low number of unsprayed structures per locality, unsprayed localities were many.

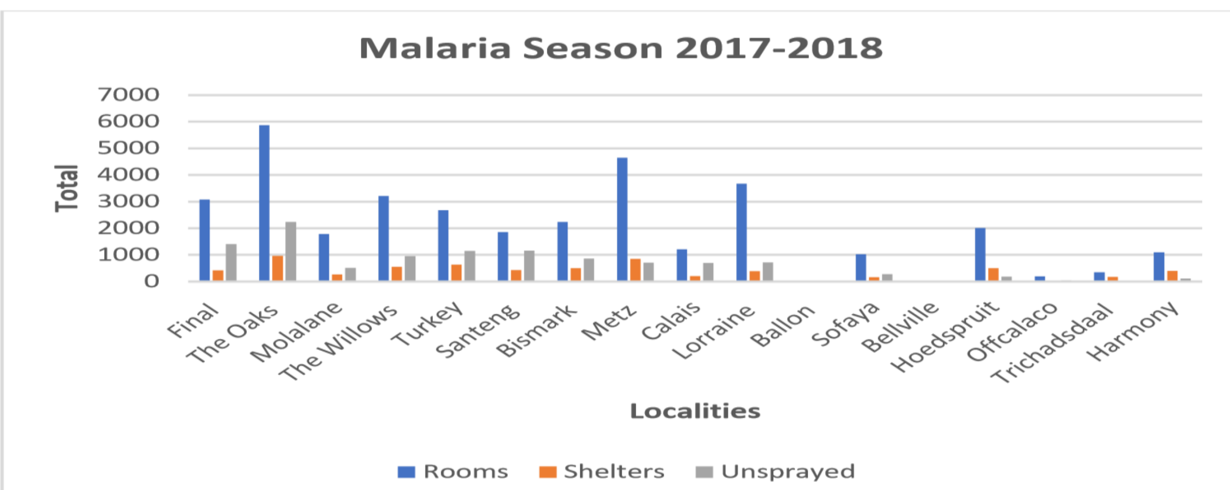


Figure 4.6f. Malaria season 2017-2018

The figure below shows the vector control among 20 localities in e season of 2018-19 and the majority of the areas sprayed were rooms as compared to shelters.

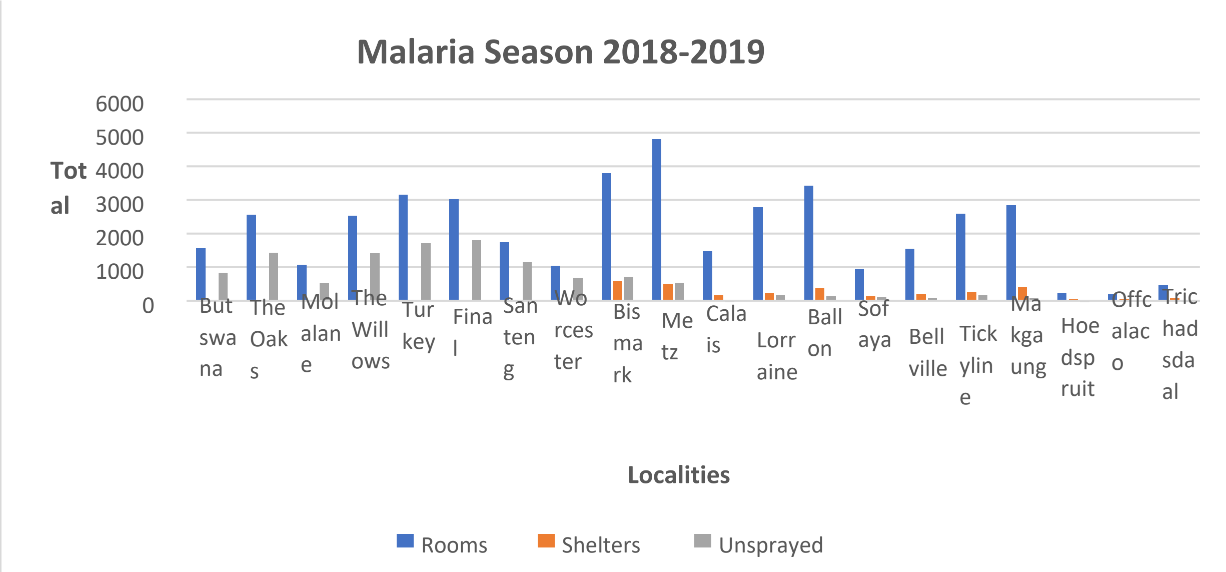


Figure 4.6g. Malaria season 2018-2019

4.7.Vector control according to Malaria seasons 2013/2019

A summary of vector control over the 6-season period of malaria below indicates that spraying rooms was at the peak between 2012/13 and 2015/16 period. However, spraying shelters were even from 2012-2016 and abruptly declined throughout 2018.

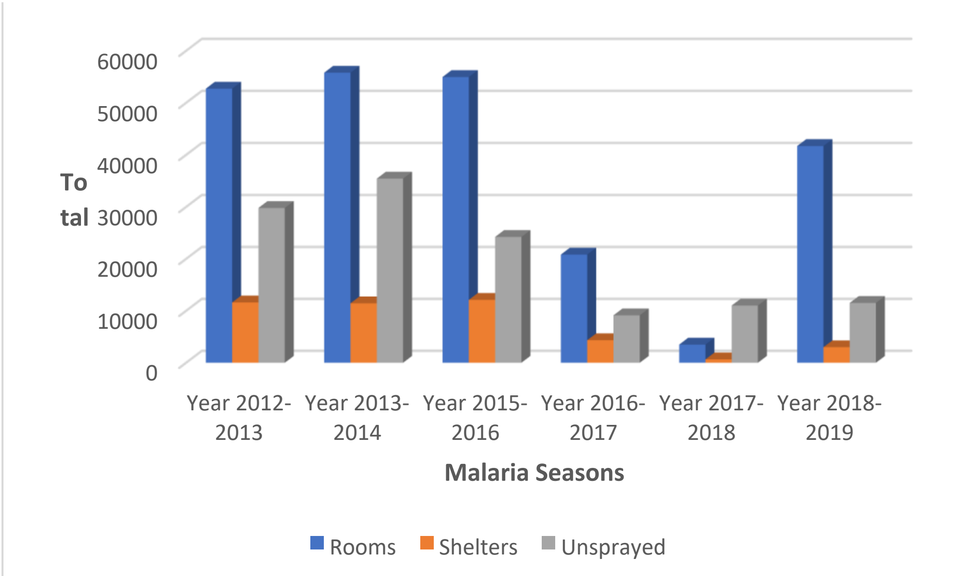


Figure 4.7. Vector Control according to malaria periods (in years)

4.8 Summary of insecticides and structures covered during vector control (2013-2018).

Table 4.4 gives a summary of the amount of residual insecticide used, the number of structures covered by the indoor residual sprays, and spray coverage in Maruleng Municipality during the 2013-2018 malaria seasons. The data shows a total of 4147.29kg of two different residual insecticides(K-Othrine=729.89 &Fendona=3417.4) were used to spray a total of 674457 structures.

Table 4.4. Summary of insecticides and structures covered during vector control (20132018).

Insecticide	**Amount of insecticide used (kg)**	**The seasonal mean insecticide used (SD)**	**Total Number of structures sprayed**
K-Othrine	729.89	6.95	450604
Fendona	3417.4	89.9	223853
Total	4147.29	96.85	674457

CHAPTER 5

DISCUSSION

5.1 Introduction

The study explored and explained the trends of Malaria incidence to determine the effect of vector control coverage in Maruleng Municipality. The study established and reported 874 cases of Malaria with 15 deaths in a period of five years (20132018).Maruleng Municipality can be regarded as a malaria high risk area. The cumulative incidence rate in the area five years prior to fieldwork was 16/1000, like other highly African and South African endemic areas (Mbacham*et al.,* 2019). Historically, most malaria surveys trends particularly in South Africa and Africa, in general, are collected and presented at a global scale, national or district levels, which does not give a detailed pattern of malaria at lower levels such as municipalities, ward, and villages (Gunda *et al.,* 2017). Therefore, study, responded the research gaps identified in Municipal malaria-endemic data from the period of 2013-2018 of Maruleng Municipality, Mopani District in Limpopo Province of South Africa.

There are confirmed cases of malaria (2013-2018), giving a more accurate picture of the malaria situation in the area compared to unconfirmed malaria cases in some previous studies. The 2013-2018time-series trends show a gradual decline in malaria morbidity and mortality in Maruleng Municipality over the past five malaria seasons. However, notable peaks in the number of cases were reported in 2017, although they abruptly dropped in 2018. Pradhan *et al.*, (2016) shared a similar observation in India, Odisha region wherein a drop in cases was witnessed in 2008 and a decline in incidence during 2009–2013 was three times steeper than 2003– 2007. The declines were associated with the intensification of antimalaria activities in 2008, and the study noted a large-scale of new intervention packages and reinforcement of existing ones in the state, from 2008.

The results show that malaria incidence is significantly associated ($p=0.003$) with age groups, 21-30 years are the most vulnerable. Therefore, it can be argued that age can play an important role in malaria transmission. This study shows a different result on the influence of age in malaria incidence compared to preceding studies, which did not regard age as an important variable like geographical elements, such as higher rainfall, because it necessarily results in significant changes in malaria cases (Lowe, Chirombo& Tompkins, 2013). A similar study in Eritrea recorded that malaria incidence was uniformly distributed across all age groups, contrary to the African situation, where malaria is considered a disease that affect children under 5 years and pregnant women (Bhatt *et al.,* 2015). Malaria transmission trends in Africa are diverse, and it should not be assumed that the burden is restricted to certain target populations and this, in other words, brings the notion of Lowe, Chirombo, and Tompkns (2013) who noted the influence of rainfall on malaria risk. It was interesting to note that males had a higher risk of malaria compared to their female counterparts.

Higher malaria incidences were reported among males than females. To explain this difference, there is need to study the role of other variables such as gender and malaria transmission which are not included in this study because of the lack of complete data on malaria interventions at the time of the study. Moreover, a study in Africa gave a detailed explanation that malaria incidence rate in males is higher than in females because males frequently move around, mostly for work and this movement might also include across the borders and malaria-endemic areas (Mbacham*et al.,* 2019).

Apart from the peak incidence at 21-30 years, the > 10 years age category is the second at risk, which accounts for malaria control interventions mostly been targeted at pregnant women and children below 5 years in the country (South Africa). Under 10 years incidence rate was lower than 21-30 years maybe because children at this age are mostly indoors at night and benefit from the indoor house spraying. However, as they get older, their sleeping patterns may be less regular; therefore, be at risk of infected mosquito bites (Maharaj *et al.,* 2019). As purported by Manh *et al.,* (2011). these interventions can resultantly lead to a decrease in incidence among these age groups and this could possibly explain fewer infections below 5 years age category. A similar study was reported in Bostwana. The study showed that 21-40 years were most affected, and they present a higher burden of malaria, which has economic implications, because the age group is the most economically productive. Therefore, it is critical for malaria control interventions to target all age categories for better impact. In areas of high transmission, children and infants constitutes malaria burden, while in areas of low transmission, older ages carry the most burden (Bai *et al.,* 2019).

Throughout the five-year period (2013-2018), the studies established that malaria cases increased from January, reached a peak in May; dropped shortly and increased again from August and dropped sharply in December. Degaregee*et al.,* (2019) supports these findings; malaria high risk was noted during the first months of the year, then decreased sharply. The increased risk observed during the first months of the year but mainly in April and May after the rains is related to the large number of breeding sites for Anopheles during this period, when rainfall becomes abundant and irrigation water is released from the barrages for farming. The other supporting study in Mpumalanga recorded inter-annual variation from 2001 to 2009, with a distinct malaria transmission season, prominent peaks in January and February and the January/February peaks could be attributed to favourable climatic conditions for malaria transmission (peak summer season) or introduced parasites by human immigration from various places of origin after the December holiday season (Khosa *et al.,* 2013).

A considerable number of the cases reported during the period (2013-2018) were imported from Mozambique and Zimbabwe respectively. Zhou *et al.,* (2016) found that in some societies, men have a greater risk of contracting malaria due to occupational reasons, particularly those working in mines, fields or migrate to high endemicity areas. Khosa *et al.*, (2013) emphasised that migrant workers to Limpopo are also predominantly males and the latter is partly reflected by the higher percentage of males in the group of cases that are (probably) not originating from the province.

The reported malaria cases throughout the five-year malaria period varied according to localities. , they were specifically higher in Bismark, Mertza, Enable and Sofaya and previous studies postulated that these differences may be due to specific characteristics of houses or their locations that may facilitate contact between humans and mosquitoes (Baeit*et al.,* 2019). An analysis of domicile characteristics including roofing and wall materials used suggest that walls made from mud, a common type of housing construction in the western lowlands of Eritrea. This increased risk for *parasitemia* compared to individuals living in houses with other types of construction materials (Bhai *et al.,* 2019). Zhou *et al.,* (2016) further emphasised that malaria diversity, and cross borders, increase the chance of potentially fatal cases and malaria intervention among this internationally moving population. Therefore, intervention in the border areas should be strengthened.

Vector control aims to limit the transmission of pathogens by reducing or eliminating human contact with the vector and it is primarily an insecticide. It relies on indoor residual spraying (IRS) of houses and the distribution of long-lasting insecticide-treated bed nets (LLINs). The study established two insecticides (K-Othrine and Fendona). The indoor residual spraying varied across years, but little was done in 2015/16, resulting in more cases in 2017 malaria season. To argue the significance of insecticides, Okiro*et al.,* (2010) reported a decline in malaria incidence burden across several countries in Africa, suggesting that the epidemiology of malaria across the continent is in transition. However, it remains a moot point to suggest that IRS is the only method to the scaling down malaria cases. Although, Pradhan*et al.,* (2016) attested that selective indoor residual spraying (IRS) remains one of the keyin-vector control strategies, but primarily used for epidemic prevention and response. The K-Othrine and Fendona insecticides are highly effective as a malaria control measure to reduce malaria incidence and deaths particularly in the 2016/17 malaria season. However, there is a worrisome larger number of unsprayed structures noted in this study.

Ngomane and De Jager (2012) emphasised that fewer people at risk of malaria are protected by indoor residual spraying (IRS)in South Africa. IRS is a prevention method that involves spraying the inside walls of dwellings with insecticides. However, the high number of unsprayed structures in Maruleng Municipality might be because of the economic cost of some chemicals. Brook *et al*., (2013) attested that the IRS coverage declines may be due to the switch from pyrethroids to more expensive insecticides in response to increasing pyrethroid resistance, or changes in operational strategies. These strategies show a decrease in countries aiming for the elimination of malaria. Although increased IRS coverage has significantly contributed to the decreasing trends in malaria cases and deaths; factors such as the combination of preventative interventions include early diagnosis, case management, effective treatment with ACT, low numbers of mosquito vectors, improved education, and awareness, improving socioeconomic indices are discussed in the subsequent section (recommendation).

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter concludes the study and provided recommendations based on the findings, and accordingly, this section will be arranged into 2 sections (conclusions and recommendations). The study sought to explore and describe Malaria incidence trends and determine the effect of vector control coverage in Maruleng Municipality. In summation, the study established a significant and sharp decrease in malaria morbidity and mortality in 2018 compared to the previous years in Maruleng Municipality. Malaria cases fluctuated, varied across age groups and statistically significant to gender. Although the death rate was low over a period and sharply declined compared to previous decades, the cases varied across localities, probably due to different levels of vector control coverage (IRS) and interventions.

6.2: Conclusions

The following conclusions were drawn from the findings:

- Malaria cases were significantly associated with gender, wherein males were more vulnerable than their female counterparts
- The cases are agespecific, high cases among the active group (0-30 years) compared to the 50^{+} years
- Although the vector control spanned across a five-year period, malariarecurrence can be attributed to the comprehensive amount of unsprayed structures, moreover, imported cases from Zimbabwe and Mozambique can also be blamed for the cases in different localities
- Although malaria cases and mortality reached a peak in 2017 the study concluded the 2018 malaria season showed a gradual decline in morbidity and mortality
- A sharp decrease in both malaria cases and mortality between 2013-18 indicates an association and time between increased IRS coverage and the reduction in malaria-related morbidity and mortality

6.3. Recommendations

Although the established a decline in malaria morbidity and mortality in Maruleng Municipality, the relative increases require more interventions. Therefore, the study outlined several recommendations. Although the study noted that only two insecticides were used during the IRS, it is important to recommend a holistic approach that includes a combination of other control interventions. The results highlight the need to continue with current control strategies such as IRS until interruption in local malaria transmission is completely achieved and alternative control strategies are implemented. To ensure a constant improvement in malaria control and subsequent elimination, a comprehensive intervention plan which encompasses a combined set of widespread interventions is required. The following practice, policy and research recommendations were formulated to address the issues identified to eliminate malaria from a public health concern problem particularly in Maruleng Municipality and the globally in general:

- Vector control coverage through IRS has been shown to be highly effective, historically and presently however lack of funding and weak programmatic capacity undermines programs and mean that we are not well equipped to face the pressing new challenges to malaria control VBD control. Therefore, there is an urgent need for increased investment in strengthening programmatic capacity for surveillance and control, and the development of new vector control tools.
- The role of entomologists in malaria vector control is significant. Entomological surveillance is a fundamentally important activity in a malaria vector control program. Therefore, without skilled entomological support, analysis and decision making for IRS, particularly for IRM, is impossible.
- National and provincial malaria control programmes are required to develop capacity within this field. Malaria entomologists guide and support malaria vector control programmes. Their participation in programme planning, implementation, monitoring, and evaluation is recommended. The skills required for adequate entomological surveillance include mosquito sampling in the field, species identification using morphological and molecular methods, vector incrimination using immunological methods, and insecticide susceptibility testing using standard biological (bioassay) techniques

- Considering the alarming rate of imported cases from Zimbabwe and Mozambique, it is important to strengthen the immigrant/border control, screening people before coming to South Africa
- Investing in more resources for malaria control and a holistic approach to malaria control including the department of health, agriculture, and interested non-governmental organisations is recommended. All these sectors will enable the surveillance system and the facilitation of immediate detection, notification, and response to outbreaks and individual malaria cases.
- Strengthened health promotion and awareness programmes by the health department to limit exposure to potentially harmful insecticides and promote the use of alternative control approaches are recommended.
- There is a need to create opportunities to improve the IRS through better stratification of spraying activities such as the use of geographical information systems to monitor and record spray performance at household level, and linking IRS information to malaria case notifications within communities.
- The study recommends further research across areas and platforms, while anticipating for new tools and strategies. It is important to revisit successful programs from the past and adopt a problem-solving approach that implements tailored vector control solutions from the readily available interventions, including insecticide and non-insecticide control methods
- Malaria-related mortality varying according to age and gender. It is, therefore, important to conduct further research to address the risk factors associated with malaria transmission.

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Appendix 1: Data collecting tool

SECTION 1: MORBIDITY DATA PROFILE

Study no	Date of data collection	Year of notification	Age	Gender	Resident	Date of diagnosis	Results of diagnosis	Institution of diagnosis	Institution of referral

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SECTION 2: MORTALITY DATA PROFILE

Study no	Date of data collection on	Year of notification on	Age	Gender	Resident	Date of diagnosis	Results of diagnosis	Institution of diagnosis	Institution of referral

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SECTION 3: VECTOR CONTROL DATA PROFILE

3.1 INDOOR RESIDUAL SPRAYING

3.1.1 Scheduled spraying

Study no	Date of data collection	Year/ season	Date of spraying	Number of households per block	Number of households sprayed	Number of households not sprayed

3.1.2 Re-spraying

Study no	Date of data collection	Year/ season	Date of respraying	Number of households per block	Number of household re-sprayed	Number of households not re-sprayed

3.1.3 Insecticides treated mosquito nets and other methods (if other, specify ____)

Study no	Date of data collection	Year/ season	Date of issuing / ---------------- ------	Number of households per block	Number of household issued/ ------------------------	Number of households not issued / ----------------------------

ETHICS APPROVAL CERTIFICATE

RESEARCH AND INNOVATION
OFFICE OF THE DIRECTOR

NAME OF RESEARCHER/INVESTIGATOR:
Ms SR Letsoalo

STUDENT NO:
14003884

PROJECT TITLE: Malaria incidence and vector control coverage effects in Maruleng Municipality from 2013 to 2019.

PROJECT NO: SHS/20/PH/25/1110

SUPERVISORS/ CO-RESEARCHERS/ CO-INVESTIGATORS

NAME	INSTITUTION & DEPARTMENT	ROLE
Prof TG Tshitangano	University of Venda	Supervisor
Dr KG Netshisaulu	University of Venda	Co - Supervisor
Ms SR Letsoalo	University of Venda	Investigator – Student

Type: **Masters Research**
Risk: **Minimal risk to humans, animals or environment (Category 2)**
Approval Period: **October 2021 – October 2023**

The Human and Clinical Trails Research Ethics Committee (HCTREC) hereby approves your project as indicated above.

General Conditions
While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, please note the following

- The project leader (principal investigator) must report in the prescribed format to the REC:
  - Annually (or as otherwise requested) on the progress of the project, and upon completion of the project
  - Within 48hrs in case of any adverse event (or any matter that interrupts sound ethical principles) during the course of the project.
  - Annually a number of projects may be randomly selected for an external audit.
- The approval applies strictly to the protocol as stipulated in the application form. Would any changes to the protocol be deemed necessary during the course of the project, the project leader must apply for approval of these changes at the REC. Would there be deviated from the project protocol without the necessary approval of such changes, the ethics approval is immediately and automatically forfeited.
- The date of approval indicates the first date that the project may be started. Would the project have to continue after the expiry date; a new application must be made to the REC and new approval received before or on the expiry date.
- In the interest of ethical responsibility, the REC retains the right to:
  - Request access to any information or data at any time during the course or after completion of the project;
  - To ask further questions; Seek additional information; Require further modification or monitor the conduct of your research or the informed consent process.
  - withdraw or postpone approval if:
  - Any unethical principles or practices of the project are revealed or suspected
  - It becomes apparent that any relevant information was withheld from the REC or that information has been false or misrepresented.
  - The required annual report and reporting of adverse events was not done timely and accurately,
  - New institutional rules, national legislation or international conventions deem it necessary

ISSUED BY:
UNIVERSITY OF VENDA, RESEARCH ETHICS COMMITTEE
Date Considered: August 2021

Name of the HCTREC Chairperson of the Committee: Dr NS Mashau

Signature: NS Mashau

UNIVERSITY OF VENDA
OFFICE OF THE DIRECTOR
RESEARCH AND INNOVATION
2021 -10- 12
Private Bag X5050
Thohoyandou 0950

University of Venda
"A quality driven financially sustainable, rural-based Comprehensive University"

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

Department of Health

Ref	:	LP_2021-10-006
Enquires	:	Ms PF Mahlokwane
Tel	:	015-293 6028
Email	:	Phoebe.Mahlokwane@dhsd.limpopo.gov.za

Seboke Rebecca Letsoalo

PERMISSION TO CONDUCT RESEARCH IN DEPARTMENTAL FACILITIES

Your Study Topic as indicated below;

Malaria incidence and vector control coverage effects in Maruleng municipality from 2013 to 2019

1. Permission to conduct research study as per your research proposal is hereby Granted.
2. Kindly note the following:
    a. Present this letter of permission to the institution supervisor/s a week before the study is conducted.
    b. In the course of your study, there should be no action that disrupts the routine services, or incur any cost on the Department.
    c. After completion of study, it is mandatory that the findings should be submitted to the Department to serve as a resource.
    d. The researcher should be prepared to assist in the interpretation and implementation of the study recommendation where possible.
    e. The approval is only valid for a 1-year period.
    f. If the proposal has been amended, a new approval should be sought from the Department of Health
    g. Kindly note that, the Department can withdraw the approval at any time.

Your cooperation will be highly appreciated

pp **Head of Department** 11/11/2021 **Date**

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